UGZY-01

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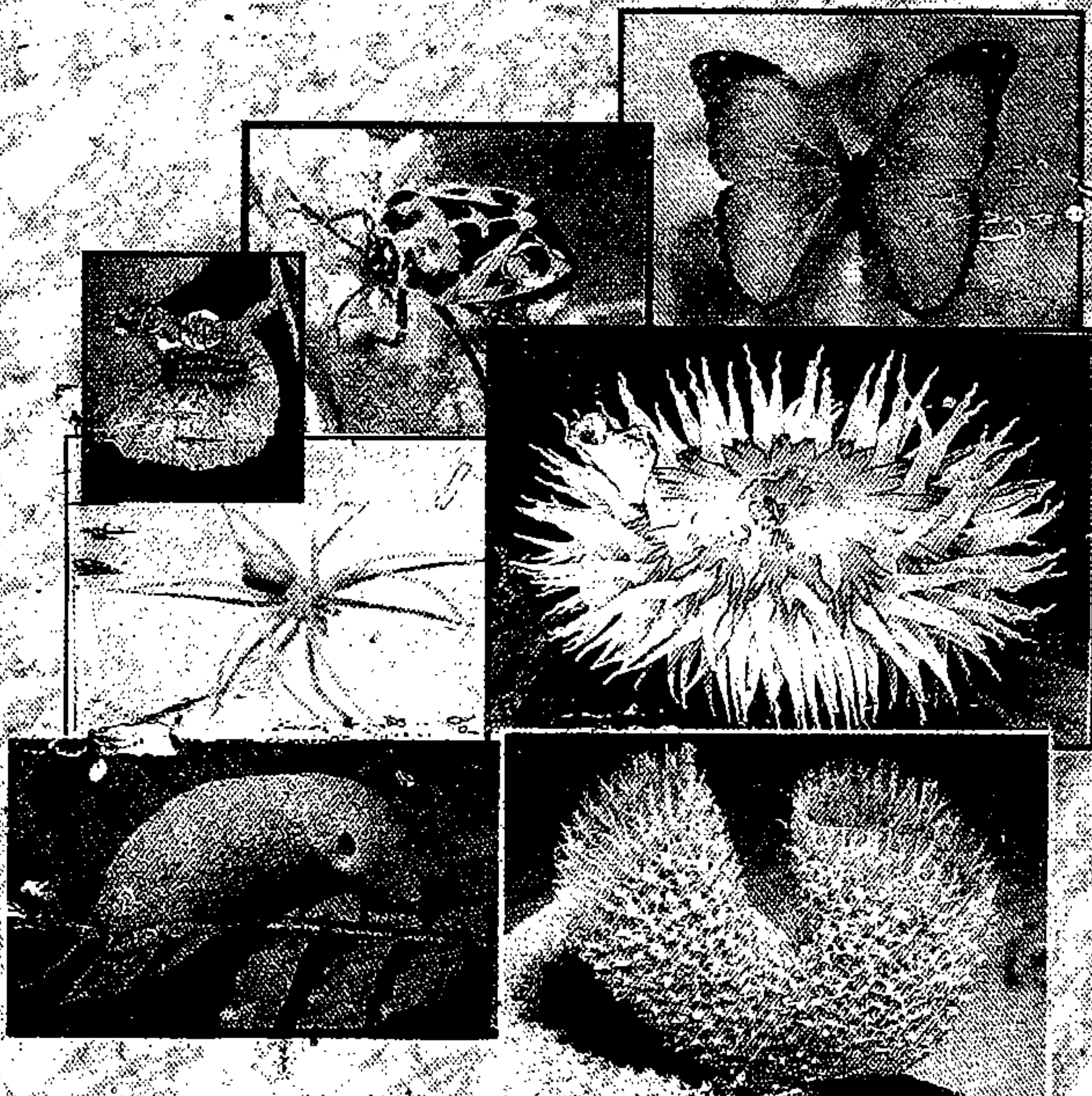
LSE-09
# ANIMAL DIVERSITY-I



# Diversity of Animal Life - I(Organisation)

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Uttar Pradesh
Rajarshi Tandon Open University

# UGZY -01
# ANIMAL DIVERSITY - I

Block

# 1

## DIVERSITY OF ANIMAL LIFE - I(ORGANISATION)

# INTRODUCTION TO ANIMAL DIVERSITY - I (NON-CHORDATA)

Nearly two million species of living organisms that inhabit our planet have been named and described. Of these only a small proportion comprise bacteria, protists fungi and plants. The majority of species of living things are multicellular organism included in the animal kingdom. The further subdivision of animals is even more unequal, with only 3% designated as, vertebrates (animals with back bones) and 97% as invertebrates (animals without backbones).

The invertebrates or the non-chordates form the subject of this course — Animal Diversity I and the course deals with their diversity as well as their comparative form and function. The variety of forms non-chordates present is mind-boggling. It has been difficult to choose from this variety and wealth of fast advancing available information regarding non-chordates, so as to keep you sufficiently informed but at the same time not overburdened.

The course is divided into four blocks. The first block deals with the classifications of animals in general. We follow the current concept of five-kingdom classification of organisms. Necessarily, the protozoans are left out of the kingdom Animalia, but these organisms are still of considerable interest to zoologists many of whom consider them animals. Zoology courses offered by various universities in India still include protozoans as part of their syllabi. Therefore, protozoans are dealt with in this course too, though as an independent unit. We wish to emphasise in this block that though all animals share in common a number of basic feature of structure and function there is a diversity of body plans within the animal kingdom suited to the habitats in which the animals live and evolve.

The second block deals with the classification of invertebrates. We illustrate and describe the known phyla with living representatives. You would notice that our descriptions are not too detailed, rather those points have been emphasised that are essential characteristics of each group and with which the student should be familiar. Thus you can compare the individual phyla by their diagnostic features. Conscious efforts have been made to limit the classification of animals upto classes only, without burdening you with too many details. This has been done to avoid confusion. However, representative examples from major orders, along with figures, are given to illustrate the diversity of animal life in a particular phylum. It has also been decided to leave out most of the lesser phyla, the so-called "minor phyla". The option has been dictated by severe constraint of space. Most of these phyla comprise very few species. Also, not much is known about these animals. These phyla, however, have been listed here; with figures illustrating organisation of that group. This will make you aware of the existence of these phyla.

It is expected that you would get a clear idea of the variety of animal life from this mode of treatment, without getting bogged down in the quagmire of classification. Very often, the most modern system of classification has not necessarily been followed; therefore, an attempt has been made to be a little orthodox in this respect while avoiding at the same time from becoming archaic. This will enable you to be in the mainsteam.

In the block that follows, comprising comparative form and function of non-chordates, organisation of the animals in relation to their function has been given, showing how these have changed during the course of evolution.

Animals are faced with four overriding compulsion in their lives: to eat; to avoid being eaten; to be able to survive in physical conditions of their environment and to pass their genes to the next generation. So, their behavior is the result of their attempt to meet these needs. In the last block of this course you will learn about the adaptive value of a particular behaviour in the life of invertebrates. You will also learn briefly about the harmful and beneficial non-chordates in this course.

Animal Diversity -I is the first course in a series of 3 courses on Animal Diversity. The entire series has been offered as a package and not as individual courses. We presume that you have already studied LSE-01, LSE-05, LSE-06 and LSE-07 before opting for

Difficult terms have been explained in the glossary given at the end of each block. A list of references has also been provided in case you are interested in learning and amplifying the information given here.

We hope that you will find this course material simple, lucid and at the same time informative and easy to comprehend.

# BLOCK 1 : DIVERSITY OF ANIMAL LIFE -I (ORGANISATION)

This block consists of three units. In the first unit — **Five Kingdom Classification** you will study how living organisms are classified into five kingdom, of which one is kingdom Animalia. In this kingdom we include all animals formerly considered Metazoans or multicellular animals.

In the second unit — **The Protozoans** you will study various aspects of certain single celled organisms — "The protozoan protists". These are according to modern concepts not part of kingdom Animalia, but out of necessity we have included them in this course. These 'animal protists', as they are often called, have been divided into seven major phyla. The general characters of each are given and special emphasis has been given to their ecological and practical importance. The harmful protozoans have been dealt in a separate section as protozoan diseases range from mildly irritating to fatal, for example, malaria is among the most important medical problems in the world today.

In the third unit **Metazoa— Origin and Evolution**, we explain the basic levels of organisation in the animal kingdom, the diverse body plans of animals that allow them to live and reproduce within particular environments. You will learn how these characters are used to categories the animals into different groups or phyla. This unit also dwells on the various speculation about the origins of multicellular animals from unicellular ancestors.

In the next block you will study the characteristic features of each invertebrate phylum, its classification upto classes with examples to illustrate the diversity of the organism included in the various phyla.

## Objectives

After studying this block you will be able to:

- discuss the five kingdom classification and the position of animals in this system of classification,
- explain that protozoans are single celled individuals with complex forms and behaviour not entirely comparable to any one cell of a multicellular organism,
- discuss the ecological and economic importance of protozoans,
- describe the various features that influence the structural organisation of animals and how these are used to classify animals into different groups.

# UNIT 1 FIVE KINGDOM CLASSIFICATION

## Structure



## 1.1 INTRODUCTION

Biology, as you know, is the study of life, living things, their relationship to one another and to their environment. This branch of Science has affected almost every aspect of our life. Advances in this area have resulted in such diverse products as vaccines and antibiotics. It has made possible the transplantation of organs and the manipulation of genes. At present biologists are working on such vital aspects as increasing food production, improving environmental quality, finding clues to health and longevity and combating dreaded ailments like heart disease, AIDS and cancer. Scientists working in this field have also increased our awareness of the complexity of the environment and the delicate balance that exists among all living and nonliving things. In the present unit, we examine how living things differ fron non-living things; we also examine how living things vary among themselves and discuss the various systems of classification. In the other units of this course, we will focus mainly on diversity of certain groups of animals which are rather lowly organized, called non-chordates.

### Objectives

After studying this unit you should be able to:

- enumerate characterisitcs of living and nonliving matter;
- point out why viruses can not be clearly identified with living organisms;
- differentiate between acellular and cellular organisms;

- distinguish prokaryotic cells from eukaryotic cells;
- describe the Cell Theory, trace its historical development and point out some exceptions to this theory;
- describe how living organisms have been classified in different ways at different times by different authorities;
- elucidate the two - three - four - and five Kingdom Classifications, explaining their limitations and implications.

## 1.2 MATTER : LIVING AND NON-LIVING

Viruses are said to border between living and nonliving things, as outside the host cells they show properties of non-living things, but when they enter host cells they use the metabolic machinery of the host cells they parasitize to carry on their own metabolism and reproduction.

Our universe is made up of two basic components: matter and energy. Matter, as you know, has mass; it occupies space. You can touch matter. It exists in two states — living and nonliving. Living things have life. It is easier for us to recognise most of the living things or non-living things than to point out the differences between the two groups. You may easily say, for example, that a rabbit is living whereas a rock is not, and may even give reasons for saying so. However, when you consider viruses for example, no clear cut answer can be given. So let us enumerate and describe the various features that are usually considered characteristic of living organisms. These can be divided into the following (1) Chemistry of living things (2) Specific organization (3) Metabolism (4) Growth and Development (5) Reproduction (6) Irritability (7) Adaptation (8) Homeostasis (9) Movement. These properties together make up the characteristics of living things and so are the basis of life.

### 1.2.1 Chemistry of Living Matter

Hydrogen, carbon and nitrogen together represent less than 1% of the atoms found in the earth's crust but about 74% of the atoms found in living matter.

All living things including ourselves, are made of protoplasm. Protoplasm is essentially a colloidal suspension of proteins in a watery solution. It is composed of molecules, the main element being carbon, which occurs in association with hydrogen, nitrogen and oxygen. Other elements like phosphorus, calcium, sodium etc. occur in small quantities. Table 1.1.

The rapid turnover of material in living things is part of metabolism, another characteristic of living things.

**Table 1.1 : Composition of elements in the earth's crust (the lithosphere) and the human body. Each number represents the percent of the total number of atoms present; for example 47 of every 100 atoms found in a representative sample of the earth's crust are oxygen atoms. Whereas there are only 19 atoms of carbon in every 10,000 atoms of the earth's crust. The four most abundant elements in the earth's crust are oxygen, silicon, aluminium and iron. While the four most abundant elements in living organisms are hydrogen, oxygen, carbon and nitrogen. So except for oxygen, in living organisms, silicon, aluminium and iron occur only in traces. About 75% of the body of most animals is composed of water and 50% of the remaining dry weight is carbon with little if any silicon. The earth's crust in contrast, consists of 28% silicon and less than 0.1% carbon.**

| Composition of Lithosphere | | Composition of Human Body | |
|---|---|---|---|
| Oxygen | 47 | Hydrogen | 63 |
| Silicon | 28 | Oxygen | 25.5 |
| Aluminium | 7.9 | Carbon | 9.5 |
| Iron | 4.5 | Nitrogen | 1.4 |
| Calcium | 3.5 | Calcium | 0.31 |
| Sodium | 2.5 | Phosphorus | 0.22 |
| Potassium | 2.5 | Chlorine | 0.03 |
| Magnesium | 2.2 | Potassium | 0.06 |
| Titanium | 0.46 | Sulphur | 0.05 |
| Hydrogen | 0.22 | Sodium | 0.03 |
| Carbon | 0.19 | Magnesium | 0.01 |
| All Others | < 0.1 | All Others | <0.01 |

This table compares the relative abundance of the most prevalent elements in the earth's crust with those in our body. As you can see from the table, living matter makes use of only very few of the elements available to it. Furthermore, the relative proportion of elements found in living organisms is different from that found in the environment. In other words, living matter can take up certain elements that are scarce in the nonliving environment and concentrate them within living cells. Moreover, there is a rapid turnover of material in living things. For example, carbon is taken up in the form of sugar, and is given out in the form of carbon dioxide. You do not see the same carbon atom in an organism permanently. Thus the organisation of atoms and molecules in living systems is more dynamic than in nonliving objects, such as rock. The rock we see today contains the same atoms it had last year. By contrast the rabbit we see today is largely composed of atoms acquired since we saw it last year.

The carbon based compounds produced by living organisms can be divided broadly into carbohydrates, fats and proteins. These then get organized into structures called cells which form the basic units involved in the specific organization of organisms.

### 1.2.2 Specific Organization

The body of all living things, no matter how different in size or appearance, is composed of cells. Viruses are of course an exception. The study of cells shows that each cell has a high degree of complexity and organisation and can be compared to a chemical factory, which is fully automated, self contained, pollution free and with no labour problems. It continues producing more and more living matter. The moment this process stops we say the cell is dead. Of course, the cell takes up material and energy from its environment. The nonliving substances do not have such a complex structural organization. The lower organisms like ameoba, bacteria etc., are unicellular and consist of just a single cell. In contrast, the body of higher organisms like humans or a neem tree is made up of billions of cells. The cells unite to form tissues. Many tissues come together to form organs, such as heart, liver or intestine in animals (Fig. 1.1).

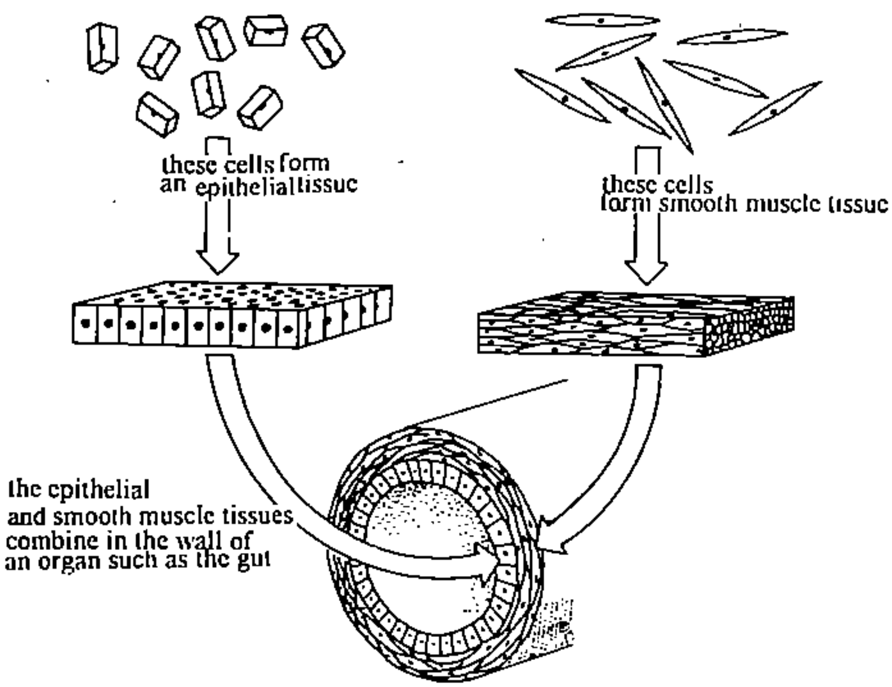



**Fig. 1.1: This figure shows in a simple manner how cells combine to form tissues and how tissues combine to form organs.**

Many organs work in a coordinated manner to form a system. For example in our body the nose, the trachea and the lungs form the respiratory system. Table 1.2 shows the various organs and the systems they form in humans.

Table 1.2: Showing the various systems of the human body.

| Name of system | Main organs in the system | Main functions |
|---|---|---|
| Respiratory system | Nose, trachea, windpipe and lungs | To take in oxygen and get rid of carbon dioxide. |
| Blood (circulatory) system | Heart, blood vessels | To carry oxygen and food round the body. |
| Digestive system | Gut, liver and pancreas | To digest and absorb food. |
| Excretory system | Kidneys, bladder, liver | To get rid of poisonous waste substances. |
| Sensory system | Eyes, ears, nose, fingers | To detect stimuli. |
| Nervous system | Brain and spinal cord | To conduct messages from one part of the body to another. |
| Musculo-skeletal system | Muscles and bones | To support and move the body. |
| Reproductive system | Testes and ovaries | To produce offspring. |

## 1.2.3 Metabolism

Metabolism as you know is a process by which living organisms acquire and use energy. A large number of biochemical reactions take place in the living organisms during various physiological activities. The sum total of all the biochemical activities of the organism is called metabolism. Broadly two types of biochemical reactions take place in the body (Fig. 1.2). In one, simple substances combine to form complex substances. This is called anabolism and involves acquisition and storage of energy. The second, catabolism, produces simpler substances as a result of the break-down of complex ones, releasing energy. Metabolic reactions occur continuously and simultaneously in living organisms and when they cease the organisms die.

The organisation of life

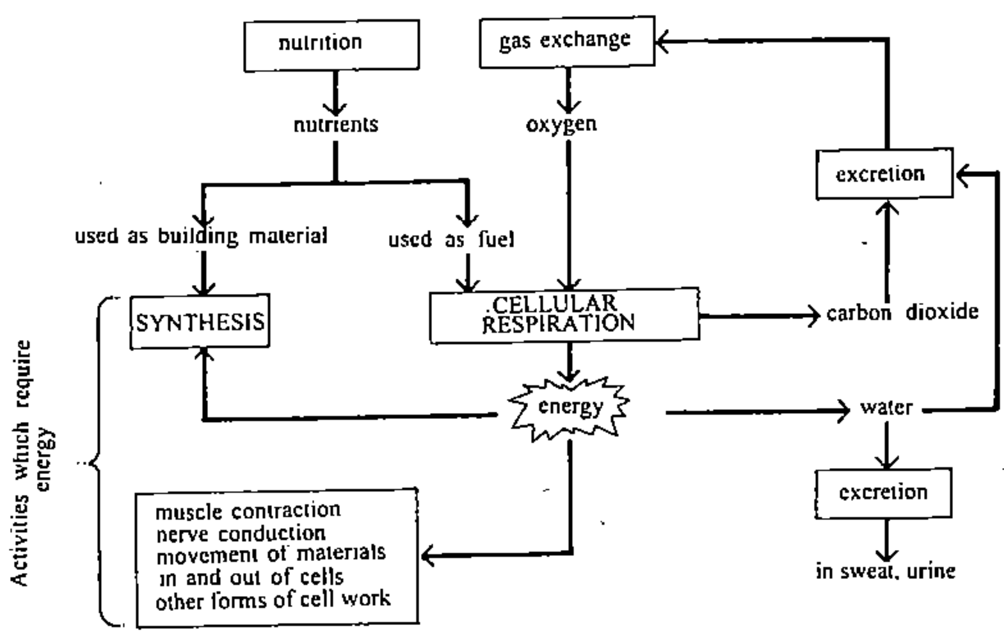



**Fig. 1.2: Metabolic (anabolic and catabolic) reactions occur continuously in every living organism. This figure shows the relationships of some metabolic activities. Some of the nutrients ingested by the organism are used to synthesize needed materials and cell parts; other nutrients are used as fuel for cellular respiration, a process that captures energy stored in food. This energy is needed for synthesis and for other forms of cellular work. Cellular respiration also requires oxygen, which is provided by the process of gas exchange. Wastes from the cells such as carbon dioxide and water must be excreted from the body.**

Two main energy pathways are recognised in living systems. These are **photosynthesis** and **cellular respiration.** Both have their respective but different **electron transfer chains.** During photosynthesis carbohydrates are synthesized from carbon dioxide and water in the presence of sunlight and the green pigment chlorophyll. This is an anabolic process. In this process radiant energy of the sun is converted into chemical energy and stored in the chemical bonds of carbohydrates.

The sun is the ultimate source of energy for all activities of living matter.

Cellular respiration on the other hand is more or less a reverse process of photosynthesis. During cellular respiration complex carbon compounds, especially the carbohydrate molecules break down into carbon dioxide, releasing energy. This is a catabolic reaction. Fats and proteins also undergo catabolic reactions. The energy released is used by the living system for various activities. To be more precise, energy released during biological oxidation of the complex carbon molecules such as carbohydrates fats and protein, is trapped by the organism into adenosine triphosphate (ATP). ATP is a high-energy phosphate, which can be stored in the cell. From this stored ATP, energy, can be tapped instantaneously. This is the source of energy for various activities of organisms. The electrons released during the process are passed on through a series of electron carriers in the electron transfer chain within the mitochondria where essentially hydrogen and oxygen combine to form water. You would have studied more about these aspects in Cell Biology. (Unit 11 and 12, Block 3).

Adenosine-Tri-Phosphate (ATP) has often been compared to a charged battery. It gives away at short notice one high energy phosphate along with the energy linked to it for work and gets itself "discharged" to Adenosine Diphosphate (ADP). The "discharged" ADP again gets charged to ATP as a result of biological oxidation. Thus, energy is stored in the cells in the form of "charged" ATP, ready for use at the time of necessity.

In nonliving matter such complex energy conversions do not occur.

### 1.2.4 Growth and Development

You must have seen beautiful plants growing in pots in a garden. The plant grows while the pot does not. As a rule living things grow, but non-living things do not. Some non-living things however appear to grow. For example, if you suspend a crystal of alum or common salt in its saturated solution you find an increase in the size of the crystal due to the deposition of more alum or common salt around it. But if you suspend the crystal in its solvent, water, you will find that the crystal becomes smaller and may ultimately disappear. If you repeat the experiments with the plant, you will observe that the plant does not decrease or disappear. Evidently the growth of the plant takes place by the addition of more living matter. A plant or animal usually starts its existence as a minute cell, not more than a fraction of a millimetre in diameter and grows to enormous size. The process by which a single cell becomes a full-fledged individual is known as development. It involves not only an increase in size but an increase in complexity as well. Growth and development are important characteristics of living beings.

Growth involves an increase in the size of cells or an increase in the number of cells, or both. It occurs when the organism takes in food from the environment, for example, food and organises it into its own structures. A cat can live on the same food that we eat. The cat however, converts the food into its own tissues becoming a bigger cat whereas we transform the food we eat into our tissues and grow as humans. In each instance the characteristic pattern into which the nutrients are assembled is goverened by the information encoded in the genes.

### 1.2.5 Reproduction

Living things do not arise spontaneously. They arise only from pre-existing living things. This is one of the fundamental tenets of biology. The ability of an organism to reproduce its kind is characteristic of living things. Reproduction involves transmission of information by the remarkable hereditary material deoxyribonucleic acid (DNA) contained in the nucleus. The heriditary material is subject to change or mutation. When provided with necessary conditions the DNA molecule is capable of replicating itself. The DNA codes for the information regarding structure and function of the organisms. For example, DNA ensures that cats always produce kittens, never pups.

In simple organisms such as protists, reproduction may be asexual. For example, a protist like amoeba reproduces by simple division (Fig 1.3a). When the amoeba grows to a certain size it makes a duplicate copy of its DNA, each copy separating into a nucleus. The amoeba divides into two, each daughter amoeba thus possessing a nucleus with a copy of DNA. However, higher plants and animals reproduce sexually. This involves the union of a male gamete and a female gamete (Fig. 1.3b). The male gamete is the sperm whereas the female gamete is the egg. The sperm fertilizes the egg to form a zygote which then developes into a new individual. Each gamete has one complete

Amoeba and its allies live for ever unless eaten by an organism or destroyed by adverse environmental conditions. Thus the amoeba does not die. Usually it becomes a part of the new generation.

copy of genes (DNA) derived from its parents. So gametes are haploid. Union of two gametes and fusion of their nuclei result in the doubling of the DNA content in the zygote, which is hence diploid. All cells derived from the zygote are diploid. Thus, each offspring is not a mere duplicate of a single parent but is the product of the interaction of various genes (DNA) contributed by both mother and father. This results in genetic variation which is important from the point of view of evolution and adaptation. Thus, though an individual dies, it perpetuates itself by the process of reproduction, and the race continues.

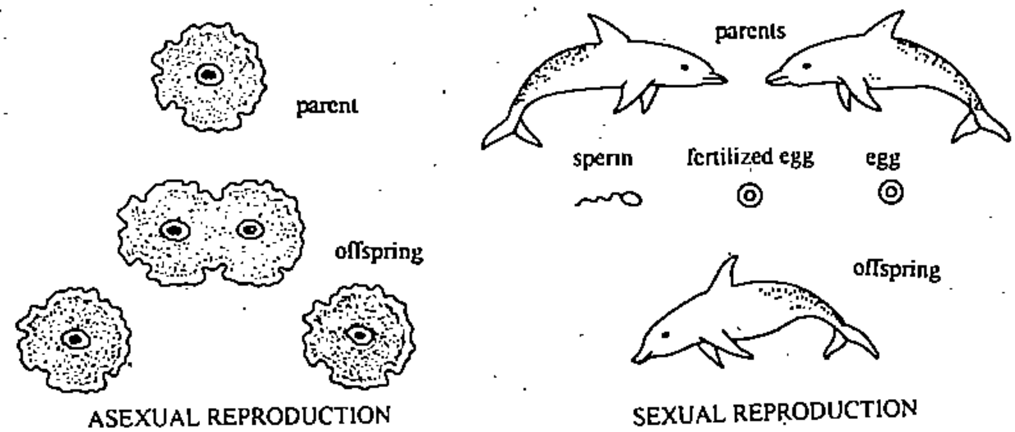



**Fig 1.3: Approaches to reproduction – (a) in asexual reproduction, one individual gives rise to offsprings which are identical to the parent. (b) In sexual reproduction, each parent contributes a sex cell; these join to give rise to the offspring which thus has the genes and traits of both parents.**

### 1.2.6 Irritability

If a bright torch of light is flashed across your eyes, you close your eyes instinctively. The bright light acts as a stimulus (pl, stimuli) and closing your eyes is the response or irritability. Irritability is the organism's response to a stimulus by complex adaptive activity, and is one of the most important characteristics of living organisms. All living things are capable of responding to different kinds of stimuli. Some of the common stimuli are light, heat, gravity, sound and various chemicals. The stimuli may be external i.e., in the environment outside the body or internal i.e., in the environment within the cells or around the cells but within the body. In higher animals there are highly specialized sense organs for receiving specific stimuli, as the human eye or ear. In simple organisms, such highly specialized organs or even specialized cells may be absent, though the whole organism may respond to stimuli.

At first you may think that plants do not respond to stimuli. However, on close examination you will note that plants also respond to stimuli such as light, gravity and water by orienting their growth towards or away from the stimuli. Some plants, like *Mimosa* (sensitive plant), Venus's fly trap (Fig. 1.4) respond to touch just like animals.

Response of an organism to stimuli involves coordination. Even the simplest organism consists of several parts and each of these must do the right thing and work in harmony for an adaptive response. In animals, nervous and endocrine systems coordinate to bring about responses accomplished by the effectors. Muscle and glands are the important effectors in animals. Plants have no nervous system and rely mainly on hormones for their coordination.

The ability to respond to stimuli or irritability is not shown by non-living things.

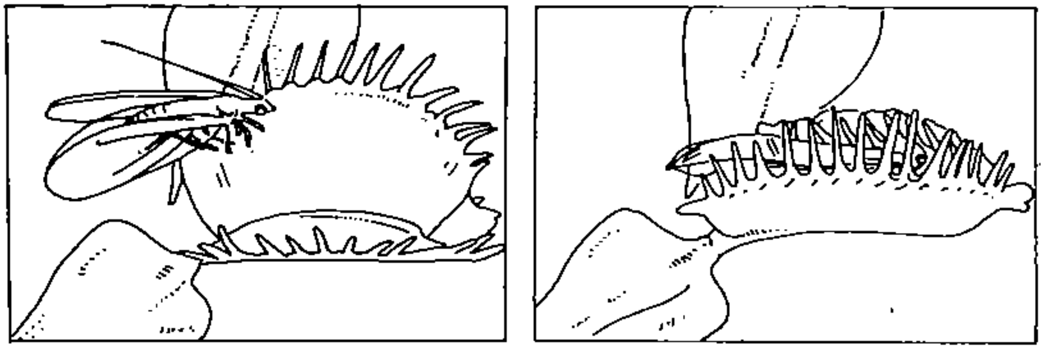


Fig. 1.4: A few plants, such as the Venus's flytrap, can respond to the touch of an insect by trapping it. This figure shows a leaf of the Venus's flytrap attracting and capturing an insect. The leaves of this plant have a scent that attracts insects. When trigger hairs on the leaf surface sense the presence of an insect, the leaf, hinged along its midrib, folds. The edges come together and hairs interlock, preventing the prey from escaping. The leaf then secretes enzymes that kill and digest the insect.

### 1.2.7 Adaptation

Closely related to irritability is the capacity of living things for adaptation. You might have noticed that whenever you go outside in the bright sun after having been in a dark room for some time, you feel uncomfortable and the light too intense. However, within a short time you cease to feel so and become quite at home in the sun. You have adjusted or 'adapted' to the new environment. Establishment of this sort of harmony between the organism and its environment is called adaptation (Fig. 1.5). The ability of the plants and animals to adapt to their surrounding enables them to survive the vagaries of the ever-changing environment. For instance, the fish like body of the whale is an adaptation for living in the sea water. The long beak of the nectar-sucking birds is an adaptation for sucking nectar from the flowers.

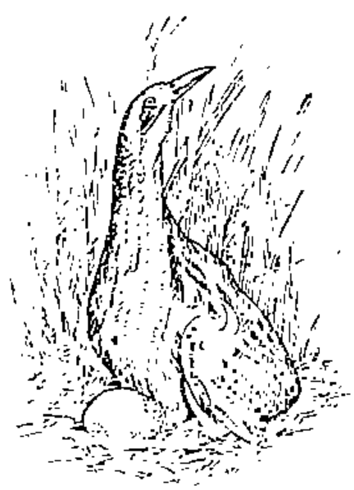


Fig. 1.5: The patterns on the feathers of the female bittern bird look like reeds. This hides her while she incubates her eggs.

### 1.2.8 Homeostasis

Homeostasis may be defined as the maintenance of constancy in the internal environment of the organism. This is essential for maintenance of life. Without homeostatis life ceases to exist. For example, your blood cells will cease to work and will be dead unless they are bathed in a medium which closely approximates blood in its composition. Your body works in such a manner that the blood composition always remains much the same. Maintenance of this harmony is due to homeostasis. The regulation of our body temperature is also an example of the operation of homeostasis mechanisms. When our body temperature rises beyond 37° C, the body senses the rise in temperature by special cells in the brain which function like a thermostat. The cells send nerve impulses to the sweat gland to increase sweat secretion (Fig. 1.6). The evaporation of the sweat from the body surface lowers the body temperature; other nerve impulses cause dilation of the small blood vessels (capillaries) in the skin making it look flushed. The increased blood flow brings more heat to the body surface to be radiated away. Non living objects do not possess such a system.

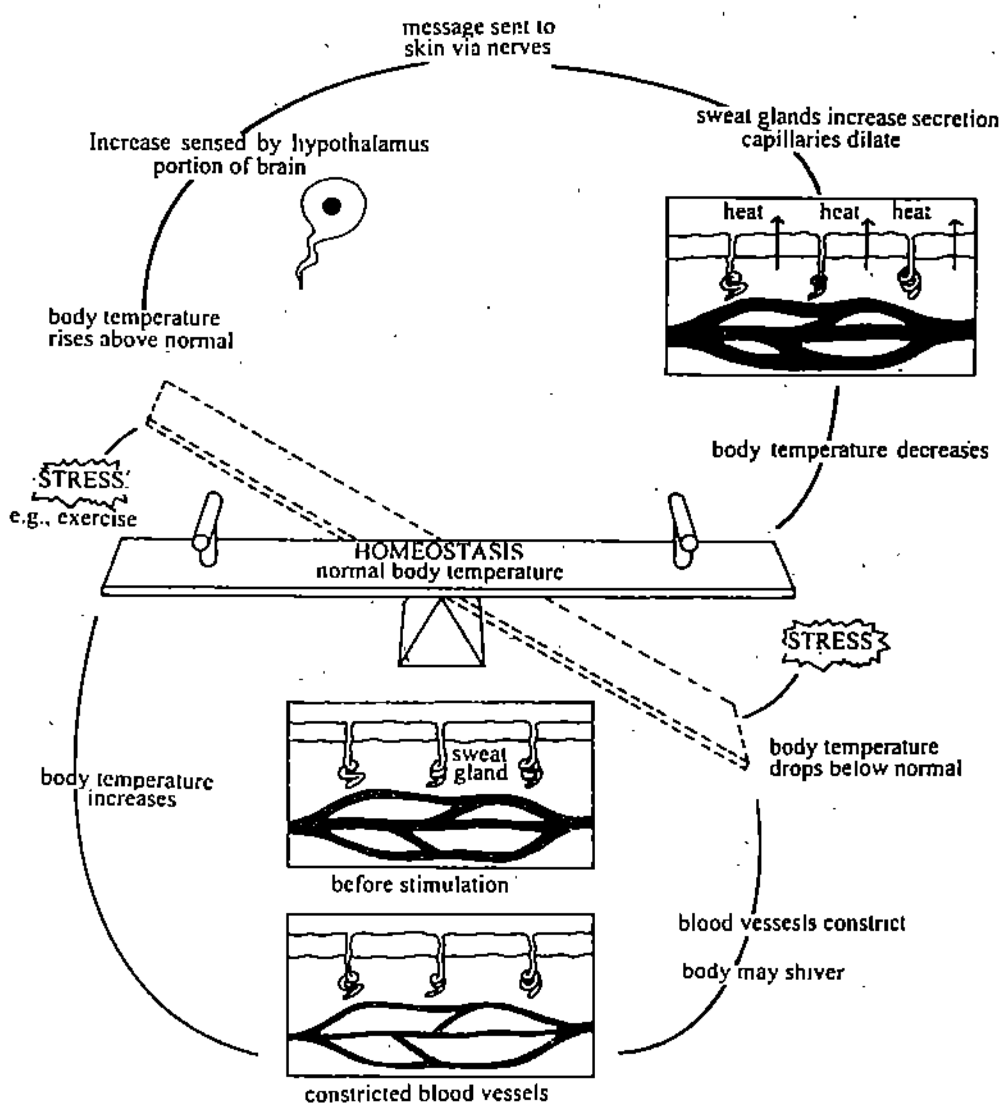



**Fig. 1.6: Body temperature in the human is regulated by homeostatic mechanisms. An increase in body temperature above the normal range stimulates special cells in the brain to send messages to the sweat glands and capillaries in the skin. Increased circulation of blood in the skin and increased sweating are mechanisms that enable the body to get rid of excess heat. When body temperature falls below the normal range, blood vessels in the skin constrict so that less heat is carried to the body surface. Shivering in which muscle contractions generate heat, may also take place.**

## 1.2.9 Movement

Movement is another characteristic of living things. It does not always mean locomotion or movement from one place to another. In animals movement is quite obvious. We move our arms and legs; we also move from place to place. Most animals can move in this manner at least at some stage of their life. Movement in plants is not so obvious. However, if you observe plant cells under a microscope, you can see streaming movement of cytoplasm within them. This is called cyclosis. Some plants like *Mimosa* and Venus's flytrap (Fig. 1.4) show obvious movements, as you have read before.

The mode of locomotion in animals varies. Some lower animals move about by the beating of tiny hair like cilia or longer flagella. Some like amoebae move about using pseudopodia, which are temporary extrusions of cytoplasm. A few animals such as sponges, corals, oysters and certain parasites do not move from place to place. However, most of these have free swimming larval stages. Morever, even in the sessile adults, cilia or flagella or tentacles move rhythmically.

Thus you find that one or more of the above characteristics distinguish living things from the non-living. However, the most important of these criteria is **reproduction** because that is the most unmistakable characteristic of living things.

SAQ 1

Indicate which of the following statements are true (T) or false (F).

a) Flickering flame of a candle is living.

b) Dried seeds of pea stored by a farmer are non-living.

c) The ultimate source of energy for all plants and animals is the sun.

d) A molecule of DNA is non-living, like any other organic compound.

## 1.3 VIRUSES: A BORDERLINE CASE BETWEEN LIVING AND NON-LIVING THINGS

Viruses are subcellular, ultramicroscopic infectious agents of 20 nm-300 nm size range. Many of them cause diseases like polio, dengue, small pox, measles, rabies, common cold etc., in animals and mosaic, dwarfing, curling etc. in plants. They are obligate intracellular parasites. In other words, they multiply only inside living cells. They consist of a protein coat or capsid surrounding a nucleic acid core of either DNA or RNA.

1 millimetre (mm) = 1/1000 metre (m)
1 micrometre (μm) = 1/1000 mm
1 nanometre (nm) = 1/1000 μm

Viruses were discovered in 1892 by a Russian biologist Iwanowsky, as 'filter-passing agents' though they were seen much later, with the advent of electron microscope. They share certain characteristics of both living and non-living things. So it will be useful to examine the properties of viruses. They are considered living because they can reproduce even though only when they are inside host cells, using the host cell machinery. On the other hand, they have some nonliving properties as well. When they are outside the host cell they can also undergo crystallisation like any other chemical substance. They do not have metabolism and so are metabolically inert. They cannot take up metabolic substances from the environment and lack the biochemical machinery like ribosomes or ATP generating systems to synthesize nucleic acid and proteins. They do not have their own enzyme system. They also do not exhibit growth or respond to stimuli.

Viruses have thus two phases to their existence (i) Inside their host cells where they exhibit certain living characteristics, (ii) outside their host where they appear as discrete particles, and can be considered non-living. You can thus see that viruses exist on the borderline between living and non-living things. They show living traits when present within the host cell; out of the living host cell they are just like any other non-living particle.

Viruses occur in a wide variety of shapes. Some are spherical or polyhedral (Fig. 1.7a). Some are helical appearing cylindrical or rod-like (Fig. 1.7b) and other are complex (Fig. 1.7c). Viruses are usually classified on the basis of their hosts, as for example, animal viruses (infecting animal cells), plant viruses (infecting plant cells) and bacteriophages (infecting bacterial cells).

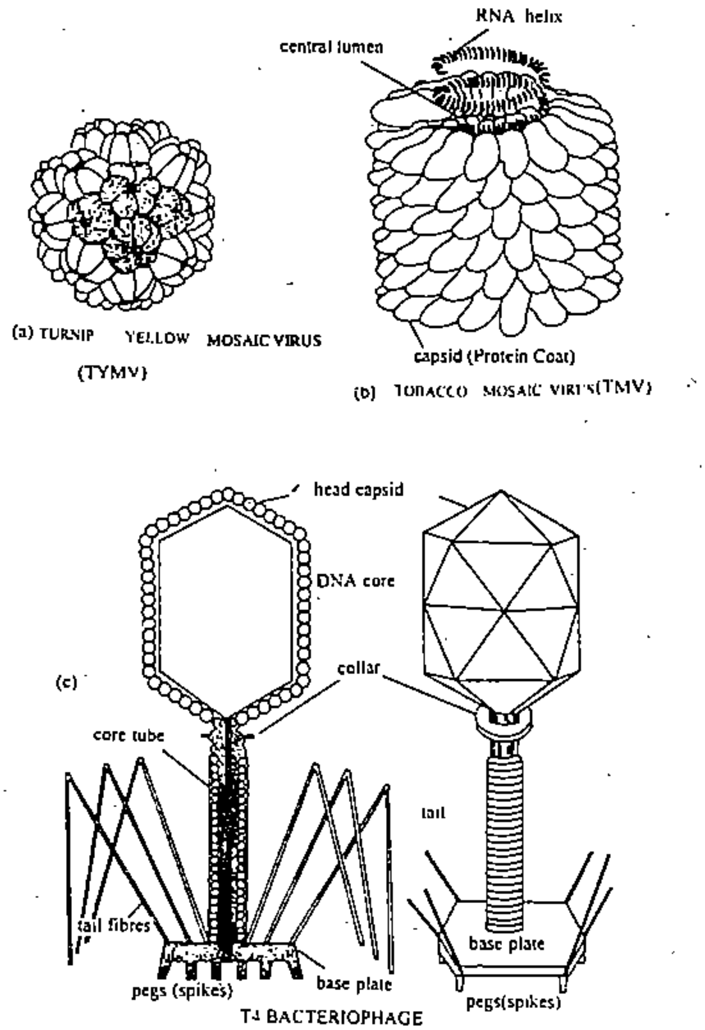



**Fig. 1.7: Different shapes in viruses: (a) Spherical, (b) Helical, and (c) Complex**

**SAQ 2**

Fill in the blanks:

a) Viruses can reproduce only inside a ____________ ____________.

b) The size of the virus is expressed in terms of the unit ____________, as the viruses are very small.

c) Viruses were discovered as 'filter-passing agents' by a Scientist named ____________ in the year ____________.

d) A virus is made up of a central core of ____________ and a protein coat known as ____________.

e) Viruses are ____________ only when inside their host.

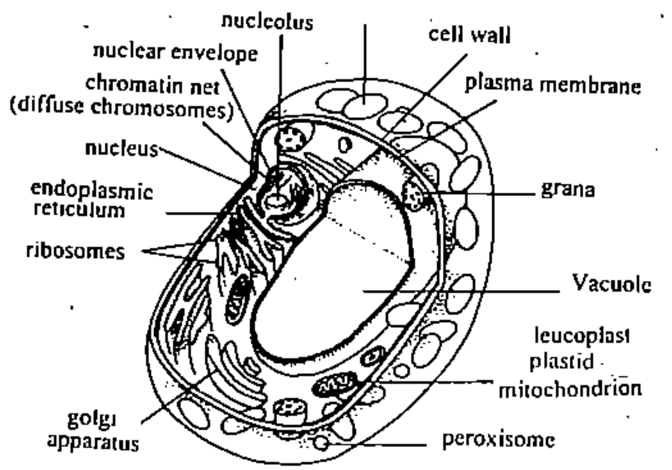
## 1.4 ACELLULAR AND CELLULAR ORGANISMS

After studying the previous section you should be able to characterise living and non-living matter. However, the boundary-line between the two is not very precise. As you have read there are forms such as viruses which do not obey many of the above criteria. Their structure is also quite different from that of the other living organisms. Thus we say that most organisms are made up of cells, or they have cellular organization. On the other hand, viruses are non-cellular or acellular. This brings us to the concept of cell, and cell theory.

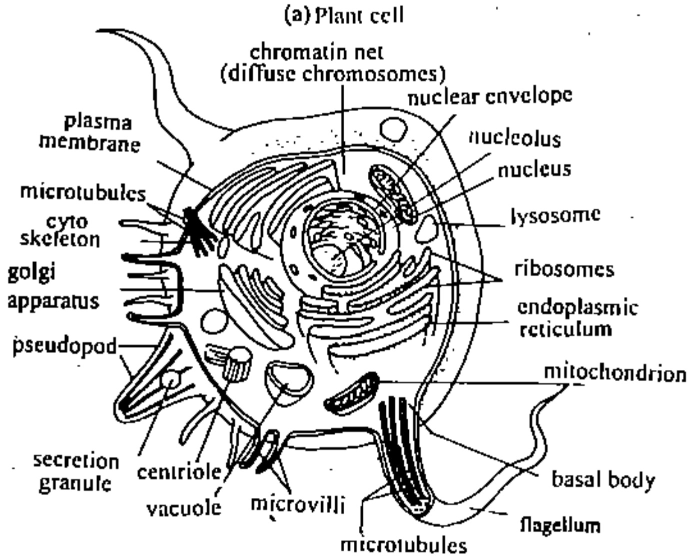
### 1.4.1 Cell Theory

The invention of the compound microscope in the 17th century stimulated the interest in living things not visible to the naked eyes. Thus, Robert Hooke discovered 'cells' in 1665 by examining cork slices under a crude microscope. He was actually describing the spaces occupied by the cells limited by the cellulose walls. Hooke and his contemporaries also described cells from other plants and animals.

However, cell theory, one of the greatest and most basic generalizations of biology, was formulated only about 200 years later. Two German investigators, Schleiden, a botanist (1838), and Schwann, a zoologist (1839) are credited with presenting independently the first concise, yet comprehensive, statements about the cell. They pointed out that, **"All plants and animals are made up of small fundamental units called cells and that some organisms are unicellular and others, multicellular."** Subsequent research led to the expansion of this concept by including further information on cells. We know that cells are surrounded by cell membrane and contain cytoplasm and nucleus (Fig. 1.8a and b) and, most importantly, cells divide into roughly equal daughter cells by a process called cell division. Thus it became known that new cells come into existence only by the division of previously existing cells. In other words, cells do not arise by spontaneous generation from nonliving matter. It follows that all cells living today can trace their ancestry back to those which existed in ancient times.




(a) Plant cell




(b) Animal cell

**Fig. 1.8: A generalized plant (a) and animal (b) cell. No one cell of either plant (a) or animal (b) has all the characteristics shown in these composite figures. Both these are eukaryote cells, which means each has a nucleus, the more or less spherical body with the double membrane or nuclear envelope, inside of which the genetic material and the dense nucleolus are separated from the rest of the cell. Within the cell's plasma membrane is a semifluid mass called cytoplasm in which are present a number of organelles and internal membranes. Both plant and animal cells have mitochondria in which food molecules are oxidized, Golgi apparatus in which manufactured cell**

materials are collected, ribosomes on which proteins are synthesized, and an endoplasmic reticulum of variable internal membranes that communicate with both the nucleus and the plasma membrame. However plant and animal cells also differ. One of the most prominent features of the plant cell is its huge vacuoles filled with cell sap. Vacuoles occur less frequently in animal cells and are usually smaller. Plant cells are encased in a thick, semirigid cell wall. The animal cell shape is more variable due to a shifting, dynamic fibrous cytoskeleton of microfilaments and microtubules. (Plant cells may have microfilaments and microtubles at some stage of growth). Centrioles are typically seen in animal cells, while plant cells often contain plastids, including the photosynthesizing chloroplasts and the leucoplasts, in which starch gains are stored, and peroxisomes, which neutralize hydrogen peroxide. The cell surface of the animal cell may be thrown up into absorbing microvilli or grasping pseudopods; some animal cells have motile, complex flagella or cilia with their associated basal bodies. Higher plants lack cilia or flagella, although ferns and lower plants have motile sperm cells with flagella. Organelle lysosomes are found exclusively in animal cells.

### 1.4.2 Exceptions to the Cell Theory

Syncytial cells are formed either when nuclear division is not followed by cell division, or by fusion of cells. These are thus only special cases and occur when individual nuclei are not separated from each other by cell membrane but are contained within a common cytoplasm limited by a common cell membrane.

Viruses, however, are not the only exception to the Cell Theory as formulated earlier. This has led scientists to take a much broader view of the problem. In Fig. 1.9 you will see some organisms like a bacterium, blue-green alga, mycoplasma, amoeba, *Chlamydomonas* and *Mucor* are composed basically of a single cell. In such cases we face another problem. You have so far learnt that the cell is the basic structural unit of an organism, something like bricks in a building. But in the examples cited above just a single cell constitutes the whole animal, which amazingly performs all the body functions like respiration, digestion, excretion, etc. The problem is further complicated by the occurrence of many multinucleate protozoans, multinucleate animal tissues etc. For example a species of amoeba, *Chaos* as well as also many other protists like the ciliate *Opalina* have many nuclei in their body. The common pond plant *Nitella* has giant cells with many nuclei in the cytoplasm. There are also tissues and cells in our body which have many nuclei. Such cells are called syncytial. For example, the striated muscle fibres of our body are syncytial in nature.

The problems listed above arose due to the fact that Cell Theory was proposed on the basis of observations on multicellular organism. This created a wrong notion that single celled organisms were totally comparable to a cell of multicellular organisms.

It is however, now established beyond any doubt that as it stands today, the present unified Cell Theory given below, is universally applicable with equal force from bacteria to protozoa to humans except for viruses.

### 1.4.3 Present Unified Cell Theory

An extension of the cell theory is required to explain the existence of unicellular organisms and in particular, organisms like viruses. Though viruses are considered living, their body organisation is acellular or non cellular.

The present unified cell theory states that (1) all living things are composed of either a single cell or of the cells and cell products. The cell is a mass of protoplasm limited by a cell membrane, and possessing a nucleus; (2) new cells are formed only by division of pre-existing cells; (3) there are fundamental similarities in the chemical constituents and metabolic activities of all cells; (4) the activity of an organism as a whole can be understood as the collective activities and interaction of its interdependent cellular units.

In view of this present cell theory the living organisms may be broadly divided into:

I. **Acellular forms** with body not composed of cells, for example viruses.

II. **Cellular forms** with body composed of cells. The cellular forms may further be classified into:

   a) **Unicellular organisms** with only one cell in their body, for example bacteria, blue-green algae, protozoans, etc. and

   b) **Multicellular organisms** having many cells in their body. In such forms the cells organise themselves into tissues, tissues into organs and organs into organ systems. Examples of these are animals ranging from sponges to man and plants ranging from most algae to all flowering plants.

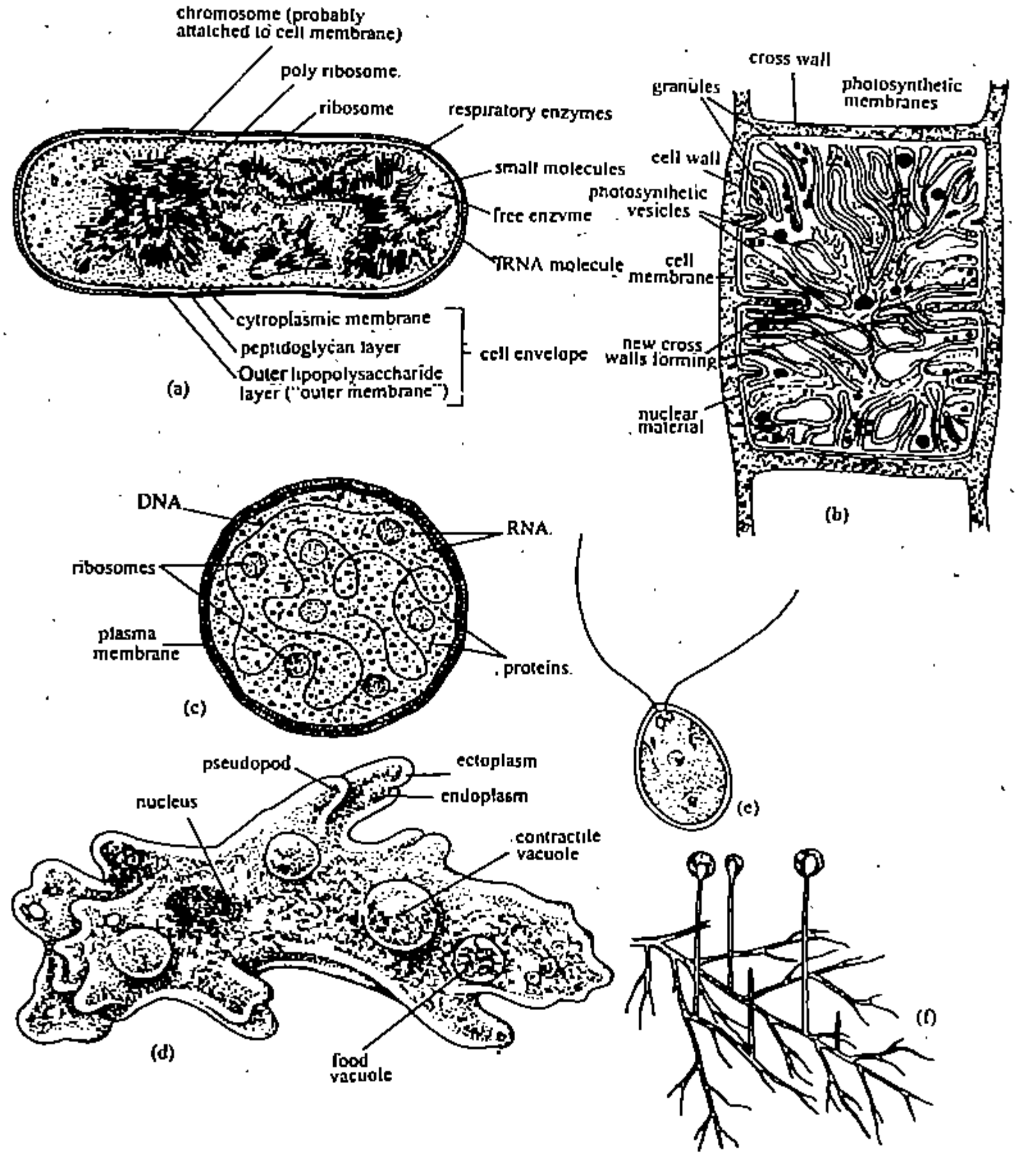



**Fig. 1.9:** Some unicellular organisms: (a) Bacterium (*Escherichia coli*), (b) Blue green alga, (c) Mycoplasma, (d) *Amoeba* (a protozoan), (e) *Chlamydomonas* (an alga), and (f) *Mucor* (a fungus).

**SAQ 3**

State which of the following statements are true or false:

a) The cell theory was formulated independently by Schielden and Schwann. (T/F)

b) Both plants and viruses are formed of fundamental units called cells. (T/F)

c) Some cells do arise spontaneously. (T/F)

d) Cells differ in their chemical constituents and metabolic activities. (T/F)

e) The collective activities and interaction of interdependent cellular units characterise the functioning of an organisms. (T/F)

## 1.5 PROKARYOTES AND EUKARYOTES

By now, you know that cell theory holds good for all living forms. However, if you examine under the microscope, the cells of a bacterium (Fig. 1.9a), a blue green alga (Fig. 1.9b) or a mycoplasma (Fig. 1.9c) on the one hand and an amoeba (Fig. 1.9d), or a *Chlamydomonas* (19e) or an individual cell of a multicellular (Fig. 1.9f) organism, whether plant or animal (Fig. 1.8a and 1.8b), on the other, you will note a distinct difference between the two groups. You will not see a well formed nucleus in the first group of organisms, as they do not have a discrete nucleus and their nuclear material is not surrounded by a nuclear membrane. You will however notice that members of the other group consisting of amoeba or *Chlamydomonas* or an individual cell of a multicellular organism whether plant or animal are characterised by a distinct well formed membrane bound nucleus, called karyon (also written as caryon). From an evolutionary point of view, absence of the membrane-bound nucleus is considered primitive while its presence is deemed advanced. Therefore, biologists have coined two separate terms to denote the two categories of organisms i.e., the **prokaryotes** or **procaryotes** whose cells lack a membrane-bound nucleus and **eukaryotes** or eucaryotes whose cells have discrete nuclei.

The prokaryotes also differ from the eukaryotes in many other ways, as you can see from Table 1.3.

**Table 1.3: Differences between the cells of Prokaryotes and Eukaryotes.**

| | Feature | Prokaryotes | Eukaryotes | |
|---|---|---|---|---|
| | | | Higher Plants | Animals |
| 1. | Size | 0.2-500 µm; mostly 1 µm | 30-50 µm | 10 µm – 20 µm; mostly 10 µm |
| 2. | Cell wall | Usually non-cellulosic and made up of peptidoglycan. | present; largely cellulosic, | absent |
| 3. | Endomembranes | Absent | Present | Present |
| 4. | Nuclear membrane | Absent | Present | Present |
| 5. | Chromosome | Single, circular. No histones | Multiple, linear; complexed with histones | Multiple linear; complexed with histones |
| 6. | Nucleolus | Absent | Present | Present |
| 7. | Division | Amitosis | Mitosis or Meiosis | Mitosis Meiosis |
| 8. | Sexual - Reproduction | Rare | Common | Common |
| 9. | Ribosomes | Smaller, 70s | Larger, 80s | Larger, 80s |
| 10. | Mitochondria | Absent; respiratory enzymes associated with plasma membrane | Present | Present |
| 11. | Plastids | Absent; photosynthetic enzymes are associated with plasma membrane | Present | Absent |
| 12. | Flagella or cilia (when present) | Present ; simple; made up of single microfibril. | Absent* | Present ; complex made up of nine peripheral and two central micro-fibril (9+2 pattern. |
| 13. | Endo and exocytosis. | Absent | Absent* | Present. |

Note : * Although absent in higher plants, these features occur in more primitive plants. Apparently they have been lost during the course of evolution.

**SAQ 4**

Give one word substitute for the following statements:

a) The organisms whose body is not made up of cells —

b) The cells which do not possess a membrane —

c) The type of cells containing endomembranes —

d) Animal and plants made up of only one cell —

e) Organisms made up of many cells —

## 1.6 CLASSIFICATION OF LIVING ORGANISMS

The world of living organisms is extremely diverse. Biologists call these diverse forms 'species'. It is estimated that over fifteen lakh (1.5 million) species of living animals and plants are known, and more are yet to be discovered. On the other hand, millions of species have become extinct or have disappeared from the surface of the earth. Individual of each species may be male or female, young or old and vary in shape, size, colour etc. The diversity of both extant and extinct animals and plants is so vast and confusing that it would be almost impossible for you to make any sense out of it unless it is arranged in some order. Arranging animals and plants into groups in an orderly manner on the basis of their similarity and relationships is called classification. This branch of science is known as **taxonomy**. Ernst Mayr, define, "taxonomy as the theory and practice of classification".

The term 'Lakh'and 'Crore' are predominantly used in India, and have their origin from Sanskrit roots. In other countries, 'Million' is the prevalent form, but note that :

1 lakh = 1,00,000
1 million = 1,000,000 (10 lakhs)
1 crore = 10,000,000.

### 1.6.1 Species — An Important Concept in Classification

You have by now already come across the word 'species'. The word has a definite meaning in biology. Although the living world is vast and variable, scientists recognise well-defined forms or kinds of animals and plants. These kinds are the **species** (singular also is species). Ernst Mayr (1969) in his **Principles of Systematic Zoology**, has given a good definition for species. According to him. "Species is a group of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups". However, in a great many cases this stringent definition or criteria cannot be applied, and so in practice the identification and description of species is largely based on morphological and anatomical features. Normally the species is the lowest category of grouping used in taxonomy.

### 1.6.2 Binomial Naming of Organisms (Binomial Nomenclature)

The modern system of classification (Binomial nomenclature) accepted by biologists today was proposed in 1758 by the Swedish botanist Linnaeus (1707-1778) in his **'Systema Natura'**. This system was based on morphology. Linnaeus proposed that each type of organism should be given a unique Latin binomial (consisting of two terms) to set it apart from every other type of organism. The first word in this binomial designates the genus to which the species belongs. A genus (plural: genera) contains one or more closely related and similar species. The second word in the binomial denotes the species itself. For example, according to this system, the domestic cat is *Felis domestica*. This indicates that the domestic cat has been placed in the genus *Felis* and within that genus, has been given the specific or species epithet *domestica*. This complete name distinguishes the domestic cat from other species in the genus *Felis*, such as *Felis bengalensis* (leopard cat) and *Felis chaus* (jungle cat), all found in India. It also means that all species coming under the genus *Felis* are more closely related and similar to one another than to species coming under any other genus. The generic name always begins with a capital. The specific name on the other hand begins always with a small letter. Both the generic and the specific names are italicised in print or are underlined in manuscript or typescript.

Viruses currently do not have binomial names. They are often named either after the place, involved in their identification (eg. Sendai Virus) or after the diseases or symptoms they cause eg. Polio Virus, Human Immuno-deficiency Virus. Tobacco Mosaic Virus. There have also been various attempts to classify viruses into families and other higher categories based on their host range and the tissues they invade. etc. A better system of classification of viruses, based on their unchanging characters is at present being worked out.

### 1.6.3 Classifying Organisms

You have now seen that the binomial nomenclature gives each species a unique and unambiguous name. It is necessary to group species into genera and genera into higher categories, as this would reveal more information regarding their similarities and relationships to one another. Thus, a number of closely related genera are grouped together into a Family; a number of closely related Families into an Order; a number of closely related Orders into a Class; a number of closely related Classes into a Phylum, (or Division in case of plants) and the various Phyla (or Divisions) into a Kingdom. The highest categories thus, in classification are the Kingdoms. Fig. 1.10 shows the main hierarchal taxonomic categories used in classification and gives you an idea of the classification of organisms.

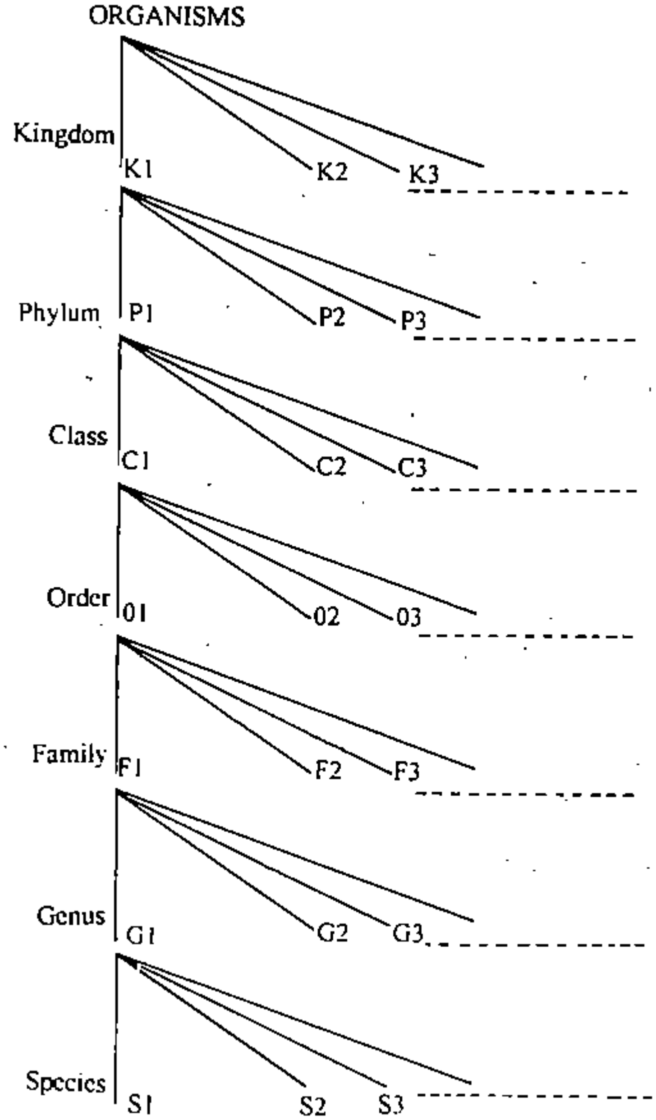



Fig. 1.10: The main taxonomic categories and the manner in which organism are classified (In plant taxonomy 'Division' is used instead of 'Phylum').

Table 1.4: Classification of *Homo sapiens* (man).

| Category | Taxon |
|---|---|
| Kingdom | Animalia |
| Phylum | Chordata |
| Class | Mammalia |
| Order | Primates |
| Family | Hominidae |
| Genus | *Homo* |
| Species | *Homo sapiens* |

The names of higher categories are often synthesized from Latin words in the same manner as generic or specific names, and always start with a capital letter (e.g. Reptilia, Amphibia, Mammalia etc.). Their vernacular versions however do not begin with capital letter (such as amphibians mammals etc.). Taxonomic terms above the level of genus and species are not italicised. Table 1.4 summarises how human beings are classified. Table 1.5 summarises the main conventions used in binomial nomenclature.

Table 1.5: Conventions for Using Binomials and Names of Higer Taxa.

| Capitalise | Examples |
|---|---|
| 1. Genus, but not species | *Ursus horribilis* |
| 2. Latin names of taxa above genus level, but not their English counterparts | Mammalia, mammals<br>Hominidae, hominids |
| **Italicise or underline:** | |
| Genus and species (binomial), but not Latin or English above genus level | *Homo sapiens*, Hominidae |

# 1.7 CLASSIFICATION SYSTEMS

## 1.7.1 Two-Kingdom Classification

The history of taxonomy is as old as man himself. It may be traced back to prehistoric times because man had learnt to designate living organisms by specific names very early in his evolutionary history. Much before the advent of civilisation living things had been categorised into animals and plants. Hippocrates (460-370 BC), Aristotle (384-322 BC) and many others had tried to put some order into the chaos of the bewilderingly large number of different life forms. Aristotle appears to have been the first to attempt a logical system of classification. He classified animals on the basis of presence or absence of blood as Sanguineous (with blood) and Non-sanguineous (without blood). He believed that in evolution, life had been directed towards a perfect animal form, having blood (Table 1.6). He incorporated this idea which is a hierachical system of classification in his book entitled *'Scala Naturae'*. He also recognised two kingdoms in the living world i.e., **Plantae** and **Animalia**. The former included mainly immobile forms, while the latter embraced mobile forms. We also know that one of the major differences between the two is that the members of Kingdom Plantae are autotrophic and obtain their food mostly by photosynthetic means and those of Kingdom Animalia are heterotrophic and obtain their food by ingestion.

**Table 1.6: Aristotle's 'Scale of life' or Scala Naturae.**

| | | |
|---|---|---|
| | | *Sanguineous* |
| VIVIPAROUS | 1. | Man |
| | 2. | Hairy quadrupeds (land mammals) |
| | 3. | Cetacea (sea animals) |
| OVIPAROUS<br>With perfect egg | 4. | Birds |
| | 5. | Scaly quardupeds and apoda (reptiles and amphibia) |
| With imperfect egg | 6. | Fishes |
| | | *Non-sanguineous* |
| | 7. | Malacia (cephalopods) |
| | 8. | Malacostraca (crustacea) |
| VERMIPAROUS | 9. | Insects |
| Produced by generative slime, budding or spontaneous generation | 10. | Ostracoderma (molluscs other than cephalopods) |
| Produced by Spontaneous generation | 11. | Zoophytes |

Kingdom Plantae was later divided by biologists into two subkingdoms,
(i) **Thallophyta** containing the phylum Algae (with chlorophyll) and Phylum Fungi (without chlorophyll) and (ii) **Embryophyta** with phylum Bryophyta (liverworts and mosses) and Phylum Tracheophyta (vascular plants). Kingdom Animalia, on the other hand, was divided into Subkingdoms **Protozoa** containing unicellular forms and SubKingdom **Metazoa** including sponges and other multicellular organisms. A third SubKingdom **Parazoa** was later created and the sponges were shifted to this SubKingdom due to their intermediate position between uni-and multicellular organisms.

## 1.7.2 Three- and Four-Kingdom Classification

The two-kingdom classification, while solving many of the problems of classification, failed to establish clear-cut distinction between plants and animals. It also could not indicate correct relationships among organisms. Difficulty was particularly felt at the unicellular level. There are forms like *Euglena* and *Volvox* which possess both plant- and animal-like characters. On the one hand like plants they contain chlorophyll and manufacture their food by photosynthesis. On the other hand they actively swim like animals. Due to this reason zoologists classified them with animals under phylum protozoa while botanists included them as plants under Thallophyta. In addition to this, there are some other organisms like *Peranema* which closely resemble *Euglena* in structure but lack chlorophyll. These are not included among plants but were always classified under Protozoa. In order to overcome such difficulties, Haeckel (1866) proposed setting up of a third kingdom under the name Protista (meaning the very first) to include all thallophytes and protozoans. This kingdom also included bacteria and blue-green algae. According to this system the old kingdom Plantae included only the members of Embryophyta while Animalia was left only with Parazoa and Metazoa. However, many forms such as blue-green algae and bacteria of Protista lack membrane-bound nuclei (you have already read in section 1.3 that such forms are called prokaryotes). So, a fourth kingdom, Monera, was later established by Whittaker in order to accommodate these forms. From the evolutionary point of view the kingdom Monera is regarded as the most primitive.

### 1.7.3 Five Kingdom Classification

You will thus find that three- and four-kingdom classifications were able to remove some of the anomalies of the two-kingdom classification system. These systems however, were not able to place appropriately the Fungi — a group of organisms which lack chlorophyll. They were classified inappropriately under protista in the four system classification despite the fact that they differed from the protista totally in form, function and behaviour. Also they could neither be considered plants nor animals, so in 1969 Whittaker erected a separate kingdom, 'Fungi', for them, thus proposing the 'Five-King Classification' (Fig. 1.11) which is generally used at present. Whittaker's classification retained the basic prokaryote — eukaryote distinction. Thus, the **Kingdom Monera** contains the prokaryotes. The eukaryotes are classified into four remaining kingdoms. The **Kingdom Protista** contains the unicellular eukaryotic organisms (Protozoa and unicellular eukaryotic algae). The multicellular organisms are split into three kingdoms on the basis of mode of nutrition and other fundamental differences in organization. The **Kingdom Plantae** includes multicellular, photosynthesizing organisms, higher plants and multicellular algae. **Kingdom Fungi** includes the moulds, yeasts and mushrooms etc. which do not have chlorophyll but obtain their food by absorption. The non chordates and the chordates make up **Kingdom Animalia.** Most of these forms ingest their food and digest it internally, although some parasitic forms are absorptive. The evolutionary relationship of the five kingdoms are shown in Fig. 1.11. The protists are believed to have given rise to all the multicellular organism, which have evolved independently.

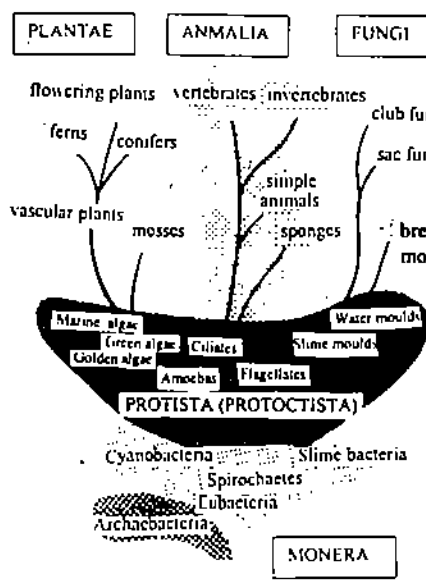



**Fig. 1.11: FIVE KINGDOM CLASSIFICATION — The five kingdoms are arranged in a manner that indicate their phylogenetic relationship to each other. The underlying kingdom, known as Prokaryota and Monera, is now being reorganized into two kingdoms, Archaebacteria (containing 'first' or 'ancient' bacteria) and Eubacteria (containing 'true' bacteria), which thus contain two obviously diverse groups of prokaryotes. Above this is the large assemblage provisionally called Protista or Protoctista. Some of its members are descended from the same lines that gave rise to plants, fungi and animals.**

At present, as you know, the trend is to follow the five-kingdom classification. However, while accepting the Five-Kingdom Classification, zoologists still treat Protozoa which comes under Kingdom Protista as the most primitive group of non chordates. This is partly because of historical reasons and partly because most zoologists are also interested in Protozoa. We have also followed the five kingdom of classification in our course. However you will also study protozoa in unit 2. Table 1.7 shows the characteristics of the five kingdoms proposed by Whittaker and followed by us in the Animal Diversity Course.

**Table 1.7: The characteristics of the Five-Kingdom proposed by Whittaker.**

| Kingdom | Characteristics |
|---|---|
| **Monera** | The earliest organisms to inhabit earth. They are microscopic, single celled prokaryotes. They lack true nuclei, but have only nuclear regions or nucleoids. The single chromosome is formed of one circular molecule of DNA not associated with any proteins. They also lack membranous organelles like mitochondria, chloroplasts etc. Mitosis or meiosis in cell division does not occur. Cells divide by binary fission. Cell walls are composed usually of peptidoglycan (a substance derived from amino acids and sugars); many secrete a capsule made of polysaccharide material. There is now a tendency to split Kingdom Monera into two separate kingdoms viz. Kingdom Archaebacteria (ancient bacteria) and kingdom Eubacteria (true bacteria). |
| | Representatives: archaebacteria, blue-green algae, actinomycetes, fruiting bacteria, rickettsias, mycoplasmas, *Bdello vibrios* etc. |
| **Protista** (Protoctista) | |
| | Protists are single celled eukaryotes; some form loose aggregations of cells called colonies. It is believed that the first eukaryotes were protists, some of which gave arise to higher eukaryotes — fungi, plants and animals that dominate the world today. |
| | Representatives: protozoa and unicellular algae. |
| **Fungi** | Diverse group of multicellular eukaryotes; plant-like but cannot carry out photosynthesis due to absence of chlorophyll. They obtain food through their surface from a living or a nonliving organic source by absorption, instead of ingesting it as animals do. In many cases they secrete digestive enzymes outside their body which break down food. The breakdown products are absorbed across the fungal wall. During reproduction fungi may produce both asexual and sexual spores. |
| | Representatives: slime moulds, moulds or true fungi, yeasts, mildew, rust, mushrooms. |
| **Plantae** | Multicellular, autotrophic eukaryotes with cell wall containing cellulose. All plants have reproductive tissues or organs and pass through distinct developmental stages and alternation of generations. Cells often have large central vacuole. Plants have indeterminate growth and often have no fixed body size nor exact shape. |
| | Representatives: multicellular algae, mosses, horse tails, lycopods, ferns and seed plants. |
| **Animalia** | Multicellular eukaryotic heterotrophs. Animals lack photosynthetic pigments and obtain nutrients by ingesting other organisms. Cells lack cell wall. Many of the members exihibit advanced tissue differentiation and complex organ systems and move about freely; characterised by quick response to stimuli, with specialised nervous tissue for coordination. Growth is determinate, mostly with definite size and shape. |
| | Representatives: sponges, jelly fishes, flat worms, round worms, segmented worms, molluscs, arthropods, echinoderms, chordates (fishes, amphibians, reptiles, birds, mammals). |

You may have observed that the Five-Kingdom-Classification of Whittaker does not include the viruses. They should probably have their own kingdom since they are unlike any other group of organisms. But kingdoms are supposed to reveal evolutionary relationships, and since the evolutionary origins of viruses are unknown, we cannot yet indicate their exact position. They are supposed to have originated after cellular organisms came into existence, because viruses depend upon the latter for their existence. So they are not the most primitive organisms from which cellular organisms have evolved.

### 1.7.4 Limitations of Five-Kingdom Classification

As already pointed out, each system of classification has its own limitations. The two-kingdom system has outlived its usefulness as it could not do justice to forms like *Euglena* and *Volvox*. The three-kingdom classification failed to accommodate properly prokaryotic forms. The limitation of the four-kingdom classification was that despite creation of kingdom Monera it failed to account for the intergradation between Protista and Animalia.

The present five kingdom system is also not the final solution to the problems of taxonomy. In this system too we have many weaknesses despite the acceptance of this system by most biologists. The exclusion of Protozoa from the animal kingdom, in this system concerns many zoologists. Protozoa share many characteristics with Metazoan animals. Most ingest their food; many have specialised organelles and advanced locomotory systems; many reproduce sexually and some flagellate protozoa are colonial with division of labour among cell types. Indeed, there is little doubt that metazoan animals evolved from one or more protozoans groups. Thus zoologists though accepting that protozoans are eukaryotic protists and not animals according to the five kingdom classification, still continue to claim Protozoa as their own. This system is also not able to show clearly the inter-relationships of various groups in all instances. Even now many phyla contain forms whose relationships are not clearly understood. Among nonchordates the grouping collectively called **Minor phyla** has unsolved problem of phylogenetic placement. Recently, many biologists have also tried to split the kingdom Monera into two: (i) Eubacteria and (ii) Archaebacteria, leading thus to the proposal of six kingdoms. In fact, during the past twenty years various revisions in the classification system have been discussed with the number of kingdoms ranging from 3-13. Biologists generally follow the five-kingdom-classification despite its inadequecies because it appears to be the most acceptable system today and indeed the most convenient one available.

### 1.7.5 Inter-relationships and Implications of Classification

The aim of classification is to put together organisms on the basis of their **similarities.** But the question is what type of similarities? You know that fish and whales live in water; birds and butterflies live in air. Should we place fish and whales, in one group and birds and butterflies in another? Perhaps you are tempted to do so because fish and whales have organs to swim; birds and butterflies possess wings to fly. One of the early biologists, Pliny, in fact, classified animals on the basis of such analogous organs, that is organs that serve the same function and have similar appearance but have different evolutionary origins. However, with the advancement in knowledge about the structure of animals it was revealed that the fish and whales or birds and butterflies have more differences than similarities between their body characters. For example, fish respire using gills while the whales have lungs for this function. Similarly, birds have an internal skeleton whereas insects like butterflies lack it; instead they have an exoskeleton. Karl Linnaeus recognised these basic differences and based his system of classification on the principle of **homology**. Homologous organs are those with the same evolutionary origin but which may not necessarily have the same appearance or serve the same function. For example, if you examine the fore-limbs of a man, the wing of a bat and the flipper of the whale (all mammals) (Figs.1.12) you will see that in each case, though the function and the appearance of each of the fore-limbs are different, their basic skeletal plan is the same and they are homologous. Furthermore, fossil records show that they all have a common evolutionary origin from the forelimbs of ancient amphibians. Thus, we conclude that all animals with pentadactyl forelimbs are related (Fig. 1.12). Thus classification based upon homology reveals an inherent relationship among groups. In other words, it tells us that all creatures sharing basic structural features are related to each other and have evolved from a common ancestor.

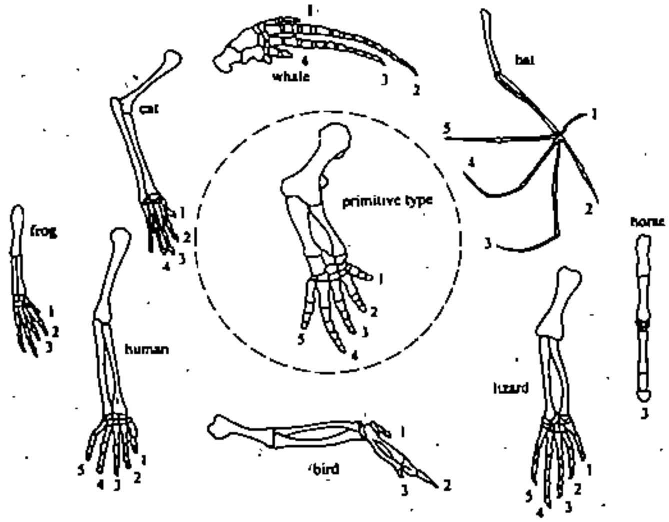



Fig. 1.12: **Homologus forelimbs of several representative vertebrates are compared with those of the suggested primitive ancestral type. In each instance, the individual bones have undergone modification, though they can still be traced to the ancestor. Since these limbs have the same embryological origin, they are said to be homologous. The most drastic changes can be observed in bird, horse, whale. Several individual bones have undergone reduction and in some cases fusion. Another obvious modification is seen in the greatly elongated finger bones of the bat.**

The implication of classification is thus to reflect a degree of kinship. On this basis one should be able to trace the evolutionary history of any group. In order to do this it would be worthwhile to keep in mind two basic postulates: one, all species in any one group, if correctly placed, should have a common ancestor; and two, no living organism is the ancestor of any other living organism. The common ancestor may not be found today in the living state and might have become extinct, leaving behind its fossilized remains.

**SAQ 5**

Tick the correct alternative in the following statements:

a) Groups of reproductively isolated interbreeding populations are called species/genus.

b) The term Protists was introduced by Aristotle/Haeckel.

c) Five-kingdom classification has raised the status of algae/fungi to the level of kingdom.

d) Organs that serve the same function but have different origin are called homologo· analogous.

e) The modern system of classification was proposed in the eighteenth centur· Charles Darwin/Karl Linnaeus.

## 1.8 SUMMARY

In this unit you have learnt that:

- Living matter possesses certain fundamental characteristics like reproduction, irritability, adaptation and homeostasis, high degree of structural organisation, capacity for acquisition and use of energy, growth and development all of which distinguish it from the nonliving matter.
- All organisms, primitive or advanced (except viruses), are composed of cells. Therefore they are called **cellular.**
- Viruses are made up of a central core of genetic material (DNA or RNA) surrounded by a protein coat or capsid. Viruses lack cellular organisation and therefore they are called **acellular.**
- Cells are of two kinds: prokaryotic, which lack an organised or true nucleus and eukaryotic having a true nucleus.

- Taxonomy is the branch of biology concerned with classification of organisms based on their relationships.
- The basic unit of classification is the species; each species is given a unique Latin binomial, one representing the genus and the other representing the species. Species are grouped into progressively more inclusive taxa (group). The main levels in the taxonomic hierarchy, from a higher to a lower category are: Kingdom → Phylum (in animal or Division in plant) → Order → Family → Genus → Species.
- Theoretically living things are classified on the basis of phylogenetic relationships. But this is often difficult; so in practice living things are often classified on the basis of morphology and anatomy.
- Different modes of classification of living organisms have been suggested from time to time. These are two, three, four- and five-kingdom classification systems. At present the five Kingdom classification is commonly used. Modern classification is based on homology and attempts to establish relationships among organisms.

## 1.9 TERMINAL QUESTIONS

1. Match the words from groups A with the most appropriate one from group B.

| List A | List B |
|---|---|
| 1. Homeostasis | a. Organisms whose cells lack a membrane bound nucleus |
| 2. Eukaryote | b. Organisms which lack chlorophyll and obtain their food by absorption |
| 3. Fungi | c. The sum total of all biochemical activities of the organism |
| 4. Metabolism | d. The maintenance of constancy in the internal environment of the organism |

2. Which do you feel is the most important criterion to distinguish a living thing from a nonliving thing?

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3. Describe in about three lines the nonliving characters of viruses.

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4. Point out two important characteristics of an eukaryotic cell.

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5. State two weaknesses of the two-kingdom classification.

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6. Briefly discuss the underlying principle of a modern classification of organisms.

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## 1.10 ANSWERS



**SAQ 1** (a) F, (b) F, (c) T, (d) F.

**SAQ 2** (a) living cell (b) nanometer (c) Iwanowsky, 1892 (d) Nucleic acid, capsid, (e) living.

**SAQ 3** (a) T, (b) F, (c) F, (d) F, (e) T.

**SAQ 4** (a) Acellular (b) Prokaryotes (c) Eukaryotes (d) Unicellular organisms (e) Multicellular organisms.

**SAQ 5** (a) Species, (b) Haeckel, (c) Fungi, (d) Analogous, (e) Karl Linnaeus.

**Terminal Questions**

1. 1 d, 2 a, 3 b, 4 c.
2. Most important characteristic of the living things in their capacity for reproduction.
3. The viruses can be crystallised; they are metabolically outside the host cell, have no enzyme system of their own and do not show irritability and growth.
4. 1. Presence of a membrane-bound true nucleus;
   2. Presence of more than one chromosome.
5. 1. Fails to clearly distinguish between animals and plants, and
   2. Does not indicate correct relationship of many organisms.
6. A modern system of classification should reflect kinship among organisms. All species in a group should share a common ancestor and classification should reveal the phylogeny of a group so that it is possible to trace the evolutionary history of that group.

# UNIT 2 THE PROTOZOANS

## Structure



## 2.1 INTRODUCTION

In the first unit you have learnt to distinguish between the prokaryotes and the eukaryotes. Prokaryotes represent only a few thousand of the estimated 2 million species of living beings known on the earth today. The rest are mostly eukaryotes that form the subject matter of the rest of this course. You have also learnt that living organisms are now classified into 5 kingdoms. Monera, Protista, Fungi, Plantae and Animalia. Of these, Protista are the primitive unicellular eukaryotes. Some of these have given rise to Fungi, others have given rise to Plantae, yet others have given rise to Animalia, all the three groups being multicellular. However, some of the Protista, though unicellular, still so much resemble Animalia that earlier, this group used to be designated **Protozoa** and was treated as a phylum under Kingdom Animalia of the two kingdom classification. Now we know that protozoans are really a heterogenous group of unicellular organisms and the term has no formal biological status. Even then, because of their similarity to animals and because most zoologists are interested in this group of organisms too and for convenience, this group is treated along with animals and thus continues to find a place in zoology text books. Following this practice we deal with protozoans also in this course. Fig. 2.1 shows broadly the five kingdom classification and its relationship to plants and animals of the two kingdom classification.

This unit is concerned with protozoans or the "animal protistans" or the unicellular animals. You will study in this unit the general characteristics of protozoans, their classification and also how to distinguish between the different types of protozoan phyla. You will also learn about some of the most common and important protozoans that parasitise human beings. Before we begin the study of classification of protozoans we will look at their general characteristics as these would help you to learn the classification of the group based on specific characteristics.

### Objectives

After studying this unit you should be able to:

- Distinguish between 'protozoans' and 'metazoans';

- list the general characteristics of protozoans;
- enumerate and distinguish between various protozoan phyla;
- discuss the various modes of nutrition, locomotion and reproduction in protozoans;
- explain how protozoans osmoregulate and respire;
- list some of the important parasitic protozoans that are found in human beings;
- outline the ways in which some protozoan parasites complete their life cycle.

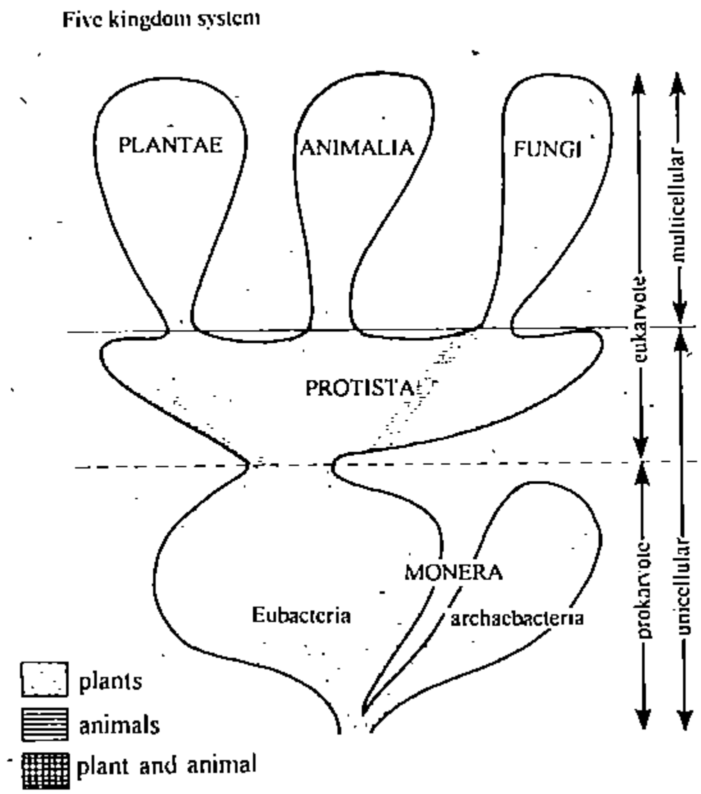


**Fig. 2.1: The Five-Kingdom System of Classification and its relationship to the plant/animal dichotomy.**

## 2.2 GENERAL CHARACTERISTICS OF PROTOZOANS

The protozoans, are eukaryotes that form a group of about 80,000 single-celled organisms under the kingdom Protista.

The unicellular level of organization is the only character which is common to all members of Protozoa. In all other respects they display extreme diversity. Protozoans exhibit all types of symmetry and great range of complexity in their microanatomical structure.

The great majority of protozoans are microscopic. They range in size from one micron as in the case of the planktonic *Micromonas* to a few millimeters like some *Amoeba* species and ciliates.

Most protozoans occur as solitary individuals but there are numerous colonial forms, for example *Volvox*. This is the earliest indication of division of labour among cells.

Protozoans are found wherever life exists. Free living protozoa occur in the sea, in various types of freshwater bodies and in the soil. There are also commensals, mutualistic and many parasitic species. Nutrition may be autotrophic, heterotrophic or saprozoic.

Reproduction may be asexual by mitotic division through budding, fission and cyst formation. Sexual reproduction by conjugation or zygote formation (syngamy) is found in some species.

Various means of locomotion through pseudopodia, flagella and cilia and direct cell movement have evolved in this group.

A protozoan, although unicellular, must be recognized as being a complete organism, carrying out all functions found in any multicellular animal. Apart from the usual intracellular structures common to all cells, protozoans possess specialised *organelles* differentiated for performing specific functions.

## 2.3 STRUCTURAL ORGANISATION AND FUNCTION

Let us now consider in this unit the ways in which the single celled protistan body plan is used by its protozoan members to become capable of adapting to varied habitats.

### 2.3.1 Body Form

The protozoan body is usually bound only by the cell membrane called **plasmalemma**. In some protozoans such as in ciliates the rigidity and the flexibility of the body is maintained by a **cytoskeleton** located immediately below the cell membrane which together with it forms the **pellicle**. The cytoskeleton is composed of filamentous proteins, microtubules or vesicles or a combinations of all three (Fig. 2.2). In many protozoans like dinoflagellates, spore forming protozoans and ciliates, vesicles occur below the cell membrane as flattened more or less continuous layer referred to as **alveoli**. They help to form a rigid skeleton.

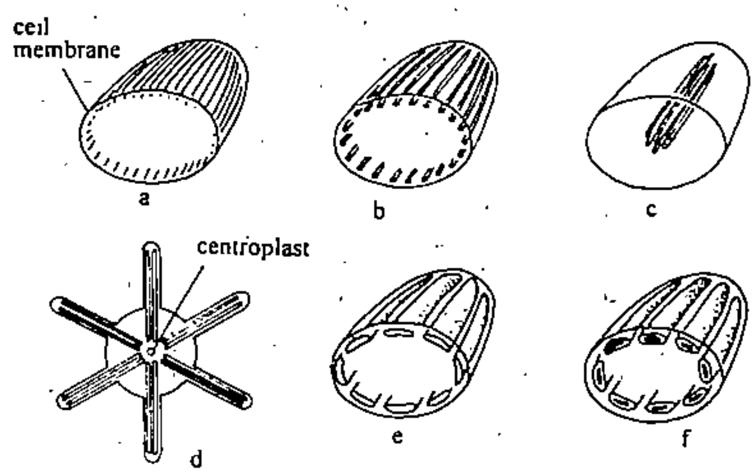


**Fig. 2.2: Endoskeletons of Protozoans**

a) **Filamentous proteins form dense mesh called epiplasm Eg. *Euglena* and some ciliates**
b) **microtubular corset in flagellates, in spore forming protozoa and some ciliates**
c) **axial skeleton of microtubes**
d) **axopod microtubules radiate like stars from centroplast**
e) **'Empty' alveoli of ciliates**
f) **Cellulose plates in alveoli of dinoflagellates form rigid skeleton.**

Exoskeletons secreted onto the outer surface of the cell are also seen in a large number of protozoans. These protozoans secrete layers of certain organic materials like gelatin, cellulose or tectin (a mucus like substance) around their plasmalemma. Some secrete an organic matrix containing minerals like silica or calcium carbonate. Often foreign bodies such as sand particles also get mixed up with the organic matrix to strengthen it. These chemicals organise to form theca, shell, lorica or cyst in different protozoans to provide protection.

(a) **Theca** — It is a close-fitting hard structure around the plasma membrane, mainly composed of cellulose. It can be compared with the cell wall of a plant cell. Theca can be one to many layers thick but still remains flexible; sometimes it may become rigid after getting impregnated with inorganic salts. The surface of theca can be smooth and plain or rough and ornamented e.g. *Glenodium* (Fig. 2.3a)

b) **Shell** — Majority of protozoans posses an exoskeleton in the form of a shell, also called test. The shell forms a loose covering around the body of the animal. It may have one to many apertures, through which pseudopodia of the animals can be protruded. The shells vary in their structure, material and mode of formation in different protozoans and are generally composed of:

i) Organic material i.e. chitin or tectin also known as pseudochitin as found in *Arcella* (Fig. 2.3b).

ii) Inorganic matter such as small sand grains or diatom shells, echinoderm plates etc., glued together by a chitinous or pseudochitinous secretion as in *Difflugia* (Fig. 2.3c). Shells of Foraminiferans (amoeboid protozoans) are beautiful and are chiefly composed of calcium carbonate (see Fig. 2.16 in sub-section 2.4.2).

c) **Lorica** — It is a covering which unlike the theca fits loosely around the organism. It is a cup, bell or vase-like structure with one opening through which protrude the animal's appendages or the anterior part of the body. In solitary protozoans, the lorica may or may not possess a stalk. *Cothurnia* which occur in couples, are contained in tectinous lorica and are stalked (Fig. 2.3d).

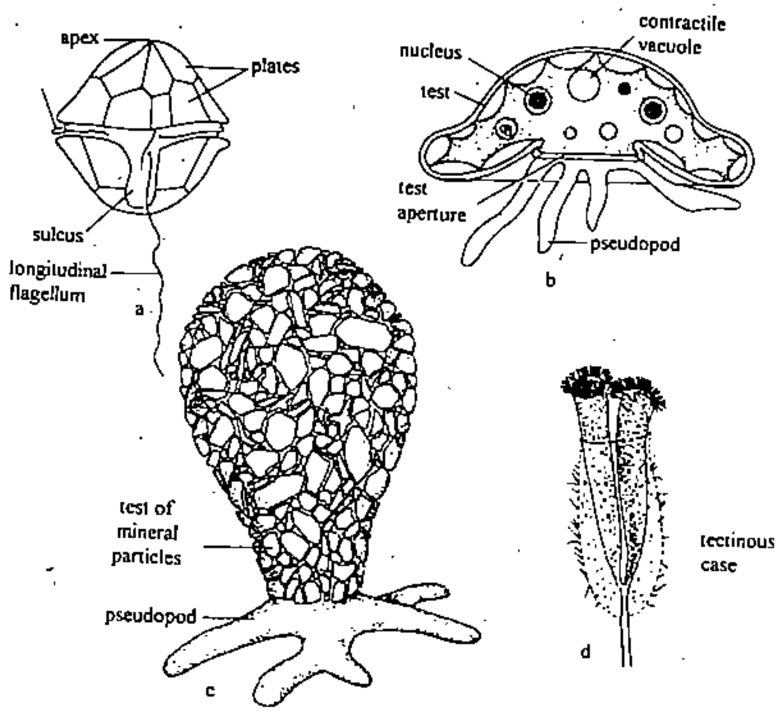


**Fig. 2.3: Exoskeletons of Protozoans:**

**a). Ornamental theca in *Glenodium***

**b) Pseudochitin in *Arcella***

**c) Inorganic matter glued together by pseudochitinous secretions in *Difflugia***

**d) *Cothurina.***

The protozoan nuclei are membrane bound, diverse in structure and method of division. Two basic types are found, vesicular with considerable amount of nucleoplasm and the other compact. When more than one nucelus is present they are usually alike except in ciliates, where a massive compact macronucleus and one or more compact macronuclei are present. Cytoplasm can be distinguished as **ectoplasm** and **endoplasm.**

Ectoplasm appears transparent under light microscope and bears the base of the flagella or cilia. The endoplasm appears granular and contains the nucleus and cytoplasmic organelles. The ectoplasm is more rigid and is in the gel state of a colloid while the endoplasm is in the sol or more fluid state.

## 2.3.2 Locomotor Organelles

The protozoan locomotor organelle may be **flagella, cilia** or **pseudopodia**. These are of considerable value in classification of protozoans.

The sperm flagella of spermatozoa of certain insects and platyhelminths are exceptions in that they exhibit a 9 + 1 arrangement of microtubules instead of ubiquitous 9 + 2 standard one.

## Cilia and Flagella

Cilia and flagella basically have a similar structure and distinction between the two on a structural basis does not exist. There is a filament or the **axoneme** which has an outer membranous covering continuous with the plasma membrane of the cell surface (Fig. 2.4). This axoneme encloses a matrix in which there are eleven sets of microtubules made up of protein, primarily globular tubulin.

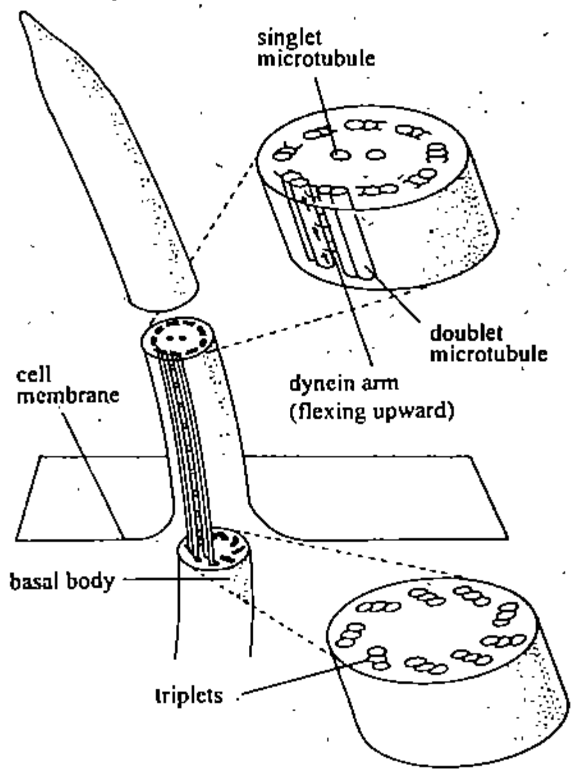


**Fig. 2.4: Diagrammatic representation of the ultrastructure of cilia or flagella.**

The arrangement of microtubules is characteristically the same by and large in all cilia and flagella of eukaryotes — nine doublets of microtubules arranged in a circle around the two single central ones. The central minerotubules terminate at a basal plate at the cell surface and the peripheral ones continue internally into the cell body. At about this point another microtubule joins each of the nine pairs so that these form a short tube extending into the cell consisting of a *triplet* of microtubules. This contributes to the formation of the **basal body** or the **kinetosome**.

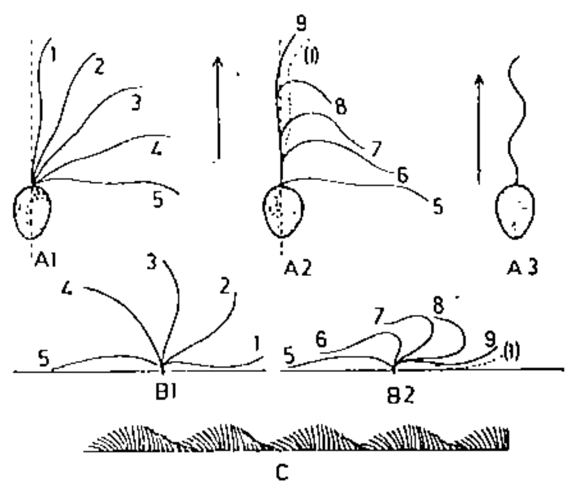


**Fig. 2.5: Activities of Flagella and Cilia. A1. Propulsive stroke, and A2. recovery stroke of a simple flagellum. Water moves at right angles to the surface of attachment of the flagellum. A3. Several waves of bending creating continuous movement. (Arrows indicate the direction of propulsion of water and locomotion). B1. and B2. Propulsive and recovery strokes, respectively, of a single cilium. C. Metachronal rhythm of ciliary beating. Each cilium is beating slightly later than the cilium in front of it, but in phase with its neighbour in adjacent row; thus waves appear to pass over the ciliated surface in the opposite direction to the effective stroke of the cilia.**

All cilia or flagella whether protozoan or metazoan have this basal body. A complex of filaments or **kinetodesmata** links the basal bodies of cilia in an infraciliature in ciliate protozoans. Though structurally cilia and flagella are not distinguishable from each other, some distinctions can be made between the two organelles (Fig. 2.5). Cilia are usually stiffer and shorter than flagella, occur in greater numbers and are mostly arranged in rows.

You would recall from Unit 6 of LSE-05 the mechanism for ciliary and flagellar movement. The current explanation is the sliding microtubule hypothesis. The movement is powered by release of energy in ATP. Direct evidence has been obtained for the sliding microtubule hypotheses by attaching tiny gold beads to axonemal microtubules and observing their movement under the microscope.

**Pseudopodia**

Pseudopodia are flowing cytoplasmic protrusions of the cell causing amoeboid movement (Refer to Unit 6 LSE-05). In protozoans pseudopodia exist in several forms. The most familiar are **lobopodia**. These are large blunt extensions of the body containing both **ectoplasm** and **endoplasm**. (Fig. 2.6). Thin extensions of the body are known as **filopodia**. These are often branching containing only ectoplasm. Repeated branching and rejoining of filopodia to form a net like mesh is known as **reticulopodia**. **Axopodia** are long thin pseudopodia supported by axial rods of microtubules. Axopodia can be extended or retracted, apparently by addition or removal of microtubular material.

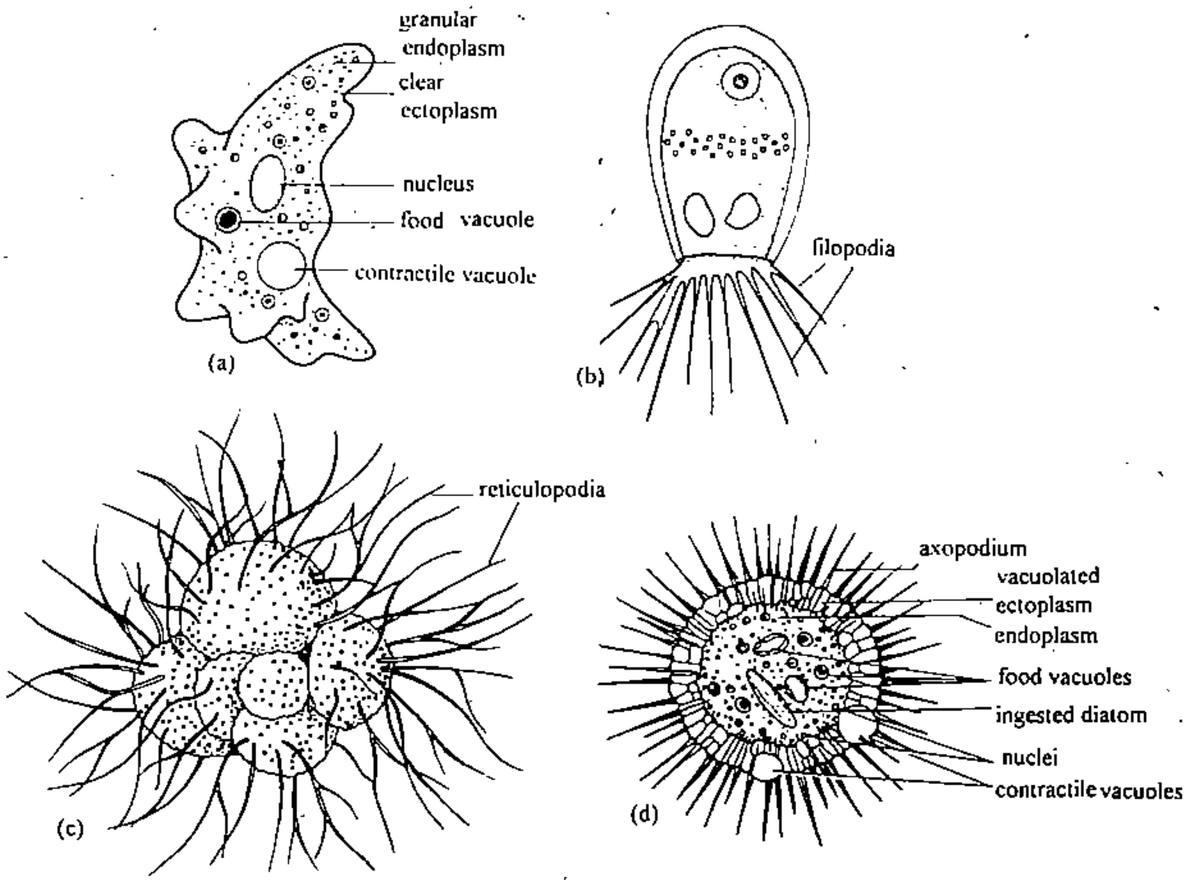


**Fig. 2.6: Pseudopodia:**

**a) Lobopodia in *Amoeba***

**b) Filopodia in *Chlamydophrys* a freshwater amoeba**

**c) Reticulopodia of *Globigerina***

**d) Axopodia of *Actinophrys sol* often called sun animalcule.**

As the amoeba's cell body throws out one or a few pseudopodial lobes, a temporary rear end or **uroid** is pulled along. The central, more fluid protoplasm, the **endoplasm** flows towards the extending pseudopodium, the advancing tip of which appears a thicker gel, the **ectoplasm**. During the amoeboid movement, the sol-like endoplasm is converted into gel like ectoplasm at the advancing tip of the pseudopodium; a reverse process simultaneously occurs at the uroid end where the gel changes into sol. At some point the pseudopodium gets attached to the substratum and the cell is moved forward.

It is also a widely accepted view that the amoeboid movements depend on the contraction of cellular proteins which are comparable to those occurring in the muscle (recall from Unit 6, LSE-05). Actin and myosin have been found to be present in amoeboid cells; tropomysin has also been demonstrated in some instances. Fig. 2.7 shows the various types of amoeboid movements.

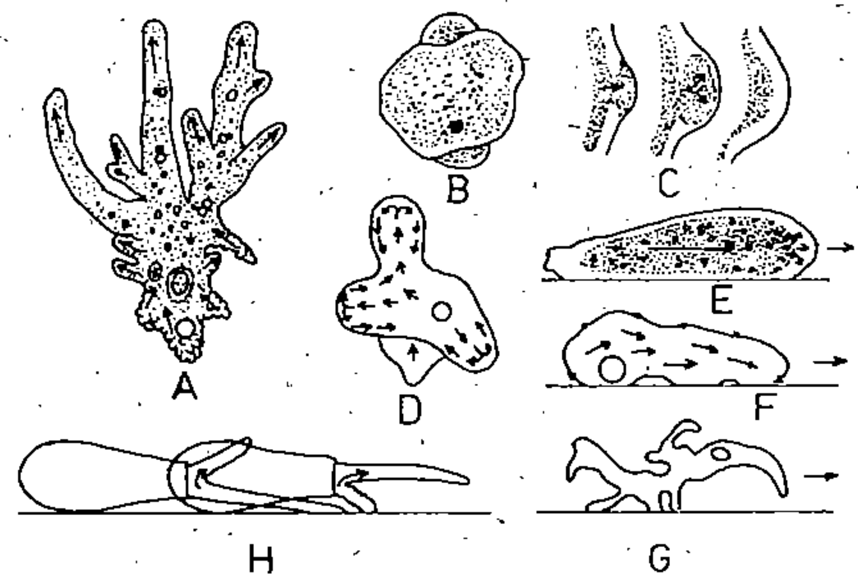


**Fig. 2.7: Amoeboid locomotion in different amoebae. A. *Amoeba proteus* (lobose pseudopodia). B. *Entamoeba histolytica* (broad lobose pseudopodia). C. Formation of lobose pseudopodia by sudden flow of endoplasm (dark zone) into ectoplasm (light zone). D. Streaming of protoplasm in an amoeba. E. Creeping movement of an amoeba. F. Rolling motion. G. Walking motion (due to the formation of multiple pseudopodia). H. Locomotion in an "inchworm" fashion in *Difflugia*.**

**SAQ 1**

Compare and contrast the methods of movement in the various groups of protozoans.

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### 2.3.3 Nutrition

All types of nutrition occur in Protozoa. Some protozoans synthesize their own food from inorganic precursors (carbon dioxide, nitrates or ammonium salts) and hence are **autotrophic**; eg. chlorophyll bearing flagellates; others are **heterotrophic** as they depend on organic and inorganic raw materials from the environment for their food. Heterotrophs have varied food habits. Some feed on soluble organic nutrients from their environment and are termed **saprozoic** or **osmotrophs**, eg. parasitic protozoa; still others are **holozoic** ingesting rigid or solid organic food, or **phagotrophs** i.e. they ingest solid food particles of animal or plant origin. Thus they may also feed on bacteria or other small protistans which are ingested whole, and digest them within food vacuoles· eg. rhizopods and ciliates.

Autotrophic protozoa use light energy to synthesize their organic molecules but they often become phagotrophic or osmotrophic. Even among the heterotrophic protozoa few follow only one mode of nutrition exclusively. For example in *Euglena* species there is considerable variety in modes of nutrition. Some species require some preformed organic molecules even though they are autotrophs, some species lose their chloroplasts if kept in the dark and become permanent osmotrophs. Phagotrophic nutrition involves

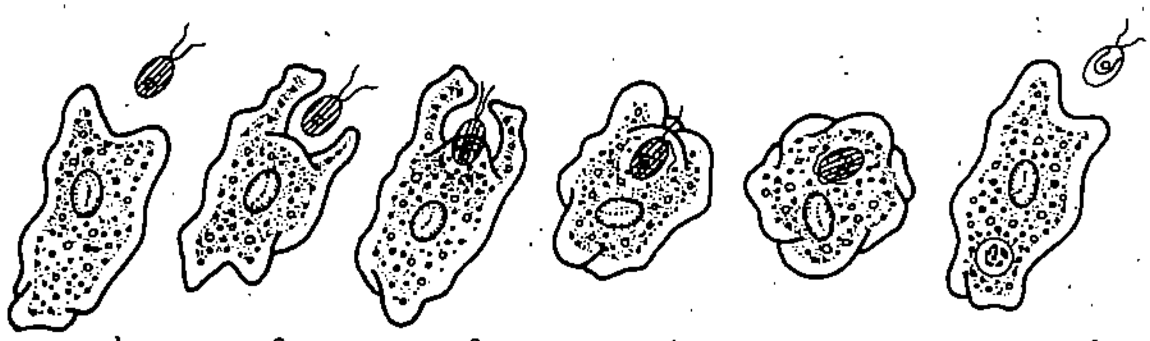


Fig. 2.8: Phagocytosis in *Amoeba*.

phagocytosis in which the cell membrane infolds the food particle (Fig. 2.8) which is then engulfed. The food particle is then enclosed in an intracellular membrane bound vesicle the **food vacuole or phagosome**. The food is then digested by the action of enzymes contained in lysosomes. These enzymes are implied into the vacuole and the undigested material is thrown out from the body by exocytosis.The digested material is absorbed by the cell. In most ciliates, many flagellates and apicomplexan the site of phagocytosis is a definite mouth structure called the **cytostome** (see Fig. 2.10). In amoebas phagocytosis occurs at any point by surrounding the food particle with pseudopodia. Flagellates may have a temporary cytosome usually in a characteristic position or the cytosome may be a permanent specialised structure.

Saprozoic feeding may take place by pinocytosis or through direct diffusion or facilitated or active transport of solutes through the membrane.

## 2.3.4 Osmoregulation and Excretion

Osmoregulation or water balance in protozoa is accomplished by contractile vacuoles. One to several contractile vacuoles may be present within the animal which may or may not have fixed sites in the cytoplasm and may have contributory canals or other vesicles opening into it. These are water and ion regulating structures, acting as pumps to remove excess water from the cytoplasm. All freshwater protozoans have functioning systems of contractile vacuoles whereas, marine and parasitic forms have these less frequently.

Excretion of metabolic wastes is done almost exclusively by diffusion. All protozoans are ammonotelic i.e., the end product of their nitrogen metabolism is ammonia, which is readily diffused in the surrounding medium.

The contractile vacuoles may differ in complexity in various groups of protozoans. In amoebae the vacuoles are carried around in the cytoplasm. Small vesicles join them emptying their contents into the vacuoles till the vacuole joins the membrane emptying its content to the outside (Fig. 2.9).

In ciliates (e.g. *Paramecium*) the contractile vacuoles have a more complex structure. The contractile vacuole is located in a fixed position with an excretory pore leading to the outside surrounded by ampullae of feeder canals (Fig. 2.10).The feeder canals are surrounded by a network of fine canals (20nm) in diameter, which are also connected to the tubular system of endoplasmic reticulum. The ampullae are surrounded by a bundle of fibrils that may have a role in contraction of the ampullae. The ampullae contract thereby, filling the vacuole and when the contents of the vacuole are discharged to the exterior the ampulae get disconnected so that back flow is prevented.

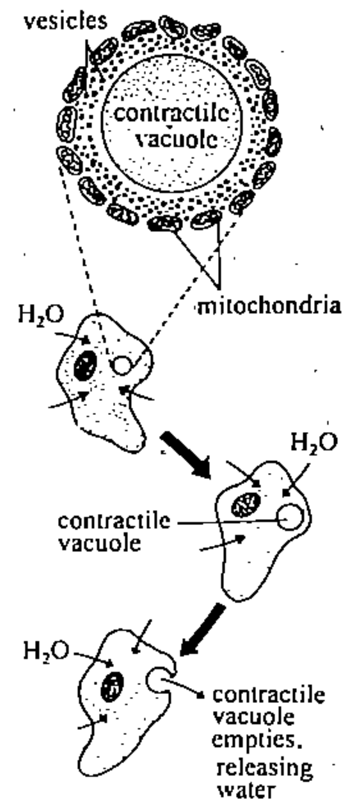


Fig. 2.9: **The contractile vacuole of *Amoeba proteus* is surrounded by tiny vesicles that fill with fluid, which is then emptied into the vacuole. Note the numerous mitochondria that are believed to provide energy needed to adjust the salt content of the tiny vesicles.**

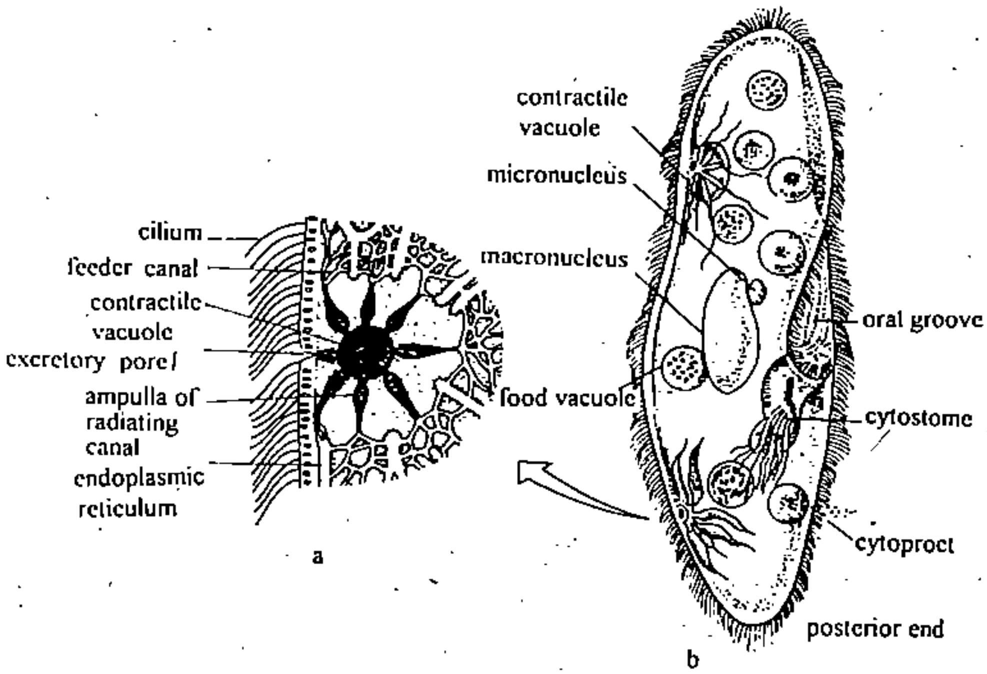


**Fig. 2.10:** a) ***Paramecium*** **with cytopharynx, food and contractile vacuoles and nuclei.**
b) **Enlarged section of a contractile vacuole in *Paramecium* which collects water and expels it outside, performing osmoregulatory functions.**

**SAQ 2**

What are the main functions of contractile vacuoles in protozoa?

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## 2.3.5 Respiration

Gas exchange occurs by the diffusion of oxygen across the cell membrane. Some protozoans utilize this oxygen but are also capable of anaerobic respiration. Examples are parasitic protozoans like *Monocystis*. Metabolic wastes such as carbon dioxide and ammonia diffuse out of the organism.

## 2.3.6 Mechanisms for Response

Protozoa are sensitive to many kinds of stimuli like touch, temperature changes, light, chemicals, etc. It is not clear how they do so but amoebae are constantly changing and their protoplasmic mass can receive stimuli as well as conduct them. Cilia and flagella are highly sensitive to touch. One special sensory organelle is the stigma or eyespot. The stigma is a redish body found in photosynthetic flagellates and usually located near the root of the flagellum. The stigma is often cupped shading the light sensitive area from one side. Again it is not clear how the stimulus is conducted from the point of reception to another point where activity may change.

## 2.3.7 Reproduction and Life Cycles

**Asexual reproduction** occurs in all protozoans through fission, budding and cyst formation. In this method the organism reproduces to form its own type without forming gametes. The parent organism transfers an entire set of diploid chromosome to the daughter cell (Fig. 2.11).

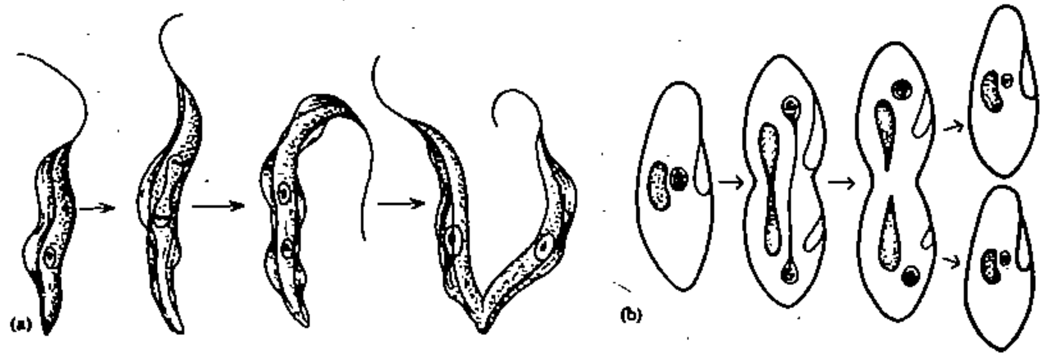


**Fig. 2.11: Binary fission in protozoans a) In a flagellate *Trypanosoma* b) In a ciliate, *Paramecium*.**

Sexual reproduction involves meiotic nuclear divisions that give rise to haploid gametes from the diploid nucleus and the union of gametes then restores diploidy. It may involve gametes from different parents in which case it is called **amphimictic** or may involve gametes that may arise from the same parent i.e. **automictic**. The uniting gametes may be the whole organism or only the nuclei. Where the whole organisms unite the process is termed **syngamy** and where only the nuclei unite the process is termed **conjugation**. Syngamy occurs in all groups where sexual reproduction occurs except in ciliates where conjugation occurs.

### Syngamy

The two gametes may be morphologically similar (**isogamètes**) or dissimilar. (**anisogametes**). The gametes also vary in form, they may be flagellated or amoeboid. The zygote usually enters into a quiescent state and later gives rise to new individuals.

### Conjugation

Conjugation is characteristic of ciliates. The details vary from species to species. The general features can be observed in *Paramecium* sps. which has one macronucleus and one micronucleus. (Fig. 2.12). Two ciliates ready for conjugation partially unite. The body surface and pellicle undergo considerable changes. The macronucleus disintegrates and the micronucleus divides twice to give rise to four haploid pronuclei. Three of these disintegrate and the fourth forms a stationary and a migratory pronucleus. The latter moves into the other conjugant. The two organisms now separate and the pronuclei unite to form zygote. After several post conjugation divisions the macronucleus and micronucleus are formed restoring the normal nuclear complement.

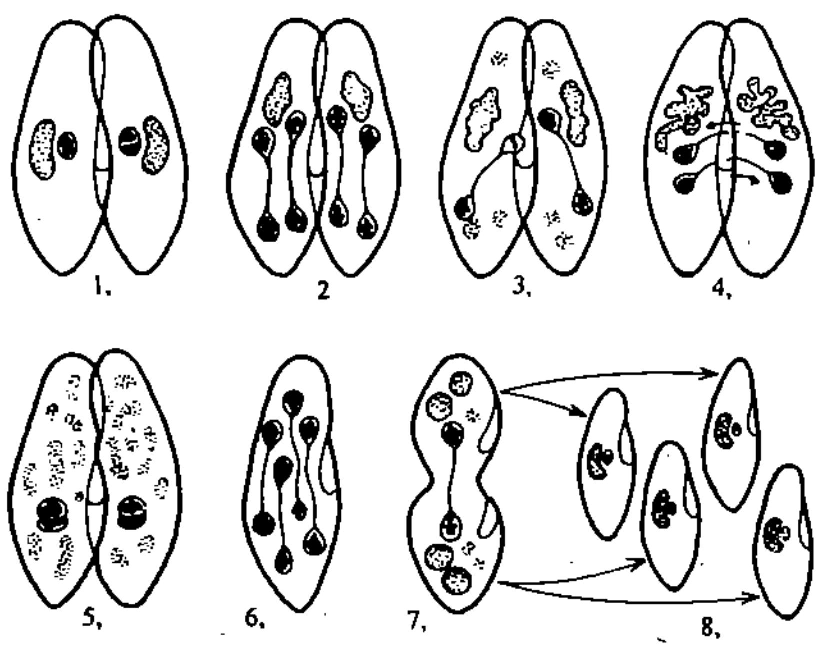


**Fig. 2.12: Conjugation in *Paramecium caudatum*.**

### 2.3.8 Encystment

Encystment is characteristic of the life cycle of many protozoans. The protozoan secretes a thickened envelope (cyst) around itself and becomes inactive with almost a complete shutdown of metabolic activity. This protective cyst is resistant to either desiccation or low temperatures and enables the animal to pass through unfavourable environmental conditions like food deficiency, desiccation, decreased oxygen concentration, pH, etc.

Reproductive phases such as fission, budding and syngamy may occur inside the cysts of some species. Encystment is however, not found or is very rare in marine species.

Protozoa may be dispersed long distances in either the motile or encysted stages. Water currents, wind, mud, debris, the bodies of birds and animals are common agents of dispersal.

Cysts of some soil inhabiting and freshwater protozoa show amazing durability. The soil ciliate *Colpoda* has been known to survive in dried soil for upto 38 years! On the other hand not all cysts are as durable. Cysts of *Entamoeba histolytica* can tolerate the acidic medium of the stomach but do not survive desiccation, temperature above 50°C or sunlight.

A return of favourable conditions initiates excystment (escape from cysts) in those protozoa in which the cysts are a resistant stage.

**SAQ 3**

I. Fill in the blanks using words from the text.

1. The protozoa are members of kingdom .............................. .
2. *Volvox* is one of the .............................. forms of protozoa.
3. .............................................form a rigid skeleton in some ciliate protozoans.
4. Pseudopodia bring about locomotion by .............................. movement.
5. Division of an organism into two similar progeny cells is called ..........................
6. .................................. is an exchange of haploid nuclei between two ciliates.
7. Nutrition is .................................. in *Amoeba*.
8. .............................. is the locomotry structure in *Euglena*.

II. Match the items given in A with the ones given in B.

| A | B |
|---|---|
| a) Microtubules | i) holozoic nutrition |
| b) Dependence on other organisms for food | ii) exoskeleton |
| c) Tests of foraminiferans | iii) parasitic protozoa |
| d) Ingestion of solid food | iv) contractile vacuoles |
| e) Anaerobic respiration | v) cytoskeleton |
| f) Osmoregulation | vi) heterotrophic nutrition |

## 2.4 CLASSIFICATION OF PROTOZOA

Traditionally, protozoans have been classified as flagellates, amoebae, sporozoans and ciliates. We have retained this broad grouping for convenience so that you can have a basis for comparing the groups and have an idea about the diversity in protozoans. At the end of this section we give an outline of the classification put forth in 1980 by the Society of Protozoologists. According to this classification seven phyla are recognised. This is more realistic. Among other things it recognizes that flagellates and amoebae are more closely related to each other than to the other groups and that sporozoans include several unrelated forms.

## 2.4.1 Flagellated Protozoans (Phylum — Sarcomastigophora; sub phylum — Mastigophora)

1. These are protozoans that move by means of one or more flagella and include the largest number of species, about 6,800.
2. Asexual reproduction is by longitudinal binary fission (see Fig. 2.11). In sexual reproduction isogametes are produced.
3. These are commonly divided into two groups on the basis of mode of nutrition.
   a) **Phytoflagellates are autotrophs** that possess chlorophyll or other related pigments, and store food as fats, oils and starches (other than glycogen). They are free-living and assigned often to the algal phyla.

   Examples are: *Euglena, Chlamydomonas, Volvox, Peranema, Gonium, Pandorina,* dinoflagellates (Fig. 2.13).

Dinoflagellates are an interesting group of phytoflagellates with brown or yellow chromatophore although some are colourless. Some species, *Noctiluca* for example are bioluminescent. Dinoflagellates can also damage other organisms when they reproduce in profusion, producing toxic substances that may be highly poisonous for other living organisms.

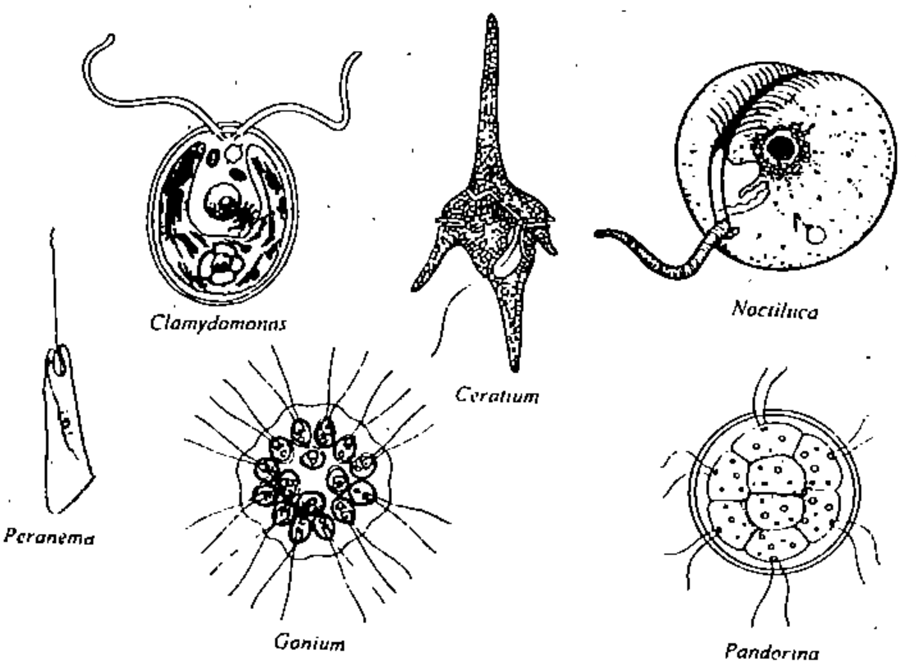


**Fig. 2.13: Diversity among phytoflagellates *Gonium* and *Pandorina* are colonial. *Noctiluca* and *Ceratium* are dinoflagellates.**

   b) **Zooflagellates** are heterotrophs that are free living, commensals or symbiotic or parasitic in other animals. A number of species eg. *Trichonympha* and *Myxotricha* (see Fig. 2.14) live within the gut of termites and digest cellulose that the wood-eating termites feed on but cannot digest for themselves. *Trichonympha* lives as a mutualistic symbiont in the hindgut of wood-eating insects (termites and woodroaches). The anterior end of these large, complex flagellates (sometimes over 300 μm long) is covered with an elaborate pellicle and hundreds of flagella, but the posterior end extends pseudopods and ingests bits of wood. The flagellate is able to produce cellulose-digesting enzymes, but the insect host cannot; and therefore, depends on carbohydrates released by its symbionts.

Spirochetes are long thin helix shaped bacteria ranging in length upto 500 μm. Their cell walls are not so rigid, therefore, they can bend easily. Though most spirochetes are harmless and live in water, soil or bodies of other animals, some are serious parasites. Syphilis one of the transmitted disease is caused by a spirochete.

Each time the insect molts, it loses the lining of the hindgut and all its symbionts. If it is unable to acquire new ones, it will starve to death, even though it continues to feed normally, for it cannot digest the wood. The flagellates are equally dependent on the mutualism and die within minutes outside the host. A young or newly-molted termite acquires symbionts by feeding directly from the anal opening of other termites in the colony. *Myxotricha* appears to be covered with flagella. But only four of these are true flagella and the others are a kind of bacteria or spirochetes (see margin remarks) attached to its surface. Their lashing movements enable the flagellate to swim about, and its own flagella help in steering.

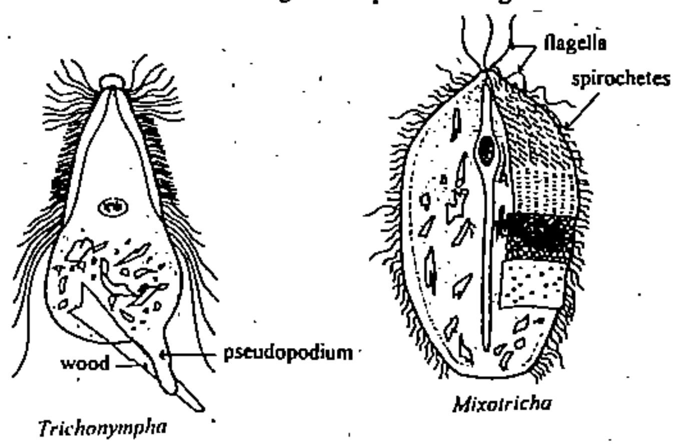


**Fig. 2.14: Zooflagellates parasitic in the gut of termites.**

Other well known parasitic species of flagellates are *Trypanosoma* and *Leishmania* found in humans and cattle in Africa and Asia. *Trypanosoma* causes **sleeping sickness** in humans and **nagana** in cattle. The blood of the host is infected with the flagellate when the **tsetse fly** bites the host. *Leishnamia* is the agent for the widespread kala-azar and related disease. It affects the immune system and causes skin lesions among other effects. The host for this protozoan is the blood sucking sand fly. We will study more about these in section 2.5.

## 2.4.2 Amoeboid Protozoans (Phylum — Sarcomastigophora; sub phylum — Sarcodina)

Amoeboid protozoans are distinguished by the presence of flowing extensions of their body known as **pseudopodia.** These are used for feeding and locomotion. The pseudopodia are given different names according to their shape and structure (Refer to Section 2.3 of this unit). This group includes the familiar *Amoeba* {Fig. 2.6(a)} and other marine, fresh water and terrestrial taxa. The amoeboid form may be the result of retention of the ancestral protistan condition in some species. In some others it may be secondarily acquired through loss of flagella, as many groups have flagellated gametes in their life cycle.

Amoeboid protozoans are either asymmetrical or show spherical symmetry. They possess relatively few organelles and may be the simplest of the protozoans. However the majority of the species have evolved complicated skeletal structures that make them uniquely beautiful organisms. There are four principal groups of amoeboid protozoans: amoebae, foraminiferans, helizoans and radiolarians. Of these the amoebae and foraminiferans belong to superclass Rhizopoda while the radiolarians and helizoans belong to superclass Actinopoda, as they have axopods.

1. **Amoebae** may be naked or enclosed in tests or shells. The marine, freshwater and parasitic naked amoebae have large commonly tubular lobopodia or fine straplike filopodia that are used for locomotion and feeding (refer to Fig. 2.6). The shelled amoebae are found in the sea, freshwater and soil. They are covered by a shell made up of secreted organic material or foreign mineral matter cemented together (see Fig. 2.3). A large aperture in the shell permits protrusion of lobopodia or filopodia. A number of commensal and parasitic amoebae inhabit the gut of different animals and humans. *Entamoeba coli* (Fig. 2.15) a commensal in human gut feeds on bacteria and intestinal debris while *E. histolytica* a parasite causes amoebic dysentery (see section 2.5)

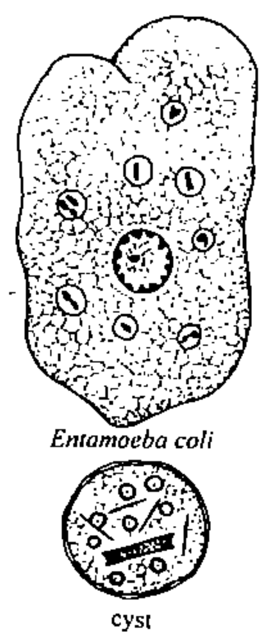


**Fig. 2.15:** ***Entamoeba coli*** **a common dweller in the human gut.**

2. **Foraminiferans** are largely benthic marine species. They have multichambered calcareous tests or shells with numerous pores, hence the name foraminifera or pore bearer. A single large opening allows the cytoplasm to protrude out. The chalk cliffs of Dover England are formed from deep sediments of foraminiferan shells (Fig. 2.16).

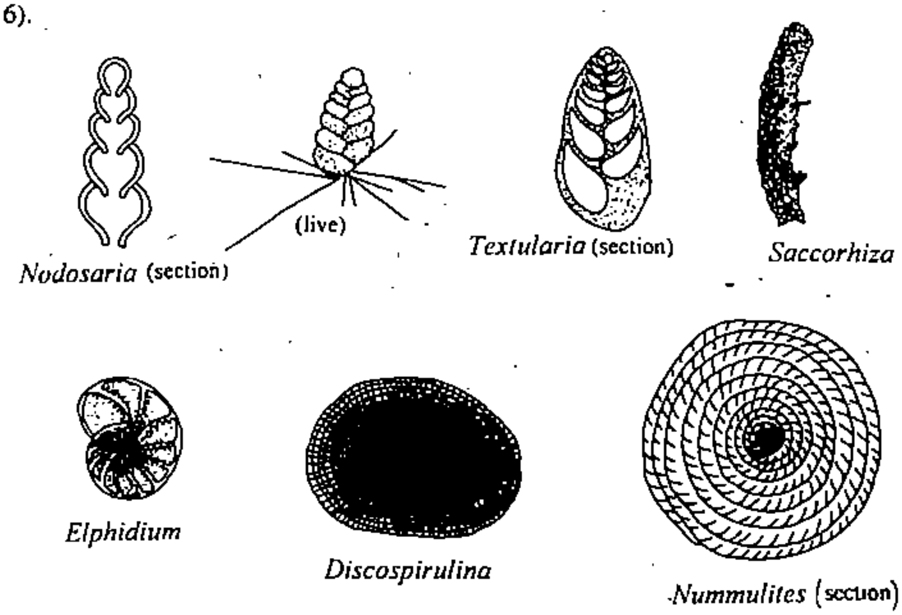


**Fig. 2.16: Various types of foraminiferan shells formed chiefly of calcium carbonate. A fossil species — *Nummulites* is an important contributor to the great limestone deposits in certain parts of the world.**

3. **Radiolarians** are entirely marine planktonic species with spherical bodies and radiating pseudopodia known as axopods. The spherical body is divided into inner and outer parts. The inner region contains one to many nuclei and is surrounded by a **central capsule** with a membranous wall. This is a distinctive feature of radiolarians. The capsule membrane is perforated with openings through which the inner capsule cytoplasm becomes continuous with the cytoplasm of the outer division of the body. This outer cytoplasm is called **calymma**.

Their skeleton is formed of silicon dioxide or strontium sulphate organised in the form of lattice spheres or radiating spines. (Fig. 2.17 a and b)

The skeletons of radiolarians and foraminiferans form a primary constituent of ocean bottoms where they form 30% or more of the sediment. It is called a **radiolarian ooze or foram.** However at depths below 4000 m, the shells tend to dissolve due to pressure.

The shelled amoeboid protozoa are the only large group of protozoa that have a fossil record. The radiolarians are amongst the oldest known fossils. Extensive accumulation of foram shell in the mesozoic and cenozoic eras contributed to the formation of great limestone and chalk deposits in different parts of the world. The quarries from which the Egyptian pyramids were built are composed mainly of foram shells.

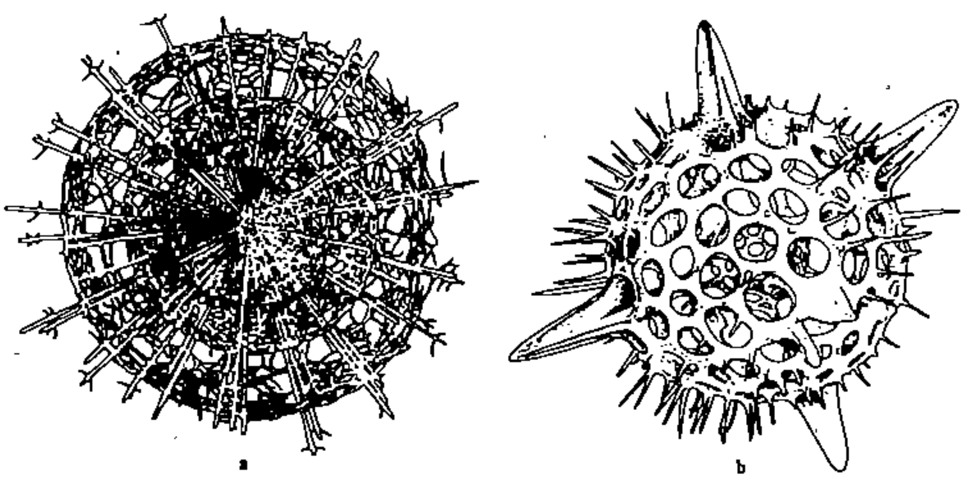


**Fig. 2.17: Skeletal structures of radiolarians. Concentric spheres along with radiating spines are common patterns.**

4. **Heliozoans** are spherical protozoans that occur in the sea or in still bodies of fresh water. They are mainly located in the bottom debris. Fine needle like pseudopodia radiate from the surface of the body. These are known as axopodia. (Refer to Fig. 2.6 d also). Each axopod has central axial rod covered by a moving cytoplasm.

The body of the helizoan consists of outer vacuolated ectoplasmic **cortex** and inner dense **medulla**. The medulla contains a dense cytoplasm, one to several nuclei and bases of axial rods (Fig. 2.18).

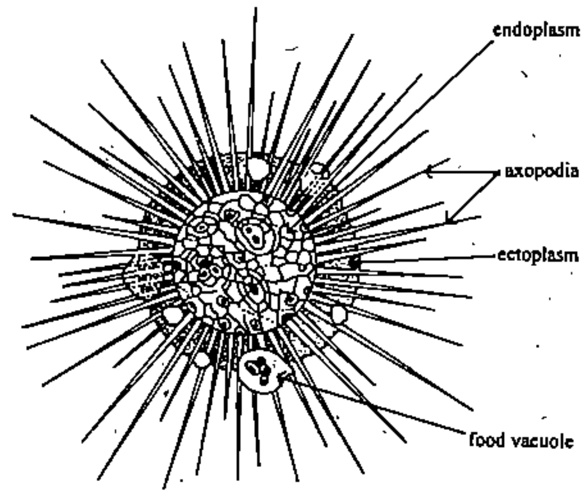


Fig. 2.18: Multinucleate heliozoan, *Echinisphaerium*.

SAQ 4

Indicate whether the following statements are true or false:

1. All flagellate protozoans are autotrophic. (T/F)
2. Some of the flagellates living as symbionts in the gut of termites are capable of digesting cellulose. (T/F)
3. Flagellate and amoeboid protozoans are currently included under a single phylum. (T/F)
4. All amoboid protozoans have one or other form of pseudopodia. (T/F)
5. All amoeboid protozoans either lack a symmetry or show spherical symmetry. (T/F)
6. Radiolarians have a spherical body and radiating pseudopodia known as axopodia. (T/F)
7. Foraminiferan and radiolarian protozoans are the only large group of protozoa that have a fossil record. (T/F)
8. There is no sexual reproduction in zooflatellates (T/F)

### 2.4.3 Spore forming Protozoans (Phylum — Apicomplexa)

There are about 4000 species of protozoa that have spore forming stages in their life cycles. Most known species of spore forming protozoa belong to class Sporozoa and are parasitic. They lack cilia or flagella or pseudopodia and live within or between cells of their invertebrate or vertebrate hosts. They possess a complex of distinctive ring like tubular and filamentous organelles at the apical end visible only under the electron microscope (Fig. 2.19). This phylum includes the **gregarines** which are extracellular parasites of insects, annelids and other worms and the **coccidians** that are intracellular parasites of blood cells of vertebrates and invertebrates. The most familiar coccidian is *Plasmodium*, the causative agent of malaria. You will study more about the malarial parasite in section 2.5. The complex life cycle of sporozoans typically involves an asexual and a sexual phase (Fig. 2.20). Sporozoans are haploid except for the zygote.

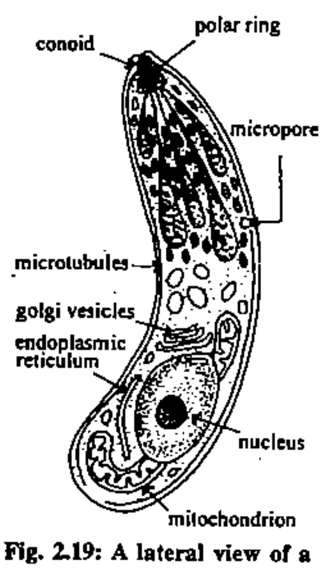


**Fig. 2.19: A lateral view of a generalized apicomplexan sporozoan. The apical complex components are shaded. (After Farmer. J.N. 1980. The Protozoa)**

The zygote undergoes meiosis that results in an infective spore like stage the **sporozoite** which by multiple fission produces more sporozoites. These invade the host and become feeding **trophozoite**. In some sporozoans the trophozoites, by multiple fission known as **schizogony** produce **merozoites**. Each merozoite undergoes multiple fission to produce more merozoites that eventually undergo **gamogony** or multiple fissions to form gametes that fuse to form zygote.

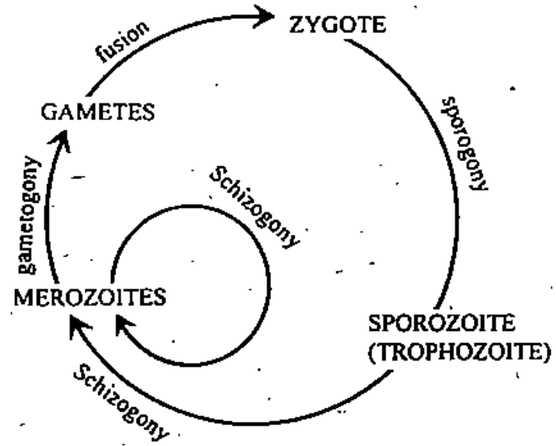


**Fig. 2.20: Life cycle of coccidian sporozoans. All stages are haploid except zygote.**

## 2.4.4 Ciliated Protozoans (Phylum — Ciliophora)

Ciliates form the largest and the most homogenous group of protozoans. They are placed under one **phylum Ciliophora** and evidence indicates that its members share a common evolutionary history. There are more than 7200 species found in fresh and marine waters and the water film of soil. About one third of ciliates are ecto and endoparasites or commensals.

The classic example of this phylum is the slipper shaped *Paramecium* (refer to fig. 2.10). Other well known examples are *Vorticella, Stentor, Didinium, Balantidium* (Fig. 2.21).

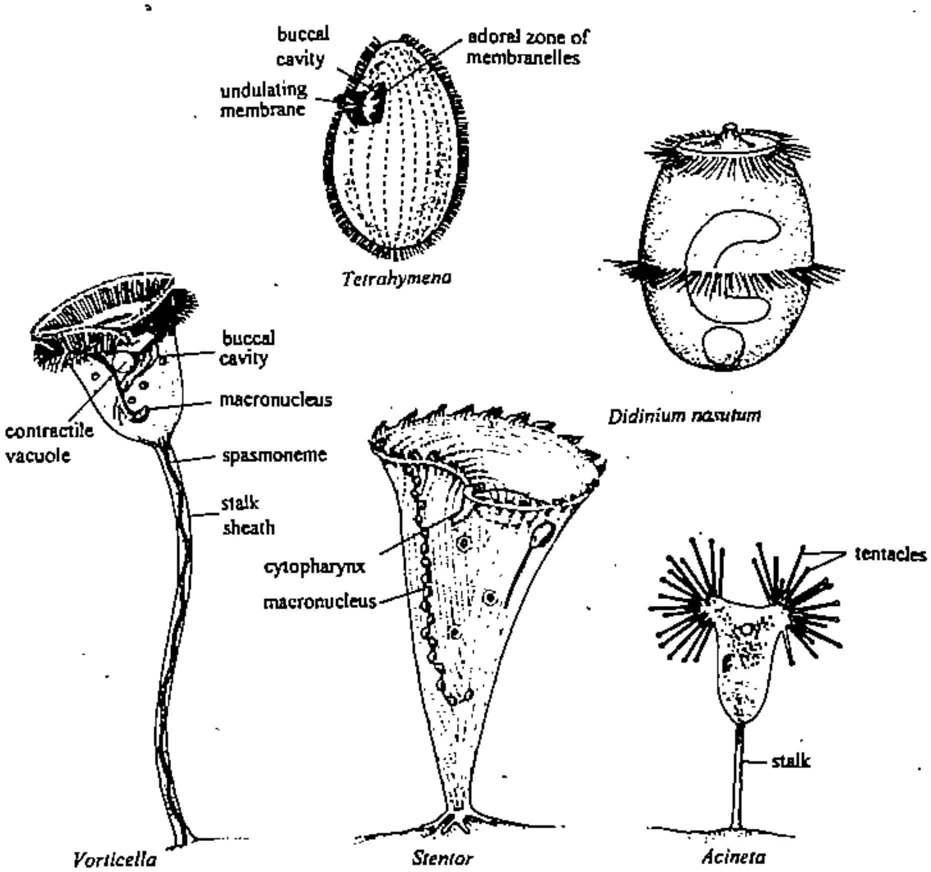


**Fig. 2.21: Various ciliates. *Vorticella* and *Stentor* sessile ciliates, *Stentor* can also release itself and swim about. *Didinium* a raptoral ciliate *Tetrahymena, Acineta* with bunches of tentacles.**

All ciliates possess cilia for locomotion and for suspension feeding. Another distinguishing feature is the presence of **kinetosomes** (ciliary basal body) and an associated complex anchorage system of fibrils connecting the kinetosomes in longitudinal rows. All of these make the subsurface ciliature or **infraciliary system.** Most ciliates have a mouth or **cytostome** and feed by sweeping particle laden water into the mouth. The cytostome and cytopharynx open into the food vacuole and undigested remains are expelled through a fixed spot. Another characteristic feature is the presence of 2 types of nuclei. One large **macronucleus** and one or more small **micronuclei.** The macronucleus is called the vegetative nucleus as it regulates the normal metabolic processes of the organism for mitotic division and for control of cellular differentiation. It is required for protein synthesis. The amount of DNA that macronucleus contains is much more than what is present in micronucleus because of duplications following the formation of macronucleus from the micronucleus.

The micronucleus on the other hand is small and rounded. It is diploid and more than one may be present, with little RNA. The micronucleus contains the genetic material responsible for genetic exchange during sexual reproduction and also for reforming the macronucleus.

Ciliates reproduce asexually by transverse fission and sexually through conjugation which involves the exchange and fusion of micronuclei at the region of contact.

SAQ 5

a) What are the functions of cilia of ciliophorans?

..............................................................................................................

..............................................................................................................

..............................................................................................................

b) What are the functions of macro and micro nuclei in the ciliophorans?

..............................................................................................................

..............................................................................................................

..............................................................................................................

## CLASSIFICATION SCHEME OF PROTOZOA

**KINGDOM PROTISTA** — single celled eukaryotes

**I) PHYLUM SARCOMASTIGOPHORA**

Locomotory organelles — flagella, pseudopodia or both types, usually with one type of nucleus; typically no spore formation, sexual reproduction through syngamy.

**i) Subphylum Mastigophora**

One or more flagella present in adult stages; autotrophic or heterotrophic nutrition; reproduction usually asexual by fission.

**Class — Phytomastigophorea**

Plant like flagellates; usually bearing chlorophyll or other pigments. Examples: *Euglena, Volvox, Chilomonas, Noctiluca, Peranema, Chlamydomonas.*

**Class — Zoomastigophorea**

Flagellates without chloroplasts; one to many flagella; amoeboid forms without flagella in some groups. Species mostly symbiotic.

Examples: *Trichomonas, Trichonympha, Trypanosoma, Leishmania, Giardia.*

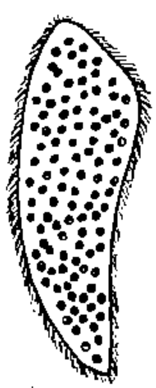

**Fig. 2.22:** ***Opalina*** **a multinucleate endozoic flagellate, parasitic in frogs and toad.**

**ii) Subphylum Opalinata**

Body covered with longitudinal rows of cilium like organelles but true ciliature absent. Parasitic; cytosome lacking; two to many nuclei of one type. Examples: *Opalina Protopalina.* (Fig. 2.22)

**iii) Subphylum Sarcodina**

Pseudopodia typically present; flagella present in developmental stages of some species; free living or parasitic.

a) **Superclass — Rhizopoda**

Locomotion by lobopodia, filopodia or reticulopodia or by protoplasmic flow without production of pseudopodia.

Examples: *Amoeba, Entamoeba, Difflugia, Arcella, Globigerina, Nodosaria.*

b) **Superclass — Actinopoda.** Often spherical; usually planktonic; pseudopodia in form of axopodia; skeleton when present composed of organic matter and/or silica, or of strontium sulphate; reproduction asexual and/or sexual; feeding cells rarely flagellated; in many species small flagellated stages whose exact nature (gametes or spore) is still uncertain.

Examples: *Acanthometra, Actinophrys, Echinospherium.*

## II) PHYLUM LABYRINTHOMORPHA

Trophic stage, ectoplasmic network with spindle shaped or spherical nonamoeboid cells. Small group living on algae; mostly marine or estuarine. Example: *Labyrinthula.*

## III) PHYLUM APICOMPLEXA

Characteristic set of organelles (apical complex) asssociated with the anterior end present in some developmental stages. Cilia and flagella absent except for flagellated microgametes in some groups; cysts often present; all species parasitic.

i) **Class — Perkinsea**

Small group parasitic in Oysters.

ii) **Class — Sporozoa**

Spores or oocysts present that contain infective sporozoites that result from sporogony; locomotion of mature organism by body flexion, gliding or undulation of longitudinal ridges; flagella present only in microgametes of some species; pseudopods ordinarily absent, wherever present they are used for feeding not locomotion; one or two host life cycles.

Examples: *Monocystis, Gregarina, Toxoplasma, Plasmodium.*

## IV) PHYLUM MYXOZOA

Parasites of lower vertebrates especially fish and invertebrates.

## V) PHYLUM MICROSPORA

Parasites of invertebrates especially arthropods and lower vertebrates.

## VI) PHYLUM ASCETOSPORA

Small group that is parasitic in invertebrates and a few vertebrates.

## VII) PHYLUM CILIOPHORA

Simple cilia or compound ciliary organelles typical in at least one stage of life cycle; subpellicular cilia present even if surface cilia are absent; two types of nuclei, with rare exceptions; binary fission transverse but multiple fission and budding also occur; sexuality involving conjugation, autogamy and cytogamy; nutrition heterotrophic; contractile vacuole typically present; most species free living but many commensal, some truly parasitic.

This is a very large group divided by the society of Protozoologists into three classes and numerous orders and suborders. The classes are separated on the basis of characteristics of the ciliary pattern especially around the cytostome

Examples *Paramecium, Didinium, Colpoda, Balantidium, Stentor, Epidinium, Vorticella, Trichodina, Ephelota, Tetrahymena.*

## 2.5 SOME PARASITIC PROTOZOANS

Out of the thousands of species of Protozoa, the majority are free living. However, many species from within the phyla Sarcomastigophora and Ciliophora are parasitic during some part or whole of their life and all members of the phylum Apicomplexa (the sporozoans) are exclusively parasitic. Many of the sporozoans lead a predominantly intracellular life in their hosts. The protozoans occurring as parasites in human beings and livestock are serious pathogens and cause immense damage to their well being and often high mortality rates among the affected populations. Let us learn about some of the most common and important protozoan parasites of humans.

### 2.5.1 Amoebae

Losch (1875), for the first time, described the disease symptoms of infection of *Entamoeba histolytica*. However, it was only in 1903 that Schaudin gave the description of the trophozoite and cyst stages. Schaudin was exprimenting on himself. Owing to acute infection of *E. histolytica* that he acquired during self-experimenting, he died at the young stage of 35.

The amoebae of the genus *Entamoeba*, vary in their biology. *Entamoeba histolytica* or the dysentery amoeba occurs as a parasite in the large intestine of man and monkeys. *E. coli* is a harmless commensal in the same location, but *E. gingivalis* lives in the mouth.

*E. histolytica* (Fig. 2.23) has three distinct phases in its life cycle, viz., trophozoite, precystic stage and cyst. Trophozoite and cyst are the stages which are commonly demonstrated in the faeces. In the tissues only trophozoite stage occurs. The trophozoite is the actively feeding and dividing form. It is about 12-30 μm in diameter. A number of red blood corpuscles may be seen in the food vesicles in various stages of digestion in cytoplasm.

The trophozoite stage continues to divide by frequent repeated binary fissions in the lumen of the large intestine, as a result of which colonisation of the parasite occurs. Some of these amoebae may invade the intestinal mucosa and become tissue dwelling. It is these tissue invaders which produce amoebic ulcers in the intestinal wall that cause diarrhoea and dysentery. Only those forms which live in the intestinal lumen are capable of producing cysts, which pass out of the host's faeces. The mature cyst has got four nuclei and is the infective stage of the parasite. When food or water contaminated with cyst containing faeces is ingested, man acquires the infectioin. The viable cysts pass via stomach into the intestine, the cyst wall gets dissolved with the action of intestinal secretions and a quadrinucleate amoeba emerges. This undergoes divisions as a result of which eight uninucleate amoebulae are formed. These small amoebae soon start a new cycle.

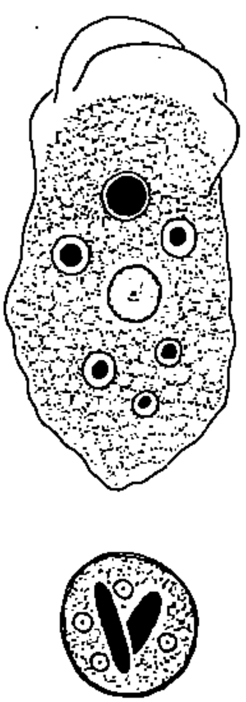

Fig. 2.23: *Entamoeba histolytica* and cyst stage (after Kudo).

### 2.5.2 Flagellates

Several flagellate protozoa parasitise man and live in the blood stream or tissues of the reticulo-endothelial system. Most significant of these are the species of the genus *Leishmania* and *Trypanosoma*. They all require two hosts in their life cycle; a blood-sucking insect transmits the infective stage of the parasite to the vertebrate host.

These protozoans are elongated slender or sometimes rounded possessing a single flagellum at the anterior end. In certain intracellular states the flagellum may be absent. The flagellum arises from a basal body or kinetosome at the floor of a flagellar pocket that occurs at the anterior or near the posterior extremity of the body. In close approximation to the basal body lies a spherical, rod or disc-shaped structure, the **kinetoplast**. The kinetoplast represents an enormous mitochondrion and contains DNA within it. It has been suggested that the kinetoplast (or the mitochondrial DNA) is a metabolic organelle which is essential for the survival of the parasite in the insect intermediate host but is not required for the life of trypanosomes in the vertebrate host's blood. Fig. 2.24 shows the fine structure of a trypanosome as seen under the electron microscope.

Most blood forms are long and slender but as they become intracellular or are taken up by the insect vector, a modification in their form, may occur. Accordingly, during the life cycle, a trypanosome may exhibit several polymorphic forms.

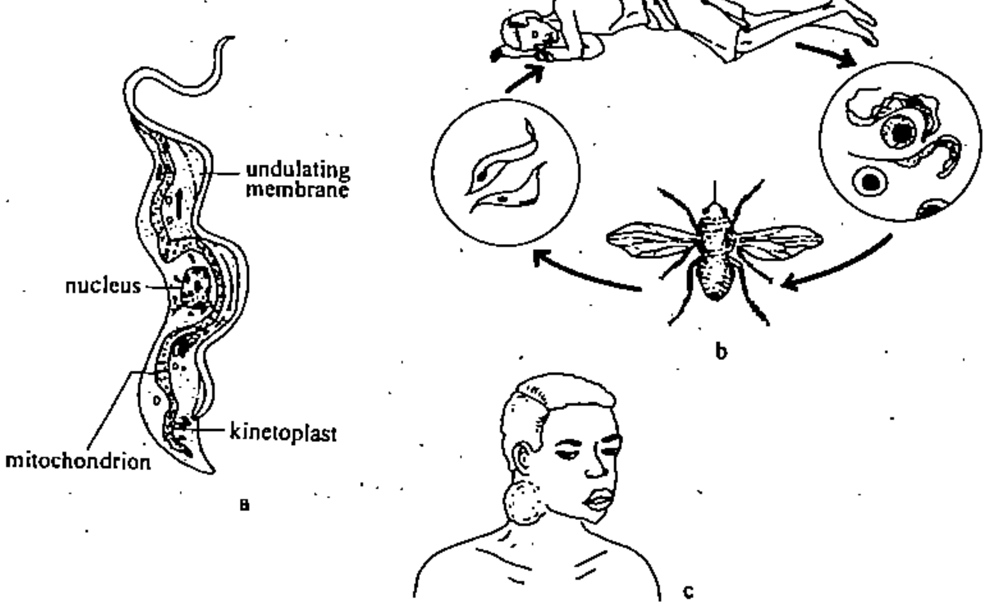


**Fig. 2.24: Trypanosomid flagellates.**

**a) The structure of *Trypanosoma brucei***

**b) Life cycle of *Trypanosoma brucei gambiense* causal agent of African sleeping sickness. The flagellate is transmitted by the bite of the tsetse fly.**

**c) swollen lymph glands where the parasite resides.**

### The Trypanosomes

The trypanosomes are among the serious pathogens that cause high mortality among human populations and domestic animals in Africa and also in South and Central America.

*Trypanosoma brucei* is a wide spread parasite of African mammals (excepting man and baboons), which produces high mortality among domestic animals. *T. gambiense* and *T. rhodesiense*, both cause sleeping sickness in man. They utilise the tsetse fly of the genus *Glossina* which transmits them to man during its blood meal.

The organisms get into the circulating blood with the bite of the fly and multiply as trypanomastigote forms in the extracellular blood fluids (blood and lymph). When the fly once again bites man, it also ingests the parasite alongwith its blood meal. The parasites multiply in the midgut of the fly, after a period of few days they move forward to the salivary glands where they multiply and form the infective stage. When the infected tsetse fly bites a new host, it transmits the infective stage of the parasite into its circulating blood (See Fig. 2.24).

*T. gambiense* produces chronic disease ultimately leading to "sleeping sickness" *T. rhodesiense* infection produces similar but more acute disease and the infected person dies within a few months.

*Trypanosoma cruzi* produces **chagas' disease** in South America.

### The Leishmanias

Species of the genus *Leishmania* are parasites of mammals including man. *Leishmania* infections occur over wide regions of the world from Asia, the near and middle East to East and West Africa and from Mexico to the northern part of Argentina.


**Fig. 2.25: (a) *Leishmania donovani* in macrophages**

**(b) Child with swollen abdomen due to enlarged spleen.**

Sandflies (*Phlebotomus* or *Lutzomia* species) serve as vectors for all species of *Leishmania*. The parasite is flagellated in sandfly. During its blood meal, the fly introduces the parasite into the skin of the mammalian host. The wandering macrophages engulf these parasites. In the host cell they lose the free flagellum and become rounded. (Fig. 2.25(a)). The parasites multiply by repeated binary fission, emerge from the host cell by destroying it and invade newer macrophages to repeat the propagative cycle. When a sandfly feeds on the blood of an infected vertebrate, it also ingests the infective stage of *Leishmania*. In the midgut of the fly the parasites change form and multiply. When the fly feeds again, it injects the parasite in a new host.

*Leishmania* species cause a wide range of disease. *L. donovani*, which is widely distributed in eastern India, China, parts of Middle East and Africa and also in some regions of Latin America, causes a serious and fatal disease, **kala-azar** or **visceral leishmaniasis** involving liver and spleen. (Fig. 2.25(b)). In Assam, 25 per cent of the population was deleted between 1890 to 1900 due to kala-azar. Sometimes severe dermal infection appears in those individuals who have earlier had kala-azar infection.

*L. tropica* which mainly occurs in the West and Central India and arid regions of the eastern hemisphere; causes cutaneous *leishmaniasis* or oriental sores. This is a mild disease in which at the site of each bite by the fly, a small ulcer is produced.

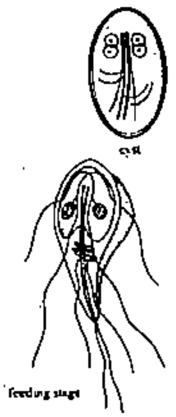

**Fig. 2.26:** *Giardia intestinalis* Cyst with two cells as often seen in faeces.

### *Giardia*

*Giardia intestinalis* inhabits the intestine of man. It has the distinction of being probably the first parasitic protozoan to be seen by Antony Van Leeuwenhoeck in 1681, in his own faeces. This is a very common parasite in humans especially in children and can cause a disease giardiasis. The trophozoite is pear shaped (Fig. 2.26) it has two nuclei between which lie 8 basal bodies giving rise to 8 flagellae by means of which the parasite can swim. Normally this protozoan lives in the small intestine but severe infestation cause diarrhoea and epigastric pain. The cysts are discharged in faeces and infection occurs via faeces contaminated drinking water.

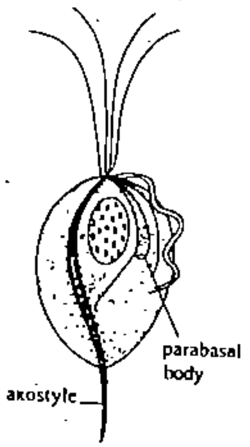


**Fig. 2.27:** *Trichomonas vaginalis.*

### *Trichomonas vaginalis*

This cosmopolitan protozoan lives exclusively in the female vagina and male urethra or prostate. It causes a mild disease called trichomonas vaginitis. The protozoan is ovoid (Fig. 2.27) has four free anterior flagella and one recurved posterior one which is attached to a thin fin like extension of the body forming an undulating membrane. Transmission is through sexual contact or contamination with infected material.

Two physicians, Leishman and Donovan, independently discovered in 1903 the causative agent of kala-azar that (the death fever), both while working in India. Their discovery became a landmark in medical science.

Our ancestors certainly had the knowledge about malaria. In the ancient medical writings from India and China, there are descriptions of intermittent fever, attributed to evil spirits. Hippocrates (5th century B.C.), though could identify the symptoms of disease, assumed that mal (=bad) air and mists from swamps and marshes caused it. This belief persisted for about 2000 years.

The Greeks and Romans even practised the control of this disease by draining swamps and marshes.

**SAQ 6**

i) Match the parasites listed in column A with the disease that they cause:

| | A | | B |
|---|---|---|---|
| a) | *Entamoeba histolytica* | i) | African sleeping sickness |
| b) | *Trypanosoma gambiense* | ii) | Kala-azar |
| c) | *Trypanosoma cruzi* | iii) | Oriental sores |
| d) | *Leishmania donovani* | iv) | Dysentery |
| e) | *Leishmania tropica* | v) | Chagas' disease |

ii) State whether the following statements are true or false. Put T or F as your answer in the box.

a) Secondary amoebiasis most commonly occurs in lungs ☐

b) The infective stage of *Entamoeba histolytica* is a four nucleate cyst. ☐

c) *Trypanosoma gambiense* occurs in blood plasma. ☐

d) All trypanosome infections are transmitted by tsetse fly. ☐

e) *Leishmania* species multiply as flagellated stage in their vertebrate host. ☐

f) *Trichomonas* spreads from one person to another through contaminated food items. ☐

## 2.5.3 Sporozoans

Sporozoans of the genus *Plasmodium* are responsible for causing a serious human disease, **malaria**. They are among the best known parasites which live in the fixed tissues of the body and circulating red blood cells of their vertebrate host. More than 100 species of *Plasmodium* parasitise a wide variety of vertebrates — lizards, birds and mammals, primates and rodents in particular. Four species of *Plasmodium* which mainly occur in man and have no other natural vertebrate host are the cause of human malaria. These are *Plasmodium vivax, P. falciparum, P. malariae* and *P. ovale* most prevalent in tropical and subtropical regions of the world.



Even 300 years before Laveran described in 1880 the asexual stages of *Plasmodium falciparum*, chemotherapy was already in use. People were using the bark of the Peruvian *Cinchona* (the fever-tree bark). The quinine and cinchonine are alkaloids derived from cinchona tree.

All malarial parasites require two hosts, one a vertebrate host in which asexual cycle of the parasite (involving schizogony and early gametogony) occurs, and the other a mosquito in which sexual phase of life cycle (involving completion of gametogony and sporogony) is completed.

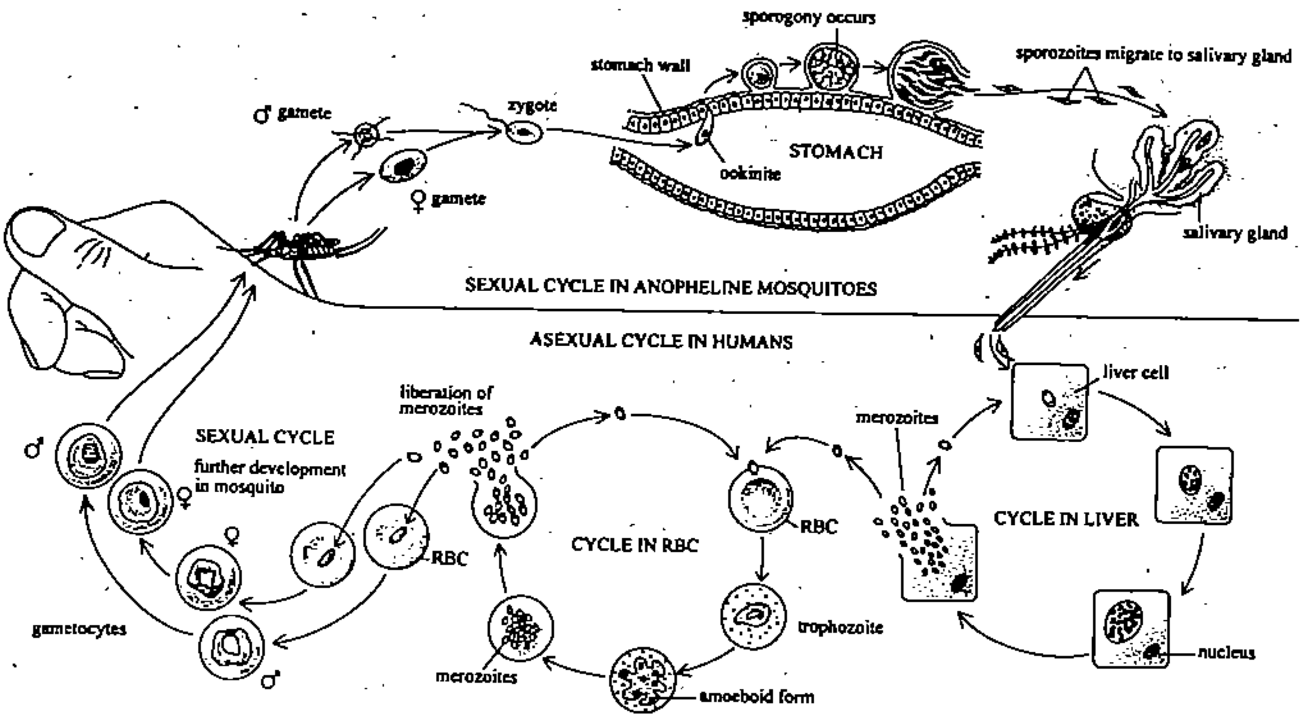


**Fig. 2.28: Life cycle of malarial parasite in mosquito and human hosts.**

The life cycle (given in Fig. 2.28) of the parasite in man begins when an infected mosquito, while biting and taking a blood meal, injects sporozoites into the human blood alongwith its salivary secretions. The sprorozoites soon disappear from the circulation and enter the cells of the liver, where they undergo multiple divisions (schizogony). As they increase in number, the parasitised liver cell ruptures, liberating a large number of parasites. We call these **pre-erythrocytic merozoites**, because they have not yet invaded the red blood cells. The period when the parasite is in the liver is known as incubation period which may last for 6-15 days depending on the species of *Plasmodium*. These pre-erythrocytic merozites initiate an asexual multiplication cycle in the red blood cells (RBC), the **erythrocytic cycle**. Inside the RBC, the parasite become amoeboid trophozoites feeding on haemoglobin. The end product of the trophozoites digestion is called **hemozoin** which accumutates in the host cell. This process of asexual reproduction in the RBC is known as **schizogony**, and a large number of organisms are produced from one individual. Schizogony tends to occur synchronously in a large number of erythrocytes and at the end of each cycle a large number of merozoites are liberated from the parasitised RBC. When the RBCs burst they also release the metabolic products of the parasite and these foreign toxins cause the characteristic chills and fever of malaria. These merozoites enter fresh RBCs and repeat the multiplicatory cycle. Since the population of merozoites released from RBC is synchronised to some degree, therefore, the episodes of chill and fever have a periodicity characteristic of each species of *Plasmodium*. In *P vivax* (benign tertian) malaria the episodes occur every 48 hrs.; in *P. malariae* (quartan) every 72 hrs; *P. ovale* every 48 hours and *P. falciparum* (malignant tertian) every 48 hours. After a few generations some of the merozoites do

In case of *P. vivax, P. ovale* and *P. malariae* a latent infection may continue to exist in the liver cells. This is the **exoerythrocytic** cycle of the parasite and provides a source for relapse of malaria even when of the erthrocytic cycle of the parasite has been eliminated by treatment. In case of *P. falciparum*, no liver cycle exists subsequent to the infection of red blood cells; thus no relapse occurs when *P. falciparum*, is the cause of malaria.

not undergo a schizogonous cycle upon entering a fresh RBC but develop into large gamete-forming uninucleate cells. This is the **gametocytic** stage of the parasite. Some of these are male or microgametocytes and some, female or macrogametocytes. These gametocytes will not develop further any more in the vertebrate host. Further development occurs only in the stomach of the mosquito. When an anopheline female mosquito bites an infected person, it also ingests the gametocytes alongwith the blood meal. (Male mosquito feeds on plant sap and is not a blood feeder). In the stomach of the mosquito the process of **gametogony** gets completed with the formation of gametes. The two gamete types fuse to form a **zygote**. The zygote becomes a motile **ookinete**. It penetrates the stomach wall and lodges itself under the outer limiting membrane forming and **oocyst**. The oocyst undergoes numerous cell divisions, grows in size and gives rise to many spindle-shaped cells, the **sporozoites**. When filled to its capacity, i.e, after 10-20 days of the blood meal, the oocyst bursts open and liberates these sporozoites into the haemocoel of the mosquito. The sporozoites reach the salivary glands of the mosquito. These are infectious to human host and are injected into the blood when the mosquito feeds on human blood. This is how the parasite completes its life cycle.

Fig. 2.29: *Toxoplasma gondii.*

Another well known Sporozoan is *Toxoplasma gonidii* which has an unusually wide host-range for a protozoan parasite. It can probably infect all warm-blooded animals. It is equally wide spread geographically. It may cause acute illness or the infection may be latent and completely inapparant. The parasite can invade any nucleated cell in the body where it divides asexually and forms cysts (Fig. 2.29). Maternal infection can be transmitted to the foetus where it can cause congenital defects. Transmission is by eating raw meat or via domestic animals and pets especially as the cysts reside in the fur of cats.

SAQ 7

Complete the following sentences:

a) Malaria is caused by the parasites of the genus ..........................

b) The cycle of malarial parasite occurring in the RBCs of man is called ........................

c) The sexual phase of reproduction of *Plasmodium* occurs in ..........................

d) Ookinete is a .......................... zygote.

e) Malarial fever caused almost every 48 hours is .......................... malaria.

### 2.5.4 Ciliates

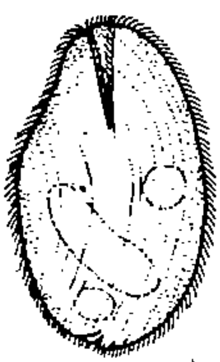

Fig. 2.30: *Balantidium coli.*

The only ciliate of medical and veterinary importance is *Balantidium coli* (Fig. 2.30) which inhabits the large intestine of man, apes, monkeys and pigs. *B. coli* has been reported from all parts of the world. It causes invasion of intestinal mucosa, thereby causing diarrhoea, nausea, vomitting. The parasite encysts in the lumen of the host's large intestine and the cysts pass out in the faeces.

## 2.6 SUMMARY

In this Unit you have learnt that:

- Protozoans are an assemblage of unicellular animal like, heterotrophic organisms, belonging to eukaryote protists. Most protozoa inhabit the sea or freshwater but there are many parasitic, commensal and mutualistic species. The body may be supported by an exoskeleton (test) or an internal cytoskeleton (microtubules, microfilaments or vesicles). Most protozoan groups are distinguished by the type of locomotor organelles; flagella, pseudopodia or cilia. Digestion is intracellular, within a food vacuole and food reaches this vacuole through a cell mouth or by engulfment. Water and ion regulation are accomplished by contractile vacuoles. Reproduction is by fission. Depending on the group, meiosis occurs resulting in the formation of gametes or in the formation of haploid spores. Encystment is common.

- Protozoan phyla were formerly placed in four groups.
  - i) Flagellates — locomotion by flagella.
  - ii) Amoeboid — locomotion by pseudopodia.
  - iii) Ciliates — locomotion by cilia.
  - iv) Sporozoans — parasitic protozoa; hence no specialized locomotory organelles.

  This large heterogenous group is now recognised to be organised in 7 phyla according to the Society of Protozoologists (1980).

- Some of the important disease causing protozoans are from among the amoebae, flagellates ciliates and sporozoans. The life cycle of the parasitic sporozoans like the malaria causing *Plasmodium* and flagellates like *Trypanosoma* and *Leishmania* have been described.

## 2.7 TERMINAL QUESTIONS

1. Explain why a unicellular protozoan may be very complex in comparison to a single metazoan cell.

   ..........................................................................................................

   ..........................................................................................................

   ..........................................................................................................

2. Distinguish among the following protozoan phyla: Apicomplexa, Ciliophora and Sarcomastigophora.

   ..........................................................................................................

   ..........................................................................................................

   ..........................................................................................................

3. In which habitats would you expect to find an encysted condition in protozoans? What are the benefits of such a condition?

   ..........................................................................................................

   ..........................................................................................................

   ..........................................................................................................

4. List the general characters of Protozoa.

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   ..........................................................................................................

   ..........................................................................................................

5. Outline the steps in conjugation in ciliophores.

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   ..........................................................................................................

   ..........................................................................................................

6. Comment on the importance of protozoan parasites to man.

   ..........................................................................................................

   ..........................................................................................................

   ..........................................................................................................

7. What factor is involved in the periodic appearance of malarial symptoms?

   ..........................................................................................................

   ..........................................................................................................

   ..........................................................................................................

## 2.8 ANSWERS

**Self Assessment Questions**

**SAQ 1**

Amoeba moves by means of pseudopodia; flagellates and ciliates by flagellum and rows of cilia that beat causing progression.

**SAQ 2**

Contractile vacuoles have an osmoregulatory rather than excretory role. They regulate the water content of the cell eliminating excess water.

**SAQ 3**

I. 1. Protista
2. Colonial
3. Microtubules
4. Amoeboid
5. Binary fission
6. Conjugation
7. Holozoic
8. Flagellum

II. a — v
b — vi
c — ii
d — i
e — iii
f — iv

**SAQ 4**

1-F; 2-T; 3-T; 4-T; 5-T; 6-T; 7-T; 8-F.

**SAQ 5**

a. Locomotion and suspension feeding

b. Macronucleus — Vegetative functions. Micronucleus — Reproductive functions

**SAQ 6**

A. a-iv; b-i; c-v; d-ii; e-iii;

B. a-F; b-T; c-T; d-F; e-F; f-F.

**SAQ 7**

(a) *Plasmodium*, (b) erythrocytic cycle, (c) mosquito (d) motile, (e) tertian.

**Answers to Terminal Questions**

1. Unlike a single metazoan cell, a unicelluler protozoan can perform a variety of functions. Infact an unicelluler protozoan is an organism by itself. Whereas any multicellular cell can perform only one type of function such as secretion, contraction, response to stimulus, reproduction etc., an unicellar protozoan can perform all these functions and hence is very complex.

2. See Section 2.4.

3. Habitats such as ponds, lakes, rivers and moist soil once they become dry harbour encysted protozoans. Under encystment organisms remain dormant over a long period of time and with the return of favourable conditions they become once again active.

4. Refer to section 2.2.

5. Refer to sub section 2.3.7.

6. You could answer this by citing the examples of protozoan parasites from the text and telling what diseases they cause.

7. The duration of the erythrocytic schizogony determines the appearance of malarial symptoms. As this cycle gets completed with the release of a fresh brood of merozoites into the blood plasma at a definite time interval, symptom of malaria appear.

# UNIT 3 METAZOA — ORIGIN AND EVOLUTION

## Structure



## 3.1 INTRODUCTION

You have already seen in Unit-1 that in the two kingdom classification, the unicellular 'animals' used to be clubbed together under a single phylum Protozoa that constituted sub-kingdom — Protozoa. The rest of the animals, all multicellular, were grouped under the sub-kingdom Metazoa under various phyla (the corresponding grouping for plants was Protophyta and Metaphyta). However, under the present concept of Five Kingdom Classification, this grouping has no relevance. Still, we often continue to use the term Metazoa to refer to the Animalia of the five kingdom classification. In this Unit we start with an explanation of the levels of body organisation in animals and the basic animal body plan. However, diverse the different invertebrates and vertebrates may appear to the eye, it is possible to group them in four master body plans. These are the unicellular plan, the cell aggregate plan, blind sac plan and tube within a tube plan. The protozoans fall into the first category and the rest three structural plans are seen in the metazoans. We next list out the characteristic features of metazoans. We shall also discuss those features that are considered of fundamental importance for describing and understanding the structure and classification of any animal. These characters are: (i) cleavage patterns and number of germ layers it has been derived from; (ii) its body symmetry; (iii) nature of body cavity; (iv) segmentation and cephalisation. It would be useful if you revise Block-3 of the course Developmental Biology (LSE-06) before reading this unit as most of the concepts discussed there would help you to understand this Unit better. In later sections of the unit we will consider the various theories related to origin and evolution of metazoans or the Animalia.

### Objectives

After studying this unit you should be able to:

- describe various levels of body organisation of animals;
- describe the various cleavage patterns found in animals;

- identify the various types of germ layers and describe the functions of their derivatives;
- identify the animal groups based on their symmetry;
- describe the different types of body cavities, segmentation, cephalisation and their functional significance;
- classify animals on the basis of their structural organisation;
- discuss the origin and evolution of Animalia.

## 3.2 LEVELS OF BODY ORGANISATION

You have learnt in your earlier course LSE-01 about the levels of organisation of matter. You may recall that the smallest structural units of all matter are subatomic particles, mainly electrons, protons and neutrons. The next larger units are atoms and many atoms get together to form combinations called compounds which are variously joined together to give a higher level of organisation called complexes of compounds. Such levels of matter can be viewed as a pyramid (Fig. 3.1).

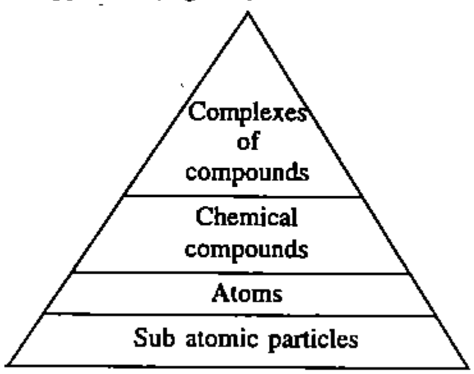



**Fig. 3.1: Levels of organisation of matter.**

In this pyramid any given level contains all lower, levels as its component and itself is also a component of all higher levels. For example, atoms contain subatomic particles as components, and atoms are themselves components of chemical compounds. Similarly, in living matter, complexes of compounds occur as submicroscopic and microscopic bodies called *organelles*, capable of carrying on specialised functions within the cell.

Organisms which are made of just one cell are the simplest and the most primitive creatures called unicellular organisms. Their level of body organisation is at the lowest and is called **protoplasmic level of body organisation.** If we try and fit the metazoan body organisation into a pyramid mode, the protoplasmic level will be at the bottom. As the organisms evolved from unicellular to multicellular grade their level of body organisation also changed from simple to complex.

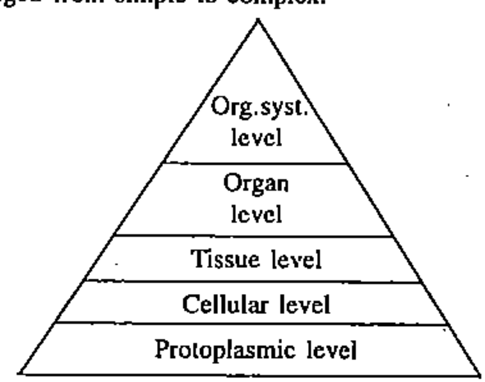



**Fig. 3.2: Level of body organisation.**

Look at the Figure 3.2, the next higher level of organisation is the **cellular level**. This is really an aggregation of cells that are functionally differentiated. A division of labour is evident so that some cells are specialised for reproduction some for nutrition. Among the metazoans, Placozoa and Mesozoa are said to belong to the **cellular level of body organisation** (Fig. 3.3 a and b).

Some authorities place the sponges (porifera) among this group too because they have several cell types differentiated for various functions but there is no true tissue organisation yet. (Fig. 3.3 c).

The phylum Placozoa contains a single species of a minute marine animal *Trichoplax adharens* composed of a dorsal and ventral epithelial layer enclosing loose mesenchyme like cells. Mesozoans comprise some 50 species of small parasitic worms that have simple structures made up of 20-30 ciliated cells covering a few reproductive cells.

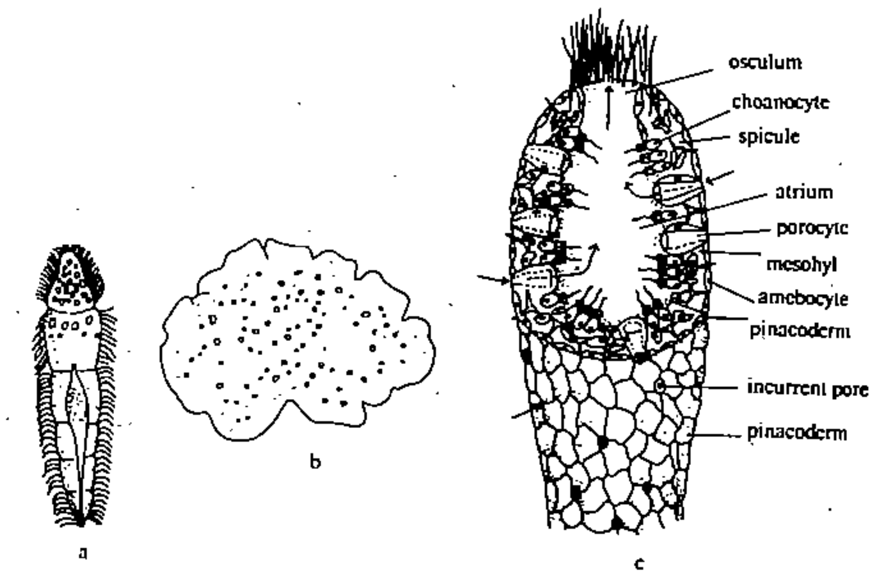



**Fig. 3.3: (a) Cellular level of body organisation in mesozoan — *Rhopalura*. (after Hyman) (b) a placozoan (after Margurlis & Schwartz 1982) (c) L.S. asconoid sponge.**

As you already know a tissue is a group of cells similar in origin and structure that perform a specific function. The next level, is the **tissue level** of body organisation which can be seen in coelenterates (Cnidaria and Ctenophora). These are made up of two germ layers ectoderm forming epidermis and endoderm forming the gastrodermis. The jelly fishes and their relatives are considered as the beginning of tissue organisation and an excellent example of tissues, in Cnidarians is the nerve net in which the nerve cells and their processes form a definite tissue structure with the function of coordination (Fig. 3.4).

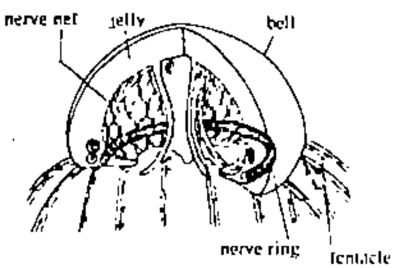



**Fig. 3.4: Tissue grade of organisation — nerve net in jelly fish.**

The next higher level of body organisation as seen in the pyramid is the **organ**. Organs are usually made up of more than one kind of tissues. This is already seen in some cnidarians, ctenophores and the flatworms or Platyhelminthes in which there are well defined organs such as the eye and reproductive organs (Fig. 3.5).

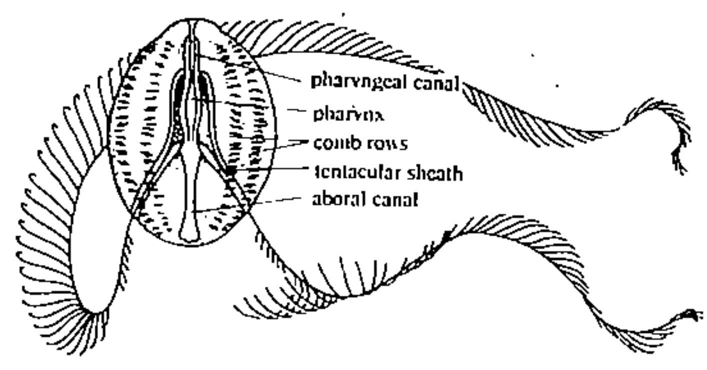



**Fig. 3.5: Organ level of organisation in a typical ctenophore.**

When organs work together to perform a specific function we have the highest level of body organisation i.e. the **organ system level** of body organisation. The systems are associated with basic body functions. This type of body organisation is seen for the first time in Platyhelminthes (Fig. 3.6) which have for example, a digestive system distinct from a well developed reproductive system. From this phylum to mammals, all animals have the highest level of body organisation.

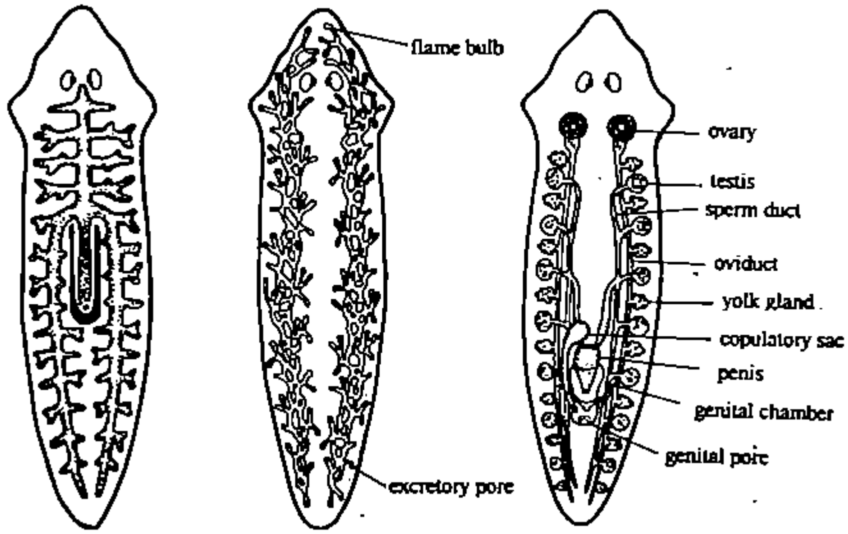



Fig. 3.6: Organ system level of organisation in *Planaria*
a) digestive system
b) excretory system
c) reproductive system.

## 3.3 CHARACTERISTICS OF METAZOA

From Unit-2 you know that the unicellular protozoans are highly versatile and successful organisms that show remarkable organisation and division of labour within the confines of the single cell. This diversity is achieved by varying the structure of their organelles at the sub-cellular level. The Metazoa or the multicellular animals have achieved their structural diversity by varying their cells that have become specialised to perform different functions. These cells are normally incapable of independent existence.

Let us list out some of the features that characterise metazoans.

1. Members of Metazoa possess a complex multicellular structural organization which may include the presence of tissues, organs and organ systems.
2. In the life-history of metazoans, typically a fertilized egg passes through a blastula stage in the course of its early embryonic development before changing into an adult.
3. Since metazoans are multicellular they are relatively larger in size than unicellular protozoans. Naturally, their nutritional requirements are more and they have to search for food. Consequently, locomotion in metazoans is highly developed and for this purpose they have evolved contractile muscular elements and nervous structures.
4. The ability for locomotions has influenced the shape of the metazoan animals which in turn has conferred specific types of symmetries to metazoan groups.
5. Most of the metazoans show differentiation of the anterior end or head (cephalization); associated with cephalisation, there is the centralization of the nervous system in the head region.

Although all metazoans share some characteristic features, their body plans differ in symmetry, internal organisation, developmental patterns and modes of formation of body cavity. These differences provide us a means of grouping them or organising them into different phyla. Let us discuss these features one by one.

## 3.4 SYMMETRY

All living organisms have some body shape and form. The general body plan of animals may be organized in one of several ways (Fig. 3.7 a-f).

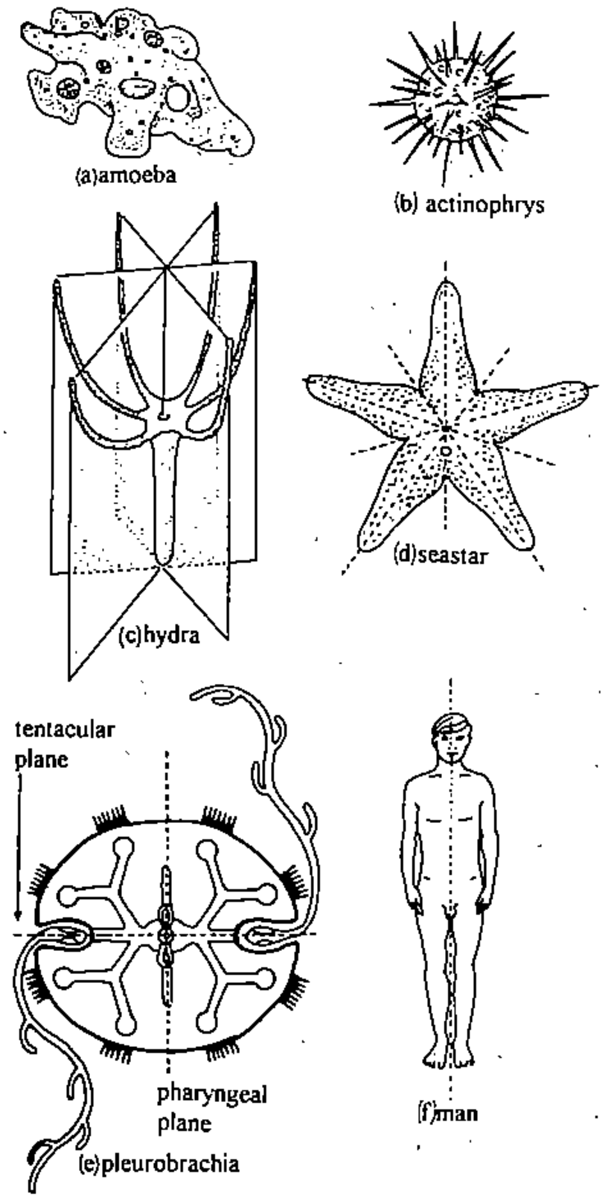



**Fig. 3.7: Different types of body symmetries a) asymmetrical b) spherically symmetrical, (c-d) radially symmetrical. (e) biradially symmetrical (f) bilaterally symmetrical.**

Arrangement of parts or organs on either side of an imaginary dividing line or around a common axis or radially around a point so that opposite parts are mirror images of one another is called **symmetry.** There are two broad divisions of symmetry,
(i) primary, or embryonic (ii) secondary, or adult. The latter may or may not be the same as the primary one. For example, the larva of starfish is bilaterally symmetry but the adult starfish is radially symmetrical. The primary symmetry is bilateral and secondary symmetry is radial. With regard to symmetry animals can be basically of five types (i) asymmetrical (ii) spherical (iii) bilateral (iv) radial and (v) biradial.

## 3.4.1 Asymmetrical and Spherical

Some creatures are asymmetrical : no matter which way we try to divide them through the middle, no two halves would appear alike (Fig. 3.7 a). In simpler words : these are animals which cannot be cut into two identical halves through any plane or axis (longitudinal, sagittal or transverse). Amoeba and most of the poriferans are examples.

At the other extreme, is spherical symmetry. The animals with spherical symmetry can be divided into identical halves along a number of planes which pass through the centre or in other words every plane through the centre will yield two halves which are mirror images of each other. This type of symmetry is found chiefly in some protozoa and is rare in other groups of animals. *Actinophrys* (Fig. 3.7 b) and colonial *Volvox* are typical examples.

### 3.4.2 Radial and Biradial

Radial symmetry is the symmetry in which the parts are so arranged around a central axis or shaft, like the spokes of a wheel, that any vertical cut through the axis would divide the whole animal into two identical halves. The common jelly fish and hydra (cnidaria) — exhibit radial symmetry (Fig. 3.7 c). The starfish and their relatives have a modified form of radial symmetry. They can be divided along 5 planes, each giving two distinct halves. This is known as pentermerous symmetry. One side of the body has the mouth and is known as the oral surface; the opposite side is aboral (Fig. 3.7). Cuts made along the oral-aboral axis will result in identical halves.

Biradial symmetry is a variant of this and it is found in sea anemones and ctenophores. Though the animal appears to be radially symmetrical, it can be divided only into two equal halves along two per-radial positions — along the tenticular plane and along the sagittal plane at right angles to it. (Fig. 3.6 e).

Radial and biradial animals are usually sessile, floating freely or weak swimmers. These animals are called the **Radiata.**

### 3.4.3 Bilateral

Bilaterally symmetrical animals have the major axis running from head (anterior) to tail (posterior). They have a ventral (lower) and dorsal (upper) surface that are different from each other. They have only two sides that look alike, the right and left. The animal can be divided into just two identical halves through a plane which passes from anterior to posterior end. Almost all animals including human beings (Fig. 3.6 e) except for sponges, ctenophores and cnidarians show bilateral symmetry. Adult echinoderms, though radially symmetrical (pentamerous) have larvae that are bilateral. This is because they have evolved from bilaterally symmetrical ancestors. In general, bilateral animals that adopt a sessile existence commonly exhibit a shift towards radial symmetry. The shift may be slight as in acorn barnacles where only protective circular wall plates are arranged radially or the shift may be profound as in the case of sea stars or starfishes. Bilateral animals are called **Bilateria.**

SAQ 1

Match the term on the left with correct statement from the list on the right.

| | | |
|---|---|---|
| (a) Asymmetrical | i) Can be divided into many identical halves. | |
| (b) Bilaterally symmetrical | ii) Can be divided into two identical halves but not more. | |
| (c) Biradially symmetrical | iii) Echinoderms | |
| (d) Pentamerous radial symmetry | iv) Ctenophores | |
| (e) Spherical | v) Cannot be divided into two identical halves | |

## 3.5 DEVELOPMENTAL PATTERNS

In the last section you learnt how the metazoans or Animalia can be divided into two groups on the basis of body symmetry. The bilateral metazoans can be divided into two great assemblages : the **Protostomia** and the **Deuterostomia**. Platyhelminthes, Mollusca, Annelida, Arthropods and a number of minor phyla are classified as Protostomes while Echinodermata, Chordata and atleast two minor phyla are included in the deuterostomes. The features used to place animals in these group are largely developmental. We consider the cleavage patterns first.

### 3.5.1 Cleavage

You have learnt in Developmental Biology (LSE-06) that the unicellular zygote begins cell division (cleavage). First, the single cell divides forming two cells, these redivide further to form four, then eight cells and so on till it gets converted into a ball of cell. The cells are called **blastomeres.**

The planes of the first and second cleavage are vertical passing through the axis, but at right angles to one another. These two cleavages together result in four blastomeres lying side by side around the axis. The plane of the third cleavage is at right angles to the first two planes and to the axis and is horizontal and hence parallel to the equator of the zygote. This results in eight blastomeres. Of the eight blastomeres four lie on top of the other four.

The pattern of cleavage and arrangement of blastomeres around an imaginary central axis in a zygote can be one of two types radial or spiral.

**Radial cleavage** produces tiers or layers of cells one on top of another (Fig. 3.8a). Radial cleavage is also said to be **indeterminate** or **regulative** because each of the blastomeres of the early embryo, if separated from the other, can regulate its development and form a complete well proportioned embryo. This happens because the blastomeres are **equipotent**; their final fate is not yet determined and there is no definite relation between the position of **early** blastomeres and specific tissue it will form in the embryo (hence indeterminate). This type of cleavage is found in some cnidarianes, echinoderms and all chordates.

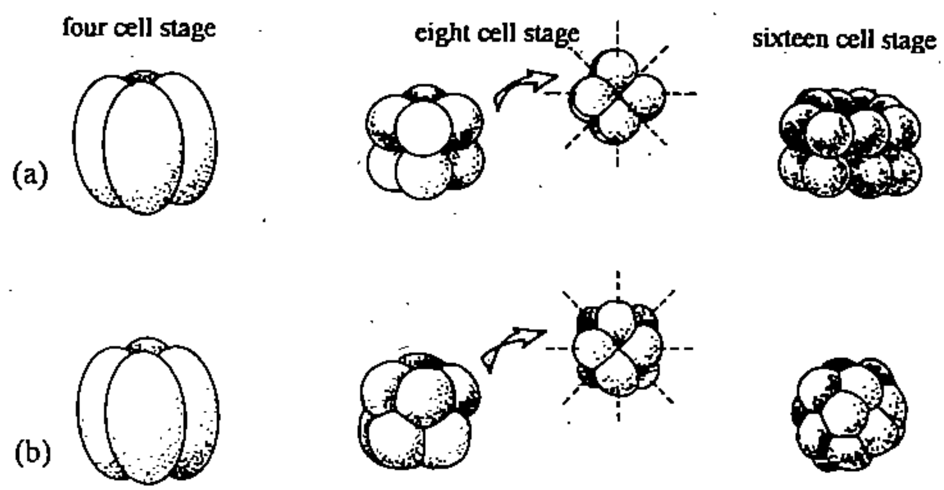



**Fig. 3.8: (a) Radial cleavage shown at 4, 8 and 16 cell stage.**
**(b) Spiral cleavage showing transition from 4 to 8 to 16 cell stage.**

In **Spiral Cleavage**, however, the third and fourth cleavage planes are oblique to the polar axis and the resulting blastomeres do not lie on top of one another but above the furrows between the cells (Fig. 3.8 (b)). The spindles during the third cleavage are arranged in the form of a spiral, therefore, the name spiral cleavage. This type of cleavage is seen in all invertebrate except the echinoderms (i.e. in annelids, molluscs, arthropods nemertenes and polyclad planarians).

Spirally cleaving embryos are said to have **mosaic** or **determinate** form of development. This means that the organ forming regions of the egg are strictly localised in the egg from the very beginning and the fate of the blastomere is determined early. If the blastomeres are separated, each will continue to develop upto a certain time as though it was a part of the whole and give rise to defective, partial embryos. In the early embryos an unidentified cytoplasmic factor is segregated into one of the blastomeres, the **mesentoblast** (this is also called the '4 d' cell) which gives rise to the future mesoderm.

### 3.5.2 Fate of Blastopore

Cleavage results in the formation of a ball of cells called **morula** (resembling mulberry hence the name). A space appears in the morula changing it to a hollow **blastula.** The central cavity is called the **blastocoel** and the layers of cells surrounding it the **blastoderm.** Invagination or infolding of the blastoderm gives rise to a double walled **gastrula.** The cavity of this double walled cup is called **archenteron** and the opening of the archenteron to the outside is called the **blastopore** (Fig. 3.9). As the gastrula develops further, parts of the embryo give rise to different structures to ultimately form a complete young one. In platyhelminths, nematodes, annelids, arthropods and molluscs that have spiral cleavage, the embryonic blastopore forms the mouth of the animal and the anus is formed secondarily (Fig. 3.9). Because the mouth forms first these animals are included in '**Protostomia**' (mouth first) division of Animal Kingdom.


**Fig. 3.9: Early embryology of a nemertean worm a protostome.**

In echinoderms, chaetognaths, hemichordates and chordates where radial cleavage takes place, the blastopore forms the anus of the animal and the mouth is formed secondarily, as an independent opening on the body wall as seen in Fig. 3.10. Therefore, these animals are included in '**Deuterostomia**' (mouth second), division of the Animal Kingdom.

The fate of the blastopore thus determines two fundamental lines of evolution. The protostomes in which the cleavage is generally mosaic (determinate and spiral) and the deuterostomes in which the cleavage is usually regulative (radial and indeterminate) type.

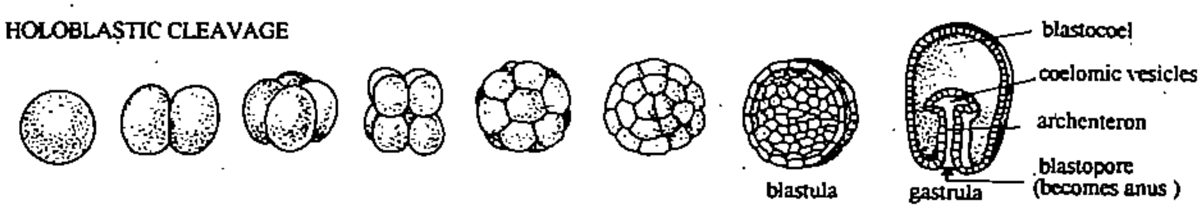



**Fig. 3.10: Blastopore formation in sea-star a deuterostome.**

## 3.6 GERM LAYERS

In the earlier section you have learnt that infolding of the blastoderm of the blastula forms a gastrula with two or more layers. The outer layer is the ectoderm and the endoderm lines the inner cup. Later in development a third layer, the mesoderm, typically develops between the two. The details are mentioned in subsection 3.7 of this Unit. These three embryonic layers from which various organs of the animal are developed are called **germ layers.**

You must know at this point that animals of phyla Cnidaria and Ctenophora are made up of only two germ layers: **ectoderm** which forms the outer covering of the animal and **endoderm** which is the inner layer and is also known as the **gastroderm**. However, a non-cellular jelly like substance **mesoglea** is present between ectoderm and endoderm which acts as a cement to bind the two layers. This layer should not be confused with the third germ layer i.e. **mesoderm**. Since animals of these two phyla do not have mesoderm, they are said to be **diploblastic**. If we cut a longitudinal section through *Hydra* we see two distinct layers bound together by a non-cellular mesoglea. The two germ layers give rise to many different cell types — as evident from figure 3.11.

Rest of the animals (platyhelminths to mammals) are all made up of three germ layers viz. ectoderm, endoderm and mesoderm. These animals are **triploblastic**. If we cut a section say through a horse (a mammal and triploblastic) can we expect to see three layers like you see two layers in diploblastic *Hydra*? No we will not, because these three germ layers do not remain as such, they differentiate and modify to give rise to different structures and organs in the body of the horse. The three layers will be distinct only during early embryology. Hence we call them the embryonic layers or the germ layers.

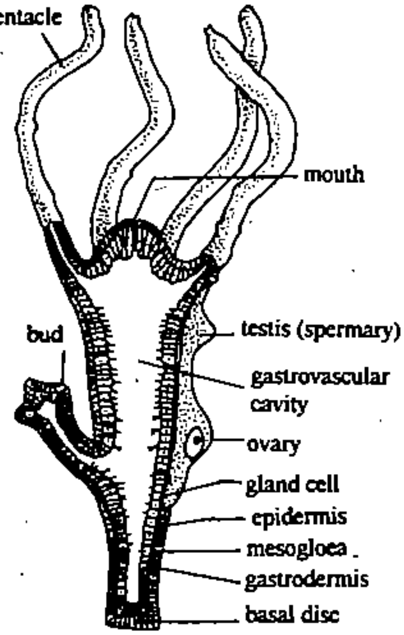



Fig. 3.11: L.S. Hydra.

### Fate of the germ layers

In cnidarians and ctenophores, all the cell types develop from either ectoderm or endoderm. Similarly all the tissues and organs in the rest of the animals develop from the three germ layers. Perhaps you would like to know how the three germ layers contribute to the different body structures as you grew from embryo to infant. Table 3.1 will illustrate this.

Table 3.1: Derivatives of the three germ layers.

| ECTODERM | ENDODERM | MESODERM |
|---|---|---|
| i) Epidermis of the skin. | i) Epithelial parts of the thyroid, thymus, parathyroid, middle ear, eustachean tube. | i) Dermis of the skin. |
| ii) Brain and spinal cord. | ii) Epithelial portions of the liver and pancreas. | ii) Skeletal system. |
| iii) Cranial and spinal nerves, oral epithelium and epithelium of oral glands. | iii) Epithelial lining of the respiratory system beginning with the larynx. | iii) Most muscles as well as adipose tissue and all other varieties of connective tissue. |
| iv) Nasal and olfactory epithelium. | iv) Epithelial lining of the vagina, urinary bladder. | iv) Certain types of scales, horns in animals. |
| v) Epithelium of anal canal. | v) Epithelial lining of the gut, except the mouth and the anal canal. | v) Dentine portion of teeth. |
| vi) Lens and retina of the eye. | vi) Auditory tube and middle ear cavity in mammals, etc. | vi) Blood vascular system including blood. |
| vii) Epithelium of sweat, sebaceous and mammary glands. | | vii) Greater part of the urino-genital system. |
| viii) Hair, nails, (feathers, hooks, scales in animals). | | viii) Adrenal cortex. |
| ix) Adrenal medulla, anterior and posterior pituitary and pigment cells. | | ix) Coelomic epithelium, mesenteries, and outer layers of the gut. |
| x) Inner ear vesicle (labyrinth). | | x) Lining of gonads. |
| xi) Enamel of teeth. | | |
| xii) Cutaneous sense organs. | | |

By going through this table you must have realized the significance of the germ layers. We now proceed to another important characteristic of animals — the cavities and coelom.

### SAQ 2

Fill in the blanks using words from the text.

(i) Archenteron appears in the .................... and is the future ................

ii) Animals of phylum Cnidaria have a middle layer called ........................ and based on the number of germ layers, they are called ...............................

iii) All chordates, including human beings have .................. germ layers and are called ........................

iv) Nasal epithelium, retina and inner ear vesicles are the derivatives of ........................

v) Dermis, adrenal cortex, most muscles are derivatives of ........................

vi) Middle ear, epithelium of vagina and respiratory tract are derivatives of ........................

## 3.7 BODY CAVITY AND COELOM

Vacuoles, spaces, lacunae and cavities have been of importance in all organisms, may it be plant or animal. All animals have cavities. The cavities perform different functions in different animals. But most of these are not usually considered body cavities. Spongocoel for example, a cavity in sponges, is really a system of water canals. Generally by the term body cavity we mean a large fluid filled space lying between the body wall and the internal organs. Bilateral animals are classified according to the presence or absence of body cavities. There are two types of body cavities in animals the **pseudocoelom** and the **coelom**.

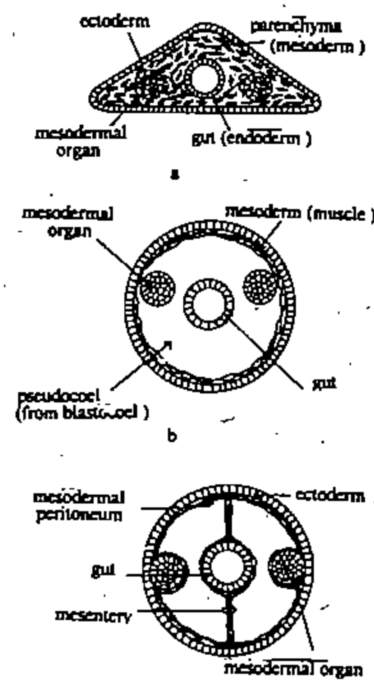



**Fig. 3.12: Section of (a) acoelomate, (b) pseudocoelomate and (c) eucoelomate animals.**

### 3.7.1 Pseudocoelom

The platyhelminths which do not have a body cavity surrounding the gut, have a solid type of body constitution (Fig. 3.12 a). The mesoderm completely fills the space between body wall and alimentary canal in the form of a network of cells called parenchyma. Such animals are called **acoelomates.** In nematodes, there is a different situation: the mesoderm is confined to specific circumscribed regions within the body cavity, and this cavity is neither lined nor filled with mesoderm. The cavity is in fact a persistent blastocoel of the embryo and is called **pseudocoel.** The internal organs are free within the pseudocoel. The body cavity has no lining of peritoneum derived from mesoderm. Animals so constructed are called **pseudocoelomates** (Fig. 3.12 b).

### 3.7.2 Coelom

True coelom is a body cavity which arises within the embryonic mesoderm so that the cavity lies between the body wall (integument; ectoderm) and gut (endoderm) and is lined by mesodermal cells. This lining is called peritoneum in higher animals. Various internal organs are housed in the coelom and are lined by peritoneum along with many mesenteries (Fig. 3.12 c), thin membranes that keep the internal organs in place. The fluid inside the cavity acts as a shock absorber and gives rigidity to the body as well as functions in circulation, excretion and respiration in invertebrates.

There are two patterns of coelom formation in animals **schizocoelous** and **enterocoelous**. In schizocoelous pattern, two teloblasts cells (primordial mesodermal cells) are given out (Fig. 3.13 A) from close to the blastopore. These proliferate into a pair of teloblastic bands. At first the bands are solid but later each splits forming a cavity within. This cavity enlarges to form the coelom. Such a coelom is known as **schizocoel** and animal characterized by body cavities of this type are designated as **schizocoelomates** — For example annelids arthropods and molluscs.

*Schizo* comes from Gk. *Schizein* to split; *Entero* is form Greek *enteron* i.e. gut.

*Coelous* comes from Greek *Koilos*, hollow or cavity.

In enterocoelous development of coelom the mesoderm arises in the embryo as paired lateral pouches growing out from the archenteron, (Fig. 3.13 B). The pouches grow and later get disconnected from the archenteron. The cavity of the pouch becomes the coelom. The inner wall of the pouch surrounds the developing alimentary canal and the outer layer lines the developing body wall. Those two layers become the future mesoderm. The animals possessing such cavities are known as **enterocoelomates.** Echinoderms hemichordates and chordates show this pattern of coelom development.

The two different patterns of origin of coelom are another expression of the protostome — deuterostome dichotomy in evolution. Protostomes typically show schizocoelous origin of coelom while in deuterostomes the coelom arises usually by enterocoely.

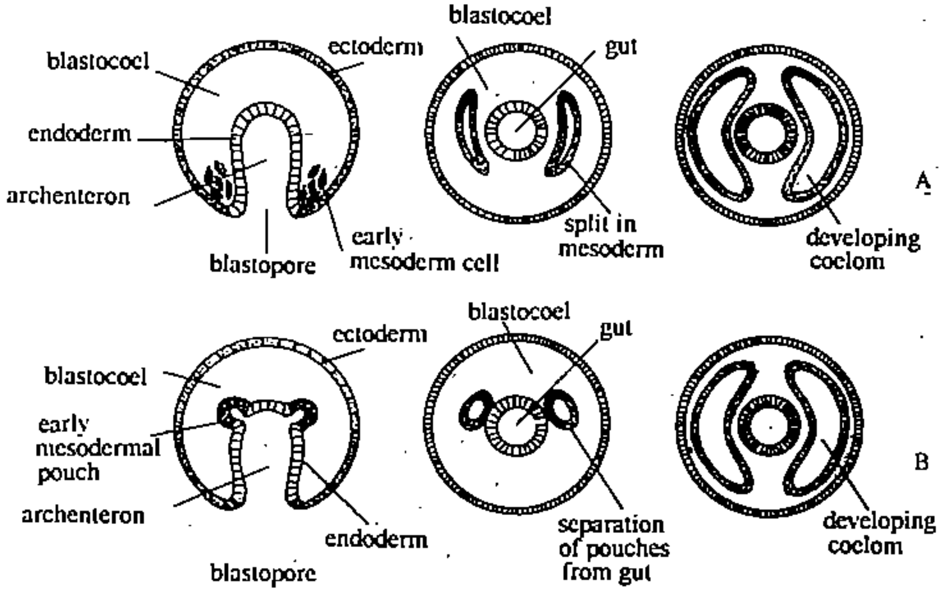



**Fig. 3.13: Development of Coelom.**
**A) Schizocoelous origin**
**B) Enterocoelous origin**

The coelom provides the coelomic animals with a tube-within a tube body plan that allows greater flexibility when compared to animals that do not have internal body cavity. The fluid filled coelom additionally serves as a hydrostatic skeleton, in some forms such as worms, aiding in burrowing and inmovement. The coelom is of great significance in animal evolution. It is a stepping stone for evolution of more complex and larger forms.

### SAQ 3

Mark true (T) or false (F) in the space provided against each statement.

i) True coelom is found in all triploblastic animals.

ii) Diploblastic animals which do not possess a true coelom are called acoelomates.

iii) Schizocoelous coelom is formed from embryonic teloblasts.

iv) Enterocoelomates are also called Protostomes.

v) Nematodes have a body cavity between the ectoderm and endoderm but it is not lined by mesoderm.

vi) In pseudocoelomates the cavity between ectoderm and endoderm is completely filled with mesoderm.

## 3.8 CEPHALISATION AND SEGMENTATION

Bilateral animals when creeping or swimming, have a tendency to keep the same end of the body forward and the same surface down towards the substratum. In such a case the sensory organs and nervous system would also have a tendency to be concentrated at the anterior end. This differentiation of a 'head end' is known as **cephalisation** (literally head development). Cephalisation has evolved to various degrees in bilateral animals. The mouth is usually located at the leading end with which become associated the organs for food capture, as the sensory organs on the head can detect food. Neurons become organised into brain in this region for rapid coordination; longitudinal nerve cords are developed for rapid transmission of information throughout the length of the body. Cephalisation in its most primitive form can be seen in Platyhelminthes (Fig. 3.14).



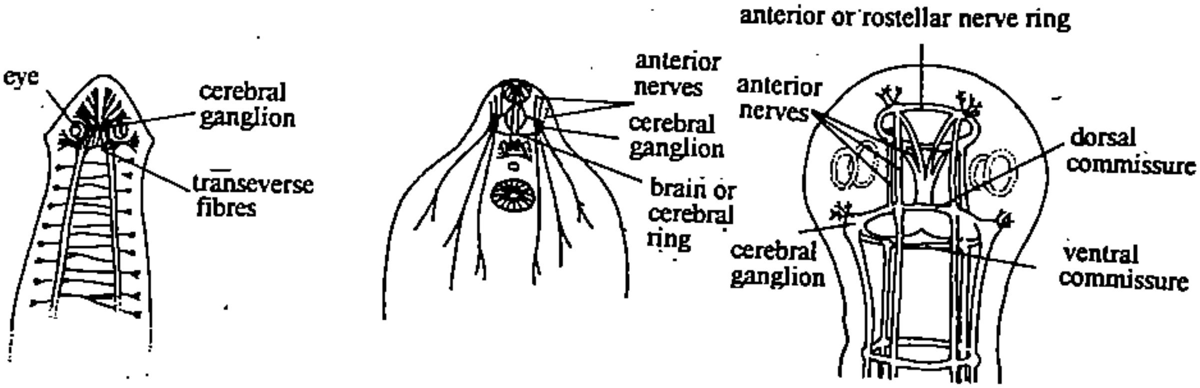



**Fig. 3.14: Concentration of nervous system in anterior region of a) Liverfluke b) Tapeworm c) Planaria.**

**Segmentation** or **metamerism** is the division of the body into smaller transverse compartments along the anterior-posterior axis. Segmentation is widespread among animals, with true segmentation occurring in annelids, arthropods and most chordates though some other groups show superficial segmentation of ectodermal body wall.

Fundamentally there are three body forms. First, monomeric where there is no division of the large body cavity at all. *Ascaris* has this type of body form. Second, oligomeric where the body cavity is divided into three and each region has a separate body cavity with no divisions on the abdomen *Phorona* is a worm with this body plan. Third, metameric in which the body is divided into head, thorax and abdomen and where abdomen is further divided into a chain of segments.

Segmented body forms can be seen in tape worms, annelids arthropods and chordates. Of these segmentation in tape worms is quite different from that seen in the others. We can observe that segmentation in tape worm is superficial, a series of ring like creases develop in the cuticle and the body wall which facilitate bending and telescoping of the body. But this segmentation is strictly ectodermal (Fig. 3.15) and this segmentation is a reproductive adaptation. The segments of the entire body are in a continuous process of being produced matured and discarded. The new segments grow in the neck region and the older ones are detached from the posterior end. Each segment functions as an independent unit without having any vital connections with the other.

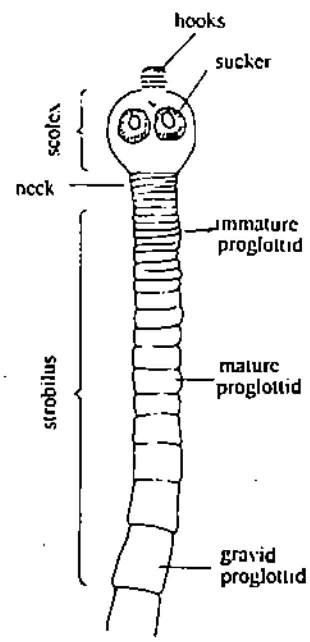



**Fig. 3.15: Superficial segmentation seem in tape-worms.**

On the other hand true metameric segment as best observed in annelids has separate schizocoelic body cavity of mesodermal origin in each segment. Individual segments are budded off in linear sequence from a proliferation region just in front of the posterior end.

Segmented animals have a specialised anterior **acron** (prostomium) and posterior **pygidium** or **telson** both of which are not segments. In between there are a varying number of segments. In near perfect segmentation, appendages, musculature, ganglion, nerves, blood vessels, coelom and all body organs are replicated in each segment. This arrangement is best seen in annelids. In chordates, segmentation is usually apparent in the axial skeleton, muscles and nerves.

Why did segmentation evolve in animal groups? What advantages does it confer on the animals in which it is seen? Let us examine this a little closely. The most important advantage is that segmentation divides a body into a series of compartments, each of which can be regulated almost independently. This in a way provided the framework for **specialisation**. In colonial animals this specialisation is seen in polymorphism of zooids while in segmented animals **regional specialisation of segments occurs**.

For example in annelids, the body is divided into a head and trunk region (Fig. 3.16). The divisions are better defined in insects and many crustaceans. In extreme cases i.e., in higher vertebrates regional specialisation has occurred to the extent that segmentation is lost even in muscle arrangement.

Regional specialisation takes place usually by three processes.

1) Restriction of certain structures to a few segments, for example, gonads are restricted to a few specialised genital segments in annelids (e.g. earthworm).

2) Structural divergence of segmental structures to perform different functions. For example some segmental appendages may be modified from those suitable for locomotion to those adapted for grasping or chewing, (e.g. insects)

3) Fusion of segments along the length of the animal. For example, fusion of anterior segments to form the head. The head of *Nereis* consists of the acron and two other segment while that of *Drosophila* is composed of five segments.

The second significant feature of metameric segmentation is its importance in the locomotion of soft bodied animals. The acoelomate animals use their musculature of longitudinal and circular muscles for locomotion but the evolution of a coelomic cavity has allowed the fluid to act as hydraulic skeleton. In invertebrates like annelids, muscles of the body wall act against this pressure. When circular muscles contract, hydrostatic pressure on coelomic fluid will result in lengthening of the body; when longitudinal muscles contract, it will result in widening of the body. Since metameric segmentation results in compartmentalisation of the body, this elongation and widening of the body can be restricted to a few segments at a time. This local change in the shape of the elongate body increases the locomotory efficiency. The broadened part of the body can be firmly fixed against the burrow especially if there are clinging structure such as setae and the lengthening of the body will produce considerable thrust resulting in progression of the animal. Thus the alternate peristaltic waves enable the animal to move forwards faster and efficiently.

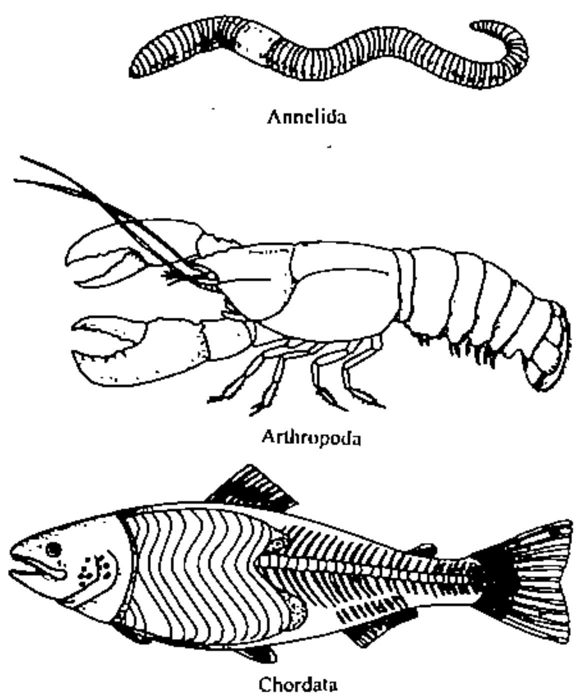
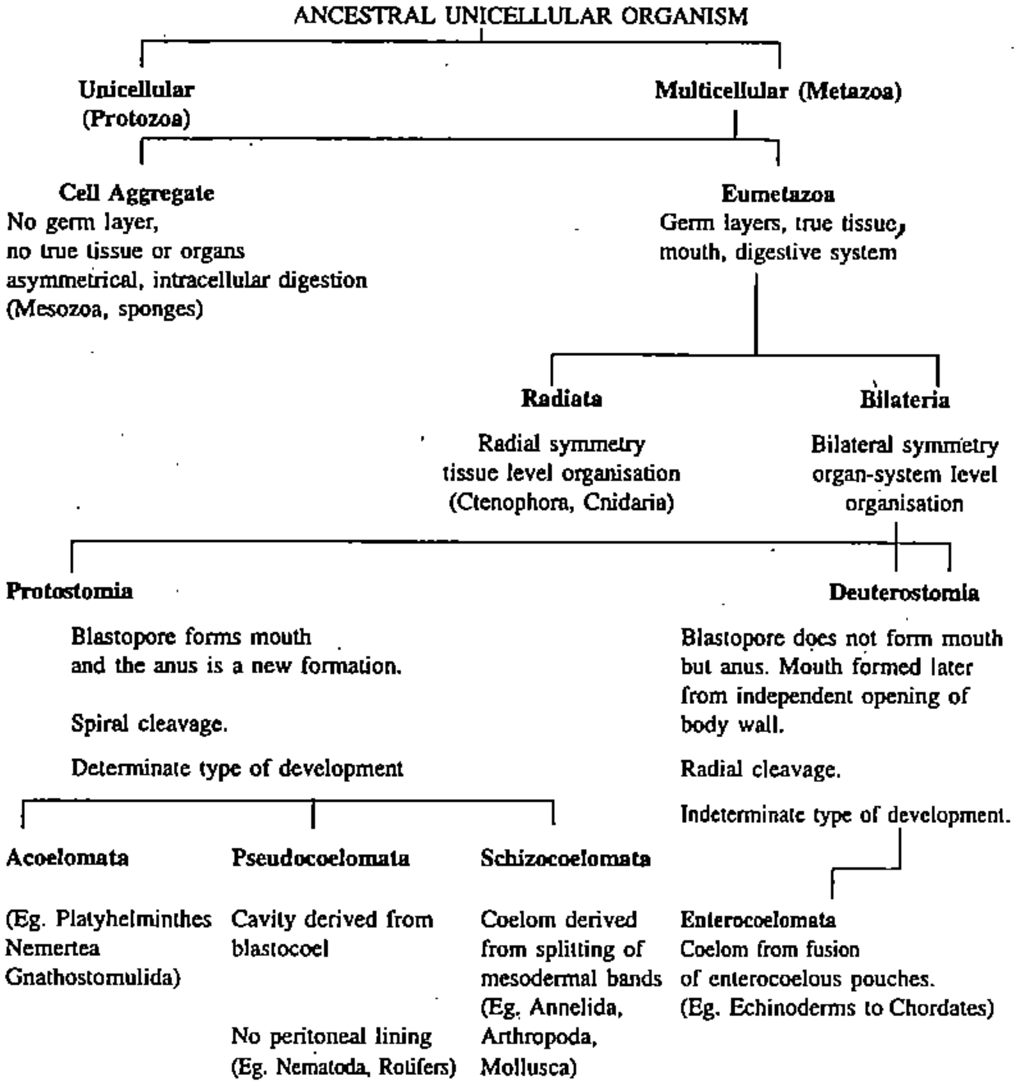



**Fig. 13.16: Phyla showing segmentation. Annelids and arthropods are related but chordates have acquired metamerism independently.**

So far in this unit we have considered the characteristic of body designs that are shared by various animals and the different body plans that distinguish major groups of animals. We can now use those characteristics to group and classify the animals as given in the accompanying chart.




## 3.9 ORIGIN AND EVOLUTION OF METAZOA

Most of the early metazoans were soft bodied and so their fossils are rare. The extremely fragmented fossil record does not shed any specific light on their origin. Therefore, most of the explanations on their origin are based on their embryology and comparative morphology.

A series of theories have been put forward to explain the origin of multicellular metazoans from unicellular organisms. Of these, three principal theories could be considered.

1) **Syncytial theory** : That the ancestral metazoans have arisen from a multinucleate ciliate by compartmentalization or cellularization.
2) **Colonial Theory** : That the ancestral metazoans have arisen from colonial flagellates by cellular specialisation and interdependency.
3) **Polyphyletic Theory** : That the metazoans have arisen from more than one group of organisms.

### 3.9.1 Syncytial Theory

This theory suggests that the ancestral metazoan was at first syncytial in structure but later became cellularised by formation of cell membranes around individual nuclei thus producing a typical multicellular body (Fig. 3.17a). **Hadzi** (1953) and **Hanson** (1977) have been the chief proponents of this theory.

As many ciliates tend to have a bilateral symmetry, the advocates of this theory maintain that the ancestral metazoan was bilaterally symmetrical similar to the present day acoelous flatworms.

The theory receives support from the fact that acoelous flatworms are (1) of the same size range as the ciliates, (2) are bilaterally symmetrical (3) are ciliated and (4) tend towards a synctial condition.

There are several objections to this theory. It ignores the embryology of flatworms in which nothing similar to cellularisation occurs, nor does it explain the presence of flagellated sperms in metazoans. Perhaps the most important objection to this theory is that it assumes that acoelous flatworms are the most primitive metazoans and therefore, presumes bilateral symmetry to be more primitive than radial symmetry and thus radial coelenterates must have been derived from bilateral flatworms. But then it is accepted that radial symmetry is more primitive than bilateral symmetry and radial coelentrates could not have evolved from flatworms.

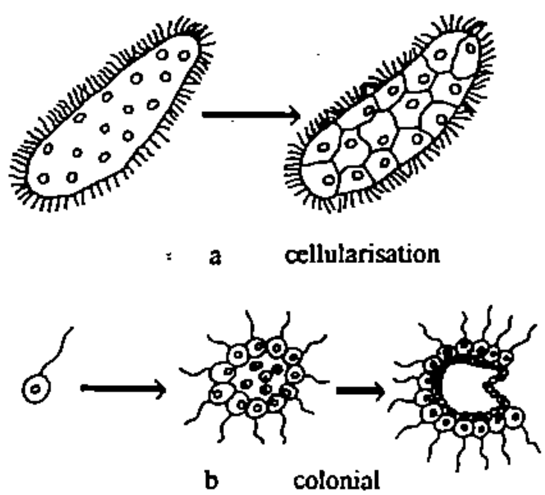



**Fig. 3.17: Possible routes for evolution of animals.**

### 3.9.2 Colonial Theory

This is the most popular theory on the origin of metazoa. The idea was conceived by **Haeckel** (1874) modified by **Metschnikoff** (1886) and revived by **Hyman** (1940).

This theory considers the flagellates to be the most probable ancestral group of metazoans. For support of this theory the following evidences are cited:

1) Flagellated spermatazoa occur throughout the metazoan series.
2) Monoflagellated cells (with a single flagellum) are also common in lower metazoans (especially among sponges and coelenterates).
3) True sperms and eggs (feature of metazoans) are present in phytoflagellates.
4) Phytoflagellates also display a type of colonial organization that could have led to a multicellular construction. In fact, differentiation between somatic and reproductive cells has been attained in *Volvox*. Although *Volvox* is often used as a model for the flagellated colonial ancestor, it is not the likely ancestor of metazoans. Ultrastructural evidence points to the choanoflagellates (a small group of animal like flagellates) as the probable ancestor. Choanoflagellates have mitochondria and flagellar structures very similar to those in metazoan cells. Also choanocytes i.e. cells with a collar of microvilli are found in a number of groups of metazoans notably the sponges.

According to the colonial theory the ancestral metazoan arose from the round or oval hollow colonial flagellate (Fig. 3.17b). In this primitive metazoan:

i) The cells on the outer surface were mono-flagellated (like in *Volvox*).

ii) There was a distinct antero-posterior axis and it swam with the anterior pole forwards.

iii) A differentiation between somatic and reproductive cells was also present.

This hypothetical organism was termed **blastaea** by **Haeckel**, and is generally believed to be represented in the development of metazoa as the blastula stage.

Further division of labour in the somatic cells led to increasing interdependence till what was a colony of unicellular organisms become a multicellular organism. This superorganism provided the transition to a new level of organisation in which specialisation occurred by differentiation of cells rather than differentiation of cell organelles.

According to Haeckel, the blastaea invaginated (bending of the posterior half into the anterior half) to form a double walled, **gastraea**, equivalent to the embryonic gastrula stage. The gastraea also had a close similarity with the double walled, single cavitied, hydrozoan coelenterates and some sponges.

Metschnikoff, however, opposed Haeckel's ideas. He pointed out that digestion is intracellular and phagocytic in the lower metazoans and so they would not have required a digestive sac or mouth. He believed that certain cells of the blastaea might wander into the interior (ingression) filling up the blastocoel resulting in a solid gastrula (Fig. 3.18). Invagination is considered a secondary process for cavity development. Thus Metschnikoff argued that the gastraea was solid rather than a hollow organism.

Following Metschnikoff's view modern workers believe that evolution of metazoans commenced with Haeckel's blastaea and then by ingression of cells into its hollow interior, a solid hypothetical organism evolved with the following features:

i) Body was ovoid and radially symmetrical.

ii) Exterior cells were mono-flagellated and performed locomotor and sensory functions.

iii) Solid mass of interior cells functioned in nutrition and reproduction,

iv) A mouth was absent and food could be engulfed anywhere from the external surface and passed to the interior.

This hypothetical form, since it closely resembled the free swimming **planula** larva of coelenterates, is referred to as the **planuloid ancestor**.

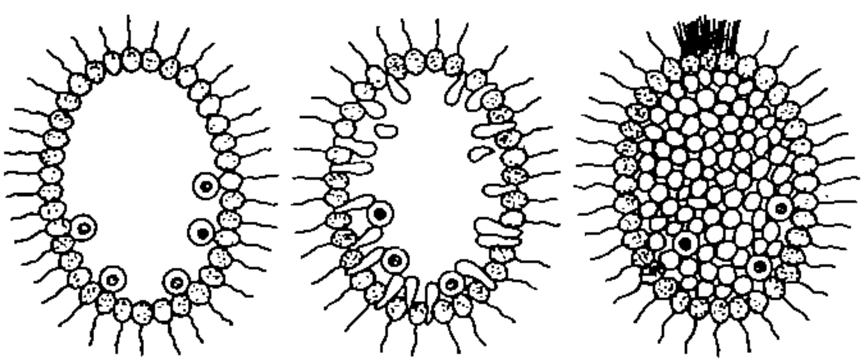


**Fig. 3.18: Formation of solid gastraea.**

From such a free-swimming, radially symmetrical planuloid ancestor, the lower metazoans could have arisen. Thus the primary radial symmetry of coelenterates could have been directly derived from the planuloid ancestor and the bilateral symmetry could have evolved secondarily in flatworms, which later gave rise to the rest of the metazoans.

**Hyman** (1951) has proposed that certain of the ancestral planuloid stock could have taken up a life on the ocean bottom, a consequence of which a creeping mode of movement developed. This led to a differentiation between dorsal and ventral surfaces and the development of a ventral mouth. This change in mode of life could have resulted in acoelid flatworms which are considered to be the forerunners of the bilateral phyla.

### 3.9.3 Polyphyletic Theory

This theory was suggested by **Greenheig** (1959) and some other workers. According to this theory, sponges, coelenterates, ctenophores and flatworms have each evolved independently from protozoans.

Sponges and coelenterates have probably arisen through colonial flagellates, while ctenophores and flatworms through ciliates or even mesozoans. It is apparent that this theory is a compromise between the syncytial and colonial theory.

### 3.9.4 Evolution of Metazoa

The sponges, coming under phylum Porifera are the closest to Protista, and can perhaps be regarded even as a colony of protists rather than being multicellular. No other group has evolved from them.

The coelenterates consisting of the Cnidaria and the Ctenophora, which are both diploblastic and primarily radially symmetrical, can be regarded as truly the most primitive of the Metazoa. They have evolved from the ancesteral planuloid metazoans as an offshoot.

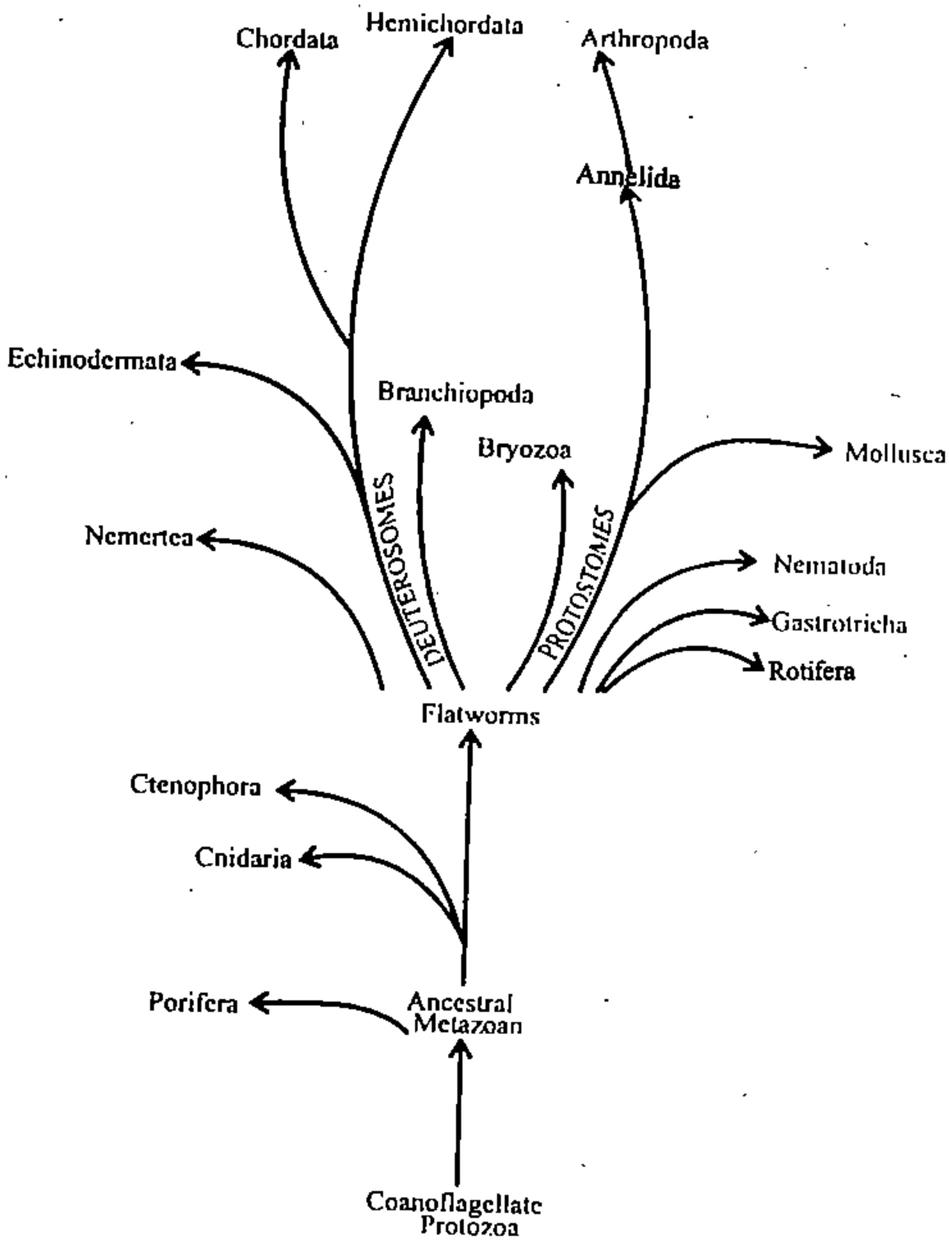



**Fig. 3.19: Phylogeny of the animal kingdom.**

The Platyhelminthes (flatworms) have also evolved from planuloid ancestor. They do not have a coelomic cavity (acoelomates) but the mesoderm is cellular, they are triploblastic and are bilaterally symmetrical. This group and all higher metazoa can be grouped as Grade **Bilateria**. (See chart in Sec. 3.8)

The **pseudocoelomate** phyla which include the nematodes and the rotifers are supposed to have evolved as an offshoot from the flatworms.

The **Eucoelomata** constitute the remainder of the Metazoa. The acoeloid flatworm like ancestors have given rise to two main stocks:

i) The molluscan — annelidan, arthropodan stock with schizocoelous coelom.

ii) The echinoderm, hemichordate, chordate stock with enterocoelic coelom. The coelom serves as skeleton in the more primitive of the coelomates. Such as the polycheate worms, earthworms etc. In arthropods and molluscs the coelom becomes reduced to the point of being represented by the cavity of the gonads. The other space in arthropod body is only a haemocael which is a mere space in the tissue filled with blood. The phylogeny of Metazoa can be summarised in Fig. 3.19.

**SAQ 4**

Choose the correct answer from the alternatives provided.

1) Of the large number of phyla included under the kingdom Animalia only one is an invertebrate/a chordate phylum.
2) Most of the early metazoans have an extremely fragmentary/rich fossil record.
3) "The metazoans have arisen from a multinucleate ciliate by compartmentalisation" is the essence of colonial/syncytial theory of origin of metazoa.
4) In a syncytium membranes are present/absent between the adjacent nuclei.
5) The polyphylectic theory states that the metazoans have arisen from one group/many groups of organisms.
6) The hypothetical metazoan proposed by Haeckel was named blastaea/gastraea.

## 3.10 SUMMARY

In this unit you have learnt that:

- The term Metazoa does not have currently any formal biological status, but is still used to refer to the organisms included in kingdom Animalia of the Five — Kingdom Classification. Increasing complexity of organisms is an evident feature in animal phylogeny. Thus we see that protoplasmic level of body organisation found in protozoans is simplest. Cellular level is found in sponges (Porifera). The cnidarians and ctenophores have attained tissue level of organisation and some of them even have organs, while the rest of the animals i.e., from platyhelminthes to mammals have the highest evolved organ system level of body organisation.

- Metazoans are characterised by a complex multicellular structural organisation. They are heterotrophic sexually reproducing diploid organisms. Many of them reproduce asexually too. Their embryos undergo progressive stages of growth and development.

- Animals have a basic body plan which is described in terms of symmetry based on which they can be identified as asymmetrical, spherically symmetrical, radially, biradially and bilaterally symmetrical. The distinction is based on, along how many planes the animal can be divided into to get equal halves: none (asymmetrical), many (spherical and radial), one (bilateral), and two (biradial).

  In Platyhelminthes, the space between the body wall and the gut is filled with mesodermal parenchymal cells; it has no body cavity. Animals above the level of Platyhelminthes have body cavity.

- The body cavity can be of two types: pseudocoel and true coelom. Pseudocoel is a remanant of the blastocoel, and is not lined with coelomic epithelium. It is found in nematodes. However, true coelom is lined with a mesodermal coelomic epithelium. In annelids; arthropods and molluscs coelom is schizocoelic whereas in echinoderms and all the chordates it is enterocoelic.

- Two quite different patterns of cleavage are recognised among animals that show a fundamental division in their evolution. Protostome embryos typically show spiral cleavage with what is called mosaic development and deuterostome embryos show radial cleavage with regulative embryonic development.

- The animals are basically either diploblastic i.e., made up of two germ layers viz. ecto and endoderm (e.g., poriferans and cnidarians) or are triploblastic i.e., made up of three germ layers viz., ecto, endo and mesoderm (e.g., Platyhelminthes to mammals). The various structures of the whole body are derived from these three fundamental germ layers which can only be seen in embryonic conditions.

- Cephalisation with concentration of sense organs and nervous tissues at the head region is characteristic of bilateral animals. It distinguishes an anterio-posterior axis in the animal's body. Segmentation or metamerism in bilateral animals provides a framework for specialisation of body regions for different functions. True segmentation is found in annelids, arthropods and chordates.

- Multicellular metazoans have arisen from unicellular organisms. Three theories have been suggested to explain their evolution; a) syncytial theory; b) colonial theory; c) polyphyletic theory.

  It is generally accepted by most zoologists that metazoans have originated from colonial choanoflagellates. The hypothelical ancestral metazoan was probably a planula like organism. Which gave rise to the sponges as a separate branch. The cnidarians and ctenopleores are probably the most primative metazoans. These form the Radiata while the Platyhelminthes and all other higher groups that have evolved from the flatworms form the Bilateria.

## 3.11 TERMINAL QUESTIONS

1) What do you understand by terms diploblastic and triploblastic? give example.

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2) In this unit we have explained three different kinds of germ layers. Write the names of any three derivatives from each kind.

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3) What is coelom? Differentiate between true and false coelom.

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4) Distinguish between bilateral, radial and biradial symmetries.

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5) Distinguish between schizocelous and enterocoelous coelom.

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6) Make a table comparing the characters of deuterostome and protostome animals.

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## 3.12 ANSWERS

**Self Assessment Questions**

1) (a)................................(v)
   (b)................................(ii)
   (c)................................(iv)
   (d)................................(iii)
   (e)................................(i)

2) (i) Gastrula, alimentary canal.
   (ii) mesoglea, diploblastic
   (iii) three; triploblastic
   (iv) ectoderm
   (v) mesoderm
   (vi) endoderm

3) (i) F
   (ii) F
   (iii) T
   (iv) F
   (v) T
   (vi) F

4) 1. Chordate
   2. Fragmentary
   3. Syncytial
   4. Absent
   5. Many groups
   6. Blastaea

### Terminal Questions

(1) Diploblastic: Animals made up of two germ layers eg. poriferans, cnidarians and ctenophoras.

Triploblastic: Animals made up of three germ layers eg. plathyhelminthers to chordates.

(2) Ectoderm: Epidermis, brain, hair and nails

Endoderm: Epithelium of thyroid, epithelium of alimentary canal, auditory tube.

Mesoderm: Dermis, muscles, blood vascular system.

(3) Coelom: It is the body cavity found between the body wall (ectoderm) and alimentary canal (endoderm) and is lined by the mesoderm from both its sides. This is referred to as true coelom. It is found in Annelida to Chordates.

False or Pseudocoelom: It is a body cavity found between the body wall and alimentary canal but is not lined by the mesoderm: instead the mesoderm is found in patches. Eg. in Nematoda.

(4) Bilateral: The animal has distinct anterior, posterior, dorsal, ventral and láteral sides. It can be cut only into two indéntical halves. The plane of cut must pass from anterior to posterior through the centre. The separated left and right or two lateral sides would be mirror image of each other, e.g. Chordates.

Radial: The animal has two-distinct surface oral and aboral. It can be cut into 3,5 or 8 identical halves. The plane of cut must pass through the centre of the animals, e.g. cnidarians and echinoderms.

Biradial: It is a specialized radial symmetry in which the animal can be cut into 3,5 or 8 identical halves, when the plane of cut passes through the centre. The peculiarity is, that, only the opposite halves would be identical not the adjacent ones.

(5) Schizocoelous coelom is true coelom and is found in Protostomes and is formed by the splitting of teloblastic bands.

Enterocoelous coelom is also true coelom and is found in Deuterostomes. It is formed by the endodermal pouches given out from alimentary canal.

(6)

| PROTOSTOMES | DEUTEROSTOMES |
|---|---|
| 1. Spiral cleavage | Radial cleavage |
| 2. Endomesoderm from d blastomeres | Endomesoderm from outpocketing of archenteron |
| 3. In coelomate protostomes coelom forms from split in mesodermal bands schizocoelous | All coelomate; enterocoelous coelom |
| 4. Mouth forms at or near blastopore; anus a new formation. | Anus forms at or near blastopore; mouth a new formation. |

# GLOSSARY

| | | | |
|---|---|---|---|
| 1. | **Acellular** | : | Containing no cell; not made up of cells. |
| 2. | **Adaptation** | : | Process of adjustment by which organism improves its ability to survive in an environment. |
| 3. | **Anabolism** | : | Constructive metabolism in which complex substances are synthesized from simpler ones. |
| 4. | **Analogous organs** | : | Organs that serve identical function, may superficially appear similar but have different origin. |
| 5. | **Catabolism** | : | Destructive metabolism in which complex molecules are broken down into simpler ones with the liberation of energy. |
| 6. | **Cellular** | : | Made up of cells. |
| 7. | **Coelomate** | : | Animal having a true body cavity or coelom. |
| 8. | **Conjugant** | : | One of a pair of fused ciliates in the process of exchanging genetic material. |
| 9. | **Cytopharynx** | : | Permanent oral canal, of ciliates that is separated from the cytoplasm by the cell membrane. |
| 10. | **Cytoproct** | : | Permanent cellular anus of some ciliates. |
| 11. | **Determinate Cleavage** | : | Type of cleavage during which the fates of the blastomeres are fixed early in development. Mosaic development. |
| 12. | **Deuterostome** | : | Member of a major branch of animal kingdom in which the site of the blastopore is posterior i.e. far from the mouth which forms as a new opening at the anterior end. |
| 13. | **Ectoderm** | : | Embryonic germ layer forming the outer wall of the gastrula. |
| 14. | **Endoderm** | : | Embryonic germ layer composing the archenteron wall. |
| 15. | **Enterocoel** | : | Coelomic cavity formed as an outpocketing of embryonic archenteron. |
| 16. | **Eukaryote** | : | Organisms whose cells possess an organised nuclei. |
| 17. | **Filipodium** | : | Pseudopodium that is slender, clear and may be branched. |
| 18. | **Gametogony** | : | Process by which merozoites develop into gametes or gametocytes in the host. |
| 19. | **Gastrodermis** | : | Cellular epithelial lining of the gastrovascular cavity of cnidarians, ctenophores and mid gut lining of bilaterally symmetrical animals. |
| 20. | **Homeostasis** | : | Maintenance of constancy in the internal environment of the organism. |
| 21. | **Homologous organ** | : | Organs having the same evolutionary origin, showing fundamental similarity of structure, embryonic development and relationship. |

| | | | |
|---|---|---|---|
| 22. | **Infraciliature** | : | The entire assemblage of ciliary basal bodies or kinetosomes and the fibres that link them together in the cortex of cilites. |
| 23. | **Kinetoplast** | : | Conspicuous mass of DNA that is situated within the single large elongated mitochondrion of trypanosome protozoans. |
| 24. | **Kinetostomata** | : | A ciliary or flagellar basal body. |
| 25. | **Lobopodium** | : | A pseudopodium that is wide with rounded or blunt tips, commonly tubular composed of both ectoplasm and endoplasm. |
| 26. | **Merozoite** | : | Individuals produced by multiple fussion of sporozoan trophozoites. |
| 27. | **Mesentery** | : | A longitudinal sheet of tissue that divides the body cavity of bilaterally, symmetrical animals. |
| 28. | **Metamerism** | : | The division of an animal's body into a linear series of similar parts or segments. |
| 29. | **Mosaic development** | : | Embryonic fate determination in which the cell fate is determined early in development and this is due to the action of specific factors that are distributed unevenly like pieces of mosaic, in the cytoplasm of the uncleaved egg. |
| 30. | **Ookinete** | : | Motile zygote in Apicomplexia. |
| 31. | **Organelle** | : | Specialized part of a cell analogous to an organ of a multicellular animal. (e.g. mitochondrion, plastid, etc.) |
| 32. | **Oxidation** | : | Process of removing electrons from a substance. |
| 33. | **Pellicle** | : | Protozoan body wall composed of cell membrane, cytoskeleton and other organelles. |
| 34. | **Peritoneum** | : | The innermost, noncontractile layer of a stratified coelomic epithelium; separates the musculature from the coelomic fluid. |
| 35. | **Phylogeny** | : | Evolutionary history of a species. |
| 36. | **Planuloid ancestor** | : | Hypothetical form representing ancestor of cnidarians and platyhelminthes. |
| 37. | **Prokaryote** | : | Organism whose cell does not contain a true nucleus, but contains only nucleoid. |
| 38. | **Protostome** | : | Member of the branch of animal kingdom in which the blastopore forms the mouth. |
| 39. | **Pseudocoelom** | : | Fluid filled body cavity that is not lined by peritoneum and not a part of digestive or blood vascular system. It is different from the hoemocoel because it lacks a heart. |
| 40. | **Radial symmetry** | : | Arrangement of similar parts around a central oral aboral axis. More than one imaginary planes through the axis yields halves that are mirror images of each other. |
| 41. | **Reduction** | : | Process of adding electrons to a substance. |

| | | |
|---|---|---|
| 42. **Reticulopodium** | : | A pseudopodium that forms a threadlike branching mesh and contain animal microtibules. |
| 43. **Schizocoelom** | : | Coelomic cavity formed by splitting apart of a solid mass of mesodermal cells. |
| 44. **Schizogony** | : | Process by which merozoites develop in the host by multiple fusion. |
| 45. **Sporozoite** | : | Infective stage I in Apicomplexia, spore like, formed from zygote by meiosis. |
| 46. **Sporogony** | : | Part of life cycle of apicomplexians in the invertebrate host. In which the oocyst undergoes meiosis to form sporozoites. |
| 47. **Stimulus** | : | Physical or chemical change in the immediate surrounding that initiates a response in the organism. |
| 48. **Trophozoite** | : | In Apicomplexia. Feeding stage that occurs when sporozoites invades the host. |

## FURTHER READING


1. Barnes, R.D. (1994) Invertebrate Zoology, 6th edn, Saunders College Publishing.
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3. Pond, C.M.C. (1990) Diversity of Organisms, Hodder & Stoughton. The Open University.

# NOTES

Uttar Pradesh
Rajarshi Tandon Open University

# UGZY -01
## Animal Diversity-I

Block

# 2

## DIVERSITY OF ANIMAL LIFE-II (CLASSIFICATION)

# BLOCK 2 DIVERSITY OF ANIMAL LIFE-II (CLASSIFICATION)

In Block 1 you have learnt that all animals share a few basic body plans and they can be divided roughly into three groups depending on the absence or presence of body cavity or coelom. Accordingly they are known as acoelomata, pseudocoelamata and coelomata. In this block you will learn about the classification, characteristic features of the various phyla of invertebrates. The block comprises unit 4-7.

Unit 4 deals with the characteristic features and classification of some of the acoelomate and Pseudocoelomate phyla comprising Porifera, Cnidaria, Ctenophora, Platyhelmithes, Nematoda and Rotifera. The salient features of each class has been described with examples.

The study of Coelomate group of animals begins with Unit 5. Annelids and arthoropods are the two groups discussed in this unit. Segmentation of the body is characteristic of the two phyla. This type of segmentation, also known as metamerism, divides a body into a series of compartments, each of which can be regulated more or less independently of others. In this unit you will study the organisation and complication of annelids and arthopods. Both the groups have adapted themselves to life in a variety of environments, although annelids still require moist environments as often their integument is also the respiratory organ. You will also study that arthopods are the most successful group of animals among invertebrates and constitute nearly 75% of all the living species found on the earth.

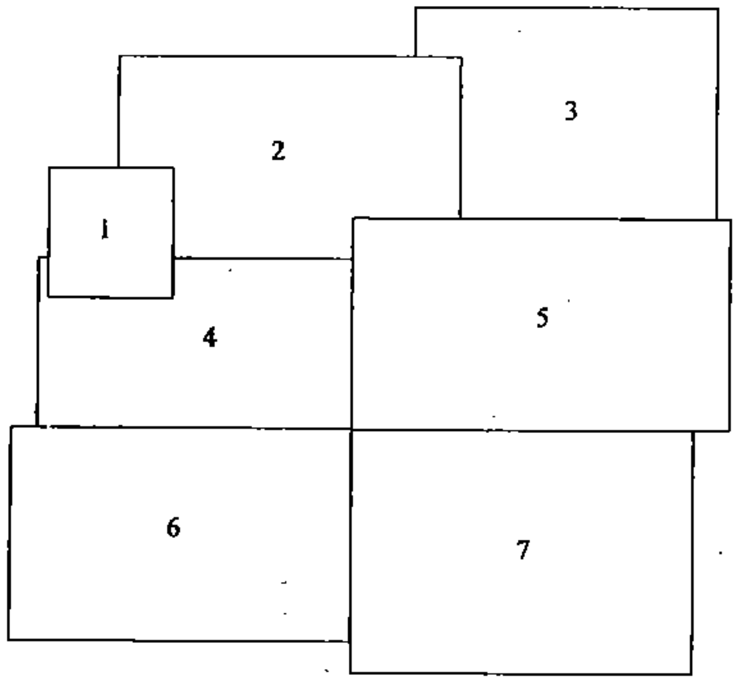
Unit 6 relates to the study of soft bodied animals, the molluscs and the spiny skinned animals, the echinoderms. Molluscs which include snails, clams, oysters, squids and octopods are the second largest group of invertebrates in terms of number of living species. Most of the molluscs are aquatic and there are a few amphibian forms. In this unit you will study the organisation and characteristics of six different classes of molluscs. The unit discusses the structure, organisation and classification of echinoderms which are exclusively marine in their habit. Towards the end of the unit, you will find a table showing the names of a number of other phyla which are not discussed in detail. Each of these phyla includes a very few species and are of uncertain phylogenetic significance, hence called minor phyla. You will not make a detailed study to these phyla but only know their names.

Unit 7 deals with the skeleton and polymorphism in metazoans. You will learn that the skeleton in metazoans is a structure which protects, supports and maintains the shape of the body. These Skeletons are basically of two types endoskeleton and exoskeleton. In addition, in this unit you will study the phenomenon of polymorphism in the metazoan groups-the cnidarians and the insects in which this phenomenon is highly developed.

**Objectives**

After studying this block you will be able to :

- list the characteristic features of the acoelomates, pseudocoelomates and eucoelomate (coelomate) phyla.
- classify the various phyla into classes with examples.
- outline the relationships between acoelomates and pseudocoelomates, pseudocelomates and eucoelomates.
- describe the skeletons of multicellular animals.
- describe the phenomenon of polymorphism in cnidarians and insects.




1. Tropical centipede
2. Stink bug
3. *Morpho menelaus* – The wing scales reflect interference colours. Tilting the wings produces a sequence of colours.
4. Brown recluse spider
5. *Tealia piscivora* – The colour is due to free or esterified carotenoids
6. *Agriolimax columbianus* - Yellow banana slug.
7. *Dasychalina cycanthina* – sub tidal sponge.

# UNIT 4 CLASSIFICATION OF MULTICELLULAR ANIMALS-I

## Structure



## 4.1 INTRODUCTION

In the previous unit you have studied how the multicellular animals (Animalia) originated from the simpler protozoan protists. You have also learnt how the simpler multicellular animals further evolved, giving rise to the diversity of the animal life which came to exist on the earth.

In the present unit you will study the characteristic features of some of the phyla comprising this animal diversity namely, **Porifera, Cnidaria, Ctenophora, Platyhelminthes, Nematoda,** and **Rotifera,** and also study their further classification into classes.

### Objectives

After studying this unit you should be able to:

- recognise characters which differentiate one phylum described in this unit, from any other;
- describe the characteristic features of different classes of animals coming under each phylum described in this unit;
- give examples of various classes of animals treated in this unit;
- give a basic idea of the organization of the body of animals belonging to different classes of animals treated in this unit;
- and explain the mode of formation of coral reefs and their significance.

## 4.2 METAZOAN BRANCHES : MESOZOA, PARAZOA AND EUMATAZOA

We have already seen that the Kingdom Animalia comprises all the multicellular animals (metazoans). These are divided into three branches : 1) Mesozoa: 2) Parazoa and 3) Eumetazoa. The Mesozoa comprise a tiny single phylum (Phylum Mesozoa): the Parazoa comprise two phyla : a tiny single phylum Placozoa and the rest make up the phylum Porifera comprising the sponges. Most of the metazoans come under the major branch Eumetazoa. You must note that the cellular layers of Porifera (sponges) are not homologous to the germ layers of Eumetazoa. Their developmental pattern is also quite different from that of the Eumetazoa. The Parazoa are regarded as an early evolutionary side branch of the animal kingdom, which did not give rise to any other group of animals.

**DISTINCTIVE FEATURES OF PHYLUM PORIFERA AND EUMATAZOA**

| | Phylum Porifera | Eumetazoa |
|---|---|---|
| 1. | Animals are sessile, with irregular shape and mostly with no symmetry. | Animal are mostly mobile, with regular shape and some form of symmetry. |
| 2. | Tissues are absent or poorly defined. | Tissues are well defined. |
| 3. | There are no organs. | Well-defined organs are present. |
| 4. | There is no mouth and digestive tract. | Animals are provided with mouth and digestive tract. |
| 5. | Body surface is porous. | Body surface is not porous. |
| 6. | No sensory cells or nerves, little co-ordination. | Sensory cells & nerves, with better co-ordination. |
| 7. | Internal cavities lined by choanocytes. | Body cavities are not lined by choanocytes. |
| 8. | Physiological division of labour is not well marked. | Physiological division of labour is well marked. |
| 9. | Cellular layers not homologous to germ layers. | Cell layers homologous to germ layers. |

The branch Eumetazoa, as we have seen above, consist of metazoans with organs, a mouth and digestive cavity. These can be divided into two groups : Radiata and Bilateria. Radiata are characterised by radial (or biradial) symmetry: they have tentacles and a limited number of organs. They have also a digestive cavity with mouth opening to the exterior. The Radiata include two Phyla : Cnidaria and Ctenophora. The Bilateria are bilaterally symmetrical animals and include the rest of the eumetazoans.

## 4.3 PARAZOA - PHYLUM PORIFERA - SPONGES

You have just now read that Parazoa comprise two phyla : a tiny phylum Placozoa and Phylum Porifera comprising the sponges. Of these two phyla, we will be dealing here with only one phylum namely, phylum Porifera, the sponges.

The word "porifera" has been derived from Latin words 'porus' (pore) and 'fera' (bearing), meaning pore - bearing organisms. Porifera are multicellular animals incapable of making movement as they are attached to the substratum like a plant. Porifera present a great variety of forms and have 5000 species or more described species. They may be cup-shaped, saucer-shaped, mushroom-shaped, lobed, digitate, branched or irregular. As a general rule, the form is extremely variable even in the same species and is, therefore, of little use in identification. They are almost always attached to foreign objects. With the exception of the fresh water spongillidae, they are marine, and are found at all depths. Individuals of the family Clionidae bore into shells and stones.

### 4.3.1 Characteristic features

As the name of the group indicates, the surface of the body presents a large number of minute pores called ostia (sing. ostium). Through these ostia, water current enters the body cavity. These pores actually lead into a system of channels which, after permeating almost the whole body, open to the exterior by one or more large exhalent openings called oscula (sing. osculum). This system of spaces connecting the inhalent pores or ostia with the exhalent oscula, is the **canal system**. The canal system may be simple as in the asconoid type or more complex as in syconoid and leuconoid types (Fig. 4.1). Through the canal system a continual stream of water is maintained by the action of the flagella. Thus the water enters the canal system through ostia and passes out through the oscula.

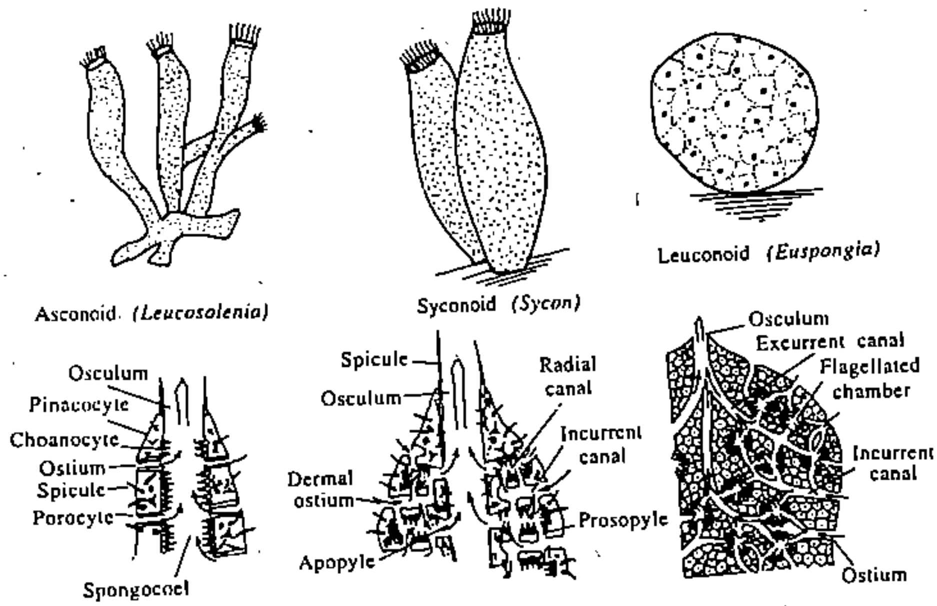



**Fig. 4.1 : Three types of sponge structure. The degree of complexity from simple asconoid to complex leuconoid type has involved mainly the water-canal and skeletal systems, accompanied by outfolding and branching of the collar cell layer. The leuconoid type is considered the major plan for sponges, for it permits greater size and more efficient water circulation.**

The sponge body is covered externally by an epithelial layer called Pinacoderm. This layer is made up of flattened cells called pinacocytes (Fig. 4.2). Some of the pinacocytes are modified into porocytes by the formation of intracellular canal opening out through the ostium (Fig. 4.1). Some are modified as contractile myocytes arranged around oscula.

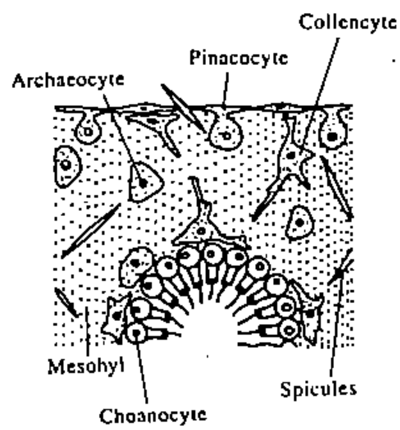



**Fig. 4.2 : Small section through sponge wall, showing four types of sponge cells. Pinacocytes are protective and contractile; choanocytes create water currents and engulf food particles; archaeocytes have a variety of functions; collencytes secrete collagen.**

The flagellated chambers of the canal system are lined by ovoid, collar cells or choanocytes (Fig. 4.3), resembling in structure the choanoflagellate protozoans. These cells carry a flagellum surrounded by a contractile collar projecting into the sponge cavity. These cells are responsible for producing water current of the canal system, and for food capture. Smaller food particles are engulfed by the choanocytes whereas the larger particles are passed on to archaeocytes or amoebocytes (Fig. 4.3), which are the principal sites of digestion.

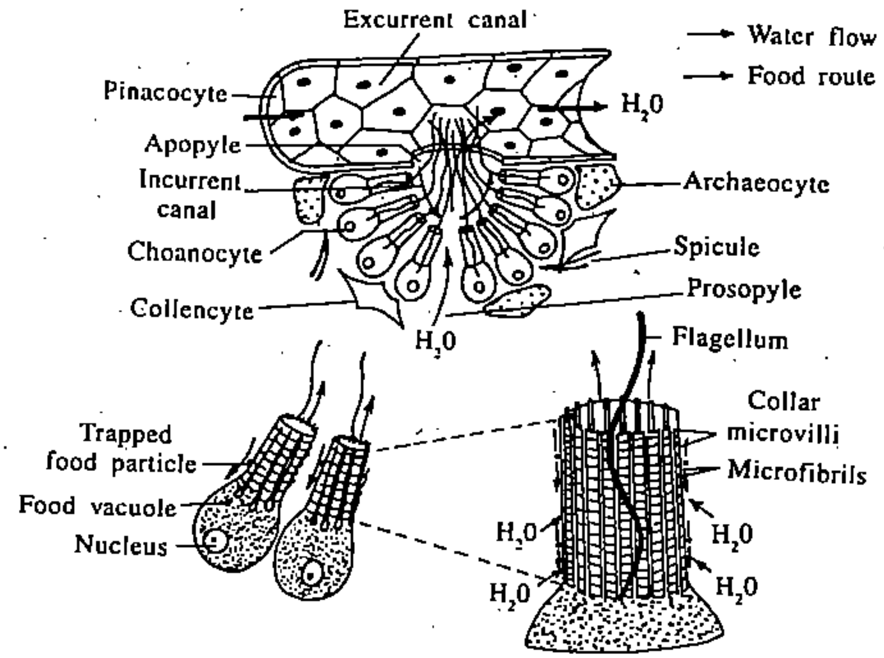



**Fig. 4.3 : Food trapping by sponge cells. A, Cutaway section of canals showing cellular structure and direction of water flow. B, Two choanocytes and, C, structure of the collar. Small red arrows indicate movement of food particles.**

Between the epithelial layer and the choanocyte layer, is a mesohyal layer consisting of gelatinous protein matrix, which contains amoeboid cells (archaeocytes) and skeletal elements. Archaeocytes are amoeboid cells modified to carry out different functions. They engulf food particles and are hence digestive in function, as we have already seen. Sclerocytes (Fig. 4.4) are specialised for secretion of spicules of the skeleton; spongocytes secrete spongin fibres of the skeleton; collencytes and lophocytes secrete collagen.


**Fig. 4.4 : A, Types of spicules found in sponges. There is amazing diversity, complexity, and beauty of form among the many types of spicules.**
**B, Section through a calcareous sponge.**

The skeleton supporting the sponge body is mainly composed of spicules of various sizes and shapes. The spicules (Fig. 4.4) may be siliceous, or of calcium carbonate. The skeleton also consists of collagen and spongin. The spicules may have one, three, four or six rays. The structural variation of the spicules is of considerable importance in classification.

Sperms arise from choanocytes; oocytes arise either from choanocytes or archaeocytes. In addition, internal buds or gemmules are formed from archaeocytes.

You have to clearly understand, in connection with histology of sponges, that the layers of the sponge body, namely, pinacoderm, mesohyal and choanocyte layer are not comparable to ectoderm, mesoderm and endoderm of higher animals.

### 4.3.2 Classification

Now that we have studied the characteristic features of Porifera. We shall discuss here the classification of Porifera, giving examples of different classes.

Phylum porifera is divided into four classes : Calcarea, Hexactinellida, Demospongiae and Sclerospongiae.

1. **Class Calcarea (Calcispongiae): These are characterised by the presence of spicules of calcium carbonate. Spicules are needle-shaped, or three- or four-rayed. All these sponges are marine, small, mostly less then 10 cm in height. These may be asconoid, syconoid or leuconoid. Examples :**

   **Leucosolenia** (Fig. 4.5), **Sycon** (Fig. 4.1).

**Fig. 4.5 : Leucosolenia**

2. **Class Hexactinellida (Hyalo-spongiae): These are commonly known as glass sponges. Skeleton is made up of six-rayed siliceons spicules. Mostly deep sea sponges, radially symmetrical, with vase - or funnel - like bodies attached by stalks to substratum. Examples :** ***Euplectella*** **(Venus's flowerbasket) (Fig. 4.6),** ***Hyalonema*** **(Fig. 4.7). Mostly syconoid, 10-30 cm. No pinococytes, but the outer layer is made up of net-like syncitium derived from interconnecting pseudopodia of amoebocytes.**

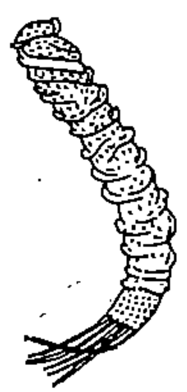


**Fig. 4.6 : Euplectella**


Fig. 4.7 : Hyalonema

3. Class Demospongiae : This constitutes the largest class, with over 90% of all sponge species. The skeleton is made up of spicules of spongin or which are siliceous, or both; spicules not six-rayed. The bath sponges belonging to the family Spongidae eg. *Spongia* have skeleton of spongin only. All Demospongiae are leuconoid. Some reach 1m in size; usually brilliantly coloured. Some are fresh water eg. *Spongilla* (Fig. 4.8), some bore into corals.

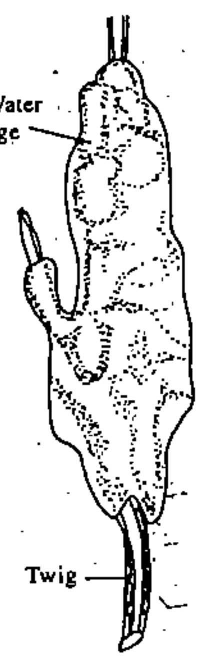



Fig. 4.8 : Spongilla

4. Class Sclerospongiae : These consist of a very small group of sponges which secrete a massive calcareous skeleton (Fig. 4.4). Compound skeleton of siliceous spicules and spongin fibres is also often present. The living tissue is

**limited to a thin superficial layer on the skeleton. All are leuconoid. They live hidden in crevices, caves and tunnels among coral reefs eg. *Merlia*.**

## SAQ 1

Complete the following sentences inserting appropriate words in blanks

i) Porifera are ________________ cellular animals incapable of ____________ as they remain ________________ to the substratum like a ______________

ii) The sponge body is covered by an outer epithelial layer made up of ________________

iii) Sponges with skeleton made up of spicules of calcium carbonate belong to the class ________________

iv) Hexactinellida are characterised by the presence of ______________ spicules.

v) The flagellated chamber of the canal system of sponges is lined by __________

## 4.4 PHYLUM CNIDARIA

You have already seen above, how sponges coming under phylum Porifera, are organized. You shall now see the organization of animals coming under phylum Cnidaria. Phylum Cnidaria, along with phylum Ctenophora, together constituting Radiata, is some times referred to as coelenterates. They include more than 9000 living species, all aquatic, mostly marine but also some fresh-water forms. Their fossils date back to more than 700 million years. They are a successful group of animals, though of great structrual and functional simplicity among metazoans. They include hydroids, jelly fishes, sea anemones, corals etc.

### 4.4.1 Characteristic features

1. All are aquatic animals.
2. Radial or biradial symmetry around an oro-aboral axis, but no head.
3. Diploblastic, with an epidermis and a gastrodermis, and a less cellular or non-cellular, gelatinous mesoglea in between.
4. A gastrovascular cavity with a single opening, the mouth; tentacles encircling the oral region.
5. No coelom, or separate excretory or respiratory system.
6. Nerve net, for diffuse conduction only, present. Some sensory organs also occur.
7. No distinct muscle tissue, but an epithelio - muscular system is present.
8. Two forms of individuals - benthic polyps and pelagic medusae - occur. Polyps usually reproduce asexually, budding sexual medusae. Sexual reproduction in all medusae and some polyps, involving gametes. Cleavage holoblastic and indeterminate. A free swimming planula larva present.

There are two forms of individuals in Cnidaria : the polyp and the medusa. Polyp is tubular, the oral end being free carrying a whorl of tentacles, and the aboral end attached to the substratum by the basal disc. The polyp is the sedentary, benthic form. The medusa is the free-swimming umbrella-like pelagic form, with mouth at the end of the manubrium on the subumbrellar side. Though polyp and medusa may appear to be quite different in form, they have basically the same plan with an outer layer of epidermis, and a gastrodermis lining the gastrovascular cavity, with a gelatinous layer of mesoglea in between them. The mesoglea in the medusa is, however, thicker (hence the term jelly fishes), and one form can be theoretically derived from the other, as could be easily understood from Figure 4.9. The gastrovascular cavity serves as the alimentary canal, opening to the outside through only one opening, the mouth.

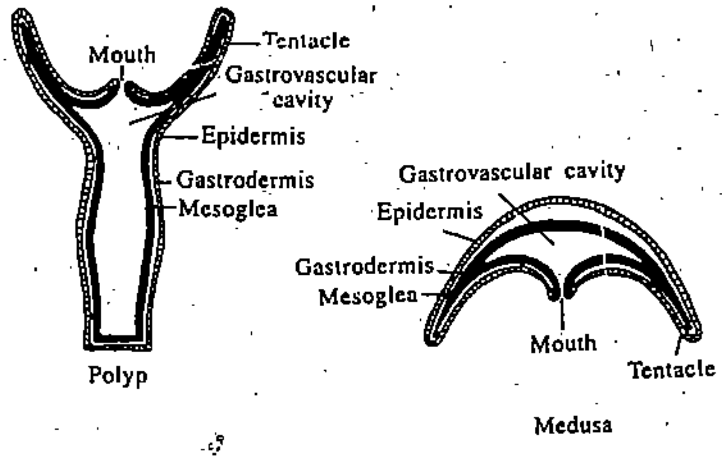



Fig. 4.9 : Comparison of Polyp and Medusa.

**Body Wall**

Structure of the body wall of cnidarians can be easily understood from a portion of the cross section of *Hydra* (Fig. 4.10). The outer, epidermal layer is made up of five types of cells.

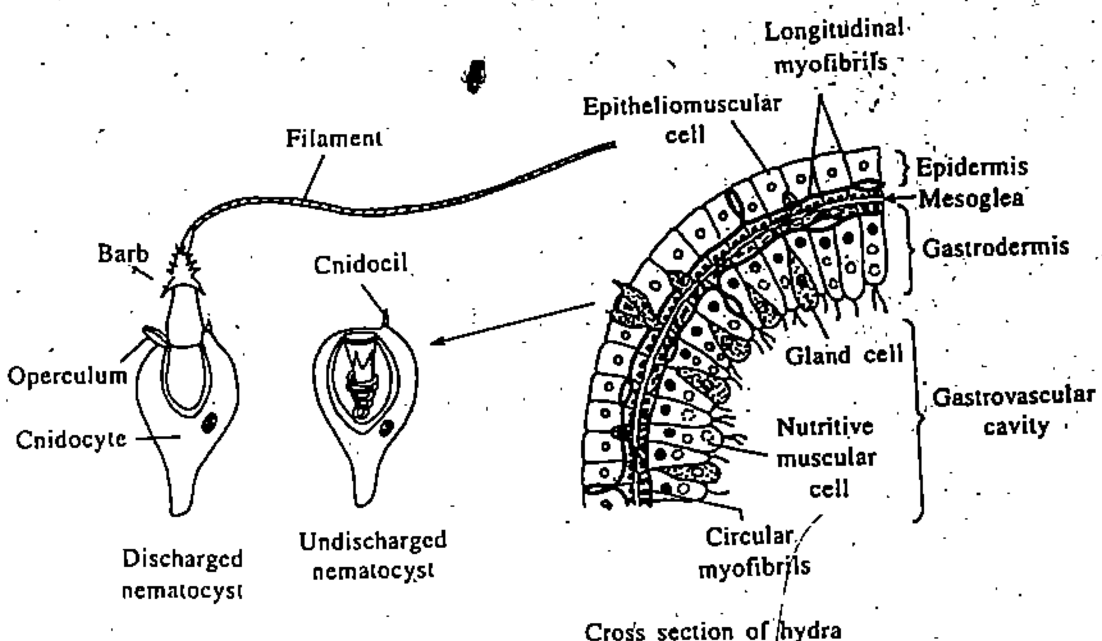



Fig. 4.10 : At left, structure of a stinging cell. At right, portion of the body wall of a hydra. Cnidocytes, which contain the nematocysts, arise in the epidermis from interstitial cells.

**Epithelio muscular cells** : These are columnar cells with basal contractile myofibrils extending parallel to the oro-aboral axis. and are hence longitudinal fibres. Their contraction results in shortening the length of the animals.

**Interstitial Cells** : These are undiffrentiated cells found among the bases of the epitheliomuscular cells. These give rise to other types of cells.

**Cnidocytes** : During development these are called cnidoblasts. When fully formed, the cnidocyte contains a stinging capsule called nematocyst containing a coiled tube (Fig. 4.11). This tube can be everted when discharged at will. At the base of the tube there are tiny sharp barbs. The capsule is covered with a lid, the operculum. Cnidocyte also has a hair-like cnidocil, which acts as a trigger. The nematocyst contains a fluid of high osmotic pressure. When the prey touches the cnidocil, the permeability of the membrane covering the nematocyst changes and there is a sudden uptake of water into

the nematocyst. This results in the eversion and discharge of the coiled tube; which is extended during the process. The coiled tube turns inside out like the sleaves of a shirt during the process. Once the nematocyst is discharged into the prey, the cnidocyte is absorbed and a new one is formed in its place. There are a variety of nematocysts in the cnidarians; they are important in classification of these animals. These structures are the weapons of offence and defence in the group; some are sticky and are used for food capture.

Fig. 4.11 : Several types of nematocysts shown after discharge. At bottom are two views of a type that does not impale the prey, rather it recoils like a spring, catching any small part of the prey in the path of the recoiling thread.

**Mucous gland cells** : They are gland cells which secrete mucous useful in protection, adhesion and for capture of the prey.

**Sensory and nerve cells** : The sensory cells are scattered among epidermal cells. Nerve cells are usually multipolar and their processes synapse with those of the sensory cells and of other nerve cells. They form a network in the epidermis.

**Gastrodermis consists of** : i) Nutritive - muscular cells. These cells engulf food particles and digest them. They have also muscular processes at the base. These processes extend at right angles to the oro-aboral axis. Hence they are called circular muscle fibers, and their contraction results in decreasing the diameter of the body. ii) Gland cells secrete enzymes into the gastrovascular cavity; iii) Mucus secreting cells.

### 4.4.2 Classification of Phylum Cnidaria

Depending mainly upon whether polyp or medusa is the dominant form in the life cycle, Cnidaria are divided into four classes (1) Hydrozoa; (2) Scyphozoa; (3) Cubozoa and (4) Anthozoa.

1. **Class Hydrozoa. They may be solitary or colonial forms. There are asexual polyps and sexual medusae, though one type may be suppressed. The feeding zooids (hydranths) do not have mesenteries. Medusa, when present, has a velum (the margin of the umbrella projecting inward in the form of a shelf). Animals may be either fresh water or marine.**

   **Hydra** (Fig. 4.12) is a common fresh water form, but atypical, being solitary and without a medusoid form, *Obelia* (Fig. 4.13) is a colonial form. It has feeding polyps with tentacles (gastrozooids or trophozooids), and reproductive zooids without tentacles, which bud off medusae (gonozooids). These individuals are connected to root-like hydrorhiza with a stalk-like hydrocaulus. The gonozooids bud off small medusae with epidermal gonads. The testes and ovaries are borne on different medusae (gonochorism). The medusae have light-sensitive ocelli, and statocysts sensitive to gravity (Fig. 4.14). In *Tubularia*, another colonial form, the gonozooids do not release medusae. The medusae remain attached to the gonozooids from where gametes are released. Then the gonozooids are called gonophores. Individuals belonging to the order siphonophora show highest degree of polymorphism. They form floating or swimming colonies made up of several types of modified medusae and polyps. *Physalia* (the Portugese man-of war) (Fig. 4.15) is such a colony with a big bright float and long tentacles arising from clusters of polyps modified differently for carrying out various functions. *Velella* (Fig. 4.16) with a small saucer shaped float (modified gastrozooid) carrying gonozooids and dactylazooids (club shaped polyps with batteries of cnidocytes which are defensive in function) is another example.

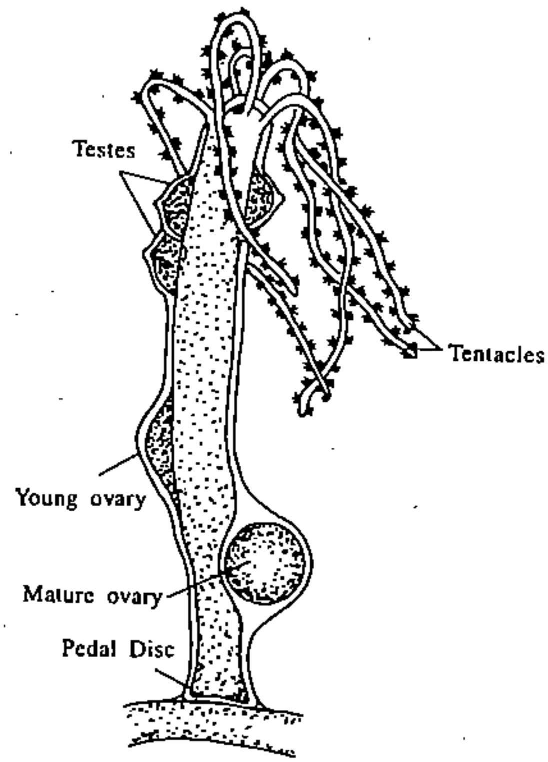



Fig. 4.12 : Hydra

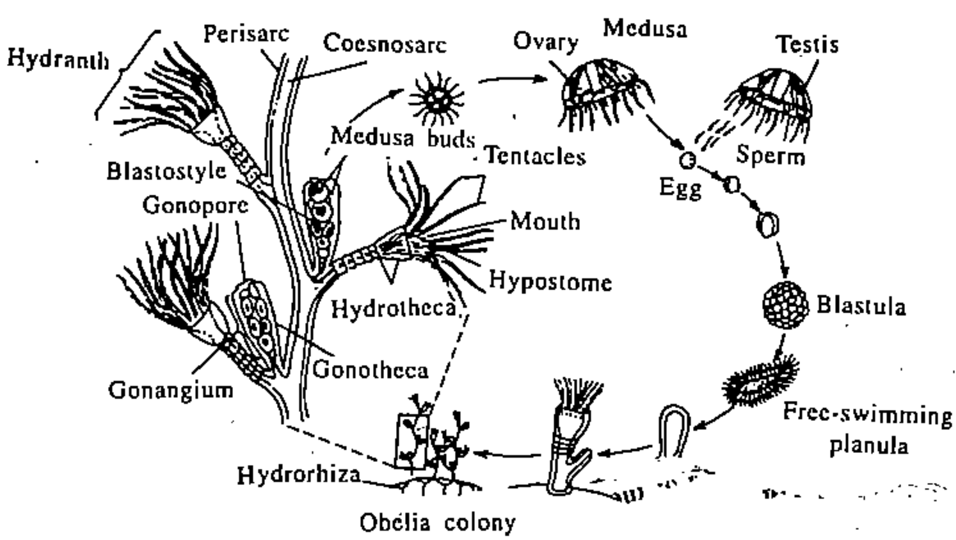



**Fig. 4.13 : Life cycle of Obelia, showing alternation of polyp (asexual) and medu stages. Obelia is a calyptoblastic hydroid; that is, its polyps as well are protected by continuations of the perisarc.**

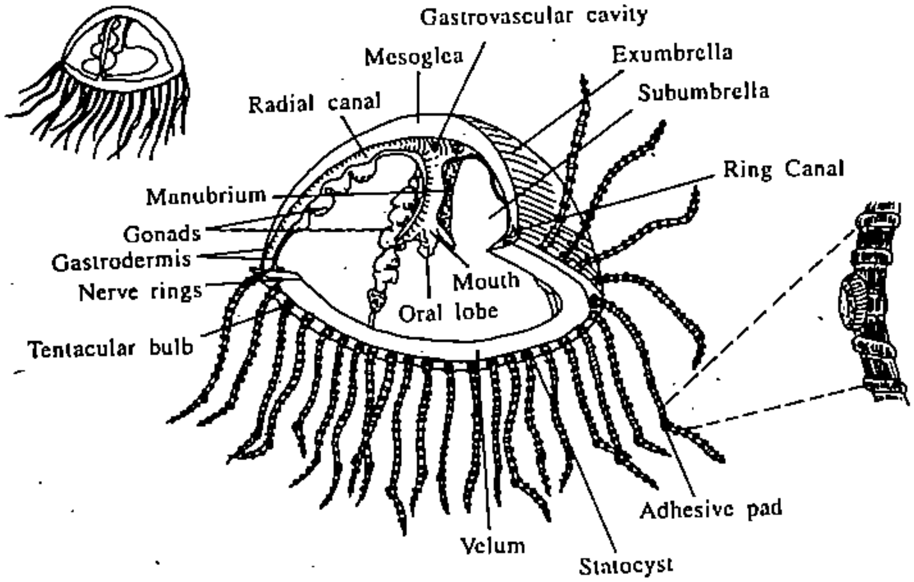



Fig. 4.14 : Structure of Gonionemus. A, Medusa with typical tetramerous arrangement, B, Cutaway view showing morphology. C, Portion of a tentacle with its adhesive pad and ridges of nematocysts.

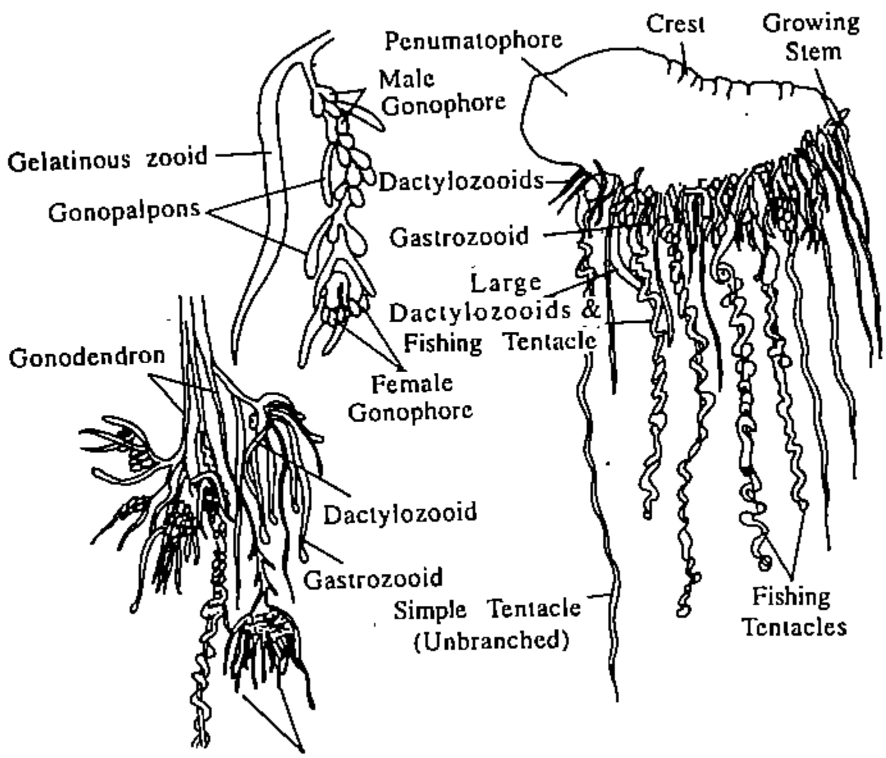



Fig. 4.15 : Physalia A - Young; B - Part of gonodendron; and C - A cluster of individuals from sexually matured Physalia.

**Examples**: Sea anemones are common. They are solitary, occurring along the coast attached to rocks in the littoral region. *Metridium* and *Tealia* are typical. Other examples of the class are *Cerianthus*, *Antipathes*, *Tubipora*, *Alcyonium*, *Gorgonia*, *Renilla* etc. (Figs. 4.20, 4.21, 4.22, 4.23).

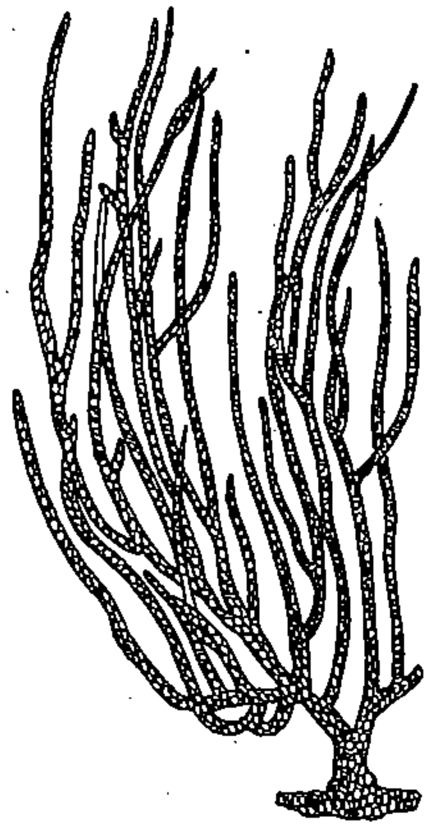


**Fig. 4.20 : Gorgonia**

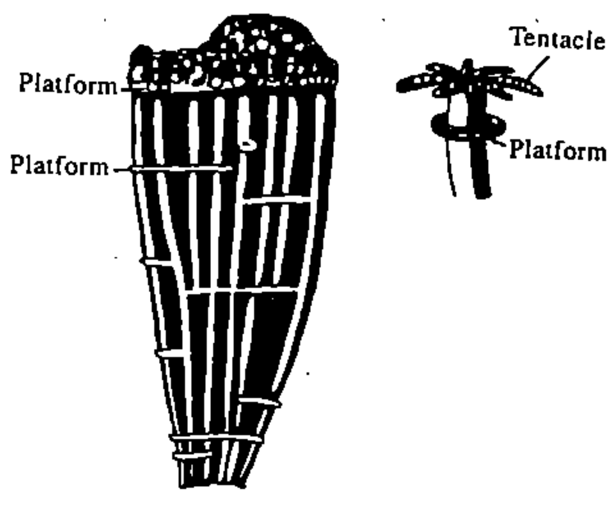



**Fig. 4.21 : Tubipora musica : A, skeleton of entire colony B, single polyp with tube and commencement of platform.**

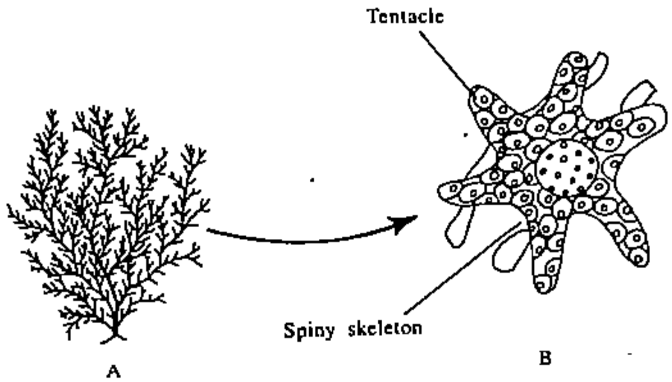



Fig. 4.22 : A, Colony of Antipathes, a black or thorny coral (order antipatharia, class Anthozoa). B, The polyps of Antipatharia have six simple, nonretractile tentacles. The spiny processes in the skeleton are the origin of the common name thorny corals.

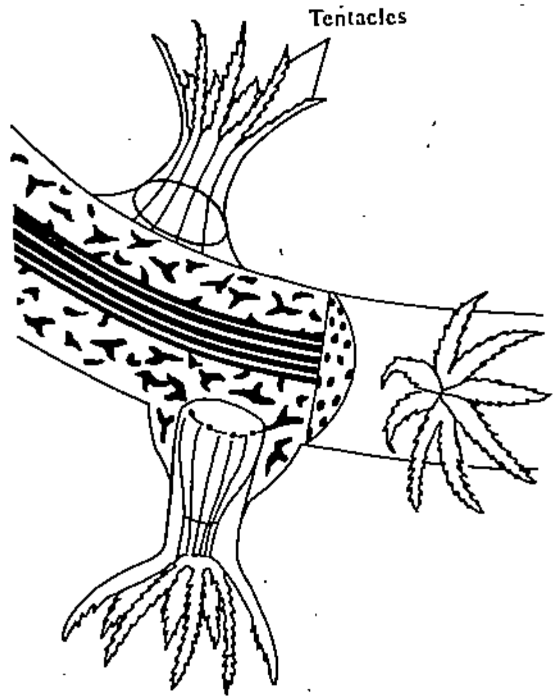



Fig. 4.23 : Polyps of an alcyonarian coral (octocoral). Note the eight pinnate tentacles, coenenchyme, and solenia. They have an endoskeleton of limy spicules often with a horny protein, which may be in the form of an axial rod.

Some animals coming under this class are colonial coral formers. In the true corals or stony scleractinian corals polyps are connected with one another laterally and they sit upon calcareous cups they have secreted outside. The skeleton here is secreted by the epidermis of the base of the column below to living tissue rather than within. So it is an exoskeleton. The polyps can be withdrawn into the skeleton. The skeleton of the colonial corals becomes massive over the years, with the living tissue covering it as a sheet outside. Alcyonarians, usually referred to as octocorals as they have eight tentacles, are also colonial, connected laterally in a branching form (Fig. 4.23). Here the amoebocytes of the mesoglea secrete the calcium carbonate skeleton, which is internal. *Corallium* is the precious red coral whose skeleton is used to make coral jewelry. The alcyonarians are soft corals, containing fewer spicules of calcium carbonate. Antipatherians form the thorny or black corals.

thickness exceeding a depth of 1250m. This atoll, like many others, is the result of subsidence as well as sea level changes.

## 4.5 PHYLUM CTENOPHORA

These are commonly known as Comb jellies, sea walnuts or sea gooseberries, and come to about 100 species, all being marine. They derive their name from comb plates used for locomotion.

### 4.5.1 Characteristic features

1. All are medusoid. No polymorphism.
2. Otherwise radial symmetry has become biradial symmetry because of the presence of two tentacles.
3. Mesoglea with amoebocytes and smooth muscle fibres.
4. Devoid of nematocysts. Instead, they have adhesive cells (colloblasts or lasso cells).
5. Locomotion by means of comb plates, which are comb-like fused ciliary plates arranged radially in 8 meridianal rows (combrows).
6. The subepidermal nerve plexus concentrated beneath comb rows. An aboral sense organ, which is a statocyst, is present.
7. Gastrovascular cavity consists of mouth, pharynx, stomach, a series of canals and anal pores, carnivorous.
8. Hermaphrodite. Gonads are gastrodermal in origin, and situated on the walls of the gastrovascular canals under the comb rows. Mosaic cleavage, accompanied by a cydippid larva.
9. All are marine, mostly pelagic and luminescent.

*Pleurobrachia* is an example (Fig. 4.27). Transparent body is 1.5-2 cm diameter. Resembles basically a cnidarian medusa. However, there are eight meridional bands on the surface extending from the aboral pole almost upto the oral pole. Each of these is made up of comb like transverse plates of long fused cilia, called comb-plates. Beating of the cilia of the comb plates results in locomotion. The nerve net beneath these comb plates and the aboral statocyst co-ordinate the activity of these animals. The two long solid tentacles can be retracted into the tentacle sheaths. The surface of the tentacles carry colloblasts which secrete a sticky substance used for catching tiny animals. The thick mesoglea or collenchyma contain amoeboid cells and muscle fibres. Though derived from ectodermal cells, the muscle cells are distinct. They are not part of the epithelio-muscular cells. The mouth opens into the pharynx, which leads into a stomach. The stomach is connected to a system of gastrovascular canals branching through the mesoglea. The aboral canal from the stomach divides into two tiny anal canals near the statocyst leading to the outside through anal pores, through which undigested material is expelled. The aboral sense organ is a statocyst (Fig. 4.27). The animal is hermaphrodite, each gonad made up of two bands : one ovary and the other testis. They are situated on the lining of the gastrovascular canals under the comb plates. Fertilised eggs are shed into the water. Cleavage is, unlike in cnidarians, mosaic (determinate). It results in a cydippid larva with superficial resemblance to the adult, into which it directly develops.

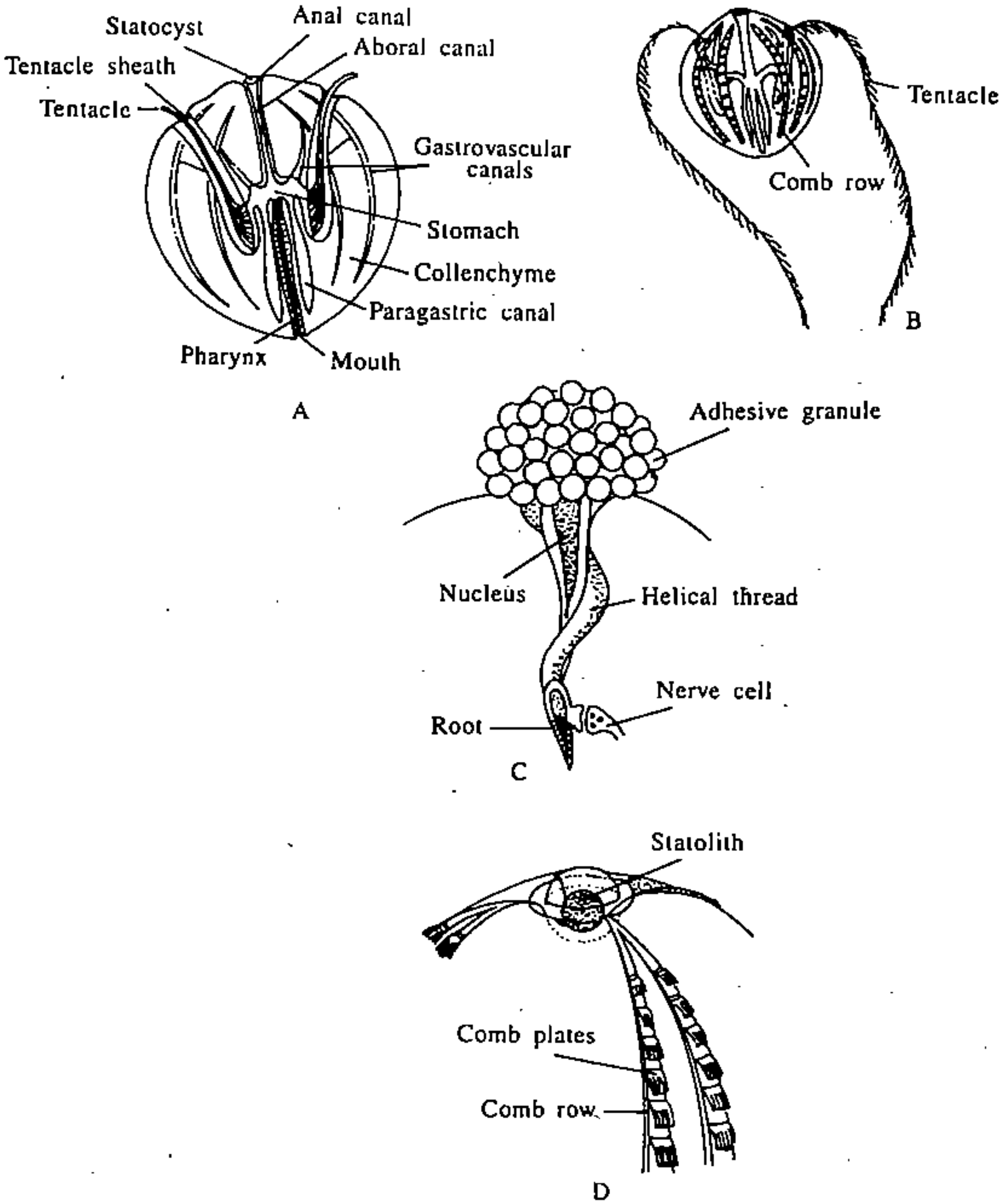



Fig. 4.27 : The comb jelly Pleurobrachia, a ctenophore. A, Hemisection. B, External view. C, Colloblast, an adhesive cell characteristic of ctenophores. D, Portion of comb rows showing comb plates, each composed of transverse rows of long fused cilia.

## 4.5.2 Classification

Phylum ctenophora is divided into two classes:

1. **Class Tentaculata. These have two tentacles. Example *Pleurobrachia* (Fig, 4.27) *Velamen*. Body is so much laterally flattened that it appears to be a transparent ribbon. *Ctenoplana* (Fig. 4.28) is flattened along the oro-aboral axis.**

2. **Class Nuda. Without tentacles, with wide mouth and expanded stomodaeum. Somewhat conical; example *Beroe* (Fig. 4.29).**

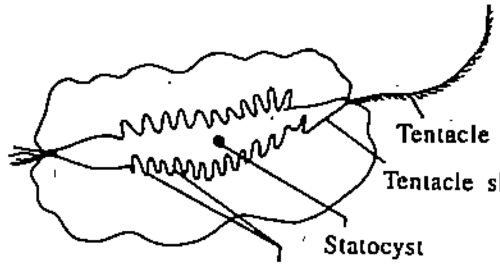



Fig. 4.28 : Ctenoplana

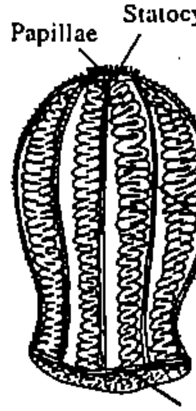



Fig. 4.29 : Beroe

**SAQ 2**

i) a) Mention two important characters of Cnidaria.
   b) Mention two important characters of Ctenophora.
   c) Name five cell types in Cnidarian epidermal layer.
   d) Name the four classes of Phylum Cnidaria.
   e) Name the two classes of Ctenophora.

ii) Fill in blanks with suitable words:
   a) Though living corals are found only upto a depth of 30m or so, most of the coral reefs of the world show far greater vertical thickness. This is because of gradual rise of the sea level due to ________________ ____________ and ____________
   b) Ctenophores show ____________ symmetry.

## 4.6 PHYLUM PLATYHELMINTHES

You have just now studied two phyla of animals (Cnidaria and Ctenophora) which are diploblastic — whose body is made up of only two germ layers — the ectoderm and endoderm. The space in between is made up mostly of a jelly like substance, with very few cells. Now you will proceed to study triploblastic animals which have in addition to ectoderm and endoderm, a third germ layer — mesoderam. The first phylum among these is phylum platyhelminthes.

Animals coming under phylum Platyhelminthes are soft bodied bilaterally symmetrical animals popularly known as flat worms which number more than 15,000 species. The gelatinous mesoglea of the cnidarians is here replaced by a mesodermal, cellular, parenchyma, a type of packing tissue consisting of more cells and fibres than mesoglea. This has laid the foundation for a more complex organization, with more organs and organ systems. These animals range in size from less than a milimeter to a few meters as in some tapeworms. They include free-living and parasitic species. Many live on land but some are fresh-water or marine, crawling on weeds and sediment.

### 4.6.1 Characterisitc Features

1. Bilaterally symmetrical, with anterior and posterior ends.
2. Body dorsoventrally flattened.
3. Triploblastic - with three germ layers.
4. Acoelomate - no internal body cavity. The space between the organs is filled with a form of connective tissue called parenchyma derived from mesenchyme.
5. Digestive system absent in some; when present, has only the mouth but no anus.
6. Nervous system ladder-like, with simple sense organs.
7. 'Excretory system' protonephridial type.
8. No respiratory, circulatory or skeletal systems.
9. Hermaphrodites, with complex reproductive system.
10. Eggs show spiral cleavage, which may be highly modified.
11. Development usually direct in free living forms; in some there is a free-swimming larva (Muller's larva or Gotte's larva). In certain parasites development may be much complicated involving many larval stages in the life cycle.

Bilateral symmetry has evolved for the first time in this group of animals and it has been maintained in all higher groups (Hence all these phyla are called Bilateria). This symmetry and the accompanying cephalisation have evolved side by side in response to progression in one direction — that end of the animal which is in front during locomotion has become the head. Of necessity, sense organs are concentrated at this end. Flattening of the body is the consequence of these animals having no circulatory system, and the animals' dependence on simple diffusion from body surface for respiration, excretion and other purposes. Another important feature of this group of animals is the appearance of a third cellular layer between epidermis and gastrodermis - the parenchyma - instead of the gelatinous noncellular mesoglea of the coelenterates.

Yet another characteristic of platyhelminthes is the protonephridia with flame cells (Fig. 4.30). The flame cell is in fact made up of two cells : a cap cell and a tubule cell. The cupshaped cap cell has a tuft of flagella arising from the inner face of the cup and extending into its cavity beating like the flickering flame of a candle (hence flame cell). The cap cell and the tubule cell are fitted into one another by means of their finger like interdigitations. At the interdigitation fenestrations occur. Beating of the flagella draws fluid into the lumen of the flame cell through the fenestrations and drive the flow further forward through the duct system. During this process, ions and various other molecules may be resorbed. Many such flame cells unite to form a duct system which may open out through nephridiopores. Though the system is often called excretory, it appears to be mainly osmoregulatory, as the system is reduced or even absent in marine forms. Nitrogenous wastes are actually removed by diffusion through the body surface.

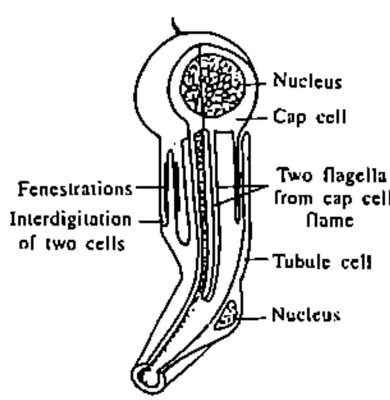



Fig. 4.30 : Protonephridial system with details of a flame cell.

Another feature in Platyhelminthes is the evolution of more elaborate and clear 'organ systems' for the first time — protonephridial, feeding, reproductive, nervous, sensory etc. involving better integration of tissues and organs.

The gut of Platyhelminthes has only one opening the mouth. Naturally, most of these animals feed on tissues of other animals though some feed on algae. Most species are parasitic, with organs specialised for adhesion to the host. In gut parasites which are surrounded by partially digested food of host gut, alimentary canal is completely absent. But the surface of the platyhelminth parasite body is suitably modified for absorption of the surrounding digested food. Reproductive system is extensive in these animals, capable of producing large number of eggs.

### 4.6.2 Classification

Phylum Platyhelminthes is divided into four classes: **Turbellaria, Monogenea, Trematoda** and **Cestoda.**

1. **Class Turbellaria. These are mostly free living and aquatic. Some are terrestrial, confined to humid areas. Body of these animals is covered with ciliated epidermal cells containing rhabdoids. Mouth is on the ventral side.**

These animals range from a few millimeter to a few centimeter. They move by means of cilia covering the body. Undulations of the body also help in locomotion of larger forms. In a transverse section (Fig. 4.31) you will see an outer covering of ciliated epidermal cells containing rod-like structures called rhabdoids. Cilia may be missing dorsally. If you disturb the animal the rhabdoids are ejected. So they are defensive in function. Rhabdoids may also form a mucus covering around the body. Beneath the epidermis you will see the circular, diagonal and longitudinal muscle fibres. These fibres are unstriated. You can also see mucus gland cells located in parenchyma. They open to the outside. A loose type of connective tissue, parenchyma, made up of aggregation of irregular cells, packs the space between internal organs. You will also see simple eyes on the head. Nerve tissue is concentrated as ganglia (brain) in the head. The gut may be a solid syncytial mass, a simple sac or a number of lateral diverticula. Apart from possessing a well-developed reproductive system, the turbellarians have tremendous capacity for asexual reproduction especially by transverse binary fission. They have also extensive capacity for regeneration. Examples are *Dugesia* (Planaria), *Microstomum* and *Planocera* (Figs. 4.32, 4.33).

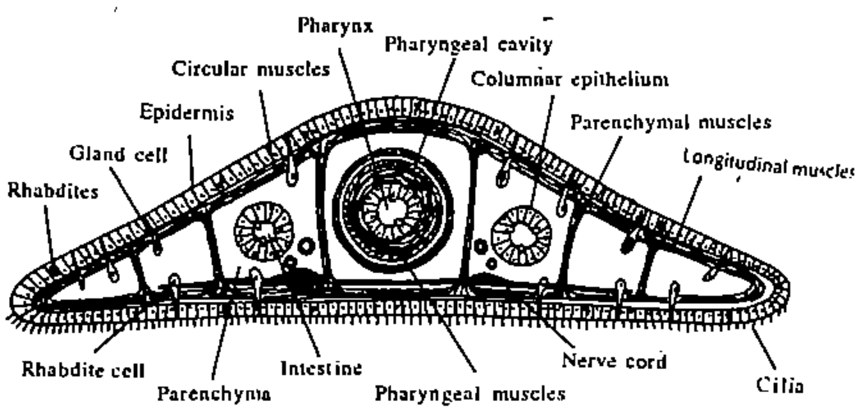



**Fig. 4.31 : Cross section of planarian through pharyngeal region, showing relationships of body structures.**

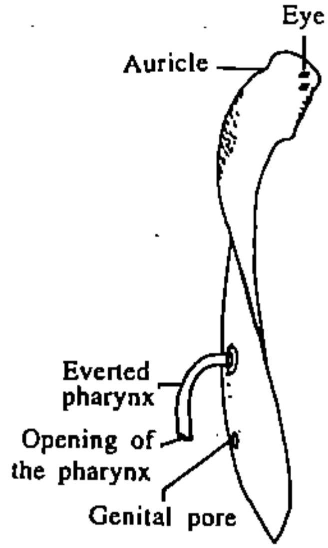



Fig. 4.32 : Planaria, side view.

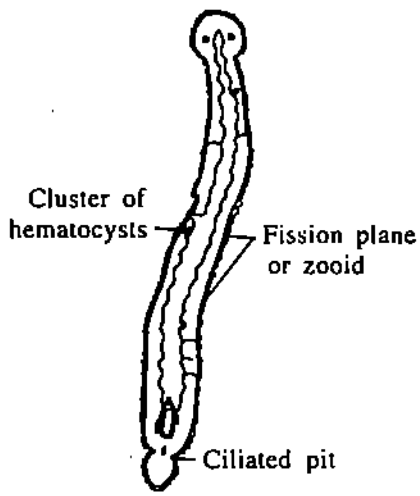



Fig. 4.33 : Microstomum

2. **Class Monogenea. Body of these animals is covered with a non-ciliated syncytium the tegument. They are leaf like to cylindrical. They are parasitic, usually on the skin or gills of fish. For this they have posterior attachment organs in the form of hooks, suckers, clamps etc. Their development is direct, with only one host. They have usually a free-swimming ciliated larva.**

These are monogenetic flukes. Important differences from the turbellerians are, that, instead of the ciliated epidermis, these have a non-ciliated, syncitial tegument. You can also note a muscular pharynx for active ingestion of food from the host, into the gut. The gut is branched into two. The adult has no sense organs. Examples : *Gyrodactylus* (Fig. 4.34), *Polystoma* (Fig. 4.35), a parasite in the urinary bladder of frogs.

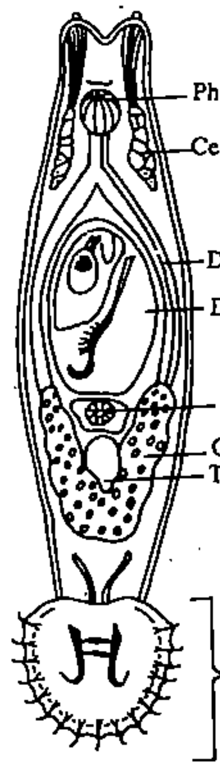



Fig. 4.34 : Gyrodactylus cylindriformis, ventral view.

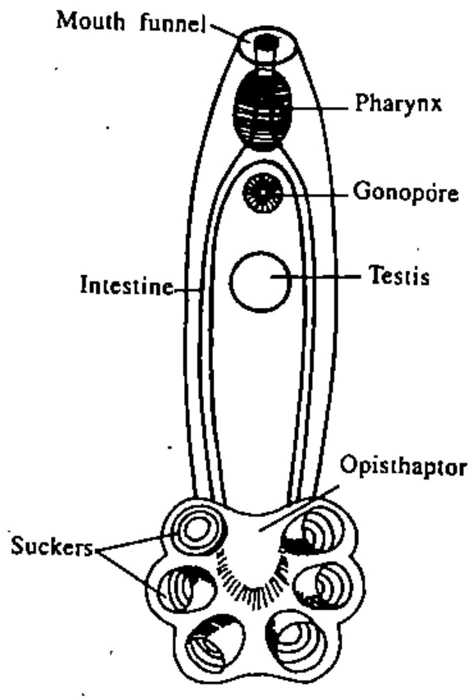



Fig. 4.35 : Polystoma

3. **Class Trematoda. Body of these animals is also leaf-like to cylindrical-covered with non-ciliated syncitium the tegument. However, they have oral sucker and ventral sucker, but no hooks. Development is indirect. The definitive host (host in which sexual reproduction takes place; it is also known as final host) is a vertebrate. First host or the intermediate host in which asexual reproduction takes place, is a mollusc.**

These are the digenetic flukes, endoparasitic, many of them causing diseases in humans and domestic animals. A typical example is *Fasciola* (Fig. 4.36). *Fasciola hepatica* causes liver rot in sheep and other ruminants. The adult lives in the bile duct of the liver. The eggs are passed along faeces, to the outside on hatching, a ciliated larva, the miracidium, emerges out. The miracidium penetrates a snail which is the secondary host. In the snail, the miracidium becomes a sporocyst. Each sporocyst contains germinal masses, which by mitoses gives rise to a number of primary rediae. Each primary redia similarly gives rise to a large number of secondary rediae. The secondary redia similarly gives rise to a number of cercariae. Thus you can see that each egg can give rise to a large number of progeny. The cercaria encysts on vegetation and is now called metacercaria. The metacercariae along with vegetation are eaten up by the ruminant, in which it excysts (comes out of the cyst) and grows into a young fluke, completing the life cycle.

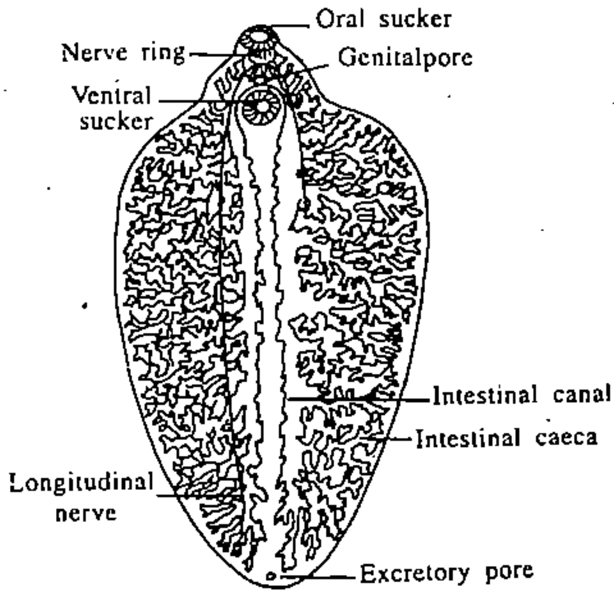



Fig. 4.36 : Fasciola.

Another example is *Schistosoma* (Fig. 4.37), the blood fluke. The species *S. mansoni*, *S. japonicum* and *S. haematobium* cause schistosomiasis in humans. You will note that schistosomatids are peculiar in that they are gonochoristic (= dioecious i.e., having separate sexes), unlike other species of this phylum. The mature males and females are found in close association with one-another (Fig. 4.37). The male has a ventral groove into which is found the slender female.

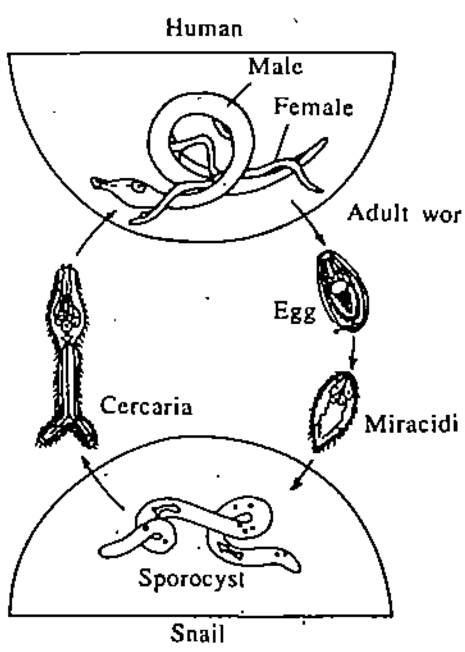



Fig. 4.37 : Life cycle of *Schistosoma mansoni*.

4. **Class Cestoda. These are the tape worms, parasitic in the digestive tracts of various vertebrates. In these animals also, body is covered with non-ciliated, syncytial tegument, but body is tape-like, with an anterior scolex carrying suckers and hooks for attachment to host tissues. Body is also divided into a number of proglottids. You will find that these have no digestive organs. Development is indirect, with two or more hosts.**

A typical example is **Taenia**. As these are found in the digested food material of the host, though these animals have no mouth or gut, food can directly be absorbed through the highly modified tegument (Fig. 4.38). The scolex end buds off immature segments or proglottids which gradually mature developing reproductive system; as they pass back new proglottids are added on (you may note that this is opposite to what occurs in annelids in which segments are formed posteriorly, and they pass on anteriorly while maturing). Mature proglottids at the opposite end (gravid proglottids) are more or less, bags of eggs. The gravid proglottids containing large number of mature eggs are ultimately shed off. The fully grown adult beef tape worm of the humans, *Taenia saginata*, having 700-1000 or more proglottids, may shed 3-10 proglottids daily, each containing 1,00,000 eggs. The proglottids passed out along with the stools, crawl on vegetation which may be eaten up by grazing cattle. In the gut of the cattle, the eggs hatch and a larva with six hooks (oncosphere) emerges out. The oncosphere penetrates the intestinal wall into blood vessels, reaching through the blood stream, the voluntary muscles. Here they encyst forming bladder worms (cysticerci) with invaginated scolex. When infected measly beef is eaten by the human host, wall of their cyst dissolves, the scolex evaginates and it attaches to the intestinal wall, developing new proglottids, thus starting its own life cycle in the human host.

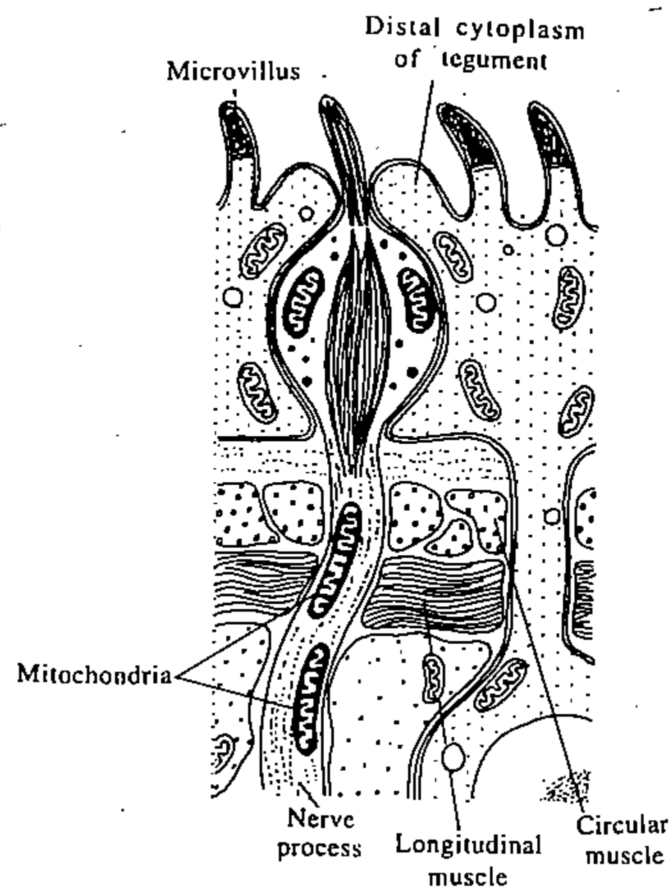



**Fig. 4.38 : Schematic drawing of a longitudinal section through a sensory ending in the tegument of Echinococcus granulosus.**

Other examples include the pork tape worm *Taenia solium* (Fig. 4.39) and the fish tape worm *Diphyllobothrium latum*. *Echinococcus granulosus* (Fig. 4.40 A) is the dog tape worm; the juveniles of this are found in many species of mammals including man. Man, in this case, is an intermediate host. The juvenile stage is a peculiar kind of cysticercus known as hydatid cyst (Fig. 4.40 B). It grows for a long time attaining very large size. The main cyst having a unilocular chamber, may bud off daughter cysts within, each containing thousands of scolices. Each scolex can produce a tape worm when eaten by dog.

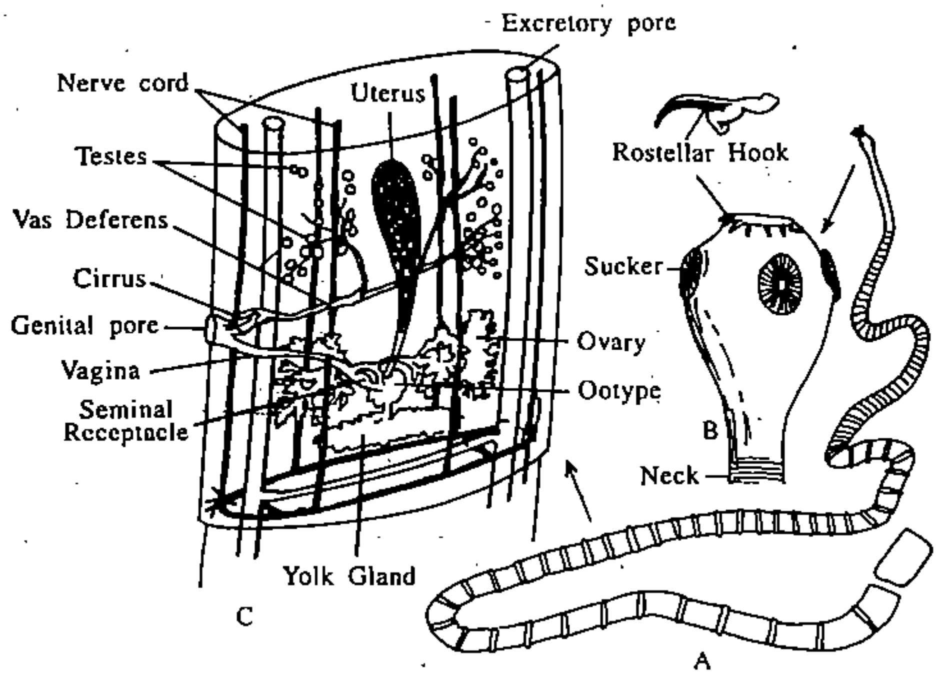



**Fig. 4.39 : Taenia solium : A- Entire specimen, B - Scolex of the same enlarged; and C - A mature proglottid enlarged.**

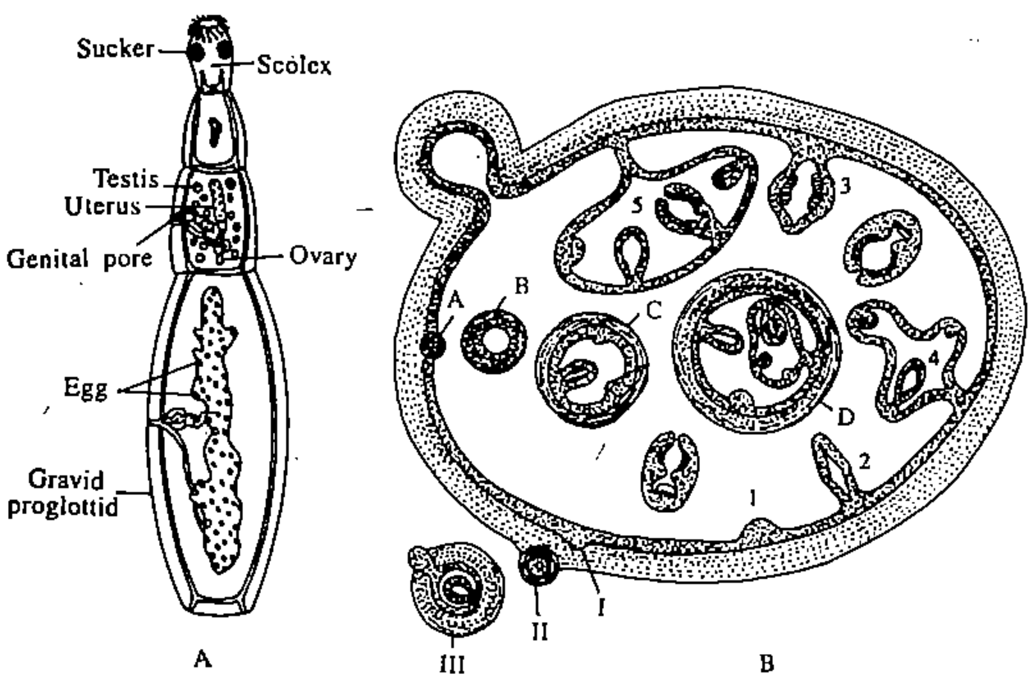



**Fig. 4.40 : Echinococcus granulosus : A - Adult tape worm lives in the intestine of dog or other carnivore, B - Hydatid cyst-1-5 stages in development of scolices from germinative layer, A-D stages in budding of endogenous layer, I-III stages in budding of an exogenous daughter cyst.**

**SAQ 3**

1) Which of the words given in the bracket is correct? Flame cells in Platyhelminthes are ___________ in function. (excretory/osmoregulatory).

2) Name three important characters of Platyhelminthes for considering them more advanced than cnidarians.

3) Arrange the character most appropriate to the class of Platyhelminthes, against it.

| Classes | Characters |
|---|---|
| a) Turbellaria | i) Presence of scolex |
| b) Monogenea | ii) Presence of oral and ventral suckers, but no hooks |
| c) Trematoda | iii) Presence of posterior hooks, suckers, clamps etc. |
| d) Cestoda | iv) Ciliated epidermal cells covering the body. |

## 4.7 PSEUDOCOELOMATA - PHYLUM NEMATODA

As we have already seen earlier, the body cavity of Pseudocoelomata is a pseudocoel. It is the original blastocoel of the embryo persisting between the alimentary canal and the body wall. It is not lined by a mesodermal peritoneal lining. This lining is a characteristic of the true coelom, the body cavity of coelomates. The pseudocoelomates comprise the following phyla: Gastrotricha, Kinorhyncha, Loricifera, Priapulida, Nematomorpha, Acanthocephala, Entoprocta, Nematoda and Rotifera. These groups are polyphyletic — they have originated from different ancestors. They are heterogeneous. We will be studying only two phyla among these : Phylum Nematoda and Phylum Rotifera.

### 4.7.1 Phylum Nematoda

Phylum Nematoda are popularly known as round worms. A highly successful group of animals with about 12,000 species known, but unknown species are expected to far outnumber these (about 5,00,000!). They are found in the soil in all types of aquatic environment, in animals and plants, as parasites and otherwise. They are also known to cause diseases in them. However, there is very little structural diversity among them, all being built on the same fundamental plan.

### 4.7.2 Charateristic Features

1. Vermiform body bilaterally symmetrical, but with a tendency for radial symmetry along longitudinal axis. Cross sectional area circular; no segmentation or appendages.
2. A complex cuticle present.
3. Body has more than two cell-layers; tissues and organs present.
4. Circular muscles absent in the body wall.
5. Body cavity is pseudocoel, with body fluid at high pressure.
6. Gut extending from the mouth at the anterior end to anus which is subterminal. Muscular pharynx.
7. One ventral, one dorsal and two lateral epidermal chords with longitudinal muscles arranged in the four quadrants in between.
8. Longitudinal nerves in the dorsal and ventral epidermal chords, with direct contact with muscle cells.
9. Muscles of the body wall are with peculiar features.

10. No circulatory system. No flame cells or nephridia. No cilia or flagella. Excretory tubules in one or a limited number of renette cells.
11. Highly determinate type of cleavage; Development direct.
12. Eutely - Growth involves increase in cell-size rather than cell number.

The cuticle of nematodes is characteristic of the group. It is non-living and many layered, with spiral fibres of one layer crossing those of the others (Fig. 4.41 A). This type of cuticular organisation affords considerable strength to withstand high hydrostatic pressure of the fluid within the body cavity.

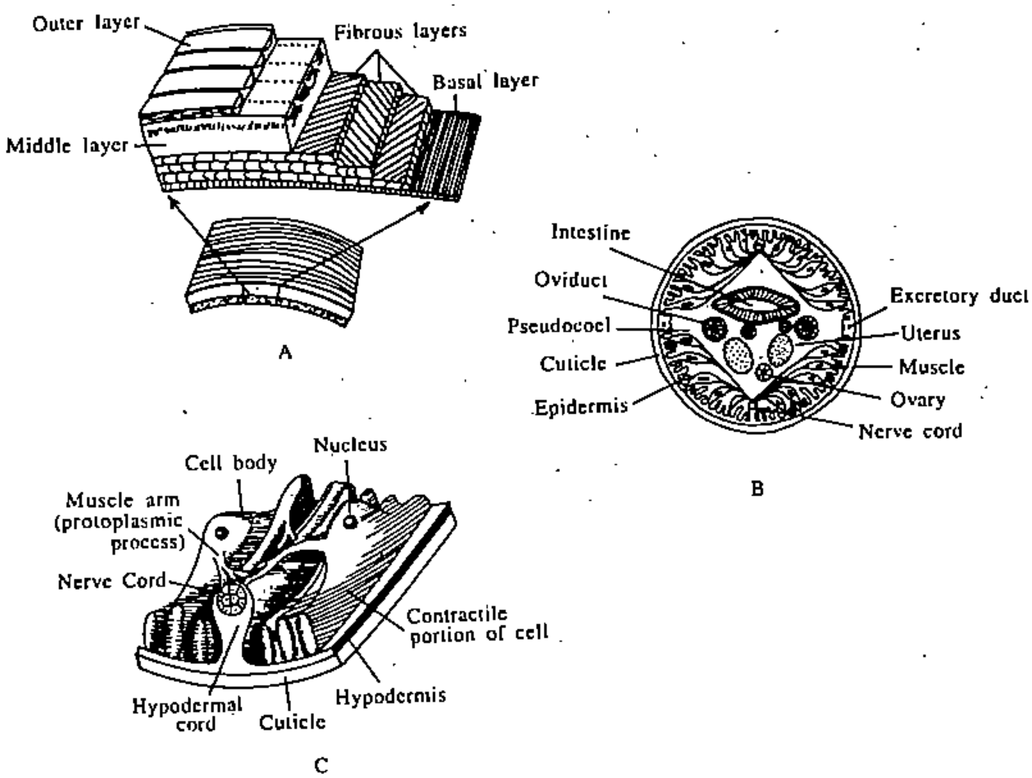



**Fig. 4.41 : A, Structure of the nematode cuticle. The cuticle consists of an outer striated layer, an inner homogeneous layer and a complex of fibrous layers; B & C, Structure of a nematode as illustrated by Ascaris female. B - Cross section. C - Single muscle cell; spindle abuts hypodermis, muscle arm extends to dorsal or ventral nerve.**

A cross section of the body wall (Fig. 4.41 B) shows epidermal layer beneath the cuticle. There are four longitudinal strands or chords in the epidermis : one midventral, one mid-dorsal and two lateral. The dorsal and the ventral chords contain the longitudinal nerve trunks : the lateral chords contain the excretory canal. The muscle fibres are peculiar in this phylum. They form neuromotor units. The contractile elements of these rest on the epidermis (Fig. 4.41 C). An innervation process proceeds from the muscle cell to the nerve chord. It enables simultaneous contraction of all muscle cells. You may note here that the system of muscle fibres sending process to the nerve fibre is unusual. It is the nerve fibre which usually sends process to the muscle fibres.

The alimentary canal is made up mostly of the non-muscular intestine. The pharynx is, however, muscular functioning to pump food into the gut. Rectum is short leading out through the anus. The body cavity is almost completely filled by the paired reproductive organs (Fig. 4.42). Sexes are separate. Fertilization is internal. The eggs, when laid, are either zygotes, or even embryos at early stage of development. They are extremely resistant.

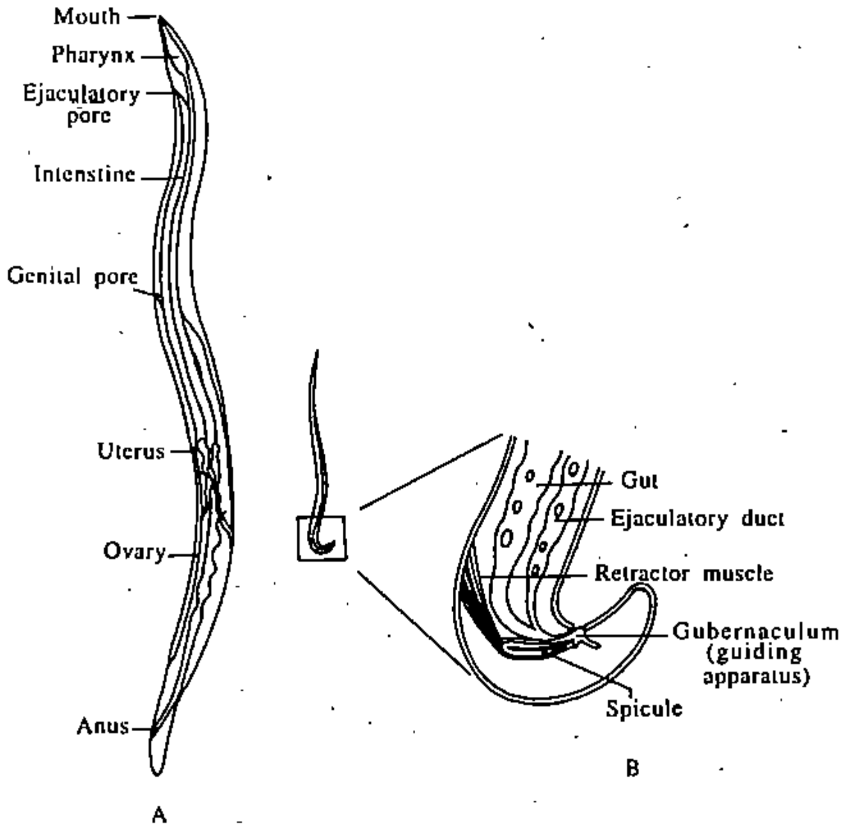



Fig. 4.42 : A - Female Ascaris, B - Male Ascaris (Posterior part)

### 4.7.3 Classification

Classification of Phylum Nematoda into classes is based on characters which are difficult for non-specialists to distinguish. The Phylum is divided into two classes: 1) Class Phasmidia (Secementea), 2) Class Aphasmidia (Adenophorea).

**Examples:**

*Ascaris lumbricoides* is the human intestinal round worm. *Ascaris megalocephala* is found in the intestine of horses. An *Ascaris* female may lay about 2,00,000 eggs per day, which pass out along the stools of the host. The eggs remain alive for years, in the soil. They gain entry into the host alimentary canal through contaminated food and there the tiny juveniles come out of the eggs. Then they burrow through the intestinal wall and enter the veins and lymph vessels, from where they are carried to the heart and from there to the lungs. There they penetrate the alveoli and enter the trachea. If infestation is severe they may cause pneumonia at this stage. When they reach pharynx they may be swallowed, passing through the stomach and maturing in about two months after ingestion of eggs. In the intestine they feed on intestinal contents and cause various symptoms, including intestinal blockade, if present in large numbers.

The hook worm *Ancylostoma duodenale* (Fig. 4.43) is a parasite of man. The anterior end curves dorsally in the form of a hook. By means of large plates in their mouth, they lacerate the intestinal mucosa of the human host and pump blood into intestine, as a result of which the host becomes anaemic. Eggs pass out through faeces and juveniles hatch out in the soil. They burrow through the human skin to blood, reaching lungs, and ultimately intestine, as in *Ascaris*.

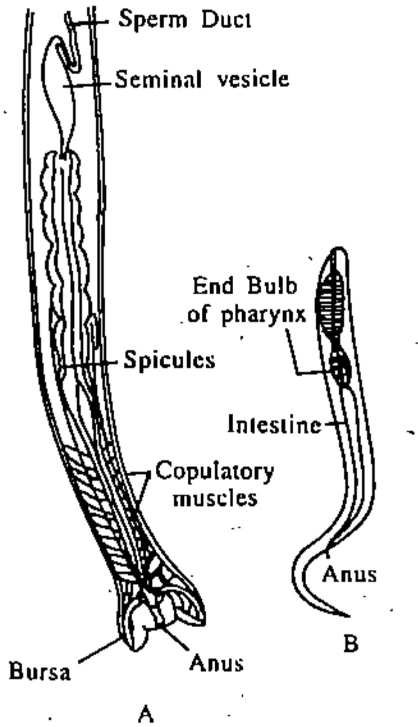



**Fig. 4.43 : A - Posterior end of male Ancylostoma duodenale; B - first stage rhabdiform.**

Other examples include the pinworm (Fig. 4.44) *Enterobius vermicularis*, the trichina worm *Trichinella spiralis* (Fig. 4.45), the Whip worm *Trichuris trichura* (Fig. 4.46) the filarial worms *Wuchereria bancrofti* and *Brugia malai* living in the lymphatic system causing obstruction and inflammation. The females of the filarial worm release small microfilariae into blood and lymphatic system. These enter the mosquito through blood. In the mosquito they undergo development upto infective stage. Then they escape mosquito and enter another human host through mosquito bite.

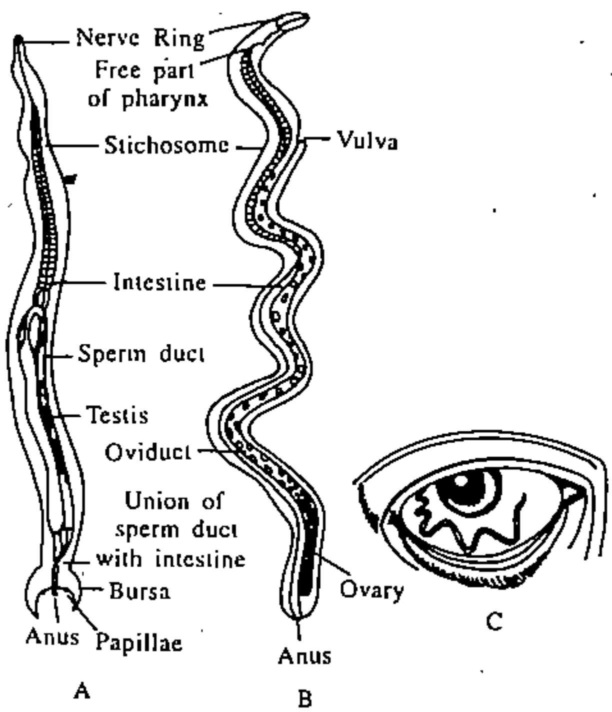



**Fig. 4.45 : A - Trichinella spiralis the trichina worm, male; B -Female; C, Eyeworm in the cornea.**

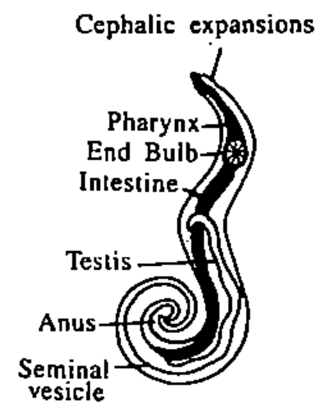



**Fig. 4.44 : Enterobius vermicularis - Male**

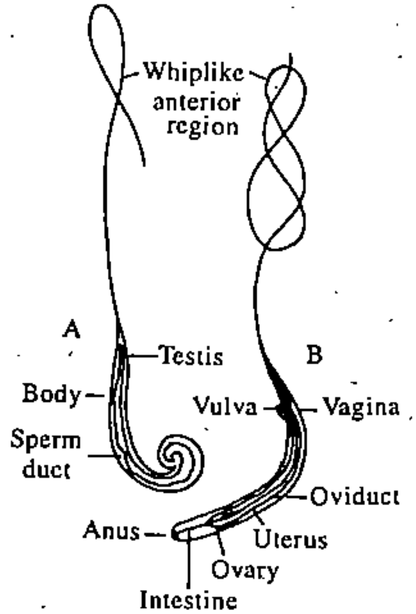



Fig. 4.46 : Trichiurus trichiura, A - male; B - female.

## 4.8 PSEUDOCOELOMATA - PHYLUM ROTIFERA

These are tiny animals bearing ciliated crown. When the cilia beat, the crown has the appearance of rotating wheel. They mostly range from 100-500 μm, and are cosmopolitan in distribution, though only about 1800 species are known. Most of them are fresh water forms. Some are marine, a few are terrestrial, epizoic living on the body of other animals, or even parasitic.

### 4.8.1 Characteristic Features

1. Body minute, bilaterally symmetrical, more than two cell layers thick, with tissues and organs. They are non-segmented.
2. A preoral and a post oral band of cilia in the form of a crown at the anterior part of the body. The crown gives the appearance of rotating wheel when the cilia beat, from which the animal derives its name (Fig. 4.47).

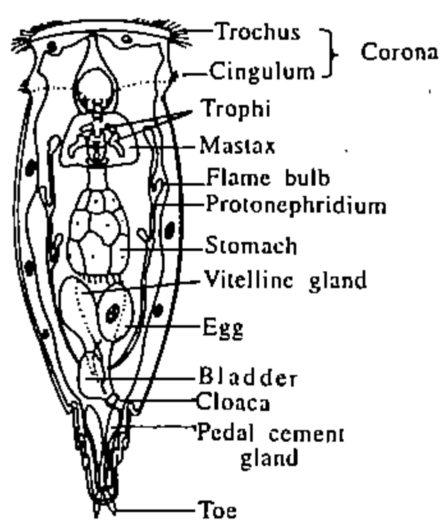



Fig. 4.47 : General features of rotiferan anatomy : ventral view.

3. Alimentary canal with a mouth, jaw apparatus, muscular pharynx. The posterior anus, opens into a Cloaca.

4. Epidermis has an intracellular cuticle. This is often thickened to form a lorica.
5. Protonephridia present.
6. Body cavity pseudocoel.
7. No circulatory or respiratory system.
8. Sexes separate. However, often no males : or when present, males are rare and dwarf.
9. Development direct, with modified spiral cleavage.
10. Most structures are syncitial, with constant number of nuclei in each species (eutely).

The body is usually enclosed in a sculptured cuplike-cuticle called lorica. The open end of lorica carries the corona and the mouth. The corona can be retracted into the cup. The lorica narrows posteriorly to form a foot which is ringed. This gives a segmented appearance to the lorica. The pseudosegments slide into one another telescopically and then the foot can be retracted. At the tip of the foot are a pair of toes which anchor the animal to the substratum.

The animals have a rather simple internal organisation. The mouth parts are, however, complicated (Fig. 4.48). The feeding apparatus (mastax) consists of certain hard parts known as trophi. One of them, the median fulcrum, supports the two rami (singular-ramus). The unci (singular-uncus) and the manubria (Sing-manubrium) hinge on the rami. There are salivary glands and gastric glands associated with the gut.

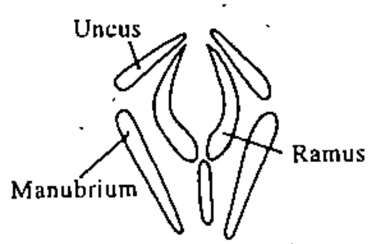



**Fig. 4.48 : The mouth parts of Rotifera.**

Tract of the protonephridial tubules has several flame cells. The system is osmoregulatory. The tubules empty into a bladder which pulsates and empties in turn into a cloaca. Into the cloaca also empty the intestine and oviducts. Sexes are separate. Males may be smaller or even unknown. Parthenogenesis is common among the group.

**Fig. 4.49 : Seison**

### 4.8.2 Classification

Phylum Rotifera is divided into three classes.

1. **Class Seisonida. Marine, elongated, with vestigial corona. Sexes identical in size and form. Female with a pair of ovaries and no vitellaria. Examples :** ***Seison*** **(Fig. 4.49) epizoic on the gills of the crustacean** ***Nebalia.***
2. **Class Bdelloidea. Swimming or creeping. Retractile anterior end. Corona with two trochal discs. Males unknown. Parthenogenetic. Two ovaries and vitellaria. Example :** ***Philodina*** **(Fig. 4.50).**
3. **Class Monogonata. Swimming or sessile. Single ovary and vitellarium. Males smaller, Eggs three types : diploid, haploid and dormant. Example :** ***Asplanchna*** **(Fig. 4.51).**

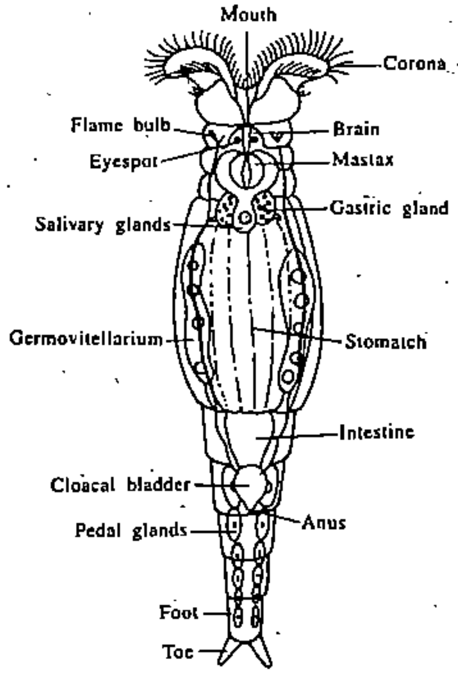



Fig. 4.50 : Structure of Philodina rotifer.

Fig. 4.51 : Asplanchna.

## SAQ 4

Match the animals given in column A with their characteristic features given in column B.

| A | | B |
|---|---|---|
| a) Nematoda | (i) | A crown of preoral and postoral band of cilia at the anterior end, giving the appearance of a rotating wheel, which the cilia beat. |
| b) Rotifera | (ii) | Complex, non-living many layered cuticle with spiral fibres of one layer crossing those of the other. |

## 4.9 SUMMARY

In this unit, you have studied the characteristic of the following phyla: Porifera, Cnidaria, Ctenophora, Platyhelminthes, Nematoda and Rotifera. You now know how to distinguish animals belonging to anyone of these phyla from those belonging to another. You have studied how to classify each of these phyla upto classes, and the distinguishing features of these classes with some examples. You have also studied the basic organisation or body plan of various animals belonging to some of these classes. You will study the organisation of various systems of animals belonging to these phyla and their functional significance in greater detail, in later units.

## 4.10 TERMINAL QUESTIONS

1. What are the salient features of Porifera? How are they classified?

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2. What are coral reefs? How are they formed?

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3. Point out the major differences between cnidaria and platyhelminthes.

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## 4.11 ANSWERS

### SAQs

1. i) multicelluar, movement, plant, attached.
   ii) pinacocytes
   iii) Calcarea
   iv) Sixrayed
   v) Choanocytes.

2. i) a) Diploblastic; presence of nematocysts.
      b) Diploblastic; presence of combplates
      c) epitheliomuscular cells, interstitial cells; cnidocytes, mucus gland cells, sensory-nerve cells.
      d) Hydrozoa, Scyphozoa, Cubozoa and Anthozoa.
      e) Tentaculata, Nuda
   ii) a) glacial melting, subsidence
      b) biradial.

3. i) osmoregulatory

   ii) a) Bilateral symmetry accompanied by cephalisation;
   b) tripoblastic nature with cellular parenchyma;
   c) Presence of many organ systems.

   iii) a - (iv); b - (iii); c - (ii); d - (i).

4. a) (ii) b) (i)

**Terminal Question**

1. Porifera are lowly organized animals. They are not capable of locomotion and bear large number of small pores (ostia) on the surface. Through these pores water current enters the cavity (spongocoel) and leaves through one or more larger pores, oscula. They have an outer layer of pinacocytes. Collar cells (choanocytes) line the spongocoel. These cellular layers are not, however, homologous to germ layers. In these animals, tissues are absent or poorly defined; naturally there are also no organs or organ systems.

   Porifera are classified into four classes based mainly on the nature of their skeleton: 1) Calcarea; 2) Hexactinellida; 3) Demospongiae; and 4) Sclerospongiae.

2. The coral reefs are built mainly of stony corals but many other organisms play considerable role in their formation. Coral reefs are mainly fringing reefs, barrier reefs or atolls. Most reefs are formed gradually either because of rise of sea level due to glacial activity or by subsidence of the substratum or by both.

3.

| | Cnidaria | Platyhelminthers |
|---|---|---|
| Germlayers: | Diploblastic, with non-cellular mesoglea | Triploblastic, with cellular parenchyma derived from mesenchyme. |
| Symmetry: | Radial, no anteroposterior axis or Cephalisation | Bilateral, with anteroposterior axis and cephalisation. |
| Organs: | Nil, or poorly developed. | Well developed, with organ systems. |
| Cnidocytes | Present | absent |
| Nervous system | diffuse nerve net | Concentrated in the form of brain in the head and cords extending into the body. |
| Protonephridia or flame cells | absent | present |

# UNIT 5 CLASSIFICATION OF MULTICELLULAR ANIMALS-II

## Structure



## 5.1 INTRODUCTION

In this unit we continue our study of metazoans. In this, as well as in the next unit you will learn about coelomate phyla. Coelom could be defined as a cavity lined by an epithelium of cells derived from the embryonic mesoderm. Phylum Annelida which includes segmented worms will be the first coelomate phylum that you will be studying in this unit. This will be followed by the study of phylum Arthropoda — a successful group of invertebrates with jointed legs. As was done in the previous unit, in this unit also we shall describe the characters of each phylum, classify the phylum upto classes giving examples and briefly describe the class characters.

### Objectives

After studying this unit you should be able to:

- enumerate the characters of phyla Annelida and Arthropoda, name the classes under the phylum and relate their salient characters.
- discuss the reasons for the success of arthropods.
- with the help of diagrams describe how the insectan mouth parts are adapted for their various feeding habits.
- briefly describe the characters of phylum Onychophora and point out the affinities of the phylum.

## 5.2 COELOMATA - EUCOELOMATA - PHYLUM ANNELIDA

The animals belonging to phylum Annelida are true coelomates and they are also called eucoelomotes. In general, annelids have elongated body divided externally into a number of rings which represent a division of the internal parts into a series of segments or metameres. You will study in little detail about different features of Coelomates in the following subsections.

## 5.2.1 The Coelom

You have already seen above that the pseudocoel gave animals certain selective advantages. Among other things, this fluid-filled space served as a hydrostatic skeleton increasing the efficiency of burrowing. However, in pseudocoelomates, organs lay loose in the body cavity (Fig. 5.1). To circumvent this disadvantage, coelom evolved within mesoderm. The result was that the new body cavity, namely the coelom, came to be lined by mesodermal layer (peritoneal layer). The various organs also came to be suspended in the coelom by the mesodermal layer called mesenteries. This enabled the body wall to become more muscular, with better developed longitudinal and circular muscles. The body cavity thus became a more efficient hydrostatic skeleton now. The alimentary canal also became more musculuar and more specialised. Various organs became better arranged in a more stable manner, without interfering with one another. The mesenteries also served as a better medium for positioning blood vessels to the respective organs. Thus, development of coelom has been a major step in the evolution of more complex and larger animals. You must keep in mind that all the phyla to be treated below in detail are coelomates.

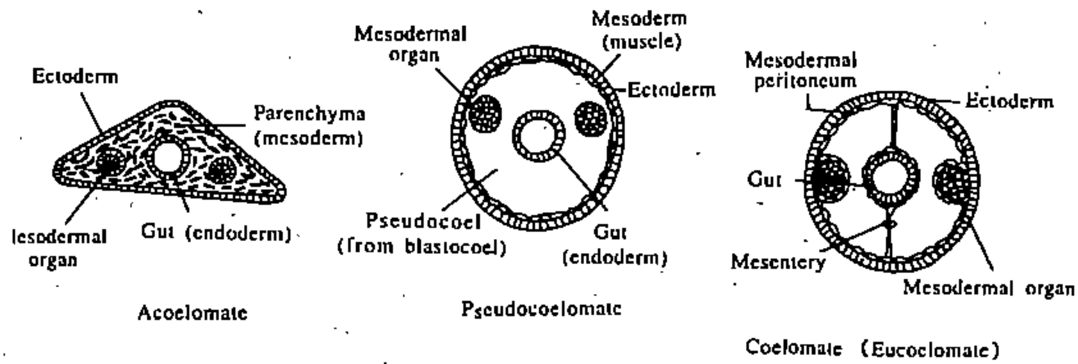



Fig. 5.1 : Acoelomate, pseudocoelomate, and eucoelomate body plans.

## 5.2.2 Metamerism (Segmentation)

In the early coelomates the coelom was not divided into segments, the entire body cavity was a single space. Hence body movements were not precise. However, with evolution, coelom became divided into a number of chambers by partitions or septa made up of the mesodermal lining, the peritoneum. This increased the efficiency and precision of body movements, as individual segments could be moved more precisely now, with the same mechanism viz., hydrostatic or hydraulic pressure. Also, each segment came to have a repetition of many other organ systems like circulatory, excretory, reproductive and nervous systems. Each body segment is thus more or less a repetition of the other and hence redundant; the animal can survive and function normally even if a few segments were lost. This phenomenon of divisions of body into a series of more or less identical segments each containing a section of almost all systems, is known as segmentation or metamerism. Each section of the body is known as a segment or metamere. Metamerism has evolved independently at least twice in the animal kingdom in protostomes (Annelida - Arthropoda) and in deuterostomes (vertebrates).

Phylum Annelida consists of segmented worms. There are about 15,000 species coming under this phylum. They include the earth worms, leeches and polychaetes.

## 5.2.3 Characterstic Features

1. Body vermiform, bilaterally symmetrical, with metamerism.
2. Triploblastic, with tissues, organs and organ systems; body wall with outer circular and inner longitudinal layers; epithelium secretes an outer transparent, moist cuticle.
3. Chitinous setae present (except in leeches).

4. Schizocoelic coelom — coelom appearing as a split or cavity within mesoderm.
5. Blood vascular system closed, often with retory pigments; plasma contains amoebocytes.
6. Gut muscular, with mouth and anus.
7. A presegmental prostomium and a post segmental pygidium.
8. Nervous system consists of a supraoesophageal ganglion (cerebral ganglion), circumoesophageal ring and ventral nerve cord with segmental ganglia.
9. Different degrees of cephalization is shown.
10. Sensory system consisting of eyes, photoreceptor cells, statocysts, taste buds and tactile organs.
11. Excretory system typically consisting of a pair of nephridia in each segment.
12. Respiration through skin, gills or parapodia.
13. Sexes may be separate, or animals may be hermaphrodites. Cleavage spiral, with mosaic development. When present, larva is a trochophore. Some animals show asexual reproduction by budding.

Let us now examine the annelid body pattern (Fig. 5.2). You will see that the annelid body pattern is basically made up of a prostomium and a segmented body followed by a pygidium respectively from infont backwards. Prostomium and pygidium are not considered segments. Mouth opens on the first segments, and anus opens on the pygidium. Anterior few segments fuse with the prostomium to form head. New segments are added on infront of the pygidium. So the youngest segments are situated posteriorly, first infront of the pygidium, and the oldest segments are situated anteriorly.

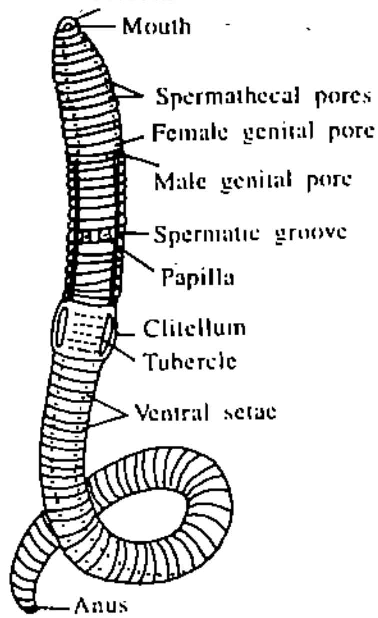



Fig. 5.2 : **Lumbricus.**

The body wall has well developed and strong longitudinal muscles and circular muscles: covering the muscular layer is the epidermal epithdium which secretes a nonchitinous cuticle. Varying number of chitinous setae are present in the body wall, except in leeches.

The coelom originates from the embryonic mesodermal cell mass, as a split or cavity on either side, and is hence schizocoelic. Ultimately the coelom becomes lined by a mesodermal layer, the peritoneum. The peritoneal layers on either side meet along the median-line forming the mesenteries, which suspend the alimentary canal as well as the longitudinal blood vessels. Other organs are also suspended by the peritoneal lining. Where the peritoneal linings of the adjacent segments meet, they form the transverse septa which form partitions between the two segments. The septa are penetrated by alimentary canal and longitudinal blood vessels. In addition, the excretory organs, the nephridia are typically positioned intersegmentally, one on either side of the median line, on the septa. Their internal openings into the coelom, the nephrostomes are positioned infront of the septum; the body of the nephridium is positioned in the segment behind. Typically, each segment has thus got a coelomic chamber; because of the hydrostatic pressure, contraction of the longitudinal muscles results in broadening of the segment; contraction of the circular muscles results in elongation of the segment. Thus the effects of contraction and relaxation of the muscles of a segment can be limited to that segment. In other words, it is localised. A sequential contraction and relaxation cycle results in peristaltic wave. This is effectively used by annelids for burrowing, swimming or crawling.

### 5.2.4 Classification

This phylum is generally divided into three classes, namely Polychaeta, Oligochaeta and Hirudinea.

1. **Class Polychaeta. There are mostly marine forms with distinct head, having eyes and tentacles, segments have lateral projections of the body wall known as parapodia which carry bundles of setae. These animals do not have clitellum. Sexes are separate (dioecious). They have no distinct or permanent sex organs, but their gonads consist of masses of developing gametes arising as swellings of Peritoneum. Eggs usually develop into trochophore larva. Many forms reproduce asexually by budding.**

Most of the polychaetes are 5-10 cm long. They live beneath rocks and in crevices, or burrow in mud. Some build tubes. Other are pelagic. These animals are broadly divided into (1) errant forms on the one hand, which are freely moving, pelagic, active burrowers, crawlers and the tube worms which leave their tubes for various purposes. On the other hand (2) the sedentary forms do not leave their tubes or burrows but may usually expose only their heads outside. Errant polychaete structure may be considered typical of a generalised polychaete. The prostomium is well developed, with various sense organs like eyes, antennae, palps and the nuchal organs. While prostomium is dorsal and preoral projecting over the mouth. The peristomium which is the first segment, carries the mouth. The predatory forms have jaws in the mouth. The peristomium is often fused with one or more subsequent segments forming the head (Fig. 5.3). These segments also usually carry sensory structures, but their parapodium also bears bundles of chitinous setae in the setal sacs. *Nereis* (Fig. 5.3) is a typical example. A cross section of its body through one of its middle segments (Fig. 5.4) shows well its internal organisation.

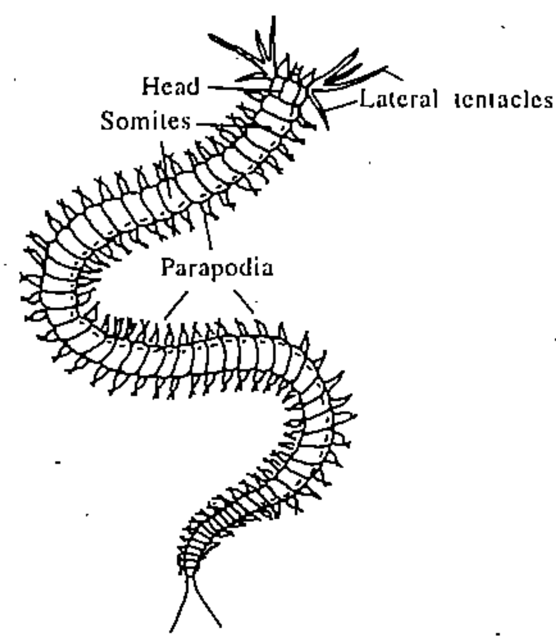



Fig. 5.3 : Nereis.

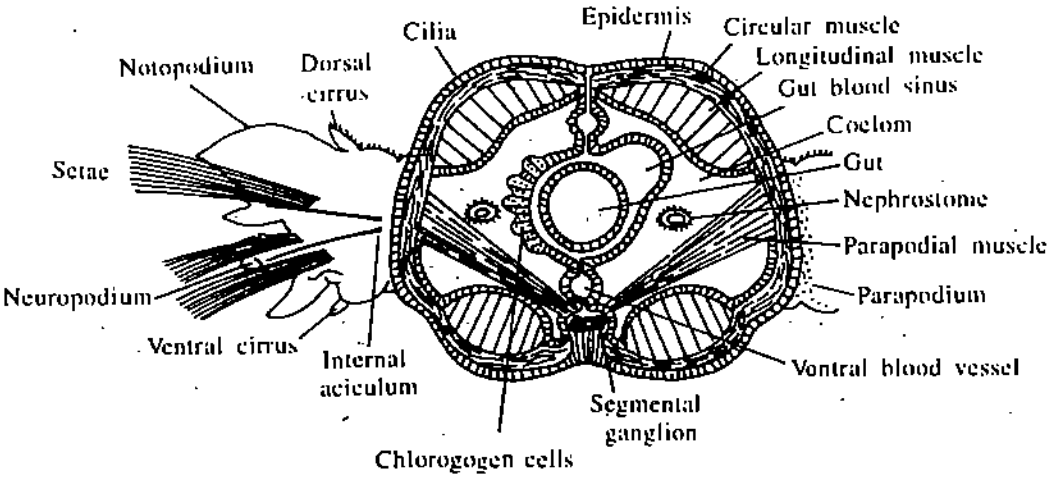



**Fig. 5.4 : Polychaete organiszation shown by cross section of trunk (Based primarily on Nereis).**

*Amphitrite* is an example of a sedentary Polychaete found in tubes built in mud or sand (Fig. 5.5). It feeds on tiny particles of food using long extensible tentacles arising from its head projecting out of its burrow. It has also three pairs of branched gills. *Sabella* (Fig. 5.6) is another sedentary polychaete. It extends its crown of tentacles (radioles) from the leathery tube which it secretes, reinforced with sand. The radioles serve to catch food. *Chaetopterus* (Fig. 5.7) is also a sedentary polychaete living in a 'U' shaped parchment like tube. It pumps in water through the tube by means of three forms. The food particles in the stream are entangled by mucus secreted by wing like notopodia of the 12th segment. *Arenicola*, the *lug* worm (Fig. 5.8A) lives in a burrow which is 'L' shaped (Fig. 5.8B) It causes water to flow into the burrow by peristaltic movements. It ingests the sand in front of it, laden with filtered and accumulated food particles. It has also gills on certain middle segments.

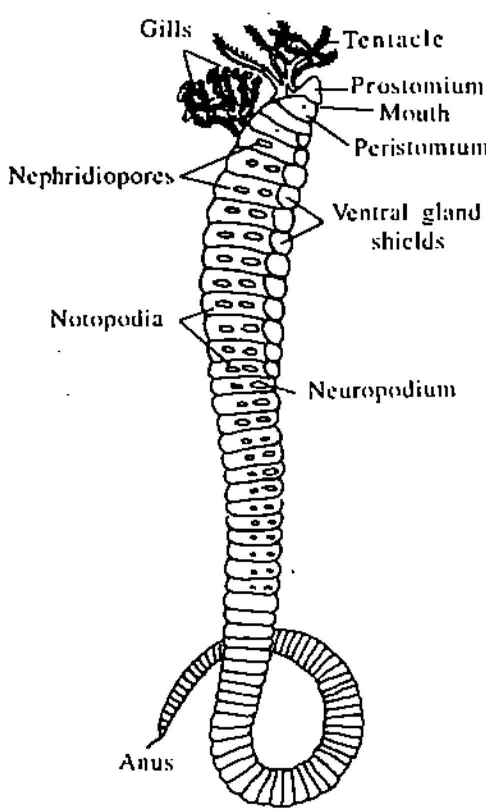



**Fig. 5.5 : Amphitrite.**

Fig. 5.6 : Sabella.

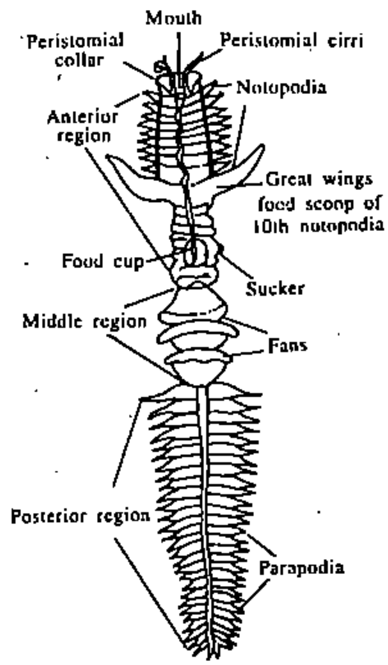



Fig. 5.7 : Chaetopterus.

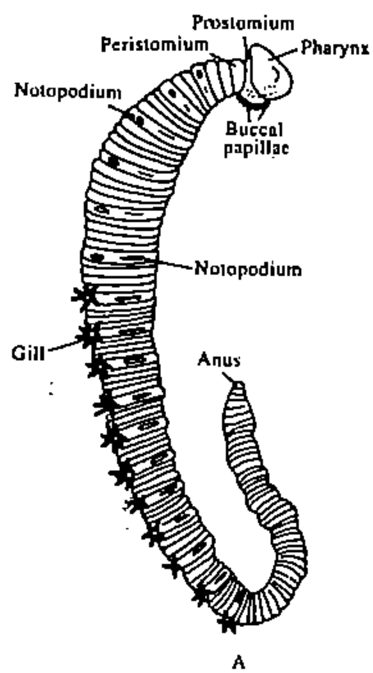



Fig. 5.8A : Arenicola.

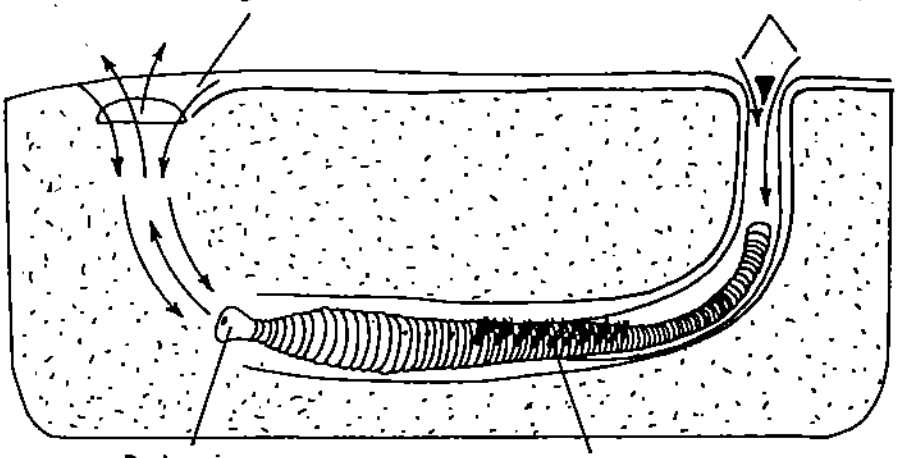



**Fig. 5.8B : Arenicola, the lugworm, lives in an L-shaped burrow in intertidal mud flats. It burrows by successive eversions and retractions of its proboscis. By peristaltic movements it keeps water filtering through the sand. The worm then ingests the food-laden sand.**

*Eunice viridis* (Fig. 5.9) the palolo worm, is an example of epitoky. It lives in its burrow most of the time in sexually immature (atokous) state. During breeding season certain segments mature sexually and become swollen with gametes. This portion (epitoke) is broken off during the swarming period and swim to the surface, bursting and thereby liberating sperms and eggs into the sea facilitating fertilization. This happens just before sunrise when the sea is crowded with large number of these epitokes. The anterior portion of the worm (atoke) can regenerate the posterior portion.

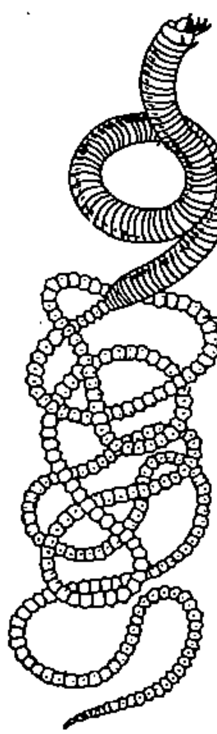



**Fig. 5.9 : *Eunice viridis*, The Samoan palolo worm. The posterior segments make up the epitokal region, consisting of segments packed with gametes. Each segment has an eyespot on the ventral side. Once a year the worms swarm, and the epitokes detach, rise to the surface, and discharge their ripe gametes, leaving the water milky. By the breeding season, the epitokes are regenerated.**

2. **Class Oligochaeta. Mostly living in soil, or in fresh water; conspicuous body segmentation but no distinct head; body has variable number of segments. Number of setae in each metamere fewer. Parapodia absent. Coelom spacious and divided by intersegmental septa; hermaphrodites (monoecious). Reproductive system more complicated, compact ovaries and testes but fewer in number. Clitellum present. No larva, development direct.**

The earthworms are the most familiar animals in this group, burrowing in soil, enriching it and producing the worm casts. These are fairly larger, usually 12-30 cm long and have 150-250 segments or more. They come out of the burrows at night. The other group of oligochaetes is aquatic, mainly fresh water, being very small.

Locomotion in earthworms is by peristaltic movement, the setae being used for anchoring the body. The body plan of the earthworms is remarkably constant. A cross section of the body (Fig. 5.63) shows a thin but water-proof cuticle over the epidermal layer. Beneath the epidermis there is a circular layer of muscle fibres, followed by large bundles of longitudinal muscles. Bristle-like setae are inserted in sacs within the body wall. They partly project out of the body wall. Setae can be moved by their own muscles. The coelom surrounding the alimentary canal is lined by outer and inner peritoneal linings. Adjacent segments are partitioned by septa. The endodermal lining of the gut is surrounded by muscle layers of the gut wall.

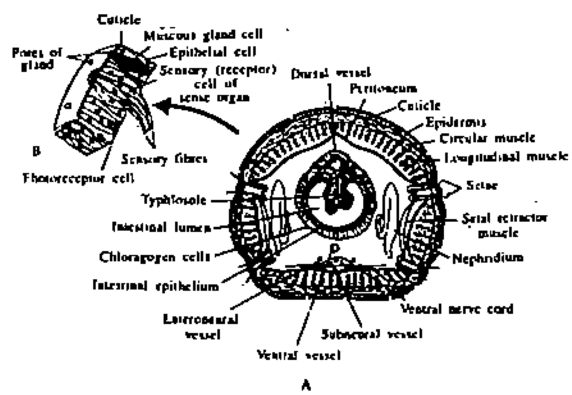



**Fig. 5.10 : Earthworm anatomy : A - Generalized transverse section through region posterior to clitellum. B - Portion of epidermis showing sensory, glandular, and epithelial cells.**

They feed on decayed organic matter. The muscular pharynx sucks in moistened food. The calciferous glands along the oesophagus regulate calcium ions of the blood by secreting excess calcium into gut. The glands are ionoregulatory and control the pH of the body fluids. The oesophagus is followed by a thin walled crop and then a gizzard. The latter grinds the food. The food is digested and absorbed in the intestine. In the intestine an infolding of its wall, the typholosole increases the surfaces area of digestion and absorption. Surrounding the dorsal blood vessel is the chlorogogen tissue. This is derived from the peritoneum and is the site of synthesis of glycogen and fat. It is also excretory in function.

Coelomic fluid as well as blood serve to transport food, waste and respiratory gases. The blood vascular system is closed, with five main longitudinal blood vessels and a capillary system. The blood has colourless amoeboid corpuscles and haemoglobin dissolved in the plasma. Excretory organs are nephridia. Each typical nephridium has a ciliated funnel or nephrostome in the segment in front of the intersegmental septum, and the main part of the nephridium (the body) lies in the segment behind. A tube leads from the nephrostome piercing the septum into the body of the nephridium where it is thrown into a number of loops, ultimately opening out through a nephridiopore. The nervous system consits of the brain situated above the pharynx and made up of a pair of cerebral ganglia. A pair of cirum-pharyngeal connectives connect the brain with the 1st ganglion of the double ventral nerve cord (subpharyngeal ganglion). The cord runs throughout the length of the animal, with a ganglion in each segment.

Earthworms are hermaphrodites. However, copulation between two worms take place (Fig. 5.11B) resulting in exchange of sperms between the two. After copulation a cocoon is secreted around the clitellum. The clitellum is a conspicuous girdle around certain adjacent segments, made up of swollen glands secreting mucus and cocoon material. Hence this region is thickened. Usually the clitellum is situated in the anterior half of the body. As the cocoon passes forward, eggs from the oviduct are deposited into the cocoon in which fertilization takes places. The cocoon ultimately leaves the worm and its ends close. Young earthoworms hatch out from the eggs. *Lumbricus* (Fig. 5.2), *Pheretima* (Fig. 5.11A) and *Megascolex* are typical examples of earthworms.

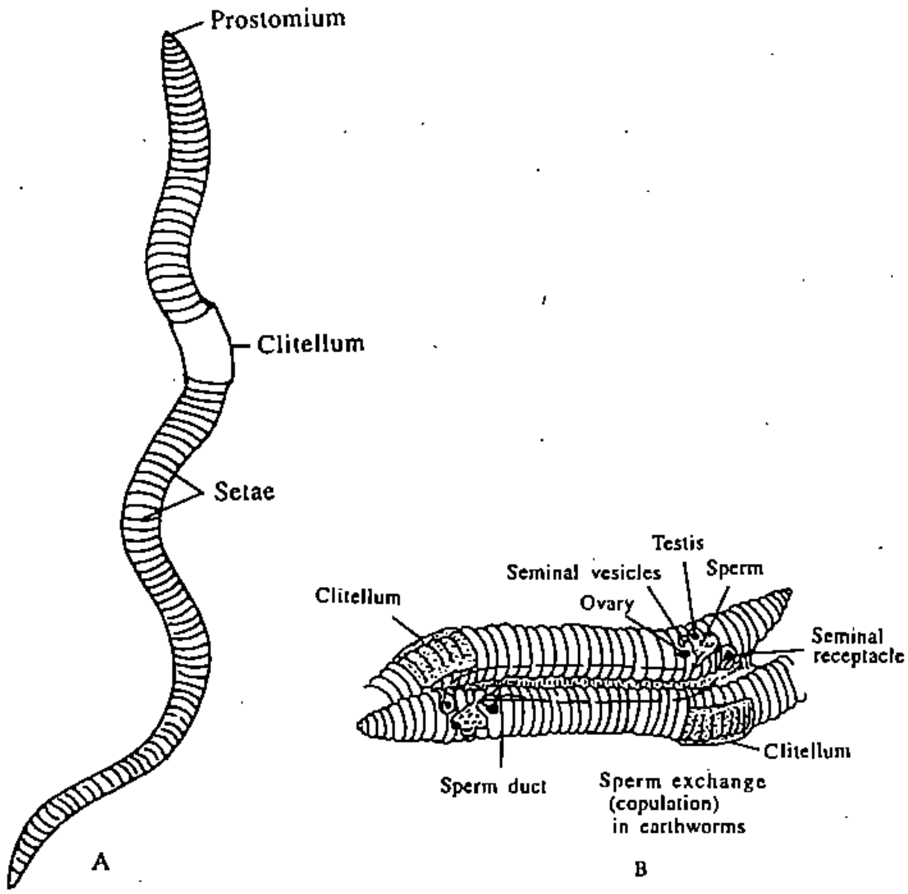



Fig. 5.11: A, Pheretima; B, Mating and reproduction in earthworms.

*Aelosoma* (Fig. 5.12) is an example of fresh water oligochaete. It is about 1 mm long. *Stylaria* (Fig. 5.13) has a prostomium extended into a long process. *Dero* (Fig. 5.14) lives in tubes and has 3-4 pairs of gills. *Tubifex* (Fig. 5.15) usually has its head burried in mud in ponds and body showing a waving movement. It is reddish in colour. All these are aquatic oligochaetes.

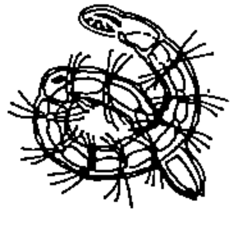


Fig. 5.12 : Aeolosoma.

Fig. 5.13 : Stylaria.

Fig. 5.14 : Dero.

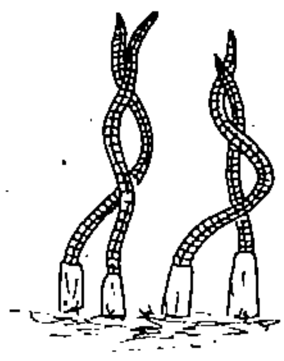


Fig. 5.15 : Tubifex.

3. **Class Hirudinea. These are leeches. Number of body segments of these animals is fixed; usually there are 34 segments; in some groups there may be only 31 or even 17. Segments have many annuli. Anterior and posterior sucker present, as also clitellum. No parapodia or setae. Coelom filled with connective tissue and muscles. Hermaphrodites; direct development, may be terrestrial, fresh water or even marine.**

The leeches vary in size from 2-6 cm in length (Fig. 5.16), and are flattened dorsoventrally. The clitellum, though present, appears only during breeding season. Their gut is highly specialized for storage of blood. Though they have only 34 segments, because the segments are marked by transverse grooves they appear to have more rings (annuli). With regard to coelom, the septa have disappeared, and the coelom is filled with a connective tissue (botryoidal tissue). The remaining spaces called lacunae are filled with coelomic fluid (Fig. 15.17).

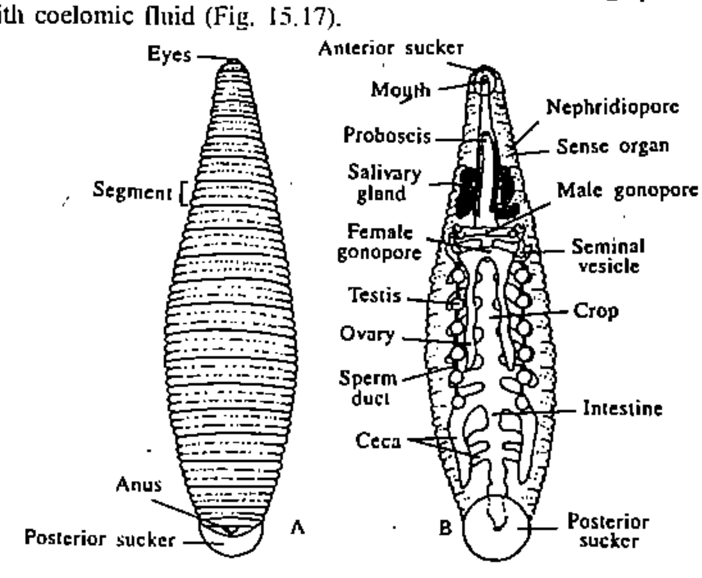



Fig. 5.16 : **Structure of a leech, Placobdella, A, External appearance, dorsal view. B, Internal structure, ventral view.**

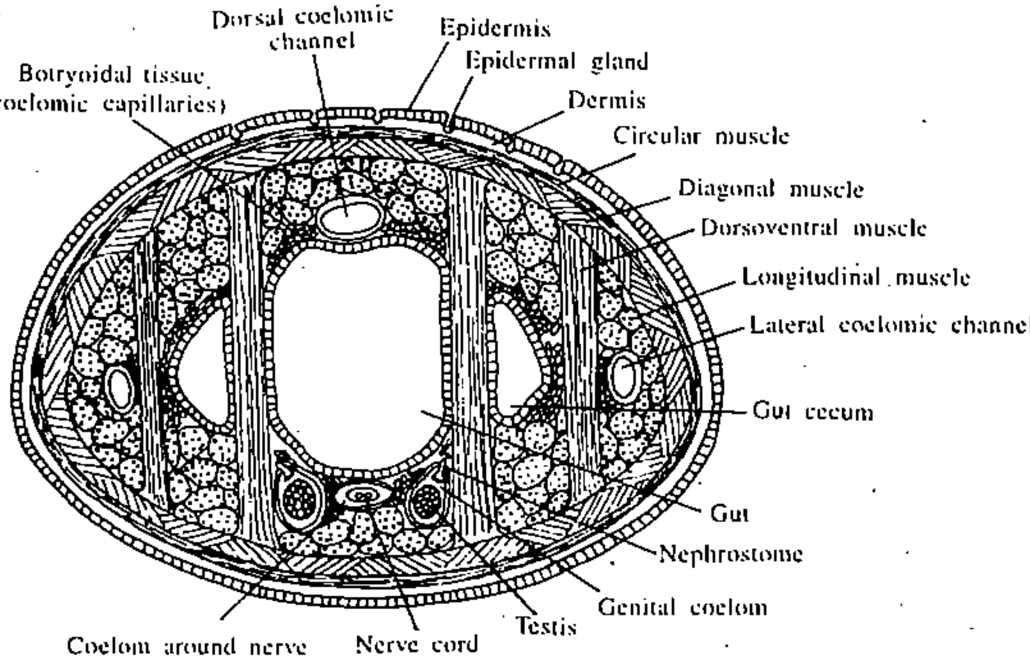



**Fig. 5.17 : Transverse section through the arhynchobdellid leech, Hirudo. In archynchobdellid leeches, the blood-vascular system has been completely replaced by the modified coelomic circulatory system.**

Locomotion is by looping movement by means of the two suckers, or by undulating movements in water. Most of them feed on blood and are bloodsuckers of either warm-blooded or cold blooded vertebrates, and have jaws for cutting tissues. Main excretory organs are nephridia. The brain consists of a ring of ganglia around the pharynx and a double ventral nerve and with a number of ganglia. They are hermaphrodites, but carry out cross fertilization. The cocoon secreted by the clitellum receives the eggs and sperms. It is deposited in the mud.

Examples : *Hirudo medicinalis* (Fig. 5.18), the medicinal leech; *Glossiphonia* (Fig. 5.19), *Haemadipsa* (Fig. 5.20), a blood sucking terrestrial leech; *Piscicola* (Fig. 5.21), a fish parasite.

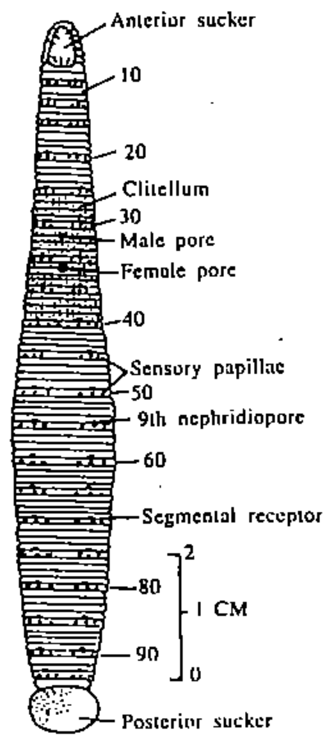



**Fig. 5.18 : External, ventral surface of the medicinal leech, Hirudo medicinalis.**

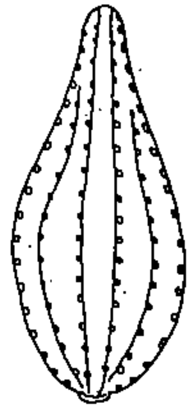


Fig. 5.19 : Glossiphonia.

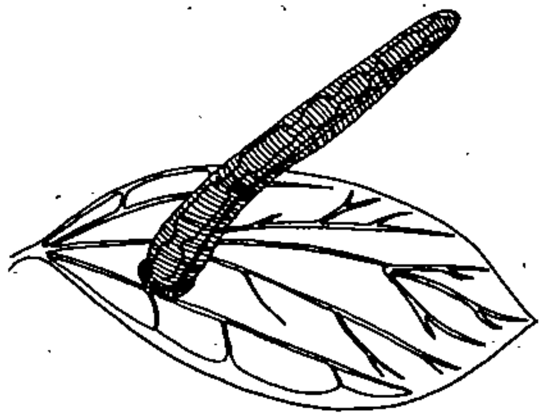


Fig. 5.20 : Haemadipsa.

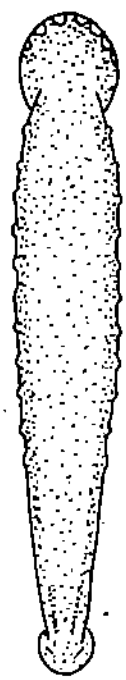


Fig. 5.21 : Piscicola.

## SAQ 1

On the basis of the given characteristics, name the class to which the annelid belongs:

| Annelid | Parapodia | Clitellum | Suckers | Setae | Class |
|---|---|---|---|---|---|
| i) | absent | Present only during breeding season | two suckers present | absent | ? |
| ii) | present | absent | absent | bundles present | |
| iii) | absent | distinct, more conspicuous during breeding season | absent | a few setae per segment present | ? |

## 5.3 PHYLUM ARTHROPODA

In the previous section you have already studied how the coelom evolved and the body of the coelomates got segmented leading to evolution of segmentation or metamerism. The advantage of serial metamerism to animals was also made clear to you. You have also seen how this feature was made use of by annelids to their maximum advantage, enabling them to occupy various niches, primarily aquatic, successfully.

We now begin the study of the largest phylum in the animal kingdom, phylum Arthropoda. This phylum includes more than 1,000,000 species of animals that have been so far described. This number constitutes more than three times the number of all the other species of animals that are known to exist in the biosphere. Arthropods having inhabited all types of aquatic habitats, are the first major group of animals to have invaded successfully the terrestrial environment occupying every possible niche there. Like annelids, arthropods are coelomates and segmented, and probably both the phyla arose from a common ancestor.

### Characteristic Features

1) Body bilaterally symmetrical and metamerically segmented; segments show a tendency to combine or fuse together to form functional units called **tagmata**, like cephalothorax and abdomen; head and trunk, or head, thorax and abdomen.

2) Segments carry jointed appendages.

3) Exoskeleton consists of a tough cuticle made up of chitin, protein and lipid, sometimes strengthened with calcium carbonate. The cuticle, secreted by the underlying epidermis, is shed periodically to permit growth of body.

4) Absence of cilia.

5) Coelom present but highly reduced and obliterated in the adult. The main body cavity is haemocoel, a characteristic space between organs and tissues, filled with blood.

6) Circulatory system, open type.

7) Well-developed muscular system with striated muscles attached to the exoskeleton, and visceral organs having smooth muscles.

8) Mouth parts modified from appendages; well developed alimentary canal.

9) Respiratory organs are usually tracheae, booklungs or gills.

10) Excretory organs either Malpighian tubules, coxal glands, antennal glands or maxillary glands.

11) Nervous system is of the annelidan plan.

12) Sexes are separate: fertilization internal: development often involves metamorphosis.

Fig 5.22 : Articular membrane between two segments.

One of the distinguishing features of arthropods is the presence of a tough, chitinous exoskeleton called cuticle which covers the entire body surface. It is a product of secretion of the underlying epidermis. The cuticle is generally thick and rigid. But to give flexibility, the cuticle between two segments and at joints remains extremely thin and flexible and is called articular membrane (Fig. 5.22). The cuticle in each segment form a dorsal plate the **tergum,** a ventral plate **sternum** and the lateral structures the **pleura** (sl. pleuron) (Fig. 5.23). In all other parts there is some degree of fusion of segments to form functional groups called tagmata (sl. tagma). Such a fusion of segments has resulted in body parts like: the head and trunk; or head, thorax and abdomen; or cephalothorax and abdomen. The infolding of the cuticle has resulted in endoskeletal structure called apodemes (Fig. 5.24). Muscles are attached to these apodmenes.

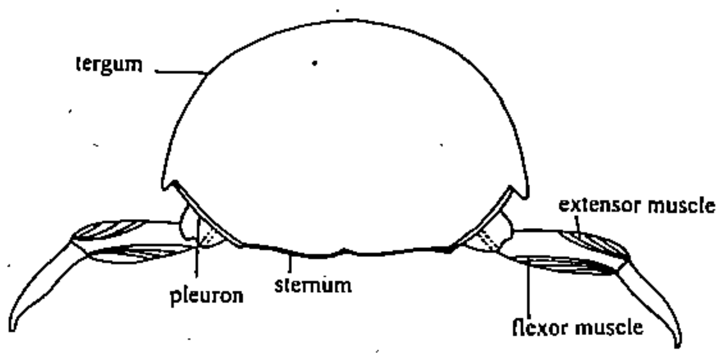



Fig 5.23 : Structure of a generalised segment.

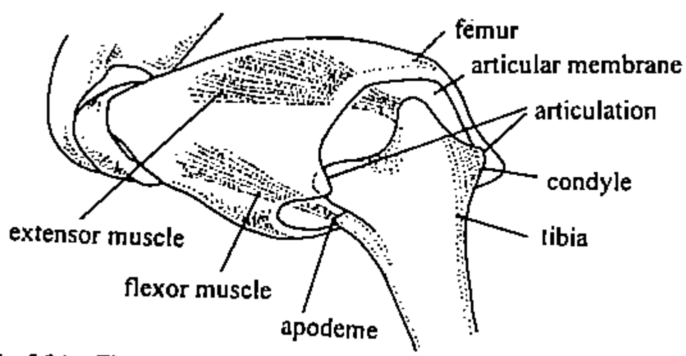



Fig 5.24 : Figure showing apodeme, the site of muscle attachment.

The integument in arthropods has an epidermal layer that rests on a basement membrane. The epidermis secretes the cuticle as we stated above. The cuticle is essentially a chitin-protein complex. The colour of arthropods in general is due to the deposition of brown, yellow, orange and red melanin pigments within the cuticle. Physical colours are produced by the fine sculpturing of the cuticle that provides elevations and depressions which diffract light and give the appearance of colours. Though when laid down, cuticle is flexible, as a result of a complex chemical process known as tanning or sclerotisation, it soon becomes hard. Once this happens it is not possible for the body to grow any further. So the animal sheds the cuticle periodically, to enable growth of the animal. This shedding of the old cuticle is known as **moulting or ecdysis.** Ecdysis is hormonally controlled. During moulting, part of the old cuticle is resorbed and made use of for building up the new cuticle (Fig. 5.25).

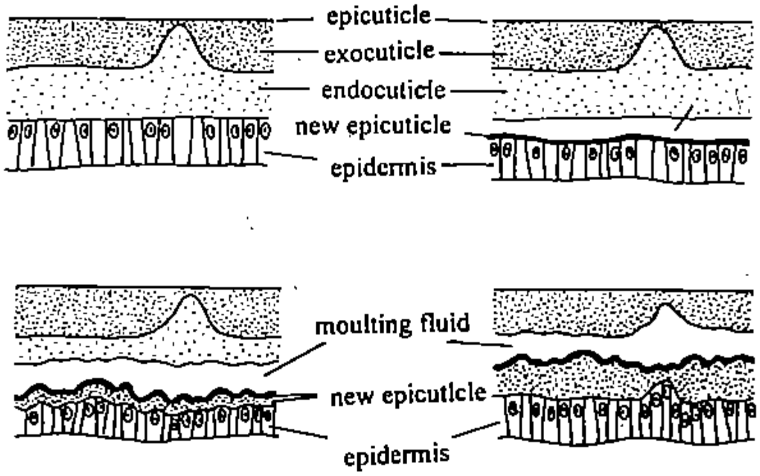



**Fig 5.25 : Moulting in an arthropod.**
**(a) Fully formed cuticle; (b) Separation of epidermis and secretion of moulting fluid and new cuticle; (c) Digestion of old endocuticle and secretion of new procuticle.; (d) Newly formed cuticle and the old cuticle before it is shed.**

Coelom has undergone drastic reduction in arthropods as compared to annelids. The coelom is often represented by a cavity in certain excretory organs or around gonads. The major body space in arthropods is not the coelom but haemocoel. The haemocoel is a blood filled space between various structures, and is characteristic of arthropods. The blood vascular system in arthropods is composed of a tubular heart, a dorsal aorta and the blood-filled cavity. the haemocoel (Fig. 5.26). The tubular heart enclosed in a pericardium is contractile and is the centre of blood propulsion. There are no blood capillaries and the system is open type. The blood plasma contains heamocyanin as the respiratory pigment, and in a few species the pigment is haemoglobin.

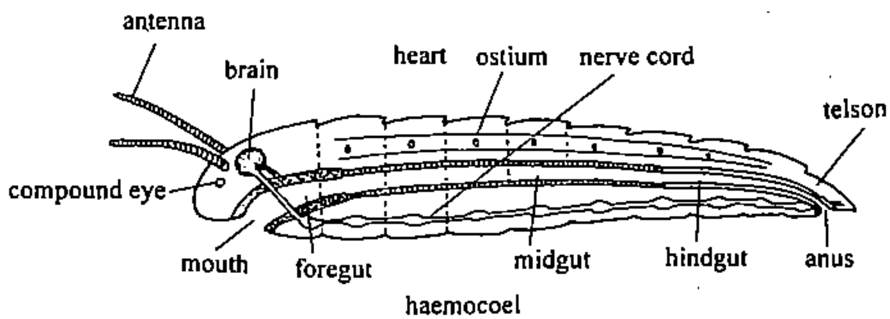



**Fig 5.26 : Structure of a generalised arthropod.**

Excretion is carried out by structures called **Malpighian tubules** generally found in terrestrial arthropods as blind tubular elongations of the gut. and lie freely in the haemocoel. The aquatic forms have generally paired coxal glands, **antennary glands** or **maxillary glands** which are homologous to the metameric nephridia of annelids (Fig. 5.27).

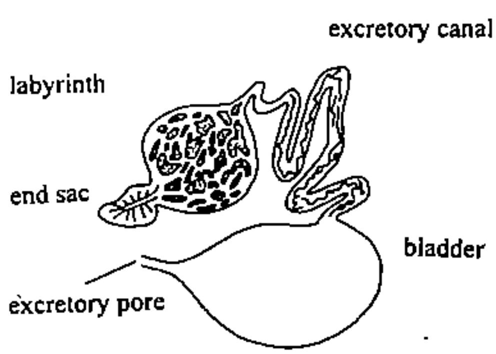



**Fig 5.27 : Excretory organ of aquatic arthropods.**

Arthropod digestive tract is generally divided into three parts the **foregut** or **stomadaeum**, the **midgut** or **mesenteron** and the **hindgut** or **proctodaeum** (Fig. 5.28). The stomadaeum and proctodaeum are ectodermal in origin and are lined with thin chitinous layer. Mesenteron is endodermal in origin. Salivary glands, hepatopancreas and hepatic caecae are different types of digestive glands found in different groups of arthropods.

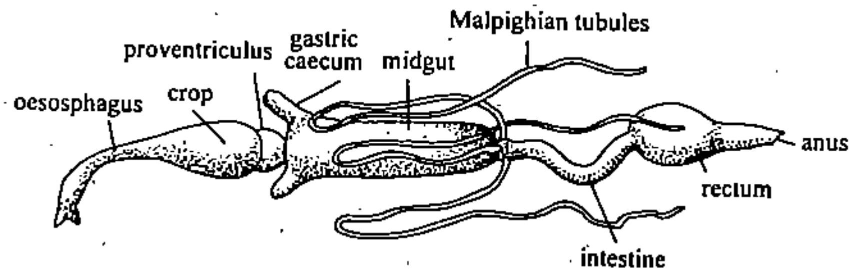



**Fig 5.28 : Generalised digestive tract of an arthropod.**

The nervous system of arthropods is built on the annelidan plan (Fig. 5.29). There is a brain dorsally connected to suboesgohageal ganglion by circumoesophageal connectives. The double ventral nerve cord bears segmental ganglia which may be fused variously in different groups. Arthropods have a variety of sense organs. The sensory receptors of arthropods basically comprise various types of sensilla. The sensilla vary from hairs, bristles, setae etc. (Fig. 5.30) with sensory neurones plus a number of cells that produce the cuticular housing apparatus. Insects and crustaceans have compound eyes formed of a number of many long, cylindrical units called **ommatidia** (sl. ommatidium) possessing all the elements for light refraction and reception (Fig. 5.31).


**Fig. 5.29 : Generalised structure of nervous system of an arthropod.**

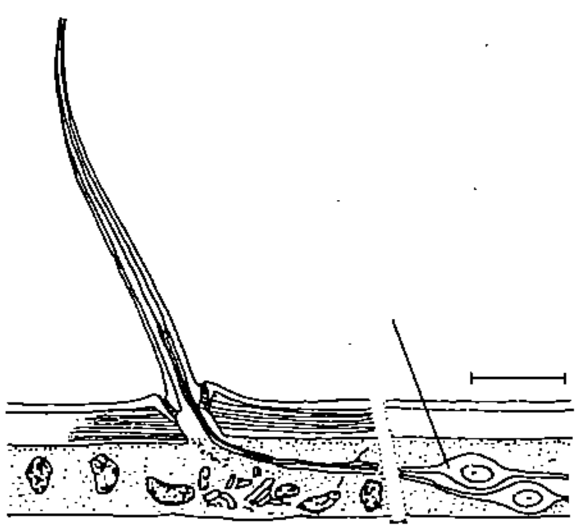


**Fig. 5.30 : A chemo sensory hair of an arthropod.**

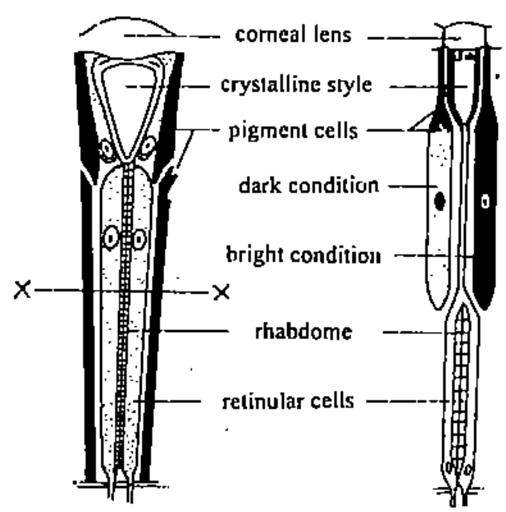



**Fig. 5.31 : Insect ommatidium.**

Most of the aquatic arthropods have gills as the respiratory structures. In terrestrial arthropods air tubes called tracheae are the respiratory structures. There may also be book lungs in some groups for respiration (Fig. 5.32).

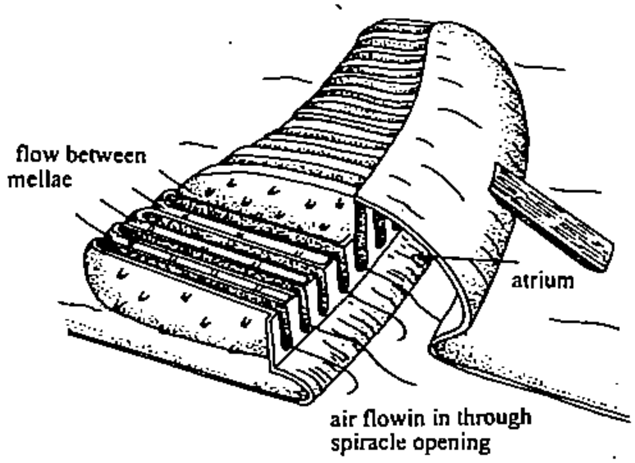



Fig. 5.32 : Book lung of an arachnid. (Diagrammatic)

Generally arthropods are dioecious. Sperm transfer by copulation is common and the appendages are modified for such a purpose. Fertilisation is internal in all terrestrial arthropods as well as in some aquatic forms but in certain aquatic forms external fertilisation is not uncommon. Arthropods have centrolecithal eggs with rich yolk. Cleavage is superficial. Development may include one or more larval stages. Viviparity is observed in some groups of arthropods.

Arthropods include crustaceans, common examples being prawns, lobsters and crabs; arachnids including scorpions, spiders, ticks and mites.; myriapods comprising mainly centipedes and millipedes; and insects such as grasshoppers, bugs, beetles, moths and butterflies, houseflies, mosquitoes, ants, bees and wasps.

We have outlined above some of the general characters of the phylum Arthropoda. Arthropods have evolved along four main lines. Each of these lines is treated as a subphylum. (See the Chart) Of the four subphyla, subphylum **Trilobitomorpha** consists of only extinct forms with no living representative today. Subphylum **Chelicerata** contains mostly terrestrial arthropods such as scorpions, spiders and ticks and mites and the aquatic **horseshoe crabs**. Subphylum **Crustacea** comprise mostly aquatic arthropods, such as copepods, barnacles, shrimps, lobsters and crabs. Subphylum **Uniramia** includes mostly terrestrial forms, the centipedes, millipedes and insects. Although the phylum had its origins in the sea, uniramians and several of the chelicerates appear to have evolved on land.

Before you proceed with your study of the subphyla answer the following SAQ.

## SAQ 2

I. Fill in the blanks with appropriate words.

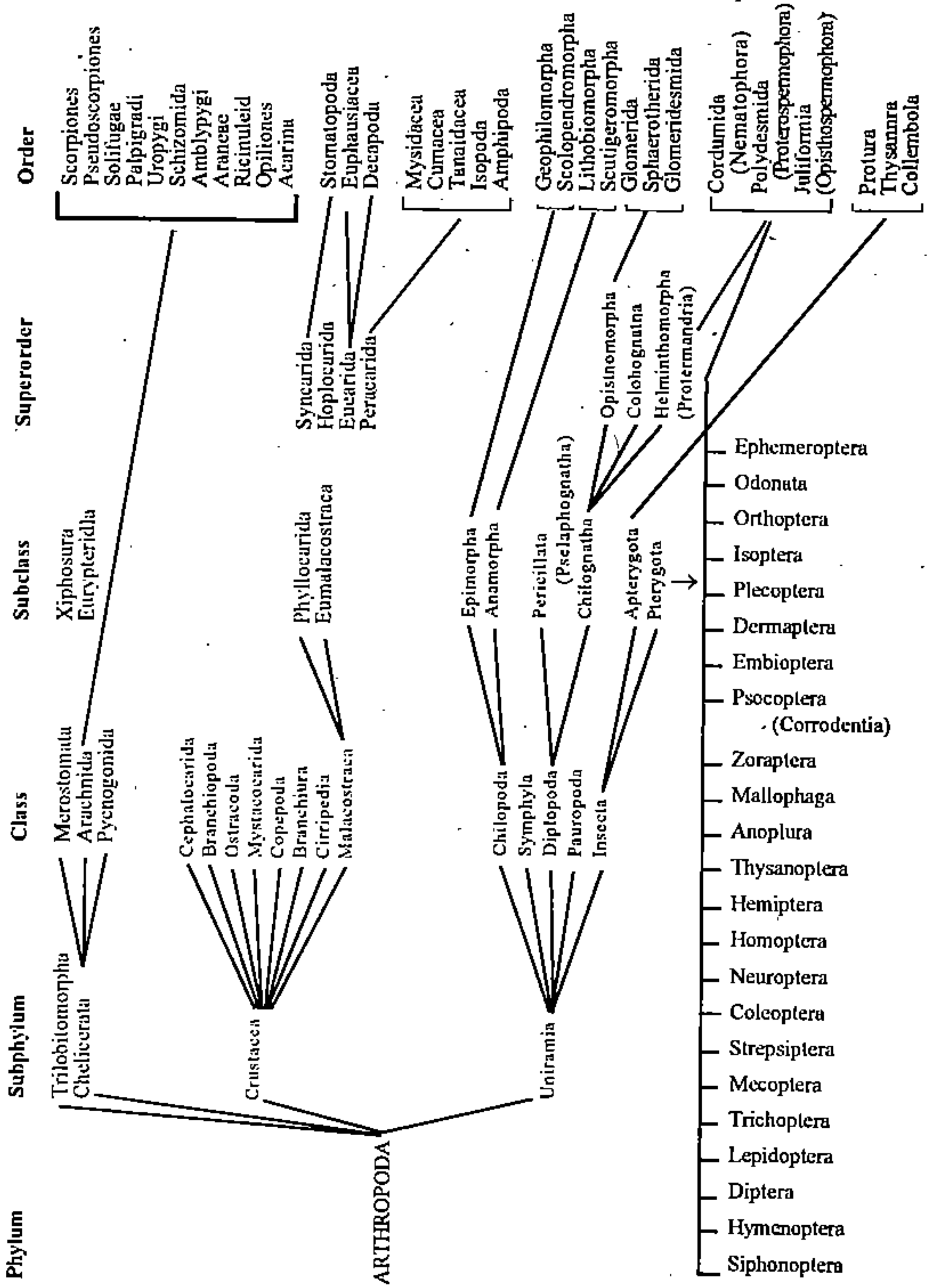
1. Phylum Arthropoda includes nearly ______________ species of animals.
2. The term "Arthropoda" means ____________________.
3. The different segmental appendages of various arthropods are said to be ______________ organs.
4. The branched appendages of crustaceans are known as ______________ organs whereas the unbranched ones of centipedes, millipedes and insects are ____________________.
5. The dorsal chitinous plate of each segment in arthropods is ____________, the ventral plate is __________ and the lateral structures are ___________.
6. The cavity enclosing the gonads and the end sacs of the excretory organs in crustaceans is the ______________.
7. ______________ and __________________ are the excretory organs of arthropods.

8. The component unit of a compound eye is called ____________.
9. The four subphyla of phylum Arthropoda are 1) ____________. 2) ____________.
3) ________________ & 4 ________________.

II. List any five distinctive characters of phylum Arthropoda.

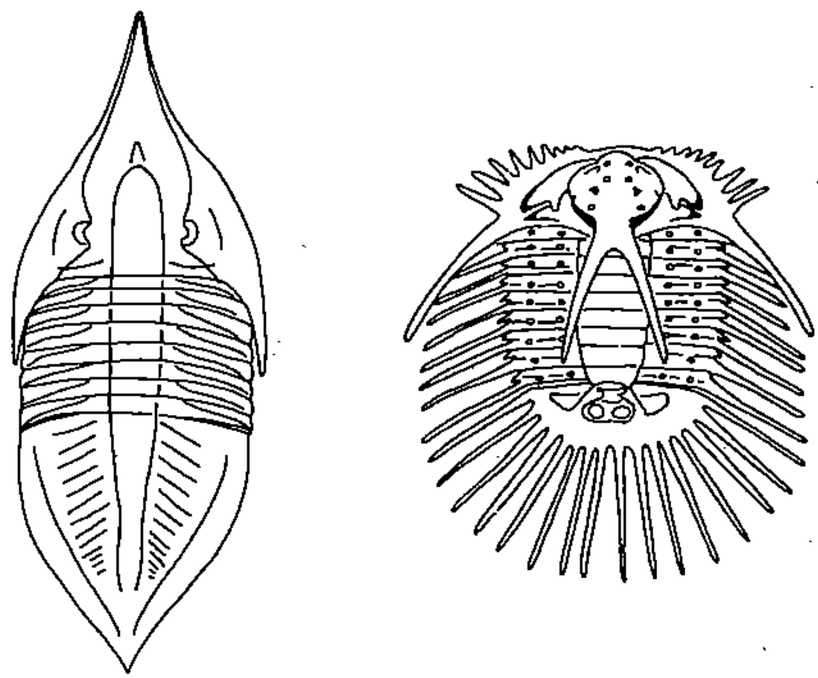
1) ____________________
2) ____________________
3) ____________________
4) ____________________
5) ____________________

**Chart showing the classification of phylum Arthropoda**



### 5.3.1 Subphylum Trilobitomorpha

Subphylum Trilobitomorpha includes the trilobites (Fig. 5.33). All species are extinct and the fossils indicate that they were all marine forms belonging to palaeozoic era. They are the most primitive of all arthropods. Body was divided into three lobes by means of two furrows longitudinally; distinct head, thorax and abdomen were present. Appendages biramous. It appears that trilobites had a variety of habits; they included burrowing, epibenthic, crawling, planktonic and swimming forms.



(a) (b)

**Fig. 5.33 : Extinct trilobites (a) Megalaspis sp.-burrowing form (b) Radiaspis sp.-planktonic form.**

### 5.3.2 Subphylum Chelicerata

Chelicerate body is divided into two parts: an anterior **cephalothorax** or **prosoma** and a posterior **abdomen or opisthosoma.** Antennae are absent. The first pair of appendages are known as **chelicerae** which are food capturing structures. The second pair of appendages are the **pedipalpi**, performing a variety of functions in different groups. Following pedipalpi, the cephalothoracic region has four pairs of walking legs.

Subphylum Chelicerata includes there classes: **Merostomata, Arachnida** and **Pycnogonida.**

**Class I Merostomata : Aquatic chelicertates in which five or six pairs of abdominal appendages are modified into gills for respiration. At the end of the body there is a spike like telson.**

The group includes two subclasses : (1) **Xiphosura,** the horseshoe crabs and (2) **Eurypterida** which is extinct now.

**Subclass I Xiphosura :** Xiphosurans are known to exist from cambrian period. Most species have become extinct. Only four species are known to exist from cambrian period. The most common genus of horseshoe crab is *Limulus,* (Fig. 5.34). This lives in shallow waters with soft bottom. They reach a length of 60 cm and are dark brown in colour. The cephalothorax is covered by means of a shield-like or horseshoe shaped convex exoskeletal plate called **carapace** that facilitates the organism to push through sand. The carapace also forms a cover to protect the ventral appendages. The head bears a pair of compound eyes and a pair of simple median eyes. The prosoma bears a pair of chelicerae and five pairs of walking legs. The abdomen or opistohosoma is unsegmented and bears six pairs of appendages. The first pair of appendages are fused to form a genital operculum bearing two genital pores. The other five pairs are modified as gills. Each gill has about 150 leaflike folds or lamellae arranged like the leaves of a book. So these appendages are sometimes called **book gills**. Horseshoe crabs are omnivorous. They have well developed digestive and circulatory systems. Excretion is by four pairs of coxal glands which open to the exterior at the base of last pair of walking legs by a common excretory pore. The brain is formed by the fusion of several ganglia including the ganglia of first seven segments. Abdomen has five ganglia. Sexes are separate. Female *Limulus* lays 2000 to 30000 eggs. Cleavage is total and development includes a **trilobite** larval stage (Fig. 5.35). This larva resembles the trilobites. Sexual maturity is reached after 3 years or more and life span is around 19 years. Since xiphosurans have lived on earth for over 200 million years without having undergone much change, they are an **evolutionary relic** and sometimes considered **living fossil**.

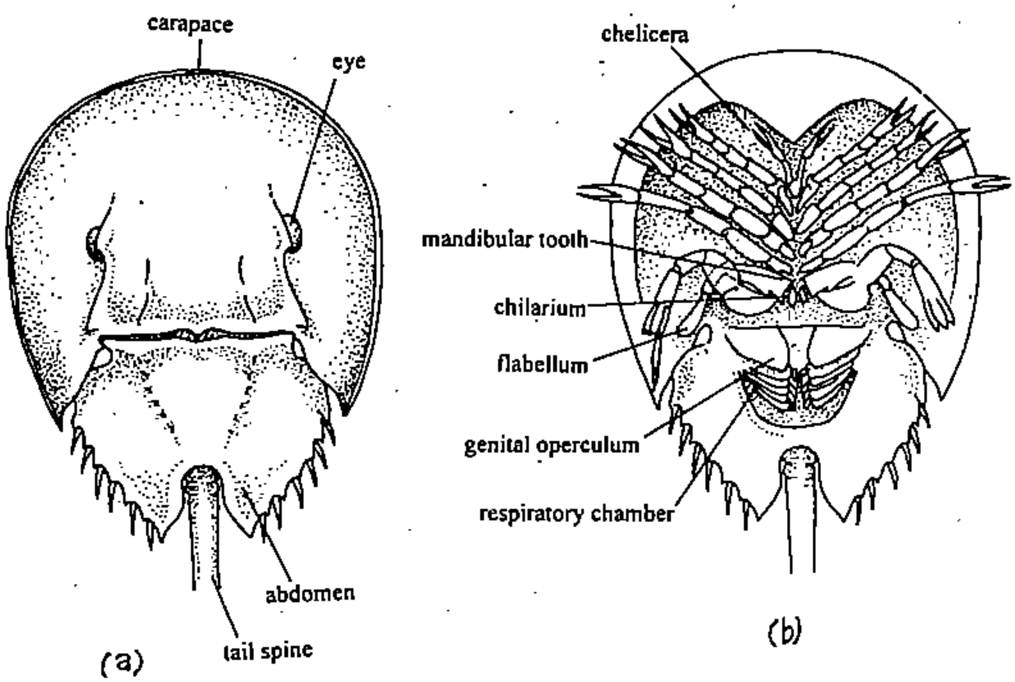



Fig. 5.34 : *Limulus* (a) dorsal view (b) ventral view.

**Subclass 2 Eurypterida** : Eurypterida are a group of giant, extinct merostomes. They were aquatic forms and existed from ordovician to permian period. A species of the genus *Pterygotus* was about three meters long. The body plan of eurypterids was similar to xiphosurans. They also resembled the scorpions. However, their cephalothorax was smaller. Abdomen was made up of separate segments, with a seven segmented preabdomen (mesosoma) with appendages, and a five segmented post-abdomen (metasoma) without appendages. Besides the marine environment, they also appear to have inhabited brackish water, freshwater and terrestrial environments. It is also suggested that eurypterids could have been the ancestors of arachnids; eg. *Eurypterus* (Fig. 5.36).

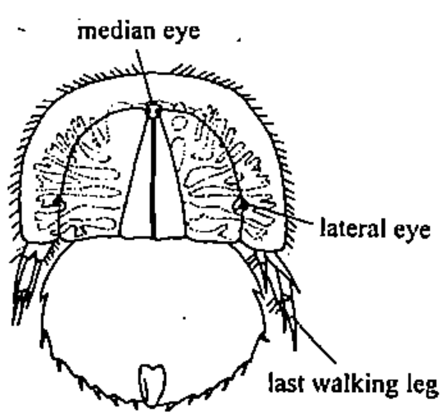



Fig. 5.35 : Trilobite larva.

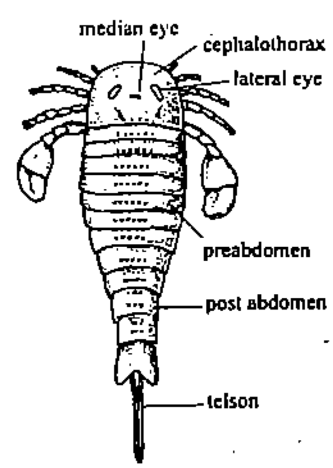



Fig. 5.36 : *Eurypterus*.

**Class 3 Arachnida : Body divided into cephalothorax and abdomen. Cephalothorax with four pairs of legs; abdomen segmented or unsegmented, with or without appendages. Respiratory organs are, either tracheae, or book lungs. Excretory organs are Malpighian tubules or coxal glands. Brain bilobed connected to ventral ganglionic mass forming a ring. Eyes simple. Mainly oviparous; no matamorphosis.**

Arachnids, the largest of all the chelicerate classes, include some of the common and familiar but diverse forms, like spiders, ticks, mites, scorpions, pseudoscorpions, whipscorpions, harvestmen (daddy longlegs) etc. Arachnids are one of the oldest classes of arthropods, the fossil forms dating back to silurian period. Most living arachnids are terrestrial. As a result, the epicuticle has became waxy reducing water loss, the book gills became modified into booklungs for use in air and the appendages became better adapted for terrestrial locomotion.

The body of arachnids (Fig. 5.37) shows three district regions: the **prosoma** which is unsegmented and covered by a carapace: the **mesosoma** or preabdomen and the **metasoma** or postabdomen. Except in scorpions, in other arachnids the two divisions of the abdomen are not conspicuous and the segments are fused. The appendages are usually confined to prosoma and consist of a pair of chelicerae, a pair of pedipalpi and four pairs of walking legs. There are no antennae and mandibles.

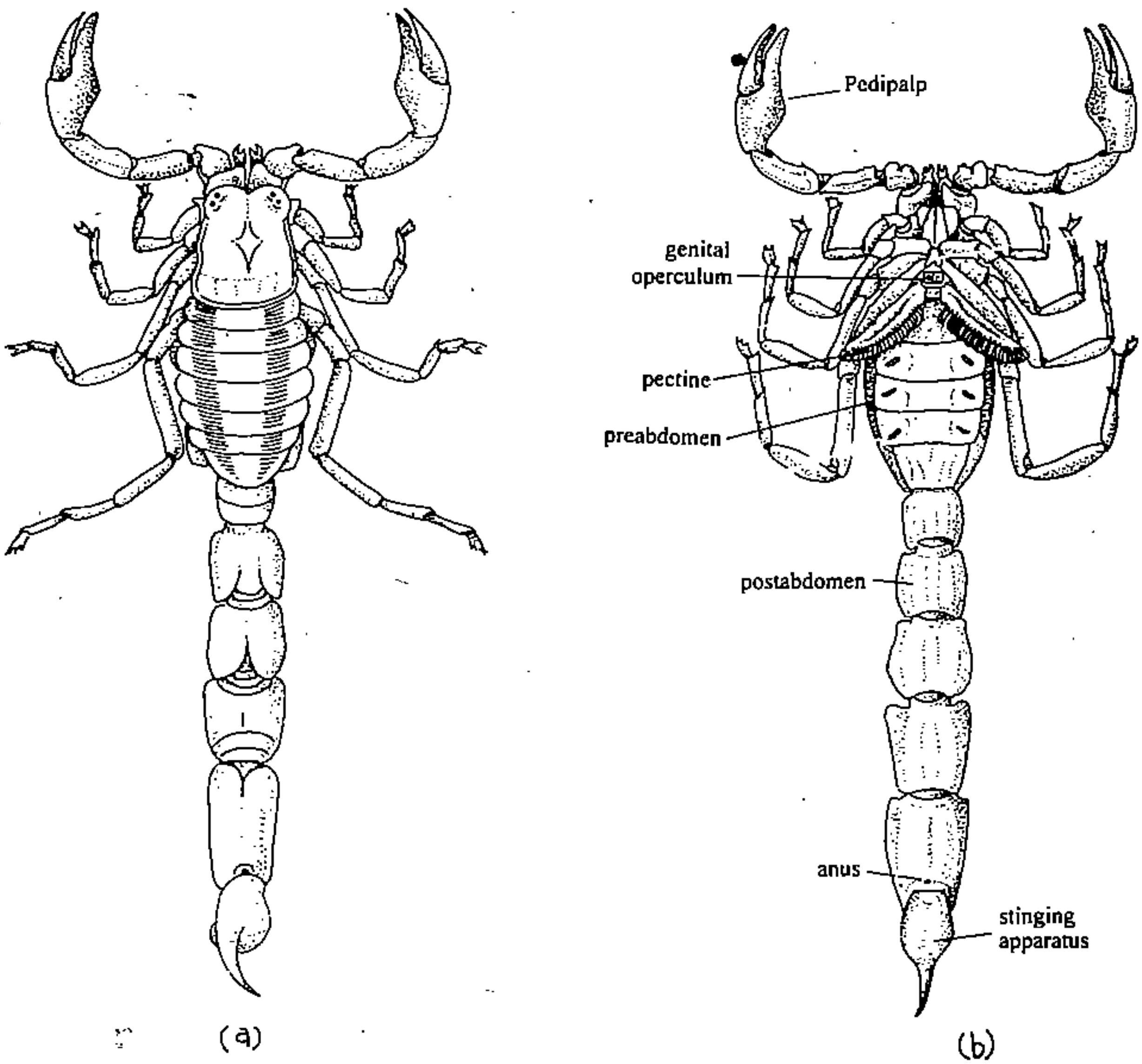



Fig. 5.37 : Scorpion (a) dorsal view (b) ventral view.

Arachnids are generally carnivorous and partial digestion of food takes places outside the body of the animals. The small arthropods captured as prey are killed by pedipalpi and chelicerae. The enzymes from the midgut are poured over the prey held by the chelicerae. The partially digested liquid food is taken in through the mouth, by means of the strong sucking pharynx. The midgut is a specialised structure with a central tube and lateral diverticula (Fig. 5.38). The diverticula located both in prosoma and abdomen become filled with partially digested food and further digestion occurs here. The midgut continues into the posterior part of the abdomen as rectum where it opens outside by anus.

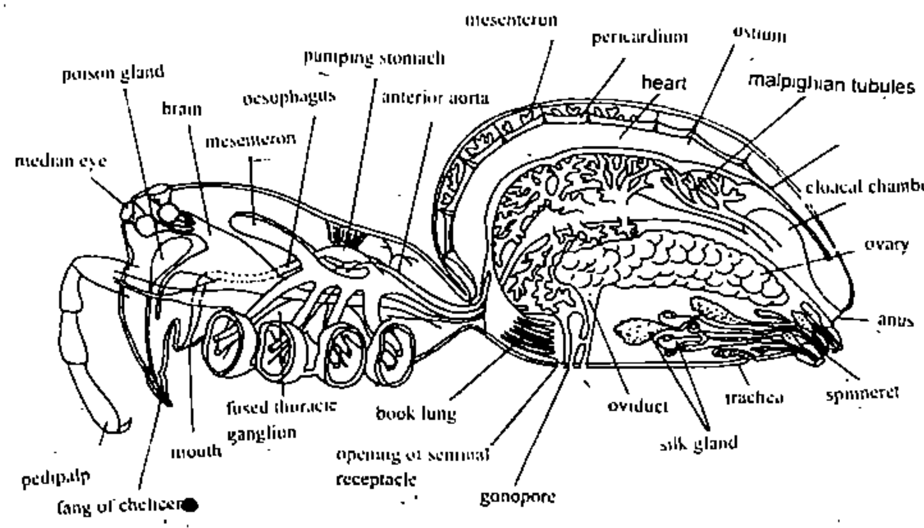



**Fig. 5.38 : Internal organisation of a spider.**

The nervous system (Fig. 5.39) is highly concentrated. The brain is composed of protocerebrum and tritocerebrum and in many orders most or all the thoracic and abdominal ganglia have moved forward and fused with suboesophageal ganglion. Thus often the nervous systems appears in the form of a ring around oesophagus. The sense organs include sensory hairs, eyes and slit sense organs. The sensory hairs are chemoreceptors or olfactory in function. The slit sense organs which occur singly or in groups respond to changes in the tension of exoskeleton, load stress in locomotion, gravity, and to airborne vibrations. The slit organs occurring in groups are called **lyriform organs.** Scorpions have a pair of peculiar comblike sense organ called pectines (Fig. 5.37). These are located ventrally behind the genital plates and attached to the second abdominal segment. Some mites have special type of sensory organs known as **pseudostigmatic** organ for monitoring air currents.

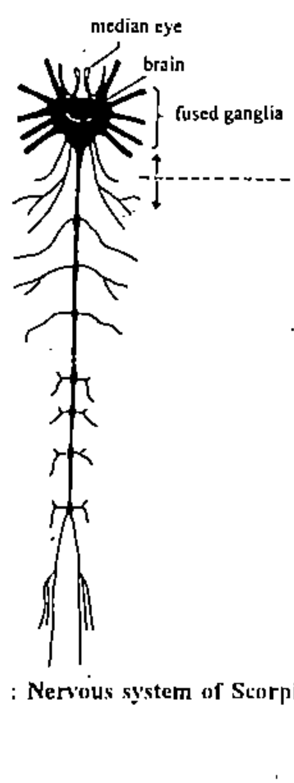



**Fig. 5.39 : Nervous system of Scorpion.**

Arachnids possess booklungs (Fig. 5.32) or trachea of both as respiratory organs. Book lungs are considered to be modified book gills and resemble them in structure. However, they occur as pockets of ventral abdominal wall. One of these walls is folded into lamellae in which blood circulates; outside these lamellae there is circulation of air, enabling respiration. The heart is located in the anterior half of the abdomen. In scorpions there are seven pairs of ostia each corresponding to a segment. But in other arachnid orders, varying degrees of reduction in number of ostia are found. Excretion is carried out by means of coxal glands (Fig. 5.27) and Malpighian tubules. Coxal glands are derived from coelomic sacs. Their ducts open on the coxae of the leg. Malpighian tubules are slender tubes airsing from the midgut and opening into it.

Gonad (Fig. 5.40) is either single or paired, genital opening being on 2nd abdominal segment. Sperm-transfer is through spermatophore, a bag of sperms. The male deposits the spermatophore, to which the female is attracted. Most arachnids exhibit a complex courtship or precopulatory behaviour preceding mating. The females of many arachnids brood their eggs in their reproductive tract and give birth to live, developed young ones. Thus viviparity is common among arachnids.

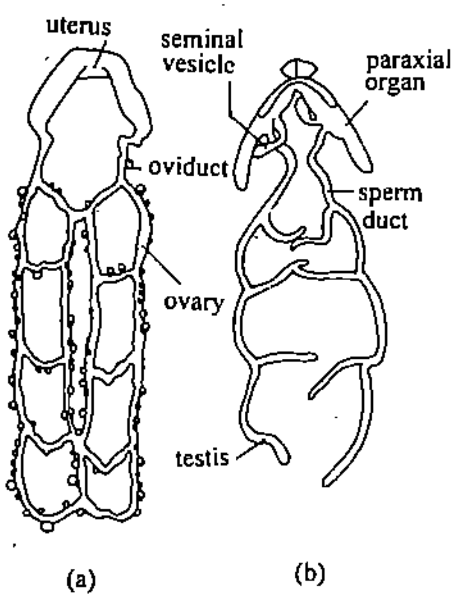



Fig. 5.40 : Reproductive system of Scorpion (a) male (b) female.

Of particular interest, is the silk glands and the associated spinnerets of many spiders. The spinnerets or the spinning organs (Fig. 5.41) are modified appendages and are located on the abdomen ventrally, in front the anus. They bear a number of spigots, which are the openings of the silk glands. The silk glands themselves are large with a reservoir and duct opening on the spinneret. Silk plays a very important role in the life of spiders. The web is used to catch the prey; many spiders use silk thread as a drag line or a safety line as used by mountain climbers; silken nets may be used as their retreats; their eggs are usually wrapped in silken cocoons.

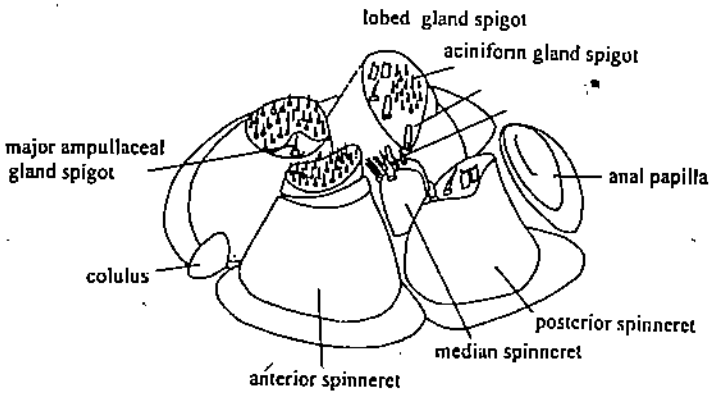



Fig. 5.41 : Spinnerets of a spider.

**Examples**

**Order 1 Scorpiones :** Includes scorpions: eg. *Buthus, Palamnaeus* (Fig. 5.42). *Androctonus, Centruroides. Heterometrus.* Their abdomen ends in a stinging a apparatus.

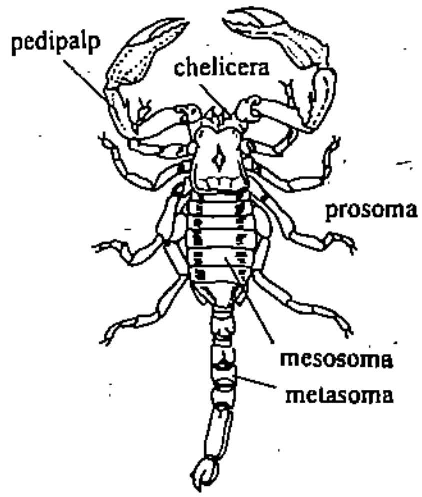
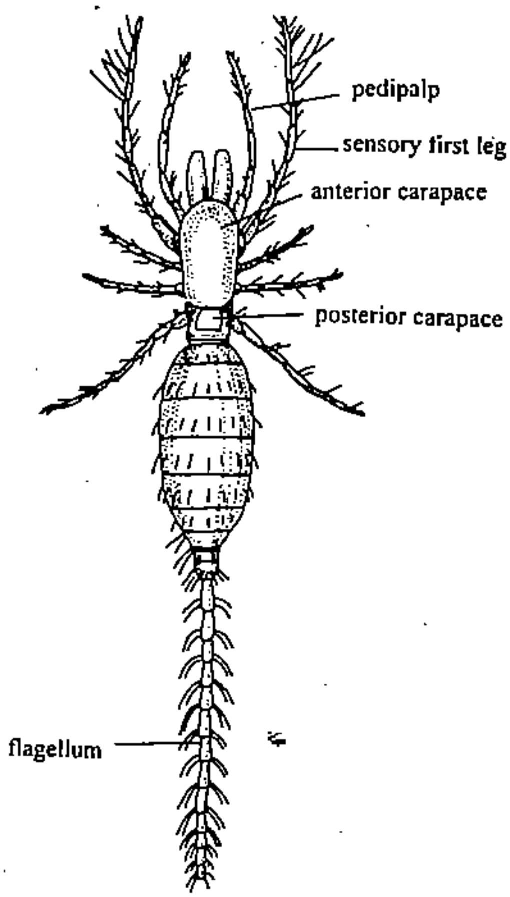



Fig. 5.42 : *Palamnaeus.*

**Order 2 Palpigradi :** These are the palpigrades; eg. *Eukoenenia* (Fig. 5.43).



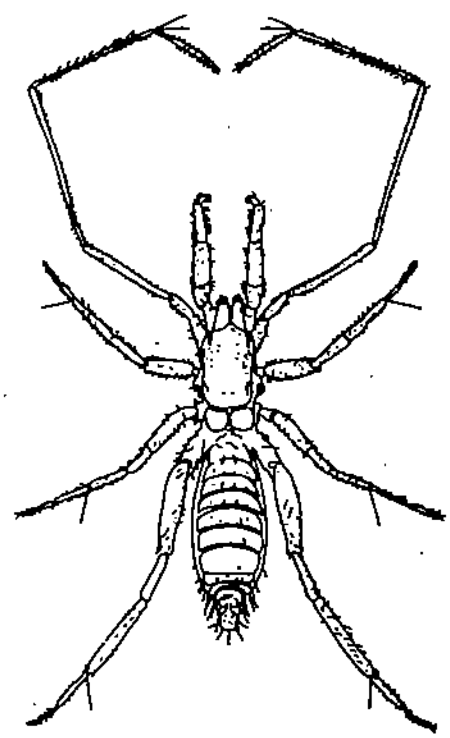



Fig. 5.43 : *Eukoenenia.* Fig. 5.44 : *Schizomus.*

**Order 3 Schizomida :** These include tailless whip scorpions; eg. *Schizomus* (Fig. 5.44).

**Order 4 Uropygi :** These are the whipscorpions; eg. *Thelyphonus* (Fig. 5.45).

**Order 5 Araneae :** These comprise spiders: eg. *Latrodectus*, black widow spider (Fig. 5.46); *Synema*, a crab spider.

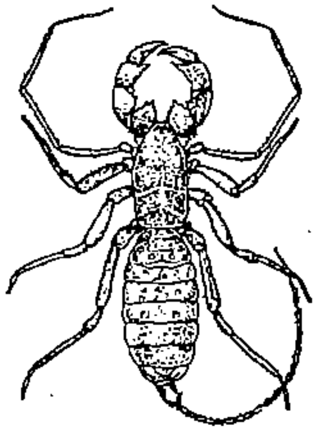


Fig. 5.45 : Whip scorpion.

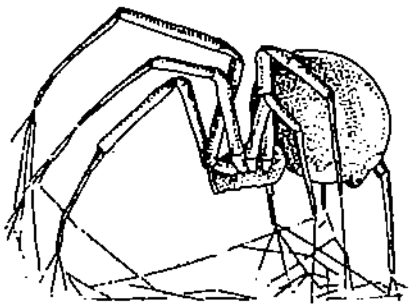


Fig. 5.46 : Black widow spider.

**Order 6 Amblypygi :** These are found beneath logs, barks, stones, leaves etc.; eg. *Tarantula*, *Charinus* (Fig. 5.47).

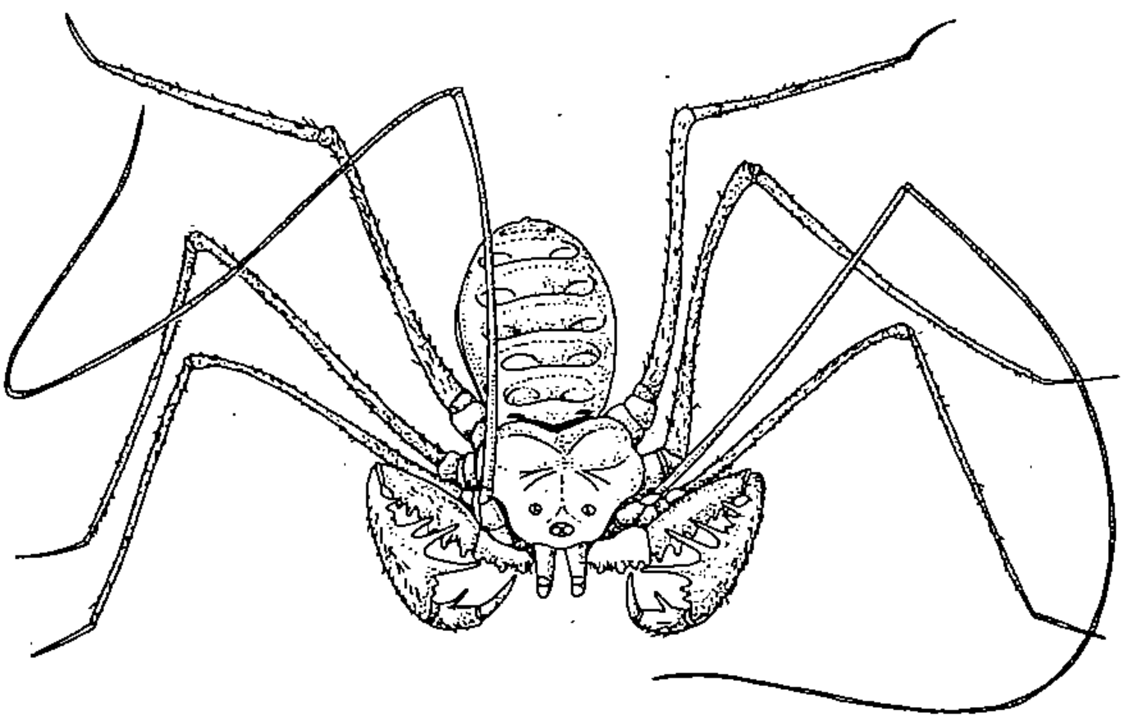


Fig. 5.47 : *Charinus*.

**Order 7 Ricinulei :** These are known as tick spiders (Fig. 5:48) mostly confined to Africa and America; eg. *Cryptocellus, Ricinoides.*

**Order 8 Pseudoscorpiones :** Includes pseudoscorpions found beneath barks, stones etc.: eg. *Chelifer* (Fig. 5.49).

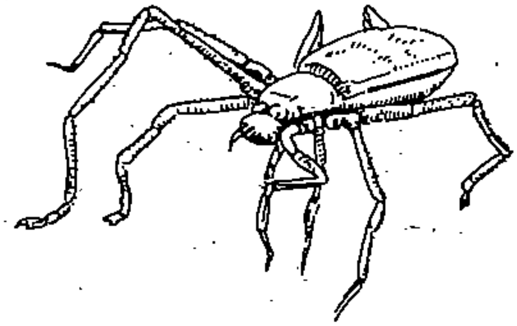


**Fig. 5.48 : A Ricinuleid.**

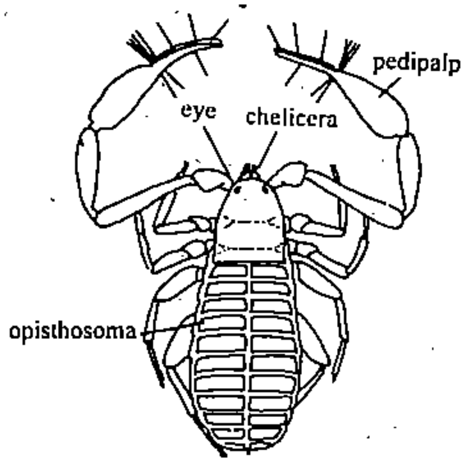



**Fig. 5.49 :** ***Chelifer.***

**Order 9 Solifugae :** Commonly called sun spiders or wind scorpions. They live under stones and crevices and many are burrowing forms; measure a maximum of 7 cm; eg. *Galeodes* (Fig. 5.50).

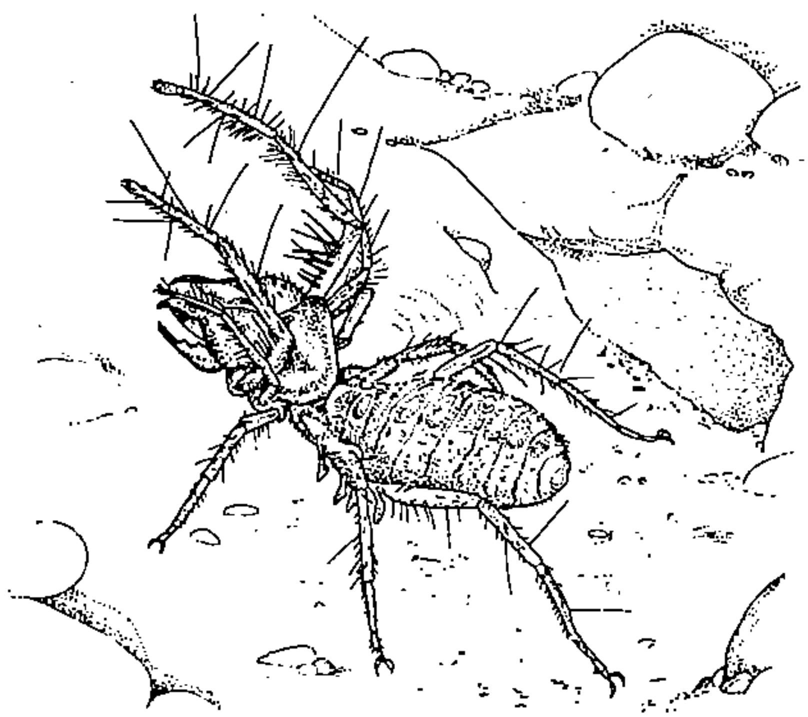


Fig. 5.50 : *Galeodes.*

**Order 10 Opiliones or Phalangida :** Opiliones or phalangids commonly known as harvestman or daddy long legs inhabit humid places both in temperate and tropical regions. Phalanigids are found to live in forest floors, tree trunks, fallen logs and humus. They usually measure about 5 to 10 mm in length. The legs of opiliones are long and slender and exceed body length several times. eg. *Leiobunum* (Fig. 5.51).

**Order 11 The Acarina :** The Acarina are a group of very diverse assemblage of arachnids known as ticks and mites (Fig. 5.52 and 5.53). Many species are ectoparasites on humans, domestic animals and crops. They can also cause damage to man's possessions as well as to food. Free living mites have varied habitats as they live on moss, plants, fallen leaves, humus, soil, rotten wood and detritus. They are also aquatic, inhabiting both freshwater and sea. Nearly 30,000 species have been described thus far but many more unidentified species still exist. They generally measure 0.25 to 0.75 mm. Ticks are slightly larger, some species may reach upto 3 cm in length. The small size has enabled them to inhabit many microhabitats such as the trachea of insects, wings of beetles, quill feathers of birds and hairs of mammals. The head region carrying the mouth parts is called **capitulum** or **gnathosoma** (Fig. 5.54). A structure called **buccal cone** is attached to the anterior region of the body like a socket that can be extended or retracted. The chelicerae and pedipalpi are attached to the buccal cone. Ticks remain attached to hosts and attack all groups of terrestrial vertebrates including man. American rocky mountain spotted fever-tularemia, Texas cattle fever, relapsing fever, and lyme disease are some of the human diseases caused by ticks. A species of mite *Sarcoptes scabiei* causes scabies or seven year itch by tunneling into epidermis.

Fig. 5.51 : *Leiobunum*.

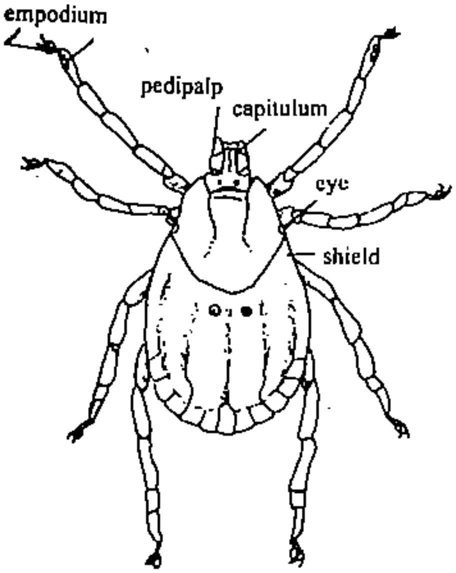



Fig. 5.52 : A tick.

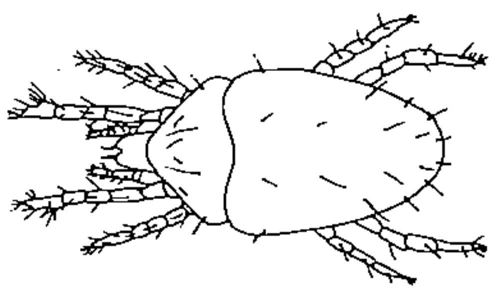


Fig. 5.53 : A mite.

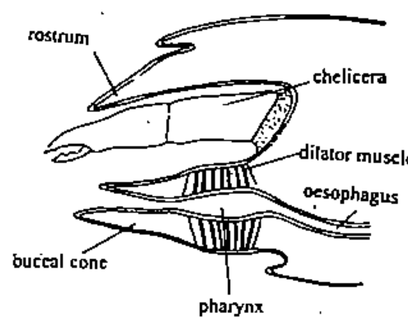



Fig. 5.54 : Capitulum of a mite.

A six legged larva emerges from the eggs and the larva passes through **protonymph**, **deutonymph** and **tritonymph** stages before becoming adult.

**Class 3 Pycnogonida : Measures usually 3-4 mm; body chiefly made up of cephalothorax, abdomen being very small; generally four pairs of walking legs; long proboscis with a mouth; simple eyes, four in number; no excretory or respiratory organs.**

These are commonly known as sea spiders (Fig. 5.55) occur in all the seas. The narrow body is formed of a number of distinct segments. Prosoma (cephalothorax) is the prominent region of the body and opisthosoma (abdomen) is much reduced. The head or cephalon bears four simple eyes mounted on the dorsal surface on a tubercle and a cylindrical proboscis. It also bears a pair of comparatively small chelicerae and palps each. The trunk is formed of four cylindrical segments, of which the first one is fused with the head. From each of the four segments, a pair of lateral processes project out to which the long walking legs are articulated. The legs are eight segmented and are usually much longer than the body. The abdomen appears as a short conical process.

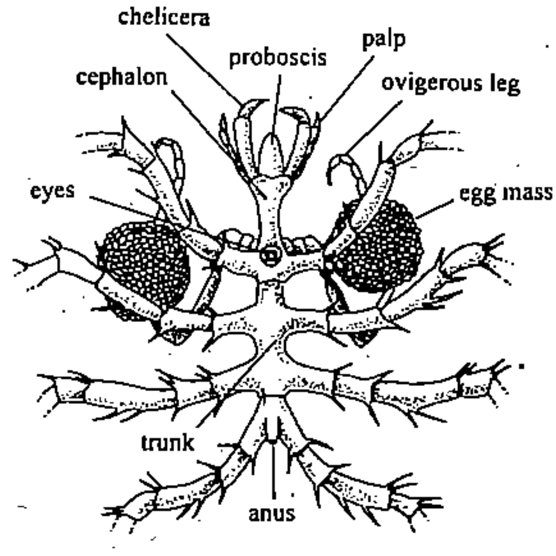



Fig. 5.55 : A sea spider.

Pycnogonids are mostly carnivorous and feed on soft coelenterates, bryozoans, polychaets and sponges. Most parasitic forms live on molluscs. The pharynx acts as a pump and also macerates food by means of the bristles located there (Fig. 5.56). From the extensive intestine (midgut) caeca extend into appendages. The circulatory system consists of a heart, dorsal vessel and the haemocoel. Special respiratory or excretory organs are absent and gas exchange is by body surface. Nervous system resembles that of other chelicerates.

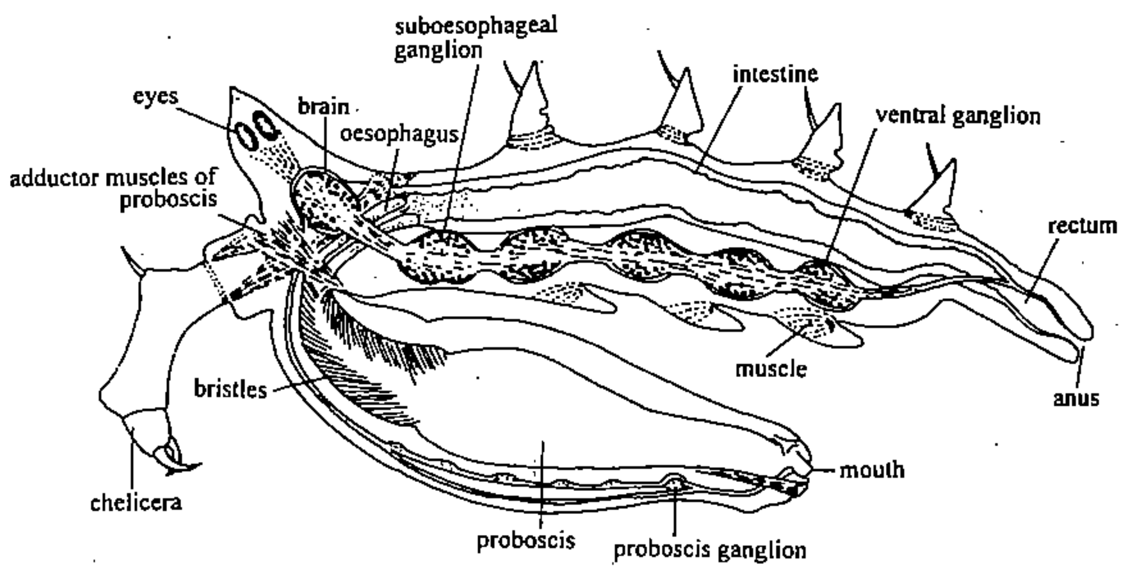



Fig. 5.56 : Sagittal section of a sea spider showing internal organisation.

In pycnogonids sexes are separate. Genital openings are multiple, located on the ventral side of the coxae of second and fourth pair of legs in males and of all legs in females. The gonads are located in the trunk, but lateral branches extend into the legs. The eggs released by the females are collected in ovigerous sacs of the males. A larval stage known as **protonymphon** (Fig. 5.57) which may remain in the ovigerous legs of the male or may develop among the hybrids and corals. A sequence of moults and development lead to the transformation of larvae into adult.

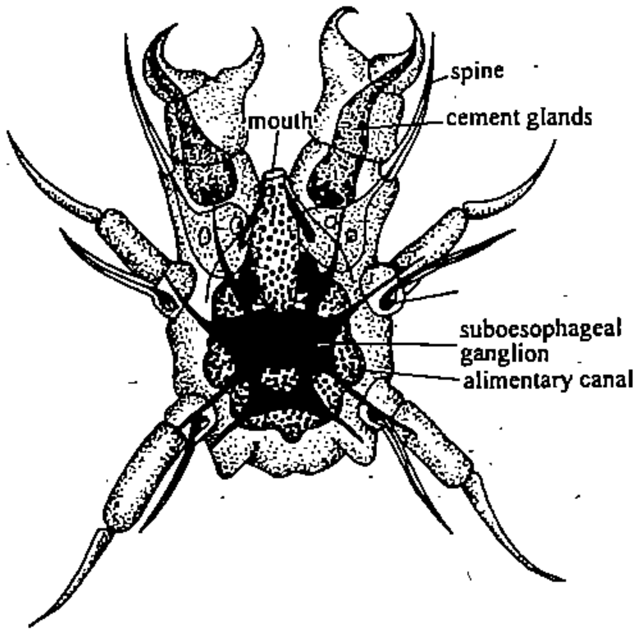



**Fig. 5.57 : Protonymphon larva of a sea spider.**

The systematic position of pycnogonids is not clear. The structure of nervous system, nature of sense organs and presence of chelicerae — all find for them a place among chelicerates. But the presence of multiple gonopores, ovigerous legs, and segmented trunk distinguish them from chelicerates. It could not be said with certainty whether pycnogonids are related to arachnids or not.

## SAQ 3

I. Choose the correct word from the alternatives given:

1. Trilobites are a extinct group of primitive/advanced arthrodpods.
2. One of the characteristic features of chelicerates is presence/absence of antennae.
3. The second pair of appendages of chelicerates is known as chelicerae/pedipalpi.
4. Class Merostoma consists of terrestrial/aquatic chelicerates.
5. Class Xiphosura/Arachnida are regarded as living fossils.
6. Spiders, ticks, mites and scorpions are included under the class Eurypterida/ Arachnida.
7. In scorpions the post-abdominal region is known as mesosoma/metasoma.
8. Spinning organs or spinnerets are characteristic of Araneae/Acarina.
9. Order Solifugae/Acarina includes mites.

II. Fill in the blanks with suitable words:

1. The three classes of the subphylum Chelicerata are ______________, ________________ and ________________.
2. Horse-shoe crabs are included under the subclass ______________.
3. Xiphosurans are called ________________ ________________ because they have continued to live on earth for over 100 million years without having undergone much change and have remained an evolutionary relic.
4. The slit organs of arachnids that occur in groups are called ______________ ______________.
5. The special comb-like sense organs of scorpions are ______________.
6. ________________ are the arachnids that are popularly known as daddy long legs or harvestman.

7. Many members of Acarina are ________________ on humans, domestic animals and crops.

8. Some of the diseases caused to humans by ticks are ____________, ______________, __________________ and ________________.

9. ________________ organ is the sense organ in mites that are useful in detecting air currents.

10. Sea spiders belong to the class ________________.

### 5.3.3 Subphylum Crustacea

**Crustacea are mostly aquatic arthropods with gills for respiration. Cephalothorax has usually a carapace; appendages biramous but modified for various functions. Head has a pair of antennules, a pair of antennae, a pair of mandibles and two pairs of maxillae. Development with a nauplius stage, but this may be absent in higher forms.**

Crustacea includes arthropods most of which have an aquatic existence. The group abounds in species diversity and biomass. It includes crabs, shrimps, lobsters, crayfish, woodlice etc. Although largely aquatic, there are some semiterrestrial and terrestrial species. Their success on land is not significant.

Let us briefly look into the structural peculiarities of crustaceans. The body of crustaceans is divided into three regions, head, thorax and abdomen (Fig. 5.58). The head and thoracic segments may be fused to form the **cephalothorax.** The thorax and abdomen may together form a trunk in some forms. The thoracic segments are covered by a dorsal shield known as **carapace.** The carapace is a posteriorly directed fold of the body wall of the head and fused with varying number of segments behind it. Carapace may overhang the sides of the body to some extent or in some cases it may enclose the entire body.

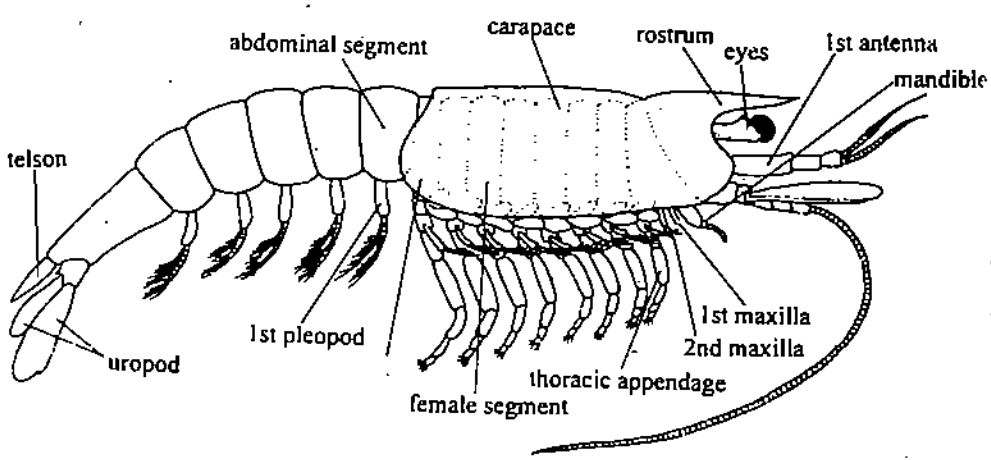



**Fig. 5.58 : A generalised Crustacean.**

The head has five pairs of appendages, corresponding to its five segments. The first two appendages (Fig. 5.59) are **antennules (first pair of antennae) and antennae (second pair of antennae).** Thus crustanceans are the only arthropods with two pairs c antennae. These are followed by a pair of **mandibles**-short and heavy structures with apposing and grinding surfaces and two pairs of accessory feeding appendages the **first pair of maxillae** and the **second pair of maxillae.** All these appendages as well as those present on the thorax and on the abdomen, are **biramous.** In each biramous appendage, there is a large **protopodite** composed of two pieces-a **coxa** and a **basis.** Attached to the basis is an inner branch called **endopodite** and an outer branch, the **exopodite,** each of which is made of one or several segments. The different appendages are modified to do different functions such as food handling, crawling, walking, swimming, prehension, sperm transfer and egg brooding (Fig. 5.60). The number of segments in curstaceans very: most have 16-20 segments. Malacostraca, the most advanced class of

Crustacea which includes lobsters, prawns, shrimps, crabs etc. have in addition to head, a thorax of eight segments and an abdomen of six segments. In addition, the head carries a non-segmented **rostrum** and the posterior end has a non-segmented **telson**. The telson the last abdominal segment and its **uropods** together form the tail fin. Smaller crustaceans in general are capable of swimming. Large forms have taken to benthic zones and the appendages are modified for crawling and burrowing mode of life.

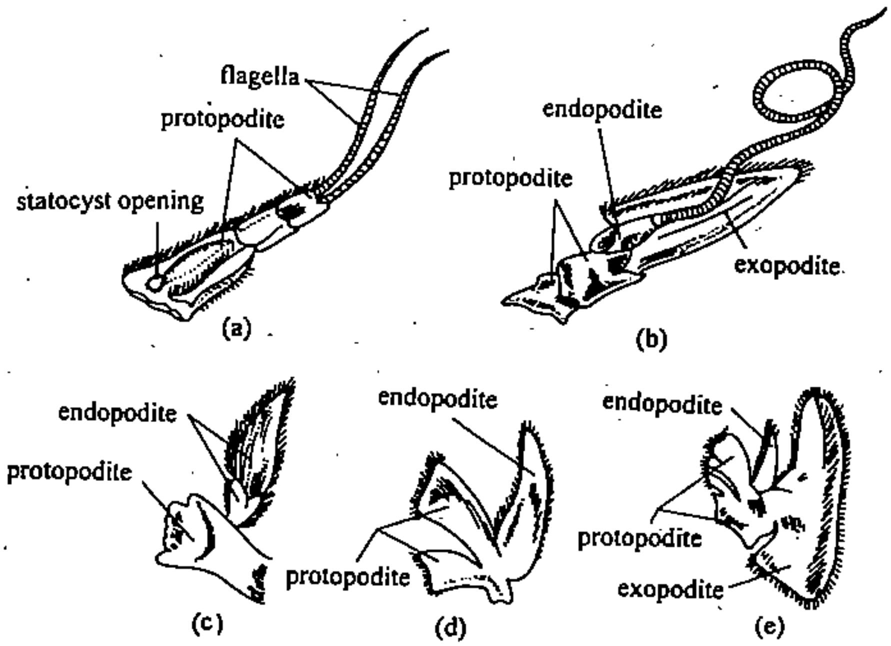



**Fig. 5.59 : Cephalic appendages of prawn.**

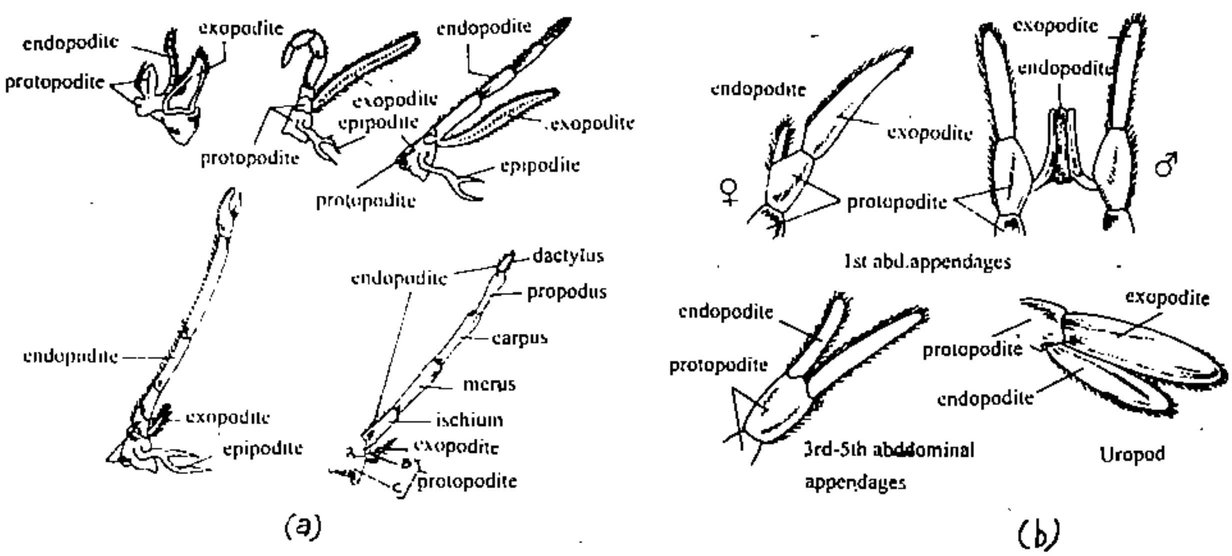



**Fig. 5.60 : Thoracic and abdominal appendages of prawn.**

The cuticle of curstaceans usually contains calcium salts. Tanned proteins and pigments may also be present. Most crustaceans are also capable of changing their colour to suit environment. This is by concentration or dispersal of various pigments contained in certain cells known as **chromatophores**, which are subepidermal. Many crustaceans are predators, many are also adapted for filter feeding of tiny organisms constituting planktons and detritus. Generally a few of the trunk appendages are modified for this purpose and these are the **maxillepedes**. Mouth is ventral in position and the digestive tract is a straight tube. **Hepatopancreas**, the spongy digestive glands, arise as a diverticulum of the midgut. Circulatory system is open type and typically arthropodan although the heart varies in structure from being a long tube to a compact vesicle. The blood contains large cells called **amoebocytes** which are involved in phagocytosis and blood clotting. The gills are the respiratory organs. They are usually associated with segmental appendages. The ventilating currents produced by the beating of the appendages are helpful in the exchange of gases.

The excretory organs are similar to the coxal glands of chelicerates and consist of an end sac, an excretory canal and a short exit duct (Fig. 5.24). Depending on their position, the excretory organs are called **antennal or maxillary glands.** Nervous system is characterised by varying degrees of concentration and fusion of ganglia. Sense organs of crustaceans include simple and compound eyes, statocysts, sensory hairs. Compound eyes are highly developed.

Most crustaceans are dioecious. Certain appendages are modified for clasping the female during copulation and for sperm transfer. Some crustaceans also produce spermatophores. Many crustaceans have non-flagellated spermatozoa. Many crustaceans brood their eggs, for which there may be brood chamber at various parts of the body or other mechanisms. There are many larval stages in crustaceans: **nauplius, metanauplius, protozoea, zoea, mysis** and **megalopa** are some of them (Fig. 5.61). Primitive crustaceans have fewer larval stages; more advanced forms have several larval stages.

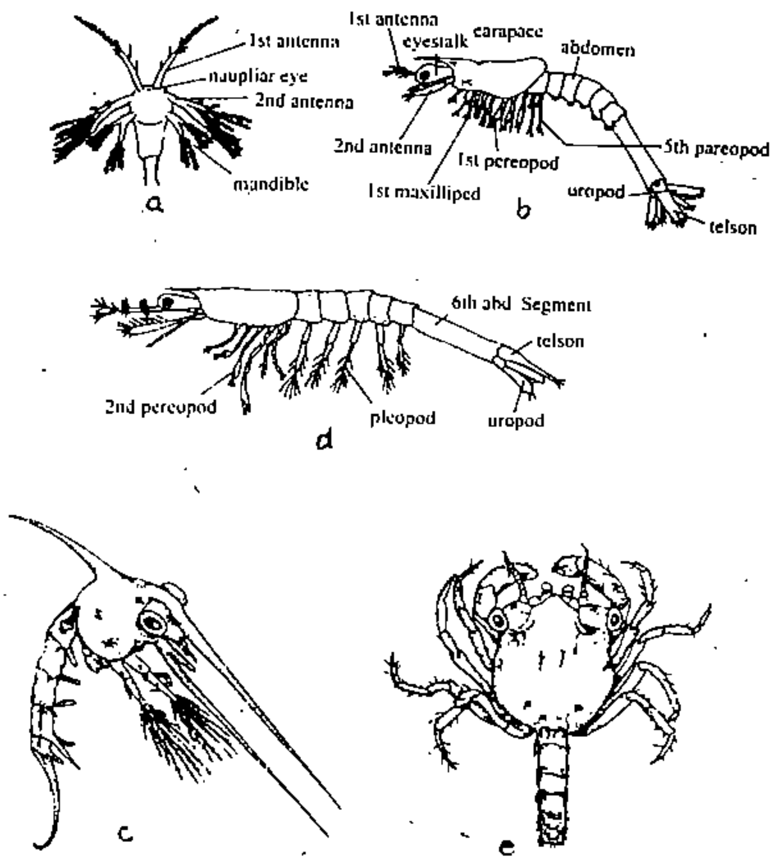



**Fig. 5.61 : Some larval stages of crustaceans.**

| | | | |
|---|---|---|---|
| (a) | Nauplius | (b) | Protozoea |
| (c) | Zoea | (d) | Mysis |
| (e) | Megalopa | | |

Crustacea include such a diversity of organisms that it is very difficult to give a concise account of its classification with any amount of justice to the subject, at the same time avoiding confusion to the student. We here stick to our plan of classifying the group only upto classes, but attempt has been made to give examples of representatives from various major orders. The crustacea are accommodated into six major classes. These are:

(1) **Branchiopoda**

(2) **Ostracoda**

(3) **Copepoda**

(4) **Branchiura**

(5) **Cirripedia**

(6) **Malacostraca**

**Class 1 Branchiopoda :** These are small fresh water crustaceans. The trunk appendages are flattened and leaf like and are useful for locomotion as well as respiration hence the name Branchiopoda. The first antennae and second maxillae are much reduced. The anal segment bears a pair of large terminal processes called cercopods. eg. *Triops,* the tadpole shrimp (Fig. 5.62) *Branchinecta,* the fairy shrimp (Fig. 5.63), *Daphnia,* waterfleas (Fig. 5.64), *Artemia* the brine shrimp (Fig. 5.65) that lives in salt lakes and ponds.

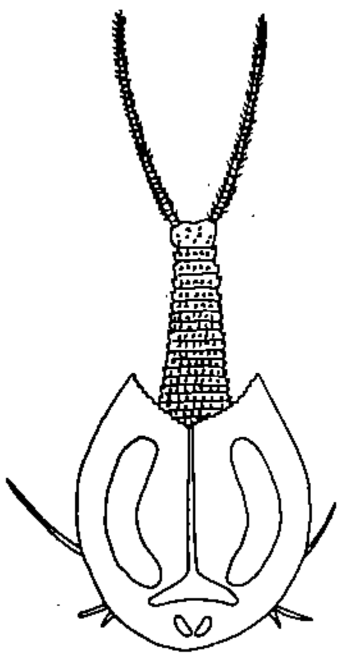


Fig. 5.62 : *Triops.*

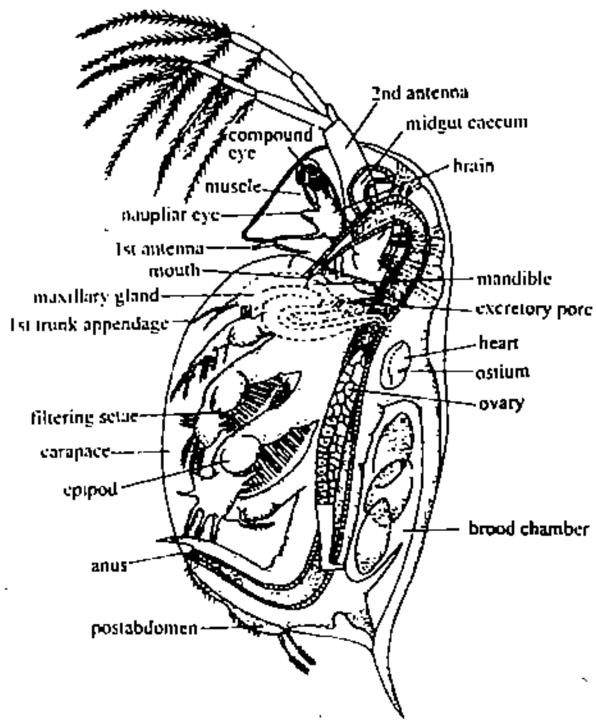



Fig. 5.64 : *Daphnia.*

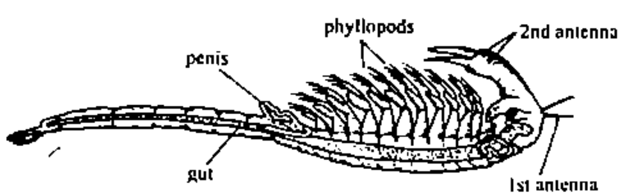



Fig. 5.63 : *Branchinecta.*

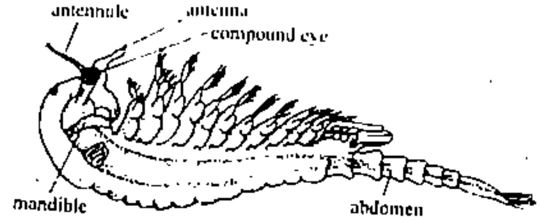



Fig. 5.65 : *Artemia.*

**Class 2 Ostracoda :** Commonly called mussel or seed-shrimps, ostracods include both fresh water and marine forms. The small crustaceans, measuring a few mm have their body covered in a carapace formed by two elliptical valves. The head is the dominant part of the body, with well developed appendages. The trunk is much reduced and unsegmented. Only two pairs of appendages are found. Single median eye is common among all ostracods and a few have sessile compound eyes. Some of the fresh water forms are parthenogenetic. eg. *Cypricercus*, *Gigantocypris*, *Cypris*, *Ponticypris*, *Candona* (Fig. 5.67).

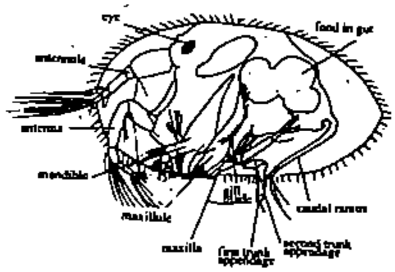



Fig. 5.66 : *Cypricercus.*

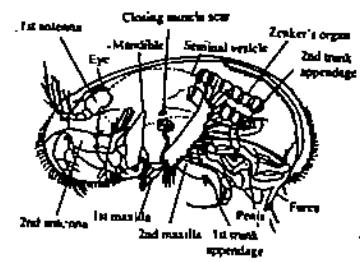



Fig. 5.67 : *Candona.*

**Class 3 Copepoda :** Copepoda is a large class of small (1-5mm) crustaceans occupying both marine and freshwater environments. Copepods form the most abundant and conspicuous members of planktonic collection. Many are parasitic. Most copepods are brightly coloured and some of the species are also bioluminescent. The body is cylindrical and tapering antero-posteriorly. The trunk is divided into thorax and abdomen. The first and sometimes the second thoracic segment is fused with the head. A median eye is present. The first pair of antennae are large and uniramous. The first pair of thoracic appendages are maxillepeds used for feeding. Abdomen has five segments and lacks appendages. Last abdominal segment has a pair of caudal rami. Planktonic copepods are either saprophytic feeders, or they may feed on phytoplankton or detritus. Some are carnivores. Nauplius larval stage seen. eg. *Calanus*, (Fig. 5.68), *Diaptomus*, *Monstrilla*, *Haemocera* (Fig. 5.69) — both parasitic on polychaetes; *Salmincola* and *Penella* (Fig. 5.70) — adults parasitic on freshwater and marine fish invertebrates. *Cyclops* (Fig. 5.71) and *Doropygus*. *Ergasilus* (Fig. 5.72) and *Chondracanthus* are parasitic copepods living in marine fish and invertebrates.

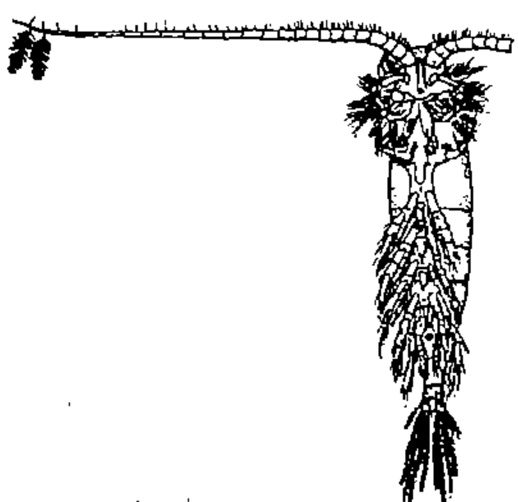


Fig. 5.68 : *Calanus.*

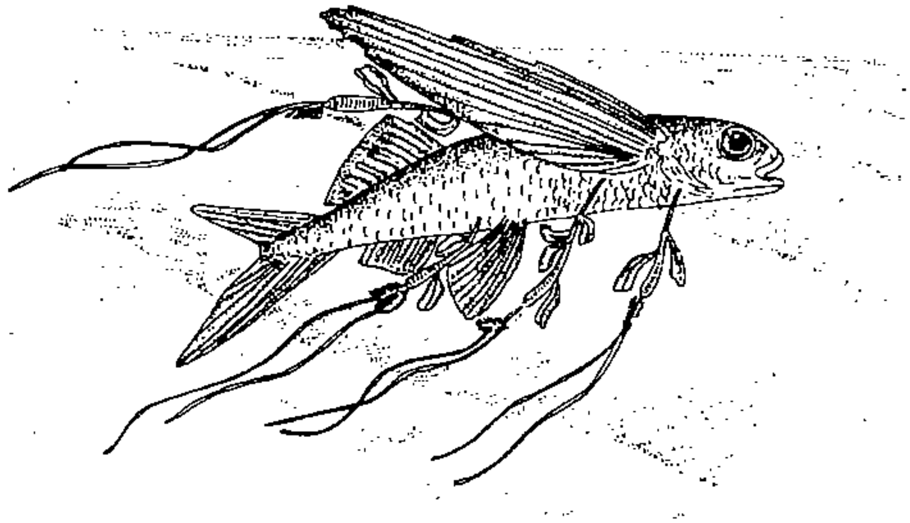


Fig. 5.70 : *Penella* attached to flying fish.

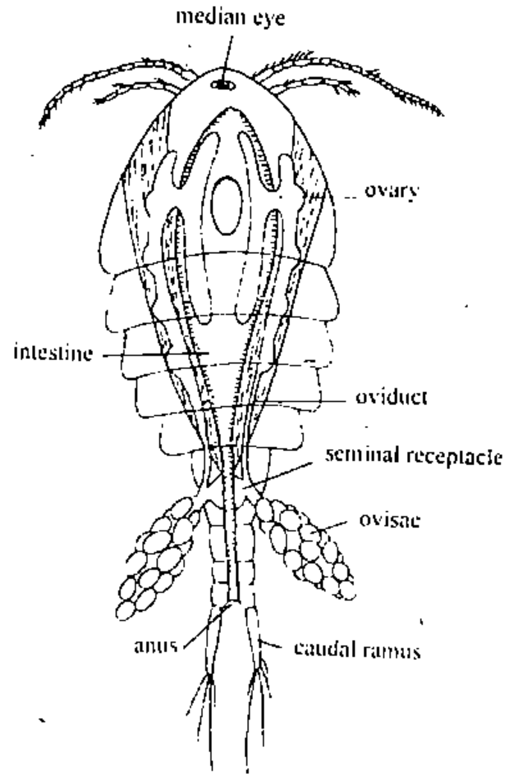



Fig. 5.71 : *Cyclops*.

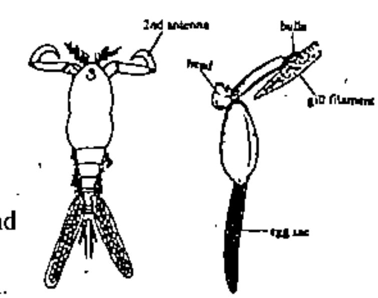



Fig. 5.72 : *Ergasilius*.

**Class 4 Branchiura:** Branchiura includes only around 130 species of ectoparasitic crustaceans living mostly on the integument and gill cavities of freshwater and marine fish, feeding on the mucus and blood of their hosts. A pair of sessile compound eyes and a large shield like carapace that covers both the head and thorax are the distinguishing features of branchiuran morphology. Abdomen is small, unsegmented and formed of two lobes. Both the pairs of antennae are much reduced. The first pair of antennae are provided with a large claw to enable organism to attach itself to the host. First pair of maxillae are also modified into large suckers aiding in the attachment to the host There are no maxillipids or they are vestigial. Mouth parts are adapted for feeding on mucus and blood of the host. The four pairs of thoracic appendages are well developed; they enable the branchiurans to swim in water and switch from one host to the other. Eggs are deposited at the bottom of the waters. The larvae that emerge are also parasitic. eg. *Argulus* (5.73) *Porocephalus*.

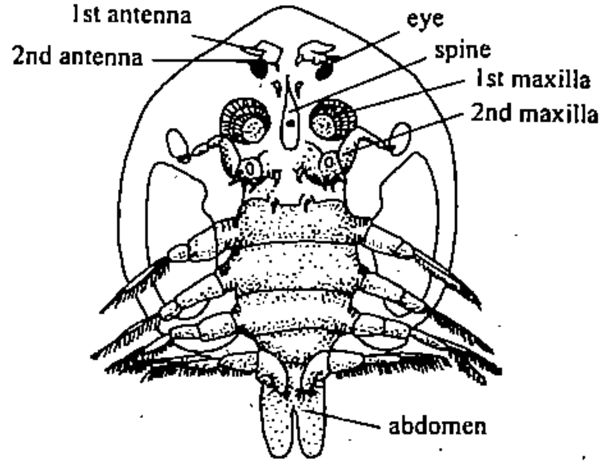



Fig. 5.73 : *Argulus*.

**Class 5 Cirripedia :** These crustaceans are exclusively marine, and include the barnacles. Most species are free living, attached to rock, shell, coral, timber and other objects. Some are commensals living on whales, fish, turtles and other organisms. Some are parasites. Free living forms are either stalked or sessile. The stalked froms (goose barnacles) measure a few mm to 75 cm in length. Sessile forms are a few centimetters long. Stalked forms have a muscular, flexible stalk or **peduncle** which is attached to the substratum at its lower end and has the major parts of the body, the **capitulum,** at the other end. The peduncle is the preoral end of the animal and bears the vestiges of the larval first antennae and the cement glands. The secretion of the cement gland is adhesive in nature. The capitulum includes the entire body except the preoral parts. The body is covered by a carapace or the **mantle.** The mantle is covered by five plates (Figs. 5.74) : a posterior dorsal plate **carina,** a pair of **terga** and a pair of **scuta.** Sessile **barnacles** are attached to the substratum by a membranous or calcareous, **basis.** This forms the preoral region of the animal and contains cement glands. The animal is surrounded by a wall of plates and within this wall the animal is covered by an operculum formed by movable terga and scuta.

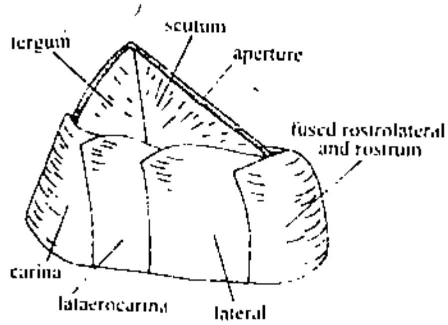



Fig. 5.74 : *Balanus-a* sessile barnacle.

Inside the shell, the soft body is held flexed at 90° to the point of attachment of the head and the thoracic appendages (cirri) are directed upward. The body is made up mostly of head and thorax. There is no external evidence of segmentation. First pair of antennae are much reduced and the second pair are absent in adults. Six pairs of long, biramous thoracic appendages called **cirri** are present (hence the name Cirripedia) (Fig. 5.75). The cirri carry many long setae on them and are useful in suspension feeding.

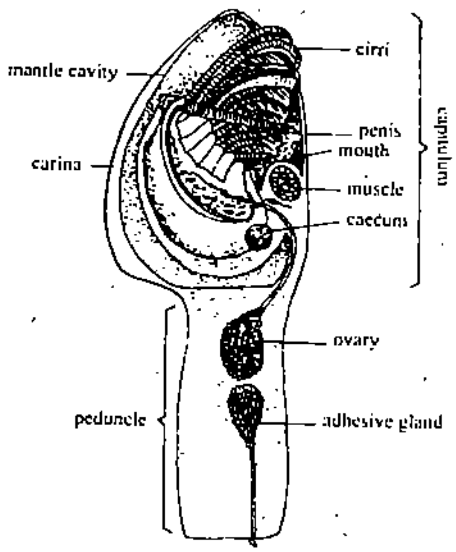



Fig. 5.75 : ***Lepas*** **- stalked barnacle — Showing internal organisation.**

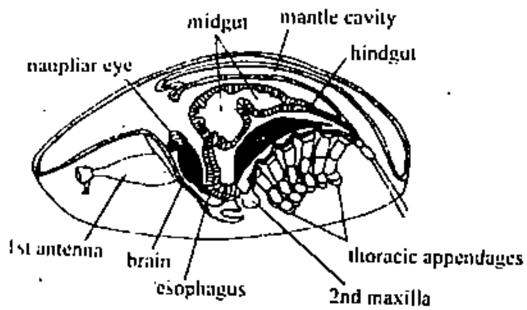



**Fig. 5.76 : Cypris larva.**

Sexes may be separate or the animals may be hermaphrodites. Sperm transfer is direct. There are six nauplius instars before the emergence of non-feeding **cypris** larva. (Fig. 5.76) The cypris larva settles onto a substratum and metamorphoses into an adult. eg. *Ascothorax*, (Fig. 5.77) *Dendrogaster* — Parasitic on invertebrates; *Trypetesa, Berndtia* — bore into calcareous substratum such as shells or corals. *Lepas* (Fig. 5.78). *Scalpellum, Verruca* are all freeliving barnacles or commensals. *Sacculina* (Fig. 5.79). *Peltogasterella* belong to the order Rhizocephala; they are parasitic barnacles living mostly in decapod crustaneans, the crabs. A few are parasitic in tunicates. Appendages and digestive system are absent. From the peduncle absorptive processes are given out to obtain nourishment from the hosts.

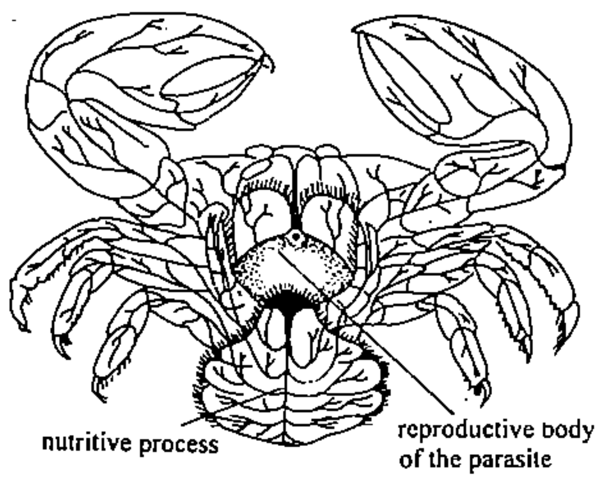



Fig. 5.79 : *Sacculina.*

Fig. 5.78 : *Lepas.*

**Class 6 Malacostraca :** Malacostraca includes most of the larger forms such as crabs. lobsters, shrimps etc. and constitute the majority of crustacean species. The cephalic region is formed by the fusion of five segments; the trunk region consists of five thoracic and six abdominal segments. Additionally, a postabdominal telson forms part of the tail fin. A carapace covering the thorax may or may not be present. The thoracic appendages called **paraeopods** or walking legs have well developed endopodites used for crawling and prehension. The thoracic legs have gills, usually modified epipodites. In many malacostracans, first pair of thoracic appendages are modified into **maxillepeds** used for feeding. The first five pairs of abdominal appendages called **pleopods** are the swimming legs. Besides swimming, they may also be used for burrowing, carrying eggs in females and often for gas exchange. In males the first pair of abdominal appendages are modified as copulatory organs.

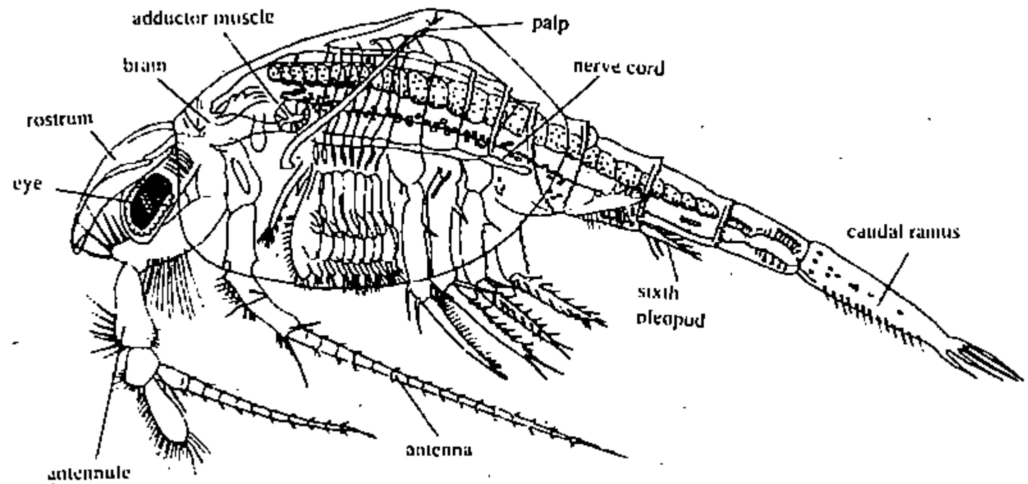



Fig. 5.80 : *Nebalia.*

Malacostracans generally have a foegut modified as a two chambered stomach with triturating teeth and comblike filtering setae. The female gonopores are located on the sixth thoracic segment and the male gonopore on the eight. The life cycle of malacostracans include many larval stages but the nauplius stage is usually passed in the egg. *Nebalia* (Fig. 5.80) in many respects differs from most other malacostracans, and is included with a few other similar species, under subclass phyllocarida (order Leptostraca). It has eight abdominal segments. The group is supposed to be the most primitive of the present day malacostracans. First thoracic segment fused with head. *Anaspides* (Fig. 5.81): Freshwater forms; *Euphausia* (Fig. 5.82); one of the krills that is pelagic in marine waters. Biramous thoracic appendages: the anterior ones are not modified into maxillipeds. Gills not tightly enclosed in a carapace.

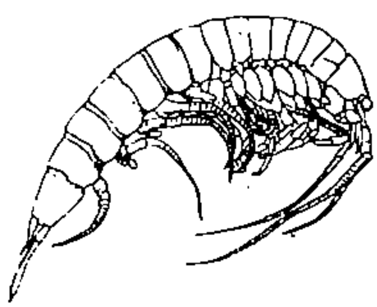


Fig. 5.81 : *Anaspides.*

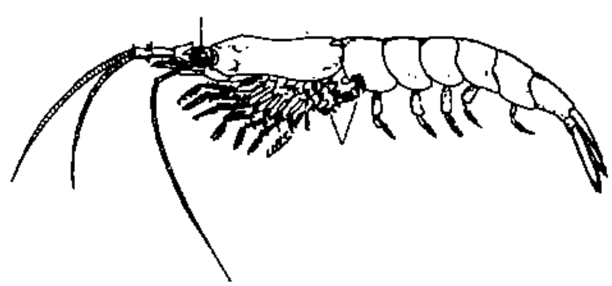


Fig. 5.82 : *Euphausia.*

In the Order **Decapoda** the first three pairs of thoracic appendages are modified as food capturing devices, the maxillipeds. Gills are tightly enclosed in carapace. This includes freshwater, brackish water and marine forms commonly known as:

Shrimps: eg. *Penaeus* (Fig 5.85) and *Palaemonetes*, *Macrobrachium* (Fig. 5.84)

Crayfish:eg. *Astacus;*

Lobsters:eg. *Homarus, Palinurus;*

Hermit crabs:eg. *Clibanarius;*

Mole crabs:eg. *Hippa,* (Fig 5.86) *Albunea;* and

Crabs:eg. *Portunus, Potamon, Uca, Ocypode.*

Other malacostracan examples are:

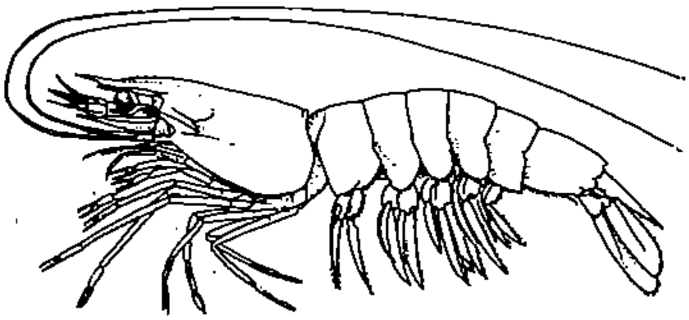


Fig. 5.83 : *Penaeus.*

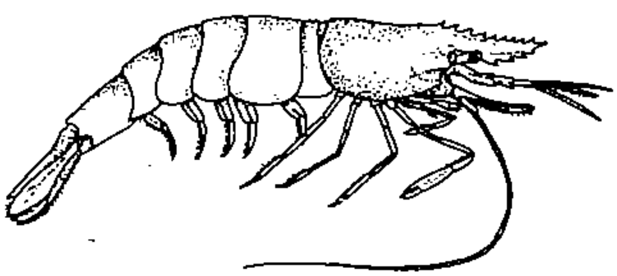


Fig. 5.84 : *Palaemonetes.*

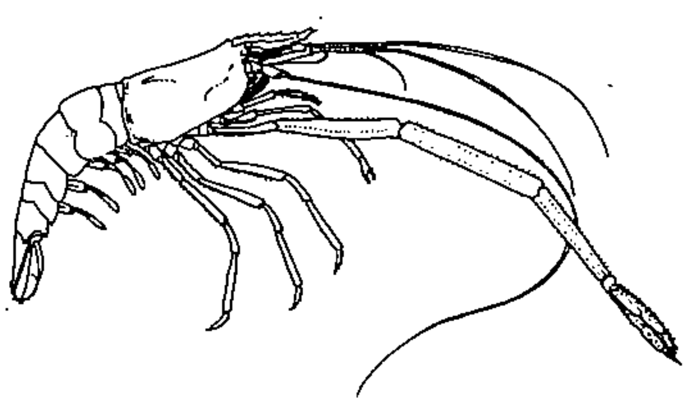


Fig. 5.85 : *Macrobrachium.*

*Mysis*; *Diastylis*, (Fig. 5.87); *Armadillidium* and *Ligia* (Fig. 5.88) are dorsoventrally flattened and terrestrial, known as wood lice, belonging to order Isopoda; *Tanais, Leptochelia.*

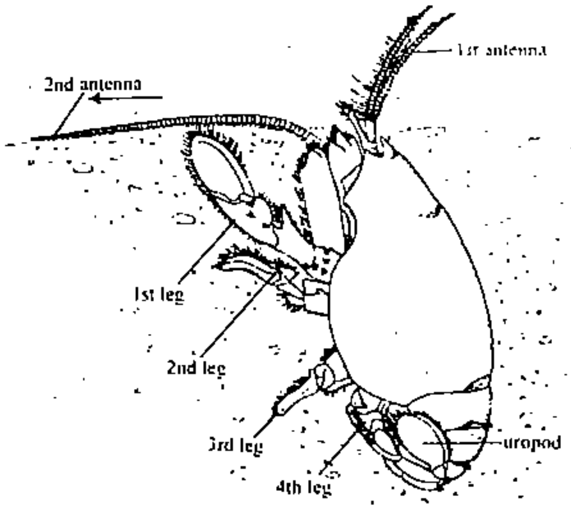



Fig. 5.86 : *Hippa.*

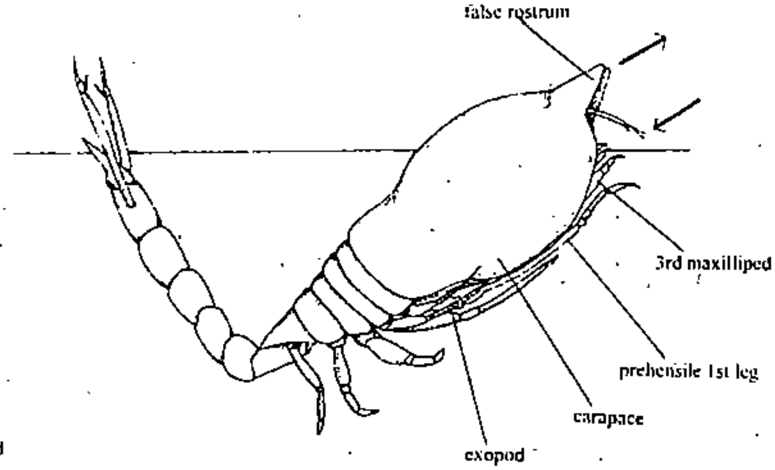



Fig. 5.87 : *Diastylis.*

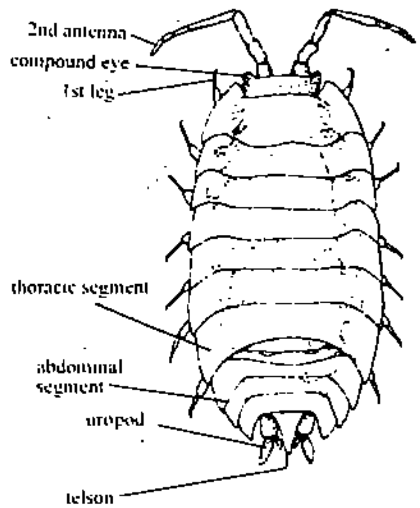



Fig. 5.88 : *Ligia.*

## SAQ 4

I. Indicate whether the following statements are true or false.

1. In most crustaceans there is fusion of head and thorax to form cephalothorax. T/F
2. There are six pairs of appendages in the head of crustaceans corresponding to six segments. T/F
3. Protopodite, exopodite and endopodite are three divisions of the appendages of crustanceans. T/F
4. In crustaceans maxillipeds are the trunk appendages modified for filter feeding. T/F
5. Trachea are the respiratory structures of crustaceans. T/F
6. The excretory organs of crustaceans are called antennary or maxilliary glands depending on their position. T/F
7. Most crustaceans are hermaphrodites. T/F
8. Crustaceans mostly undergo direct development into adults, without passing through larval stages. T/F
9. Malacostracans account for over 60% of all the crustaceans. T/F
10. Crabs, molecrabs and horseshoe crabs are all the members of the subphylum Crustacea. T/F

II, Match the items in A with those in B

| | | | |
|---|---|---|---|
| A. | Branchiopoda | (i) | Mussel Shrimps |
| B. | Ostracoda | (ii) | Barnacles |
| C. | Copepoda | (iii) | *Argulus* |
| D. | Branchiura | (iv) | Lobsters |
| E. | Cirripedia | (v) | Water fleas |
| F. | Malacostraca | (vi) | *Cyclops* |

### 5.3.4 Subphylum Uniramia

Uniramia, the largest subphylum of phylum Arthropoda includes myriapods and insects. Because of the unbranched nature of the appendages of its members, the subphylum is designated Uniramia, as against those of crustaceans and primitive chelicerates that are branched and hence biramous. The uniramians have mandibles which are non-jointed, unbranched appendages without any palps; there have only a single pair of antennae which correspond to the second cephalic segment (second antennae). Uniramians having taken to terrestrial mode of life, have developed trachea as gas exchanging organs; hence the subphylum is also known as **Tracheata.** Malpighian tubules are the excretory organs. Uniramia includes over a million species of arthropods, of which nearly a million species are insects. About 10,500 species belong to four other classes **Chilopoda, Diplopoda, Pauropoda** and **Symplyla.** These latter four groups are collectively known as myriapodous arthropods. Let us now study briefly the class characters of each class of subphylum Uniramia.

**Class 1 Chilopoda** : Chilopoda comprise the centipedes (Fig. 5.89). The class contains some 2500 species that have been described so far. They inhabit both tropical and temperate regions of the world, living in soil and humus, beneath stones, barks and logs.

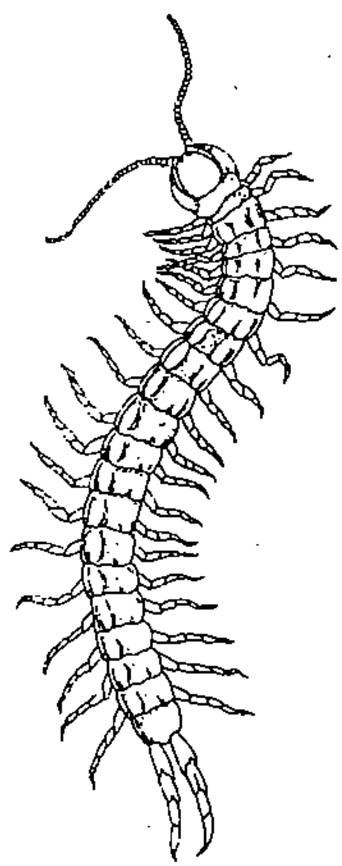


**Fig. 5.89 : A centipede.**

They have somewhat flattened body and generally measure from 3-20 cm in length and are red, brown, green, blue, yellow or in combination of these colours. A pair of **antennae**, a pair of **mandibles** and two pairs of **maxillae** are the appendages of the head. Covering these mouth parts, there is a large pair of maxillipeds (forcipules or the poision claws) which are the appendages of first pair of trunk segments. Each forcipule ends in a terminal pointed fang through which the duct of the poision gland opens. Following the first trunk segment there may be 15 or more trunk segments each having a pair of legs and the last pair of legs has sensory or defensive function. Appendages are usually absent in the last two trunk segments. These animals are generally adapted for running. For this purpose the legs are long and are of same length. The centipedes are predaceous and feed mostly on other arthropods. Prey is paralysed with forcipules. Some forms, partial digestion of the food may occur before ingestion. The digestive system (Fig. 5.90) is a straight tube and the salivary glands open into the buccal region. Gas exchange is carried out by the tracheal system and usually there is one pair of spiracles per segment. The spiracles cannot be closed. Many of the chilopods have a single pair of Malpighian tubules.

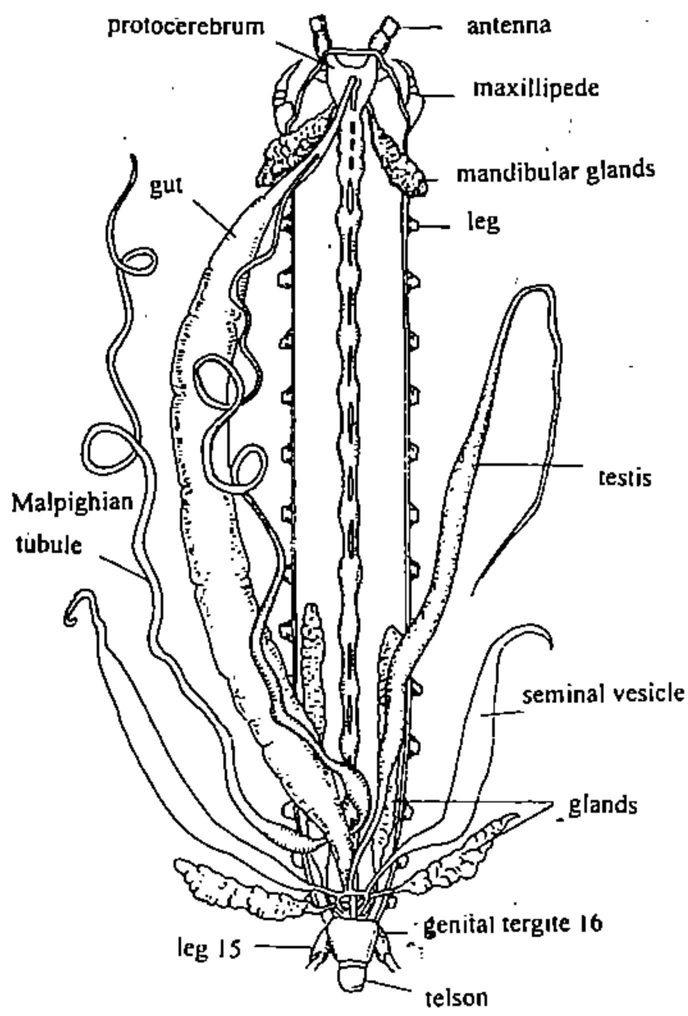



**Fig. 5.90 : Internal structure of a centipede.**

The nervous system is typical arthropodan. Eyes are absent in many; but in some forms a few to many ocelli may be present. Many chilopods have a sense organ called **organ of Tomosvary** of uncertain function located in the head at the base of antennae. It may detect vibrations. The ovary is an unpaired, tubular structure lying above the gut and the oviduct opens to the exterior by an aperture located on the ventral surface of the posterior legless ventral segment. The testes are paired and the common genital duct also opens by a median gonopore on the ventral side of the posterior genital segment. The genital segment of both sexes carries small appendages called gonopods. Sperm transfer is indirect, via spermatophores. Centipeds exhibit elaborate courtship behaviour. The young hatching out of the egg, may have full complement of segments (**epimorphic development**), or in some species the young may have only a limited number of segments (**anamorphic development**); the rest they acquire later.

**Examples:**

*Geophilus*, (Fig. 5.91) *Strigamia*; *Scolopendra*, (Fig. 5.89) *Theatops*; *Lithobius* (Fig. 5.92); *Scutigera* (Fig. 5.93), young ones do not possess the full complement of segments on hatching. Adults have 15 pairs of legs.

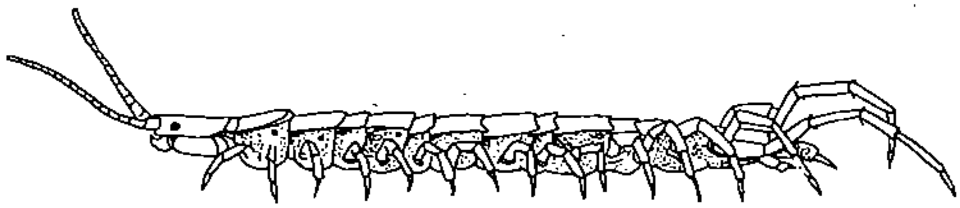


Fig. 5.92 : *Lithobius*.

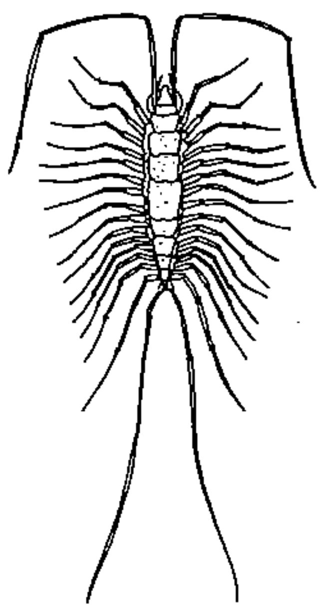


Fig. 5.93 : *Scutigera*.

**Class 2 Diplopoda :** Diplopoda comprise the millipedes which are nocturnal and live beneath leaves, stones, bark and logs as well as in soil an in caves. As the name indicates, these have large number of legs. They are mostly cylindrical and are abundant in the tropics. They vary in size from 2 mm as in *Polyxenus* to nearly 30 cm as in *Spirostreptus*. The distinguishing features of diplopods is the presence of **diplosegments** (Fig. 5.94), formed by the fusion of two originally separate segments. Each diplosegment bears two pairs of ventral ganglia, two pairs of legs, two pairs of ostia in the heart and two pairs of spiracles. The head bears a pair of large chitinuous mandibles and a fused pair of maxillae called **gnathocilarium** (Fig. 5.95). The second pair of maxillae are absent. The first segment following head is legless and is called the **collum.** The collum is not a diplosegment. The second, third and fourth segments carry only one pair of legs. In some millipedes the last five segments may also be legless. The trunk ends in a telson at the base of which the anus opens. The exoskeleton of most of the millipedes is impregnated with calcium carbonate.

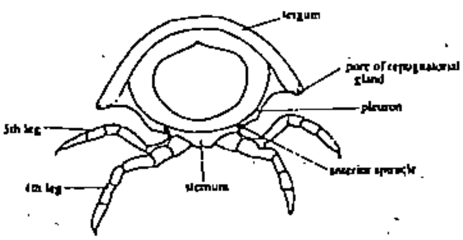



Fig. 5.94 : A diplosegment.

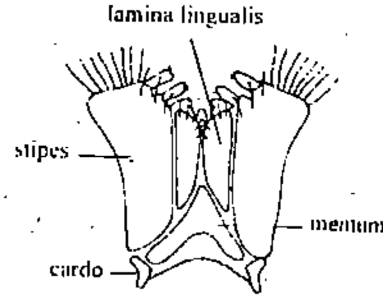



Fig. 5.95 : Gnhathocilarium.

Millipedes are generally herbivorous, feeding on decomposing vegetation. The food moistened by salivary secretions is scraped by mandibles. Some millipedes feed on plant juices. A few are carnivorous predating on insects, earthworms and centipedes. Respiration is by tracheal system. Each diplosegment has two pairs of spiracles in the sternum. There is a tubular heart that ends blindly posteriorly but continues anteriorly as an aorta. Excretion is by a pair of Malpighian tubules. Eyes are generally absent but some forms of have ocelli which vary 2 to 80 in number. The tactile hairs and conical projections present in antennae serve as chemoreceptors. As in centipedes, organ of Tomosvary is present in millipeds also.

A pair of long, fused tubular ovaries are present. The two oviducts open separately into a pouch like atrium located in the third segment known as genital segment. Testes appear as paired structures with transverse connections. In males the sperm ducts open at the base of the second pair of legs. Millipèdes also fabricate spermatophores for sperm transfer. As in centipeds there is courtship behavour prior to mating. Most millipedes reproduce parthenogenetically. Development is anamorphic. The eggs which hatch after several weeks produce young ones with only three pairs of legs and seven segments. Additional legs and segments are added with each moult.

**Examples:**

*Polyxenus* (Fig. 5.96), *Lophoproctus*: minute, with soft integument. The integument has scale like setae, 13 to 17 pairs of legs are present. No gonopods. Distribution is worldwide; *Glomeridesmus*, *Sphaerotherium* (Fig. 5.98), and the pill millipede: *Glomeris* (Fig. 5.99) are the forms with arched tergal plates: last two pairs of legs modified for clasping; *Polyzonium*, (Fig. 5.97); *Narceus*, *Rhinocricus*, *Spirostreptus*, (Fig. 5.100) *Orthoporus*; *Julus*, *Blaniulus*, *Chordeuma* (Fig. 5.101) have one or two pairs of legs located on the seventh segment are modified as gonopods for sperm transfer; *Polydesmus*, *Oxidus*, flat back, with lateral tergal keels; gonopods present; *Cleidogona*, *Chordeuma*.

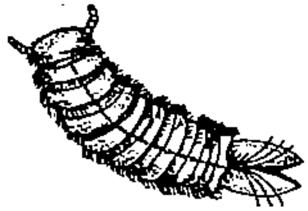


Fig. 5.96 : *Polyxenus.*

Fig. 5.97 : *Polyzonium.*

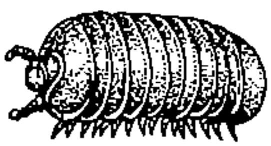


Fig. 5.98 : *Sphaerotherium.*

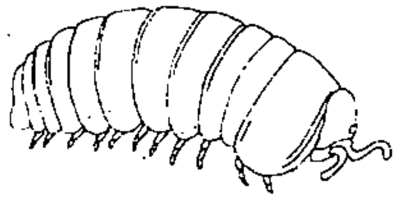


Fig. 5.99 : *Glomeris.*

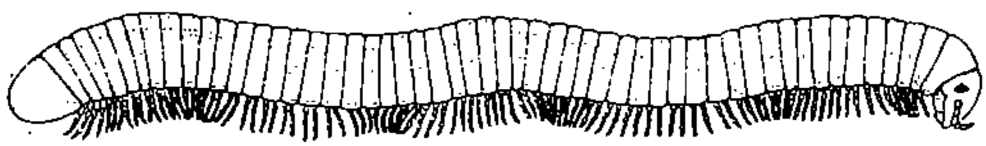


Fig. 5.100 : *Spirostreptus.*

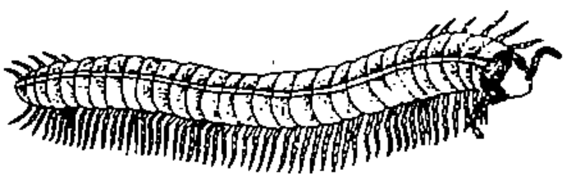


Fig. 5.101 : *Chordeuma.*

**Class 3 Pauropoda :** A small group of uniramians, there are 500 species of pauropods described so far. The minute organisms measuring about 1.5 mm in length, live in leaf mold or in soil. The body is eleven segmented and nine of them bear a pair of legs each. The first and eleventh segments are legless. The tergal plates are very large, overlapping adjacent segments. The collum of pauropods is inconspicuous dorsally but expanded ventrally. The head bears on each side a sense organ comparable to the organ of Tomosvary. The antennae are biramous. One branch ends in a single flagellum and the other in two flagella and a club shaped sensory structure. Pauropods mostly feed on decomposing plant tissue. Heart and trachea are usually absent owing to the small size of the organism. The third trunk segment is the genital segment. Sperm transfer is indirect and via spermatophores. Development is anamorphic. Examples: *Pauropus.* (5.102) *Allopauropus*

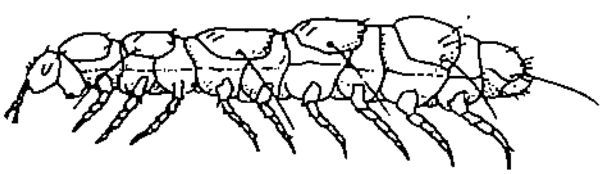


Fig. 5.102 : *Pauropus.*

**Class 4 : Symphyla :** Symphyla is yet another small myriapodous group that includes around 160 described species. These are also soil living forms and live in leaf molds as well. They measure around 1 to 8 mm in length and have a trunk made of 13 segments but 15-22 tergal plates. Only 12 segments bear a pair of legs each and the 13th segment bears a pair of cerci or spinnerets. The 13th segment also bears a pair of sensory hairs called **trichobothria.** These animals can run rapidly through humus. The trunk terminates in a tiny telson. Mouth parts include a pair of mandibles, two pairs of maxillae of which the second pair of maxillae is fused to form labium. A pair of spiracles opens, on each side of the head and the trachea arising from them supply only the first three segments. Eyes are absent but a pair of Tomosvary's organs are present. Symphylans exhibit peculiar copulatory behaviour. The males deposit 150 to 450 spermatophores which are swallowed by the female. There are stored in special buccal pouches. Then she releases the eggs through a single gonopore located on the ventral surface of the fourth segment. The eggs are attached to the substratum and the sperms are smeared over the eggs by the female to fertilise them. Development is anamorphic. Parthenogenesis is also common in symphylans eg. *Scutigeralla* (Fig. 5.103).

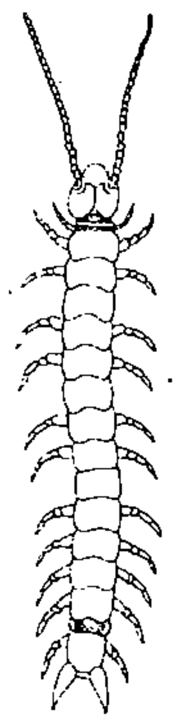


Fig. 5.103 : Scutigeralla.

## SAQ 5

Write brief answers to the following questions:

1. Why is the name Uniramia given to centipendes, millipedes and insects?
2. Name the five classes included under the subphylum Uniramia?
3. Name the cephalic appendages of chilopods.
4. What is a diplosegment?
5. a. The fused pair of maxillae of millipedes is called ________________.
   b. The legless first trunk segment of millipedes is ________________.
6. What is the peculiarity of the antennae of pauropods?
7. What is the sperm transfer mechanism in symphylans?

**Class 5 Insecta** : Class Insecta contains nearly a million described species. There are more species of insects than all the other species of animals combined. The most important characteristic features of insects are the division of body into three tagmata namely, head, thorax and abdomen; presence of three pairs of legs and two pairs of wings on the thoracic region of the body, though some insects may have no wings.

Insects have conquered the terrestrial environment so completely that they occupy every possible niche. They have also invaded the aquatic habitats though there are only a few marine species. Insects affect the ecology and human life in a number of ways. They have been both friends and foes of man. Evolution of flight, an impermeable cuticle and tracheal respiration are some of the factors that have contributed to their success on land.

The head of insects is a composite structure. It bears a pair of antennae and a pair of compound eyes. There are also usually three ocelli. Three pairs of appendages constitute the mouthparts. They are, a pair of **mandibles** and two pairs of **maxillae**, of which the second pair of maxillae are fused to form the **labium**. The mandibles are covered in front by an upper lip or labrum. Into the anterior region of buccal cavity projects a median lobe like process, the **epipharynx**. This arises from the base of the labium.

The head is followed by a three segmented thorax — **prothorax, mesothorax** and **metathorax** (Fig. 5.104). The tergum of the thoracic segments of insects is known as **notum**. The two pairs of **wings** articulate with meso and metathorax. While some primitive insects do not have wings (apterygotes), some higher forms have lost their wings secondarily. A pair of legs articulate with each of the three thoracic segments. Each leg is a jointed structure formed by **coxa, trochanter, femur, tibia, and tarsus.** The legs of different insects are variously modified to suit various functions like walking, food collecting etc. The abdomen is composed of 9 to 11 segments. Abdomen bears a pair of sensory structures called **anal cerci** on the 11th segment. An intromittent organ in males for the transfer of spermatozoa and an ovipositor in females for the deposition of eggs are also present in the genital segments of insects.

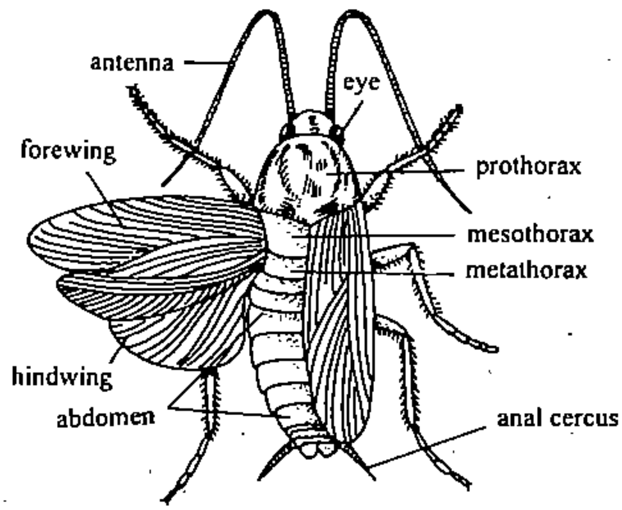



Fig. 5.104 : Cockroach external organisation.

**Mouth parts:**

Insects have adapted themselves to a variety of food habits. Consequently their mouth parts, the organs of feeding, are also variously modified.

These can be broadly divided into two types: (1) Mouth parts adapted for biting and chewing solid food. These are considered more primitive (2) Those adapted for sucking up liquid food. These are derived from the former, by elongation of certain components and loss of certain other.

1. **Biting and chewing type** : These are found in many insects like the primitive apterygotes, crickets, grasshoppers, cockroaches etc. They consist of an unpaired **labrum** or upper lip in front of the mouth; a pair of **mandibles** and a pair of **maxillae** along the sides, and a **labium** forming the lower lip (Fig. 5.105) There is also a median hypopharynx behind the mouth.

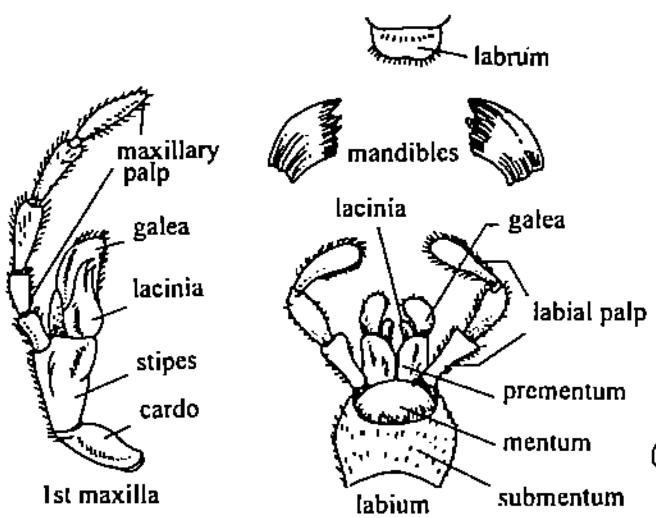



Fig. 5.105 : Mouth parts of cockroach.

The mandibles are strongly sclerotised, often differentiated into a biting incisor region and a chewing molar region. They are provided with strong muscles, and are articulated with the cranium.

The maxillae are made up of many parts. The proximal part has a basal cardo, and a flat distal stipes. The stipes carries two lobes; an inner lacinea and an outer galea; the stipes also has an outer, jointed palp. The palp is sensory by means of which the insect checks the quality of food. By means of lacinea and galea, food is scraped into mouth; they are also used for cleaning.

The labium is comparable in structure to the maxillae, but fused along the median line. It has a basal postmentum which is constituted by a proximal submentum and a distal mentum. Mentum carries a prementum in front. The prementum has four lobes in front two glossae medially and two paraglossae laterally. Glossae, together with paraglossae are known as ligula. Prementum also carries a pair of jointed palps laterally. The hypopharynx is a lobe behind the mouth; the duct of the salivary glands opens at its base.

2. **Sucking type:** In moths and butterflies, the mouth parts are adapted for sucking nectar from flowers (Fig. 5.106). Here, the two galea form a long tube (proboscis) for sucking food. The proboscis is kept coiled when the insect is not feeding.

In bees (Fig. 5.107) the galeae and labial palps form a tube around the long fused glossae. Labrum and mandibles are retained in the chewing condition, to handle pollen and wax.

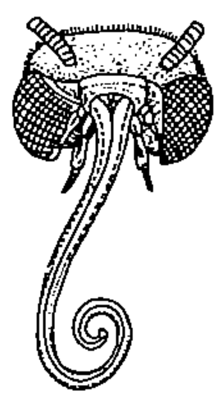


**Fig. 5.106 : Mouth parts of a butterfly.**

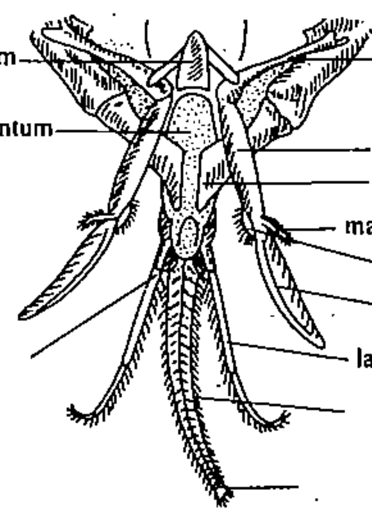



**Fig. 5.107 : Mouth parts of a honeybee.**

Piercing mouth parts are found in insects such as plant bugs and aphids which suck plant juice, as well as in blood sucking insects like mosquitoes. In these insects, the mouth parts are elongated to form a long beak in different ways. In bugs (Fig. 5.108) the mandibles and maxillae form opposing stylets. These lie in the labium which forms a groove covering them. The paired stylets form separate salivary and food canals. In mosquitoes (Fig. 5.109) however, labrum and the labium together form the food canal, whereas the salivary canal runs through the hypopharynx.

In the biting flies the sharp mandibles produce a wound; the blood coming out is collected by a sponge like labium, and carried to the mouth by means of a tube formed of hypopharynx and part of the labrum (epipharynx). In house flies (Fig. 5.110) sponge-like labium serves the purpose, mandibles being reduced. Closely associated with sucking type of mouth parts, often, a feeding pump for drawing up liquid food, and salivary pump for injecting saliva are also present.

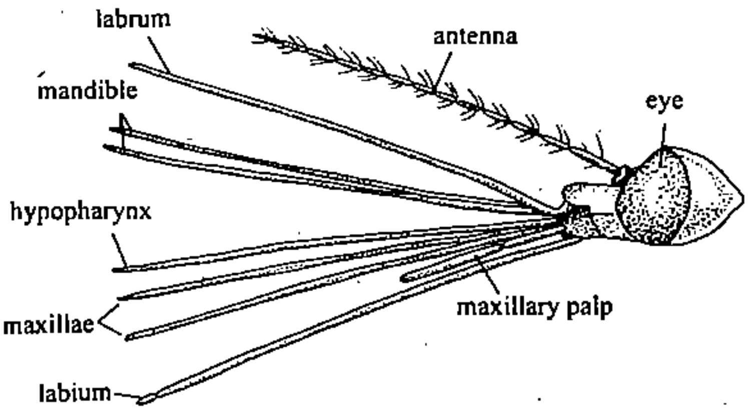



Fig. 5.109 : Mouth parts of a mosquito.

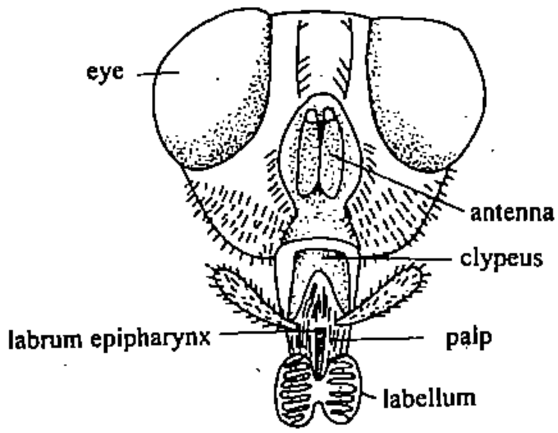



Fig. 5.110 : Mouth parts of a house fly.

The alimentary canal (Fig. 5.111) of insects has three regions, the **foregut, the midgut** and the **hindgut.** The foregut and hindgut are lined with cuticle and the midgut with a **peritrophic membrane.** The foregut consists of a **pharynx, oesophagus, crop** and **proventriculus** or **gizzard.** Many insects possess a pair of salivary glands as digestive glands. The midgut, variously named as ventriculus or mesenteron is a tubular structure and is the main site of enzyme secretion and digestion. At the junction of foregut and midgut, fingerlike projections called gastriç caeca or hepatic caeca are present. The hindgut shows three divisions, **ileum, colon** and **rectum.**

The body cavity of the insect is a blood filled space called **haemocoel.** Structures called **fatbody** are present in haemocoel. Fatbody is the site of storage in insects and is comparable to liver of vertebates in its functioning.

The circulatory system consists of a tubular heart that is enclosed in a pericardium. (5.112). The tubular heart extends through the first nine abdominal segments. Anteriorly the heart continues as aorta. The blood contains a variety of haemocytes. It plays very little role in gas exchange. Gas exchange is carried out by a well developed **tracheal system** (Fig. 5.113). Eight to ten pairs of spiracles are generally located on the lateral surface in the plural memberane. The spiracle leads into a trachea which branches and finally end in minute tubules the **tracheoles** (Fig 5.114). Exchange of gases occurs by diffusion. Aquatic insects which utilise dissolved oxygen in water have structures called **gills** (eg. larvae of dragonflies and of mayflies). Aquatic insects which depend on the atmospheric air for their oxygen needs, trap air in the form of bubbles or film held against the body surface by special unwettable hydrofuge hairs.

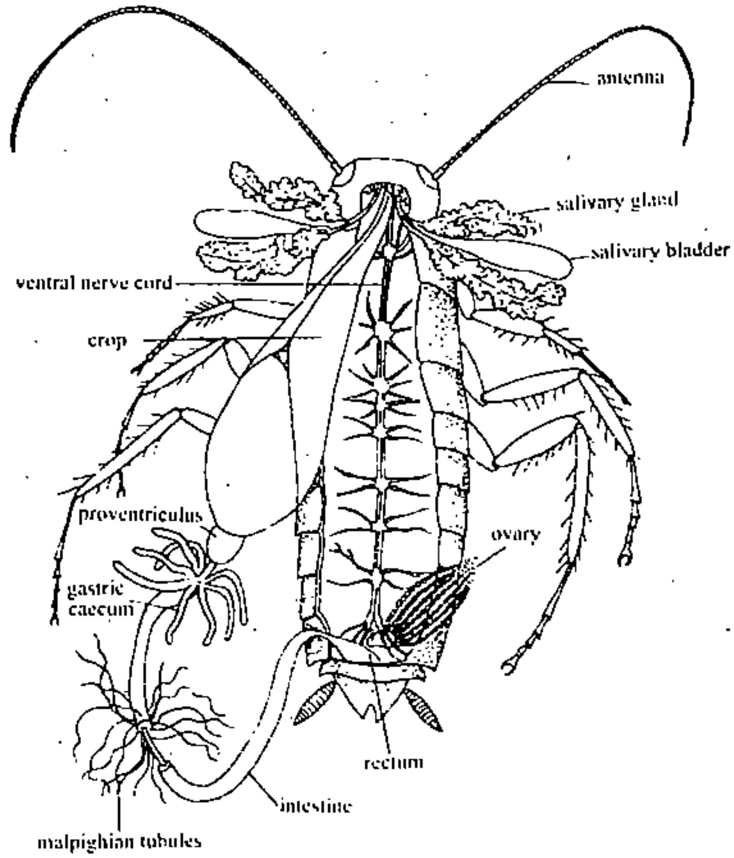



Fig. 5.111 : Viscera of a cockroach.

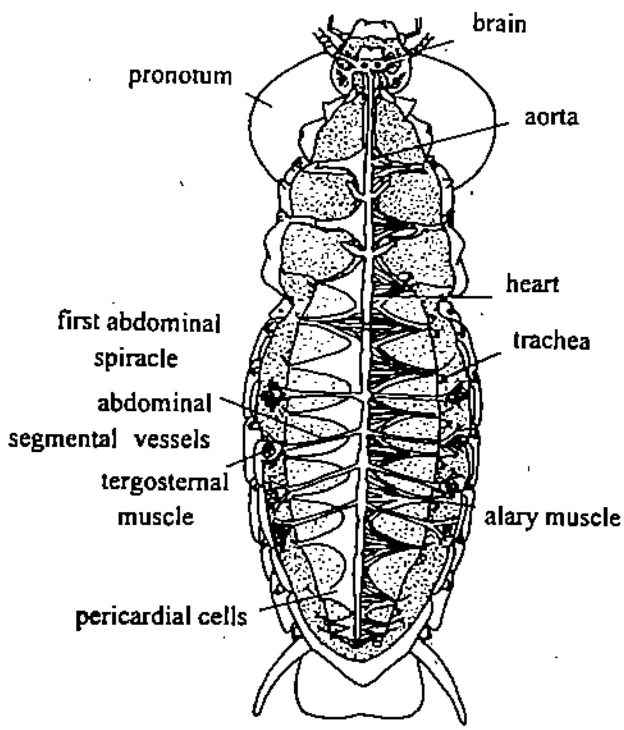



Fig. 5.112 : Circulatory system of cockroach.

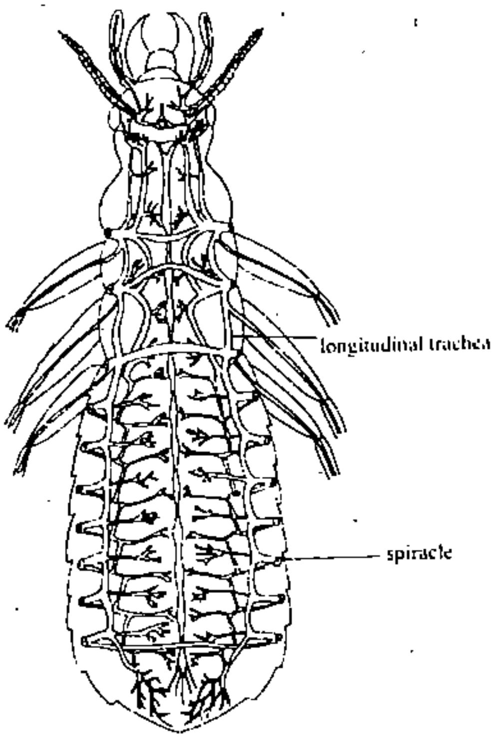



Fig. 5.113 : Tracheal system of cockroach.

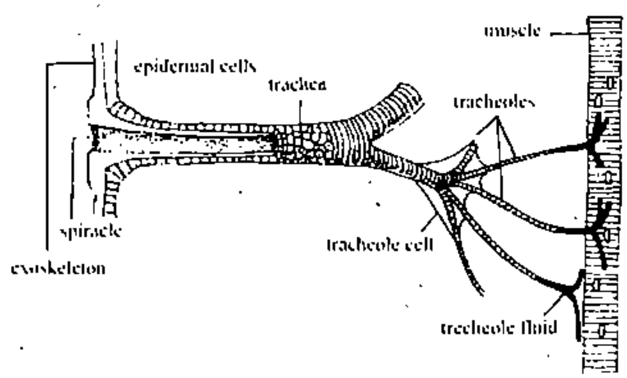



Fig. 5.114 : Tracheoles and their ending in tissues.

In most insects excretion is carried out by Malpighian tubules. The Malpighian tubules are attached to the junction of midgut and hindgut and their distal ends lie freely in the haemocoel. The tubules vary in number from two to 250.

Insects possess typically arthropodan nervous system. Brain, suboeohageal ganglia, double ventral nerve cord and segmental ganglia are the components of nervous system. In some insects the fusion of ganglia has taken place more commonly in the abdomen. **Corpora cardiaca** and **corpora allata** located ventral to the brain. and prothoracic glands are the endocrine glands in insects that regulate the growth, metamorphosis and reproduction.

Most insects have well developed compound eyes. In addition, various types of sensilla also occur all over the body, and in large numbers at particular places forming peculiar organs discharging various functions. **Tympanic organs** for examples, are found in grasshoppers, cicadas and crickets.

In females the reproductive system consists of a pair of ovaries (Fig 5.115a) . Each ovary is formed of tubular structures called **ovarioles**, and paired oviducts which unite to form a common oviduct. The common oviduct opens ventrally in the 7th, 8th or 9th segment. **Spermathecae or seminal receptacles** which are the sperm storage structures and various accessory reproductive glands are also present. The male reproductive system consists of a pair of testes, a pair of lateral ducts and a median duct that opens through a ventral penis called **aedeagus** located in the 8th segment (Fig 5.115b). Sperm transfer may be direct of as spermatophores. Development may occur without metamorphosis as in silver fish, or incomplete metamorphosis as in bugs where the young ones resemble the adults except for the development of wings and reproductive organs. Complete metamorphosis (5.116) occur in many as in butterflies, beetles and houseflies. In these insects the larva does not resemble the adult, and develops into a nonfeeding quiescent **pupa** before becoming as adult.

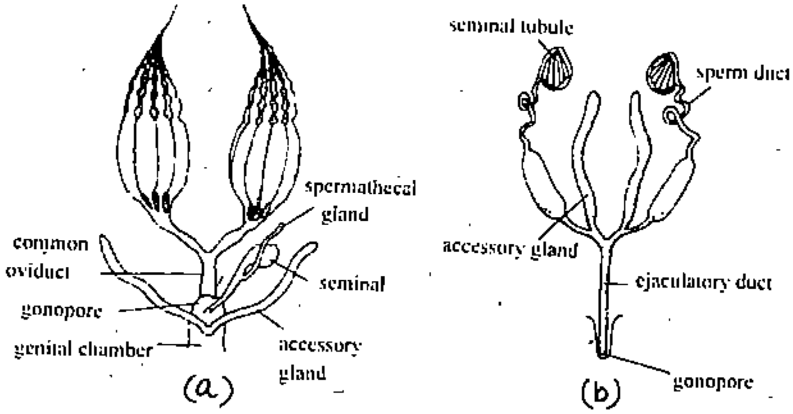



**Fig. 5.115 : Reproductive system of an insect. (a) female (b) male**

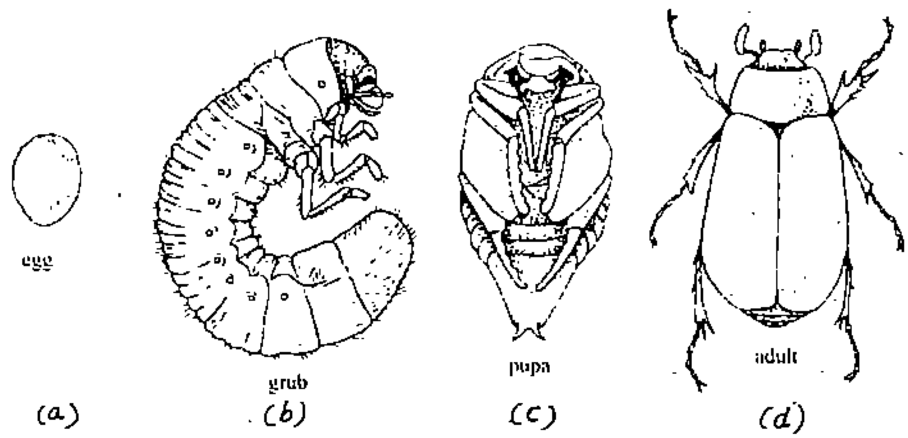



**Fig. 5.116 : Complete metamorphosis in a beetle.**
**(a) egg (b) grule (c) pupa (d) adult**

Examples: see the classification chart (Fig. 5.117).

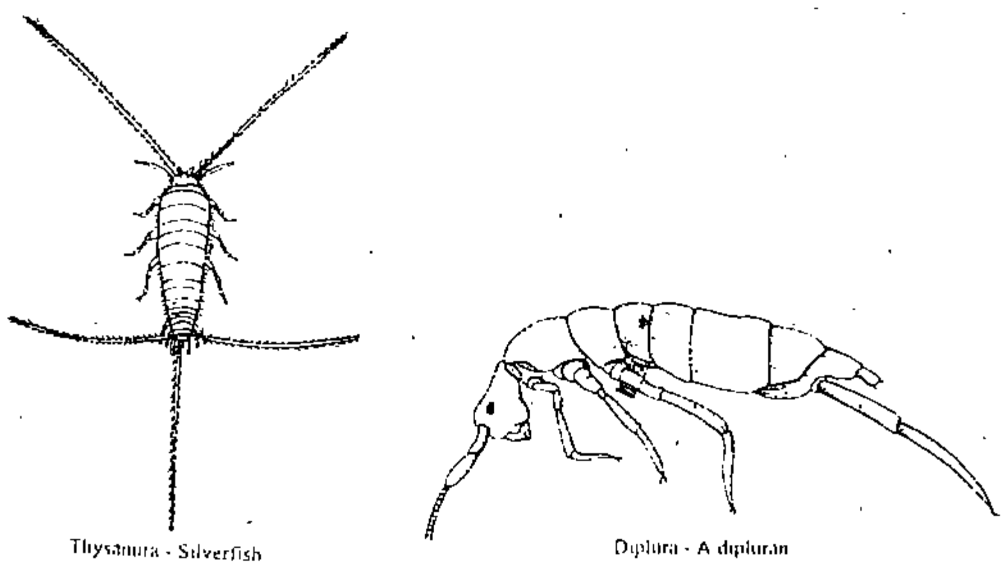
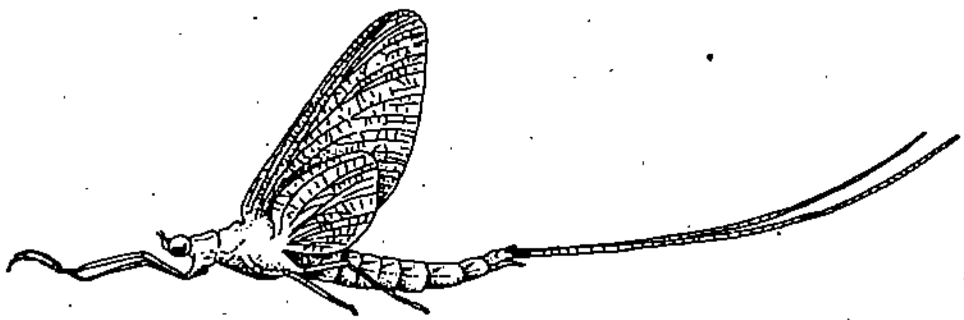
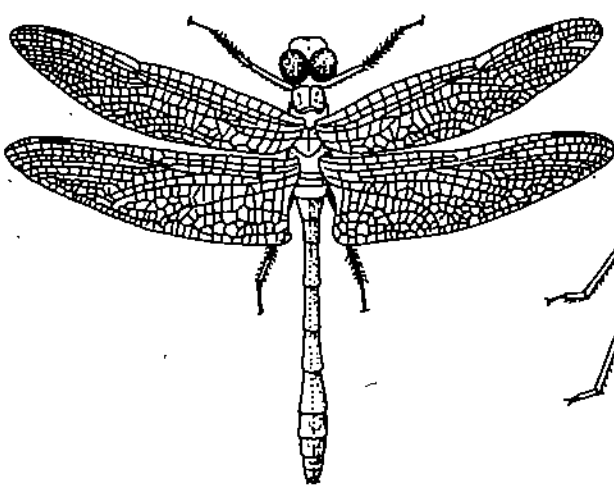




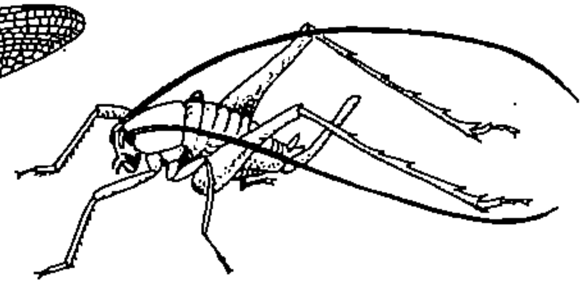

**Fig. 5.117 : Example of insects.**



Ephemeroptera - Mayfly

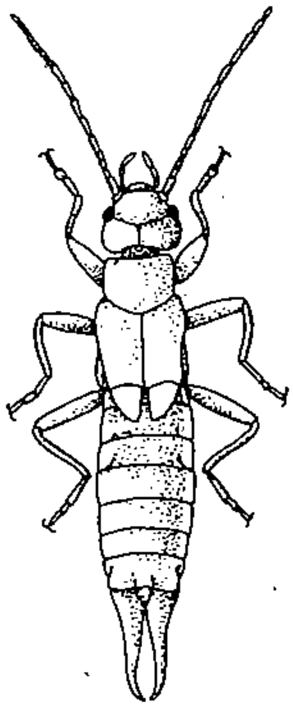


Odonata - Dragonfly

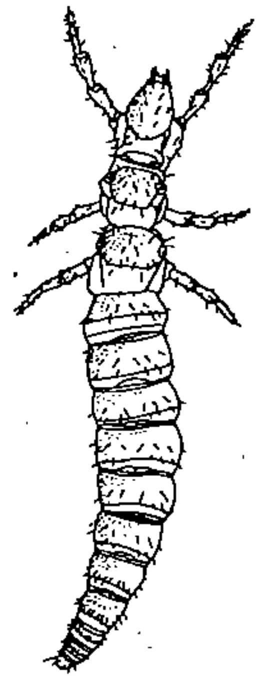


Orthroptera - Cricket

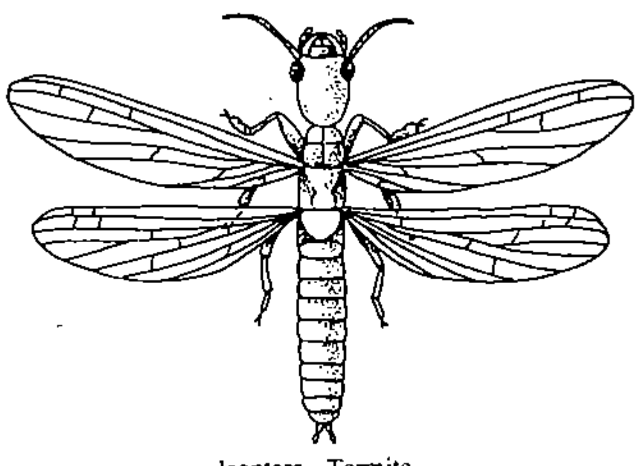
Example of insects (Contd.)



Dermaptera - Earwig



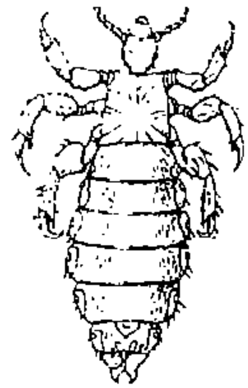
Protura - A proturan



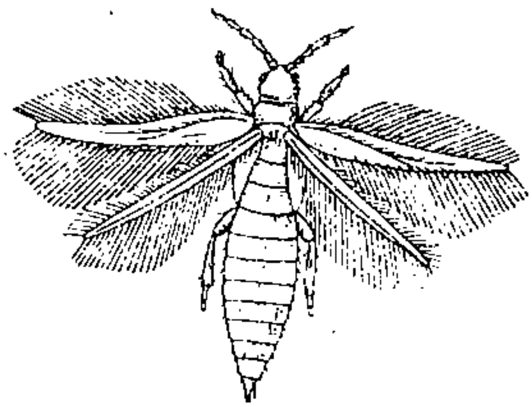
Isoptera - Termite



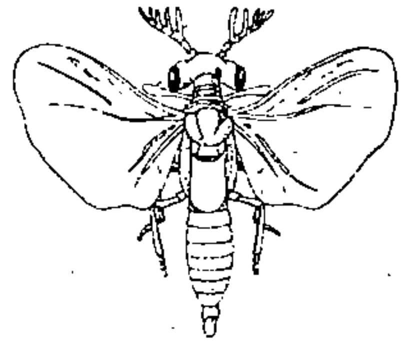
Example of insects (Contd.)



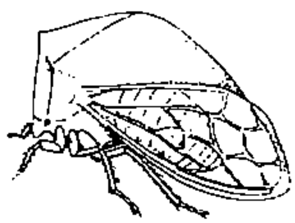
Mallophaga - Head louse



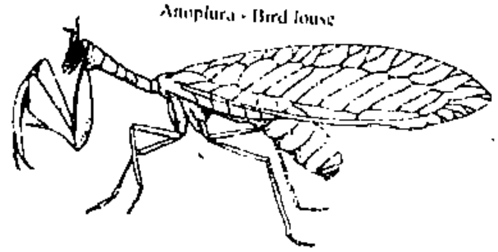
Anoplura - Bird louse



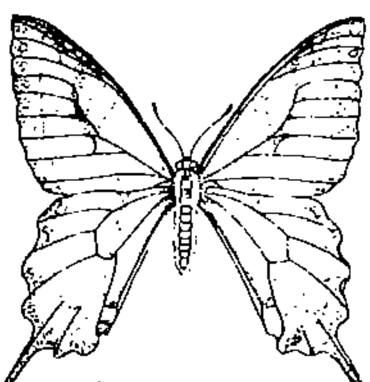
Strepsiptera - Twisted wing parasite



Homoptera - Tree hopper

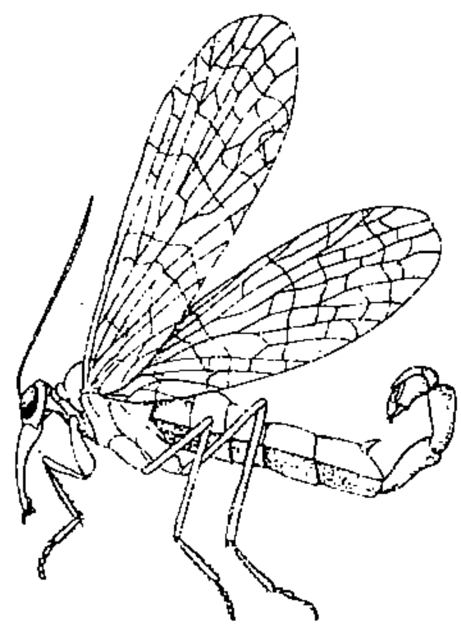


Trichoptera - Caddis fly

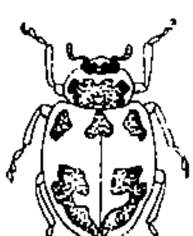


Lepidoptera - Butterfly

Diptera - House fly



Mecoptera - Scorpion fly



Coleoptera - Beetle

Siphonoptera - Flea

**Example of insects (Contd.)**

## SAQ 6

I. State whether the following are true of false:

1. Class insecta is the largest class in the animal kingdom. T/F
2. The presence of three pairs of legs, main digestive system and the presence of mouthparts are the reasons for the success of insects in terrestrial environment. T/F
3. The body of insects is made up of three tagmata. T/F
4. The two pairs of insect wings are articulated with pro and mesothorax. T/F
5. The mouth parts of all adult insects are identical in structure despite the differences in their food habits. T/F
6. Haemocoel is the site of intermediary metabolism in insects. T/F
7. The exchange of gases in the tracheal systel of insects occurs by diffusion. T/F
8. All aquatic insects depend on dissolved oxygen in water for their respiratory needs. T/F
9. The secretion of prothoracic glands regulate metamorphosis in insects. T/F

II. Match the insects listed in A to their respective orders listed in B.

| A | | B | |
|---|---|---|---|
| 1. | Silver fish | a. | Lepidoptera |
| 2. | Grasshopper | b. | Coleoptera |
| 3. | Plant bug | c. | Hymenoptera |
| 4. | Dragonfly | d. | Ephemeroptera |
| 5. | Mayfly | e. | Thysanura |
| 6. | Housefly | f. | Hemiptera |
| 7. | Beetle | g. | Odonata |
| 8. | Moth | h. | Orthroptera |
| 9. | Wasp | i. | Isoptera |
| 10. | Termites | j. | Diptera |

## 5.4 PHYLUM ONYCHOPHORA

### Characteristic Features

1. Free living, terrestrial.
2. Body is bilaterally symmetrical, elongated, cylindrical, vermiform, with tissues and organs.
3. Body wall has thin flexible, chitinuous cuticle over epidermis; layers of circular, oblique and longiotitudinal smooth muscles beneath.
4. 14-43 pairs of short, unjointed, fleshy legs which are hollow invaginations of body wall with terminal pad and terminal claws.
5. Gut straight, complete, with a pair of claw-like mandibles; foregut and hindgut lined with cuticle; no digestive diverticula.
6. Body cavity is a well developed haemocoel.
7. Open circulatory system with tubular heart but no other blood vessels; paired ostia present.
8. Serial pairs of excretory organs: anteriorly they form salivary glands and posteriorly gonadoducts.
9. Respiration through tracheae which are simple and tubular but appear in bundles, opening out through large number of small spiracles scattered all over the body.
10. Nervous system consists of a brain and ladder-like ventral nerve cord widely separated. Sense organs consists of a pair of antennae and simple eyes.
11. Sexes are separate; gonads paired; produce spermatophore. Fertilisation internal; development direct.

Onychophora are a small group of invertebrates closely related to arthropods. They have not changed much in their structure since cambrian period. The most common genus is *Peripatus* (Fig. 5.118). The group shows discontinuous distribution and are mostly confined to tropical regions of the world, found between stones, logs and leaves or along the banks of streams.

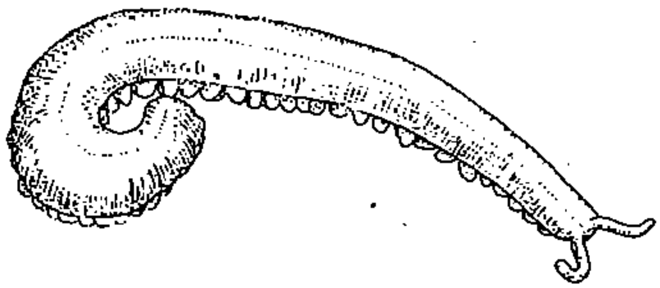


Fig. 5.118 : Peripatus.

The cylindrical body ranges from 1.5 cm to 15 cm in length. The anterior end has pair of large annulated antennae and a ventral mouth (Fig. 5.119). A pair of mandibles and a pair of conical papillae constitute the mouth parts. The number of legs vary from 14 to 43 pairs. These legs are the only external indications of metamerism. The legs appear as non-jointed protuberances from the body ending in a pair of claws. The body surface is covered with large and small tubercles encircling the trunk as well as the legs. The tubercles are covered with scales.

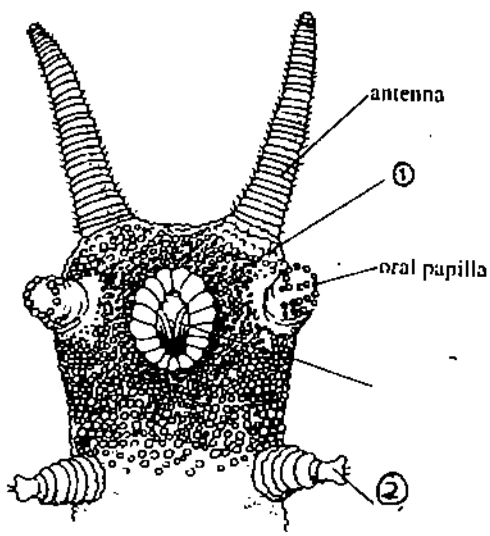



Fig. 5.119 : Anterior end of an onychophoran.

The body is covered by an exoskeleton, the cuticle. The composition of cuticle is very similar to that of arthropods. But here it is thin, flexible, permeable and untanned (not sclerotised). Beneath the cuticle there is a layer of epidermis and circular, diagonal and longitudinal layers of smooth muscle fibres (Fig. 5.120). Thus the body wall is similar to those of annelids; and the coelom is reduced to gonadal cavities and nephridia. A haemocoel is present as in arthropods.

Onychophorans are predaceous and feed on small snails, insects and worms. A pair of **slime glands** (Fig. 5.121) open at the end of the oral papillae. They produce slime which is squirted out to a distance of even upto 15 cm. The slime hardens and engulfs the prey. The mouth leads into a chitin-lined foregut comprised of pharynx and oesophagus and this is followed by a large, straight intestine (Fig. 5.121). The rectum opens through anus located at the posterior end of the body.

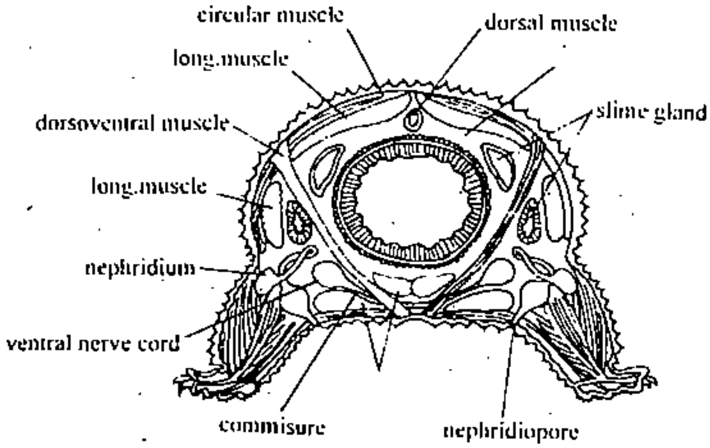



**Fig. 5.120 : A cross section of the bodywall of an onychophoran.**

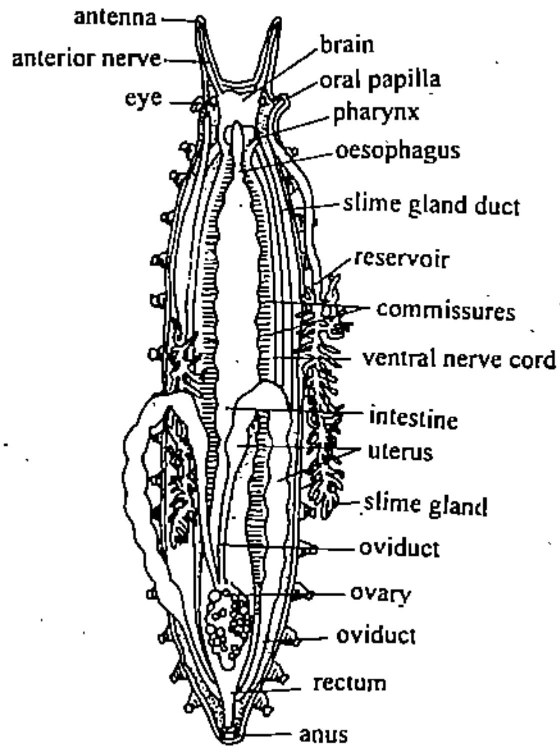



**Fig. 5.121 : Viscera of an onychophoran.**

Circulatory system is open type. It consists of a tubular heart, paired lateral ostia, pericardial sinus and haemocoel. The blood is colourless and contains phagocytic amoebocytes. Excretion is by paired nephridia which are serially repeated. The nephridiopore is located at the base of each leg. Respiration is by tracheal system and spiracles appear as minute openings located in large numbers all over the surface of the body between the bands and tubercles. Nervous system has a bilobed brain and a ladder like nerve cord with a number of commissures. Antennae and the simple eyes are the sensory structures of Onychophora. Sexes are separate. Some species transfer sperms as spermatophores. Onychophorans are oviparous or viviparous or ovoviviparous.

## AFFINITIES

Onychophorans possess both annelidan and arthropodan characters. Arthropodan characters include reduced coelom, chitionuous cuticle, moulting, possession of appendages modified for feeding, tubular heart and haemocoel for circulation. The annelidan characters are suggested by the structure of the body wall, nephridia, and thin and flexible cuticle and non-jointed appendages. Also onychophorans resemble annelids in the embryonic development. Onychophorans were once thought to be a missing link between Annelida and Arthropoda. It is now believed that onychophorans probably shared a common ancestor with arthropods.

## 5.5 SUMMARY

In this unit you have learnt:

- In pseudocoelomates, the fluid filled space served as a hydrostatic skeleton increasing the efficiency of burrowing and the organs lay loose in the body cavity. To overcome this disadvantage the coelom came to be lined by mesodermal layer i.e., peritoneal layer. Consequently the various organs also came to lie suspended in the coelom by mesodermal layer called mesenteries. This modification enabled the body wall to become more muscular with better developed longitudinal and circular muscles. With evolution, coelom became divided into number of chambers by partitions or septa made of the mesodermal lining. Each segment came to have a repetition of many other organ systems like circulatory, excretory, reproductive and nervous systems. Each segment of the body is known as a segment or metamere. The phylum comprises three classes namely Polychaeta, Oligochaeta, and Hirudinea.
- Phylum Arthopoda with over a million species is the largest phylum of Kingdom Animalia. The phylum includes four subphyla Trilobitomorpha, Crustacea, Chelicerata and Uniramia. Trilobitomorpha is an extinct group. Chelicerata includes three classes, Xiphosura (horse shoe crabs), Arachnida (scorpions, spiders, pseudoscorpions, phalangids etc.,) and Pycnogonida (sea spiders). Subphylum Crustacea includes six classes. Class Branchiopoda (shrimps and water fleas), Class Ostracoda (mussel shrimps), Class Copepoda (*cyclops*), Class Branchiura (ectoparasites such as *Argulus*) , Class Cirripedia (barnacles) and the largest class among crustaceans — Malacostraca (prawns, lobsters and crabs). And subphylum Uniramia includes five classes: Chilopoda (centipedes), Diplopoda (millepedes), Pauropoda (*Pauropus*), Symphyla (*Scutigerella*) and the largest class of Animalia — Insecta which comprises of nearly a million species (cockroaches, grasshoppers, bugs, antlions, moths, butterflies, housefly, ants, bees wasps, beetles etc.,).
- The appendages of head of arthropods are the food capturing devices and the post-cephalic appendages are locomotory in function. The digestive system shows regional specialisation with foregut generally serving as a storage and mastigatory organ; the midgut is the region of digestion and absorption; and the hindgut is the region for processing and expelling the undigested waste materials. Respiration is by gills or book gills in aquatic forms and by trachea or book lungs in terrestrial forms.
- Excretion is carried out by coxal glands that are structurally homologous to metanephridia of annelids. Terrestrial arthropods have evolved structures called Malpighian tubules for the removal of nitrogenous waste materials. Circulation in arthropods is open type, and the body cavity filled with the body fluid, the haemolymph, is called the haemocoel. Nervous system consists of a bilobed brain, segmental ganglia and a double ventral nerve cord. In many arthropods there is a fusion of segmental ganglia. A variety of sense organs to carry out the functions of photoreception, chemoreception and mechanoreception are present in arthropods. Sexes are separate. Sperm transfer is either direct or via spermatophores. Fertilisation is internal. Development is through metamorphosis and includes more than one larval stage.
- Phylum Onychophora possesses characters that are both annelidan and arthropodan. The embryonic development of onychophorans resembles those of annelids. Once believed to be the connecting link between Annelida and Arthropoda, phylum Onychophora probably shared a common ancestor with arthropods.

## 5.6 TERMINAL QUESTIONS

1. Enumerate some major differences between Nematoda and Annelida.

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2. List the characters of phylum Arthropoda.

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3. a) Briefly describe the characters of subclass Xiphosura.
   b) Why is Xiphosura considered an evolutionary relic?

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4. Write short notes on the following, with suitable diagrams.
   a) book lungs of Arachnida b) pectines of scorpions
   c) coxal glands of Arachnida.

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5. Write descriptive notes on:
   a) class copepoda b) barnacles

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6. Briefly describe the organisation of Malacostraca. Give a few examples of decapod malacostracans.

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7. What are the classes included under Uniramia ? Give examples of a few genera under each class.

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8. What is a diplosegment ? List the characters of class Diplopoda.

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9. Insects have dominated the terrestrial environment. What are the reasons for the success of the insects in the terrestrial environment?

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10. Name the orders to which the following insects belong:
a) silverfish b) grasshopper c) plant bug d) dragon fly
e) antlion f) head louse g) moth i) housefly j) wasp
k) beetle

## 5.7 ANSWERS

### SAQ 1

(i) Hirudinea

(ii) Polychaeta

(iii) Oligochaeta

## SAQ 2

I. 1. a million 2. jointed legs 3. homologus
4. biramous, uniramous 5. tergum, sternum, pleuron
6. coelom 7. coxal glands and malpighian tubules
8. ommatidia 9. Trilobitomorpha, Crustacea, Chelicerata, Uniramia.

II. 1. Segments fuse to form functional units called tagmata.
2. Segments carry jointed appendages.
3. Cilia are absent
4. Coelom is reduced and confined to the cavity enclosed by excretory organs and gonads.
5. Development often involves metamorphosis.

## SAQ 3

I. 1. primitive 2. absence 3. pedipalpi 4. aquatic 5. Xiphosura 6. Arachnida 7. metasoma 8. Araneae 9. Acarina

II. 1. Merostomata, Arachnida, Pycnogonida. 2. Xiphosura 3. living fossils
4. lyriform organs 5. pectines 6. phalangids 7. ectoparasitic
8. tularemia, relapsing fever and lyme disease 9. pseudostigmatic organ
10. Pycnogonida

## SAQ 4

I. 1. T 2. F 3. T 4. T 5. F 6. T 7. F 8. F 9. T 10. F

II. A-v; B-i; C-vi; D-iii; E-ii; F-iv

## SAQ 5

1. The appendages of millepedes, centipedes and insects are all unbranched, hence the name Uniramia.
2. Chilopoda, Diplopoda, Pauropoda, Symphyla and Insecta
3. A pair of antennal, a pair of mandibles and two pairs of maxillae
4. A diplosegment is the segment of diplopods formed by the fusion of two originally separate segments.
5. (a) gnathochilarium (b) collum
6. The antennae of paurpods are biramous.
7. The males of Symphyla deposit 150-450 spermatophores which are swallowed by the female. They are stored in buccal pouches. The sperm are subsequently smeared over the eggs once they are deposited.

## SAQ 6

I 1. T 2. F 3. T 4. F 5. F 6. T 7. T 8. F 9. T

II 1. e 2. h 3. f 4. g 5. d 6. j 7. b 8. a 9. c 10. i

Answers to terminal questions.

| 1. | **Nematoda** | **Annelida** |
|---|---|---|
| Cuticle | Complex | Simple |
| Body cavity | pseudocoel | Coelom |
| Metamerism | absent | present |
| Muscles | Body wall with special type of muscle cells-neuromotor units. No circular musles. | Well developed circular and longitudinal muscles for the body wall and alimentary canal |
| Cephelisation | Poor | Well developed |

| | | |
|---|---|---|
| Blood vascular system | Nil | Well developed |
| Nervous system | Poorly developed | Well developed |
| Excretory system | Poorly developed | Well developed |

2. Refer to section 6.2

3. Refer to class 3: Arachnida under subphylum Chelicerata (6.2.2)

4. a) and b) Refer to subclass Xiphosura under subsection 6.2.2

5. Refer to class 3: Copepoda and class 5: Cirripedia under subsection 6.2.3.

6. Refer to class 6: Malacostraca under subphylum Crustacea (6.2.3)

7. Class Chilopoda, class Diplopoda, class Pauropoda, class Symphyla and class Insecta.

   Chilopoda : *Scolopendra, Lithobius* and *Scutigera.*

   Diplopoda : *Spirostreptus, Sphaerotherium Glomeris*

   Pauropoda : *Pauropus, Allopauropus*

   Symphyla : *Scutigerella*

   Insecta : *Periplanata, Musca, Apis*

8. A diplosegment, found in class Diplopoda, is formed by the fusion of two originally separate segments. Each diplosegment bears two pairs of ventral ganglia, two pairs of legs, two pairs of ostia in the heart and two pairs of spiracles. For the characters of class Diplopoda refer under subsection 6.2.4.

9. Refer under class Insecta of subsection 6.2.4.

10. a) Thysanura b) Orthoptera c) Hemiptera d) Odonata
    e) Neuroptera f) Anopleura g) Lepidoptera h) Diptera
    i) Hymenoptera j) Coleoptera

# UNIT 6 CLASSIFICATION OF ANIMALS - III

## Structure



## 6.1 INTRODUCTION

In this unit we continue our study of coelomate invertebrates. You have learnt that coelom could be defined as a cavity lined by an epithelium of cells derived from the embryonic mesoderm. Phylum Mollusca which includes soft bodied animals with a shell is the first phylum that you will be studying in this unit. This will be followed by the study of a group of spiny skinned, exclusively marine living animals, the echinoderms. Towards the end of the unit you will study the names of certain phyla, the minor phyla, each of which comprise of a limited number of species and whose systematic position is not very clear. As was done in the previous unit, in this unit also we shall describe the characters of each phylum, classify the phylum upto classes giving examples and briefly describe the organisation of the group.

### Objectives

After studying this unit you should be able to:

- relate the general characters of phylum Mollusca and have a clear understanding of the major classes it comprises,
- point out the characteristic features of phylum Echinodermata, briefly relate their structural organisation and mention the important characters of various classes included under the phylum Echinodermata.

## 6.2 PHYLUM MOLLUSCA

Phylum Mollusca is one of the largest phyla among the invertebrates and includes over 50,000 living species and about 35,000 fossil species. They comprise **snails, clams and squids** etc. The rich fossil record of the phylum is due to the presence of a mineralised shell in many species. Although the majority of molluscs are aquatic, occupying both fresh and marine waters, some species live on land as well. We shall first study the general characters of the phylum and then study each class briefly.

Characteristic Features

1. Bilaterally symmetrical.
2. Generally there is a distinct head and a muscular foot; the dorsal body wall forms the mantle folds which enclose the mantle cavity.
3. Often there are gills and lungs for respiration, formed by modified mantle.
4. A hard, calcareous shell secreted by mantle, protecting the soft body, is common.
5. Coelom is limited to spaces around the heart (pericardial cavity), in the gonads and in the kidneys.
6. Circulatory system is open type in most forms, with heart, blood vessels and sinuses.
7. Excretory organs are metanephridia, the sac-like kidneys, opening proximally into the pericardium and distally into the mantle cavity.
8. Nervous system consists of well-developed ganglia (cerebral, pedal, pleural and visceral) most of them concentrated into a ring with connectives and commissures.
9. Digestive system is complex, with characteristic rasping organ, the radula; anus emptying into the mantle cavity.
10. Spiral cleavage, usually with indirect development, accompanied by first a trochophore larva and sometimes with a second veliger larva.

Molluscs generally measure several centimeters in length. Though molluscs appear to be a heterogenous assemblage of animals, they have a basic body plan. This can be understood from the study of the generalised body plan of a hypothetical ancestral mollusc (Fig. 6.1). The ventral surface of the body is flat and muscular and forms the locomotory organ, the foot. The head is close to it, at one end. The dorsal side of the body is more or less ovoid in shape and contains the internal organs, the visceral mass. The visceral mass is covered by an epidermis, the **mantle or pallium**. The mantle encloses a cavity, the **mantle cavity**. The mantle secretes the overlying protective shell and the edges of the mantle are most active in secreting the shell.

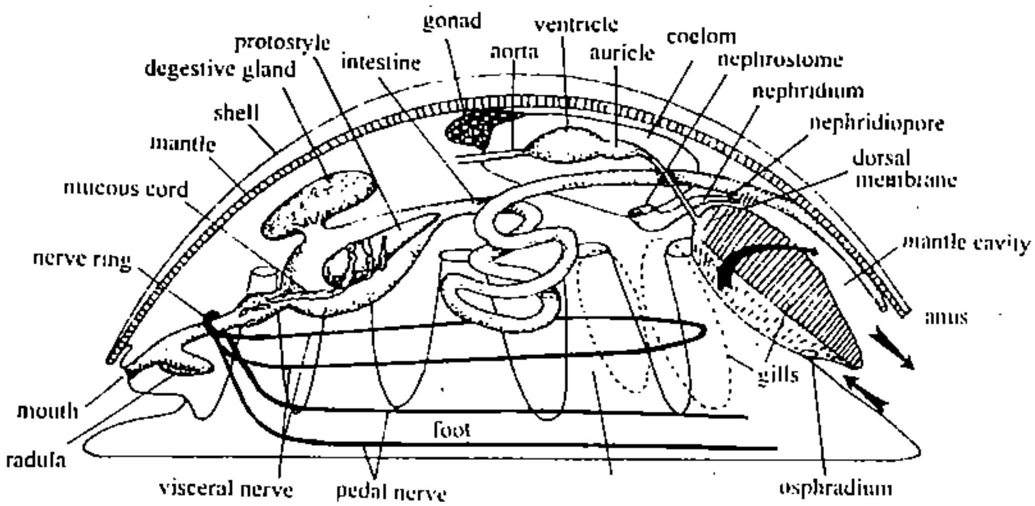



**Fig. 6.1 : Organisation of a generalised mollusc.**

The shell has three layers (Fig. 6.2): (1) The outer, horny layer made up of **conchiolin**, a modified protein. This layer is called **periostracum**. It is protective to the underlying layers and is secreted by the fold of the mantle edge only. (2) The middle **prismatic layer** is made up of prisms of calcium carbonate dorsally packed, in a matrix of protein. This layer is also secreted by the glandular margin of the mantle. (3) The innermost is the **nacreous** layer. This is calcareous material, and is layered down by the mantle surface continuously. This is the iridescent mother-of-pearl of many molluscs. Pearl is formed between mantle and shell in response to trapped foreign particles when they get covered with nacreous layer.

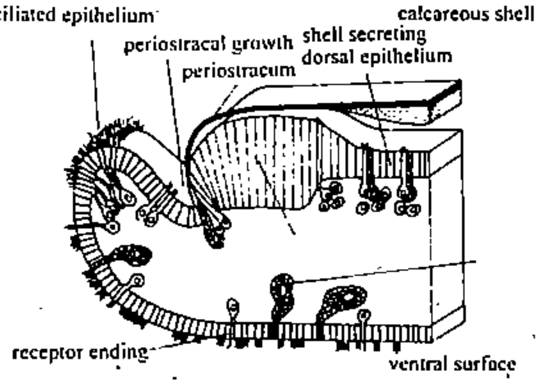



**Fig. 6.2 : A section through the mantle edge of a gastroped shell.**

In molluscs, the respiratory structures are usually gills or **ctenidia** (Sing. Ctenidium) (Fig. 6.1). The ctenidia are located one on each side of the mantle cavity. Each gill consists of a long, flattened **axis** projecting from the anterior wall of the mantle cavity (Fig. 6.3). The axis contains the muscles, nerves and blood vessels. Triangular gill filaments are attached to the sides of the broad surface of the axis as in a comb. When the filaments are found on only one side of the axis the ctenidium in known as **monopectinate;** when they are found on both sides, it is **bipectinate.** Water enters the lower part of the mantle cavity from the posterior end, travels upwards, flows back posteriorly to leave the cavity. Cilia are located on the gills in the lateral, frontal and abfrontal regions (Fig. 6.4).

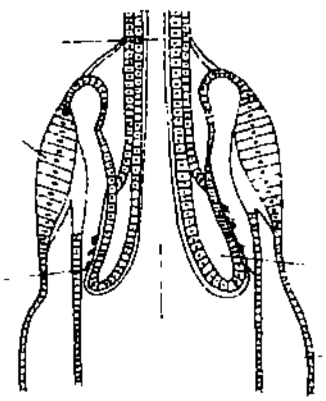


**Fig. 6.3 : Frontal section through a gill.**

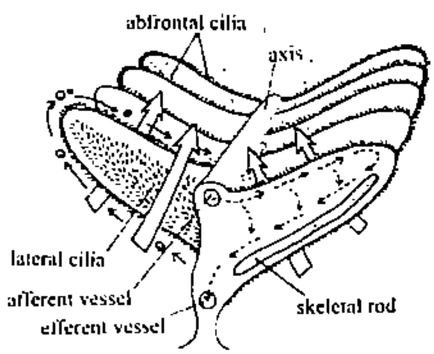



**Fig. 6.4: Transverse section through a gill.**

The axis harbours two blood vessels: an **afferent** vessel that carries blood to the gills and an **efferent** vessel that collects blood from the gills. The flow of the blood is from the afferent vessel through the gill filaments to the efferent vessel. The blood thus runs countercurrent to the water flowing from frontal to the abfrontal margin maximising the oxygen uptake by the blood.

Many molluscs are herbivores, feeding on algae and plants. The mouth leads into a cuticle-lined **buccal cavity**. On the floor of the buccal cavity, there is a structure called **odontophore.** Odontophore is an elongated, muscular and cartilagenous structure that bears a membranous belt called **radula** (Fig 6.5). The radula which lies in a radular sac has transverse rows of teeth. The radula and the odontophore together do the function of scraping and collecting the food. Due to the repeated scraping activity there is loss of radular teeth which are continuously secreted at the posterior end of the radula. At least one pair of salivary glands open into the buccal cavity of molluscs. The buccal cavity leads into oesophagus followed by stomach (Fig. 6.1). The anterior region of the stomach is lined with chitin except for a short, ciliated and ridged region called the sorting region. The **hepatopancreas** constitute the digestive glands: their ducts open into stomach. The stomach is followed by a long, coiled intestine. The posterior region of intestine functions as a rectum concentrating the faecal pellets. The faecal materials expelled through the anus located at the posterior margin of the mantle cavity are swept away by the exhalent water current (Fig. 6.1).

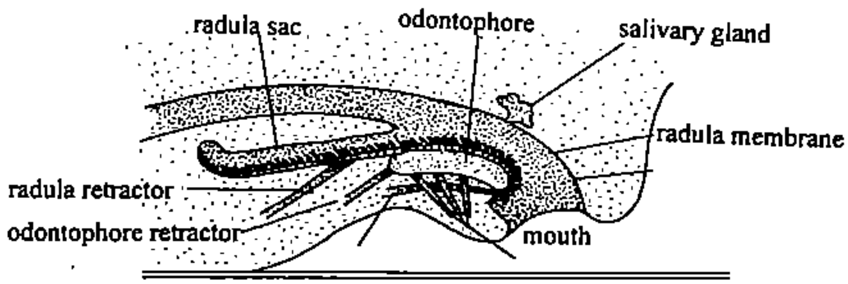



Fig. 6.5 : The inner view of molluscan radular apparatus.

The coelomic cavity is highly reduced and is confined mainly to the pericardium surrounding the heart dorsally and a portion of the intestine ventrally. The heart of molluscs is three chambered with an unpaired anterior ventricle and a pair of posterior auricles (Fig. 6.1). From the ventricle an aorta arises and it branches, supplying blood to the blood sinuses. From these sinuses blood returns to the heart via the excretory organs and gills. In cephalopods (squids and octopuses) the blood is enclosed in vessels, and the sinuses are absent. The blood contains the respiratory pigment haemocyanin, and amoebocytes.

Excretion in molluscs is carried out by one or two nephridia or kidneys. Each kidney is a **metanephric tubule** with the **nephrostome** opening into the coelom at one end and the **nephridiopore** opening into the mantle cavity at the other end. In many molluscs the nephridium is a blind sac. The urine is discharged through the nephridiopore into the mantle cavity (6.1).

The nervous system of molluscs consists of a nerve ring around the oesophagus from which two pairs of nerve cords extend posteriorly (Fig. 6.1). Of these two pairs, one pair, the **pedal nerve cords** innervate the foot and its muscles. The other pair, the visceral pair innervates the mantle cavity and visceral organs. Transverse connections occur between each pair of nerve cords. The sense organs of molluscs include **tentacles**, a pair of eyes, balancing organs-the **statocysts** and the chemoreceptors the **ospharadia** (Fig. 6.1).

Molluscs may be hermaphrodites or the sexes may be separate. The mature gametes may be released into water in which case fertilisation will be external. In forms where fertilisation is internal, sperm transfer may occur directly or the sperm will be packaged into structures called spermatophores and transferred. Cleavage is spiral and a free swimming **trochophore** larva (Fig. 6.6) develops from the gastrula. The trochophore in many molluscs transforms into another larval stage the **veliger** larva (Fig. 6.7) in which the foot, shell and other structures begin to appear. Veliger larva metamorphoses in to an adult.

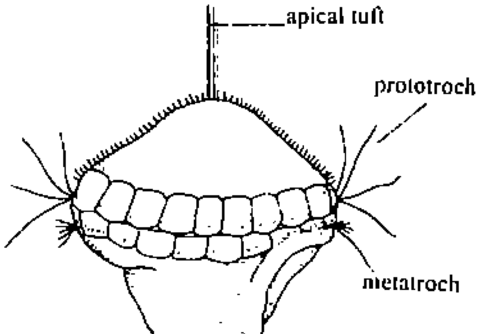



Fig. 6.6 : Trochophore larva of gastropod.

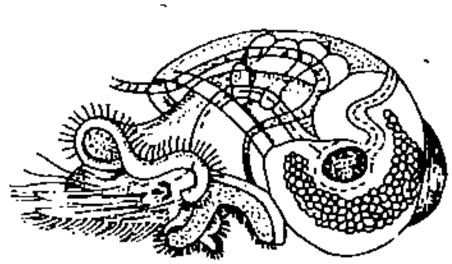


Fig. 6.7 : Veliger larva.

## SAQ 1

Fill in the blanks with suitable words.

a) The molluscs comprise the following major groups, commonly known as ______, ______, and ______.

b) The rich fossil record of molluscs is due to the presence of ______ ______ in many organisms.

c) The ovoid dorsal side of the body of molluscs that contains the internal organs is called ______ ______

d) ______ is an epidermal covering over the visceral mass.

e) The gills of molluscs are known as ______.

## Classification of Mollusca

Thus far we described some of the salient features of the phylum Mollusca. Phylum Mollusca includes seven classes. They are:

**Class Monoplacophora**

**Class Polyplacophora**

**Class Aplacophora**

**Class Gastropoda**

**Class Bivalvia**

**Class Scaphopoda**

**Class Cephalopoda**

Of these seven classes, class Monoplacophora is a primitive group of molluscs. The first living specimen of class Monoplacophora was discovered as late as 1952. This is the genus *Neopilina* that was dredged out from pacific coast of Costa Rica. We shall now study these classes in detail.

### 6.2.1 Class Monoplacophora

**Bilaterally symmetrical, with broad flat foot and single shell, mantle cavity has five to six pairs of gills; six pairs of nephridia of which two function as gonoducts; radula present; sexes separate. Extant species are included in three genera. These are found at great depths in the sea. Also many fossil forms belonging to Cambrian and Devonian times are known. The monoplacophorans can be regarded as the ancestors of all molluscs.**

Monoplacophorans have following salient characters:

- The shell varies in shape from a flat shield to short cone; length of the animals ranges from 3 mm to 3 cm (Fig. 6.8).

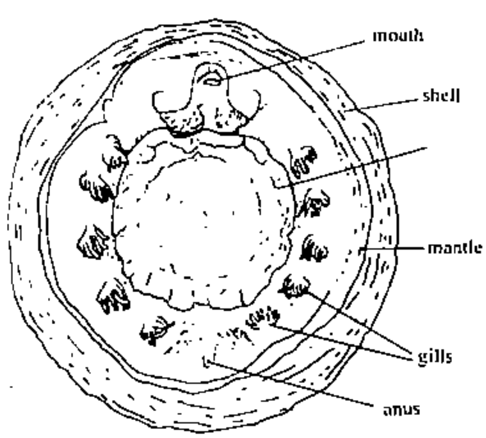



**Fig. 6.8 : Monoplacophoran *Neopilina* (ventral view**

- The foot is broad and flat.
- The mouth lies in front of the foot and the anus opens posteriorly in the mantle cavity. There is a preoral fold in front of the mouth extending laterally as a larger ciliated palp like structure. Another fold projects behind the mouth on either side as postoral tentacles.
- The mantle cavity has 5 or 6 pairs of monopectinate gills.
- Six pairs of kidneys are present.
- Heart has two pairs of auricles and a pair of ventricles (Fig. 6.9) and is surrounded by paired pericardial coelom.
- The buccal cavity has a radula and a subradular organ. The stomach has a crystalline style. There is a long and coiled intestine.
- Nervous system is typical with a pair of cerebral ganglia, circumoral nerve ring, a pair of visceral nerves and a pair of pedal nerves.
- Sexes are separate. Two pairs of gonads are located in the middle of the body. Fertilisation is external. Example : *Neopilina.*

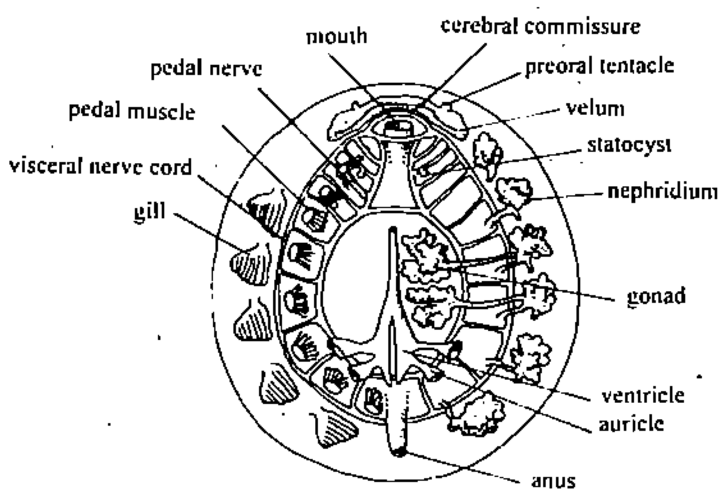



Fig. 6.9 : Internal anatomy of *Neopilina.*

## 6.2.2 Class Polyplacophora

**Bilaterally symmetrical elongated, dorsoventrally flattened; head reduced, with radula, shell consists of eight dorsal plates, foot flat and broad; multiple gills along sides of the body; sexes separate. Trochophore larva in life cycle; no veliger larva.**

Class Polyplacophora include chitons (Fig. 6.10). They live attached to rocks. The body is dorsoventrally flattened and is covered by eight overlapping shell plates: hence the name Polyplacophora. Their important general characters are as follows:

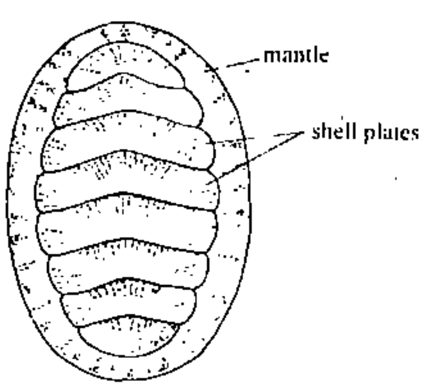





Fig. 6.10 : Chiton.

- They range usually from 3 to 12 cm in length and occupy intertidal zones.
- They have eight shell plates covered by the mantle. The mantle is thick and stiff at forming a periphery, **girdle**, where it may bear scales, bristles or spicules or may be smooth.
- The broad and flat foot occupies almost the entire ventral surface of the animal and is used for adhesion to the hard substratum. The eight shell plates are transversely divided and articulated with each other. Such an arrangement besides aiding in locomotion helps the animal to roll up into a ball as a defense mechanism when disturbed. There are no eyes or well developed sense organs on the head.
- Chitons feed on algae and other attached organisms. The mouth leads into a chitinised buccal cavity that bears a long radula. The buccal cavity leads into stomach through an oesophagus. Pharyngeal glands open into the oesophagus (Fig. 6.11). The stomach is followed by intestine which loops and continues as posterior intestine where faecal pellets are formed. The anus is located at the midline behind the posterior margin of the foot.

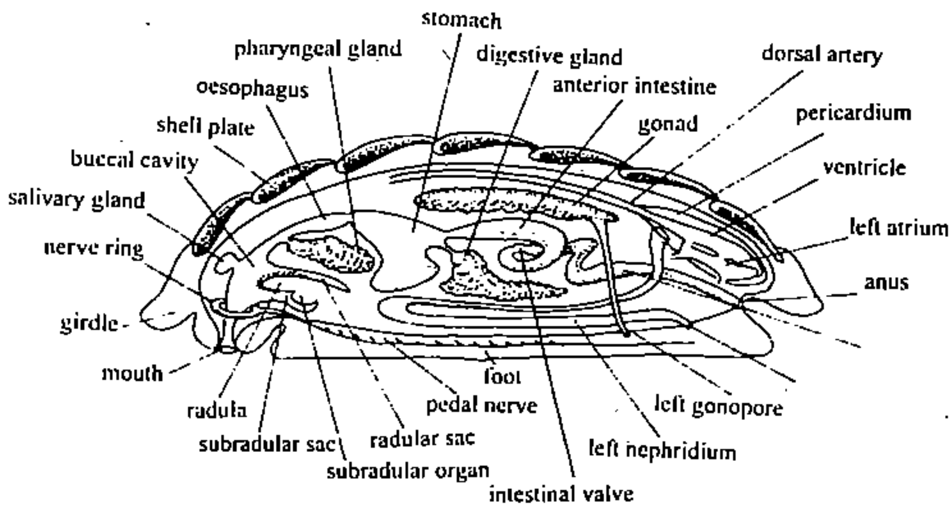



**Fig. 6.11 : Internal anatomy of chiton.**

- The gills are arranged in linear series. The number and size of the gills vary.
- The heart is located beneath the last two shell plates, enclosed in a pericardial cavity. It has a pair of auricles and a single ventricle. The nephrostomes of the large U shaped kidneys open into the pericardial cavity. The nephridiopore opens into the pallial groove.
- The nervous system is typically molluscan (Fig. 6.12). However, ganglia are lacking or poorly developed. From the circumoesophageal nerve ring, the pedal nerves and pallioviscerai nerve arise. The sense organs include subradular organs, girdle hairs and mantle structures known as **esthetes** of unknown sensory function.

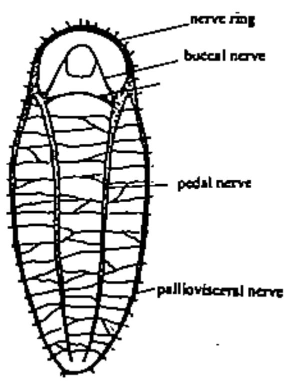



**Fig. 6.12 : Nervous system of chiton.**

- Most chitons are dioecious. The median gonad is located anterior to pericardial cavity beneath the middle shell plates. The gonoducts open separately to outside by gonopores located in the mantle groove. Gametes are shed into the sea and fertilisation is external in water or in the mantle cavity of females.
- Development includes a free swimming larval stage.

### 6.2.3 Class Aplacophora

**Worm-like, no shell, head or excretory organs; mantle with chitinous cuticle or scales or spicules; mantle cavity posterior.**

Aplacophorans are a group of small worm like molluscs devoid of any shell, (Fig. 6.13) called solenogasters. They occupy ocean depths, although some shallow water species are also known. Their biology is poorly understood. You will very briefly study their salient features.

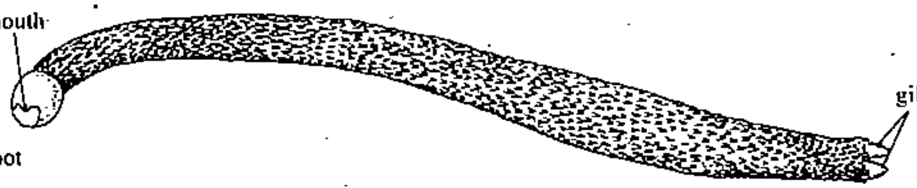



**Fig. 6.13 : An Aplacophoran.**

- They are less than 5 cm length with a poorly developed head and a cuticle-covered integument in which calcareous scales or spicules are embedded. The upward rolling of mantle margins provide worm like appearance to creeping species. The foot is much reduced in burrowing forms. The posterior end of the body has a chamber, the mantle cavity, into which anus opens. In some forms the gills are located inside the mantle cavity. There is no shell.
- Burrowing forms feed on small organisms and deposited materials, and the creeping species feed on cnidarians. A radula may or may not be present.
- Most forms are hermaphrodites and the gonoducts open into the mantle cavity. The eggs may develop directly into adult or pass through a trochophore larval stage.

Thus far you have studied three classes of primitive molluscs - Monoplacophora, organisms with a single shell plate; Polyplacophora, organisms with many shell plates and Aplacophora, organisms with no shell plate. Before we proceed with the other classes, you may attempt the following SAQ.

## SAQ 2

Match the following classes given in Section A with their characters in Section B.

i) Aplacophora
ii) Monoplacophora
iii) Polyplacophora

a) Presence of esthetes.
b) Heart with 2 pairs of auricles and a pair of ventricles.
c) Body covered by a cuticle lined integument embedded with calcareous scales or spicules.
d) Presence of 8 shell plates that articulate with each other.
e) Worm like organism devoid of any shell plate.
f) 5 to 6 pairs of monopectinate gills.
g) Presence of broad and flat foot used for adhering to hard rocks and shells.
h) Presence of single flattened shell.
i) Radula may or may not be present.

### 6.2.4 Class Gastropoda

**Body asymmetrical, shows torsion or its effects; shell coiled in most, well developed head with radula; large flat foot; gills one or two or with pulmonary cavity (lung); mostly with single auricle and single kidney. Nervous system with cerebral, pedal, pleural and visceral ganglia; usually with trochophore and veliger larvae.**

Gastropods, the largest class of molluscs, show extensive adaptive radiation, having adapted to life for bottom as well as pelagic and littoral existence in sea. They have also invaded fresh water and many have successfully conquered land as well. In this subsection you will study the organisation of their body.

Gastropods differ from the other groups you have studied so far in four major ways.

(1) There is the development of a distinct head;

(2) Body shows dorsoventral elongation;

(3) Plate like shell is converted into a spiral asymmetrical shell that serves as a protective retreat for the animal;

(4) The visceral mass undergoes a 90 to 180 degree twist with respect to head and foot, a phenomenon known as **torsion.**

Of the four major changes in the organisation of gastropoda torsion is the most distinctive one. You should remember that torsion is not the coiling of the shell, but it is the twisting of the body (see Box 6.1). In this process most of the body behind the head including visceral mass, mantle and mantle cavity are twisted 180 degrees in the anticlockwise direction and when viewed dorsally the gills, mantle cavity, anus and nephridiopores come to be located at the anterior part of the body behind the head. Torsion also results in the looping of the digestive tract and twisting of the nervous system into a figure 8. Only the head and foot remain untorted. The shell is usually a conospiral.

**Box 6.1**

Torsion is the most distinctive character of gastropods and in no other group of molluscs this phenomenon occurs. You will have to recall here the basic body plan of the bilaterally symmetrical, hypothetical ancestral mollusc with a simple hump like conical visecral mass and a close fitting shell of shallow cone above and a flat foot below for creeping. Further it had a mouth in front and a mantle cavity behind with gills, and into which opened the anus and the nephridiopores. During evolution of gastropods, visceral mass lengthened dorsoventrally. Simultaneously they underwent a phenomenon known as torsion which is quite distinct from coiling (see below). During this process of torsion, the posterior end of the body turned 180 degrees in a counterclockwise direction (looking from dorsally) carrying with it the mantle cavity along with the organs it held. This also affected the visceral mass and the organs it contained. The mantle cavity along with its various organs, earlier situated behind came now to occupy in front, above the mouth (Fig. 6.14). The gill and kidney originally on the right side came to occupy the left side. The intestine was thrown into a 'U' turn loop and the anus came to open in front above the head. The anterior portion of the nervous system constituting the ring was not affected by torsion: only the posterior portion got involved in this process. Thus the two visceral nerve cords connecting the pleural ganglion and the visceral ganglion of the corresponding side got twisted into a figure of 8 (Fig. 6.15). During this process, the original right parietal ganglion came to occupy the left side and higher up the visceral mass, and hence it also came to be referred to as supraparietal ganglion, the original left one now occupying the right side being referred to as the infraparietal ganglion. What necessitated this torsion during evolution is not exactly known. But this gave rise to fouling of water in the mantle cavity because of the discharge of faecal matter and excretory products near the gills. Torsion actually takes place in the larval stage of gastropods, and is due to the asymmetrical or uneven growth of the right and left retractor muscles that connect the shell with the foot.

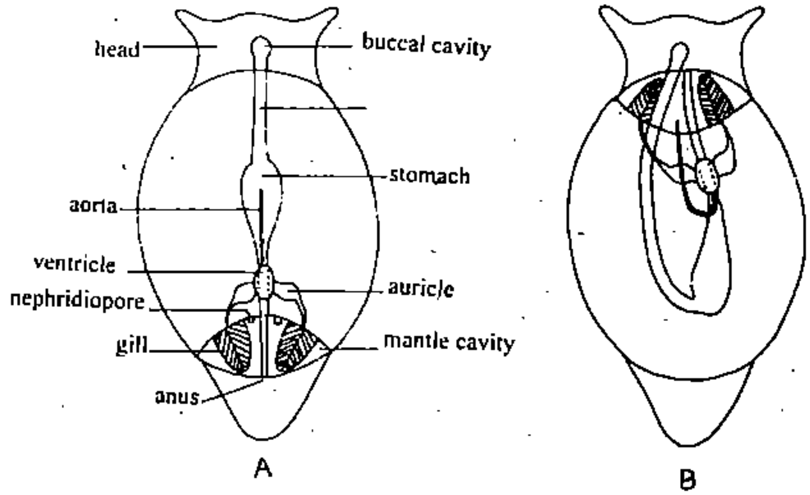



**Fig 6.14 : Torsion in a gastropod:**
**A : before torsion B : after torsion.**

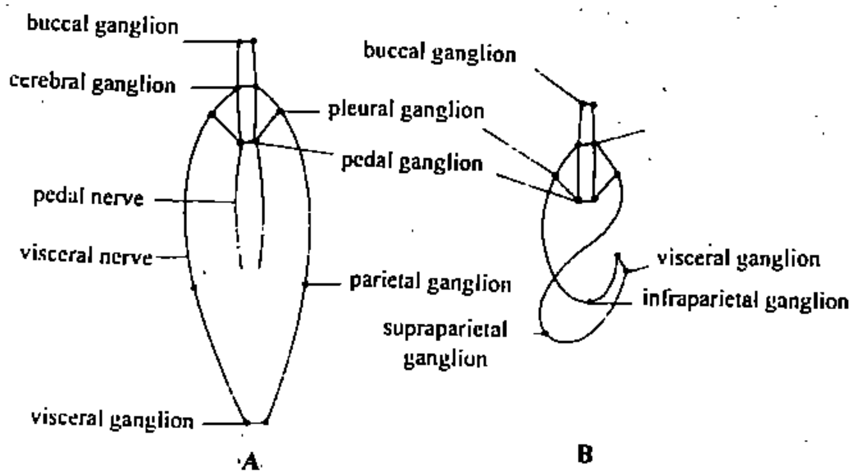



**Fig. 6.15 : A: pre torsion nervous system.**
**B: post torsion nervous system.**

The condition described above is seen in the primitive gastropods (subclass Prosobranchia) to which most gastropods belong. In pulmonates which includes the land snails, the gills have disappeared and the mantle cavity is modified into a pulmonary chamber or lung. In subclass Opisthobranchia a reverse process known as **detorsion** has taken place and they have once again become bilaterally symmetrical secondarily. In them the shell and mantle cavity are either reduced or absent. Examples are the sea hares and nudibranches.

Quite apart from torsion of the visceral mass described above, gastropods have also undergone coiling. The primitive gastropods had a bilaterally symmetrical planospiral coiling of the shell, all whorls lying in the same plane. As this type of shell is not compact, the conospiral type evolved (Fig. 6.16). In this type, the succeeding whorl is at the side of the preceding whorl, but around the same central axis. This type of coiling in its turn created problems in balancing the conospiral, too much weight being on one side of the body. This was solved by shifting the shell upward and posteriorly, with shell axis positioned oblique to the foot axis. This new position of the shell and the body limited the mantle cavity mostly to the left side of the body, almost the whole visceral mass pressing against the mantle cavity on the right side of the body. This has resulted in atropy or disappearance of the gill, kidney and auricle on the right side of the body. This has also enabled the animal to get over the problem of fouling. Water now enters the left side of the mantle cavity, bathes the gill there, receives the faeces from the anus and excretory products from the nephridiopore situated on the right side of the mantle cavity and leaves from the right side of the mantle cavity.

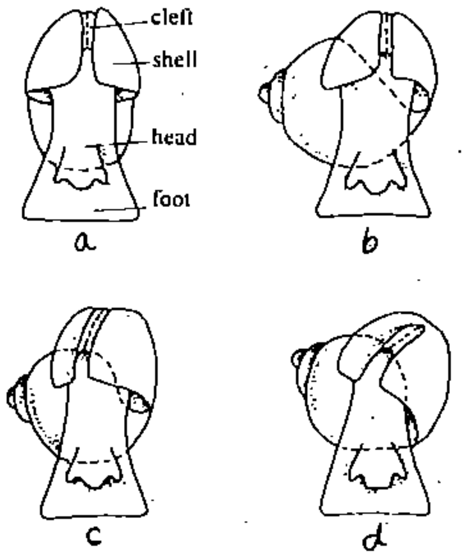



**Fig 6.16 : Evolution of the asymmetrical gastropod shell (a) Ancestral planospiral shell (b) Apex of the shell is drawn out producing a more compact shell (c) Position of the shell over the body is shifted producing a more equal distribution of weight (d) Final position of the shell over the body as seen in most living gastropods.**

**Box 6.2**

Most gastropods possess a shell. Gastropod shell is a "portable retreat" for the animal. These shells vary very much in their size and shape and this is not surprising considering the number and diversity of the species in the class. They range from microscopic size to about 60 cm in length as in the giant marine snail *Pleuroploca gigantea*. Many of them are of exquisite beauty. They present varying hues, shapes and surface sculptures of ridges, grooves, ribs, tubercles, spines etc.

The typical gastropod shell is asymmetrical, conical spiral (Fig. 6.17) around an axis called columella (Fig 6.18). It has evolved from the primitive planospiral shell as a result of torsion (Fig 6.19). The spiral turns are thrown as whorls. The whorls are limited by sutures, and are generally in contact with one another. The succeeding larger whorls partially cover the preceeding smaller whorls. The remaining smaller whorls together constitute the spire. The spire has a pointed apex. However, as in vermitids, the whorls may stand apart resembling the tube of a worm. *Tenagodus* is an example. The body whorl has a large opening, the aperture, through which the foot and the head come out. When distributed the entire foot and head can be retracted into the body whorl and in many species the aperture can be closed tightly by means of an independent lid like piece of shell called operculum on the foot as in the turban shell *Turbo* (Fig. 6.20). The body whorl and the aperture may often be drawn out into a spout in front forming a siphonal canal that contains the siphon as in *Cowries* (Fig. 6.21). Some like the olive shell also show a similar but smaller posterior canal.

If you hold the shell in your hand in front of you, the aperture above and apex turned away from you, usually the aperture will be on the right hand side. Then the shell is described a right handed spiral and is called dextral. Rarely you may come across a sinistral shell with a left handed spiral, in which case the aperture will be on the left hand side. The coiling i.e., whether dextral or sinitral, has genetic basis.

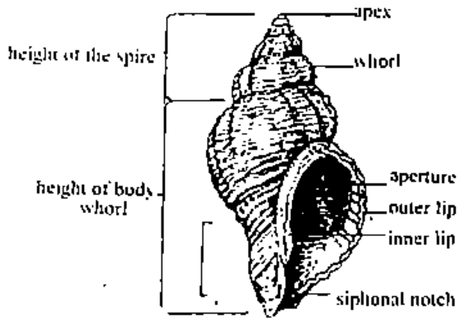



Fig 6.17 : A typical conospiral shell of a gastropod.

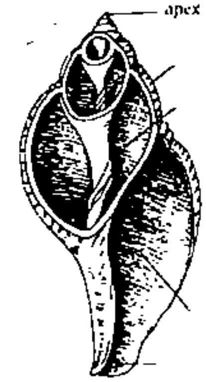



Fig 6.18 : A Longitudinal section through shell.

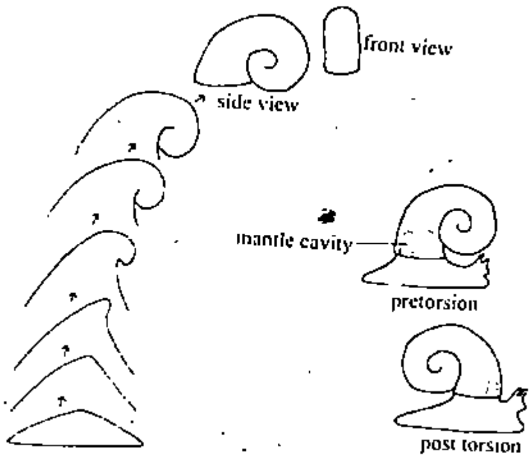



Fig 6.19 : Planospiral shell (a) before torsion (b) after torsion.


Fig 6.20 : Shell with operculum.

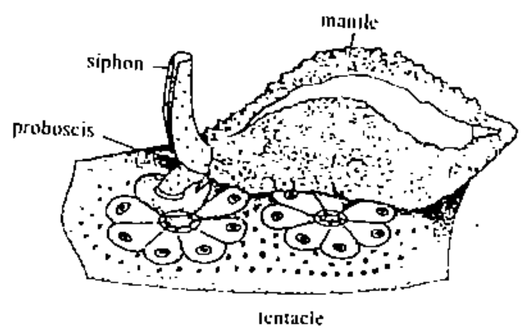



Fig 6.21 : The Cowrie.
(feeding as a tunicate)

Some of the conspicuous variants from the typical shape described above include the long and slender tower shell of *Turitella* (Fig. 6.22) with large number of whorls on the one hand, and the short broad smooth shell of *Laoma* (Fig. 6.23) with the large body whorl and the tiny spire, on the other. The spire is not even visible in the shell of *Cylindrella* (Fig. 6.24). The limpets (Fig. 6.25) also have a broadly conical shell, with a broad aperture but apparently no spire. The cowries also have a broadly conical shell, with a broad aperture but apparently no spire. In the cowries the aperture has become slit-like and the successive whorls enclose the previous whorls. Shell may become internal and even undergo reduction and ultimately disappear in the adult, as in nudibranches.

Fig 6.22 : *Turitella.*

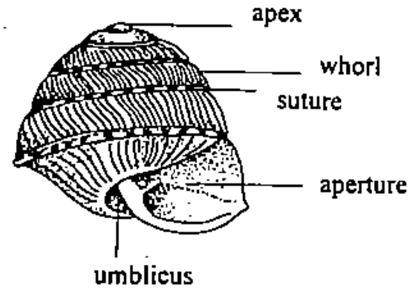



Fig 6.23 : *Laoma.*

Fig 6.24 : *Cylindrella.*

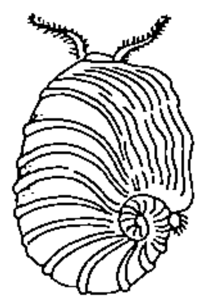


Fig 6.25 : *Fissurella.*

The shell basically consists of an outer periostracum and a varying number of inner calcareous layers. But there is quite a lot of qualitative and quantitative variations in the composition of the shell. The periostracum may be worn off, or may be even completely absent when the shell is covered by the mantle. The number and composition of inner layers also vary; basically they are made up of largely calcium carbonate, but may be either calcite or aragonite, differing from one another in crystalline properties. Calcium carbonate may also occur in an amorphous form.

The colouration of the shell is due to pigments such as pyrroles, melanins, porphyrins etc; They are supposed to be derived by the molluscs from their diet or are metabolic products and are secreted into the shell as a method of disposal from the body. Chromoproteins occur in higher gastropods.

Typically the gastropod foot is a flat creeping sole adapted for locomotion on a variety of substrata. The sole of the foot is ciliated and the gland cells located in the foot secrete mucus over which the animals moves. The snails are propelled by a wave of muscular contraction that sweeps along the foot. In burrowing forms the foot acts like a plough and anchor. Limpets, abalones and slipper snails are adapted for clinging to rocks and shells. In pteropods (sea-butterflies), a group of pelagic gastropods the foot is modified into effective fin like swimming organ (Fig. 6.26).

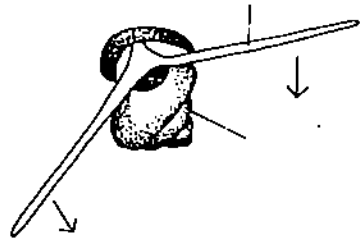



Fig 6.26 : Sea-butterfly.

Gills (ctenidia) of gastropods could be either monopectinate or bipectinate. Most gastropods have only one ctenidium. The land snails among gastropods have their mantle highly vascularised and converted into a lung for purposes of gas exchange.

Gastropods exhibit a variety of feeding habits. There are herbivores, carnivores, scavengers, deposit feeders, suspension feeders and parasites. Due to torsion the stomach has been rotated 180 degrees and as a result the oesophagus joins stomach posteriorly and the intestine leaves the stomach anteriorly (Fig. 6.27). Many suspension and deposit feeders have a structure called crystalline style that secretes the enzyme amylase. You will learn more about crystalline style during our study of bivalve molluscs.

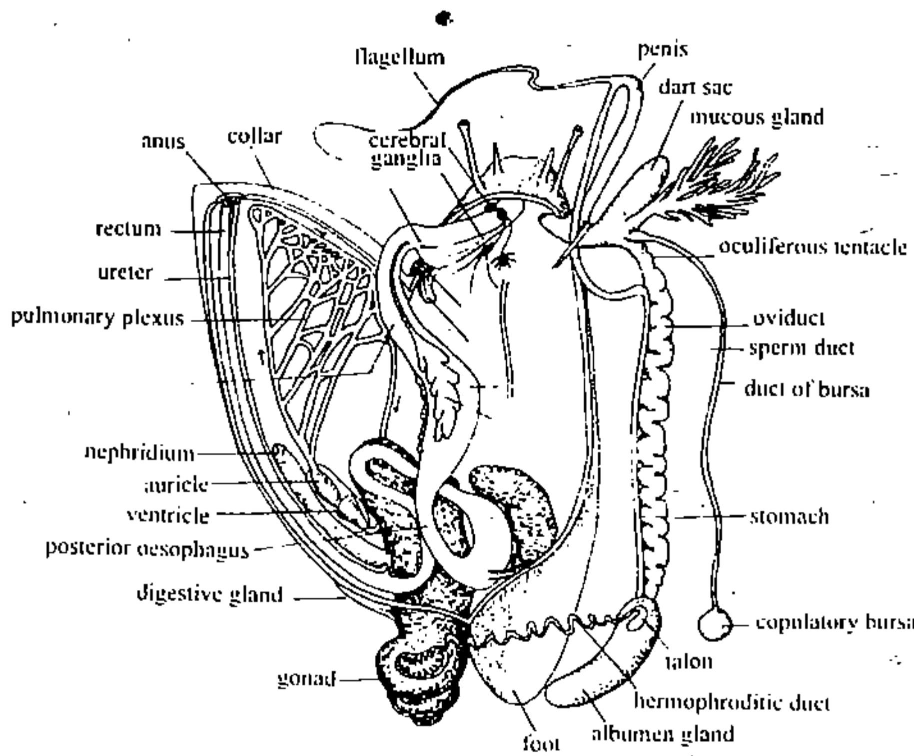



Fig 6.27 : Viscera of a land snail.

The heart is located anteriorly in the visceral mass. In most gastropods, the right auricle is reduced or even absent. From the ventricle an anterior and a posterior aorta arises. The anterior aorta supplies blood to head and foot and the posterior aorta to visceral mass. In the foot and head region blood is collected into a sinus. Blood also passes into kidneys before entering into respiratory structures (Fig. 6.28).

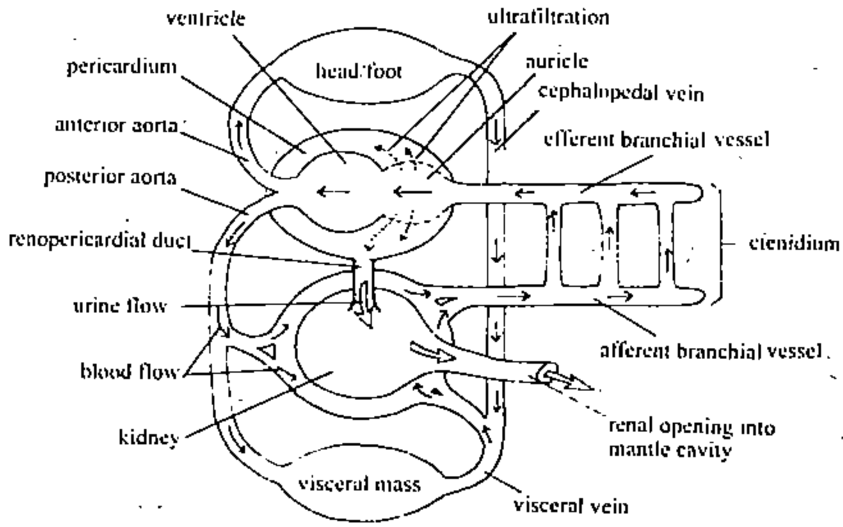



**Fig 6.28 : Blood circulation in a gastropod.**

The nervous system consists of a pair of cerebral ganglia located over the oesophagus. Eyes, tentacles, statocysts and buccal cavity are the structures innervated by cerebral ganglion. Other ganglia include pleural, pedal, buccal, parietal and visceral, innervating the respective organs: their connectives and commissures are shown in the figure 6.15.

Gastropods may be hermaphrodites or dioecious and possess unpaird gonad. Fertilization is mostly internal. Fertilised eggs may sometimes be enclosed in egg capsules in large or small numbers. Veliger larva may be present, or the larval stage may be spent in egg capsule, animals emerging as young ones.

**Examples:**

*Haliotis* (Fig. 6.29), *Fissurella, Patella, Trochus, Nerita*: all are primitive forms; *Pila, Crepidula, Strombus*: (Fig. 6.30); *Murex* (Fig. 6.31), *Nucella*: These are all examples of subclass **Prosobranchia**. They show torsion, and have gills.

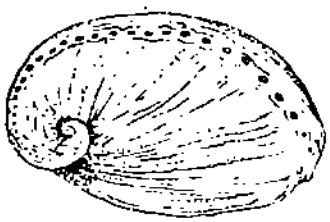


**Fig 6.29 : *Haliotis*.**

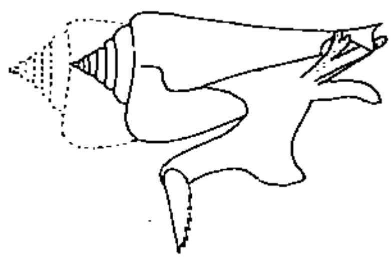


**Fig 6.30 : *Strombus*.**

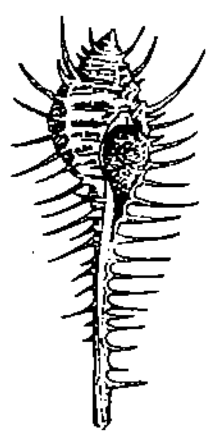


**Fig 6.31 : *Murex*.**

Subclass **Opisthobranchiata** includes those gastropods which have undergone detorsion. Many species have reduced shell or no shell at all and a reduced mantle cavity. Detorsion has restored bilateral symmetry secondarily in many forms. Examples include: *Acteon, Hydatina* (Fig. 6.32); *Odostomia* is an ectoparasitic opisthobranch, the buccal cavity has a stylet instead of a radula for piercing into host organs to draw food; *Aplysia* (Fig. 6.33) a large opisthobranch commonly known as sea-hare, exhibits bilateral symmetry in its external morphology. The shell is very much reduced and is hidden in the mantle. Both gill and mantle cavity are present. The foot of the animal is provided with extensions called lateral parapodia. *Pleurobranchus* (Fig. 6.34); *Clio, Cavolina* (Fig. 6.35): Provided with shell; but the foot has large extensions called parapodia. Hence called pteropods and popularly known as sea butterflies; *Pneumoderma, Cliopsis* (Figs. 6.36) pteropods without shell, these organism lack a mantle cavity. Structures called parapodial fins help in locomotion; commonly called sea-slugs which lack both mantle cavity and shell. The body has attained a bilateral symmerty secondarily. *Doris* (Fig. 6.37) and has secondary gills around anus.

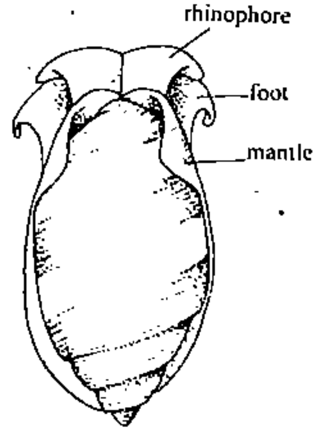



Fig 6.32 : *Hydatina.*

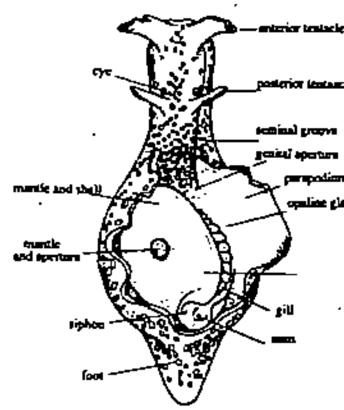



Fig 6.33 : *Aplysia.*

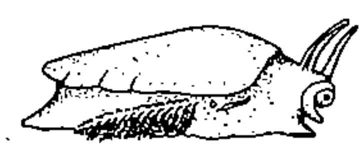


Fig 6.34 : *Pleurobranchus.*

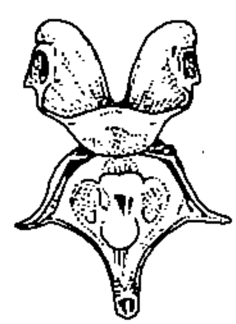


Fig 6.35 : *Cavolina.*

Subclass **Pulmonata** are gastropods with one auricle and one nephridium, and includes many terrestrial forms. To suit the terrestrial mode of life the mantle cavity is vascularised for purposes of gas exchange in air or secondarily in water.

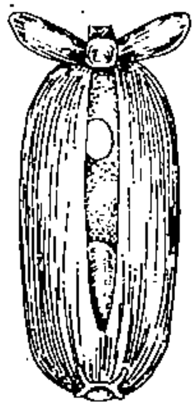


Fig 6.36 : *Cliopsis.*

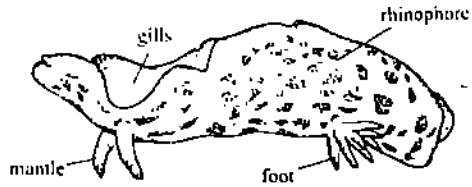



Fig 6.37 : *Doris.*

Examples are: *Onchidium* (Fig. 6.38); slugs. Unlike the other pulmonates where anus opens laterally, anus is located posteriorly, *Lymnaea, Planorbis* (Fig. 6.39) are fresh water forms; The eyes are borne on a pair of cephalic tentacles; Giant African snail *Achatina, Helix, Limax* are terrestrial pulmonates with 2 pairs of cephalic tentacles. The eyes are borne at the tip of the upper tentacles.

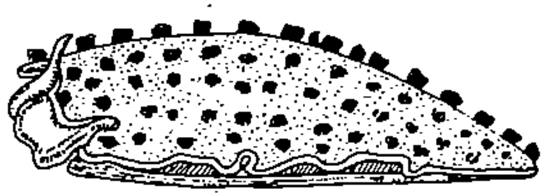


Fig 6.38 : *Onchidium.*

## 6.2.5 Class Bivalvia

**Body within a bilobed mantle enclosed in a two-valved shell; head reduced; mouth with labial palps but no radula; foot wedge-shaped; plate-like gills; sexes separate; trochophore and veliger larvae.**

Class Bivalvia is also known as **Pelecypoda** or **Lamellibranchia.** It includes clams, oysters and muscles. The body of the these molluscs is laterally compressed and the shell is formed of two valves hinged dorsally. The shell covers the body completely. The foot of the animal is also laterally compressed. Bivalves have the most spacious mantle cavity among the molluscs. The large gills that are enclosed in the mantle cavity function as organs of gas exchange and food gathering apparatus producing ciliary currents helping in filter feeding. Bivalves do not have a distinct head or radula. Most of the bivalves burrow in the bottom of fresh water bodies or sea and the body is suitably modified for such a habitat. But there are other forms which have taken to other modes of life as well.

**Box 6.3**

The shell of bivalves consists of two more or less similar oval valves (Figs. 6.40). Each valve has a dorsal protuberance called **umbo.** This is the oldest portion of the shell, and the lines around it indicate growth of the shell. The two valves are kept closed by a pair of adductor muscles. The valves are also attached and articulated dorsally by a hinge ligament, an elastic protein band serving to open the valves when the adductor muscles relax. There are ridges and grooves on the shell to tightly lock them in position.

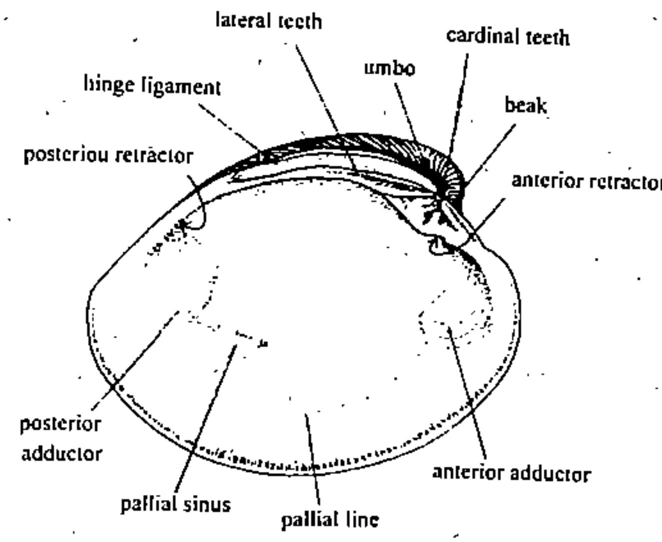



**Fig 6.40 : Inner surface of the left valve of a bivalve.**

The structure of the bivalve shell as well as its composition is basically molluscan as described previously, with layers of periostracum and calcium carbonate. Calcareous layers are made up of aragonite and calcite, in the form of prisms and sheets called nacre in a matrix of organic matter. The shells vary very much in shape, colour and surface patterns. In size they vary from 1 mm to over 1 m.

Pearls of quality and commercial value are deposits of concentric layers of nacre around foreign objects such as sand grains or parasites. The pearl oysters *Pinctada margaritifera* and *Pinctada mertorsi* produce best quality natural pearls. Oysters can be artificially induced to produce pearls.

Bivalves range in size from 2 mm in length to giant forms such as *Tridacna* which measures over a meter in length. The line of the mantle attachment to the inner surface of the shell is called pallial line.

Bivalves have adapted themselves to filter feeding method. Generally water enters the mantle cavity posteriorly and ventrally through incurrent siphon and leaves the mantle cavity posteriorly and dorsally through excurrent siphon. Primitive bivalves possess a pair of postero-lateral bipectinate gills (Fig. 6.41). In these forms the margins of the mouth elongate forming structures called tentacles. Each tentacle is associated with a large fold composed of two flaps called **labial palp.** In higher bivalves the gills act as filters and the gill cilia produce a current which transport the food particles trapped in mucus to the buccal palps and mouth.

The stomach of lamellibranchs (Fig. 6.41a) contains a structure called **crystalline style,** a compact and often a long gelatinous rod that secretes enzymes like amylase and lipase. The heart is three chambered and is folded around the rectum, and pericardial cavity surrounds the heart. The pericardial cavity thus encloses both the heart and a section of the posterior part of the digestivtract. Gills also function as organs of gas

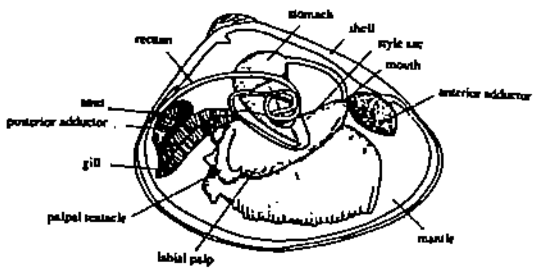
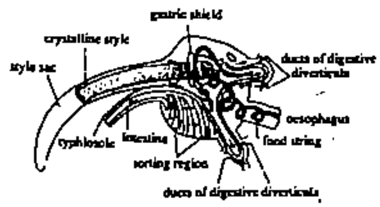



**Fig 6.41 : Internal organisation of a bivalve.**




**6.41a : Crystalline style.**

exchange (Fig 6.42). Paired nephridia or kidneys are the excretory organs. These are located beneath the pericardial cavity and above the gills. The nervous system is bilaterally symmetrical consisting of three pairs of ganglia connected by commissures and connetives (Fig. 6.43). Statocysts, ocelli and osphradium are the sense organs in bivalves. Sexes are separate in most bivalves but a few hermaphrodite species are also known. Development includes **trochophore and veliger larval** stages (Fig 6.44). Some clams have **glochidium** as the larval stage (Fig. 6.45).

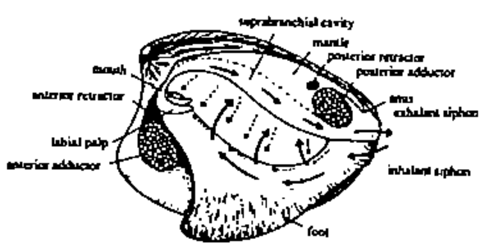



**Fig 6.42 : Route of entry and exit of water for gas exchange.**

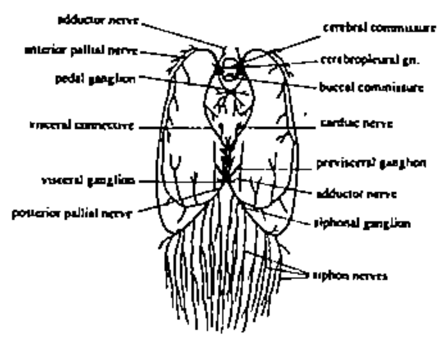



**Fig 6.43 : Nervous system of a bivalve.**

Examples: *Nucula*: the shell valves are equal and carry a row of teeth along the hinge. *Arca*, the arks (Fig. 6.46). *Mytilus* (Fig. 6.47). *Pinna*. *Pteria* (Fig. 6.48) pen shells and winged oysters. *Pecten* (Fig 6.49) (scallop) *Spondylus* (thorny oyster). *Ostrea* (oyster) *Placuna* (window pane clam) *Lima*. *Union*. *Lamellidens* (Fig. 6.50), the fresh water forms; *Solen* (Fig. 6.51), *Entovalva*, burrowing forms with thin shells and well developed siphons; *Mya(clam)*. *Teredo*, *Bankia* (wood boring forms). Pholas (rock boring) (Fig. 6.52).

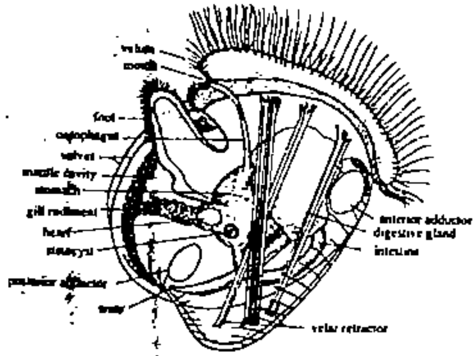



Fig 6.44 : *Veliger Larva.*

Fig 6.45 : *Glochidium.*

Fig 6.46 : *Arca.*

Fig 6.47 : *Mytilus.*

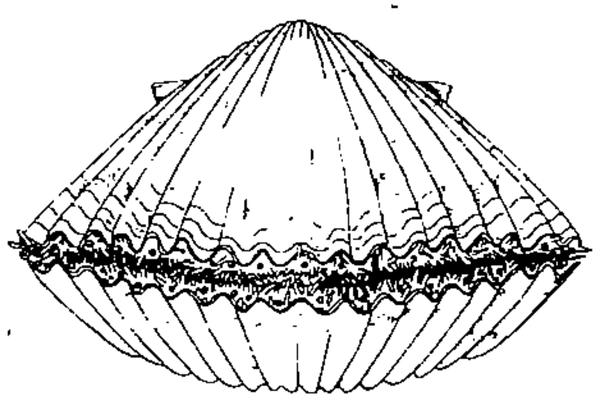


Fig 6.49 : *Pecten.*

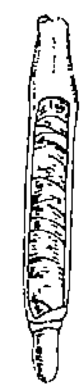


Fig 6.51 : Solen.

## 6.2.6 Class Scaphopoda

**Body within a single tusk-shaped shell open at either ends; foot conical; mouth has radula and tentacles; no head; no gills; sexes separate; trochophore larva.**

Class Scaphopoda includes marine burrowing forms commonly known as tusk shells or tooth shells, due to the resemblance of the shell to the tusk of the elephant (Fig 6.53a). The size of the shells usually ranges on an average from 3 to 6 cm. The shells are mostly white or yellowish. Both ends of the tube are open.

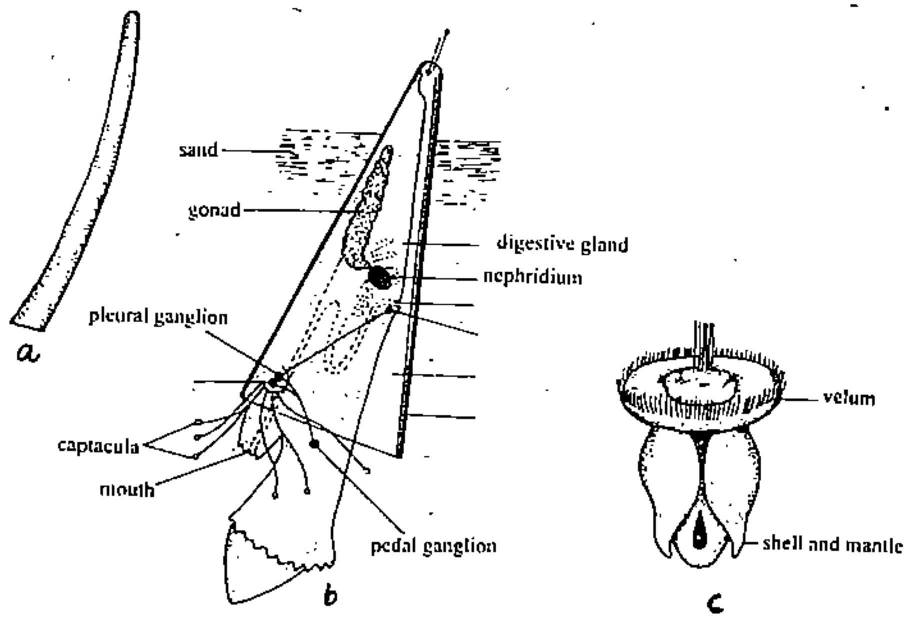



**Fig 6.53a : Shell of *Dentalium*.**
**Fig 6.53b : Organisation of *Dentalium*.**
**Fig 6.53c : Veliger larva.**

The body of scaphopods is elongated and the head and foot project from anterior larger aperture of the shell (Fig. 6.53b). The mantle forms a tube covering the viscera. Scaphopods have a large mantle cavity extending the entire length of ventral surface. The gills are absent and the mantle surface functions as a respiratory structure. Unique thread like tentacles **captacula** with ciliated knob at their tips aid in food capturing. Heart is absent and circulatory system consists of only blood sinuses. Typical molluscan nervous system consisting of cerebral, pedal, pleural and visceral ganglia is present. Eyes, sensory tentacles and osphradia are absent. A pair of nephridia serve as excretory organs. Sexes are separate. Development includes a free swimming trochophore and bilaterally symmetrical veliger larva (Fig. 6.53c) e.g. *Dentalium*, *Cadulus*.

## 6.4.7 Class Cephalopoda

**Shell reduced or absent except in *Nautilus*; head well developed with well developed eyes; head bears tentacles; foot modified into siphon; well developed brain with fused ganglia; sexes separate; development direct.**

Cephalopods are the most active and highly organised of all molluscs, adapted for pelagic, free swimming life. The group includes cuttlefishes (Fig 6.54a), squids, octopods(Fig 6.54b) and *Nautilus* (Fig. 6.54c). The body is lengthened in the dorsoventral axis and this has in effect became the antero-posterior axis. The mantle cavity is now ventral. The head projects into a circle of large prehensile tentacles or arms at the anterior region. These tentacles are homologous to the anterior portion of the foot. On an average cephalopods range in length from 6 to 70 cm; giant forms over 15 m (*Archeteuthis*) are also known. Locomotion in most cephalopods is by swimming. Swimming is achieved by jet propulsion of the body by rapidly expelling water from the mantle cavity through a ventral tubular structure, the funnel, which is a modified portion of the foot. The external shell is now seen only in four living species of genus *Nautilus* from Indo-Western Pacific Sea and the other genera completely lack a shell. Cephalopods use gas filled shells to maintain buoyancy in water.

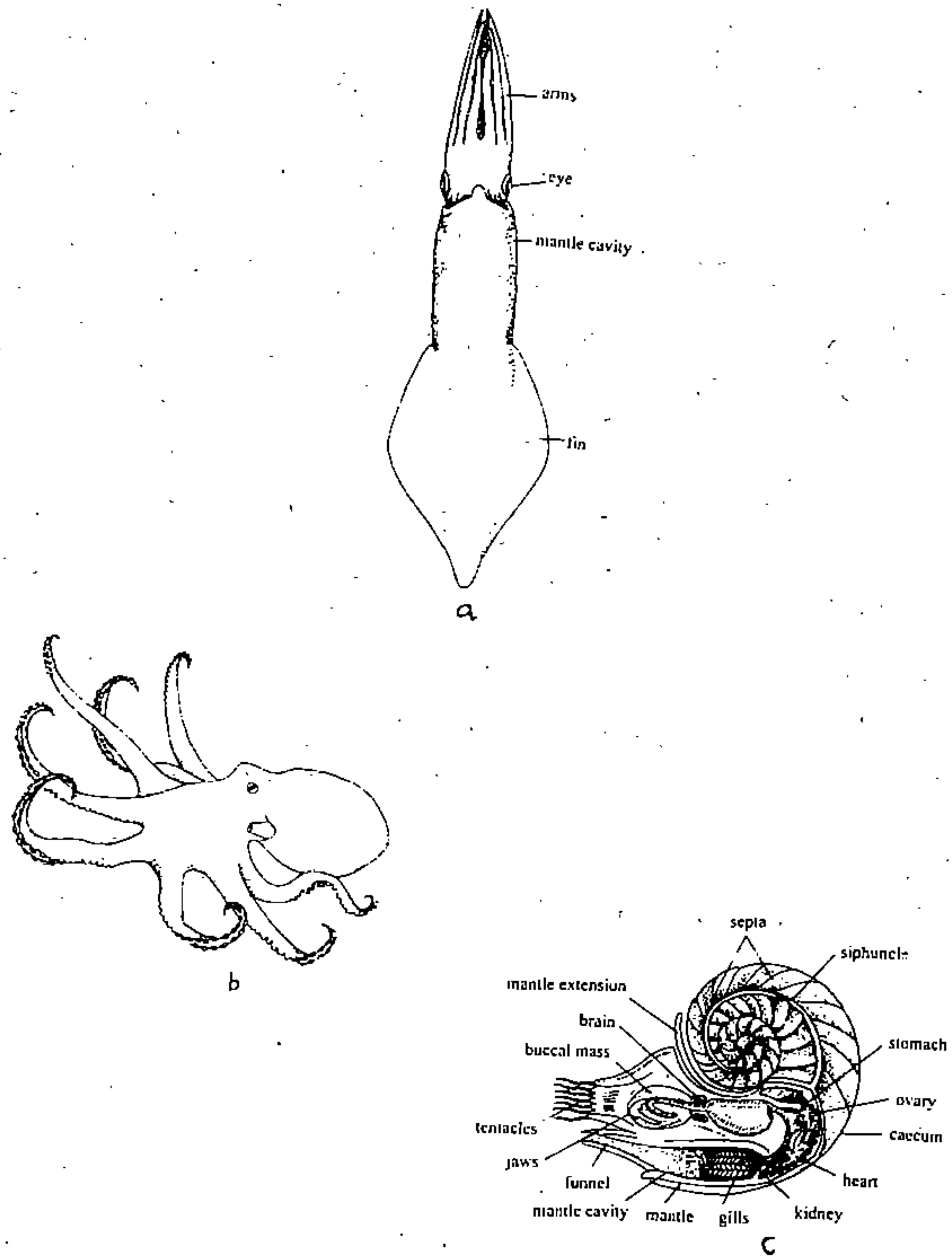



**Fig 6.54 : Some Cephalopods.**
**a: Cuttlefish *Sepia***
**b: *Octopus***
**c: *Nautilus***

**Box 6.4**

The shell of *Nautilus* is a planospiral (Fig. 6.54c). The inner whorls are covered by the last two whorls. The shell is divided by transverse septa, and the animal occupies only the last chamber. The septa is perforated at the centre through which a siphuncle passes. The Siphuncle secretes gas into the chambers. This makes the shell buoyant. The shell has an outer pearly white smooth layer made up of prisms of calcium carbonate embedded in an organic matrix. There is also an inner nacreous layer.

In the cuttle fish *Spirula* (Fig. 6.55) the internal shell is coiled. In the *Sepia* and *loligo*, the shell is reduced to a "pen" (Fig. 6.56).

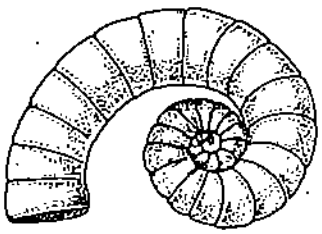


Fig 6.55 : Shell of *Spirula*.

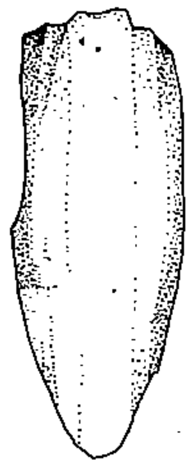


Fig 6.56 : Shell of *Sepia*.

Cephalopods are carnivorous and capture their prey by tentacles or arms. Squids and cuttle fish have ten arms of which one pair is long, called tentacles. Octopods have eight arms. The inner surface of each arm contains adhesive discs that function as powerful suckers. The suckers are stalked in *Octopus*. The buccal cavity has a radula and a pair of powerful beak-like jaws.

There are two pairs of salivary glands emptying into the buccal cavity (Fig 6.57). The digestive glands include a diffuse "pancreas" and a solid "liver". Anus is located near the funnel and the excretory wastes are carried away along with exhalent water jet. Respiration is by gills. The circulating water in the mantle cavity is the source of oxygen for the gills.

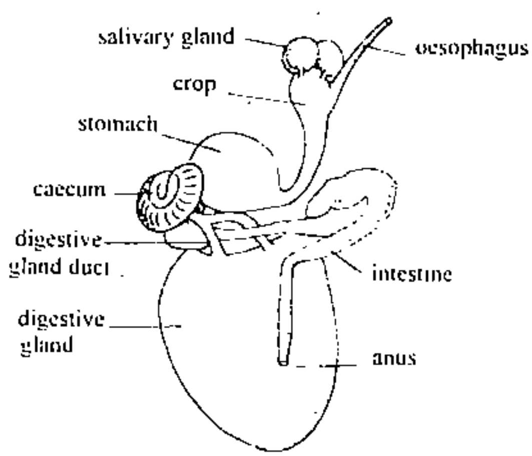



Fig 6.57 : Digestive System of *Octopus*.

Nephridia are the excretory organs (Fig 6.58). Circulatory system in Cephalopods is closed. It consists of extensive system of vessels and capillaries lined by endothelium.

closely resembling those of vertebrates. Heart is a three chambered structure with two auricles and a ventricle (Fig. 6.59). Besides there is a pair of branchial hearts that pump blood through the gills. Blood contains the pigment haemocyanin for transporting oxygen to the tissues from the gills. Nervous system is also well developed with a higher degree of cephalisation. The brain is perhaps the best developed among invertebrates. It is formed by the fusion of all ganglia that are typical of molluscs. Besides, there are **brachial gangalia** providing nerves to the arms: on each side, the mantle wall has a **stellate ganglion** that innervates the mantle musculature. Sense organs include well developed eyes strikingly similar to those of fishes, statocysts and osphradia. The colouration of the body is due to pigment cells or chromatophores present in the integument. The animals can rapidly change their colour, which is an effective means of communication. Except in *Nautilus* in other cephalopods there is a large ink sac (Fig. 6.58) that secretes brown or black fluid or ink made of melanin pigments. The ink sac opens into the rectum. When the organism is distributed the ink is released into the surrounding water. This cloud of ink is used as a decoy confusing the intruders and predators and the animal makes good its escape.

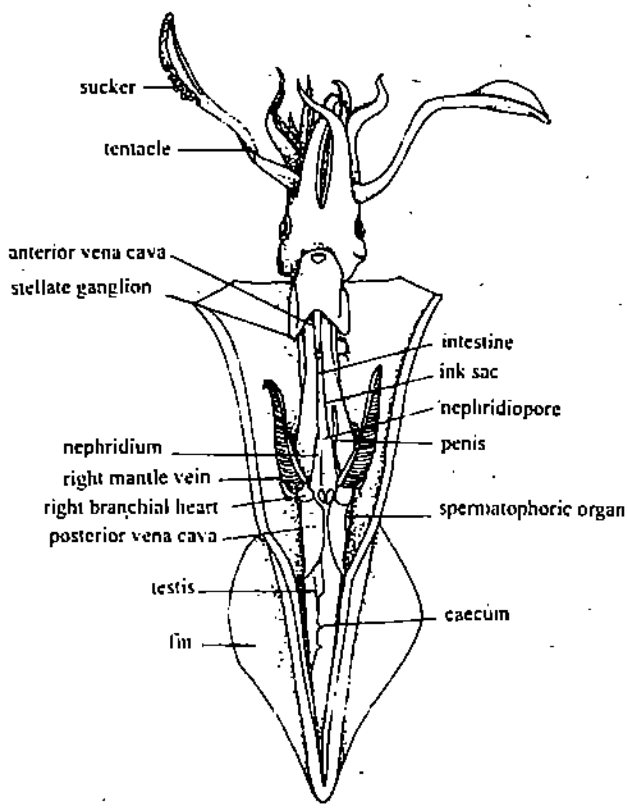



**Fig 6.58 : Internal anatomy of squid.**

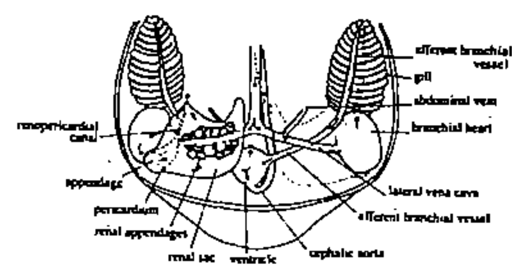



**Fig 6.59 : Excretory and Circulatory systems of Octopus.**

Sexes are separate. The males fabricate elaborate spermatophores for sperm transfer. One of the arms of the adult male is modified into an intromittent organ called **hectocotylus.**

Cephalopoda includes three subclasses: **Ammonoidea, Nautiloidea** and *Coleoidea.* Subclass Ammonoidea is extinct and Nautiloidea contains only one living genus *Nautilus* while the rest are extinct. *Nautils* have coiled external shell and many slender suckerless tentacles. Gills and nephridia occur in two pairs. Bulk of the cephalopods belong to subclass Coleoidea.

**Subclass Coleoidea:** Includes both living and extinct forms. Internal shell is present in some forms. In others shell may be reduced or absent. The arms are provided with suckers. A pair of gills and nephridia are present. First recorded in Missisipian period; includes five orders.

*Sepia, Spirula* : Cuttle fishes: Eight arms and two tentacles. Shell provided with septa. Greatly reduced internal shell. In some forms shell is absent; *Architeuthis, Loligo* and squids. The shell appears as a flattened blade, the pen. Elongated body with 8 arms and two small filaments. The eight arms are united with a web. *Octopus* : octopuses are with fins and without gills. All forms have a globular body and eight arms.

## SAQ 3

I. Answer the following questions briefly.

i) Name four major differences between the Gastropoda on the one hand, and Aplacophora, Monoplacophora and Polyplacophora on the other.

ii) What is meant by torsion?

iii) What is the composition of molluscan shell?

iv) Name the respiratory organ of pulmonates.

v) Name the three subclasses of class Gastropoda.

II. State whether the following statements are true or false:

(A) Class Bivalvia includes snails, slugs, limpets and abalones. T/F

(B) Bivalves have the smallest mantle cavity among molluscs. T/F

(C) The inner surface of shells of bivalves have a lustrous appearance. T/F

(D) Bivalves have adapted for filter feeding methods. T/F

(E) The crystalline style of bivalves produces digestive enzymes. T/F

(F) The crystalline style is a long gelatinous rod. T/F

(G) The gills of bivalves play a key role in filter feeding mechanism. T/F

(H) The blood of cephalopods contains haemocyanin. T/F

(I) Cephalopods have one of the best developed nervous systems among invertebrates. T/F

(J) Development in bivalves includes trochophore and veliger larvae. T/F

III. Fill in the blanks with suitable words.

(A) Tusk shells belong to the class _________.

(B) __________ are the tentacles of scaphopods provided with a ciliated knob at their tips.

(C) _________ is the only living genus under the subclass Nautiloidea.

(D) Some Cephalopods have ________ filled shells to maintain their _________ in water.

(E) In cephalopods a pair of __________ hearts pump the blood through the gills.

(F) The blood vessels and capillaries in cephalopods are lined by _________ as in vertebrates.

(G) The mantle is innervated by __________ ganglia..

(H) Male cephalopods fabricate elaborate ____________ for sperm transfer.

## 6.3 PHYLUM ECHINODERMATA

**The characteristic features of phylum Echinodermata are:**

**1. Echinodermata is deuterostomous phylum. Adults mostly with pentamerous symmetry; all are marine.**

2. **Body not metamerically segmented; rounded, cylinderical or star shaped, without head.**
3. **No brain. Few specialised sense organs. Central nervous system in the form of circumneural ring and radial nerves.**
4. **Digestive system complete.**
5. **Coelom enterocoelic and extensive. Forms perivisceral cavity and the cavity of the unique water vascular system.**
6. **Blood vascular system (haemal system) very much reduced and surrounded by perihaemal sinuses (extensions of coelom).**
7. **Exoskeleton made up of abnormal calcareous ossicles with spines in most organisms; or calcareous spicules in the dermis of some. Pedicillariae present in some.**
8. **Locomotion mainly by tube feet; in some by spines or by movement of arms.**
9. **Respiration by dermal branchiae, tube feet, respiratory tree or bursae.**
10. **No olfactory organs.**
11. **Sexes usually separate; gonads large simple gonoducts. Fertilization external.**
12. **Indeterminate type of development; radial cleavage; free swimming, bilaterally symmetrical larval stages usually present during development.**
13. **Autotomy and regeneration extensive.**

Now you will begin the study of echinoderms. The phylum includes some 6000 species, all marine animals and comprises sea stars, sea urchins, sea lilies and sea cucumbers. Majority of echinoderms are bottom dwellers and measure several centimeters in diameter.

A remarkable feature of the group is the **pentamerous radial symmetry**. This means that their body can be divided into five equal parts arranged around a central axis. But the radial symmetry of adult echinoderms is secondary. The larvae of echinoderms are **bilaterally symmetrical**. During metamorphosis the bilateral symmetry of the larvae is replaced by radial symmetry in adults. Also, echinoderms have no relationship with other radially symmetrical invertebrates. Yet another characteristic of echinoderms is the presence of internal skeleton formed of **calcareous ossicles**. The ossicles may articulate with one another or they may be sutured together. Spines of tubercles project out from the surface of the body that gives the animal a warty or spiny appearance and hence the name of the phylum Echinodermata, meaning spiny skinned animals. A third characteristic feature of echinoderms is the presence of an unique system, the water vascular system. This system formed by coelomic canals and certain surface appendages, besides functioning as food gathering and gas transport system, also aids in locomotion of the animals. Echinoderms possess an extensive coelom that forms perivisceral cavity as well as the cavity of water vascular system. The coelom is of enterocoelous type. The coelomic fluid contains amoebocytes. The blood vascular system of echinoderms is much reduced and does not play any significant role in circulation. Structures known as **dermal branchiae** and tube feet of water vascular system are the respiratory organs. The class Holothuroidea have a structure called respiratory tree, that aids in gas exchange. In another class, Ophiuroidea, bursa plays a role in respiration. Echinoderms can lose their body parts by autotomy and have the power of regeneration as well. Phylum Echinodermata includes five classes. They are:

1. **Class Asteroidea**
2. **Class Ophiuroidea**
3. **Class Echinoidea**
4. **Class Holothuroidea**
5. **Class Crinoidea**

You will study the characters of the class Asteroidea in detail and their characters of other classes briefly.

### 6.3.1 Class Asteroidea

**Star shaped; arms not sharply demarcated from central disc; ambulacral grooves open; tube feet on oral side and with suckers. Arms and madreporite on the aboral side; pedicellaria are present.**

The class includes sea stars or starfishes (Fig. 6.60). The sea stars are variously coloured free living animals common along the rocky shores. They are found on the sea bottom crawling over the rocks or corals or living in sand and mud.

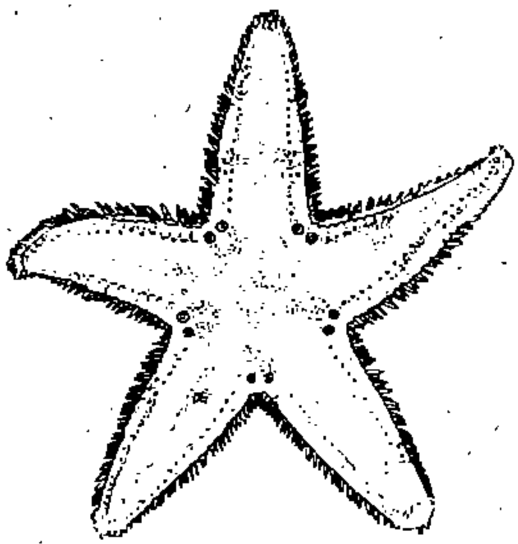
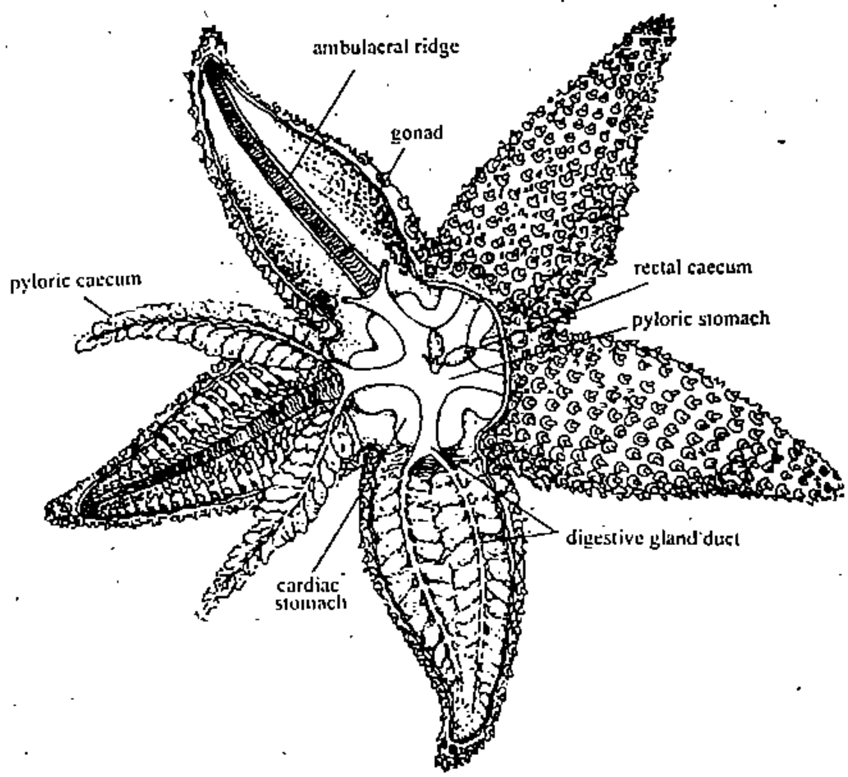


**Fig 6.60 : Aboral view of seastar.**

The body has a central disc from which five arms project out giving the animal pentamerous radial symmetry. They range from 12 to 24 cm on an average. The arms are not very distinct from the central disc: rather they imperceptibly grade into the central disc. The mouth is located at the centre of the disc on its under surface, which is hence called **oral surface** (Fig. 6.61). From the mouth a furrow called **ambulacral groove** extends into each arm radially. The groove harbours two or four rows of small tubular projections called **tube feet or podia**. The groove may be kept partly closed by movable spines that are located on its margins. Each arm bears at its tip one or more tentatcle like sensory tube feet and a red pigment spot. The upper surface of the animal is called **aboral surface** (6.62) and it bears anus at the centre. A large button like structure the **madreporite** is also present on the aboral surface on one side of the central disc between two of the arms.


**Fig 6.61 : Central disc and part of one arm of oral surface of starfish *Asterias*.**

The body wall consists of an outer epidermis formed of monociliated epithelial cells, mucous gland cells and sensory cells. Below the epidermal layer is a thick dermis formed of connective tissue that houses hard skeletal pieces called **ossicles**. The ossicles are variously shaped as rods, crosses or plates and are arranged as a lattice or network bound together by connective tissue. Ossicles are made up of magnesium rich calcite. The dermis is followed by muscles that aid in the bending of the arms. The coelom is lined by a ciliated peritoneal membrane. Some seastars have on their body surface specialised jaw like or pincer like appendages, the **pedicellaria** (Fig. 6.63) meant for the protection of the animal from small animals and larvae that try to settle on the sea stars. The pedicellariae may be stalked or sessile.



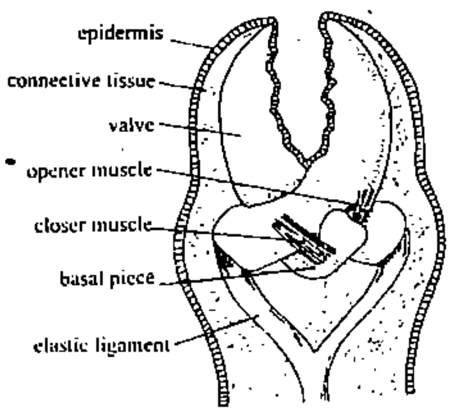




**Fig 6.63 : A pincer like pedicellaria of starfish.**

**Fig 6.62 : Aboral surface of starfish showing the internal anatomy.**

### Water Vascular System

Echinoderms have a unique system that consists of canals and appendages of body wall called water vascular system (Fig. 6.64) This system is a coelomic derivative; it is lined with ciliated epithelium and filled with fluid. In asteroids the water vascular system is well developed and is mainly locomotor and food gathering in function. It also serves in respiration and excretion.

The water vascular system communicates with the exterior by the button shaped madreporite located on the aboral surface. The madreporite has a number of pores on it. The pores open into a **stone canal** that runs from the aboral side to the oral side and joins the **ring canal** that surrounds the mouth. From the ring canal arises radial canals to each arm just beneath the ambulacral groove. The radial canal gives rise to a large number of **lateral canals** on either side along its entire length. Each lateral canal has a bulb like **ampulla** and a tube foot or podium. The ampulla is a small muscular sac which bulges into the perivisceral coelom. The ampulla is connected with the tubefoot or podium. The podium is located in the ambulacral groove and is a short, tubular, external projection of the body wall and its tip is flattened to form a **sucker.** The water vascular system is filled with a fluid similar in composition to sea water and the fluid contains coelomocytes and proteins. Arising from the ring canal and at the interradial position are **polian vesicles** which are elongated muscular sacs and paired pouches called **Tiedmann's bodies.**

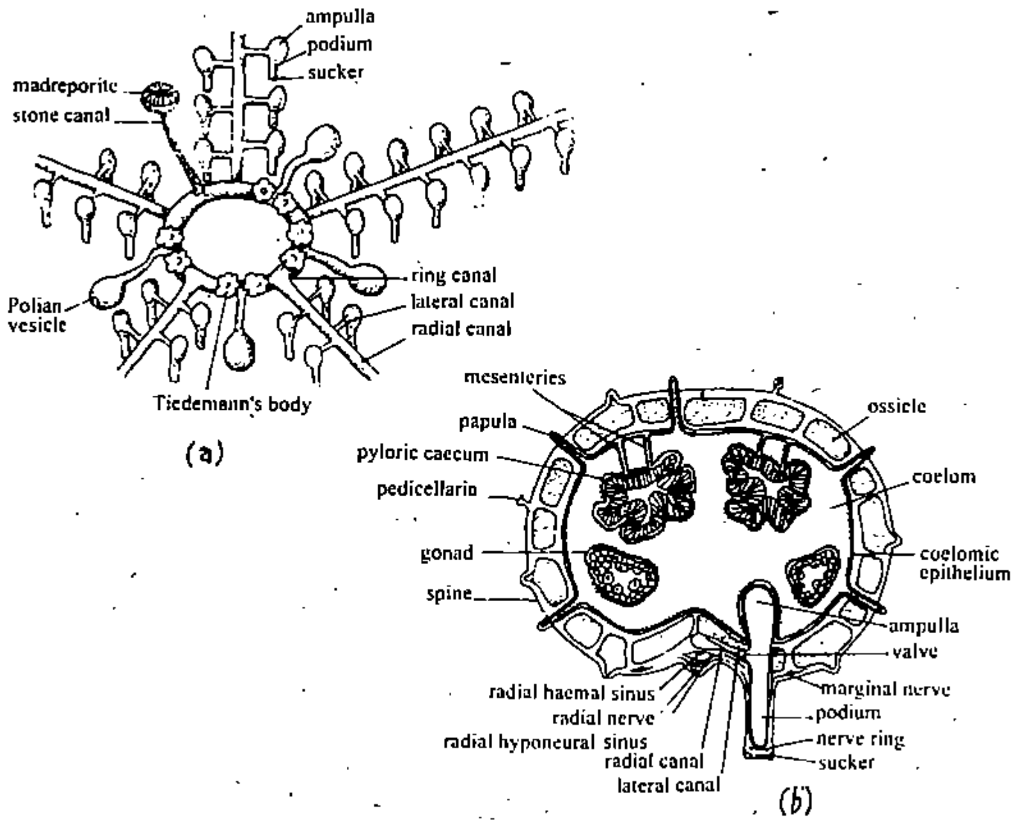



**Fig 6.64(a) : Water vascular system of starfish (b) Cross section through an arm of starfish.**

## Digestive System

Most asteroids are scavengers or carnivores and feed on snails, bivalves, polychaets, other echinoderms, fish, sponges, sea anemones and polyps of hydroids and corals. Some feed on plankton and detritus. The digestive system of sea stars extends between the oral end and aboral disc of the animal. The mouth lies at the centre of a muscular peristomial membrane. The mouth is followed by a short oesophagus that in turn opens into a large stomach. The stomach occupies most of the interior of the disc and is divided by a horizontal constriction into a large oval **cardiac stomach** and a smaller, flattened **pyloric stomach** (Fig 6.65). The walls of gastric stomach are pouched. In each arm a pair of digestive glands or pyloric caeca are present and their ducts open into pyloric stomach. The pyloric stomach leads into a short tubular intestine on the aboral side. The intestine opens to the outside through a minute anus at the centre of the aboral surface of the disc. A number of small outpocketings called rectal ceaca arise from the intestine.

## Circulation, Respiration and Excretion

Asteroids depend on the circulation of coelomic fluid for the transport of gases and some nutrients. The blood vascular system called **haemal system** in echinoderms is not very well developed in asteroids. The channels lack a lining. However, these channels are surrounded by extensions of coelom called perihaemal sinuses. There are four coelomic circulatory systems in asteroids (Fig. 6.65) (i) The **perivisceral coelom** and the **fluid** that circulates in it, supplies the viscera (2) The **water vascular system** that supplies the muscles of the tube feet that aids in locomotion (3) **hyponeural sinus system** that supplies the nervous system (4) **genital coelom** that supplies the genital organs. Echinoderms live exclusively in sea water with which their body fluid is isotonic. The nitrogenous excretory wastes are removed through the thin areas of body surface, such as tube feet and papulae by diffusion. Besides, coelomocytes also play a role in removing the metabolic wastes from the coelom.

Gas exchange in asteroids is achieved by papulae (dermal branchiae), soft projections of coelomic cavity standing out through the spaces between ossicles. Tube feet are also principal respiratory organs.

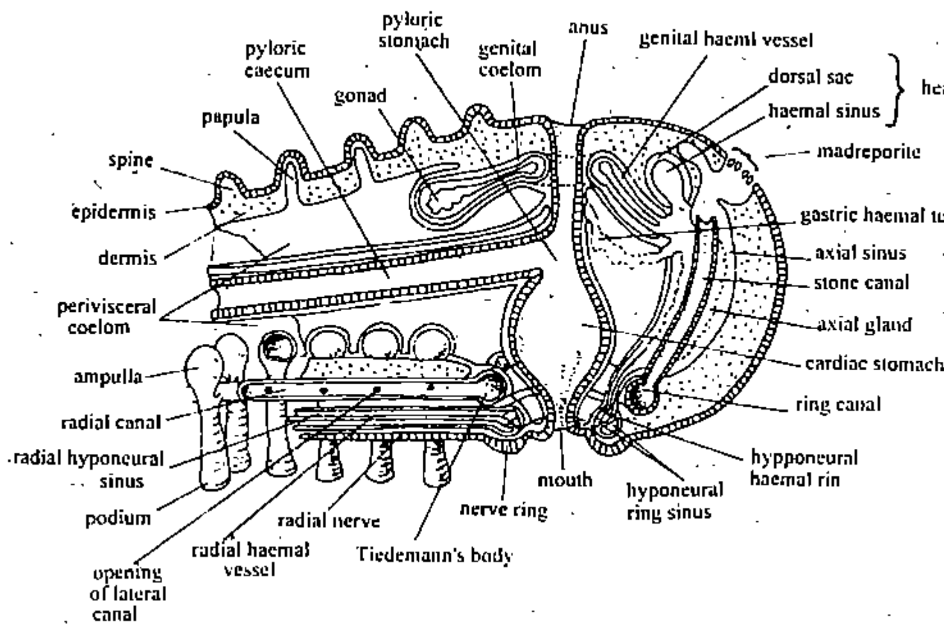



**Fig 6.65 : Diagram showing blood vascular and coelomic system in a Starfish.**

## Nervous System

The nervous system of steroids is not ganglionated and is closely associated with epidermis. It consists mainly of a **circumoral nerve ring** surrounding the mouth. From this nerve ring radial nerves extend into each arm. The radial nerve supplies branches to the podia and ampullae and is continuous with the subepidermal nerve net. Sense organs in asteroids are the eye spots found at the tip of the arm. The epidermis has also sensory cells that probably function as photoreceptors, chemoreceptors and mechanoreceptors. The epidermal sensory cells are more prevalent on the suckers of tube feet, tentacle like sensory tube feet and along the margins of the ambulacral groove.

## Reproductive System

Sexes are separate in most asteroids. There are ten gonads, two in each arm. They appear tuft-like or as cluster of grapes. Mature gonads occupy almost the entire arm. The gonopore is located between the bases of the arms. In the majority of seastars the sperms and eggs are shed into sea water and fertilisation is external. A single female may shed as many as 2.5 million eggs. Development includes a larval stage — the **bipinnaria** larva (fig. 6.66). The free swimming larva is provided with ciliary bands and arms that function in both locomotion and feeding. The bipinnaria larva then transforms into another larva, the **brachiolaria** larva (Fig. 6.67) with the appearance of additional arms at the anterior end. The branchiolaria then metamorphoses into an adult.

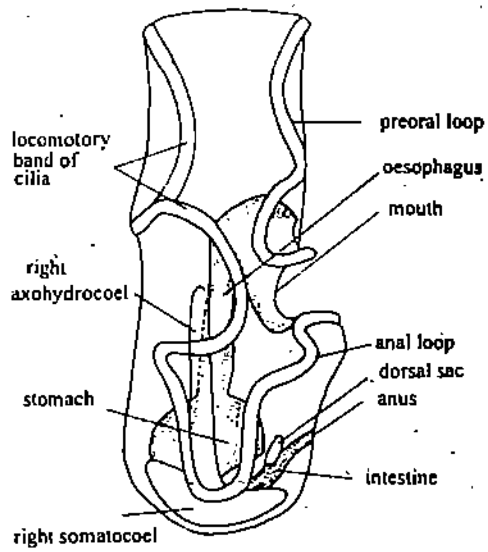



Fig 6.66 : Bipinnaria larva.

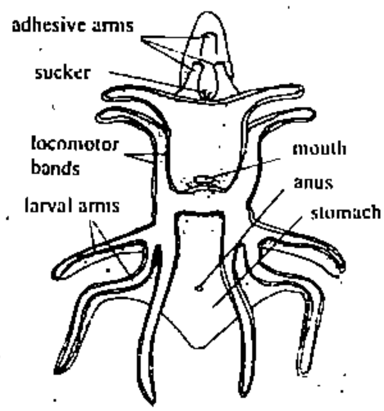



Fig 6.67 : Brachiolaria larva.

Now you have studied in detail the organisation of asteroids. Since the members of the other classes of the arm basically similar in organisation to those of asteroids. in the next section we will be highlighting only the salient features of other classes, and the differences they exhibit from asteroids. But before you begin the study of other classes of echinoderms, answer the following SAQs.

## SAQ 4

Fill in the blanks with suitable words.

a) Adult echinoderms exhibit _______ symmetry and the larvae show ________ symmetry.

b) The endoskeleton of most echinoderms is formed of ______.

c) In echinoderms the system of coelomic canals and tube feet is called ______ ________ system.

d) The respiratory structures of echinoderms are _______ ________ and ________ ________.

e) The pincer like structures that are found on the surface of the body of asteroids meant for protection are called ________.

f) The larvel stages of asteroids are _________ and ________.

### 6.3.2 Class Ophiuroidea

**Body star shaped but arms sharply demarcated from the central disc; ambulacral grooves covered by ossicles; tube feet have no suckers; no pedicellaria; no arms.**

Class Ophiuroidea includes brittle stars (Fig. 6.68), the largest class of echinoderms in terms of number of species. They inhabit benthic zones of sea. Ophiuroids feed on a variety of objects either browsing or by filter feeding.

Fig 6.68 : Brittle Star.

Although the brittle stars like asteroids have five radial arms, the arms are slender and sharply demarcated from the central disc. Pedicellariae are absent in brittle stars. The ambulacral grooves are covered with ossicles. The tube feet lack suckers, and hence they are helpful in feeding but have no role in locomoton. Unlike in asteroids, in ophiuroids madreporite is located on one of the oral shield ossicles. The tube feet also lack ampullae. Each arm of the animal has a column of articulated ossicles. These ossicles are covered by plates and connected by muscles usually called vertebral ossicles. Locomotion is brought about by the movement of arms. The mouth is surrounded by movable plates, the jaws. The integument of the animal is leathery and harbours dermal plates and spines. The visceral mass is confined to the central disc. There is a sac-like stomach and no intestine. Anus is absent. The undigested food is discarded through mouth. Nervous and haemal systems are similar to those of asteroids. The central disc harbours five pairs of sac like structures called **bursae** (sl. bursa), found only in ophiuroids among the echinoderms. The bursae open towards oral surface by genital slits at the base of arms. Gas exchange occurs in these bursae when water flows in and out of them. The gonads, small in size, located on the coelomic wall of the bursae, discharge the gametes in the bursa from where they find their way to the water through the genital slits. Sexes are usually separate. Fertilisation is external. Development includes a larval stage **ophiopluteus** (Fig. 6.69). Asexual reproduction is observed in the form of regeneration eg. *Ophiura, Ophioderma.*

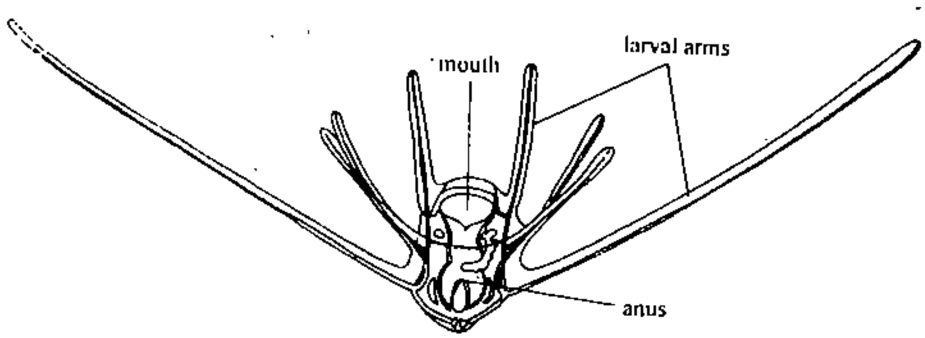



Fig 6.69 : Ophiopluteus larva.

### 6.3.3 Class Echinoidea

**Globular or disc shaped, without arms. Skeleton compact made up of dermal ossicles closely fitted with one another. Spines movable; ambulacral grooves closed; tube feet having suckers; pedicellariae present.**

Class Echinoidea includes sea urchins (Fig.6.70), sand dollars (Fig.6.71) and heart urchins. Echinoids have a compact body that is enclosed in an endoskeletal test or shell. The test is made up of dermal ossicles which are closely sutured with each other forming a compact structure. The plates bear stiff movable spines. The five pairs of ambulacral rows have pores and are homologous to the five arms of star fishes. Through the pores, the long tube feet are protruded. Echinoids also have pedicellariae which help the animals to keep the body clean and to capture small organisms.

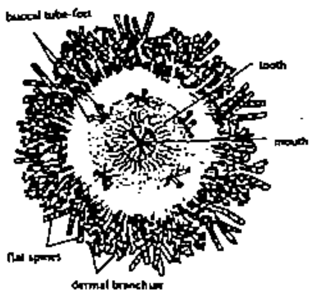



Fig 6.70 : Sea urchin.

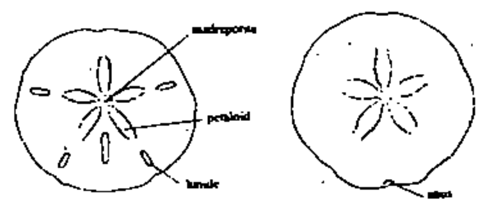



Fig 6.71 : Sand dollar.

The mouth of sea urchins lies at the centre of five converging teeth. The teeth are part of a complex chewing organ called **Aristotle's lantern** (Fig. 6.72). Sea urchins feed algae and other organic materials. Inside the test there is a coiled digestive system in which the oesophagus is directly connected to the intestine by a ciliated siphon enabling water to bypass the stomach (Fig. 6.72a). Thus the animal can concentrate the food for digestion in the intestine. The anus is located at the aboral surface.

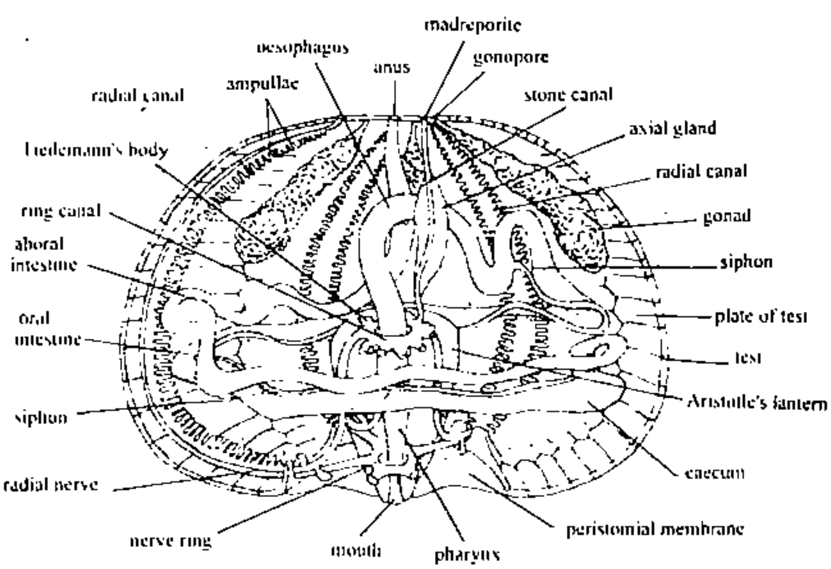



Fig 6.72a : Internal anatomy of a sea urchin.

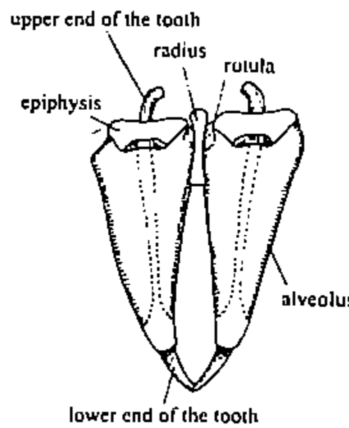



Fig 6.72 : Aristotle's lantern.

The circulatory and the nervous systems are similar to those of asteroids. The ambulacral grooves are closed and the radial canals of the water vascular system are located on the ambulacral radii just beneath the test.

The tube feet are provided with ampullae which lie inside the test and respiration is carried out by podia. In echinoids sexes are separate. Gametes are shed into water and the fertilisation is external. Some individuals may brood the young ones in the depression between the spines. Development includes a larval stage, the **echinopluteus** larva (Fig. 6.73). The larva leads a planktonic life for several months before metamorphosing into an adult. Common general are *Arbacia, Strongylocentrous* (sea urchins) ; *Dendraster* (sand dollar).

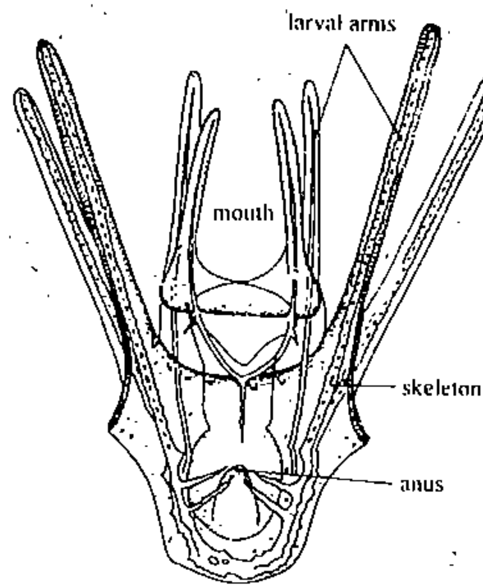



Fig 6.73 : Echinopluteus larva.

### 6.3.4 Class Holothuroidea

**Body cucumber-like; no arms; no spines; no pedicellariae; ossciles minute and embedded in muscular wall; anus present; tube feet with suckers; ambulacral grooves closed; modified tube feet in the form of circumoral tentacles present; madreporite internal.**

Holothuroida are commonly known as sea cucumbers because of their resemblence to cucumber (Fig. 6.74). They differ from the rest of the echinoderms in many respects. Holothurians have greatly elongated oral-aboral axis. The ossicles (Fig. 6.75) are highly reduced and are embedded in a muscular, thick and leathery body wall as a result of which the animals are soft-bodied. They either burrow or crawl on the sea-bottom or are found beneath rocks. As they usually lie on one side, the locomotory tube feet may be present only on that side of the body limited to the three ambulacra. This side is called the sole. In some species however the tube feet may be distributed in five ambulacral areas or all over the body. There are between ten to thirty retractile oral tentacles that are modified tube feet. Sea cucumbers are sluggish animals. Suspended food particles are entangled in the mucus secreted by the oral tentacles. The tentacles are then stuffed on by one through the mouth into the pharynx and the food particles are sucked off.

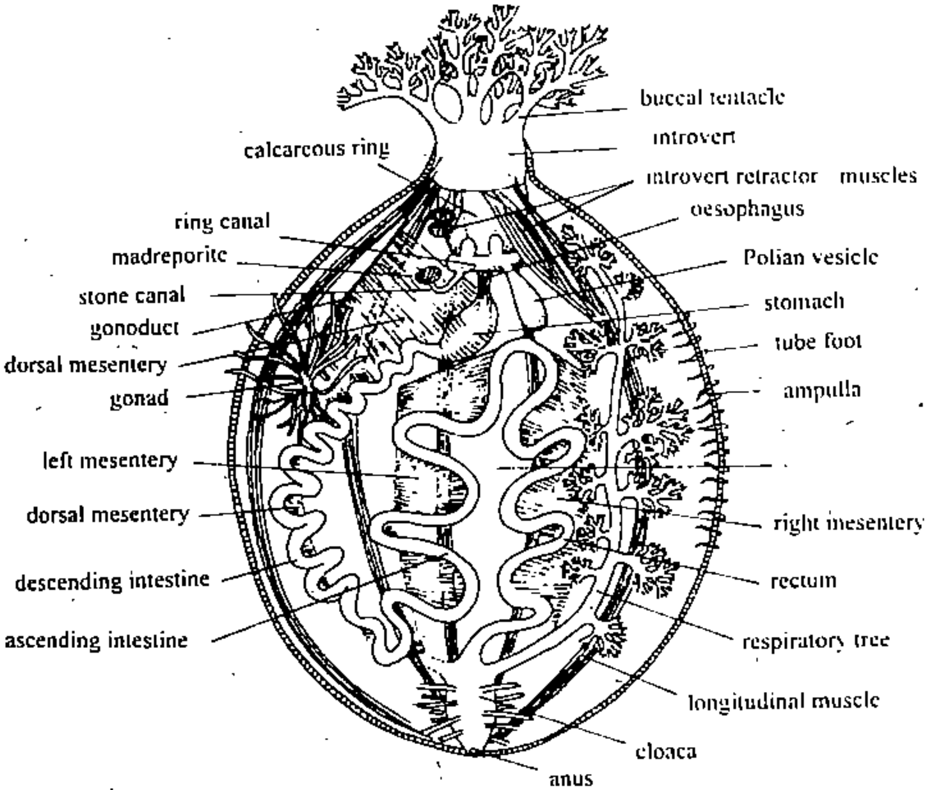



**Fig 6.74 : Internal organisation of a sea cucumber.**

A spacious, fluid filled coelomic cavity is present in holothurians. The digetsive system consists of oesophagus, stomach and intestine. The intestine opens to the exterior by a cloaca (Fig. 6.74). There is a unique respiratory tree (Fig. 6.75) in the coelomic cavity. It is composed of two long highly branched tubes. It opens into the cloaca. The cloacal muscles pump water into cloaca for purpose of gas exchange. Gas exchange is also carried out by skin and tube feet. The respiratory tree also has a role in excretion. The haemal or circulatory system as well as the water vascular system are present. The madreporite is peculiar in that it lies in the coelom.

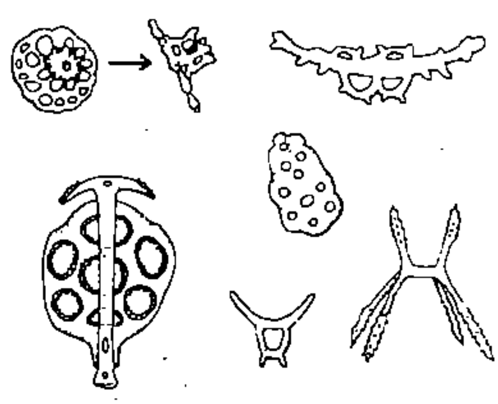


**Fig 6.75 : Ossicles of sea cucumber.**

Sexes are generally separate. Holothurians have an unpaired gonad that appears as one or two clusters of tubules.

Gametes are shed into water and fertilisation is external. A free swimming larva called **auricularia** (Fig. 6.76) emerges from the fertilised egg and metamorphoses into adult. Sea cucumbers can self-mutilate their body as a form of self-defense. When disturbed they may cast out a part of their viscera by rupturing their body wall. It may also evert the contents through the anus. The lost parts are then regenerated. eg. *Cucumaria*, *Leptosynapta*, *Synapta*.

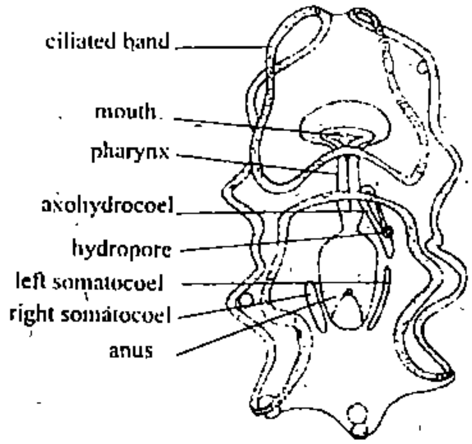



Fig 6.76 : Auricularia larva.

### 6.3.5 Class Crinoidea

**Five arms but branching at base; they carry pinnules. Oral surface has ciliated ambulacral grooves with tube feet resembling tentacles. No spines, no madreporite, no pedicellaria.**

Class Crinoidea includes sea lilies (Fig 6.77) and feather stars. They constitute the most primitive of living echinoderms. More fossil forms are known than the living ones. The living crinoids range in length from 15-30 cm. Sea lilies have flower shaped body at the top of an attached stalk. The feather stars are free living and have long, many branched arms, although the adults remain in the same spot for very long periods. Also, the feather stars which remain sesile or stalked during metamorphosis, detach themselves from the stalk to become free living. Many crinoids live at great depth but some of the feather stars occupy shallow waters.

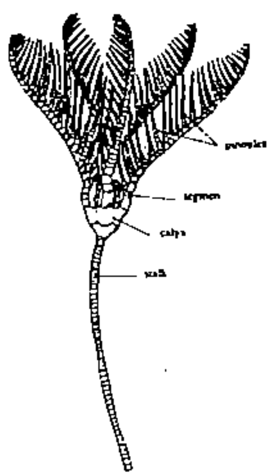


Fig 6.77 : A sea lily.

The body disc of crinoids called **calyx** is covered by a leathery skin, the **tegmen**. Tegmen contains calcareous plates. There are five flexible arms which branch off to give rise to more arms. Each arm carries many lateral pinnules that are arranged like barbs on a deather. The calyx and arms together are called the **crown.** In forms that are attached, there is a long stalk present on the aboral side of the body. The stalk itself is formed of many jointed plates and may bear cirri. In crinoids mádreporite, spines and pedicellariae are absent.

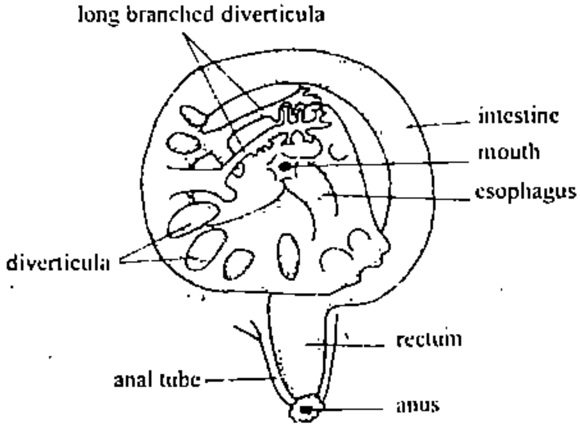



**Fig 6.78 : Digestive system of a sea lily.**

The mouth leads into a short oesophagus followed by the long intestine (Fig 6.78). The intestine bears diverticila and runs aborally for distance before taking a complete turn to open through anus located on a raised cone. Crinoids feed on small organisms that are caught in the ambulacral groove with the help of tube feet and mucous nets. The ciliated ambulacral grooves transport the food to the mouth. The water vascular system is built on typical echinoderm plan although the madreporite is absent. The nervous system has a oral nerve ring from which a radial nerve enters each arm. Sense organs are scanty and primitive. In crinoids sexes are separate. The gonads appear as masses of cells in the genital cavity. The sperm and ova escape by rupturing the wall. Fertilisation is external. Development includes a free swimming larval stage **Doliolaria** that later on attaches itself to a substratum before metamorphosis into adult, eg. *Antedon. Heterometra.*

## SAQ 5

I. State whether the following statements are true/or false.

1. Brittle stars are pelagic. T/F
2. Bursae in ophiuroids are respiratory in function. T/F
3. In brittle stars tube feet aid in locomotion. T/F
4. Echinoid shell is compact, formed by close suturing of dermal plates. T/F
5. Aristotle's lantern is a complex chewing organ of sea T/F
6. Holothurians closely resemble other echinoderms both morphologically and physiologically. T/F
7. The respiratory tree of holothurians is respiratory and excretory in function. T/F
8. Sea lilies and feather stars are most advanced echinoderms. T/F
9. Crinoids do not have madreporite. T/F

II. Match the items given in A with those given in B.

| | A | | B |
|---|---|---|---|
| 1. | Holothuroidea | a) | Doliolaria |
| 2. | Crinoidea | b) | Bipinnaria |
| 3. | Asteroidea | c) | Echinopluteus |
| 4. | Echinoidea | d) | Ophiopluteus |
| 5. | Ophiuroidea | e) | Auricularia |

## 6.4 OTHER PHYLA

You have now studied all the major invertebrate phyla. In addition to these, there are a few other phyla of animals in invertebrates. Each of them contains a very limited number of species of animals only. Information on most of these phyla is very often far from sufficient and hence it is difficult to understand their affinities with other animals with any degree of certainity. So assigning them proper position in the animal kingdom has been very difficult.

It is not possible here to treat these phyla in detail as it is beyond the scope of this course. So instead, given below is the list of these phyla. The approximate number of species in each phylum is given in parenthesis. Their broad position in the animal kingdom is also indicated against them. You will get a brief idea of these phyla from this account.

| Name of the phylum | Number of species | Position | |
|---|---|---|---|
| Placozoa | 1 | Parazoa | |
| Mesozoa | 50 | Protostomia | Acoelomata |
| Nemertina (Nemertea) | 650 | -do- | -do- |
| Gnathostomulida | 80 | -do- | -do- |
| Gastrotricha | 400 | -do- | Pseudocoelomata |
| Kinorhyncha | 100 | -do- | -do- |
| Nematophora | 230 | -do- | -do- |
| Acanthocephala | 500 | -do- | -do- |
| Entoprocta | 60 | -do- | -do- |
| Loricifera | (most recently described) | -do- | Schizocoelomous coelomates |
| Priapulida# | 9 | -do- | -do- |
| Sipunculida (Sipuncula) | 300 | -do- | -do- |
| Echiura | 100 | -do- | -do- |
| Pogonophora | 80 | -do- | -do- |
| Tardigrada | 400 | -do- | -do- |
| Pentastomida | 90 | -do- | -do- |
| Phoronida (lophophorate) | 10 | -do- | -do- |
| Ectoprocta (lophophorate) | [illegible] | -do- | -do- |
| Branchiopoda (lophophorate) | 280 | -do- | -do- |
| Chaetognatha | 50 | Deuterostomia | Enterocoelous |
| Hemichordata | 80 | -do- | -do- |

## 6.5 SUMMARY

In this unit you have learnt

- Phylum Mollusca is a large phylum of soft bodied animals and includes over 50,000 living species. The bilaterally symmetrical animals are usually provided with an outer calcareous shell that offers protection to them. A ventral muscular foot aids in locomotion. Dorsally, the body of the animal, known as visceral mass, is covered by a body wall, the mantle that encloses a space, the mantle cavity. Gills or ctenidia located in the mantle cavity are the respiratory structures. Many molluscs are herbivores feeding on algae and other plants. Food collecting organs, the odontophore and radula are located in the buccal cavity. Coelom is confined to a place enclosed by the pericardium dorsally and a portion of the intestine ventrally. Circulatory system consists of a three chambered heart, blood vessels and blood sinuses. Excretion is by nephridia or kidneys.

Nervous system consists of brain, pleural, pedal and visceral ganglia and the associated commissures and connectives. Molluscs may be hermaphrodites or dioceous. Fertilisation may be external or internal. In organisms with internal fertilisation sperm transfer may be direct or via spermatophores. Development may include one or two larval stages, the trochophore and the veliger larvae.

- Phylum Mollusca includes seven classes. Of these, Class Monoplacophora includes most primitive molluscs Class Polyplacophora includes chitons that have a dorsoventrally flattened body covered by eight overlapping plates. Class Aplacophora comprises of shell less molluscs, the solenogasters. The remaining four classes are Gastropoda, Bivalvia, Scaphopoda and Cephalopoda. Gastropods, the members of the largest class of Mollusca occupy marine, fresh water and terrestrial environment. They include snails and slugs. The snails possess a conospiral shell and the visceral mass has undergone a 90 to $180^0$ twist - the torsion. The foot, a flat, creeping sole is the typical locomotory organ. The class Bivalvia, as the name suggests comprises of molluscs that have a shell formed of two valves and the body is laterally flattened. And the caphalopods, with the exception of *Nautilus* have no external shell. Cephalopods can be regarded as highly advanced of all the invertebrates because of the presence of a well developed nervous system as well as the circulatory system.

- Echinoderms are the largest deuterostomous group and are exclusively marine in habitat. The adults have a radial symmetry although the larvae are bilaterally symmetrical. They live in benthic zones in the sea and are particle feeders, browsers, scavengers and predators. Echinoderms generally have five arms around a central disc. Head and specialised sense organs absent. The side in which the mouth is present is the oral surface and generally anus opens on the aboral surface. They have dermal ossicles as endoskeleton, respiratory papulae and open ambulacral areas. Structures called pedicellaria may be present as organs of protection. The water vascular system, unique to echinoderms, derived from some of the coelomic cavities does varied functions such as food gathering, locomotion, respiration and circulation. Hemal or circulatory system of undefined function is seen in echinoderms. Sexes are separate and reproductive systems are simple. Development invariably includes a larval stage. Includes five clases: Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea and Crinoidea.

## 6.6 TERMINAL QUESTIONS

1. List the diagnostic characters of phylum Mollusca.

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2. Briefly write about the organisation of chitons.

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3. What is torsion? briefly discuss the process of torsion in gastropods.

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4. Write brief notes on:
   a) Shell in Bivalvia
   b) Crystalline style

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5. What are the characteristics of echinderms that are unique to them and not found in other phyla ?

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6. Describe the water vascular system of a seastar?

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7. List the various classes of phylum Echinodermata giving one example for each class.

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## 6.7 ANSWERS

### SAQ 1

a) snails, clams and squids

b) mineralised shell

c) visceral mass

d) mantle

e) ctenidia

### SAQ 2

(i) c.e.i.　　(ii) a, b, f, h　　(iii) d, g

## SAQ 3

I (1) (1) Development of distinct head (2) Dorsoventral elongation of the body (3) Gastropods exhibit torsion (4) conversion of plate like shell into a spiral asymmetrical shell.

(2) Torsion of the twisting of the visceral mass 180$^{0}$ with respect to head and foot. The anticlockwise twist behind the head results in the positioning of the gills, mantle cavity, anus, and nephridiopore at the anterior part of the body behind the head when viewed dorsally.

(3) Molluscan shell has three layers, the outer horny layer made of conchiolin, a modified protein. The middle layer is prismatic layer made up of prisms of calcium carbonate packed in a matrix of protein. And the inner nacreous layer is the calcareous layer.

(4) The large gills that are located in the spacious mantle cavity are the respiratory organs in bivalves.

(5) Prosobranchia, Opisthobranchia, Pulmonata.

II A-F; C-T; D-T; E-T; F-T; G-T; H-T; I-T; J-T.

III A. Scaphopoda B. captacula C. *Nautilus* D. gas, buoyancy
E. branchial F. endothelium G. stellate H. spermatophores

## SAQ 4

a) radial, bilateral b) dermal ossicles c) water vascular
d) tube feet, dermal branchiae e) pedicellariae f) bipinnaria, brachiolaria

## SAQ 5

I 1-F; 2-F; 3-T; 4-T; 5-T; 6-F; 7-T; 8-F; 9-T

II 1-e; 2-a; 3-b; 4-c; 5-d.

**Answers to terminal questions**

1. Refer to section 6.2
2. Refer to section 6.2.2
3. Refer to section 6.2.4
4. (a) Refer to section 6.2.5
   (b) Crystalline style is a structure found in the stomach of lamellibranchs. It is a compact and long, gelatinous rod that secretes enzymes amylase and lipase.
5. (i) Occurrence of pentamerous radial symmetry.
   (ii) Presence of an endoskeleton in the form of calcareous ossicles.
   (iii) The presence of water vascular system that takes care of the functions of locomotion, respiration and transport of nutrients.
   (iv) Lack of distinct head or brain.
   (v) Respiration by dermal branchiae, tube feet and respiratory tree (Holothuroidea) and bursae (Ophiurodea)
   (vi) Absence of excretory organs
   (viii) Occurrence of bilateral symmetry during the larval stages.
6. I Refer to Section 7.5.1

   II

| | | |
|---|---|---|
| 1. | Asteroidea | Sea star |
| 2. | Opiuroidea | Brittle star |
| 3. | Echinoidea | Sea urchins |
| 4. | Holothuroidea | Sea cucumber |
| 5. | Crinoidea | Sea lily |

# UNIT 7 SKELETON AND POLYMORPHISM

## Structure



## 7.1 INTRODUCTION

In the present unit you will be studying two aspects of the invertebrate metazoans, namely: (1) skeleton and (2) polymorphism. In section 7.2 you will study skeleton, which is 'any structure that maintains shape, supports or protects a body and allows for the transmission of forces'. In this you will also study with the help of examples the three kinds of skeletons that occur in invertebrates - (a) exoskeleton (b) endoskeleton and (c) hydrostatic skeleton.

In section 7.3 you will study polymorphism, a phenomenon in which two or more forms occur in a single species. There are various kinds of polymorphism which occur in different animal groups. You will study this phenomenon in two groups in which this is well developed and documented : (a) the cnidarians and the (b) arthropods.

### Objectives

After studying this unit you should be able to:

- define skeleton and differentiate between exoskeleton, endoskeleton, and hydrostatic skeleton.
- describe the different types of exo and endoskeletons occurring in the different phyla of invertebrates,
- define polymorphism,
- describe polymorphism in cnidarians and insects,
- explain alternation of generations.

## 7.2 SKELETON

You all know that the skeleton forms the framework of the body of different organisms in the animal kingdom. Besides giving shape to the animal, it also gives protection and support and serves as a point of attachment for the muscles. Not only the vertebrates, but many invertebrates also have skeleton in different forms. If the skeletal structures are present embedded within the body of the animals, they form the endoskeleton and if such structures are present on the surface of the animal body and are visible externally, they constitute the exoskeleton. Both these are rigid skeletons. However, some invertebrate animals use their body fluids as an internal hydrostatic skeleton.

Let us study the three kinds of skeletons found in different phyla of invertebrates.

### 7.2.1 Exoskeleton

In the majority of the invertebrate phyla, the skeletal structures are found outside the body and are visible from the outside. You will do a phylum-wise study of the exoskeleton found in various invertebrates.

I. **Cnidaria** - Among the cnidarians, the exoskeleton is a typical feature of the many Anthozoa and some Hydrozoa. The members of Anthozoa have cylindrical, column-like bodies called polyps. They are sessile and remain attached to the substratum in the sea. They often form colonies and secrete a hard skeleton around themselves e.g. *Madrepora* (Order Madreporaria or Scleractinia) (Fig. 7.1). They are generally called true stony corals. The solitary polypoid hydrozoans lack a solid exoskeleton. Most hydrozoan colonies have an exoskeleton, atleast partially, for anchoring and support. One group of colonial hydrozoans called hydrocorals, however secrete a complete, solid exoskeleton of calcium carbonate around the colonies e.g. *Millepora* (Order Hydrocorallina) (Fig. 7.2).


**Fig 7.1: The hard exoskeleton of *Madrepora*.**


**Fig. 7.2: Hard exoskeleton of Millepora, composed of calcium carbonate.**

The skeleton of a solitary coral is known as a corallite. It is secreted by the epidermis and is made up of calcium carbonate. A corallite is cup-shaped and encloses the aboral portion of the polyp. The cup-wall is called the **theca**, its basal part is known as the **basal plate**. A number of vertical septa - **sclerosepta** radiate from the inner side of the theca-towards the centre of the cup. The inner ends of the sclerosepta may be fused to form a central skeletal mass of irregular shape called the columella (Fig. 7.3).

In colonial corals, the corallites of individual polyps fuse together to form a skeletal mass known as corallium. The coral colonies grow in size by budding off polyps and form extensive masses of coral skeletons or corallites. This results in the formation of huge structures called coral reefs. Reefs are mainly formed by stony corals i.e., members belonging to order Scleractinia (Madreporaria) of class Anthozoa.

The coral exoskeletons are generally white, but they may also be brilliantly coloured — red, green or blue. Out of these, the red coral, *Corallium rubrum* (moonga) is considered to be a semiprecious stone in India and China and is believed to be auspicious.

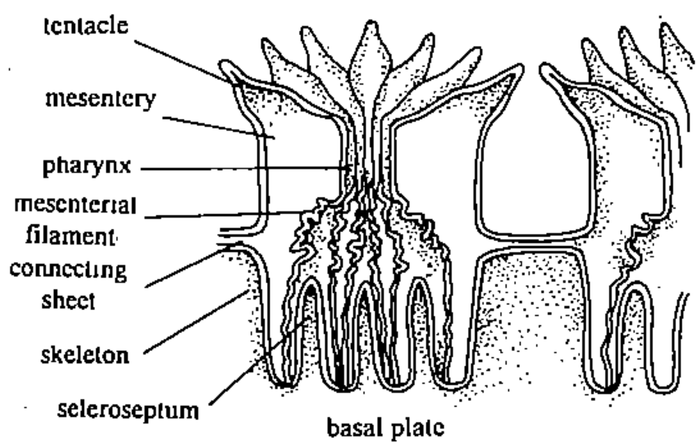



**Fig. 7.3 : Colonial Scleractinian corals showing a coral polyp within its skeletal cup (longitudinal section).**

II. **Arthropoda** - In the majority of arthropods including crabs, insects and spiders the exoskeleton consists of a hard, complex cuticle made up of a polysacchride and protein complex bound to form chitin. In addition, calcium carbonate is incorporated into the exoskeleton of crabs and other crustaceans.

The cuticle of arthropods is secreted by the underlying epidermis. It is composed of a thin, surface epicuticle and a much thicker procuticle. (The epicuticle, especially of terrestrial species contains waxes; when these are absent, the exoskeleton is relatively permeable to gases and water). The procuticle is subdivided into an outer exocuticle and an inner endocuticle. The epicuticle is stronger than the other parts, as it is tanned and its molecular structure has been stabilised by reactions with phenols and by formation of additional cross linkages in the protein molecules. The exoskeleton bears sensory processes. It is often traversed by ducts of various glands through which secretions are discharged outside. (Fig. 7.4a).

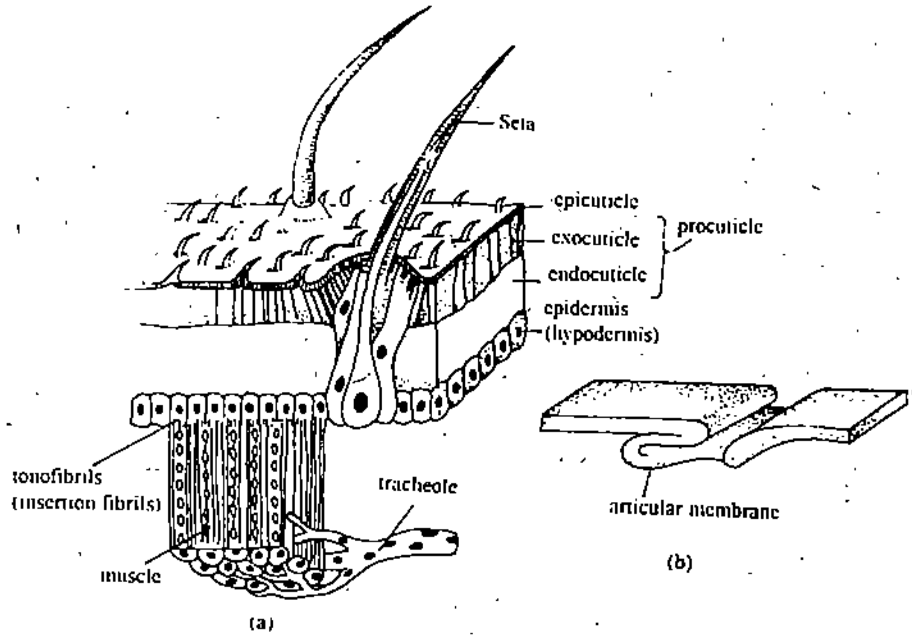



**Fig. 7.4 : (a) Three-dimensional section of an arthropod integument (b) An intersegmental joint showing the articular membrane folded beneath the segmental plane.**

The arthropod exoskeleton is divided into plates or sclerites on the head and the trunk, and into a series of strong tube like segments on the appendages. These are connected to each other by thinner, folded, flexible and uncalcified membranous structures called articular or arthorodial membranes. (Fig. 7.4b). These membranes provide movement and flexibility. In different classes of phylum Arthropoda, the thoracic and abdominal sclerites may be divided into a dorsal plate called tergum, a ventral plate called sternum, and lateral flap like plates called pleura (Fig. 7.5).

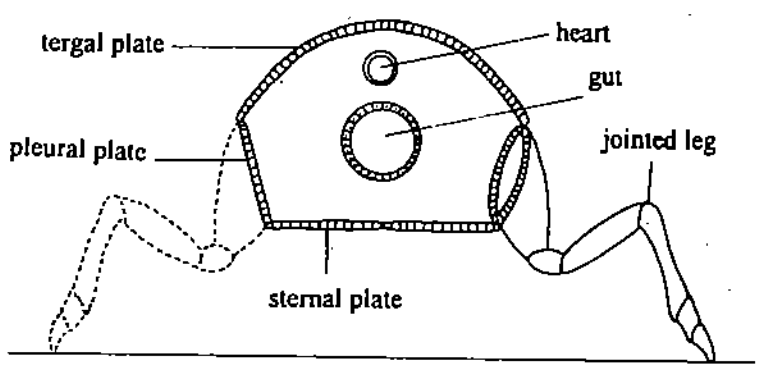
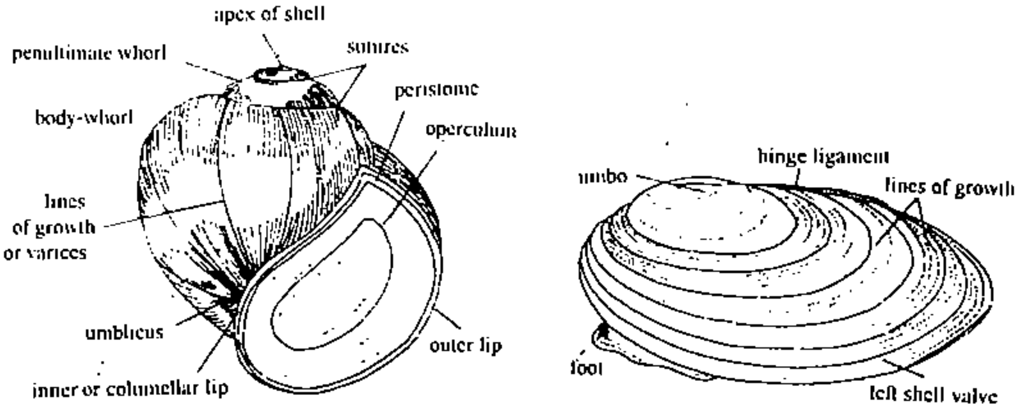



**Fig. 7.5 : A cross section of a generalized arthropod through the thorax or abodomen region showing the tergum, sternum and pleura of a sclerite.**

This cuticular exoskeleton not only provides protection but also imparts rigidity to the body of the animal which is otherwise very soft. It also serves as points of attachment for the muscles.

**III.** **Mollusca** - Exoskeleton is clearly and evidently seen in most of the animals belonging to phylum Mollusca. Molluscs possess an exoskeleton in the form of a hard shell. This shell forms a kind of house in which the animal lives (Fig 7.6).




(a) Pila (b) Unio

**Fig. 7.6: Different shapes of shells (exoskeletons) occur in molluscs.**

The Shell is chiefly made up of layers of calcium carbonate prisms or plates, deposited within an organic framework. Conchiolin, a horny protein covers the outer surface of the shell. The shape of the shell may be globose and spiral as in *Pila* (Fig. 7.6a), or it may consist of two convex halves that are joined by a strong hinge ligament as in *Unio*,(Fig. 7.6b). The shell is secreted by a thin flap of skin called mantle, which covers the whole animal and forms the inner lining of the shell. Fig. 7.7 shows the position of shell and mantle in a mollusc. The surface of the shell is marked by numerous lines of growth as seen in Fig. 7.6.

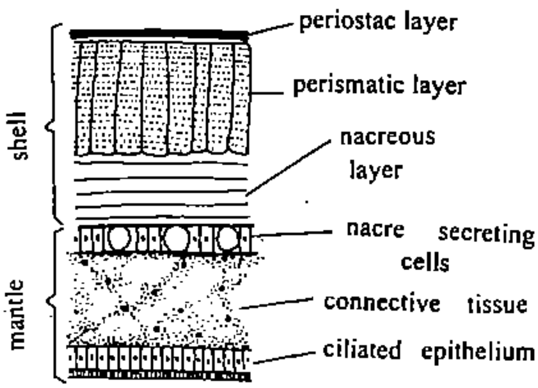



**Fig. 7.7 : A part of shell and mantle in T.S.**

## 7.2.2 Endoskeleton

Now we shall study the endoskeleton i.e. internal supporting skeleton, of invertebrates.

I. **Porifera:** Almost all the poriferans or sponges posses an endoskeleton which supports their body and maintains their shape. This endoskeleton is formed of needle like mineral spicules or a network of organic spongin fibres or both, which are secreted by special cells. The endoskeleton may thus be made up of (i) calcium carbonate e.g. in *Scypha* (Fig. 7.8a) or (ii) silica e.g. *Euplectella* (Fig. 7.8b) or (iii) spongin fibres e.g. *Euspongia* (Fig. 7.8c); (iv) some may posses a combination of both spicules and spongin fibres e.g. *Cliona* (Fig. 7.8 d). The endoskeleton may be supplemented and reinforced by foreign particles such as sand grains, skeletons of minute organisms or spicules of other sponges, which may be acquired from the surroundings.

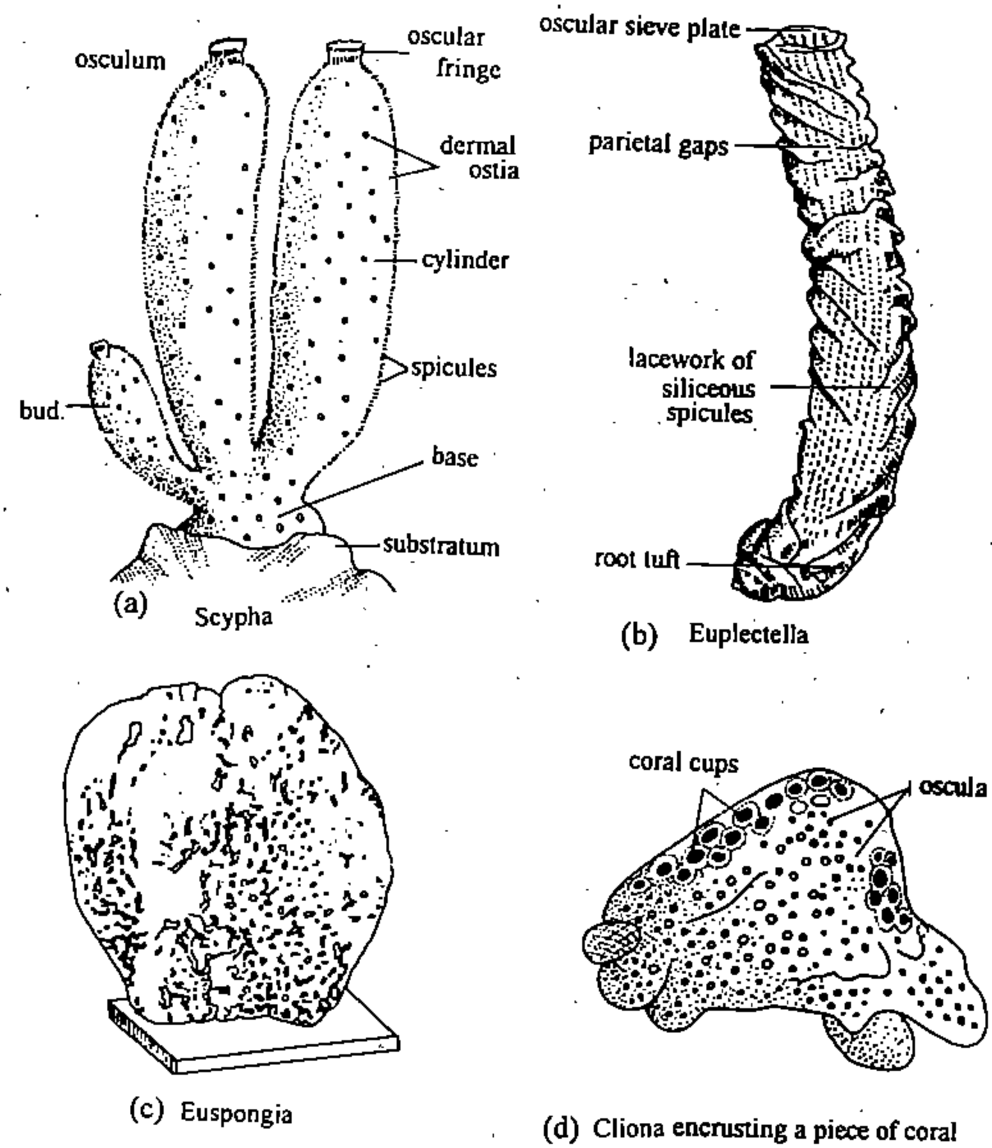



**Fig. 7.8 : Endoskeletons of a few poriferans composed of different materials (a) calcium carbonate endoskeleton in *Scypha*, (b) silica endoskeleton in *Euplectella* (c) spongin fibre endoskeleton in *Euspongia*, (d) a combination of spicule and spongin fiber endoskeleton in *Cliona*.**

Fig. 7.9 : Spongin fibres.

Spongin (Fig. 7.9) is an organic elastic substance. It is chemically a scleroprotein (an insoluble protein present in skeleton, hair, nails and claws of higher animals) containing sulphur. It is resistant to protein digesting enzymes. Spongin fibres may be present in the form of a network in which siliceous spicules (made of silica) are embedded, as in *Cliona*. In animals like *Euspongia* the spicules are totally absent and the spongin alone forms a continuous, branching, firm supporting framework for the soft body. It is this tough fibrous skeleton of Euspongia that is dried and sold as commercial bath sponge.

**Spicules:** The spicules are small, needle like crystalline bodies which make the body stiff, reducing deformation by water currents. Spicules are composed of calcium carbonate or silicon dioxide. In calcareous sponges, the calcareous spicules are composed of calcium carbonate in the form of calcite with traces of sodium, magnesium and sulphate as in *Leucosolenia* and *Scypha*.

In siliceous sponges the spicules are composed of clear glassy, hydrated or colloidal silica called opal as seen in *Euplectella* (hexactinellida), where the spicules are arranged beautifully in a lattice work with a definite pattern. In other sponges, the spicules may be scattered all over the body.

According to their shape the spicules may be termed:

(i) **Monaxons** - These are simple rod like or needle like spicules that are formed due to growth in one or both directions along a single axis (Fig. 7.10 a).

(ii) **Triaxons** - A triaxon or hexactinal spicule consists of 3 equal axes that intersect at right angles, resulting in six rays (Fig. 7.10b). These may be modified by reduction, loss, branching or curving of rays and by the development of spines or knobs on them.

(iii) **Tetraxons** - These spicules are four-rayed; all the rays are not in the same plane but radiate from a common point. These are also referred to as tetraradiate or quadriradiate. Usually one of four rays is elongated, or sometimes it may be lost and the spicule then becomes triradiate (Fig. 7.10c).

(iv) **Polyaxons** - These are the spicules with several rays radiating from a central point. These may be grouped to give a star like appearance (Fig. 7.10d).

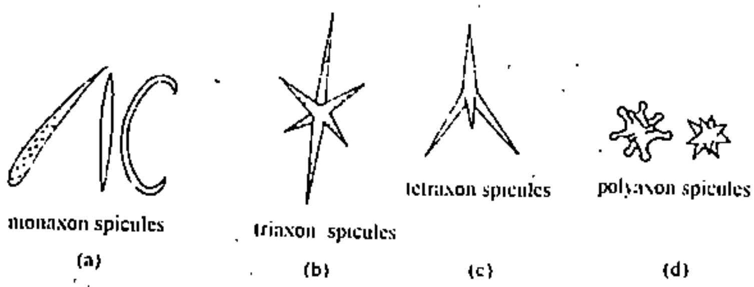



**Fig. 7.10 : The different shapes of spicules that occur in sponges.**

**Echinodermata** - The endoskeleton of Echinoderms is mesodermal. The dermis of the body wall of star fish, sea urchin and most other echinoderms is supported by small internal ossicels made up of calcium carbonate. These ossicles are interconnected in a lattice-like array in the wall of sea stars (Fig 7.11) but form a nearly solid shell or test in sea urchins. The test is perforated by many small openings for various organs. The skeleton is secreted by the dermis and may be of various shapes, such as spines, rods, cones or plates. The ossicles are irregularly arranged on the aboral side. On the oral surface, five oral ossicles are present surrounding the mouth:

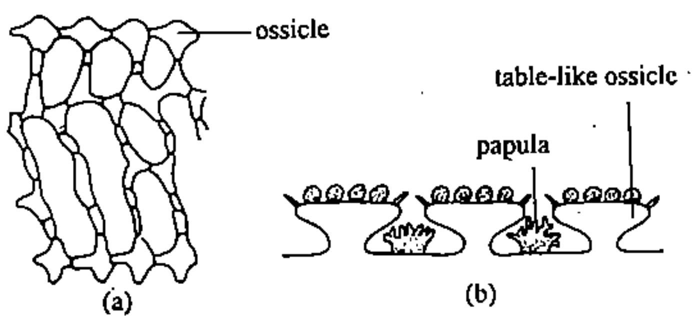



**Fig. 7.11 : (a) Arm of a sea star showing lattice-like arrangement of skeletal ossicles.**
**(b) Diagrammatic cross section through several paxillae of *Luidia*. The raised, table-shaped ossicles bear small, rounded spines on the surface and flat movable spines along the edge. Dendritic papulae (black) are located in the spaces between the projecting edges of the paxillae and associated spines.**

### 7.2.3 Hydroskeletons

Hydroskeletons, also called hydrostatic skeletons, but better called hydraulic skeleton, may provide the primary skeletal support for some animals. The coelomic fluid of an earthworm is an example of a primary hydroskeleton, as is the blood flowing into the foot of a clam for pushing the foot into the sand or mud. Jumping spiders have only flexor muscles that can bend their legs. The forceful extension of the legs during a jump comes from the rush of body fluid into the leg. (Refer Unit 3 of this course for more details)

### SAQ 1

Match the following:

| | | | |
|---|---|---|---|
| 1. | Calcareous spicules | a) | Mollusca |
| 2. | Ossicles | b) | Arthropoda |
| 3. | Chitin | c) | Echinodermata |
| 4. | Shell | d) | Porifera. |

## 7.3 POLYMORPHISM

Some animals are solitary, while others live in small groups, or in colonies. The colonies (groups) among animals can be of two types 1) The individuals of the same species live together, they are structurally quite similar but perform different functions. (e.g. group of bees; (2) The individuals of a species get together, assume different forms, (which is a unique property) perform different functions and collectively form one complete functional organism. These cannot survive individually. Both these types of colonies are also called "polymorphic colonies." The individuals of the colony are called zooids or castes.

As the name suggests 'poly' means many and 'morphs' means forms, that is "many forms". Those species are called polymorphic whose individuals occur in different forms and perform different functions. This phenomenon is known as polymorphism. It is an amazing feature in the lives of a few animals. You will study this phenomenon in Cnidaria and Arthropoda as a number of animals of this group show this phenomenon distinctly.

### 7.3.1 Polymorphism in Cnidaria

Polyps may be solitary or colonial

In general, all cnidarian forms fit into one of the two morphological types: (a) the hydra like polyp or hydroid form which is adapted for a sedentary existence and (b) an umbrella like medusa or jelly fish form which is adapted for a floating or free swimming life. (Fig. 7.12)

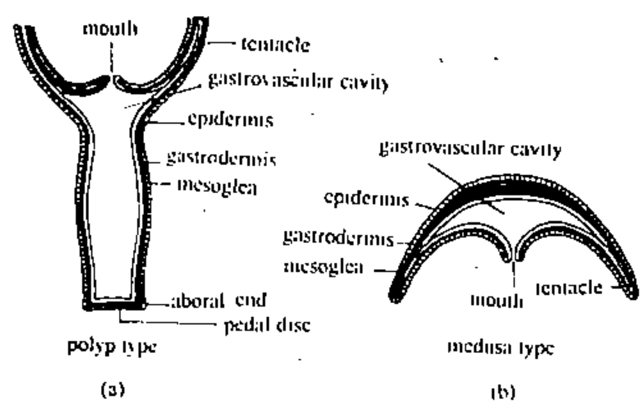



**Fig. 7.12 : (a) A typical polyp having a tubular body with a mouth at one end surrounded by tentacles. The basal or aboral end is usually attached to the substratum by pedal disc or other device. (b) A typical medusa which is bell shaped or umbrella shaped and has tetramarous symmetry (body parts arranged in fours). The mouth is usually on the concave side and tentacles extend from the rim of the umbrella. The medusa are usually free swimming.**

Many hydroids of class Hydrozoa, exhibit polymorphism which is associated with their colonial organization. Most hydroids are dimorphic or polymorphic, with at least two or sometimes, more, structurally and functionally different kinds of individuals within the same species. They are polyp during some part of their life.

Polymorphism is a characteristic of many but not all colonial animals.

Super ficially the polyp and medusa may seem very different, but actually each has retained the sac like body plan basic to the phylum (Fig. 7.12). The medusa is essentially an unattached upside-down polyp with the tubular portion widened and flattened into a bell shape.

Both the polyp and medusa have the three body layers typical of cnidarians - (a) the outer the ectoderm (b) the inner endoderm and (c) the middle jelly-like layer the mesoglea. The mesoglea is much thicker in the medusa, forming the bulk of the animal and making it more buoyant.

Let us now study polymorphism in some cnidarians.

## OBELIA

Obelia is a marine, plant-like animal found attached to the substratum. It is a colonial and branching hydrozoan of the phylum Cnidaria (Fig. 7.13). It is widely distributed and lives as deep as 250 feet below sea level.

***Obelia geniculata*** **is most common. It is found attached to sea weeds, sunken ship wrecks, rocks and even on shells of other sea animals. It grows only upto 1-4 inches. It is light brown in colour and is commonly called as "Sea fur".**

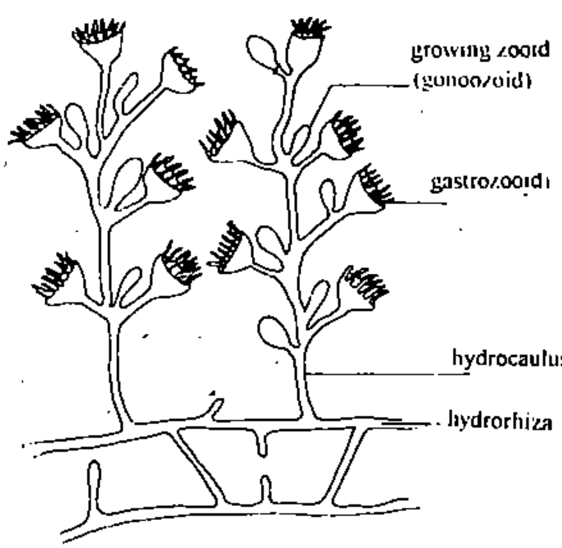



Fig. 7.13: Obelia Colony.

It is interesting to note that the *Obelia* colony, which appears like a small plant, is actually an animal which is made up of simple individuals living together and having different forms and functions. The colony results from asexual reproduction by budding, from the original zooid.

The Obelia colony is formed of three types of individuals (zooids):

i) Nutritive zooid or hydranths or gastrozooids or trophozoid (feeding function)

ii) Budding zooids or gonangia or blastostyle

iii) Medusa or sexual zooids (medusa is singular; medusae is plural).

The *Obelia* colony is thus trimorphic (tri=three, morph=forms). The Obelia colony has a common stalk called hydrocaulus which gives rise to one or more stalks. The hydrocaulus is connected below to a root like stolon or hydrorhiza. The living cellular part of the hydrocaulus is the tubular coenosarc, composed of the three typical cnidarian layers. These layers surround the central coelenteron (gastro-vascular cavity). The protective covering of the hydrocaulus is a non-living yellow, chitinous sheath secreted by the ectoderm called the perisarc (Fig. 7.14). Attached to the hydrocaulus are the individual polyps or zooids. All the zooids are attached to each other through the continuous enteron or gastro-vascular cavity. Most of the zooids are feeding polyps called gastrozooids or hydranths.

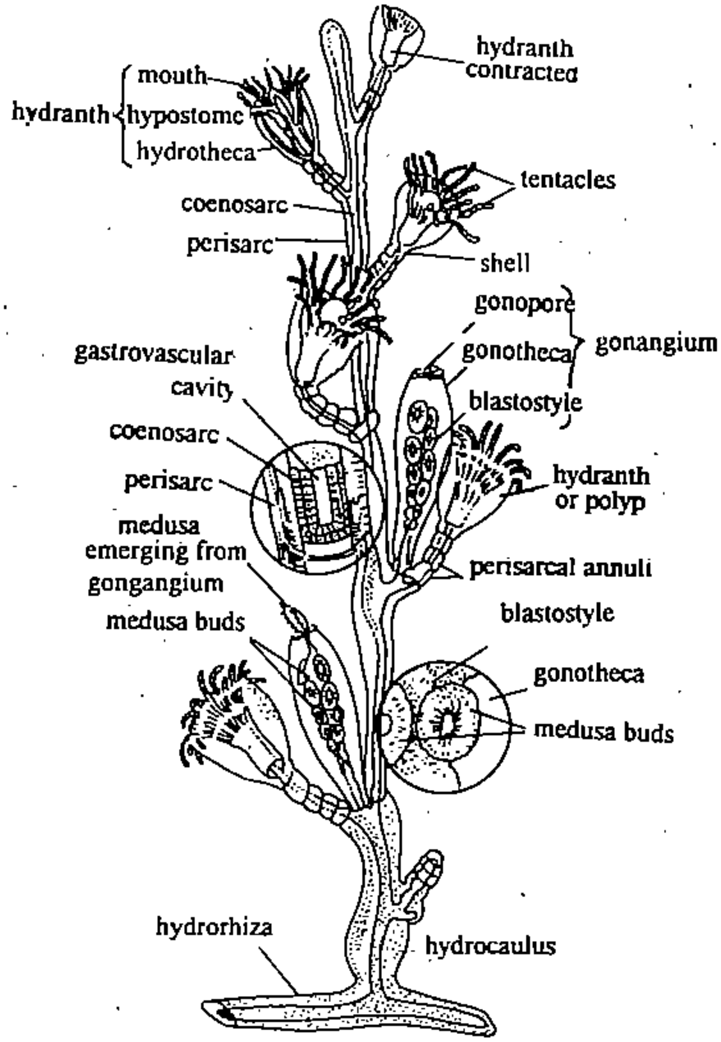



Fig. 7.14: Obelia colony, showing in detail the various zooids which occur in it.

## POLYPOID FORMS

Hydroids with a hydrotheca surrounding a polyp proper are said to be 'thecate' and those without the hydrotheca 'athecate'.

(i) **Gastrozooid or Hydranth** - Each *Obelia* colony has many hydranths or gastrozooids. Each hydranth is like a mini hydra. It has a cylindrical, tube-like, bottle shaped or vase-like body, with a terminal mouth which is surrounded by tentacles. Each zooid has an enteric cavity, which opens to the outside through the mouth. The zooid is attached to the hydrocaulus. This mini hydra is enclosed in a cup shaped hydrotheca (Fig 7.15a). *Obelia* feeds on small aquatic animals such as worms, crustaceans and other arthropods. The tentacles of the hydranths help in catching the prey. The food is digested in the enteric or gastrovascular cavity. The nutrients are sent to the entire colony through the enteric canals.

(ii) **Gonangium (gonos-seed, angeion=vessel)** - In *Obelia*, the medusae are budded off from a reproductive polyp called gonangium. This polyp or zooid is club shaped and elongated. The immature gonangium often detaches itself from the parent *Obelia*, settles down and starts growing into a new Obelia colony. This is an asexual or vegetative way of reproduction. If the gonangium does not detach, then it only grows into a mature gonangium with a central mother blastostyle (Fig. 7.15b) on which small growths or buds appear. These buds grow gradually in size and develop into male and female medusae or gonophores. This whole structure is covered by an extension of the perisarc, the transparent gonotheca (Fig. 7.15b). This zooid has no tentacles and no mouth, it has instead a gonopore through which the medusae are set free. The *Obelia* colony is hence an asexual generation.

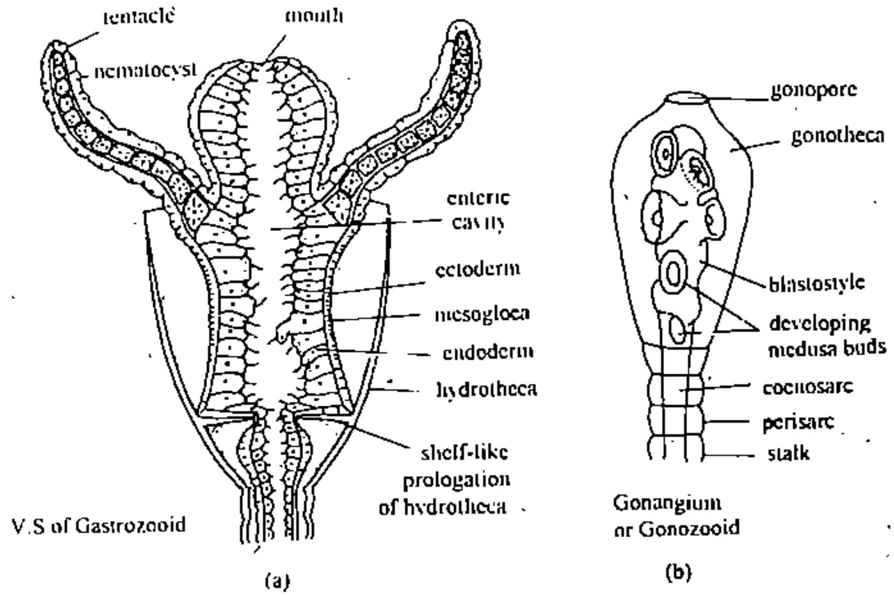



**Fig. 7.15 : Different types of polyps, occurring in an Obelia colony (a) V.S. of gastrozooid (b) Structure of a gonangium.**

## MEDUSA

(i) The medusa are reproductive zooids and can be either male or female. Medusa reproduces sexually and is a sexual generation. Each medusae is a free swimming zooid of Obelia which on being mature, produce gametes (eggs or sperms). The medusa is umbrella-like in appearance. The outer convex side is called ex-umbrella and the inner concave side is sub-umbrella. The margin of the umbrella has a circelet of tentacles. For nutrition these medusae (Fig. 7.16) have a mouth and a gastric cavity. If the medusa is a male it has four testes and if a female four ovaries (Fig. 7.16).

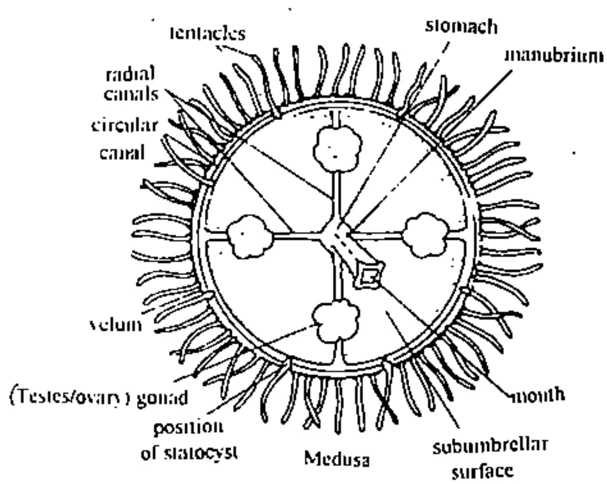



**Fig. 7.16: Oral view of medusa of *Obelia*.**

The presence of two body forms in the life history of *Obelia* and various other colonial cnidarians alternating between asexual and sexual generations, has been referred to as 'metageneses' or 'alternation of generation'.

In *Obelia* and various other colonial cnidarians both the polyp and medusa are diploid and only the gametes are haploid. Thus the asexual polyp reproduces asexually by budding, and occasionally produces buds or sexual medusa (also asexually) which may be male or female. This sexual medusa asexually produces male or female gametes that fertilise and give rise to asexual colonies.

Obelia alternates between sexual and asexual phases of life. This is called metagenesis or alternation of generation. It can be explained by the figure 7.17 a and b.

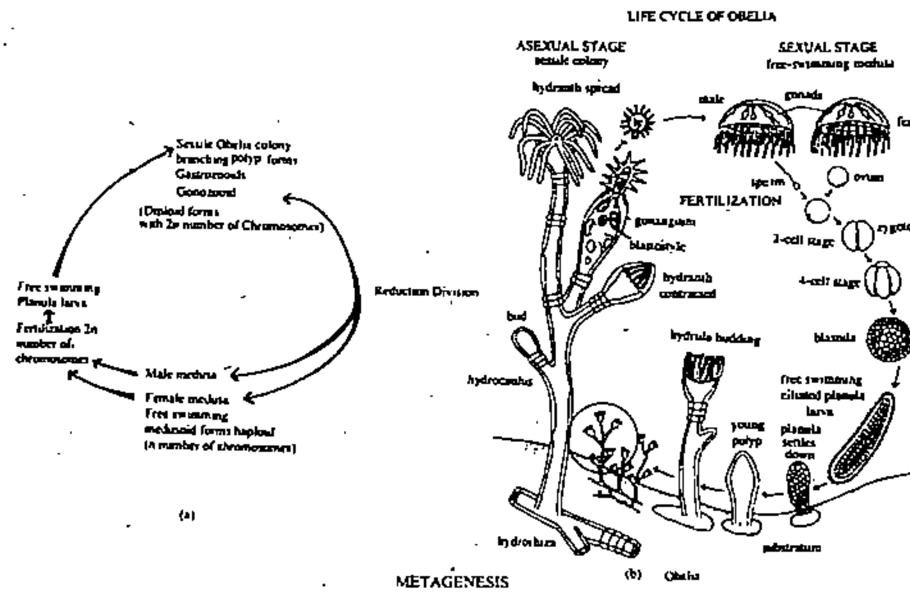



Fig. 7.17 : Alternation of generation (metagenesis) in *Obelia* depicted by (a) a flow chart (b) diagram of life cycle.

After going through this sub-section, you may have understood that *Obelia* is peculiar in the following ways:

i) It is a colony of different individuals.

ii) These individuals are called zooids and have different forms and functions.

iii) The colony breeds asexually by budding and remains sessile during this phase.

iv) It reproduces asexually by forming male and female medusae, which are free swimming forms.

v) The medusae or the sexual individual form gametes (eggs or sperms).

vi) The eggs and sperms fertilise to form zygote, which develops into a planu larva which in turn settles down and by budding (asexual method) gives rise to an asexual colony.

## BOUGAINVILLEA

Another Cnidaria, Bougainvillea (Fig. 7.18) also exhibits polymorphism similar to Obelia.

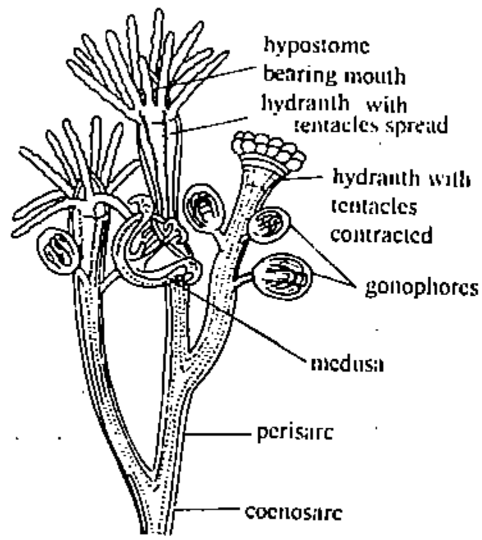



**Fig. 7.18: Bougainvillea colony.**

## HYDRACTINA

However, a somewhat greater degree of polymorphism is found in the Cnidaria *Hydractinia*, (Fig 7.19) which is an encrusting form and normally grows on the snail shells occupied by certain hermit crabs. Five types of polyps arise individually and irregularly from the encrusting base, or stolon which consists of roots or runners (collectively called hydrorhiza).

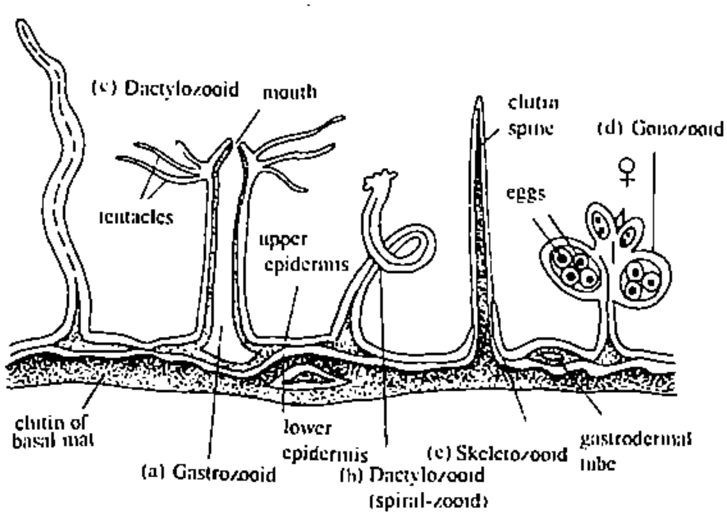



**Fig. 7.19: Polymorphy in *Hydractinia*. Five types of polyps occur in the colony.**

Each type of polyp found in *Hydractinia* colony has a specific function. The five types of polyps are:

1) Gastrozooids or feeding polyps each with many tentacles around the mouth and a relatively large gastrovascular cavity. (Fig 7.19a)

2) Two types of dactylozooids or protective individuals. These have no mouth and no tentacles but possess masses of nematocysts. The two types of dactylozooids are (i) The spiral zooid (Fig 7.19b) and (ii) the larger type of dactylozooid (Fig 7.19c) that look like a long single tentacle and occurs near the edge of the hermit crab's shell.

3) The gonozooids or blastostyle (7.19d) are the reproductive individuals and bear the medusa buds which are never released. The gonads develop in the bud or gonophore and the egg or sperm are eventually shed into the sea.

It should be noted that these colonies as well as most of the hydroid colonies are dioecious, that is to say, the colony bears either male or female medusa-buds but not both together.

4) Finally, there are the skeletozooids, which are just a thin covering of tissue over spiny projections of chitin arising from the chitinous mass of the encrusting base (Fig. 7.19a).

Polymorphism is also a distinct feature of many other individuals belonging to the phylum Cnidaria. It reaches its pinnacle in Siphonophora.

## SIPHONOPHORES

The Siphonophore colonies are extremely beautiful. They are delicate, transparent, free floating glass like marine colonies. They have super specialization of the individuals. Some Siphonophore colonies are *Physalia, Halistemma, Velella, Stephalia,* and *Diphyes* (Fig. 7.20).

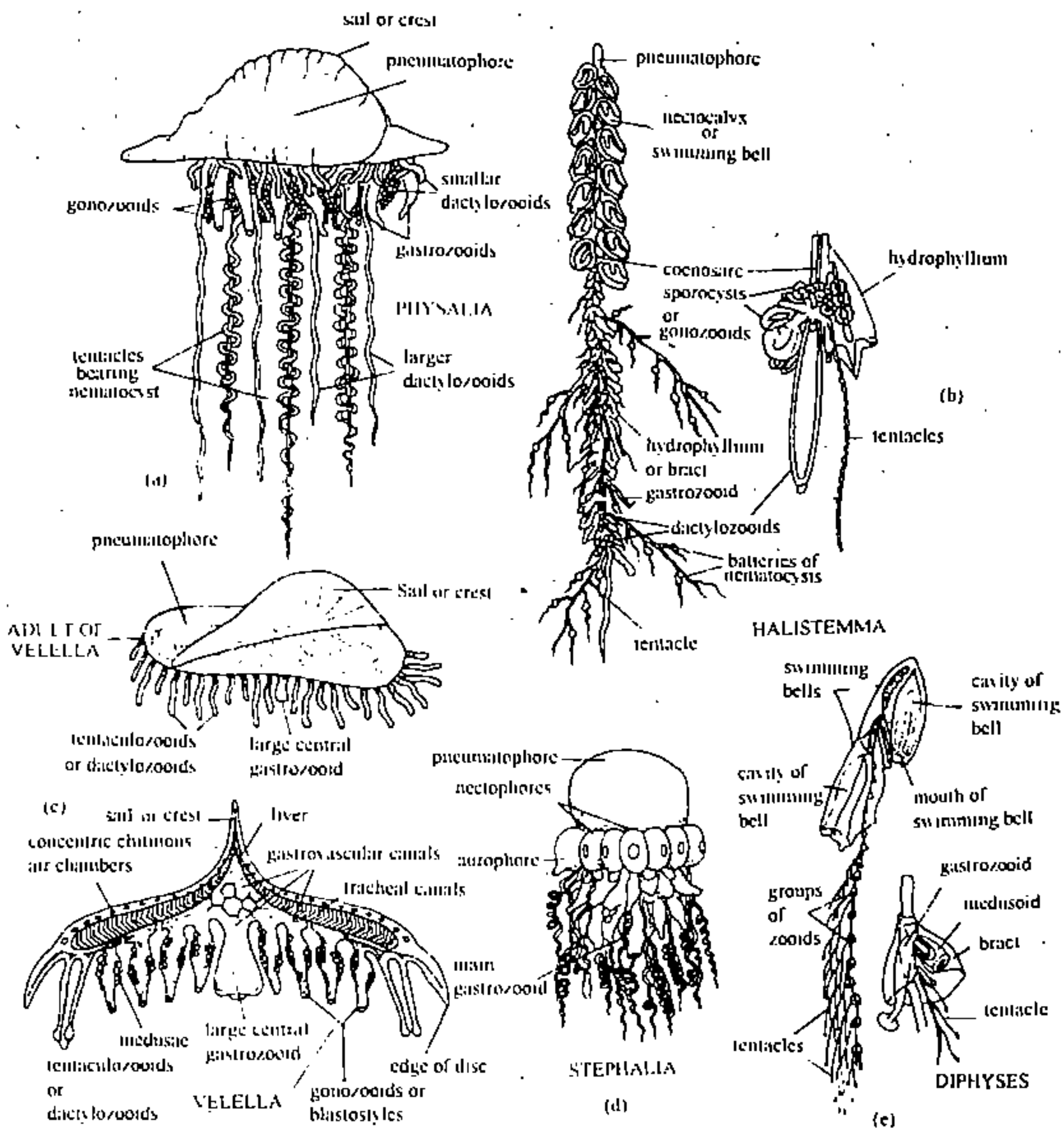



**Fig. 7.20 : Colonies of various Siphonophores: (a) *Physalia* (b) *Helistemma* (c) *Valella* (d) *Stephalia* (e) *Diphyes***

A typical siphonophore colony can be represented by a general plan (Fig. 7.21). Similar to other cnidarian colonies it is made up of two types of zooids: polyp and medusae.

The polypoid zooids are as follows:

i. Gastrozooids

ii. Dactylozooids

iii. Gonozooids

The medusoid zooids are as follows:

i. Pneumatophore

ii. Phyllozooids

iii. Nectocalyces or nectophores

iv. Gonophores.

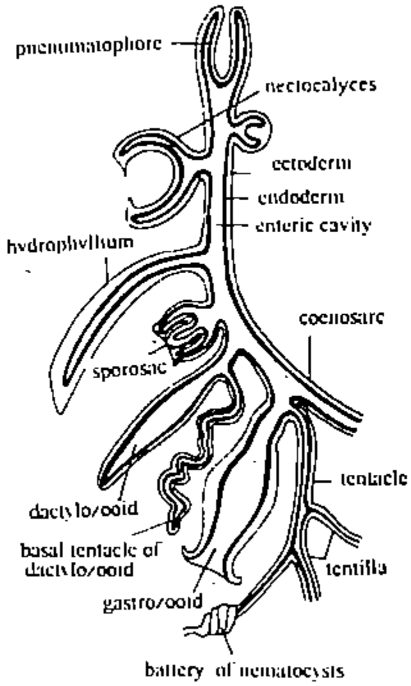



**Fig. 7.21: General plan of a typical Siphonophore colony.**

## POLYPOID FORMS

**i. Gastrozooids:**

The zooids which catch and digest food and thus provide nourishment are the gastrozooids (also called siphons). They have the polyp form. They have a mouth which may be (as in *Obelia)* or may not be surrounded by tentacles. Sometimes just one long tentacle with numerous coiled sticky tentialla arises from the base of the gastrozooid which is full of stinging cells. (Fig. 7.22a).

**ii. Dactylozooids:**

They are also called as tentaculozooid, palpons, fellers and tasters. Their function is protection. They have no mouth. They are closed bag-like structures full of stinging cells From the base of this bag arises a long, non branching, basal tentacle (Fig. 7.22b). These zooids are long and wave continuously in the sea water to explore their surroundings and to detect any approaching predator. These defensive polyps also help to capture prey.

**iii. Gonozooid:**

As the name suggests, gonozooids are reproductive zooids (also called as blastostyles). They are devoid of mouth as well as tentacles and hang like bunches of grapes (7.22c). They are oval structures of two types, containing either male or female gonads or gonophores.

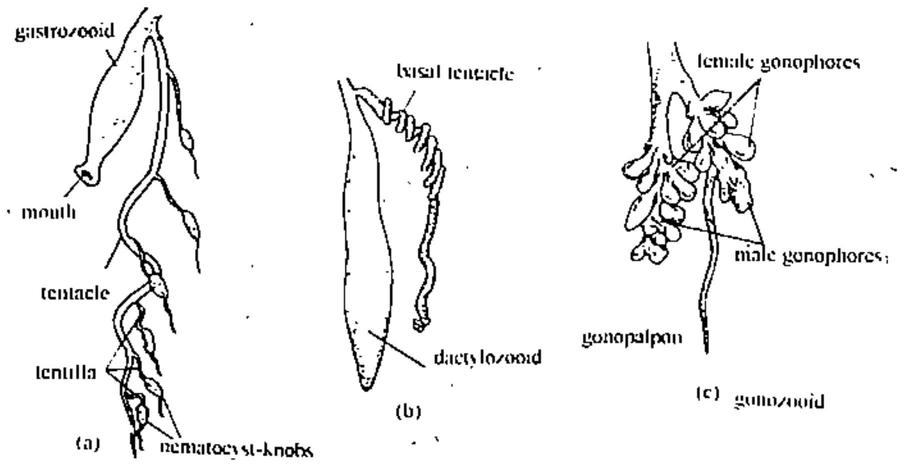



**Fig. 7.22 : Typical polyps of a Siphonophore colony (a) Gastrozooid (b) Dactylozooid. (c) Gonozooid.**

## MEDUSOID FORMS

i) **Pneumatophores:** As mentioned earlier polymorphic siphonophores are free floating colonies. They have air-filled structure for keeping them afloat. Pneumatophores are the main float. They are gas filled, bladder like structures. They are modified medusae, devoid of mesogloea. The walls of these bladders are muscular and double layered. The space between the two walls is the gastrovascular cavity (Fig. 7.23). The floats among different siphonophores are of various shape, size and structure (Fig. 7.20).

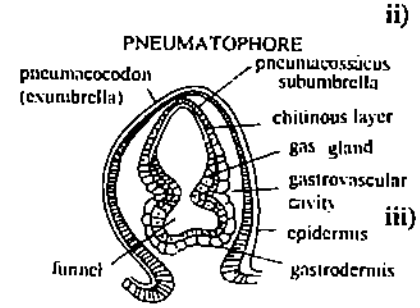



**Fig. 7.23: T.S. of pneumatophore of polymorphic siphonophore colony.**

ii) **Nectocalyes:** The Pnenmatophore which is the main float, generally has supporting smaller floats, called nectophores (nectozooids, nectocalyces or simply floating bells). They are clearly seen in *Halistemma* and *Stephalia* (Fig. 7.20b and d). The nectocalyces are also medusoid individuals, devoid of mouth and tentacles. They get their nourishment through the enteric canals of the colony. Their sole function is to help the colony in keeping afloat and swimming.

iii) **Phyllozooids:** These are also called bracts (hydrophyllia). They do not have typical medusoid features (Fig. 7.20 b and c). They can be like prism, shield, leaf or helmet. They have thick mesoglea between the ectoderm and endoderm. Their function is to provide protection to other vital zooids (specially gonozooids/ gonophores) by making a hood or covering over them.

iv) **Gonophores:** These are sexual medusoids. They occur singly or in clusters on blastostyles (Fig. 7.24). They are underdeveloped medusae with no mouth and tentacles. In *Physalia* (Fig. 7.20a) the female gonophore is medusa-like and the male gonophore is sac-like. The gonophores may remain attached to the colony as in *Physalia* (where they keep producing sex cells) or are set free as in (*Porpita*, and *Velella)* (Fig. 7.20c). The gonophores die once they discharge the sex cells as they cannot feed.

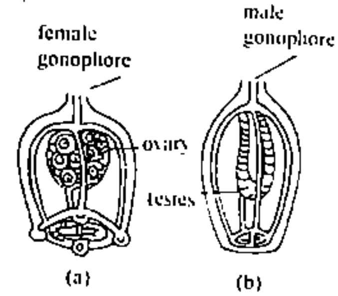



**Fig. 7.24 : Gonophores (a) Female (b) Male.**

Now you have understood that many colonial forms of the phylum Cnidaria, which look so simple, are actually a consequence of a joint venture of many individuals living together in perfect harmony. Polymorphism is essentially a phenomenon of division of labour which is advantageous to each individual of the colony. Polymorphic colonies are made up of small individuals, but collectively they appear large and can feed, reproduce and fight predators more effectively.

**Advantages of Metagenesis in Cnidaria**

In this unit you have studied that a large number of Cnidarian colonies are polymorphic and exhibit alternation of generations. This alternation of generation or metagenesis confers tremendous advantages for the particular species.

a) **Proximate (immediate) advantages:**

i) Metagenesis provides alternative method of reproduction, asexual and sexual, in case either one fails to work.

ii) Sessile (attached to the substratum) forms like *Obelia* produce free moving medusae as part of metagenesis. This allows wider distribution of species, which in turn improves the chances of exploring and finding better shelter, food and environment.

iii) Metagenetic animals escape adverse climatic conditions by changing from one body form to the other body form.

b) **Ultimate advantages:**

Continuous asexual reproduction causes genetic homogeneity. To prevent this, alternate sexual forms allow cross fertilization, mixing of genetic material and variation which is good for species survival and evolution.

In addition to *Cnidarians*, polymorphism is clearly seen among certain orders of the Class Insecta of Phylum Arthropoda.

## SAQ 2

Mark true (T) or false (F) in the space provided against each statement.

i) The gonangium in *Obelia* colony has mouth and tentacles [ ]

ii) Polymorphism is a unique phenomenon best shown by siphonophores [ ]

iii) Corals are polymorphic [ ]

iv) The function of pneumatophore is to keep the colony afloat [ ]

v) In metagenesis male forms alternate with female forms [ ]

## 7.3.2 Polymorphism in Insecta

In terms of evolution each organism is concerned primarily with satisfying the biological requirements for self survival and reproduction. Any interaction between two or more individuals leading to mutual benefit constitutes social behaviour. These associations can sometimes be simple aggregations (collecting together around a common source like light, heat, water, food and mate). For example certain, lepidopterans migrate in aggregation; individuals of earwigs and passalid beetles stay together to make their nests and rear their larvae respectively, then they separate. None of these groups is, strictly social or polymorphic. Aggregation is a temporary collection of individuals whereas, social, polymorphic groups are permanent in nature. Such true societies that exhibit polymorphism are best represented by two orders of Insecta such as Hymenoptera (honey bees and ants) and Isoptera (termites). In these, the continuity of the society depends on one or more reproductive by fertile individuals that throughout their lives often do nothing else than continuously produce new members for the colony. They are fed and cared for by their offspring, which remain in the nest as more or less sterile workers. The workers also clean, repair and protect the nest, collect the food and raise each new brood of sisters and brothers. The social group of each one of these animals (honey bee, ants, termites) has a well structured colony, where individuals of different form and structure perform different social functions.

Castes are determined partly by fertilization and partly by what is fed to the larva. Drones develop from unfertilized eggs and so are haploid. Queen and workers develop from fertilized eggs and so are diploid. The queen and worker differ because of the different types of food they are fed.

## HONEY BEE

The honey bees have one of the most complex social organization in the insect world. Instead of lasting one season, their organization continues for more or less an indefinite period. As many as 60,000 to 70,000 honey bees may be found in a single hive.

The members of a bee colony belong to one of the three types of castes. (i) There is usually a single sexually mature fertile female or the queen (ii) a few hundred sexually mature males or drones, and iii) the rest are sterile or sexually inactive genetic females or workers (Fig. 7.25).

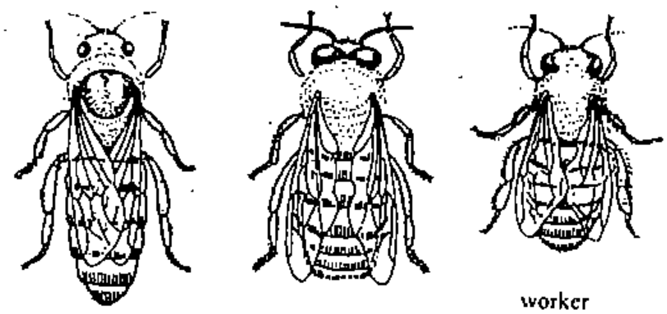



**Fig. 7.25: Various polymorphic forms of honey bee.**

The components in the 'Royal jelly', that are essential for queen determination have so far not been identified.

**Functions of the queen:** The queen develops from a fertilized egg in a large chamber. The larvae that are destined to become queen are especially fed on royal jelly (honey+pollen+glandular secretions of the nurse workers). Only one queen survives and she alone lays the eggs and is the mother of all the members of the hive. She lives for approximately 7-8 years and lays 15,00,000 eggs during her life span. The abdomen of a mature queen is highly enlarged to accommodate the large number of eggs. She controls the function and number of individuals of other castes.

**Functions of the drones:** The drones do not work and may be seen taking honey from the workers. They develop parthogenetically from the unfertilized eggs laid by the queen and exist only to mate the new queen. The growing larvae of drones are fed bee bread (honey + Pollen only).

**Functions of the workers:** The worker bees are also fed only on bee bread. They are sterile females arising from the fertilized eggs laid by the queen. They are kept undernourished and are made to grow in small cells, and so remain small. They are also prevented from maturing sexually by certain pheromones in the 'queen's substance' which is produced by the mandibular glands of the queen. Thus the workers are incapable of sexual reproduction. These workers execute all the duties—indoor as well as the outdoor. The workers bring loads of nectar, pollen, gum and water which are received and stored properly. Among the workers some attend to the queen and feed her, while others look after the nurseries feeding the young ones. The builder workers manufacture wax and build new combs. The repairers repair the hive, cleaners remove the dirt and dead bodies. Fanners beat their wings to ventilate the comb. There are store keepers as well and guard bees watch and guard the gateway of the busy but well ordered 'city'.

At the advent of swarming or when the vitality of the queen diminishes, the production of the queen's pheromones declines. In the absence of the inhibiting effect of the pheromone, the nursing workers construct royal cells into which eggs, royal jelly, and a greater quantity of food are placed. Those larvae which feed on the royal jelly develop into queens. At the same time when queens are being produced, unfertilized cells are deposited into cells similar to those for workers. These develop into drones.

### Reproductive Behaviour

The behaviour of the honey bees to come out of the hive in large numbers is called swarming. This usually occurs when the queen leaves the hive to establish a new hive, accompanied by a large number of older workers and drones. It is usually the mother queen or the older queen which leaves to found a new colony. The old colony is left behind with young workers and several new developing queens still in their cells but approaching emergence. The first one to hatch usually becomes the queen of the parent hive. The emerging queen stings her younger sisters to death.

### Nupital or marriage flight

About a week after emergence, the newly hatched virgin queen takes her first aerial flight. During this she is followed by a number of drones. Mating occurs in mid air. One drone, sometime more fertilize the queen during the mating flight, at which time enough sperms are stored in her seminal receptacle to last her a life time. The pair then falls to the ground. The male or males dies after mating and the queen after pulling herself away returns to the hive. Three to four days after mating the young queen begins to lay eggs. A queen may live as long as five seasons laying thousands of eggs in that time. Drones have no stings and are usually driven out or killed by the workers at the end of the summer. Fertilized eggs are laid in workers or queen's cell while unfertilized eggs into the drone's cells. The formation of queen and workers depends as you know on the diet which the larvae receive and on certain phermones secreted by the queen. Fig 7.26

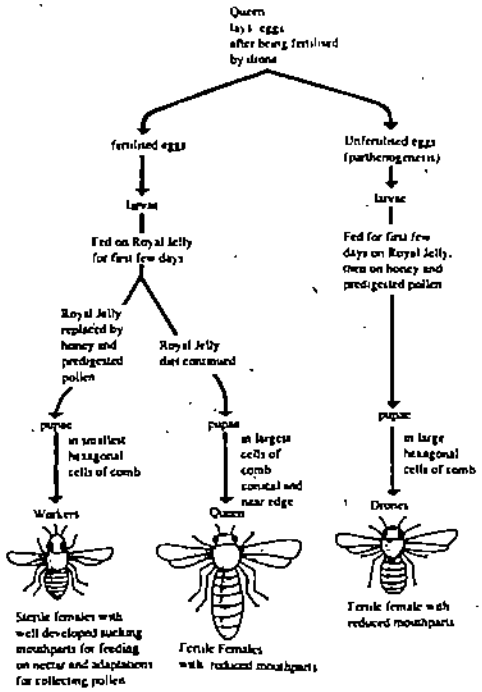



**Fig 7.26 : Summary of the caste system and how it develops in a honey bee colony the structure and behaviour of each kind of individual is determined by its chromosome constitution as well as its upbringing which is adapted according to the requirements of the community as a whole.**

## ANTS

Ants show an extreme case of polymorphism. Ant colonies resemble those of termites and are usually housed within a gallery system in soil or wood or beneath stones. The main castes in a typical nest of ants are queens, males, soldiers and workers (Fig. 7.27).

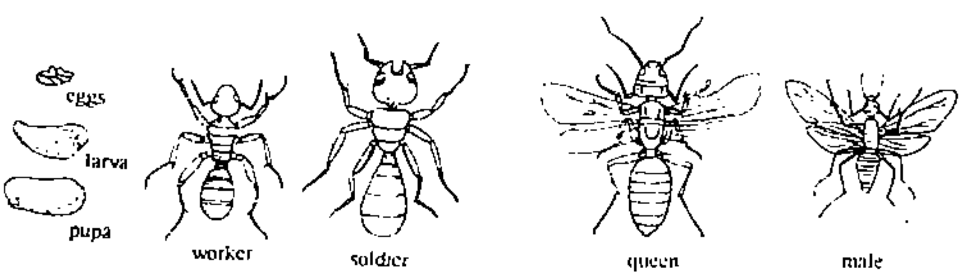
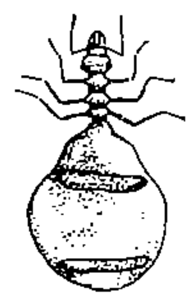



**Fig. 7.27: Polymorphic forms of ants.**



Honey ants (worker) also collect honeydew
They store it in part of their body

**Fig. 7.28 : A specialized worker ant.**

### i) Workers or ergates

They are sterile females. Similar to honeybees they are also underfed to make them small as well sterile. They are the smallest members of the nest. They are many in number and are assigned different functions by the queen of the nest. They may be builders, foragers, repairers, nurses and retinue (contingent to look after queen) etc. These individuals are morphologically similar. Only their functions are different. Fig. 7.28 shows a specialized ant worker.

In some species, the soldier ants raid the nests of other species and carry away their larvae and pupae to be raised as "slaves".

### ii) Soldiers

These are morphologically and functionally modified workers. They have large heads and extremely powerful mandibles. Their powerful jaws have two distinct functions (i) they serve to crush the seeds and other hard foods: and (ii) help to fight and protect the nest from enemies. If you are observant enough you must have seen them wandering in your house and feared them because of their powerful bite.

### iii) Queens or females

Unlike honeybees, the ant's colony has many queens. These are the fertile females with well developed reproductive organs. The queens are longer than the other members of the group. Their appendages are relatively shorter and stouter. They have wings only till they mate. Their initial duties include (i) cell building (ii) brood rearing and (iii) defence. Hence they retain a wide behavioural repertorie till they lay eggs. Thereafter they only lay eggs and feed.

### iv) Males

These are small, fertile, winged individuals with well formed sense organs and reproductive organs.

**Mating** occurs in a nuptial flight. The adult males and females (queens) are winged. Mating takes place in the air. After mating the males usually die while the mated females shed their wings and look for a place to start a new colony. In due course, the queens lay their eggs which hatch into larvae. The queens feed them with their saliva until they pupate. After that the workers take charge of the growing young ones and then the queens only lay eggs and feed.

## TERMITES

The termites are extremely social insects living in large colonies or nests usually constructed in the soil. In many species the nest may be huge and structurally complex. The termite colonies contain several castes comprising of fertile individuals, both males and females, and sterile individuals (Fig 7.29). As you will study some of the fertile individuals may have wings and may leave the colony, mate, lose their wing and as king and queen establish a new colony. Wingless fertile individuals may under certain conditions substitution for king or queen. Sterile members are wingless and become workers or soldiers. The reproductive male is a permanent member of the colony. Termites differ from social hymenopterans, in that the workers of the termite colony are sterile individuals of both sexes and may be juveniles or adults. Let us now study in greater detail the social organization of termites.

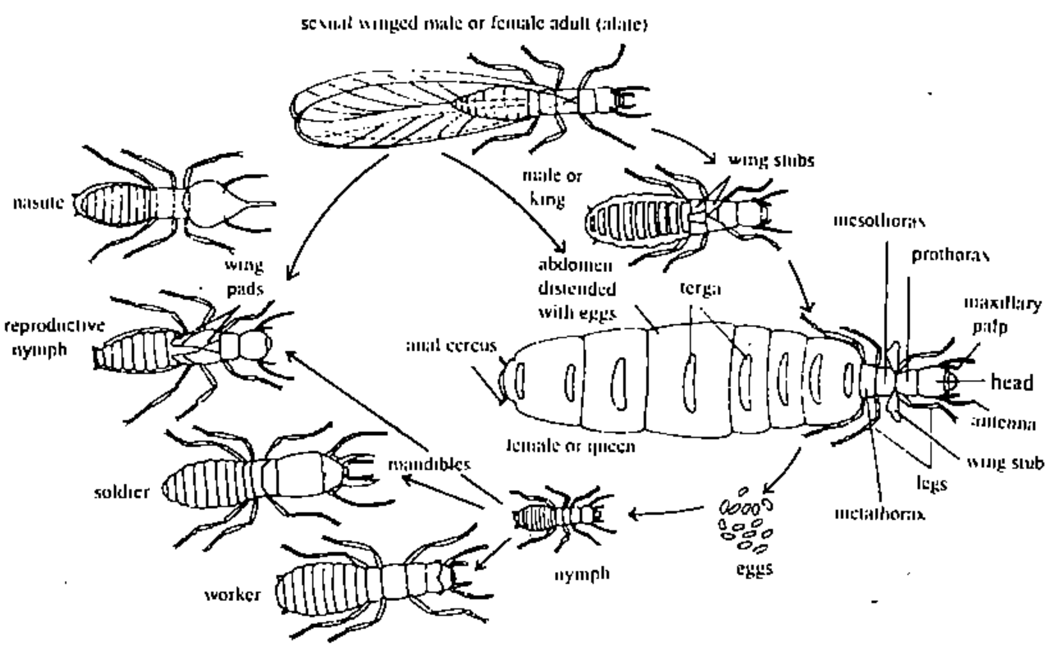



Fig. 7.29: Polymorhpic forms of termites.

**Caste system in termites:**

The principal castes belong to two categories:

i. Fertile castes ii. Sterile castes

**i. Fertile castes**

This includes -

a) Macropterous or long winged forms.

b) Brachypterous or short winged forms.

c) Apterous or wingless forms.

**a) Macropterous or long winged forms**

These are the normal winged individuals forming the true kings and queens. They live in royal chambers. Their body is pigmented, yellow, brown or black. Their eyes are large and widely separated. Their wings are in two pairs, and are well developed and longer than the body. After the nuptial flight and subsequent mating, the wings are ultimately discarded. The female who has successfully mated becomes the queen and changes dramatically. Her abdomen increases in size tremendously.

**b) Brachypterous or short winged forms**

These are sometimes designated as supplementary or substitute or neotenic kings and queens. Their body is less pigmented. Their eyes are small. Their two pairs of wings are short, vestigial and pad like.

**c) Apterous or wingless forms**

These are worker like substitute kings and queens which occur in more primitive species. Their body is without pigmentation.

**ii). Sterile castes**

These are the wingless forms with rudimentary reproductive organs. They are found in three forms:

a) **Workers**

The workers are more numerous than any other caste. They perform all the duties of the colony except reproduction. They care for the eggs and the young, feed and look after the queen, collect food, construct tunnels and nests. Their bodies have little or no pigmentation. Their eyes are usually absent.

**The young individuals, the soldiers and the royal forms are fed by the workers with regurgitated food and saliva.**

b) **Soldiers**

These are most highly specialized individuals. They are concerned with the defence of the colony. They are large headed individuals with prominent mandibles or with a frontal projection through which defensive secretions are excreted. Their heads are exceptionally prominent and jaws are extremely powerful, but surprisingly, they do not have eyes.

c) **Nasutes**

In some genera, the soldiers are replaced by peculier snouted forms called proboscideans. They have vestigial mandibles. Their head is prolonged into a rostrum, bearing the opening of a large frontal gland at its apex.

In the rainy season the macropterous forms (queens and kings) come out from their nests, in huge numbers and start swarming. After a brief flight, these winged royal forms come to the ground and shed their wings. The flight is not a true nupital flight, but only a dispersal flight, since mating does not take place in the air. Termites mate on the ground. The majority of them die but the few surviving fortunate ones form new colonies. A royal pair forms a small cavity called nuptial chamber in the ground. The first laid eggs develop into workers. When the, workers are enough in numbers they assume the duties of feeding the royal couple and enlarging the nest.

As mentioned earlier, the queen undergoes drastic modifications. Her ovaries and fat bodies increase greatly. She has a gigantic belly with the tiny head peeping like a black pin struck in a sausage. She lays 4,000 eggs per day. The moment the queen's power of producing egg is minimized, her feeding is stopped by the workers. The queen then dies of starvation and her fatty remains are engulfed with great relish by the other members of the colony.

The mechanism for caste determination in termites is under the influence of chemical substances called pheromones. This pheromone is produced by the royal pair, transferred throughout the colony to the nymphs through a mutual feeding process called trophallaxis so that they become sterile workers.

### SAQ 3

Fill in the blanks using appropriate words:

i) Many queens are found in the ________ colony.

ii) In the bee colony royal jelly is produced by ____________ ________________.

iii) In bees generally after mating the _________ die.

iv) In termite colonies the macropetrous castes form the ______ and the _________.

## 7.4 SUMMARY

In this unit you have studied that:

- The skeleton in different invertebrates is formed of endo and exoskeletal structures. Some invertebrates such as earthworms and molluscs use their body fluids as support.
- Exoskeleton occurs in Cnidaria, Arthropoda and Mollusca.
- Endoskeleton occurs in some members of Porifera and Echinodermata.
- There are different types of colony forming animals; the most peculiar are those which show polymophism.
- A polymorphic colony is made up of individuals who look different from one another in form and perform different functions. Individually they can not survive but collectively they form a complete functional unit of a colony.
- Polymorphism is most elaborate in some groups of Hydrozoa (Cnidaria) and in Insecta (Arthropoda).
- Many Polymorphic hydrozoans show alternation of generations.
- A typical polymorphic cnidarian colony is made up of basically two types of zooids — polyp and medusa.
- An *Obelia* (Cnidaria) colony has (1) polypoid zooids — gastrozooids and gonangia and (2) the non polypoid, sexual form, the medusa.
- A siphonophore (Cnidaria) colony has many types of polypoid zooids like gastrozooids, dactylozooids and gonozooids and may types of medusoid zooids like pneumatophores, nectocalyces, phyllozooids and gonophores.
- There are many advantages to these species because of polymorphism and alternation of generations.
- In Insects, polymorphic forms are best seen in honey bees, termites and ants.
- Honey bees have three forms of castes — queen, drones and workers.
- Ants have queens, males, soldiers and workers.
- Termites have queen, king, nasutes, soldiers, workers and reproductive nymphs (macropterous forms, Brachypterous forms, apterous forms).

## 7.5 TERMINAL QUESTIONS

1. Differentiate between exo- and endoskeletons.

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2. What are the functions of skeleton?

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3. What kinds of spicules are found in Porifera?

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4. What do you mean by polymorphism?

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5. Describe the functions of the various polymorphic forms of siphonophores?

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6. Name the different castes found in termites?

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## 7.6 ANSWERS

Self Assessment Questions

(1) 1 - d
2 - c
3 - b
4 - a

(2) i) F
ii) T
iii) F
iv) T
v) F.

(3) i) ant ii) nurse workers iii) drones/males (iv) kings and the queens.

### TERMINAL QUESTIONS

1. When the skeletal structures are found embedded within the body of the animals and not fully visible from outside then the skeleton is known as endoskeleton. If the skeletal structures are present on the surface of the animal though partly embedded inside the body and are visible externally, then the skeleton is called exoskeleton.

2. The skeleton mainly forms the framework of the animal's body and gives shape and support to the animal. It also protects the body, and serves for the attachment of muscles.

3. Endoskeleton in phylum Porifera consists mainly of spicules which are small crystalline rod like or needle like structures. These may be made up of:
   i) Calcium carbonate (or silicon dioxide) as in the animals belonging to class calcarea e.g. *Scypha*.
   ii) Silica (silicon-dioxide) as in the animals belonging to class hexactinellida e.g. *Euplectella*.

   The spicules may also be of various shapes such as those consisting of only one ray-monaxons, or of three rays - triaxon, or of four rays - tetraxon, or of many rays - polyaxon.

4. Polymorphism is the phenomenon in which individuals of the same species may have different forms and each form may be discharging different functions. It is conspicuous in many Hydrozoans (Cnidaria) siphonophores and many insects (Arthropoda).

5. A typical siphonophore has two forms, polyp and medusa. The polypoid zooids are of the following types -
   1. Gastrozooid : to catch and digest food and so provide nourishment to the colony.
   2. Dactylozooid : to protect the colony.
   3. Gonozooid : the reproductive zooid which contain the either male and female gonads.

   The medusoid zooids are the following types -
   1. Pneumatophores - That form the main float of the colony.
   2. Nectocalyces: That are smaller supporting floats.
   3. Phyllozooids: That provide protection to different zooids by forming a protective cover around them.
   4. Gonophores: Which are the sexual medusoids and their function is reproduction.

6. Termite social group has two major castes:
   a) Fertile castes b) Sterile castes.

   The fertile castes include -
   a) Macropterous b) Brachypterous c) Apterous individuals

   The sterile castes include -
   a) Workers b) Soldiers and c) Nasutes.

## GLOSSARY



**Aboral** : a region opposite the mouth.

**Atoll Coral** : reef that rests on the summit of submerged volcano.

**Binary fission** : asexual division that produces two similar individuals.

**Bud** protozoans : the smaller of two progeny cells resulting from fission. Metazoans : asexually - produced progeny that either remains attached to the parent as a colonial zooid or undergoes differentiation before being released as a separate individual.

**Calcareous** : composed of calcium carbonate.

**Caste** : one of the polymorphic forms within an insect society. Each caste has its specific duties as queen, worker, solidier so on.

**Chitin** : a horny substance that forms part of the cuticle of the exoskeleton of arthoropods and is rarely found in other invertebrates. It is a nitrogenous polysacchride, insoluble in water, alcohol, dilute acids and digestive juices of most animals.

**Cnidocil** : a short, stiff, bristle like cilium that is borne on a cnidocyte.

**Cnidocyte** : a cnidarian cell that contains an eversible thin, long and sharp tube, the cnida.

**Coelenteron** : the body cavity and gut of cnidarians and ctenophores, Gastrovascular cavity; archenteron.

**Coelom** : body cavity in triploblastic animals lined by a mesodermally derived epithelium (peritoneum).

**Colloblast** : a glue secreting cell (adhesive cell) situated on the tentacles of ctenophores.

**Colony** : an association of unicellular or multicellular organisms of the same species; individuals may be separate from or connected to other members of the colony and there may be some division of labour among them and sharing of resources.

**Cuticle** : a protective, non-cellular, organic layer secreted by the internal epithelium (hypodermis) of many invertebrates. In higher animals the term refers to the epidermis or outer skin.

**Dactylozooid** : a finger-shaped, defensive hydrozoan polyp.

**Dimorphism** : existence within a species of two distinct forms, according to colour, sex, size, organ structure and so on. Occurence of two kinds of zooids in a colonial organism.

**Dioecious** : having separate sexes; i.e. some individuals of the species contain male reproductive system and other individuals contain the female system.

**Epidermis** : the outer, non vascular layer of skin of ectodermal origin; in invertebrates a single layer of ectodermal epithelium.

**Eutely** : condition of a body composed of genetically fixed, constant number of cell or nuclei in all adult members of species as in rotifers, acanthocephalans and nematodes.

**Fringing reef** : reef that extends seaward directly from the shore.

**Gastrozooid** : nutritive or feeding polyp of cnidarians which is similar to a short hydra.

**Gonangium (pl Gonangia)** : type of gonozooid that consists of a central blastostyle, bearing gonophores and is surrounded by an extension of the perisarc (gonotheca) - reproductive zooid of hydroid colony (Cnidaria).

**Gonophore** : a hydroid reproductive bud that bears the germ cells and may become a free swimming medusa or a variously modified sessile medusa. Medusoid.

**Gonopore** : the external gential pore found in many invertebrates.

**Gonozooid** : a hydrozoan reproductive polyp which is often reduced, lacking mouth and tentacles and bears gonophores. A sexually reproductive zooid of thaliaceans.

**Hermaphroditic** : having both male and female reproductive systems in the same individual.

**Hydranth :** nutritive zooid of hydroid colony.

**Hydroid :** the polyp form of cnidarian as distinguished from medusa form. Any cnidarian of the class Hydrozoa, order Hydroida.

**Hydroskeleton (Hydrostatic skeleton) :** a mass of turgid fluid or plastic parenchyma enclosed within a muscular wall or within one of the body spaces that provide support or rigidity to an organism or one of its part, necessary for antagonistic muscle action: for example, parenchyma in acoelomates and perivisceral fluids in pseudocoelomates serve as hydrostatic skeletons.

**Madreporite :** sievalike structure that is for the intake for water-vascular system of echinoderms.

**Medusa :** a jelly fish, or the free-swimming stage in the life of cycle of cnidarians.

**Ossicles :** small separate pieces of echinoderm endoskeleton. Also tiny bones of the middle ear of vertebrates.

**Parthenogenesis :** unisexual reproduction involving the production of young not fertilised by the males; A parthenogenetic egg may be diploid or haploid.

**Paxilla :** an echinoderm ossicle crowned with small movable spines.

**Polymorphism :** the presence in a species of more than one structural type of individual.

**Rostrum :** a snout like projection on the head.

**Sclerite :** thickened area of cuticle in the exoskeleton of arthropods.

**Sedentary :** stationary, sitting inactive: staying in one place.

**Sessile :** attached at the base; fixed to one spot, not able to move about.

**Shell :** a relatively heavy exoskeleton of calcium carbonate in (molluscs and brachiopods) or chitin (in arthropods).

**Siliceous :** containing silica.

**Spicule :** one of the minute calcareous or siliceous skeletal bodies found in sponges, radiolarians, soft corals and sea cucumbers.

**Spongin :** fibrous, collagenous material making up the skeletal network of horny sponges.

**Sternum :** the primary ventral plate of an arthropod body segment; breast bone of vertebrates.

**Tergum :** primary dorsal exoskeletal plate each arthropod segment.

**Test :** a shell or hardened outer covering.

## FURTHER READING

Invertebrate Zoology by Rupert/Barnes Sixth International Edition, 1994.

Integrated Principles of Zoology, by Hickman, Roberts, Larson, Ninth Edition, 1995.

# NOTES

# NOTES

Utter Pradesh
Rajarshi Tandon Open University

# UGZY -01
# ANIMAL DIVERSITY-I

Block
# 3
## COMPARATIVE FORMS AND FUNCTIONS

# BLOCK 3 COMPARATIVE FORMS AND FUNCTIONS

In Block-2 you have studied about the characteristic features and classification of some of the acoelomates and pseudocoelomate phyla comprising Porifera, Cnidaria, Ctenophora, Platyhelminthes, Nematoda and Rotifera and the Coelomate group of animals beginning with Annelids and Arthropods. Also you had the accounts of soft bodied animals which included molluscs and the spiny skinned animals, the echinoderms. The present block consists of 6 units (unit 8 to unit 13).

In Unit 8 on comparative forms and functions you will study about locomotion that involves movement of the body as a whole from place to place. The unit describes the various types of locomotion exhibited and the structural components of locomotory machinery among different nonchordate animals.

Unit 9 deals with the different aspects of nutrition, excretion and osmoregulation in multicellular nonchordates as these animals exhibit a wide variety of feeding habits. In this unit you will study nutrition, that is, the feeding habits, and the various adaptations for feeding and digestion in the nonchordates in the first part whereas in the second part you will learn about excretion that is concerned with removal of metabolic wastes arising as a result of oxidation of energy rich compounds and metabolism of protein and nucleic acids. The third aspect of this unit relates to the regulation of water and ionic contents of the body of nonchordate metazoans.

Unit 10 describes about the respiratory system and many types of organs that help in respiration. You will study that in small animals passive diffusion serves the purpose of respiration whereas in the larger animals respiratory gases have to be transported between the surrounding medium and the area of metabolic activity for which the circulatory system comes in handy. The unit also deals with the different types of circulatory systems found in the different phyla of nonchordates.

In Unit 11 you will study how different organs of the body are coordinated in efficient and purposeful manner by the nervous system. The animal has to perceive any change in the environment, compute the changes and ultimately translate these computations into requisite actions in a manner most profitable and adaptive to the animal. You will learn that the nervous system has receptor components comprising sense organs, coordinating centres in the central nervous system and the motor components controlling the motor elements.

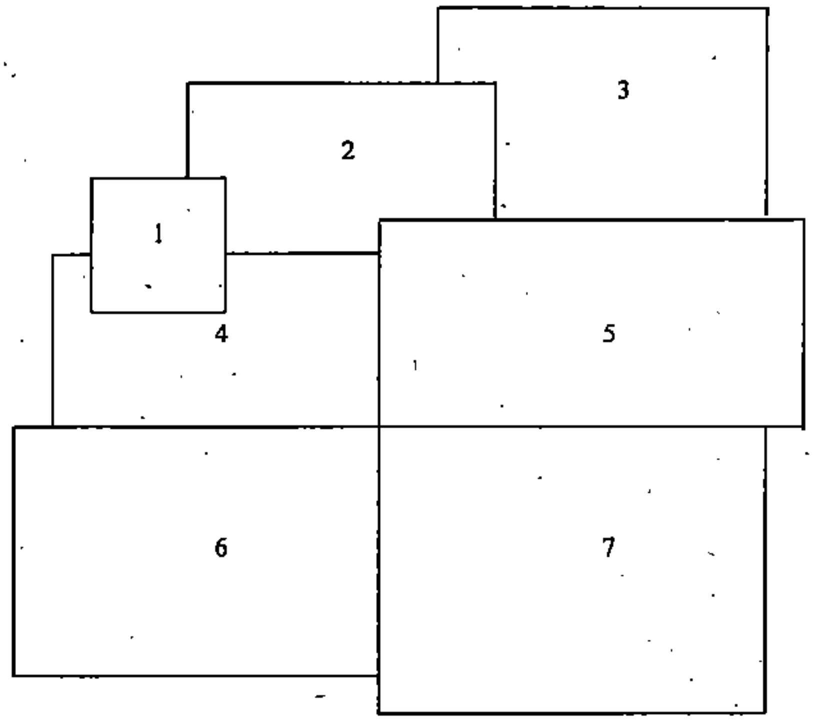
Unit 12 the Endocrine System, deals with transmission of messages from one part of the body to another bringing about integration and coordination of various activities of the animal through a system of chemicals. You will learn that the endocrine system brings about communication through chemical substances called hormones produced by endocrine glands.

In Unit 13 of this block you will study about reproduction which is the most significant phenomenon of life enabling a species to continue generation after generation. This unit will familiarise you with reproduction in nonchordates ranging from simple splitting into two to very complicated methods of sexual reproduction, parthenogenesis, alternation of generation, etc.

## Objectives

After studying this block you will be able to:

- list various types of locomotion and structural components of locomotory machinery among different nonchordates,
- describe the structures associated with feeding, excretion and osmoregulation and their mode of functioning in different nonchordate organisms occupying different habitats,
- describe the various types of respiratory and circulatory systems found in different phyla of nonchordate animals,
- describe the basic unit of the nervous system, its origin and evolution among non-chordate metazoans,
- explain the difference between neural and hormonal integration, concept of neurosecretion, name the major endocrine structures, and importance of hormones in the life of nonchordates,
- illustrate the various types of asexual reproduction, regeneration, phenomenon of parthenogenesis and sexual reproduction and its significance in nonchordates.




1. Tropical centipede

2. Stink bug

3. *Morpho menelaus* – The wing scales reflect interference colours. Tilting the wings produces a sequence of colours.

4. Brown recluse spider

5. *Tealia piscivora* – The colour is due to free or esterified carotenoids

6. *Agriolimax columbianus* – Yellow banana slug.

7. *Dasychalina cycanthina* – sub tidal sponge.

# UNIT 8 LOCOMOTION

## Structure



## 8.1 INTRODUCTION

In the previous two units, you have studied the structural organisation of the nonchordate animals. You have also seen how complexity of organisation increases gradually from lower to higher animals. However, despite this difference in the level of organisation, all animals, simple or complex, are capable of performing necessary bodily functions. One of these functions is **Locomotion.**

Motility is one of the characteristics and fundamental attributes of all forms of life. It is a general property of protoplasm. Intracellular streaming movement of cytoplasm, Chromosome movement during cell division, special kinds of cell motility within the body of metazoans, such as movement of intestinal villi, transport of substances in the axons, and ciliary beating in the respiratory tubes, etc. are all examples. However, locomotion involves movement of the body as a whole from place to place. This is brought about in different animals in different ways and involves different structures in various animals. In this unit you will study the various types of locomotion exhibited and the structural components of the locomotory machinery among different nonchordate animals.

### Objectives

After studying this unit you should be able to:

- describe various modes of locomotion among nonchordates,
- describe the various organs of locomotion and mode of their functioning in annelids, arthropods and molluscs, and
- explain how locomotion is accomplished in echinoderms.

## 8.2 LOCOMOTION - ITS VARIETY

Some animals are sendentary, remaining attached to some substratum. These animals may move parts of their body but this does not result in the movement of the animal from place to place. On the other hand most animals make slow or swift movements from one place to other.

This may involve crawling, creeping, leaping, walking, swimming or flying.
As you have already studied in Unit 2 of this course in protozoans, locomotion is brought about by special organelles. These organelles may be temporary formations such as pseudopodia in **Amoeba** or may be permanent differentiations of the cell such as cilia and flagella. The metazoans are, however, characterised by the development of specialized contractile tissue called muscles for this purpose. The motile machinery required for

movement in metazoans may comprise simple or specialized organs of locomotion and operates mainly based on the contraction and relaxation of associated muscles. Though the locomotor machinery appears to be quite different in protozoans on the one hand and metazoans on the other, the basic components involved are identical. They involve fibrous threads which are polymerisation products to large protein molecules. These threads have contractile properties. When these are associated with skeletal structures, these bring about movement. Physiology of muscle is dealt with in unit-6 of Animal Physiology-II (LSE-05, Block 2) course. We are here concerned with how muscles bring about locomotion in animals. In this unit we shall discuss mainly locomotion performed due to muscular contraction.

## 8.3 LOCOMOTION IN LOWER METAZOANS AND ANNELIDA

### Locomotion in Coelenterates, Flat worms, Nematodes

With the further evolution of contractile muscular component in their organisation, higher metazoans are capable of more efficient locomotor activity. The pseudocoelomates (e.g. nematodes) possess a fluid-filled body cavity, the pseudocoel which is surrounded by the body wall with muscles. This forms a hydrostatic skeleton used for locomotion. The elastic cuticle serves important role in their locomotion. The nematodes thus show undulatory movements caused by contraction waves passing along the longitudinal muscle fibres of the body wall. In the higher coelomate invertebrates, the coelom forms the hydrostatic skeleton. Evolution of metameric segmentation and the development of many specialized structures have resulted in still greater locomotor efficiency. Let us now discuss the locomotor machinery occurring in these higher metazoan groups.

You have already studied about the mode and mechanism of locomotion in protozoans in Unit-2 and Block-1 of this course. In cnidarians the body stalk and tentacles can extend, contract, or bend to one side or the other. The gastrodermal fibers in most parts of the body of hydra are so poorly developed that movement is due entirely to the contractions of the longitudinal, epidermal fibres. Fluid within the gastrovascular cavity plays an important role as a hydraulic skeleton. By taking in water through the mouth as a result of the beating of the gastrodermal flagella, a relaxed hydra may stretch out to a length of 20 mm, whereas contraction of the epidermal fibres can reduce it to a mere 0.5 mm. Hydra can also detach and shift locations by somersaulting or floating. The free-floating medusae, though wafted passively hither and thither by the currents of the ocean, exhibit co-ordinated contractions of the bell. Co-ordinated swimming movements and capture of food while afloat are reflected by the presence of more specialised muscular and nervous systems than those of hydropolyps.

In ctenophores, the combs mostly provide the locomotive power. The ciliary beat functions in generation of waves beginning at the aboral end of the row. The effective sweep of each comb is towards the aboral pole, so the animal is driven with the oral end forward, but the ciliary beat can be reversed.

Very small flatworms swim or crawl about bottom debris by ciliary propulsion. The contraction of the muscle layer permits turning, twisting, and folding of the body. The movement of larger turbellarians also involves delicate undulatory waves of muscle contraction. The dorsoventral flattening of the body is probably in part an adaptation for locomotion. With increased size, a flattened shape provides a large surface area upon which the body can be carried. Glands in the epidermis and underlying tissue secrete a mucus film over which the animal glides. In many species the mucous is derived from the disintegration of rod shaped bodies, called rhabdites, produced by epidermal gland cells.

Many small turbellarians possess special two gland systems which provide for temporary anchorage. One gland of the pair secretes an adhesive substance; the other provides a secretion that breaks the adhesive bond, releasing animal from anchorage. **Hydrostatic Skeletons** also called Hydroskeletons provide the primary skeletal support and rigidity to the body. Not all skeletons are rigid, many invertebrate groups use their body fluids as an internal hydrostatic skeleton. For example the muscles in the body wall of the earthworm have no firm base for attachment but develop muscular force by contracting against the coelomic fluid, which is enclosed within a limited space and are incompressible, much like the hyudraulic brake system of an automobile. Alternate contractions of the circular and longitudinal muscles of the body wall enable the worm to thin and thicken, setting up backward moving waves of motion that propel the animal forward (Fig. 8.1). Earthworms and other annelids are helped by the septa which separate the body into independent compartments. The advantage is that if a worm is punctured or even cut into pieces, each part can still develop pressure and move. For example, lug worm.

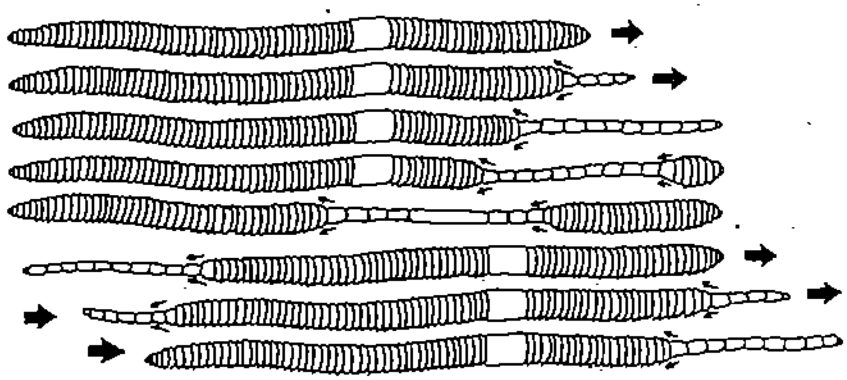


**Fig. 8.1: How an earthworm moves forward. When circular muscles contract, longitudinal muscles are stretched by internal fluid pressure and the worm elongates. Then, by alternate contraction of longitudinal and circular muscles, a wave of contraction passes from anterior to posterior. Bristle like setae are extended to anchor the animal and prevent slippage.**

**Arenicola** which lacks internal compartments, are rendered helpless if the body fluid is lost through a wound.

**Locomotion in Annelida**

Before we discuss the details of locomotion in annelids, we must recapitulate the major subdivisions of the phylum Annelida. Phylum Annelida consists of Polychaeta, Oligochaeta and Hirudinea. The Polychaeta, as typically represented by the marine bristle worm **Nereis**, have parapodia with numerous setae. The Oligochaeta, comprising mostly the earthworms and a few aquatic species, do not possess parapodia and have fewer setae. The Hirudinea, represented by leeches, lack parapodia and setae but suckers are present on either extremities of the body. These are used in locomotor activity. Thus, the locomotor components in Annelida include (a) body musculature, (b) hydrostatic skeleton, and (c) locomotor structures. Locomotion is thus the result of co-ordinated effort of all these.

## 8.3.1 BODY MUSCULATURE

The layout of the muscle layers surrounding the coelom is essentially the same in all the major classes of Annelida. The body wall has a layer of circular muscles below the epidermis (Fig. 8.2). This is followed by a layer of longitudinal muscles. In polychaetes the circular muscles are thin and the longitudinal muscles are usually arranged in four blocks, two dorsolateral and two ventrolateral; in some polychaetes oblique muscle strands may extend between the circular muscles of the dorsal and ventral sides in each segment, obdiquely. In oligochaetes, the longitudinal muscles form a continuous layer inner to the circular muscle layer and their long fibres may extend over 2-3 segments; well developed oblique muscles help in localized contraction and expansions of the body segments. In both these groups, the coelom is divided internally by means of transverse septa. The latter help in resisting the stress caused due to change in the hydrostatic pressure of the coelomic fluid. Of course, in polychaetes, the septa are less developed and broken down, with coelomic communication between segments. The body musculature is best developed in Hirudinea where, in addition to a double layer of oblique muscles between the circular and longitudinal muscles, there are vertical columns of muscles, namely the dorsoventral muscles. Contraction of dorsoventral muscles results in flattening the body of the animal and causes efficient undulations of the body resulting in swimming. But in leeches, coelom is very poorly developed.

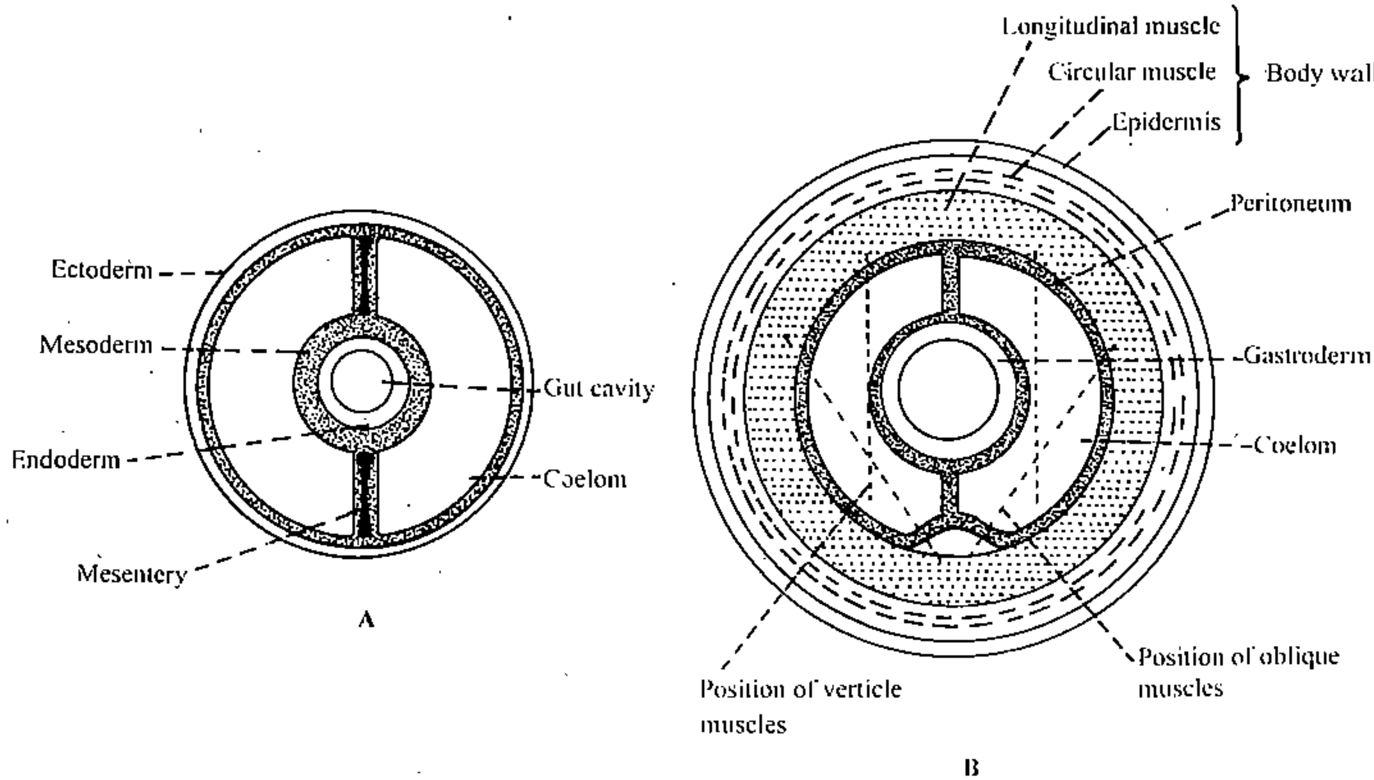



**Fig. 8.2 : The pattern of worm organisation. A. Cross section depicting the basic triploblastic coelomate plan. B. Cross section of a generalised annelid, showing the layers of the body wall and additional muscles in some polychaetes and all Hirudinea.**

Each segment has a complete set of muscles and nerves and the adjacent segments are linked to one another by metamerically repeated neural connections which allow a well-coordinated rhythmic locomotor activity.

## 8.3.2 HYDROSTATIC SKELETON

The functioning of the hydrostatic skeleton in an animal depends upon the musculature being arranged around an enclosed volume of fluid. Then, contraction of some of the muscles can cause pressure on the fluid, which can be transmitted to the rest of the body, in all directions.

In annelids, the coelom along with the fluid in the coelomic space (or spaces) together with the surrounding musculature constitute the hydrostatic skeleton. The coelomic fluid has a constant volume. Generally speaking, contraction of any muscle in the body wall of an annelid would cause an increase in the hydrostatic pressure, which in turn would cause stretching of flaccid muscles. In annelids with circular and longitudinal muscles, contraction of one set of muscles is accompanied by stretching of the other.

Polychaetes have feebly developed body musculature. The spacious coelom is compartmentalised by transverse septa. However, there are perforations in the transverse septa which allow continuity of the coelomic fluid between compartments. So in polychaetes the hydrostatic skeleton is not well developed. In oligochaetes, the body musculature is well developed and the transverse septa do not have the perforations during locomotion. The coelom in the adjoining segments remains mostly isolated. As the longitudinal muscles of a segment contract, the circular muscles relax and owing to the incompressibility of the coelomic fluid, the segment becomes shorter but thicker. Simultaneous protrusion of the setae help the worm anchor to the substratum (Fig. 8.6). When the reverse happens, i.e., when the circular muscles contract, the longitudinal muscles relax, the segments become long and thin, the setae are withdrawn and the body progresses forward. However, the contraction and relaxation activities are localised being

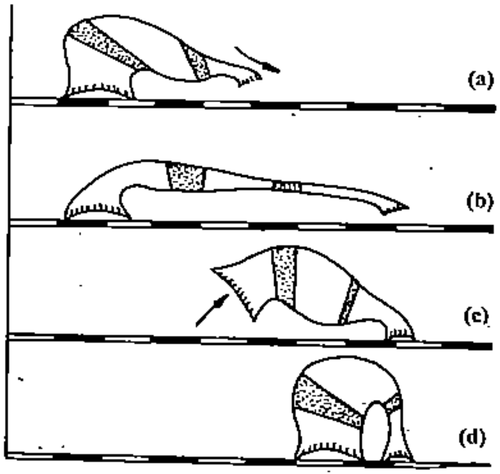
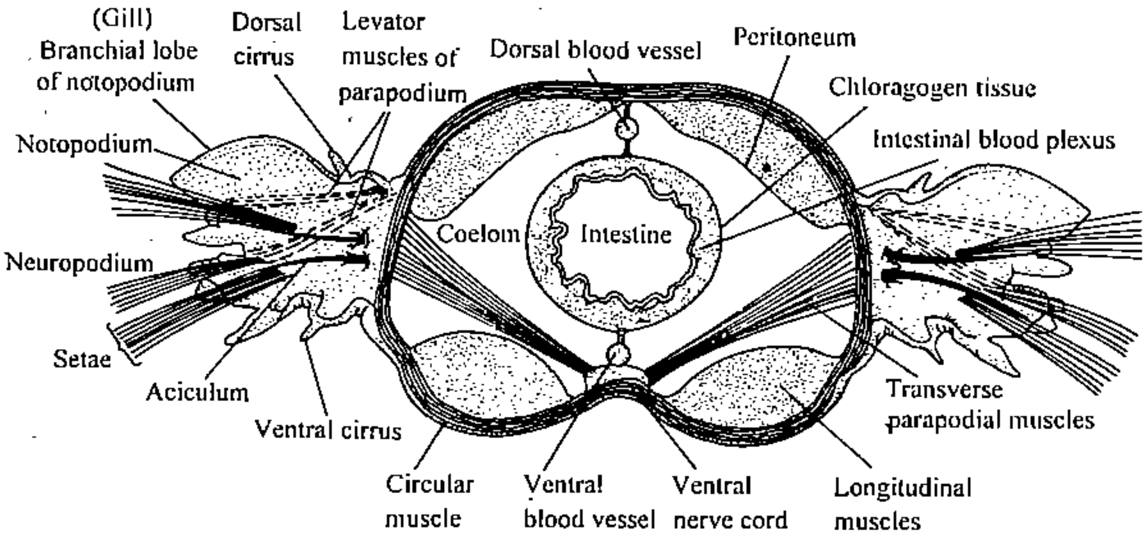
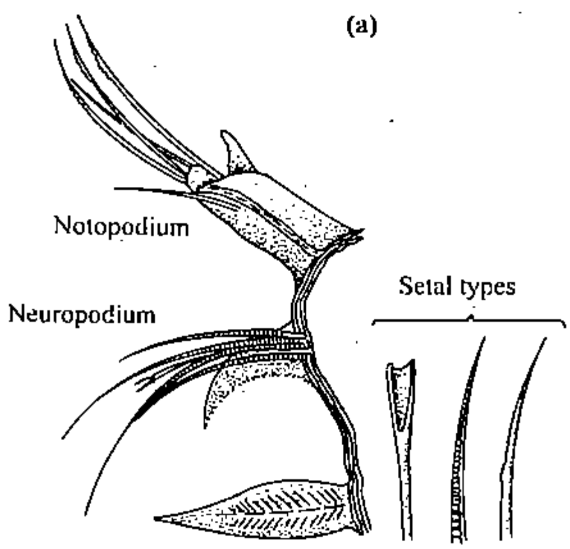



**Fig. 8.3 : Successive stages in leaping or crawling locomotion in a leech. With the circular muscles fully contracted, the leech becomes thin and elongate. Contraction of longitudinal muscles makes it short and thick.**




(a)




(b)

**Fig. 8.4: a) Transverse section of *Nereis* at level of intestine, showing a pair of parapodia. b) Parapodium and setae of *Scoloplos rubra*. Note that the setae are not all of the same type.**

limited to a few segments of the body, the wave of contraction and relaxation passing from one end to the other. This results in the animals progression.

In comparison with the polychaete and oligochaete annelids, in Hirudinea the body musculature is better developed; the coelom is greatly reduced; coelomic cavity is not septated as the transverse septa are lacking and the coelomic fluid is to a large extent replaced by the botryoidal tissue. The suckers present at either end of the animal can attach to the substratum. The Posterior sucker is attached to the substratum. The wave of circular contraction results in elongation of the body, which is extended forward. The anterior sucker is now attached and the posterior sucker is released. The longitudinal contraction results in shortening of the body and the posterior sucker is brought forward. This is repeated and thus the crawling movement, so typical of a leech (Fig. 8.3) is brought about.

## 8.3.3 LOCOMOTORY STRUCTURES

Annelids possess three types of locomotory structures, namely parapodia, sètae and suckers.

**Parapodia** (Fig. 8.4) are segmentally arranged, lateral, hollow extensions of the body into which also extends the coelomic cavity. Each parapodium basically consists of two lobes, a dorsal **notopodium** and a ventral **neuropodium** and each lobe bears a bundle of bristles or setae supported by an **aciculum**. Associated with each parapodium are dorsal and ventral sets of oblique muscles, and also the intrinsic protractor and retractor muscles. During movement, two parapodia of a segment remain in opposite phases of motion and thus cause a sort of paddling activity through water. The bristles and acicula are protruded and withdrawn through the activity of the intrinsic muscles. Parapodia are the main locomotory organs of polychaetes. In accordance with the different functions that they perform, parapodia exhibit variations of form among different polychaetes (Fig. 8.5).

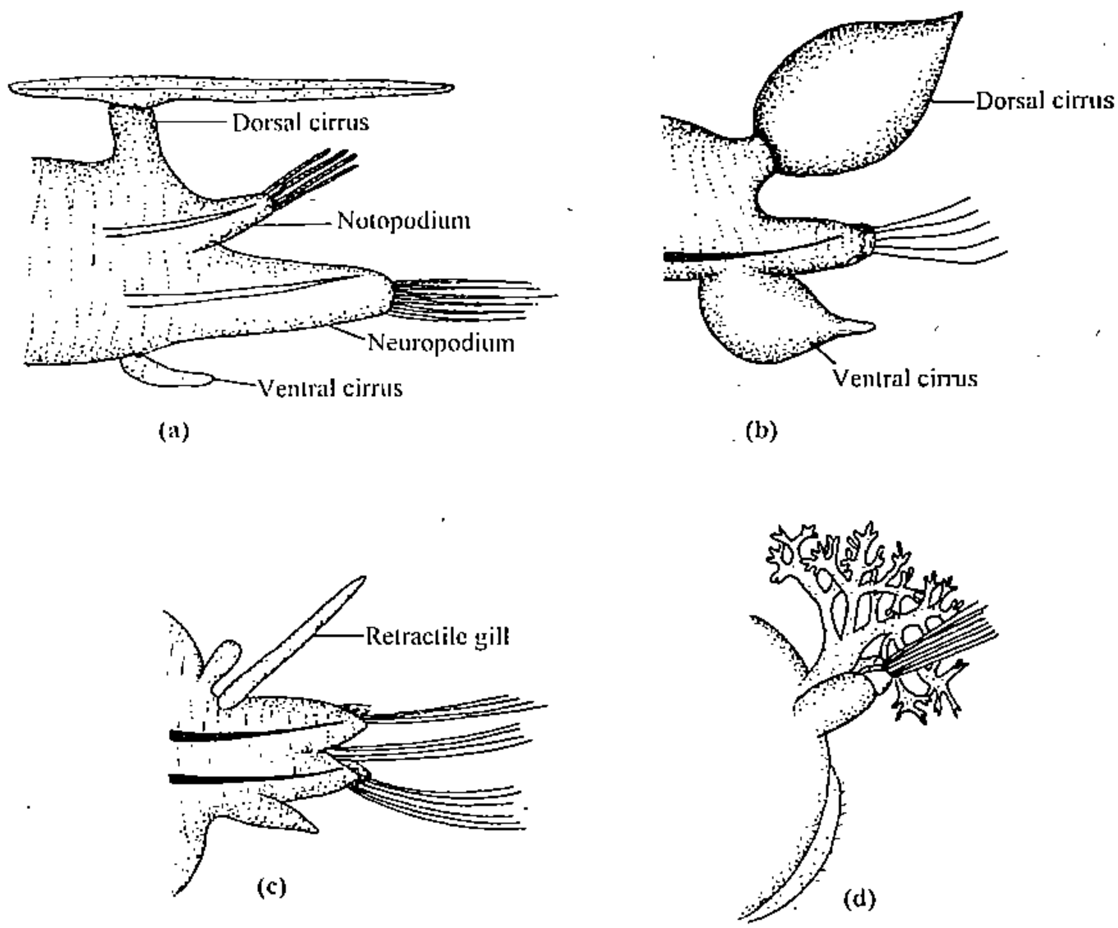



**Fig. 8.5: Modifications of parapodia among polychaetes. A. Lepidonotus. B. Phyllodoce. C. Glycera. D. Arenicola.**

Creeping and swimming forms have well developed parapodia; the burrowing forms and the tube dwellers have feebly developed parapodia especially in the posterior part of their body.

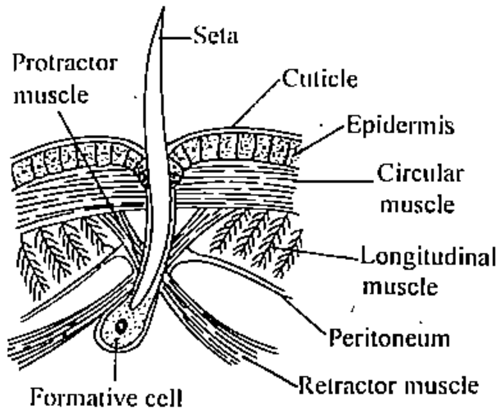



**Fig. 8.6: Seta with its muscle attachments showing relation to adjacent structures.**

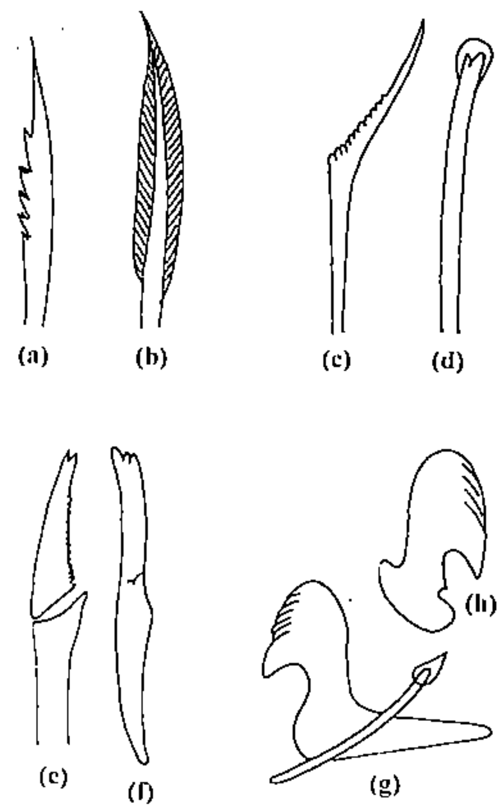



**Fig. 8.7 : Different types of setae.**

**Setae** are the main locomotor structures in oligochaetes, but as already seen, they are also present in polychaetes. In oligochaetes they are mostly present in the ventral region of the body; setae are secreted by setal sacs (Fig. 8.6). They are moved by protractor and retractor muscles. Like parapodia, setae may also show variations in form reflecting their functional significance (Fig. 8.7). Burrowing forms have short, simple and blunt setae (Fig. 8.7 D,E,F,G,H), while the swimming forms have characteristically long, forked or plumose setae (Fig. 8.7 A,B,C).

**Suckers** are characteristic of Hirudinea which lack setae and parapodia. One sucker is present at the anterior end and the other at the posterior end of the body; they are formed by the fusion of several body segments. The powerful longitudinal muscles converge to the suckers; the suckers have their ciruclar muscles concentrically arranged. Secretion from the associated epidermal glands also helps in adhesion of the suckers to the substratum.

## 8.3.4 MECHANICS OF LOCOMOTION

Among annelids, polychaetes, though more primitive than the other two groups, show a more complex mode of locomotion. Essentially, the locomotion in polychaetes is dependent on the antagonistic action of muscles on either sides. When the longitudinal muscles of one side of a segment are contracted, those of the opposite side are in a fully stretched or relaxed state. In this way, a series of waves can be formed along the whole body of the animal. Polychaetes exhibit several types of locomotion (Fig. 8.8).

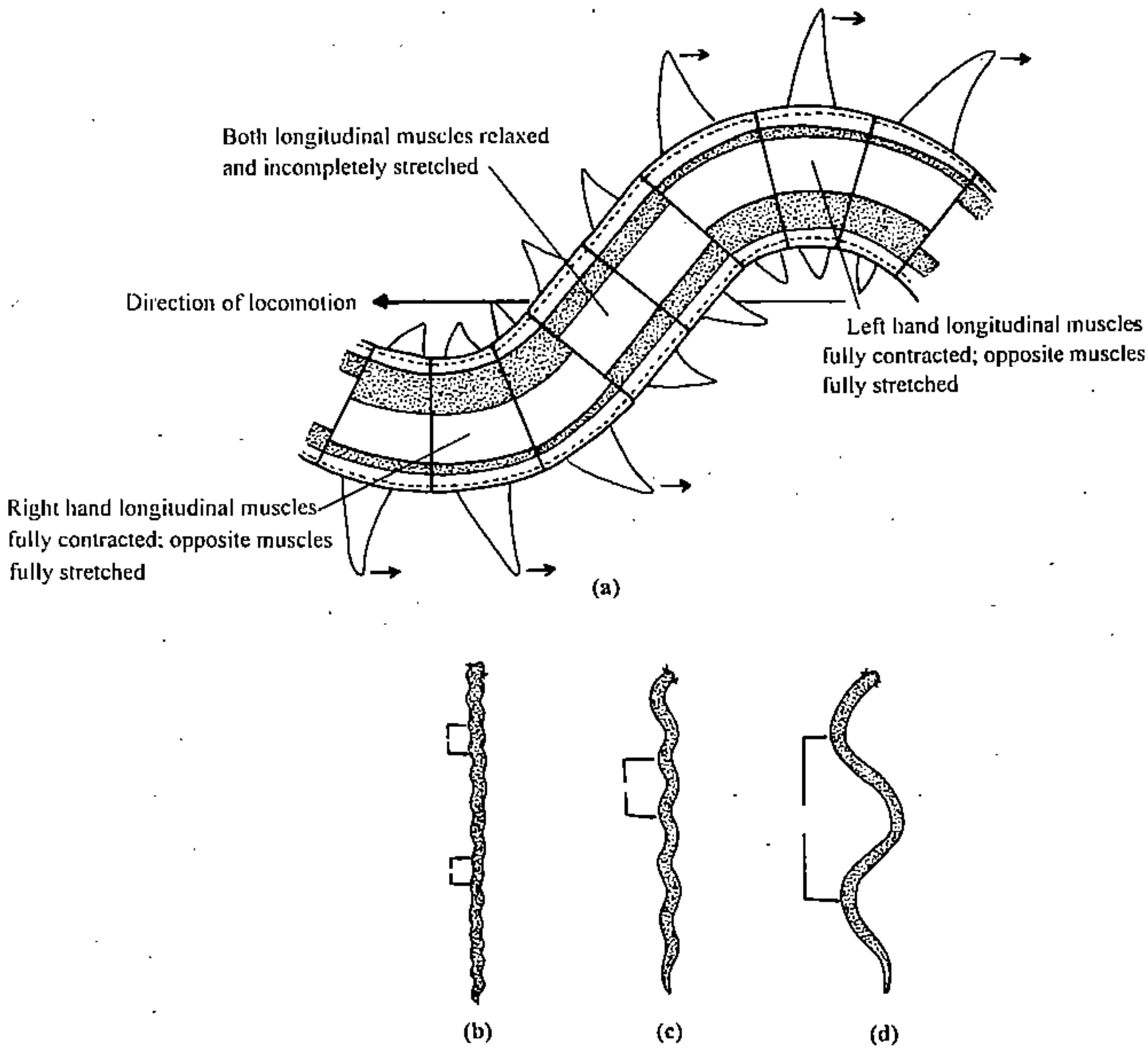



**Fig. 8.8 : Locomotion in a polychaete. A. Position of longitudinal muscles and parapodia in a rapidly crawling *Nereis*. Longitudinal muscles of the left and right sides of a segment work antagonistically. In segments where longitudinal muscles of the left side are fully contracted, the parapodia are maximally retracted; longitudinal muscles of the right side are fully stretched and the parapodia are maximally protruded. B. Slow walking. C. Rapid crawling. D. Swimming. Note that the wave length increases from slow walking to swimming activity.**

### i) Slow walking or crawling

This type of locomotion is seen when the animal moves on the substratum. It involves a metachronal rhythm of action in the parapodia. Every fifth or sixth parapodium on one side of the body is at the same stage in the cycle of forward recovery stroke and backward effective stroke. During each effective stroke (Power stroke) the parapodium on one side is turned down towards the ventral side on the substratum, the Parapodia as well as the setae protruded. The parapodia on the other side of the segment is now raised toward the dorsal side and carried forward in a recovery stroke with the setae withdrawn. Next the parapodia reverse their role: those which completed backward effective stroke perform the forward recovery stroke and vice versa. Polynoids or scale worms are very efficient walking annelids. During these movements, the parapodia and setae work against the substratum. However, they are not used as paddles.

## ii) Rapid crawling

This movement depends mainly on the contralateral waves of contraction of the longitudinal muscles of the body wall, causing lateral undulations of the body. The parapodial activity described above supplements the body undulations. This results in rapid crawling. The crawlers include polychaetes of many families like nereids, syllids, phyllodocids etc.

## iii) Swimming

The movements involved are basically similar to rapid crawling mentioned above but during swimming the waves are fewer but larger and more frequent. The animals are pelagic, having no contact with the substratum. Many crawlers also swim, but some like alciopids (Fig. 8.9 A & B) and tomopterids (Fig. 8.9 C) are exclusively pelagic.

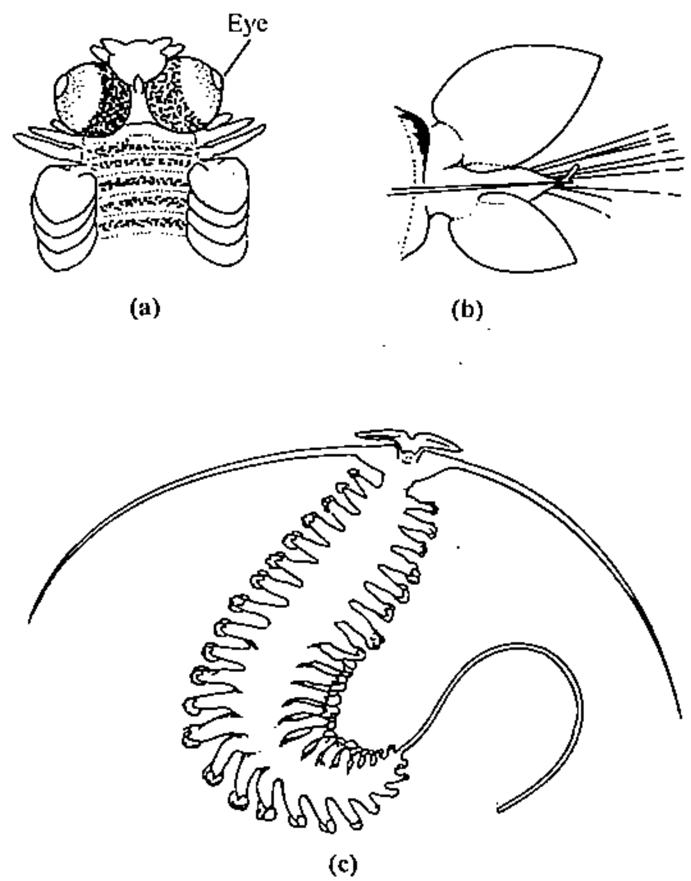



**Fig. 8.9 : Pelagic polychaetes. A. dorsal view of an alciopid and, B. its parapodium, C. a tomopterid (*Tomopteris renata*).**

## iv) Burrowing

Some polychaetes are burrowing. Examples are glycerids and capitellids. Their parapodia are smaller. Burrowing is done by protrusion of proboscis (buccal cavity and pharnx). Later, proboscis is withdrawn into the body and, and the animal crawls into that space. Burrowing in polychaete.is different from that in obigochaetes.

Oligochaetes show crawling and digging or burrowing movement. The action of longitudinal and circular muscles upon the coelomic fluid creates a peristaltic wave, while the setae, which are fewer in number and are shorter help in, getting a local grip on the substratum (Fig. 8.10). Neural connections help in co-ordinating the peristaltic action by alternate stretching and contraction of muscles. The digging or burrowing action is accomplished by the forward extension of the anterior segments into the spaces of the soil particles. Increase in hydrostatic pressure now causes widening of the space. The animal now pulls the posterior part of the body forward.

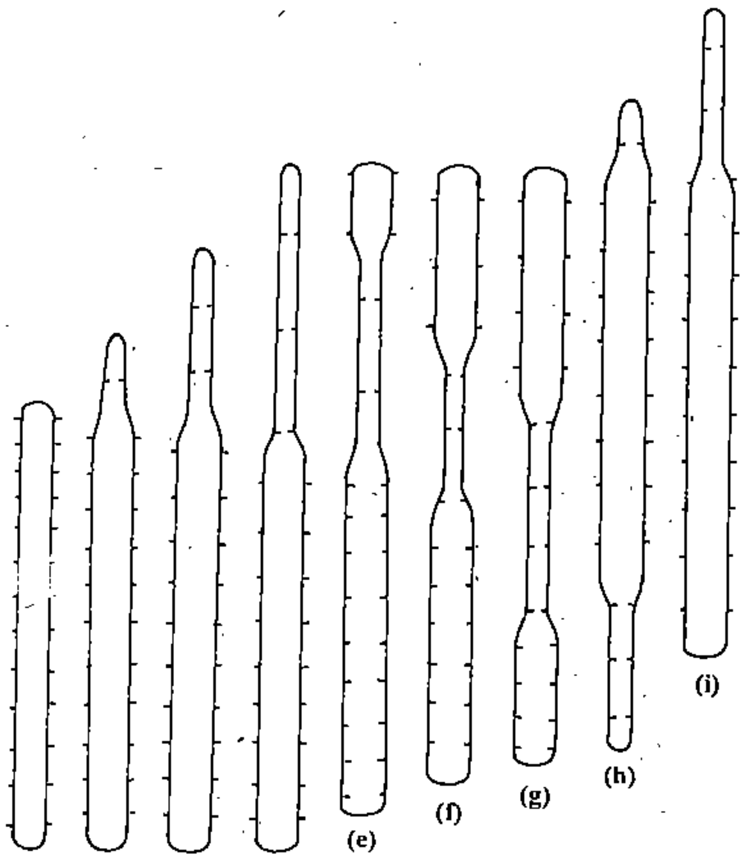



**Fig. 8.10 : Contractions of the longitudinal and circular muscles and the movements of setae during crawling locomotion of the earthworm.**

The Hirudinea (leeches) exhibit crawling (leaping) and swimming movements. During crawling or leaping, a leech shows looping movements by alternate attachment of its anterior and posterior suckers (Fig. 8.3). As the posterior sucker attaches to the substratum, the anterior sucker is released; the circular muscles of the body contract and the longitudinal muscles stretch in antagonism, so that the leech elongates. The anterior sucker is fixed to the surface, the posterior gets detached; the longitudinal muscles now contract and the circular muscles stretch causing the body to shorten and thicken. The posterior sucker is then drawn forward and gets fixed close to the anterior one. The anterior sucker then gets freed again and the whole process is repeated. The oblique muscles reinforce the activity of other muscles and help to increase the hydrostatic pressure so as to enable the leech to acquire an upright position on its posterior sucker, during this movement. However, during swimming movements, the dorsoventral muscles remain contracted resulting in keeping the body flat and ribbon like. Waves of contraction of longitudinal muscles result in dorsoventral serpentine movements of the body. This brings about efficient swimming motion of the leech in water.

## SAQ 1

a) Fill in the blank by choosing the correct word.
   i) In ctenophores the ............................ mostly proide the locomotive power.
   ii) In the annelid, the........................ coelom alongwith the fluid in the coelomic space together with the surrounding musculature constitute the ..............................skeleton.
   iii) The oligochaeta, comprising mostly the earthworms and a few aquatic species do not possess ................ and have fewer setae.
   iv) Contraction of dorsoventral muscles results in flattening the body of the animal and causes efficient undulation of the body resulting .....................

v) Setae are the main locomotor structures in oligochaetes but they are also present in ........................

vi) During crawling or leaping a ......................... shows looping movements by alternate attachment of its anterior and posterior.........................

b) List three types of locomotion which annelids show.

..........................................................................................................................

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## 8.4 LOCOMOTION IN ARTHROPODA

The Arthropoda are characterised by the presence of some special features which can be considered key to their success. These include a rigid exoskeleton made up of a chitinous cuticle which resists deformation, metameric segmentation of the body, and jointed appendages made up of a system of levers. The jointed arthropod limb and its associated muscles allow highly complex movements. Besides, the haemocoel has replaced the septate coelomic cavity of the Annelida. The muscular body wall is broken down into distinct, separate muscles. This enables precise and localized contractions. This inturn has greatly reduced dependence on the hydrostatic skeleton for locomotion, increasing efficiency of locomotion.

The arthropod appendages, typically a pair in each metamere, are often shifted in their position. This is due to tagmatization, e.g. fusion of several segments of the body into

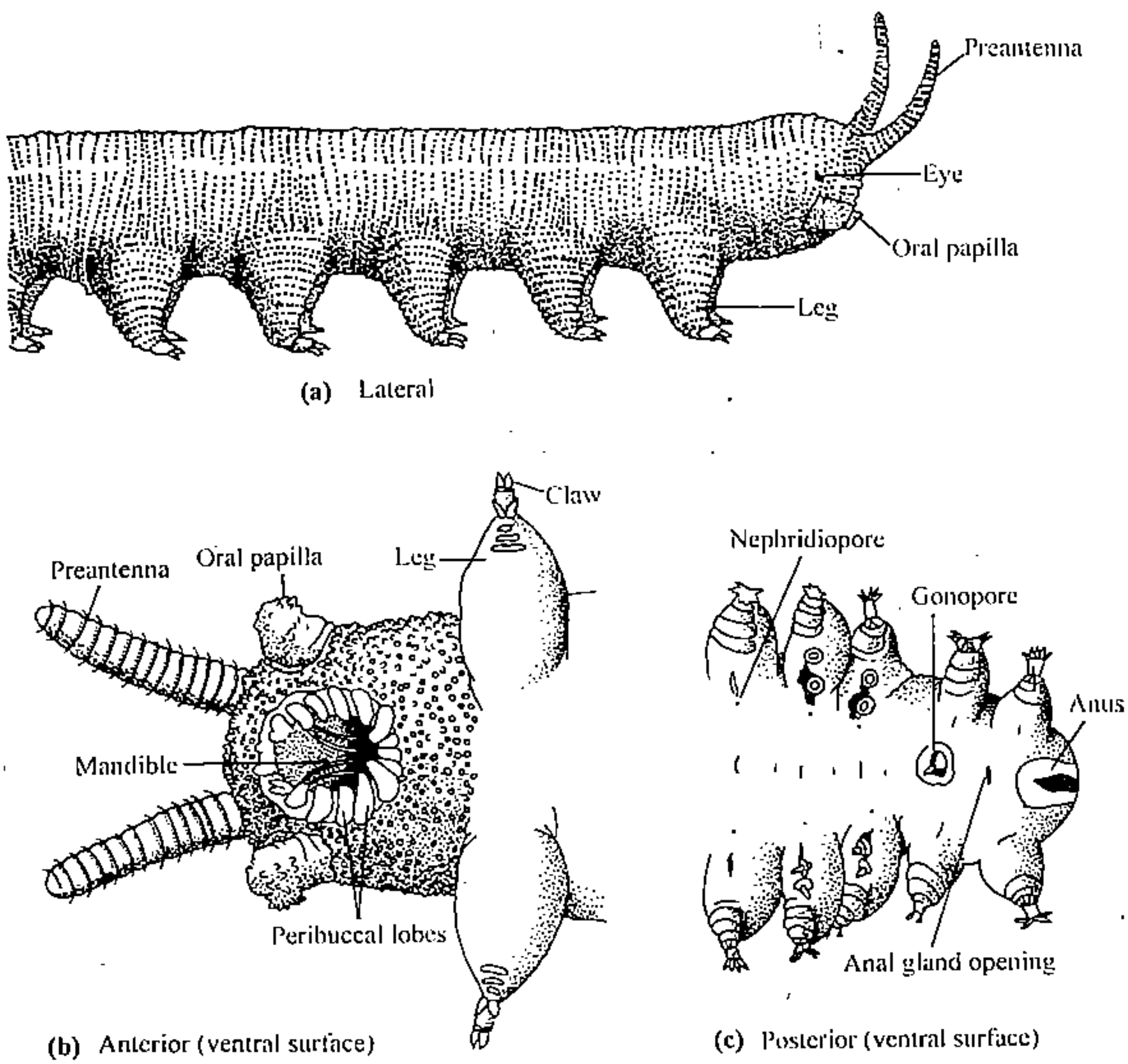



**Fig. 8.11: Peripatus A. lateral view of head, B. Anterior ventral surface, C. Posterior ventral surface.**

clearly defined regions called tagmata (sing. tagma). In general, the appendages are used as tactile or sensory structures, in food capturing, in locomotion and in reproduction. Accordingly they are highly specialised and modified in relation to their function, and have come to be known as antennae, maxillae, mandibles, maxillipeds, walking legs (Stenopodia) and paddle-like phyllopodia etc. We shall mainly talk about the appendages that are involved in locomotor function in various constituent groups of Arthropoda.

The primitive **arthropods**, Onychophora (e.g. *Peripatus*) have a series of **paired legs** (Fig. 8.11) which are not jointed but have a ringed appearance due to the presence of rows of papillae on them. Each leg consists of two parts, a conical proximal part with their extrinsic muscles, and a small distal part having a pair of claws. The limbs are protracted and retracted. Using these legs, and by extension and contraction of the body for working the legs they crawl. When a segment is extended, the legs are lifted and moved forward; subsequent effective stroke gives the animals a pushing force.

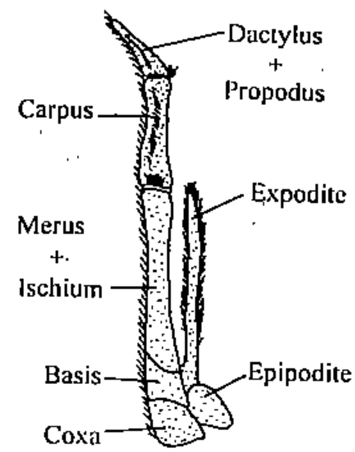



**Fig. 8.12: Prawn (Palaemon), a third maxillipede**

The **Crustacea** exhibit a great morphological diversity of appendages which may be grouped into three categories, cephalic, thoracic and abdominal. Their appendages are typically biramous (i.e. haiving two branches). Such appendages typically have a basal segment, **protopodite**, made up of two pieces - a coxopodile or coxa and a baspodite or basis. The basipidite carries the two "brnahces" namely an inner **endopodite** and an outer **exopodite** (Fig. 8.12). These may have different number of segments. Some of these components may be lost; there may be processes such as exite, endite, epipodite etc. of cephalic appendages (which include a pair each of antennules or first antennae,

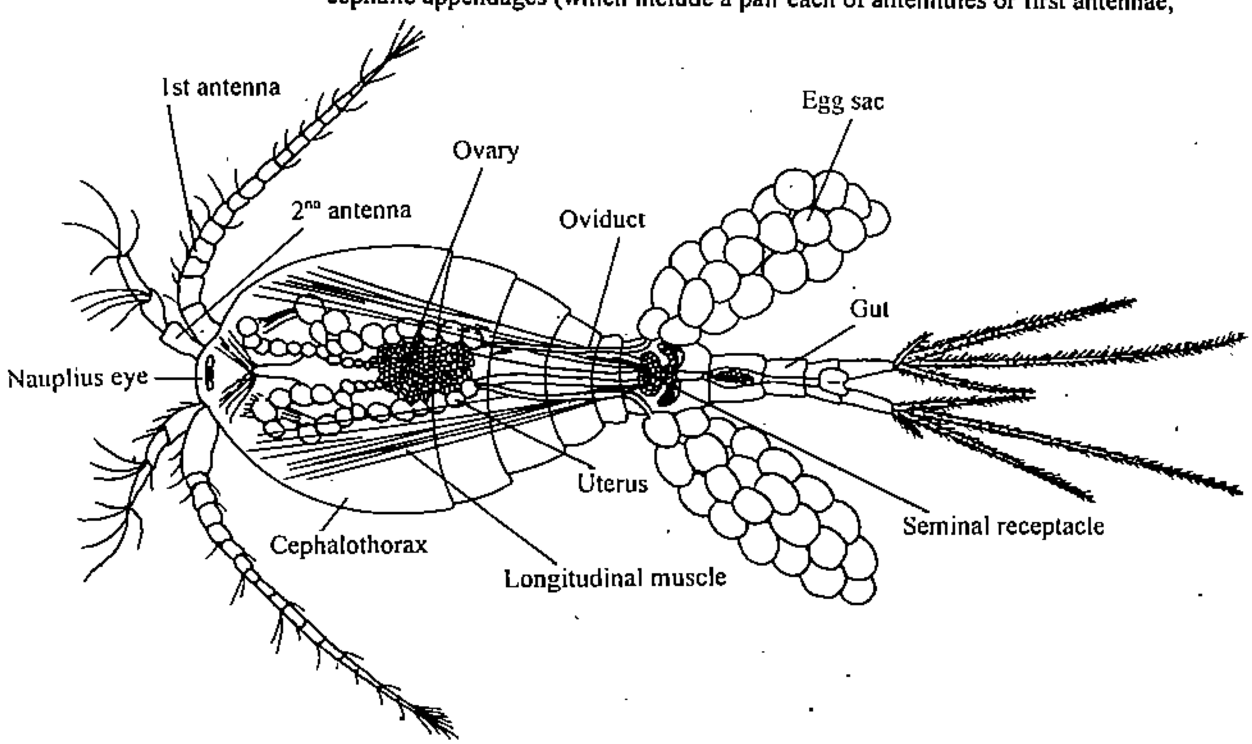



**Fig. 8.13: A cyclopoid copepod, *Macrocyclops albidus* (dorsal view).**

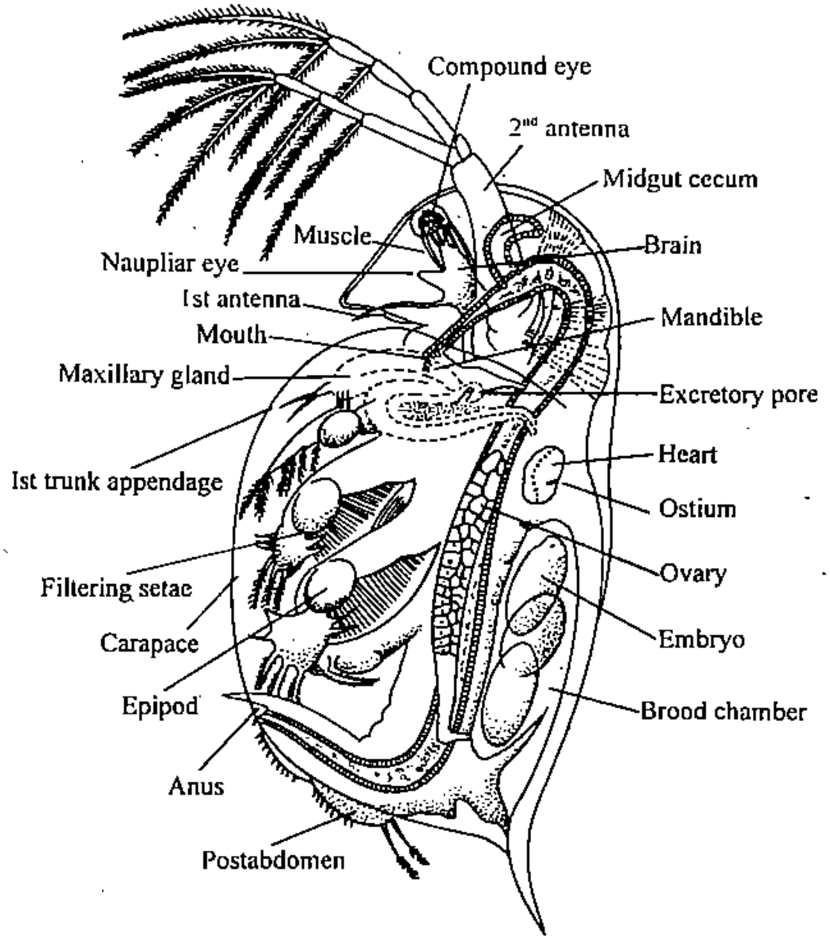



**Fig. 8.14: Female of the Cladoceran, *Daphnia pulex* (Lateral view).**

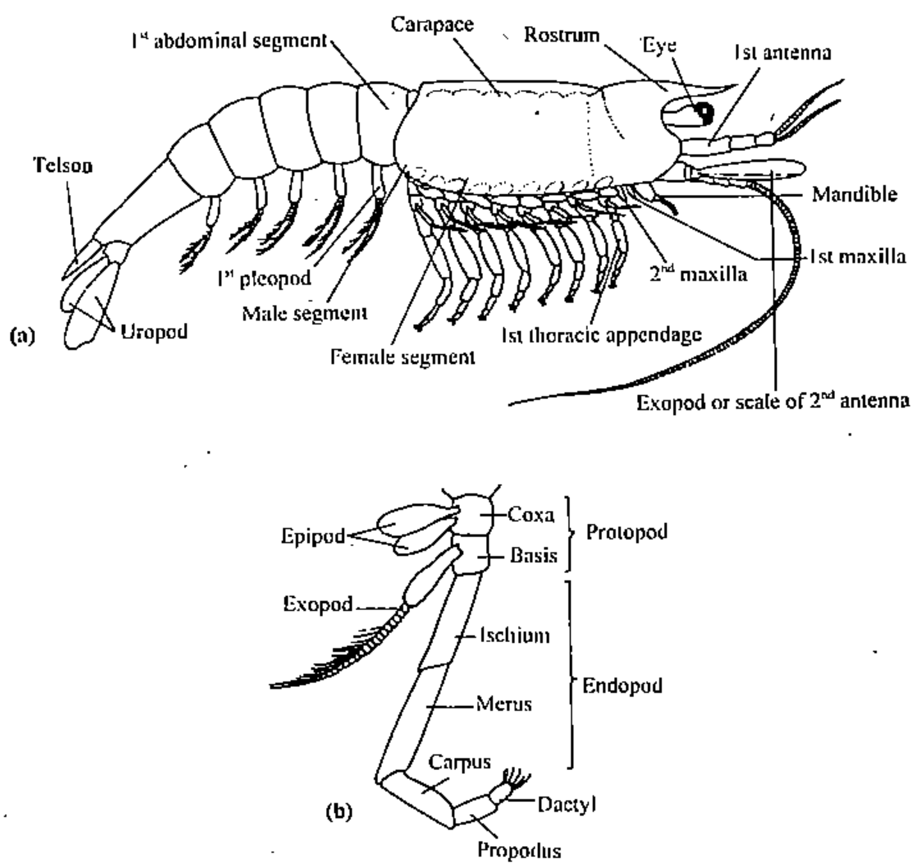
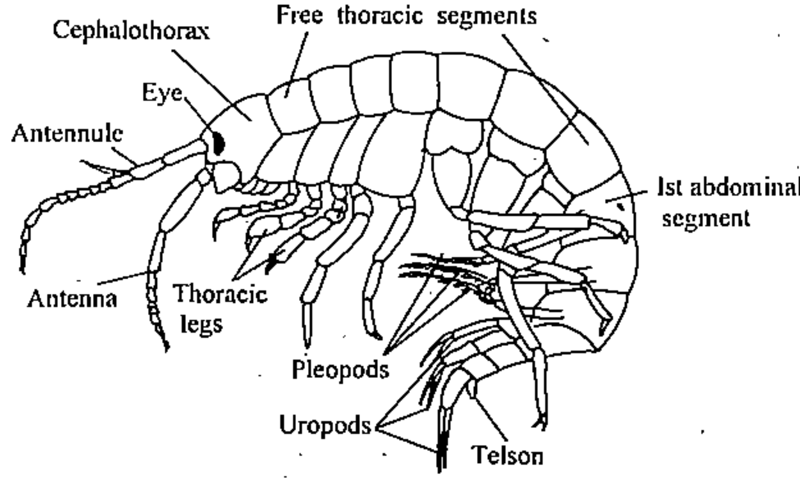
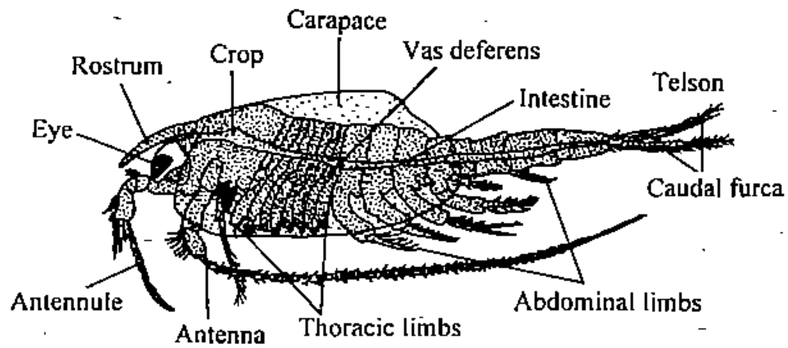



**Fig. 8.15: A generalized malacostracan. A. Lateral view of body. B. A thoracic appendage.**




(a) *Gammarus*




(b) *Nebalia*

**Fig. 8.16: Shrimps. A. *Gammarus*, B. *Nebalia*.**

second antennae and mandibles, and two pairs of maxillae), most have a sensory function or are used for food capturing. However, some of the cephalic appendages may get modified so as to serve locomotion e.g. the antennules in copepods (Fig. 8.13) and second antennae in Branchiopoda (Fig. 8.14). Thoracic appendages show variation in number and function in different crustaceans. While in Ostracoda there are 2-4 pairs of thoracic appendages which are leg like, there are five pairs of them in **Branchiopoda** and free swimming Copepoda. **Malacostraca** possess eight pairs of thoracic appendages (Fig. 8.15); in some members of the group the first few pairs become maxillipeds or food jaws to work as accessory feeding apparatus and only the remaining posterior pairs differentiate as walking legs. Abdominal appendages are usually locomotor in function; however, these are lacking in many crustaceans, such as Copepoda, Branchiopoda and Ostracoda. Malacostraca have 6-7 pairs of these appendages but variations are exhibited in different forms (Fig. 8.16). While the first three are biramous swimming appendages, the posterior three may modify as jumping styliform uropods as in the case of **Gammarus** (Fig. 8.16); in others the last two pairs may be uniramous as in **Nebalia** (Fig. 8.16); the last pair may become a fan-like uropod, as typically seen in prawns.

Members of **Myriapoda** possess cephalic and trunk appendages, of which, the latter are the legs (Fig. 8.17). Each trunk segment has a pair (as in centipedes) or two pairs (as in millipedes) of jointed legs. Legs of the seventh segment are modified as copulatory organs in male millipedes.

The **Chelicerata** (including horse-shoe crab, scorpions, spiders, ticks etc.) possess cephalothoracic and abdominal appendages. The latter appendages usually are not involved in locomotion. In most arachnids anterior segments are fused together to form a **prosoma** and their appendages. These include **Chelicerae, pedipalpi** and **walking legs.** They may be variously modified for special functions such as sensory, food capturing, adhesive or sperm storage. In Xiphisurida (e.g. **Limulus**) the third to sixth pairs of

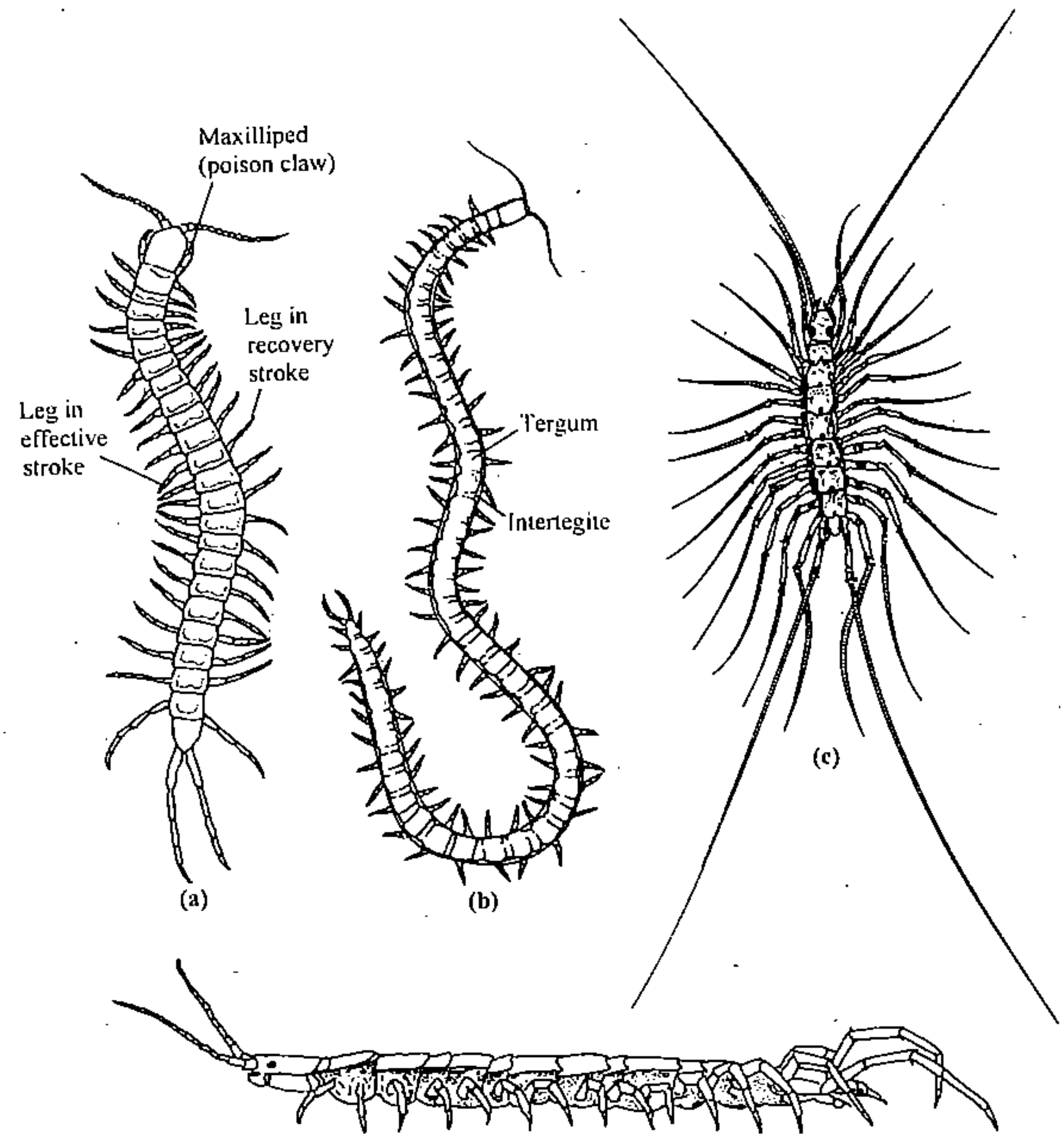



**Fig. 8.17:** **Chilopoda. A.** ***Otocryptops sexspinnosa*****, a scolopendromorph centipede. B. A geophilomorph centipede. C.** ***Scutigera coleoptrata*****, the common house centipede, a scutigeromorph. D.** ***Lithobius*****, a lithobiomorph centipede.**

appendages are walking legs (Fig. 8.18), all of which are chelate; the last leg or the fifth, bearing spines at its tip, is used for digging. Arachnids possess four pairs of 7-jointed (coxa, trochanter, femur, patella, tibia, metatarsus and tarsus) walking legs (Fig. 8.19) on the prosoma.

In **Insecta** as in myriapods, appendages are uniramous (not branched, unlike in crustaceans). Here it is the thoracic region which bears the locomotor structures, legs and **wings**, leaving the abdomen free. There are three pairs of legs, one on each thoracic segment. Each leg has five joints; the coxa is the first or the basal segment and the trochanter is somewhat immovably attached to the femur, following which are tibia and tarsus (Fig. 8.20). The distalmost tarsus may have a single or paired claws, pad or sucking disc. The legs exhibit morphological diversity in accordance with the habit of the insect. For example, the legs are slender in walking insects as in grasshopper (Fig. 8.20), long and powerful in jumping insects as in flea (Fig. 8.21) and paddle like in swimming forms as in water bugs (Fig. 8.22). In some butterflies the front legs are hair-like structures of no functional significance (Fig. 8.23) and many larval forms or caterpillars have 'prolegs' suited for crawling (Fig. 8.24).

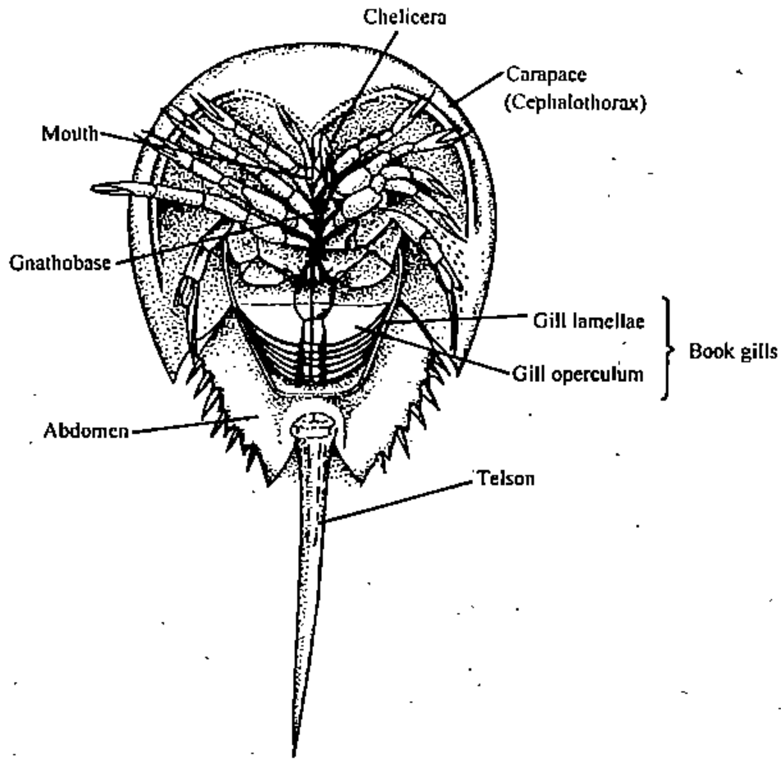



Fig. 8.18: *Limulus*.

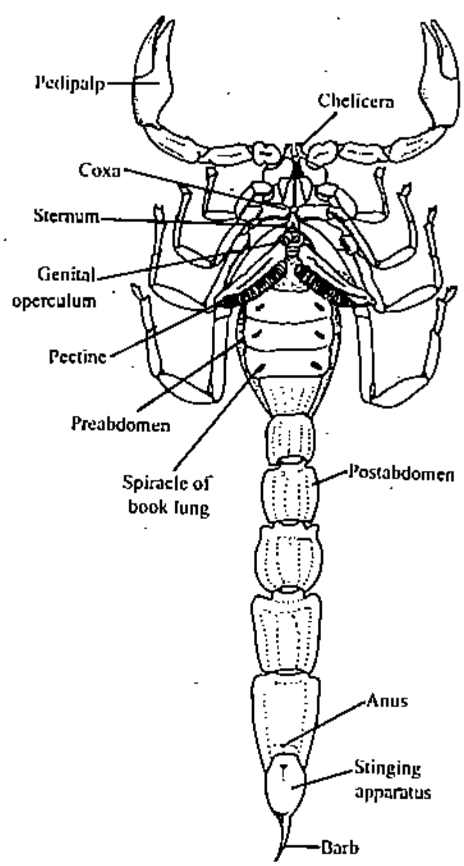



Fig. 8.19: *Androctonus australis* (ventral view).

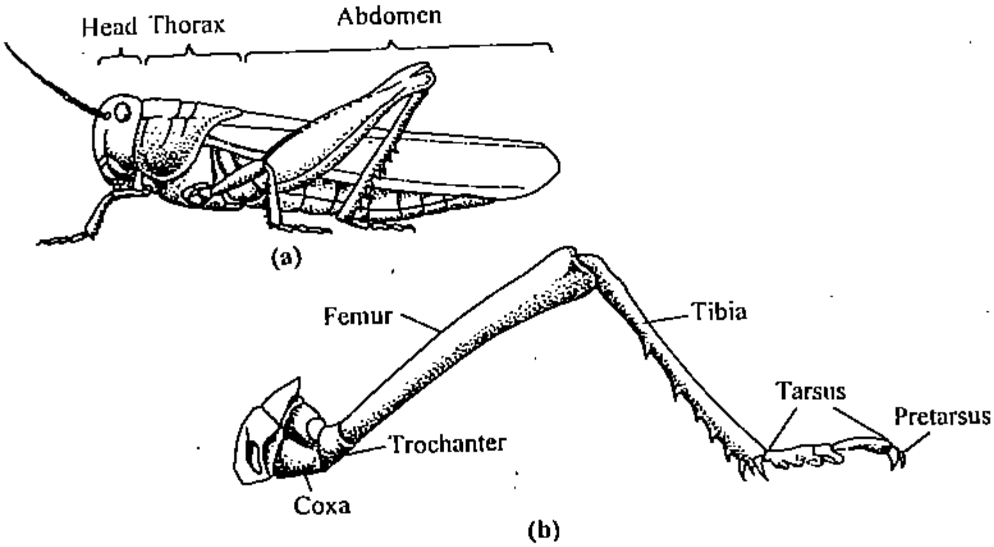



**Fig. 8.20: Grasshopper, A. Lateral view of the body; B. lateral view of a wingless thoracic segment; C. Leg of a grasshopper.**

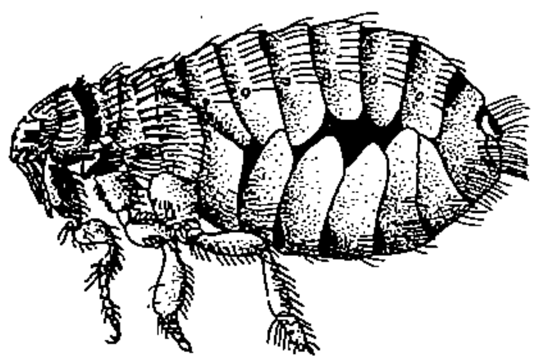


**Fig. 8.21: Flea.**

Wings are special devices used for flying by many insects. They are extensions of the body wall and are not jointed. Typically, the pterygote insects possess two pairs of wings, one on the mesothorax and the other on the metathorax. Branching veins carrying the tracheae support the wings. Like legs, wings also show variations with regard to their number and shape among different insects. Primitive insects (Apterygota) have no wings. Lice, fleas and bedbugs have lost wings secondarily. In beetles, the metathoracic

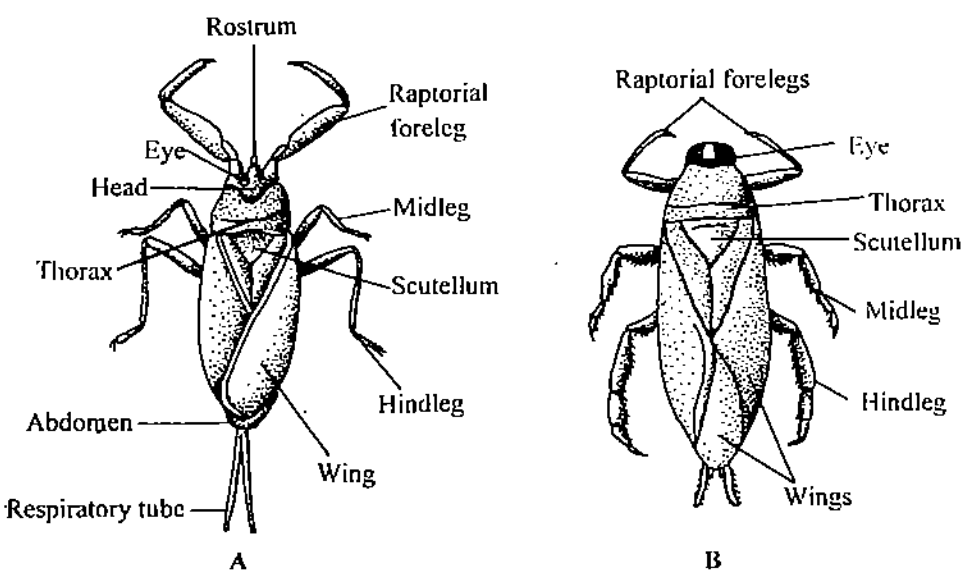



**Fig. 8.22: Water bugs A. *Nepa*; B. *Belostoma*.**

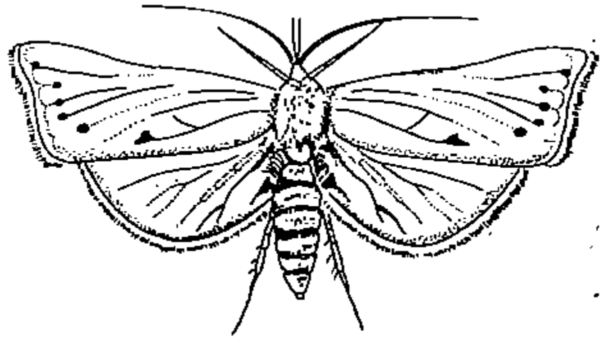


Fig. 8.23: Butterfly.

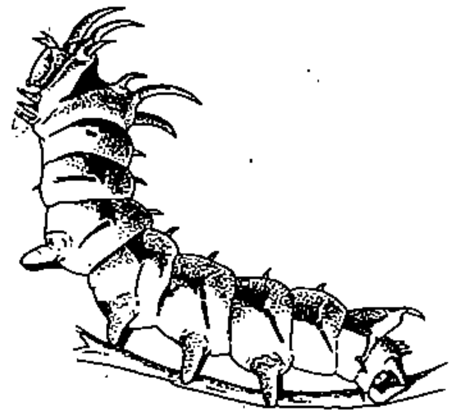


Fig. 8.24: Caterpillar.

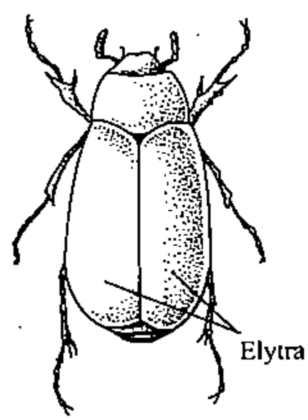



Fig. 8.25: Beetle.

wings (hind wings) are thin and membranous, and are used for flying whereas the meso thoracic wings (forewings) called elytra are hard. They are not used for flight, but cover the hind wings (Fig. 8.25). The dipterans (flies, mosquitoes) have well-developed mesothoracic wings and the second pair are short and called balancers or **halteres** (Fig. 8.26). Wings in Lepidoptera (butterflies, moths) have a variety of fascinating patterns formed by coloured scales.

## Mechanics of Locomotion

As you have already seen, arthropods exhibit a variety of locomotor activities. Swimming movements of the aquatic forms involve varied appendages. Abdominal pleopods or swimmerets of crayfishes (Fig. 8.27), paddle-like fifth pair of thoracic appendages of crabs (Fig. 8.28), and second antennae of copepods and cladocerans (Fig. 8.14) accomplish swimming movement. In **Limulus**, basically a bottom dweller, crawls and usually ploughs through the upper surface of the sand and mud. For this, the shape of its body is highly suited. The last pair of (5th) walking legs are used for pushing the body into soft mud or sand.

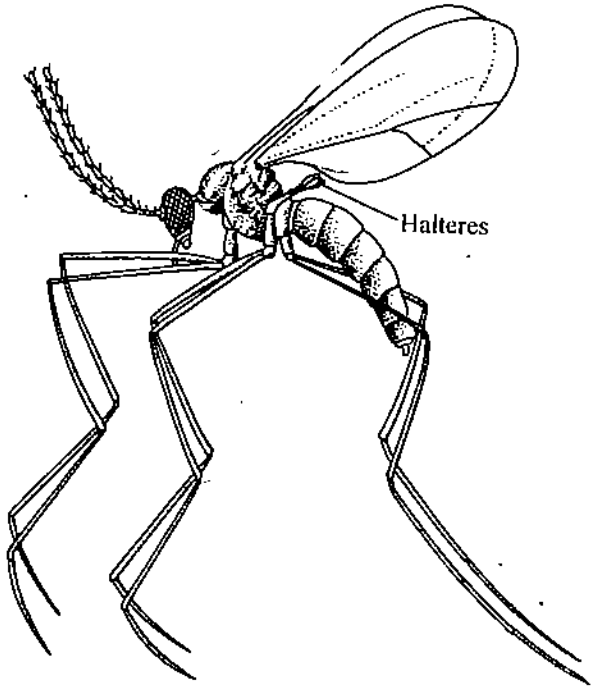



Fig. 8.26: Order Diptera; a gall gnat.

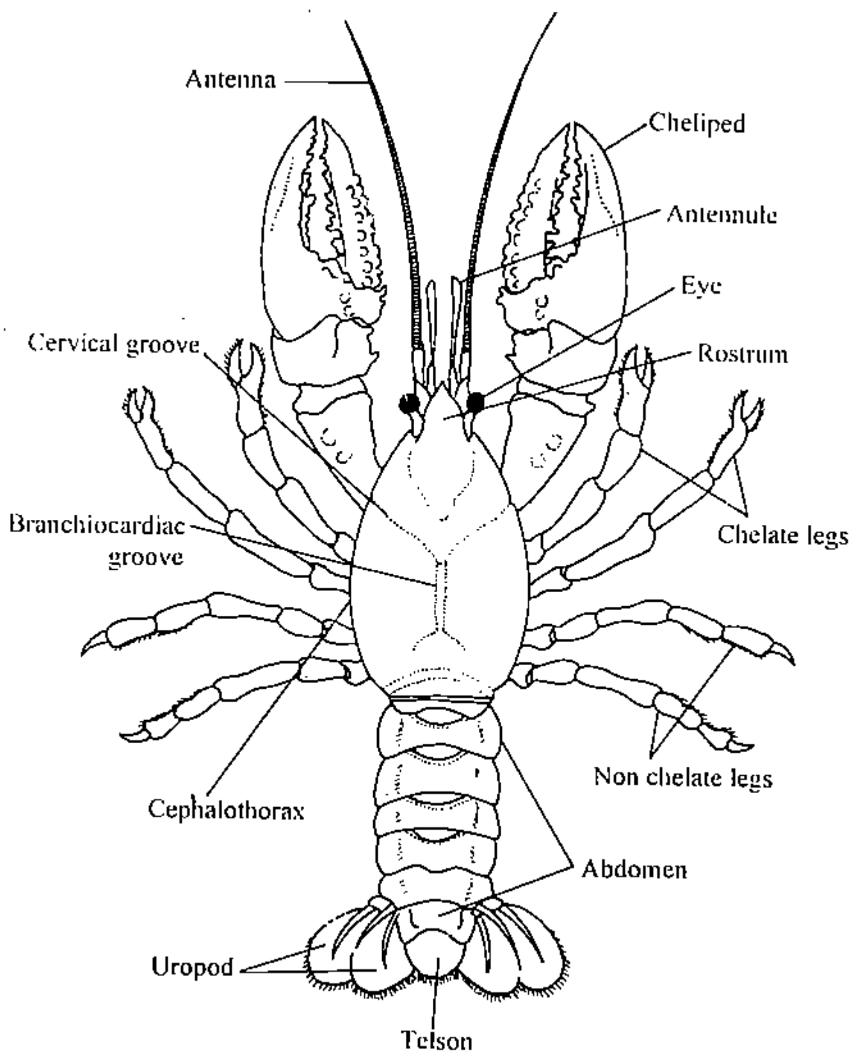



Fig. 8.27: Crayfish - *Astacus*.

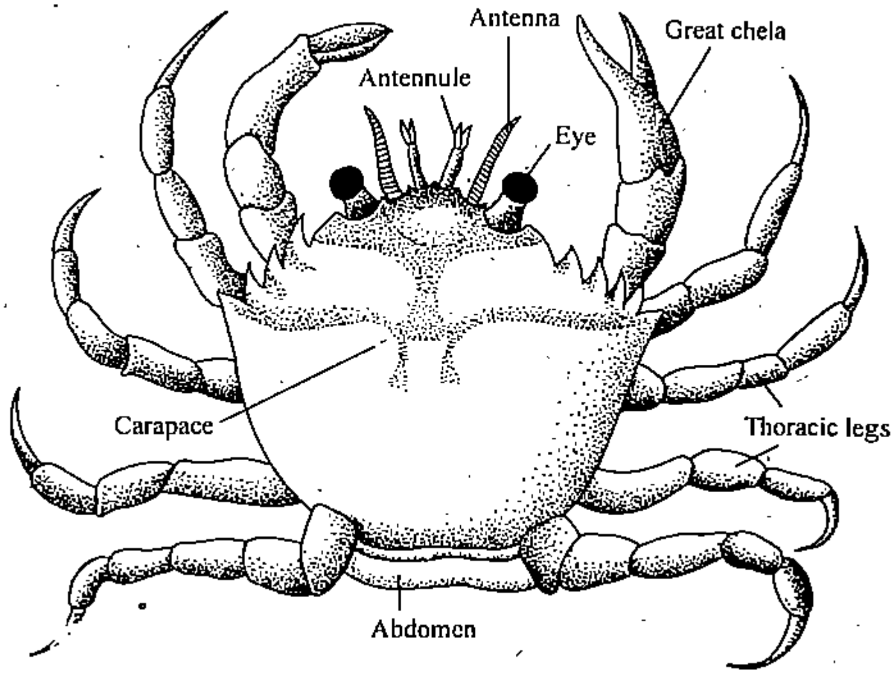



**Fig. 8.28: The common crab *Carcinus*.**

Land arthropods show crawling, walking, rapid running, jumping, digging and climbing activities. The precise orientation of the flexible articular membranes in relation to the rigid elongate segments of the limb allows a great deal of mechanical efficiency and a variety of movements is achieved. The actual propulsive force is generated by the contraction of the associated extrinsic and intrinsic muscles of the legs (Fig. 8.29) accompanied by precise orientation of the limbs. The body musculature (longitudinal and circular muscle of the body wall) is no more used for making undulations of the body for pushing the body forward. Thus unnecessary wastage of energy is avoided during locomotion.

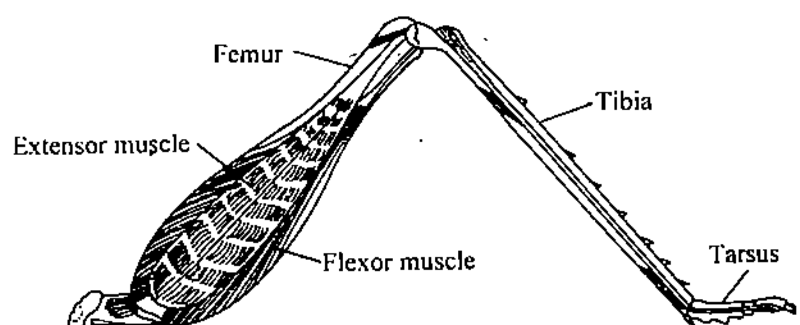



**Fig. 8.29: Hindleg of grasshopper. Muscles that operate the leg are found within a hollow cylinder of exoskeleton. Here they are attached to the internal wall, from which they manipulate segments of limb on the principle of a lever. Note pivot joint and attachment of tendons of extensor and flexor muscles, which act reciprocally to extend and flex the limb.**

In the multi-legged systems of terrestrial arthropods represented by millipedes and centipedes, most of the legs participate in locomotion and the whole body is involved, there being no distinct locomotor tagma such as the thorax of insects or the prosoma of arachnids. Having many and relatively short legs and short, wide segments, millipedes are slow moving. However, as they can have a very large number of legs at a given moment involved in effective traction stroke, they can produce great force, pushing the body through soil and humus into which they often burrow. Centipedes have however fewer but longer legs and long narrow segments; so they are fast moving, but they cannot burrow into soil easily.

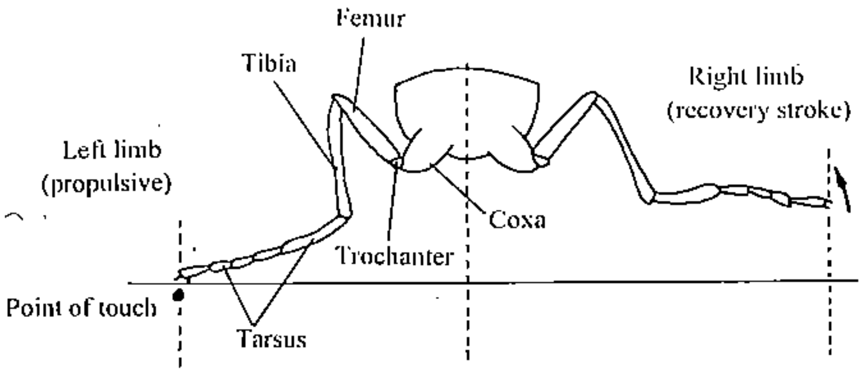



Fig. 8.30 : Schematic representation of a pair of thoracic limbs in an insect during walking in which the left leg is propulsive and the right, in recovery stroke.

With the acquisition of a higher degree of tagmatization and reduction in the number of legs when compared to myriapods, insects and spiders have emerged as more successful terrestrial arthropods. The three pairs of legs in insects and four pairs of legs in arachnids articulate with the trunk (thorax in insects and prosoma in arachnids) near the centre of gravity of the body. Thus, the propulsive force is applied to the body near a single centre (thorax or prosoma). The sideways undulation of the body is avoided. The slender long limb with a pointed tip allows the propulsive force to be applied to a single 'point of touch' on the substrate. In general, as the insects walk, the legs of a pair move in opposite phase and a leg is lifted only after the leg behind it has touched the substrate (Fig. 8.30).

Insects have successfully achieved aerial movement. Wings, along with the structural framework of thoracic exoskeleton and associated with thoracic muscles, bring about flying movements. You would study the details of flight in insects in Unit 13 of this course.

## 8.5 LOCOMOTION IN MOLLUSCA

The main locomotor organ in Mollusca is the foot, which is a characteristic feature of these animals. In its simplest form the foot is a flat ventral sole which is best suited to secure attachment and progression of body by creeping. As coelom highly is reduced, it is not important as a hydrostatic skeleton in this group of animals. On the other hand, the foot is muscular and is provided with cilia and mucus cells. Along with this, the hydrostatic properties of blood system make it an excellent organ of locomotion. In bivalves, shell also plays an important role in locomotion. The foot also exhibits a wide diversity of forms to serve as an organ not only for crawling, but for burrowing, leaping and swimming as well. These activities are related to the environment and mode of living of the mollusc. Let us see the various modifications of foot (Fig. 8.31) associated with the locomotor function in different groups of Mollusca.

### 8.5.1 FOOT AS A CREEPING AND CRAWLING ORGAN

Small molluscs, especially aquatic gastropods, glide by means of cilia on the ventral surface of the foot. Larger animals creep or crawl by muscular waves passing over the ventral surface of the foot. This type of movement involves interaction of muscular contractions with the pressure of the haemocoelic fluid. Secretion of mucus over pedal surface makes gliding easier (Fig. 8.32). The simplest form of locomotor organ, represented by foot with a ventral groove with ciliated ridges occurs in aplacophoran **Proneomenia** (Fig. 8.31 A); in **Chaetoderma** even this foot groove is absent. The Polyplacophora show better development of foot which may be broad and flat as in **Chiton** (Fig. 8.31 B) or narrow as in **Chitonella**. Among the bivalves, the creeping foot may be triangular as in **Unio** and **Anodonta**; **Nucula** (Fig. 8.31 C) has a laterally compressed foot. Gastropods show a range of shapes of foot for efficient creeping movements. A foot in the form of a large flat lobe occurs in cowries (**Cypraea**) (Fig. 8.31 D), **Actaeon** (Fig. 8.31 E) and **Patella** (Fig. 8.31 F). It may be contractile as in **Triton**, highly glandular with a long backwardly bent siphon as in **Conus** (Fig. 8.31 G) or peculiarly encircling the whole body as in **Bullia** (Fig. 8.31 H).

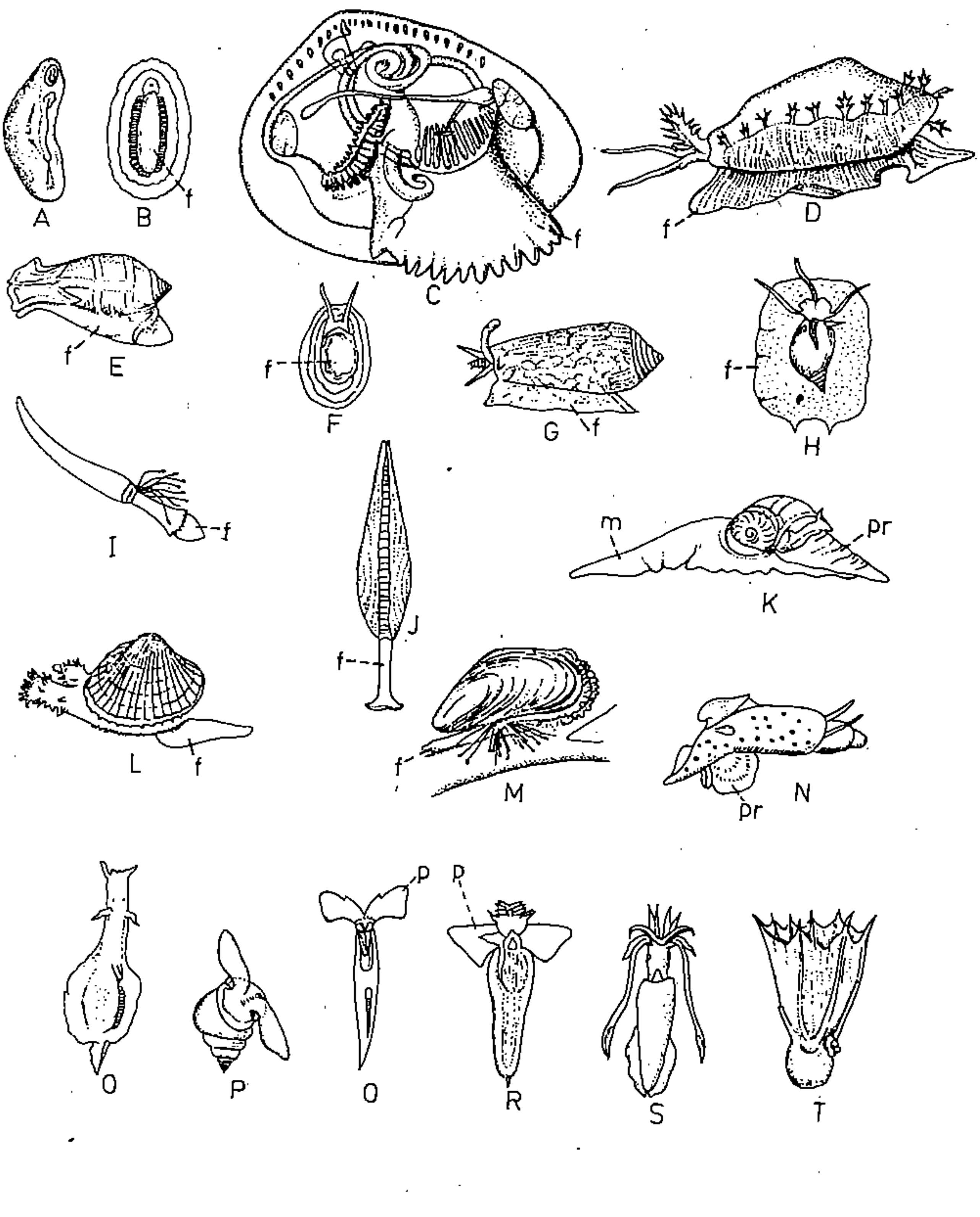



Fig. 8.31 : Foot modifications in Mollusca. A. *Proneomenia*. B. *Chiton*. C. *Nucula*. D. *Cypraea*. E. *Actaeon*. F. *Patella*. G. *Conus*. H. *Bullia*. I. *Dentalium*. J. *Yoldia*. K. *Sigaretus*. L. *Cardium* M. *Mytilus*. N. *Carinaria*. O. *Aplysia*. P and Q. Pteropods. R. A pteripod, *Clione*. S. *Loligo*. T. *Amphitretus*. f. Foot; m. metapodium; p. parapodium; pr. protopodium.

### 8.5.2 FOOT AS A BURROWING ORGAN

The Scaphopoda, which typically have burrowing habit, possess foot suitably modified for burrowing purpose. The conical and protrusible foot of **Dentalium** (Fig. 8.31 I) is trilobed at its distal end. It can be thrust into the sand when burrowing occurs. A lobe encircling the cone can be erected to increase its anchorage. Among burrowing bivalves, in some like *Pholas* which bores into rock the blunt, short foot is used for boring. They attach by the sucker-like surface of the foot; the muscles of the foot produce various movements producing the requisite cutting force; the anterior ends of the valves provide the sharp cutting edge. The shipworm **Teredo** bores into wood using more or less the same mechanism. In **Yoldia** (Fig. 8.31 J), the two sides of the foot can be folded to form a wedge shape for easy burrowing into the sand or mud. In some burrowing gastropods, e.g. **Sigaretus** (Fig. 8.31 K), the anterior part of the foot, called **protopodium**, is also specialized to become wedge like. The burrowing action in molluscs is typically accomplished by thrusting the blade of the foot into the sand or mud. The distal part of the foot is dilated with the aid of protractor muscles and when this is accompanied by blood pressure it acts as an anchor. Contraction of the retractor muscles now pulls the animal downward.

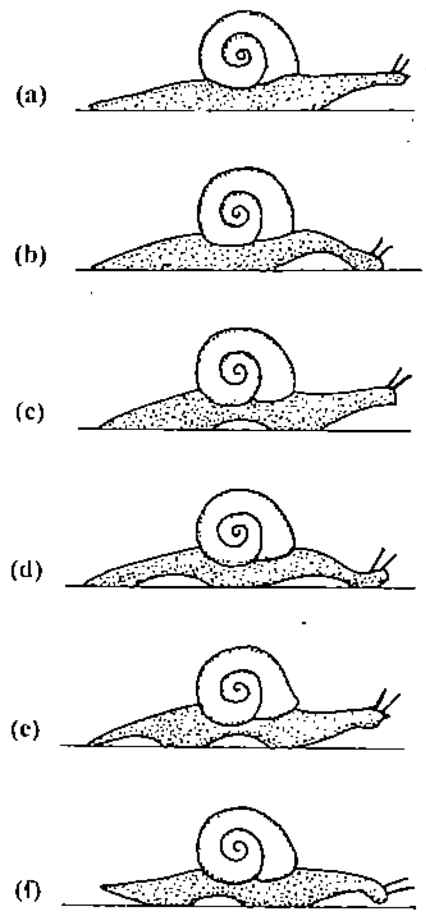



Fig. 8.32: Successive stages of creeping motion in a pulmonate gastropod.

### 8.5.3 FOOT AS A LEAPING ORGAN

Many bivalves utilise foot as an efficient leaping organ. The anteroposteriorly compressed foot of **Trigonia** forms a keel. In **Cardium** (Fig. 8.31 L), the foot is bent upon itself, and it can leap when the foot is rapidly extended from the folded position. The change in habit from soft sandy or muddy substrates to hard rocky and exposed ones is correlated with a reduction of foot and its associated musculature and development of accessory structures, such as the byssus apparatus. The latter is of common occurrence among the larval bivalves, though in some cases it may also persist in the adult stage. In **Mytilus** (Fig. 8.31 M), byssus threads, formed by the secretion of glands associated with the foot, keep the animal anchored to rocks. Foot is atrophied in the scallop **Pecten**, but the mollusc accomplishes movement in peculiar way by flapping its thin broad valves.

## 8.5.4 FOOT AS A SWIMMING ORGAN

Swimming habit is common amongst gastropods and cephalopods. Swimming gastropods exhibit a wide variety of foot modifications. In the pelagic forms, such as the heteropod prosobranch **Carinaria** (Fig. 8.31 N), the middle portion of the foot, the **mesopodium,** is like a thin muscular fin which helps to produce undulating movements. The fin is held up, the animal swimming upside down. The nudibranchs swim by having flattened bodies with thin lateral projections of foot called parapodia which act like fins. **Aplysia** or 'sea-hares', can creep; but they can also swim. Their parapodia are fan-shaped; they flap them while swimming. Pleurobranchs swim in this fashion. In some species the parapodia may form a tunnel by closing themselves. By shooting a strong jet of water backward through the tunnel a forward propulsion of the body is effected. The pteropods or 'sea-butterflies', are planktonic in habit, having wing-like parapodia (Fig. 8.31 P, Q), as in **Oxygyrus, Clione** (Fig. 8.31 R).

Among **Cephalopoda** the foot is modified to such an extent that it has lost its typical form. It is represented as a part of an efficient siphonal apparatus in association with a large mantle cavity. These animals swim by jet propulsion, by discharging water from the mantle cavity through the funnel with great force. Cephalopods are also provided with a number of arms and tentacles surrounding the head. Some scientists consider these structures to be the modification of the anterior region of the foot. Probably, this is not true; arms and tentacles may be cephalic structures, and not pedal. Their number varies in different forms. Octopuses have eight arms; **Loligo** (Fig. 8.31 S) and **Sepia** possess eight non-contractile arms and two retractile tentacles each. In **Amphitretus** (Fig. 8.31 T) the arms are joined together by a web, giving the structure the shape of an umbrella. The mantle wall in all actively swimming cephalopods has a well developed musculature consisting of circular, radial and longitudinal muscle fibres. Contraction of these muscles results in ejection of a very powerful water-jet which, in turn, causes a rapid and powerful propulsive movement of the body. Rapid swimming movement is facilitated by streamlining of the body of these animals, and by providing stabilising fins as in Loligo. However, Octopus and their allies crawl, using their powerful arms. They are poor swimmers.

In sessile molluscs, foot may be reduced or feebly developed. In the more or less sessile gastropods such as Crepidula, the foot is feeble or is reduced. In truly sessile forms like worm shells (vermetidae and Siliquariidae) also, which have a tube-like shell, the foot is reduced. The parasitic mesogastropods and bivalves (e.g. Entovalva), which usually occur as endoparasites of echinoderms, also possess reduced foot.

## SAQ 2

a) List two features in the organisation of arthropods which are significant in their efficient movement.

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b) In the table below which organs of locomotion given in column 2 are used in the groups mentioned in column 1. List the structures against each group.

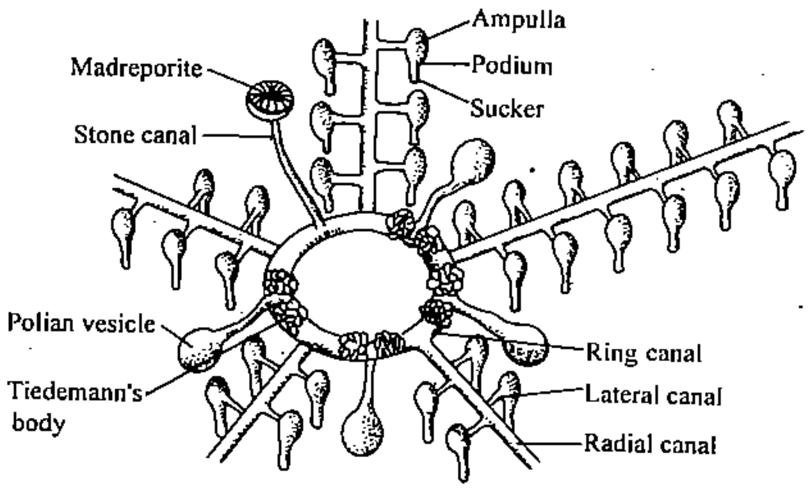
| | Column 1 | | Column 2 |
|---|---|---|---|
| i) | Insecta | a) | Uropods |
| ii) | Crustacea | b) | Wings |
| iii) | Arachnida | c) | Trunk appendage |
| iv) | Myriapoda | d) | Walking legs |
| e) | Antennules | | |

c) Foot is the organ for locomotion among Mollusca. Cite one example of a mollusc which utilises its foot for:

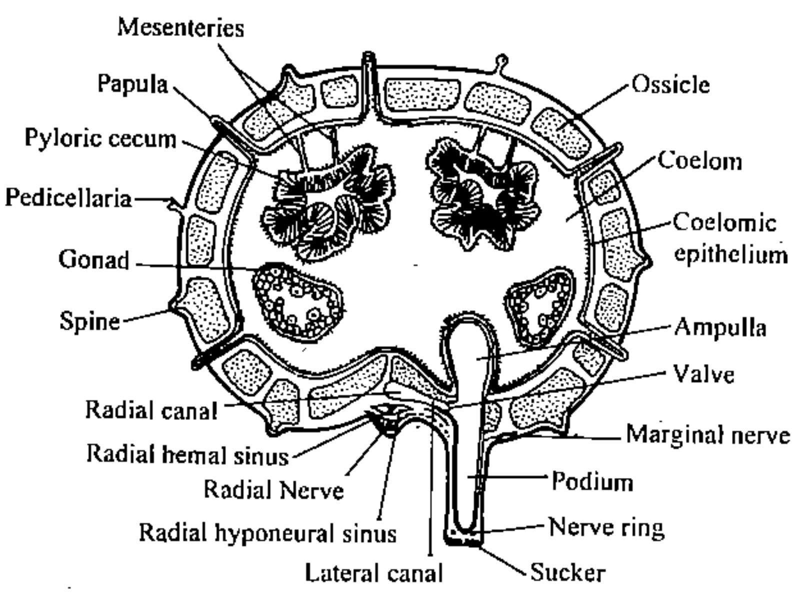
i) burrowing into the soft sand
ii) creeping
iii) swimming
iv) leaping

## 8.6 LOCOMOTION IN ECHINODERMATA

Locomotion in echinoderms is accomplished by a unique canalicular system which is known as the **water-vascular system**. This system is characteristic of echinoderms, in most of which it is quite well developed. It consists of a series of canals derived from the coelom. The canals contain a fluid. Sea water has free access to the system via a perforated sieve plate called the **madreporite** on the aboral side of the animal. The fluid is much like seawater but has a high content of potassium ions. Some proteins, and several types of amoebocytes float in it.




(a)




(b)

**Fig. 8.33: A. Diagram of the asteroid water-vascular system. B. Diagrammatic cross section through the arm of a sea star.**

The structural organisation of the water-vascular system is basically the same in all echinoderms, though deviations from the basic plan occur. To study the components of the system, we may take the water-vascular system of the star-fish, as typical example (Fig. 8.33). Its main component relevant from the point of view of locomotion, consists of a pentagonal circumoral vessel which is known as the ambulacral **ring canal**. From the ring canal are given off five **radial vessels**. Each radial canal extends up to the tip of the arm. It gives off a large number of side vessels along its course. Each side vessel leads into a **tube-foot** or podium, which is a hollow conical or cylindrical process with an ampulla and a terminal sucker. A Valve is present at the junction of lateral vessel with the tube-foot. (To understand how the tube foot works, see mechanics of locomotion).

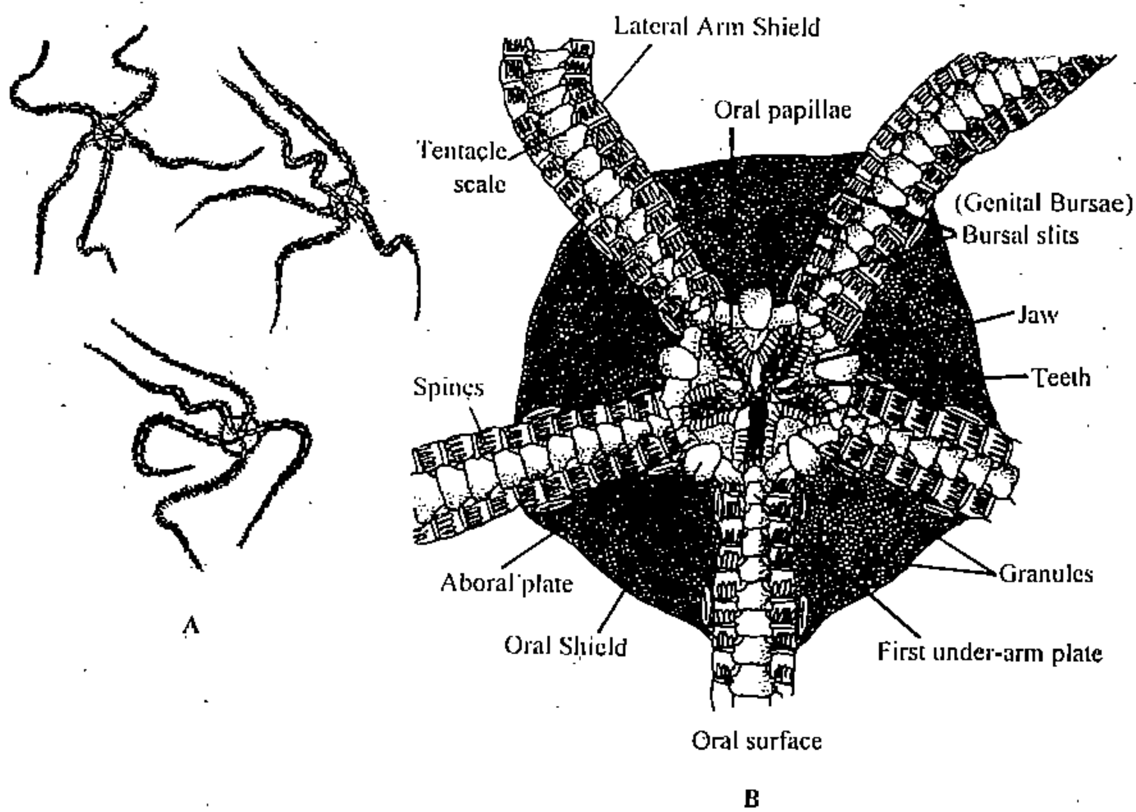



**Fig. 8.34: A. Caribean brittle star; B. External anatomy of an Ophiuroid.**

A short slightly curved canal extends vertically between the circumoral ring canal and the madreporite situated aborally. This canal is known as the **madreporic canal**. As it has calcareous deposits in the wall, the madreporic canal becomes quite hard, hence also the name **stone canal**. The madreporite is situated on the aboral side of the central disc of the animal in an inter-radial position and is perforated by minute pores called the madreporic pores.

Some accessory structures are also associated with the water vascular system (Fig. 8.33). A series of pear-shaped appendages, the **Polian vesicles**, are attached to the ring canal in inter-radial position. These have long necks and thin walls, and are believed to be involved in altering the fluid pressure in the system and in manufacturing amoeboid cells. There is also present a pair of small glandular bodies, the **Tiedemann's bodies**, associated with the neck region of the Polian vesicles. There are two Tiedemann's bodies in each inter-radius except in the one that contains madreporite, where only one is present. These are also believed to be some kind of lymphatic glands.

Slight variations from this typical organisation of water-vascular system are shown by different groups of extinct Echinoderms. The tube-feet subserve multiple functions. They may be used in locomotion, feeding, respiration and sensation. Though the tube-feet have usually a terminal sucker and are highly muscular, they may be peg like in some species. Asteroids having suctorial tube-feet, such as **Asterias, Asterina, Solaster**, use them for climbing and descending hard surfaces and also for food capturing. Peg-like tube-feet with pointed tip usually occur amongst forms that inhabit soft muddy surfaces, e.g. **Astropecten, Luidia** and are used as oars for digging, walking etc.

In **Ophiuroidea** (represented by brittle stars) the tube-feet are reduced and largely function as non-suctorial sensory tentacles. The locomotion in these echinoderms is accomplished by the vigorous whip-like movement of flexible long arms (Fig. 8.34). The usual number of arms is five; some species have 6-7 arms. In **Astrophyton** (the basket fish), the arms branch repeatedly.

The arrangement of the water-vascular system in Echinoidea (sea urchins) is essentially similar to that in asteroids (Fig. 8.35). However, the radial canals and other radial structures are internal to the skeleton. The stone canal lacks calcareous deposits in its wall. The Polian vesicles occur as small outgrowths in each inter-radius and there are five Tiedemann's bodies. The circumoral tube-feet are used as tactile organs. The spherical urchins use their tube-feet as anchor and for movement along the vertical surfaces; in addition, their spines are also involved as stilts during locomotion.

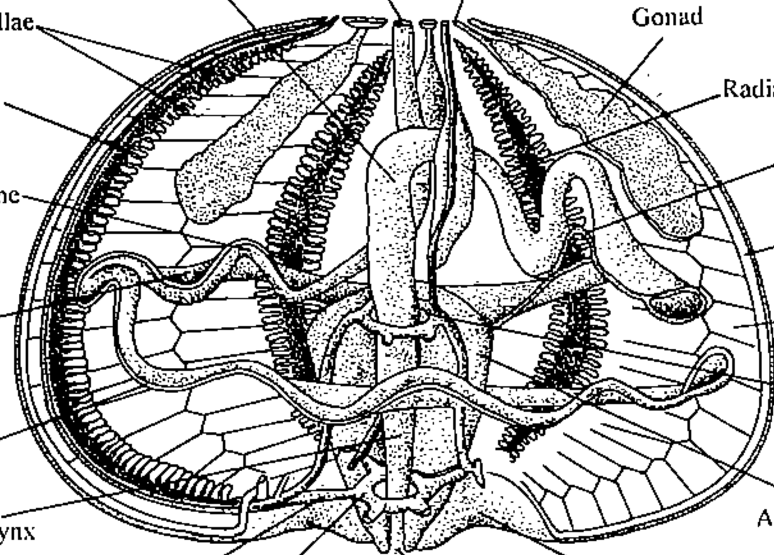



Fig. 8.35 : Internal structure of the sea urchin Arbacia (lateral view).

Holothuroidea (sea-cucumbers) have a closed water vascular system, like the echinoids, with the radial canals and other structures being internal. The madreporite is also internal, at the end of the stone canal which lies free in the body cavity or is attached to the body wall (Fig. 8.36). The ring canals are absent in some, (e.g. **Leptosynapta**). In most holothurians, tube feet are well developed with suckers, only on the creeping, ventral sole (Eg. **Cucumaria**). Other tube feet are reduced or even absent (eg. **Psolus**). Tube feet are altogether lacking, in **Leptosynapta.**

In Crinoidea (represented by feather-star **Antedon**, sea-lilies), the ring canal gives off radial canals into each arm; this canal forks into all branches and pinnules of the arm. A number of ciliated tubular structures, which are connected with the ring canal, are suspended into the coelom. These structures, called the water tubes, may open into the coelom at their extremities. Besides, numerous ciliated canal (ciliated funnels) with minute openings, the hydropores, lead through the ventral wall of the disc and open into the underlying coelomic spaces. These are comparable to the madreporite of echinoids and asteroids. The ciliated tubes and vessels correspond to the stone canal which in its typical form is lacking in crinoids. These echinoderms also lack Polian vesicles and Tiedemann's bodies. The tube-feet have no ampullae; they are also without a terminal sucker, but bear numerous sensory papillae and are called tentacles. They may have tactile or respiratory function. By their lashing movements, these tentacles are able to create water currents to the mouth and thus assist in capturing planktonic food, but they are of no help in locomotion. Most crinoids are sessile, attached to the bottom. However, stalkless comatulids can swim and crawl, manipulating the arms.

**Mechanics of Locomotion**

As you have seen above, the water vascular system and other components of the coelom in echinoderms are lined by an endothelium and are filled with coelomic fluid. This is of primary importance in locomotion in echinoderms. The fluid-filled tube-foot with muscular walls of its ampulla provides the basic component of a hydraulic system. The valve present at the junction of the lateral vessels with the tube-feet functionally separates the latter from the rest of the water-vascular system. The terminal sucker of the tube-foot is also muscle-operated. The walls of the tube-foot are provided with longitudinal muscles, while the ampulla also has its muscles. With the valves closed, the contraction of the ampullar muscles maintains the hydraulic pressure and causes the extension and elongation of the tube-foot in the desired direction, when the tube foot touches the substratum, the sucker produces a vacuum resulting in adhesion. Once this happens, the longitudinal muscles of the tube foot contract. This shortens the tube foot driving the fluid back into the ampulla. Echinoderms such as many asteroids, echinoids and hotothurians can creep using this mechanism; some can even climb steep rocks. In addition, holothurians can also burrow into sand or mud making use of the hydrostatic mechanism in conjunction with body muscles. The asteroid **Astropecten** which has no suckers on its tube feet, can burrow into sand or mud using tube feet. Some of its skeletal elements are used in manipulating the tube feet. Some sea urchins (eg. **Echinocardium**) can also burrow into sand. Brittle stars (ophiuroids), as a rule, move faster, using some of their arms to make rowing movement against the substratum, in leaps. Spines help in

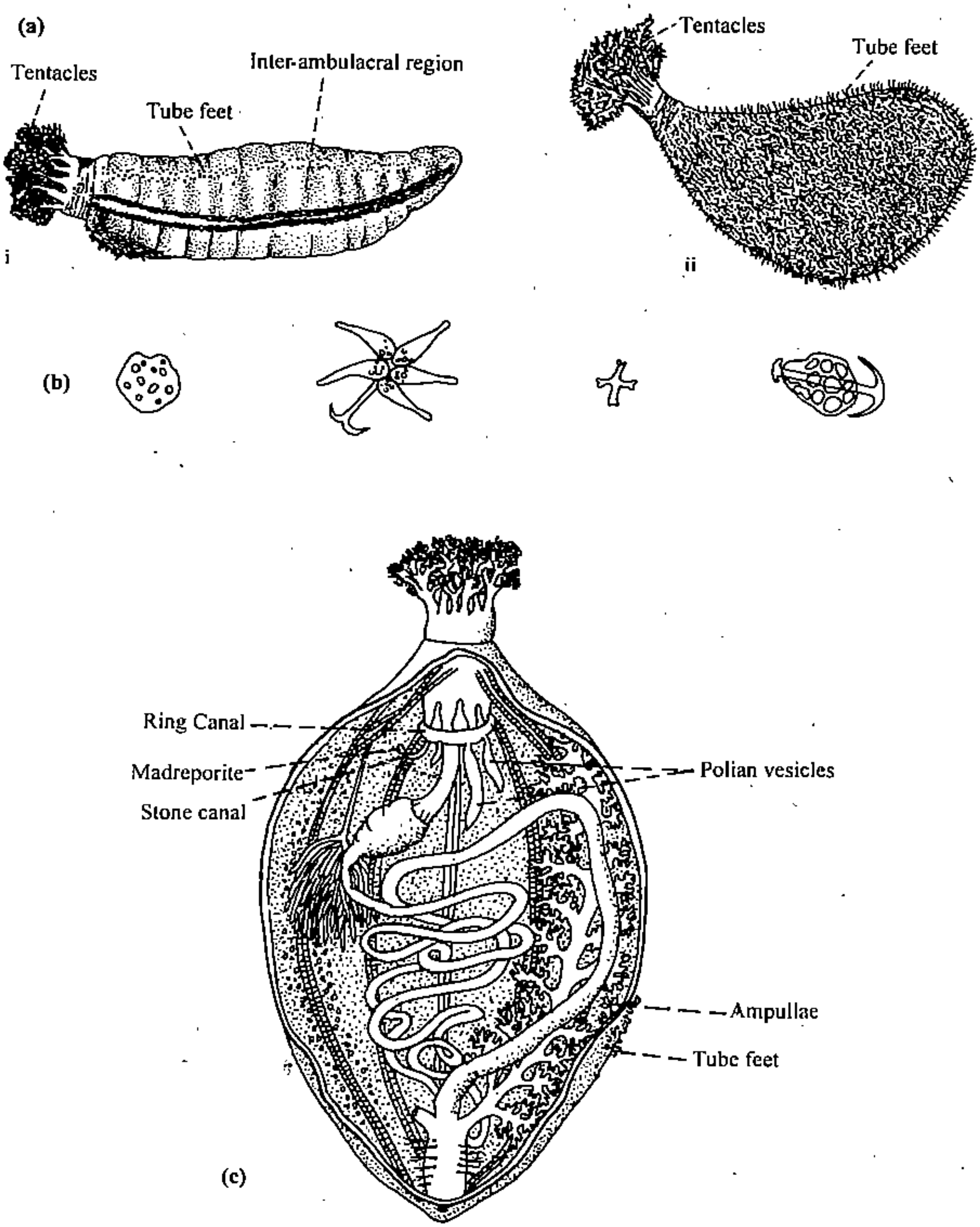



**Fig. 8.36: A. Holothurians: i) Cucumaria; ii) Thyone. B. Holothurian spicules. C. Internal anatomy of a Holothurian (Thyone).**

pushing the body forward in ophiuroids and echinoids, providing supplementary force in locomotion. Thus you can see that echinoderms adopt various mechanisms for locomotion, though they are very slow when compared to other animals.

**SAQ 3**

Fill up the blanks to complete the following sentences:

i) ............... .................. ............. is a distinctive feature of echinoderms, concerned with locomotion.

ii) ..................... prevent the back flow of the water- vascular fluid from the tube-feet to the radial canals.

iii) Tube-feet used for locomotion are usually -------- in nature, while tentacular tube-feet are used in ..................... or .......................

iv) Sea-urchins and sea-cucumbers have an ......................... water- vascular system, whereas in starfishes, the system is external.

## 8.7 SUMMARY

In this unit we have studied one important activity of living beings, namely locomotion. The term 'locomotion' implies movement of an organism from one place to other. We have seen that different devices and methods are employed for accomplishing locomotion by different animals. We now summarise the important modes and structural components of locomotion as they occur in major metazoan invertebrate groups :

- Animals which remain fixed to a place are sedentary, sometimes also called sessile. In contrast, animals which move their body from place to place are considered motile.
- Hydroskeleton also called hydrostatic skeleton provides the primary skeletal support of some animals. The coelomic fluid of an earthworm is an example of a primary hydroskeleton as also the case of blood flowing into the foot of a clam and pushing the foot into the sand or mud. Jumping spiders have only flexor muscles which can bend their legs. The forceful extension of the legs during a jump comes from the rush of body fluids into the leg.
- Very small flatworms swim or crawl about bottom debris by ciliary propulsion. Contractions of the muscle layer permit turning, twisting and folding of the body. The movement of larger turbellarions also involves delicate undulatory waves of muscle contraction. The dorsoventral flattening of the body is probably in part an adaptation for locomotion. In nematodes, the pseudocoel is well developed and its fluid functions as a hydrostatic skeleton. Waves of contractions sweeping along the layer of longitudinal muscle fibers produce undulatory or thrashing locomotory movements which drive nematodes through the spaces between algae, sand or soil particles. The contractions of the muscle cells are antagonistic to the elastic cuticle and the hydrostatic pressure.
- Annelids utilise their body musculature, hydrostatic skeleton and special structures, namely, parapodia, setae and suckers in bringing about locomotion. Polychaetes and oligochaetes accomplish locomotion by opposite action of longitudinal and circular muscles in their body wall on the coelomic fluid which is incompressible. Polychaetes have parapodia and because of the reduction or absence of coelomic septa, their several body segments move as a unit. Oligochaetes possess setae and their segmental coelomic septa limit the flow of coelomic fluid so that local body contractions and extensions occur. Hirudinea lack both setae and parapodia but possess a sucker at each end of the body; coelomic septa are absent and the coelomic fluid is largely replaced by botryoidal tissue. Annelids exhibit slow crawling, rapid crawling and swimming movements.
- Arthropoda exhibit efficient locomotion because of the presence of tough exoskeleton which resists deformation, metameric arrangement, jointed nature of appendages and their associated musculature. A wide variety of appendages, specialized according to their function, occur in different groups. Different species of crustaceans use modified cephalic, thoracic or abdominal appendages for locomotion. Arachnids have walking appendages while myriapods have several pairs of trunk legs for the purpose. In insects, the organs of locomotion are three pairs of legs and usually two pairs of wings, present on their thoracic segments. Arthropods display a variety of locomotor activities, viz., walking, crawling, running, digging, jumping, climbing, swimming, and even flight.

- Mollusca, in general, possess a muscular foot as the locomotor organ, which displays great morphological diversity related to the habit and mode of living among different groups. Accordingly, the foot may serve as an organ for creeping, crawling, burrowing, leaping and swimming. In sessile and parasitic molluscs the foot may be feebly developed or absent.
- Echinoderms possess a unique canalicular system, the water- vascular system which plays an important role in accomplishing locomotion. The blind ending branches of this system are the tube-feet, which may be modified as suctorial or tentacular structures and used in locomotion. They may however be also used for feeding, respiration and as sensory structures. The fluid-filled tube-foot and its musculature work as components of a hydraulic skeleton system helping locomotion.

## 8.8 TERMINAL QUESTIONS

1) Enumerate the principal structural specializations of Annelida towards an efficient locomotion. How is the locomotion in a leech different from that in Nereis and earthworm?

2) How is walking movement in arthropods related to the number and arrangement of limbs?

3) Point out how foot is modified in molluscs for creeping and swimming habits.

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4) Describe how the water-vascular system assists in locomotion in Echinodermata.

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## 8.9 ANSWERS

### Self-Assessment Questions

1) (a) (i) combs, (ii) hydrostatic, (iii) parapodia,
(iv) swimming, (v) potychoetes, (vi) leech, suckers
(b) slow crawling, rapid crawling, swimming.

2) (a) exoskeleton made up of tough, chitinous cuticle, jointed appendages.
(b) (i) b,d (ii) a,d,e (iii) d (iv) c.
(c) (i) **Dentalium** (ii) **Chiton**
(iii) **Loligo** (iv) **Cardium**

3) a) Water-vascular system
b) Valves
c) Suctorial, food capture, sensation
d) internal.

**Terminal Questions**

1) Metameric segmentation of the body, well-developed musculature of the body wall, and a fluid-filled coelomic cavity are the key features for efficient locomotion in Annelida. A leech utilises its anterior and posterior suckers for locomotion. The co-ordinated muscle activity of body wall and alternate attachment of the two suckers to the substrate result in typical galloping movement of leech.

Hydrostatic skeleton is not much involved in their locomotion. Nereis possesses both parapodia and setae; earthworms have only the setae, as special structures of locomotion. Antagonistic action of body muscles accompanied by changes in hydrostatic pressure plays important role in polychaete and oligochecte locomotion. Protrusion and withdrawal of the setae also are important in them in locomotion.

2) When the limbs are more in number, they are attached along greater length of the body; so the propulsive force gets spread against many articulation centres in the body and causes sideways undulations of the body. As the number of limbs is reduced to 3-4 pairs their articulation points with the body are nearer to one another and also to the centre of gravity of the body. This is the case in insects and arachnids. Propulsive force now being confined to one centre (i.e., the thorax) is more effective and checks sideways undulations of the body.

3) For creeping the foot may be in the form of a flat broad or conical muscular organ, assisted by mucus secretions of the associated glands. It may assume the shape of fins or wings in swimming forms. In cephalopods it is modified into a funnel for jet propulsion or it may form arms and tentacles at the anterior end for crawling or creeping. (You could expand the answer by citing relevant,examples from the text.)

4) The water-vascular system consists of a series of fluid- filled canals which terminate in tube-feet. The valves present at the junction of the tube-feet and the lateral canals regulate the flow of the fluid into and out of the tube-feet. When contraction of the ampulla muscles occur the valve gets closed and to maintain the hydraulic pressure, the tube-foot elongates. The sucker produces a vacuum resulting in adhesion. Now, contraction of the longitudinal muscles of the tube feet shortens the tube foot, driving the fluid back into the ampulla.

# UNIT 9 NUTRITION, EXCRETION AND OSMOREGULATION

## Structure



## 9.1 INTRODUCTION

In Unit 2 of this course, you have learnt about mechanisms of feeding and digestion as well as the mechanisms of excretion and osmoregulation in protozoans. In this unit you will study aspects of nutrition, excretion and osmoregulation in multicellular non - chordate animals. These animals exhibit a variety of feeding habits. The success with which the animals exploit the food resources could be compared only with the elegance and complexity of their structural and functional adaptations. In this unit you will first study nutrition, that is, the feeding habits, and the various adaptations for feeding and digestion in the multicellular non-chordates. The second aspect that will be covered in this unit is excretion.

Excretion is concerned with the removal of metabolic wastes that arise as a result of oxidation of energy rich compounds and metabolism of proteins and nucleic acids. This is carried out in non-chordate metazoan animals by two distinct sets of tubular structures - the nephridia and coelomoducts. The nephridia and coelomoducts are variously named in different groups of animals depending on their complexity and location. Terrestrial arthropods have evolved another type of excretory organ known as Malpighian tubules structurally different form nephridia and coelomoducts. In this unit you will study in detail these organs and how they carry out excretion.

A third aspect of study covered in this unit relates to the regulation of water and ionic content of the body of non-chordate metazoans. These may be osmoconformers or osmoregulators. Osmoconformers maintain their internal body fluid in osmotic equilibrium with the aqueous environment in which they live. In other words, the salt concentration of the internal and external media is more or less same. Other organisms are osmoregulators and they maintain the concentration of their internal body fluids relatively constant. This may be often at a different osmotic and ionic level from that of the environment. In this unit, you will also study the mechanisms of regulation of water and ionic content of body fluids in these animals.

### Objectives

After studying this unit, you should be able to:

- describe the structures associated with feeding and the mode of feeding in different non-chordate metazoan phyla,
- list the excretory organs found among the various groups of non-chordate metazoan invertebrates and describe their functioning, and

- outline the mechanisms of water and ion regulation in organisms occupying different habitats.

## 9.2 NUTRITION IN NON-CHORDATE METAZOANS

The vast majority of invertebrates feed on particulate food material of very small size. They can be broadly classified as microphagous organisms. In contrast, feeding on large masses of food is called macrophagy. Generally large invertebrates are macrophagous. Macrophagous feeders could be active predators and may feed on live material. Cephalopod molluscs, for example, are completely predaceous. Large crustaceans and in general all the living arthropods are macrophagous. Before you proceed further, it is suggested that you go back to the Unit 2, Block 1 of this course 'Protozoa' and revise the concepts on various types of animal nutrition such as 'autotrophy, heterotrophy, holozoic and saprozoic'.

Microphagous animals make effective use of their cilia or setae for feeding. They are therefore commonly known as ciliary feeders. Ciliary feeders fall into two categories. One type known as suspension feeders feed on minute organisms and other particulate matter suspended in water. In this type of feeding food particles are extracted by filtering water. Hence the organisms are known as filter feeders.

Filter feeders set up a current in surrounding water with their cilia or setae. The food is collected by filtration as well as by trapping food in mucous. Much of the filtered material may be inedible or harmful or larger than the size of the particle that the organism can feed on. Such materials are usually discarded by a well developed sorting cum rejecting mechanism. The chosen food particles are then directed towards the mouth. Both sessile and free swimming organisms have evolved filter feeding mechanisms. Free swimming animals move in water containing food particles. Sessile animals depend on natural currents in water as well as those created by cilia and other appendages. The sessile organisms also feed on deposits of organic material that accumulate on substratum as well as in the sand or mud. The deposit feeders, like suspension feeders, depend on cilia for feeding. In fact some organisms may feed on both suspended and deposited food materials. When the material is deposited on sand or mud, the substratum itself is swallowed. Other feeders depend on encrusted organisms like algae, polyzoans and sponges as food organisms. The mouth parts of such feeders are modified for rasping and browsing food. Sedentary polychaets, molluscs - more particularly lamellibranchs, sponges, pterobranchs, small crustaceans as well as a number of other groups of small animals are all microphagous filter feeding organisms. Rasping feeding is very characteristic of many gastropod molluscs and they use their radula for such a purpose. You will now study feeding and digestion in chosen groups of organisms. But before doing so, attempt the following questions

### SAQ 1

Fill in the blanks with suitable words:

i) Feeding on large masses of food is termed ..............................
ii) Microphagous animals make use of ............................ for effective feeding.
iii) The ............................ cum ............................ mechanism discards too large or otherwise unsuited particles.
iv) Rasping feeders such as gastropods make use of ............................ for feeding.

### 9.2.1 FEEDING AND DIGESTION IN SPONGES, COELENTERATES AND FLATWORMS

#### Sponges

Sponges make use of their canal system for feeding, respiration and excretion. For a detailed account of canal system in sponges, you may refer to unit 5 of Block II of this course.

Sponges feed by filtering particulate matter from nutritive water that enters into choanocyte lined spongocoel through minute pores. These pores act as simple but effective sorting device that permit the entry of only the smallest particles. Each of the choanocytes or collar cells possesses a single flagellum surrounded at its base by a protoplasmic collar. The flagella beat outwards from their base and move water forward. The smaller food particles are ingested from the water by choanocytes and the slightly larger ones by wandering amoebocytes and even by dermis cells. The digestion is intracellular, within the food vacuoles (Fig.9.1). The partly digested food vacuoles from choanocytes may also be passed on to neighboring amoebocytes. Amoebocytes serve also to store food materials. In syconid and leuconid sponges, with complex body form choanocytes line small flagellated chambers, thereby increasing the area of ingestive epithelium. Water is expelled from the spongocoel through osculum and thus the entry of new nutrient rich water is facilitated.

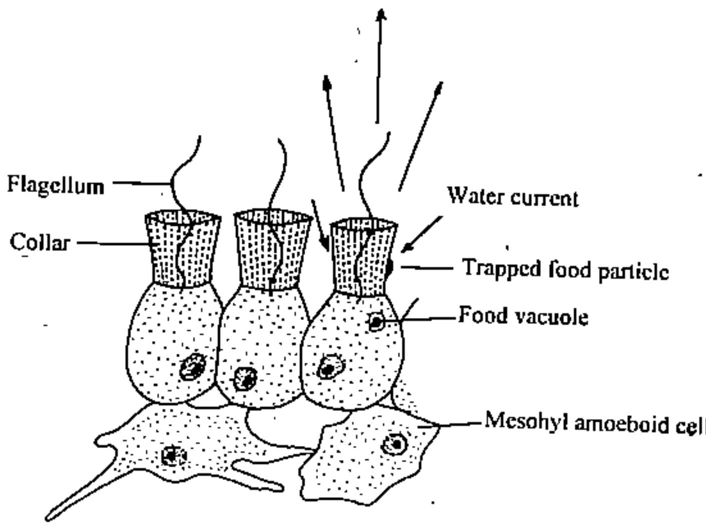



**Fig.9.1 : Intracellular digestion in fresh water sponge.**

## Coelenterates

Coelenterates have tissue grade of organisation and therefore their feeding and digestive mechanisms are also more complex. Coelenterates, in general, are macrophagous carnivores. They use their tentacles to capture the prey. Their prey include all types of small animals especially crustaceans. Some scyphozoans and anthozoans may even feed on fish (Fig.9.2). However, certain anthozoans and scyphozoans are microphagous suspension feeders. They either trap the prey in mucus secreted by the tentacles or filter plankton from water passing through tentacular fringe. For instance the anemone *Metridium* and the jelly fish *Aurelia* collect small organisms by the tentacles in a mucous secretion and move the food to the mouth by ciliary action.

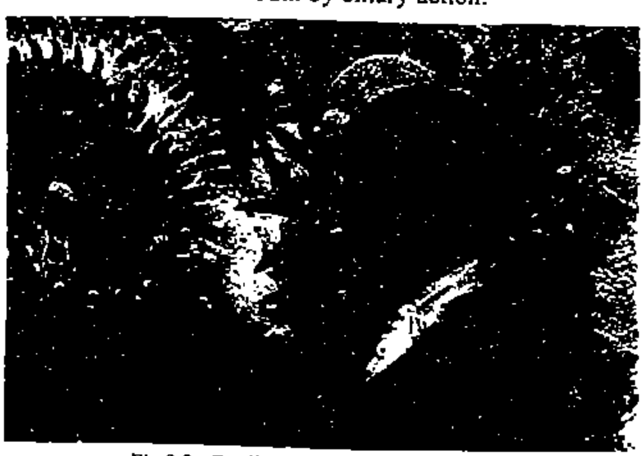


**Fig.9.2 : Feeding of a fish by an anthozoan.**

Macrophagous carnivorous coelenterates use cnidoblasts(Fig.9.3) for trapping the food by tentacles. Cnidocil projecting from cnidoblast, as is found in *Hydra*, is believed to be the sensory element. Each cnidoblast discharges one nematocyst. Each nematocyst has a pear shaped vesicle and a thread coiled within it. When discharged the nematocyst pierces into the prey and injects poison into it.

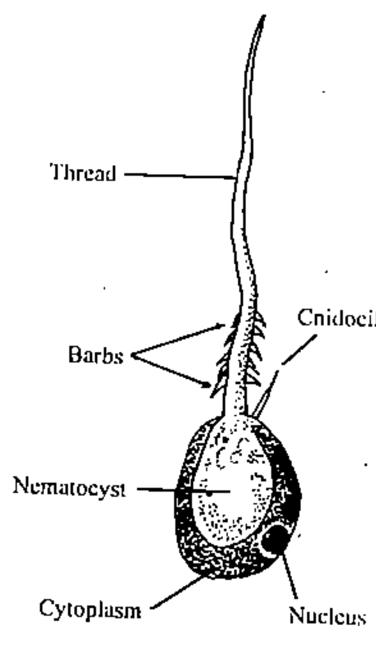



**Fig.9.3: Structure of cnidoblast.**

The swallowing of food follows its capture and paralysis by nematocysts. The swallowing is done by enlarging the mouth and expanding the gastrovascular cavity. These two actions facilitate the passage of food into coelenteron or gastrovascular cavity (GVC) (Fig.9.4) - the site of digestion of food.

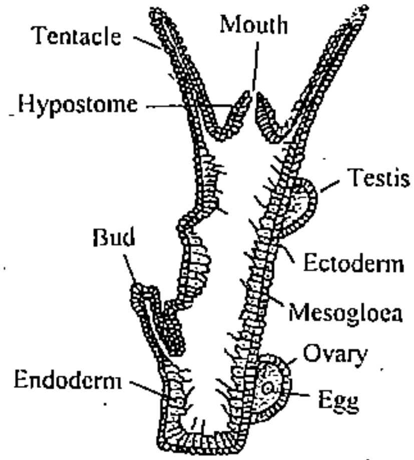
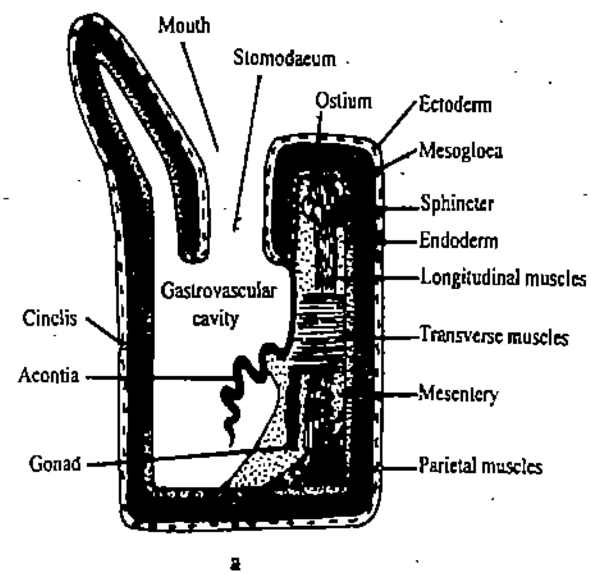



Fig.9.4: L. S. of Hydra showing the gastrovascular cavity and the endoderm.

Digestion in coelenterates is both extracellular and intracellular. During extracellular digestion, the large prey is broken into smaller particles in the GVC. Some of the endoderm cells are secretary in nature and they release the enzymes into GVC.



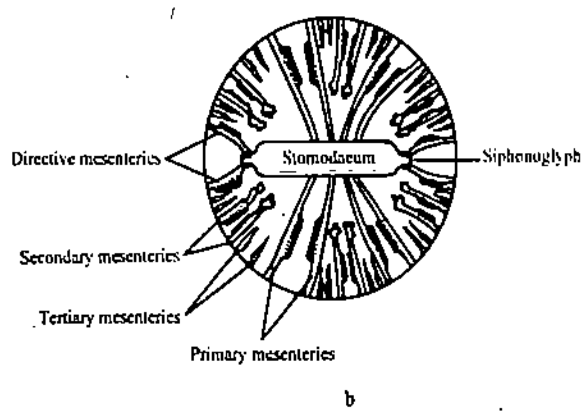




Fig. 9.5: (a) L.S of a sea anemone (b) Cross section at the level of pharynx filament.

In *Hydra*, a prey like *Daphnia* is broken down into small particles within four hours of its ingestion by secreting the enzymes into GVC. Besides the secretory cells, there are also absorptive cells which are concerned with intracellular digestion. An hour after ingestion, during which time the prey is actively broken down, the absorptive cells begin to ingest the food particles into small vacuoles and digestion is completed with in these cells. Absorptive cells also store the reserve food materials and even accumulate the undigested residues. The accumulated intracellular waste is finally released by the fragmentation of the absorptive cells into GVC. From GVC they are ejected out through the mouth. Thus a combination of intracellular and extracellular digestion takes care of the nutritional requirements.

In anthozoan coelenterates also such a combination is found. You may refer to Unit 5 of this course for a detailed account of an anthozoan organisation. You may recall that GVC of anthozoans is subdivided by the mesenteries. The thickened edges of mesenteries known as mesenteric filaments carry the secretory and absorptive cells (Fig.9.5). In macrophagous anthozoans the prey is firmly held by the filaments, with the help of nematocysts located there and the digestive enzymes are directly applied to the food. This process increases the efficiency, of the action of digestive enzymes. Coelenterates, being carnivores, secrete mostly lipolytic and proteolytic enzymes. Very weak amylase activity is also recorded. Other carbohydrases are not reported.

## Flatworms

Free living flatworms are known to digest the food (1) intracellularly, (2) both intracellularly and extracellularly and (3) exclusively extracellularly.

i) Exclusive intracellular digestion is seen in acoelan *Convoluta*. The endoderm appears as a solid syncytium that can protrude through the ventral mouth. The syncytium functions as if it were a pseudopodium and engulfs the food to form food vacuoles. Digestion occurs intracellularly.

ii) In the triclad worm *Polycelis* the food such as crustaceans is trapped in the mucous secretion. The long protrusible pharynx (Fig. 9.6) is inserted into the prey and the soft contents are withdrawn. The food is broken down to small particles extracellularly while passing to the alimentary canal. On reaching the gut, the particulate food is engulfed by digestive cells and intracellular digestion takes place. Although *Polycelis* feeds on large organisms, the food ingested is actually made up of very small particles and hence the organism is to be regarded as microphagous.

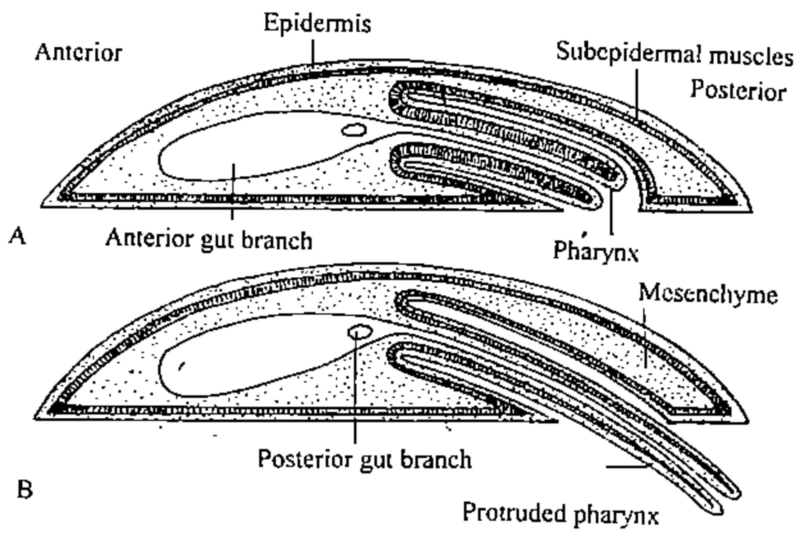



Fig.9.6: Diagrammatic L.S. of *Polycelis* to show the protrusion of pharynx.

iii) The polyclad worm *Cycloporus* feeds exclusively on ascidian colonies *Botryllus* and *Botrylloides*, sucking the individual zooids with the help of protrusible pharynx. The wall of the pharynx is ruffled and plicate. The food arrives almost intact in the gut. In contrast to *Polycelis* where digestion is exclusively intracellular, in

*Cycloporus* it is exclusively extracellular. The food is homogenised and digested with the alimentary tract and there is no intracellular digestion.

In trematodes which are parasitic, the digestive system is highly branched. The mouth leads into pharynx which is followed by a short oesophagus and a branched intestine bearing a number of diverticula (Fig. 9.7). The highly ramified diverticula fill the most of the interior of the body. A trematode such as liver fluke feeds on the biliary matter as well as the blood of the host. The muscular pharynx aids in sucking of the food. Digestive glands have lost their utility in these animals and therefore they are absent. The food is already in a state ready for absorption. The branched alimentary canal helps in the reaching of the food to all part of the body.

## SAQ 2

State whether the following statements are true or false.

i) The ingestion of food particles in sponges is done by choanocytes and wandering amoebocytes.
ii) Coelenterates are in general microphagous, herbivorous feeders
iii) Cnidoblasts are food capturing cells in coelenterates.
iv) Coelenterates digest the food extracellularly.
v) All flatworms can digest their food intracellularly.

## 9.2.2 FEEDING AND DIGESTION IN ANNELIDS

### Oligochaetes

Among annelids, the oligochaetes which comprise mostly earthworms, feed on dead, decomposing organic vegetation. They also digest organic matter contained in the soil which they swallow during burrowing. Aquatic forms feed on detritus, algae and microorganisms. Freshwater forms like *Aeolosoma* collect detritus with its prostomium. The food is collected by creating a partial vacuum when the ciliated ventral surface of prostomium is placed against the substratum and the center is elevated by muscular contraction. The partial vacuum thus created releases the food particles which are swept into mouth by cilia. Some oligochaetes like *Chaetogaster* catch amoebae, ciliates, rotifers and trematode larvae by the sucking action of pharynx.

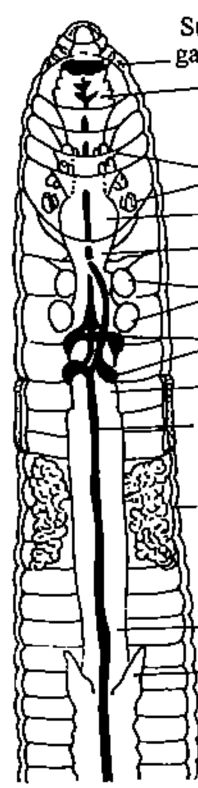



Fig. 9.7: Digestive system of an oligochaete.

Oligochaetes possess a simple and straight alimentary tract (Fig.9.7). The mouth situated at the base of prostomium leads into a buccal cavity which opens into a spacious and muscular pharynx. In aquatic forms, the pharynx is an eversible organ and is mucus covered to which food particles adhere. In earthworms, it functions as a pump.

Pharyngeal glands secrete mucus as well as digestive enzymes. Pharynx is followed by a narrow tubular oesophagus. The oesophagus is modified at different levels into a gizzard and a crop. The muscular and cuticle- lined gizzard functions as triturating organ and grinds the food particles. If crop is present it functions as a storage organ. Rest of the digestive system, starting anywhere from $18^{th}$ and $22^{nd}$ segment is intestine. Anterior half of the intestine is secretory in function and the posterior half is absorptive. Besides carbohydrases, proteases and lipases, earthworms also secrete cellulase and chitinase. The absorptive area of the intestine is increased by a fold of tissue called **typhlosole** present in middorsal wall. A layer of yellowish peritoneal cells called **chloragogen** cells around the intestine is the site of intermediary metabolism in oligochaetes. These cells have the same function as the liver in vertebrates and fatbody in insects, and is the site of synthesis as well as storage of glycogen and fat.

## Polychaetes

Polychaetes include both free moving (errant) and sedentary species. The free moving species are generally macrophagous and the sedentary forms are microphagous. *Nereis* is an example of a free moving macrophagous polychaete. But *Nereis* can also burrow and make use of its proboscis (buccal cavity and pharynx) for this purpose (Fig. 9. 8). The eversible proboscis is a feeding organ. The pharynx is lined with hooked jaws and is everted for seizing the prey. The genus *Nereis* includes species which are carnivorous. Some species of *Nereis* are omnivorous, feeding on diverse material such as algae, invertebrates or detritus on the substratum. Some are scavengers. The tentacles and palps present around the mouth assist in the manipulation of food, besides serving sensory function.

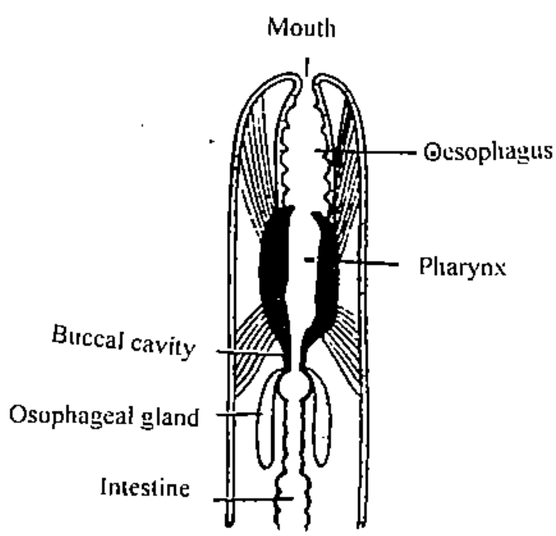



**Fig. 9. 8: The digestive system of *Nereis*.**

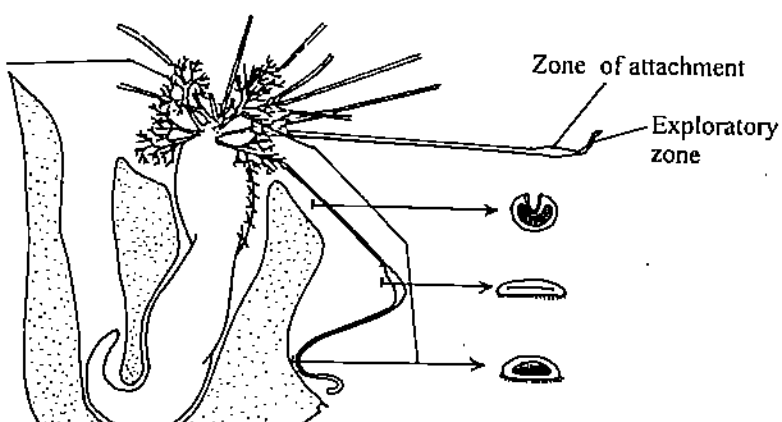



**Fig.9.9: *Terebella* in a feeding posture.**

The detritus feeding lugworms (*Arenicola* and related species) swallow the mud or sand in which the food is contained. The swallowing is done by the sucking action of the proboscis which is the anterior end of the alimentary canal. Being burrowers, they lack tentacles. Other sedentary polychaetes have evolved very fine mechanisms of ciliary-mucous feeding. For example, terebellid worms (e.g. *Amphitrite, Terebella*) live in permanent mud tubes and are detritus feeders (Fig.9.9). From the tubes they extend their long ciliated prostomial tentacle clusters over the surface of the substratum. The food particles consisting of detritus trapped in the mucus. The cilia are actively involved in the movement of food particles. The mucus-trapped food particles pass through the ciliated grooves of the tentacles and enter into the mouth.

*Sabella*, a large polychaete, builds tubes that project from the surface of mud in the littoral zone of the sea. The coordinated action of cilia present on the branchial crown of tentacles (Fig.9.10) creates water currents and the food is extracted from the currents. The branchial crown of tentacles form a wide funnel at the base of which the mouth of the animal lies. The tentacles or the filaments of the branchial crown bear rows of outgrowths called pinnules. Toward the lower part of branchial funnel, the pinnules interlock and form a filtering system in which the food particles are trapped on the pinnules. There are three types of cilia on the pinnules. These cilia produce a current of water. Food particles that enter the funnel along with the stream of water are directed into a groove that runs along the inner edge of each pinnule. The cilia located at the base of the pinnule drive the food particles to the base of pinnules from where they enter into a ciliated longitudinal groove that runs the entire length of filament and then into the mouth.

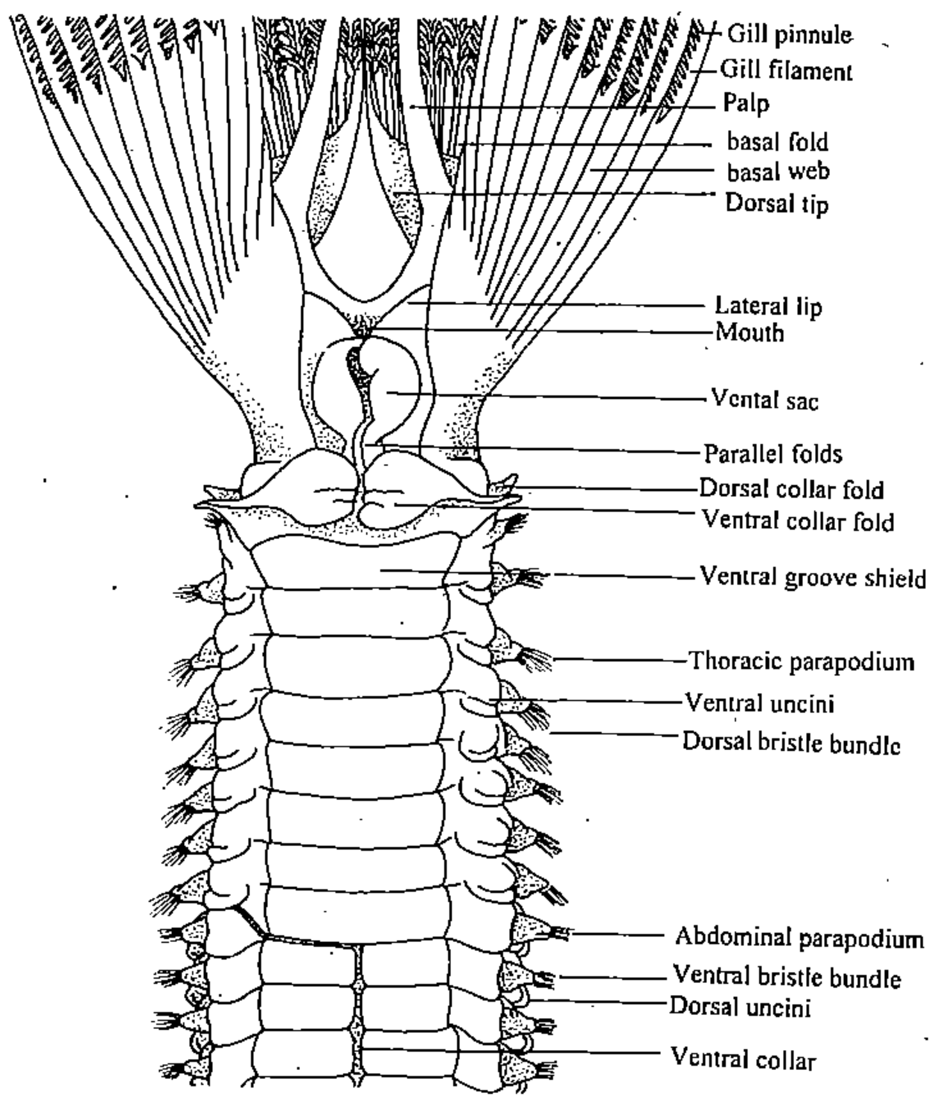



**Fig.9.10: *Sabella* with its branchial tentacles.**

In *Chaetopterus*, which lives in 'U' shaped tubes made of sand or mud (Fig.9.11), a branchial crown is absent. Water is drawn by the beating of three pairs of fan shaped structures that are derived from parapodia as well as by another pair of wing like outgrowths located anteriorly. Mucus secreted by these structures traps the food particles and is drawn into a ventral groove. Here it is shaped into a conical bag and the food particles are filtered through the bag. The filtered food is rolled into a ball by a secretion of the wing like structures. The cilia in the ventral groove transport the ball of food to the mouth.

Annelids generally exhibit extracellular digestion, although phagocytosis by the alimentary epithelium and completion of digestion of the ingested food by wandering amoebocytes are reported in *Arenicola marina*. Digestion is mostly extracellular in filter-feeding terebellids. The digestive system in polychaetes is differentiated into an oesophagus, a fore-stomach, a muscular hind-stomach and an intestine. Enzyme secretion is therefore confined to fore-stomach and fore-intestine. In general digestion occurs in fore-stomach and fore-intestine. The hind-stomach is actually a mixing region. Absorption takes place in the hind-intestine.

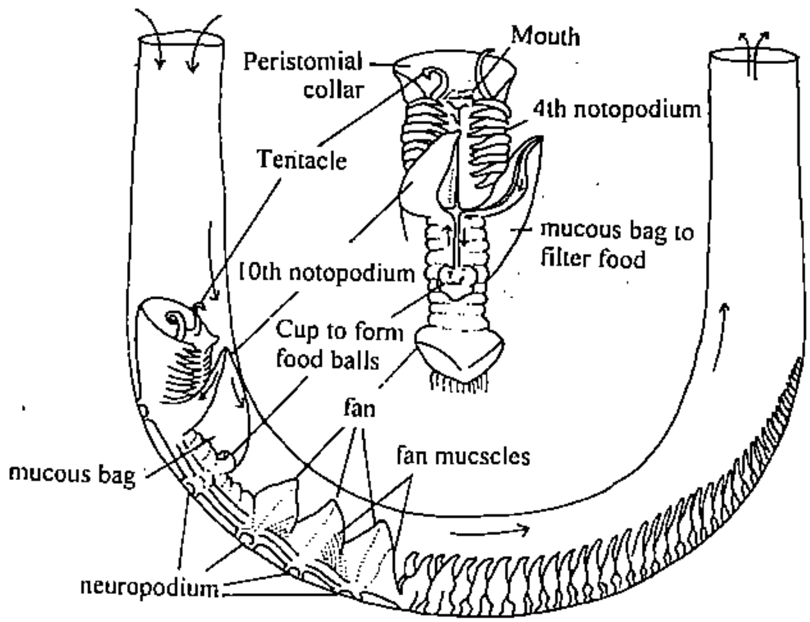



Fig.9.11: (a) *Chaetopterus* inside the tube (b) Enlarged anterior region to show the food gathering apparatus.

## Hirudinea

Hirudinea includes free living and ectoparasitic leeches. Leeches are blood suckers. The digestive system consists of a preoral chamber which accommodates a sucker at the base of which lies the triradiate opening, the mouth. The walls of the mouth are embedded with jaws, three in number, of which one is mid-dorsal and the other two ventro-lateral. Each jaw bears a row of minute teeth. The alimentary canal consists of a thick muscular pharynx followed by a short oesophagus. Unicellular salivary glands are found on either side of the pharynx. The oesophagus is followed by a crop, an extensive sac consisting of 10 to 11 chambers, the chambers communicate with each other by openings surrounded by sphincters (Fig. 9.12). Each camber is provided with a pair of backwardly directed lateral caeca. There is a progressive increase in the size of caeca, the anterior pairs being smaller in size, and the caeca of last chamber being the largest. Following the crop, there is a small round stomach with a much folded inner wall, and the stomach in turn leads into a narrow intestine the inner wall of which is provided with horizontal and transverse folds to increase the absorptive surface. The intestine is followed by rectum that opens outside by anus.

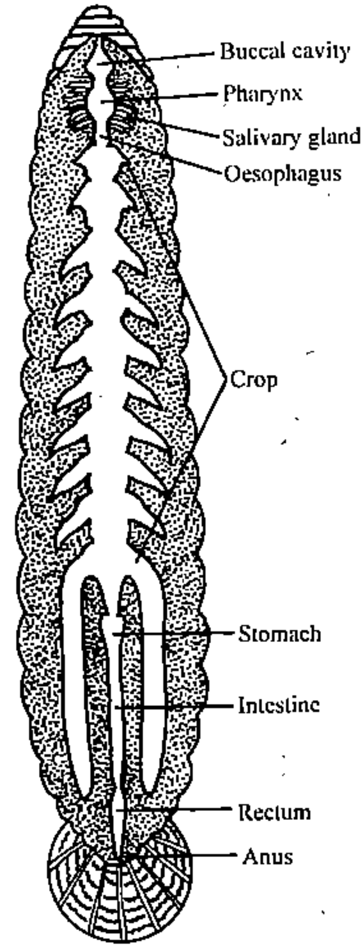



Fig. 9.12: Digestive system of a leech.

Leeches feed on blood of man and cattle. They attach themselves to the victim by their suckers and make an incision in the skin with their jaws. The muscular pharynx sucks the blood. The salivary secretions contain an anti-coagulant, the hirudin which prevents the clotting of blood and ensures a free flow of blood into the crop. The crop is thus a reservoir for the storage of blood. Once a leech has a full feed, it may not again feed for several months. The food from the crop passes into stomach from time to time and the digestion takes place in the stomach. The digested food is absorbed in the intestine.

## SAQ 3

Match the items given under **A** with the ones given under **B**.

| A | B |
|---|---|
| 1) Oligochaeta | a) macrophagous feeders |
| 2) Errant (free moving) polychaetes | b) ciliary mucous feeders |
| 3) Sedentary polychaetes | c) chloragogen cells |
| 4) Tube dwelling polychaetes | d) phagocytosis |
| 5) *Arenicola* | e) hematophagous feeders |
| 6) Leech | f) microphagous feeders |

## 9.2.3 FEEDING AND DIGESTION IN MOLLUSCS

### Lamellibranchs

We begin the study of feeding and digestion in molluscs with bivalves or lamellibranchs. Lamellibranchs resort to ciliary-mucus type of filter feeding as witnessed in some polychaetes. They are semi-sessile animals confined to their protective shells and inhabit muddy or sandy substrata. These are microphagous feeders and make use of their ciliated gills or lamellae as food-gathering devices. The lamellae are structured to filter suspended and deposited material from a current of water that enters into the animal through inhalant siphon and exits through exhalant siphon. During this, water current is maintained by the action of cilia present on the gills.

Each gill or ctenidium is formed of two demibranchs attached to a central axis and each demibranch has a parallel row of filaments. The structure of the filament varies in different groups of bivalves. In primitive protobranch, the filaments lack folds but in filibranchs and eulamellibranchs, the filaments are folded to from ascending and descending limbs (Fg.9.13). Figure 9.13 illustrates evolution of lamellibranch gills. In *Mytilus*, a filibranch, adjacent filaments are joined by ciliary junctions. In *Anodonta*, a eulamellibranch, the filaments are joined to each other by vacuolar interfilamental junctions. In lamellibranchs cilia are arranged in frontal and lateral series on gill filaments (Fig.9.14).

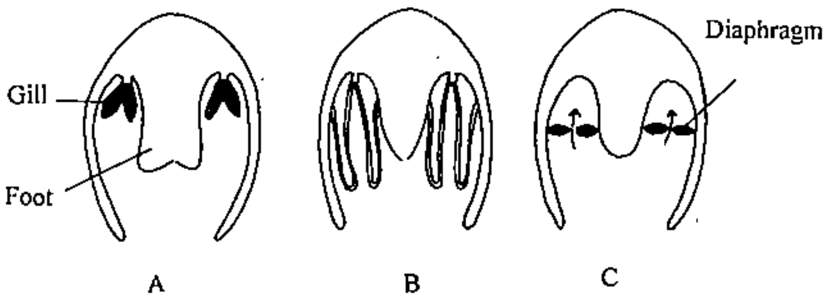



**Fig.9.13: (I) Vertical section of lamellibranchs to show the differences in the structure of ctenidia. (A) protobranch, (B) filibranch and eulamellibranch, (C) septibranch.**

Water is drawn into the mantle cavity by lateral cilia. As water passes through the filaments, the food is gathered by fronto-lateral cilia and thrown towards frontal cilia (Fig. 9.14). The food particles now entangled in mucus are swept over the surface of gill lamellae and find their way to food groove. This may be ventral marginal groove or dorsal groove along the axis of the gill, depending on the species.

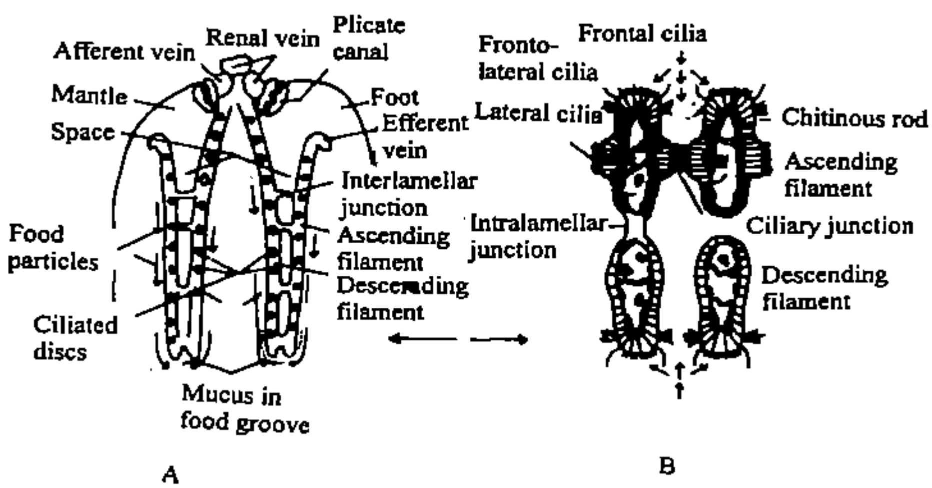



**Fig. 9.14: Structure of the gill in lamellibranchs (A) vertical section (B) horizontal section of gill in *Mytilus*.**

Food material is then carried to the two pairs of labial palps lying on each side of the mouth and from there to the mouth. The ciliary tracts on gills as well as labial palps do the sorting of food. Fine cilia on certain gill tracts convey the fine particulate food to the mouth and the coarse cilia on the other tracts reject the large particles (Fig.9.15). The sorting mechanism here depends on the weight of particles. The heavier particles that settle down on the palps are swept away by powerful ciliary currents. Lighter ones avoid this current, sink to the bottom and are swept towards the mouth. The rejected particles get entangled in mucus and are ejected out through exhalant siphon.

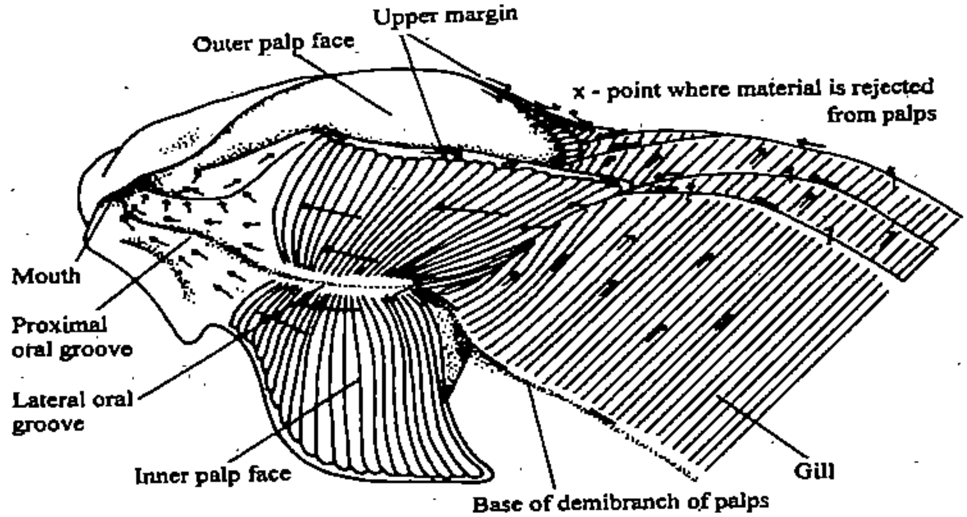



Fig.9.15: Junction of palps and gills in *Ostrea* to show the route of water and food particles. X-the point at which the material is rejected from palps.

Lamellibranchs are characterised by a structure called crystalline style, a very compact and long rod formed by the consolidation of mucus. The style is secreted by the style sac. The style sac is an extension of the stomach, either opening directly into stomach or cut off from the stomach. The style sac is lined with cilia which rotate the crystalline style and drive it forward into the stomach. The free end of the style is worn away by the alkaline stomach contents as well as its friction against the gastric shield which is a thickening of the cuticular lining of the stomach. During this process the style substance releases amylase, a carbohydrate digesting enzyme. In some species cellulase is also released. Thus extracellular digestion of carbohydrates is initiated in the stomach. The rotation of the mucus-cum-food strand by the crystalline style as well as the pH of the stomach contents(pH5-6) result in the continuous separation of the food and mucus into fine particles and their detachment from the main strand. The detached particles are sorted out by the stomach wall based on their size. The larger and heavier particles are transported by cilia into the intestine where they are converted into faecal pellets and removed. The finer particles are carried towards the openings of digestive diverticula or gland which is a characteristic feature of molluscan digestive system. Each one of the two diverticula is highly branched system of blind tubules. The ciliated epithelium lining the tubules is formed of vacuolated cells which are phagocytic. The cells ingest the fine particles into food vacuoles and digest them. Thus digestion in lamellibranchs is largely intracellular, although secretions from style sac initiate carbohydrate digestion extracellularly.

## Gastropods

In most gastropods the digestion is extracellular. However, some herbivore gastropods like *Crepidula* are ciliary feeders and has a digestive system similar to that of lamellibranchs. In them amylase is the only extracellular enzyme; the digestive diverticula do not secrete any enzyme but are only absorptive in function. *Crepidula* has also a crystalline style similar to those of lamellibranchs. Some herbivorous gastropods belonging to Taenioglossa, Rhapidoglossa and Pteropoda also possess crystalline style. It is confined to those herbivorous gastropods that are microphagous feeders, including rasping feeders that use radula (Fig. 9.16). *Patella, Haliotis, Aplysia and Helix* are some of the herbivorous gastropods that do not possess a crystalline style. Essentially in those forms where extracellular digestion has replaced intracellular digestion, a crystalline style is absent.

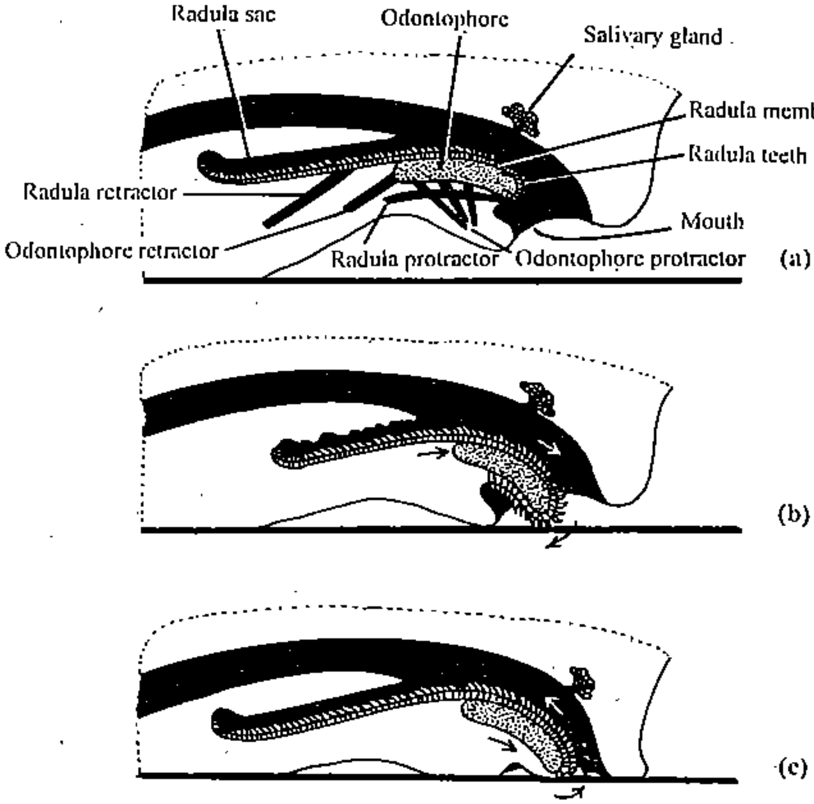



Fig.9.16: (a) Radula apparatus of a gastropod; (b) and (c) protraction and retraction of radula.

## Cephalopods

Cephalopods are carnivorous. Tentacles or arms are food capturing organs. The number of tentacles vary in different cephalopods. *Sepia* has ten arms, *Octopus* has eight and *Nautilus* has around 90 tentacles. *Sepia*, like other squids and cuttlefishes, has four pairs of short and heavy tentacles called arms and a pair of long structures called tentacles. The inner surface of the arms are provided with suckers which are stalked, cup-shaped and adhesive in nature. The suckers are provided with horny rings and hooks. In the mobile tentacles the suckers are present only at the flattened ends. The arms aid in holding the prey tightly after it is captured. Suckers are present in the arms of *Octopus* as well but they are stalkless and devoid of horny rings and hooks. Cephalopods, besides radula possess a powerful pair of beak shaped jaws in the buccal cavity. The jaws are used for tearing and biting the prey before the tongue like action of radula pulls the food down and aids in swallowing. Octopods inject the prey with poison or without a bite with jaws and the prey is flooded with enzymes. The partially digested food then passes into gut. While feeding on shelled gastropods, octopods drill a hole in the prey with radula and then inject poison into the animal through the hole. Whereas cuttlefish feed on surface inhabiting organisms such as shrimps and crabs, octopods feed on a variety of prey including clams, snails and crustaceans. *Nautilus* is a scavenger-predator feeding specially on decapod crustaceans, particularly hermit crabs.

The buccal cavity leads into an oesophagus which conducts the food into stomach by peristaltic action. In *Nautilus* and *Octopus* there is a crop, which is an extension of oesophagus. The stomach of cephalopods is highly muscular and contains a caecum attached to its anterior end. The walls of the caecum absorb the digested food and the absorptive function is carried out to a certain extent by the intestine as well. The intestine opens outside by an anus (Fig.9.17).

In cephalopods, the digestion is exclusively extracellular. The digestive glands of cephalopods include salivary glands -two pairs of them located on either side of buccal cavity. The posterior pair of salivary glands secrete poison which are glycoproteins. In *Octopus* they also secrete proteolytic enzymes. Cephalopods also possess pancreas and liver. In squids the two structures are separated from each other and the pancreas empty their secretions into the duct of the liver. Enzymes of both the glands are emptied into stomach, at the junction between stomach and caecum. In fact the 'liver' in *Octopus* performs three functions, the secretion, absorption and excretion, very similar to the hepatopancreas of other molluscs.

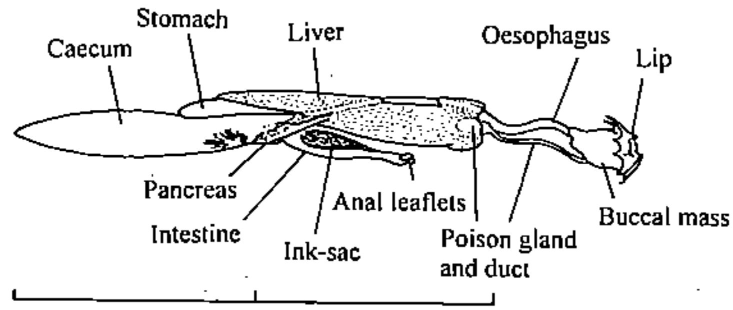


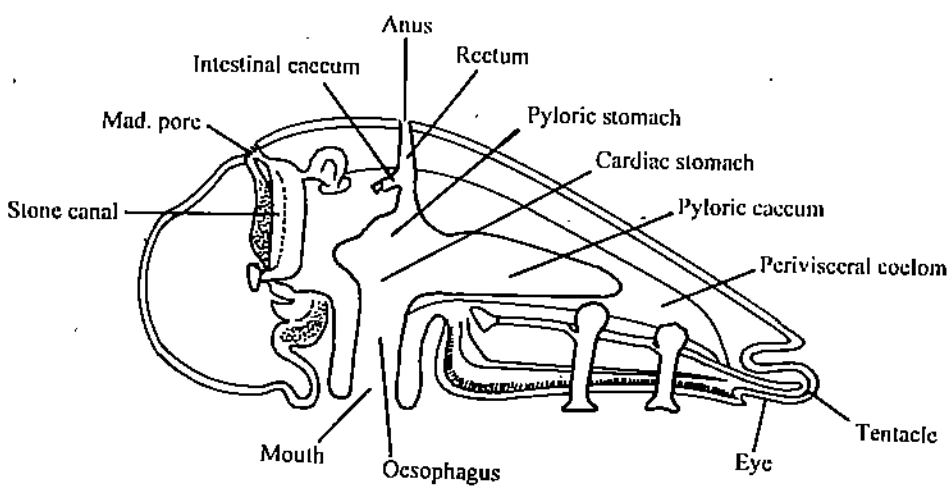

Fig 9.17: Digestive system of *Loligo*.

### 9.2.4 FEEDING AND DIGESTION IN ECHINODERMS

Echinoderms exhibit a variety of feeding habits. Most of them are carnivorous. But some of them are suspension feeders, some are deposit feeders, others could be scavengers and still others are grazers. We shall briefly study the digestive system and the nutrition of different group of echinoderms.

In asteroids (e. g. starfish) digestive system is radial, and is modified with the flattening of the body. The system is compressed on oral-aboral axis (Fig 9.18). The mouth lies in the middle of a muscular peristomial membrane and leads into a short oesophagus, followed by the stomach. The stomach shows two regions, a large oral chamber - cardiac stomach and a small aboral chamber - the pyloric stomach. The pyloric receives ducts from pyloric caeca which are the digestive glands. There are two pyloric caeca in each arm. The caeca are glandular mass of cells suspended in the coelom of the arm by a mesentery. The pyloric stomach leads in to a short intestine that opens on the aboral disc by an anus. The intestine bears a pair of caeca, the rectal caeca.

Asteroids are scavengers and carnivores, and feed on invertebrates such as snails, bivalves. Crustaceans, polychaetes and other echinoderms. When a starfish comes across a prey such as a mussel, it bends its flexible arms over the body of the prey and attaches the tube-feet to the two valves with the suckers. The two valves are pulled apart and the soft body of the mussel is exposed. Then the cardiac stomach is everted through the mouth and wrapped over the soft body of the mussel; the stomach engulfs the prey and the digestive juices are poured on it from the pyloric caeca. At the completion of the digestion, the stomach is withdrawn into the body, leaving the shell outside. The digestion is thus extracellular and the products of digestion are stored in the cells of




9.18: Digestive system of a starfish.

pyloric caeca or passed through the caeca into the coelom for distribution. The undigested waste is ejected through the anus by pumping action of rectal caeca.

Ophiuroids, of which brittle stars are examples, are also carnivorous and they could be scavengers, deposit feeders or filter feeders. The food consists of polychaetes, molluscs and small crustaceans. Food is usually captured and brought to the mouth by arm looping. The alimentary canal consists of mouth, a short oesophagus, and a saccular stomach that ends blindly. The stomach is eversible. There is no intestine or anus and the system does not extend into arms. Extracellular and intracellular digestion as well as absorption occur mostly within the stomach. During filter feeding, the arms are waved in water, and the plankton and detritus adhere to mucous strands strung between the spines of adjacent arms. The trapped food particles may be swept downward by a reduced spine called tentacular scale by the ciliary action. Or the food particles may be collected by the two pairs of tube feet located close to the mouth of each arm. The tube feet are then scraped across the tentacular scales. The collected particles are deposited in front of the scale, compacted into a bolus and passed along the mid-dorsal line of the arm towards the mouth by the ciliary action.

Echinoids consisting of sea urchins, heart urchins and sand dollars are grazers and use their teeth for scraping the substratum on which they live. They feed on a wide variety of plant and animal material, and the algae are most important food. The mouth leads into a buccal cavity and then into a pharynx, both of which are surrounded by a masticatory apparatus, the Aristotle's lantern. Oesophagus follows the pharynx and runs vertically upwards close to the aboral end continues into stomach. The saccular stomach at first has a downward course, reaches almost the oral end and then curves, runs anti-clockwise closely apposed to the inner side of the test. The stomach then continues into intestine which runs parallel to stomach clockwise (Fig.9.19). The intestine is followed by rectum. The oesophagus, stomach and intestine are all suspended by mesenteries. Attached with the stomach, at both ends, is a narrow tube, the accessory intestine or intestinal siphon. One end of the siphon opens into stomach at its junction with the oesophagus and the other end passes into the intestine. Digestion is extracellular, begins in the stomach and is completed in the intestine. The function of the siphon is to remove excess water from the food before the digestion commences in the stomach.

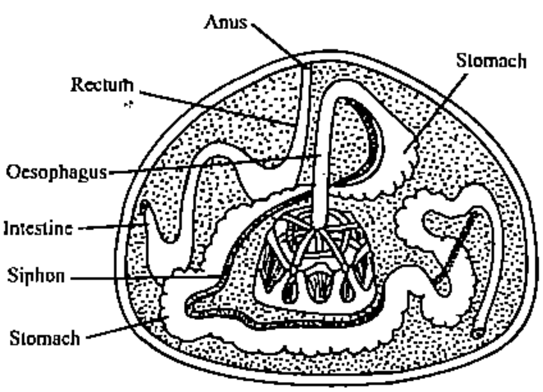



Fig. 9.19: Digestive system of a sea urchin.

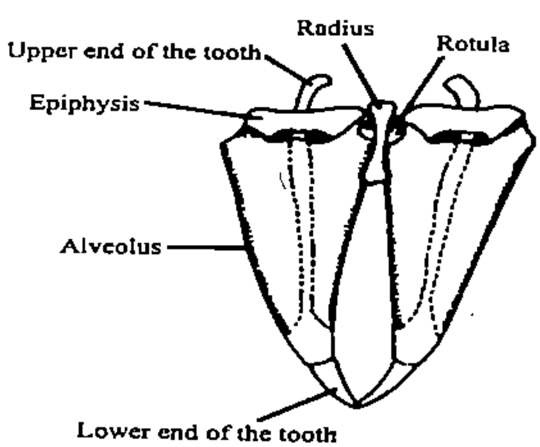



Fig.9.20: Aristotle's lantern of a sea urchin.

Aristotle's lantern, the masticatory apparatus, is formed of five plates or jaws fitted together into an inverted pyramid (Fig. 9.20) surrounding the pharynx. Each plate is a triangular framework, within which a long pointed tooth is present. Since there are five jaws, there are five teeth as well. The tooth can slide up and down in the frame by muscular action. In addition to the jaws and teeth, Aristotle's lantern also consists of a number of smaller, rod like pieces at the aboral end. The lantern can be protruded from the mouth by the action of the muscles. In addition to scraping the lantern is also useful in pulling and tearing of food. Aristotle's lantern is absent in heart urchins.

Sea cucumbers belonging to class Holothuroidea are suspension or deposit feeders. The alimentary canal consists of mouth, the buccal chamber, a wide oesophagus, an indistinguishable stomach, a long intestine and the cloaca that opens to the exterior (Fig 9.21). The mouth is located in the middle of a buccal membrane at the base of the tentaclular crown. When the animal is disturbed the mouth and the tentacles can be pulled completely into the anterior end of the body. The branched tentacles are the food capturing organs. They are either swept over the bottom or held out in sea water. In both instances the food particles are trapped on to the adhesive papillae located on the tentacular surfaces. One by one the tentacles are stuffed into the pharynx and the food particles are wiped off the adhesive papillae even as the tentacles are pulled out of the mouth.

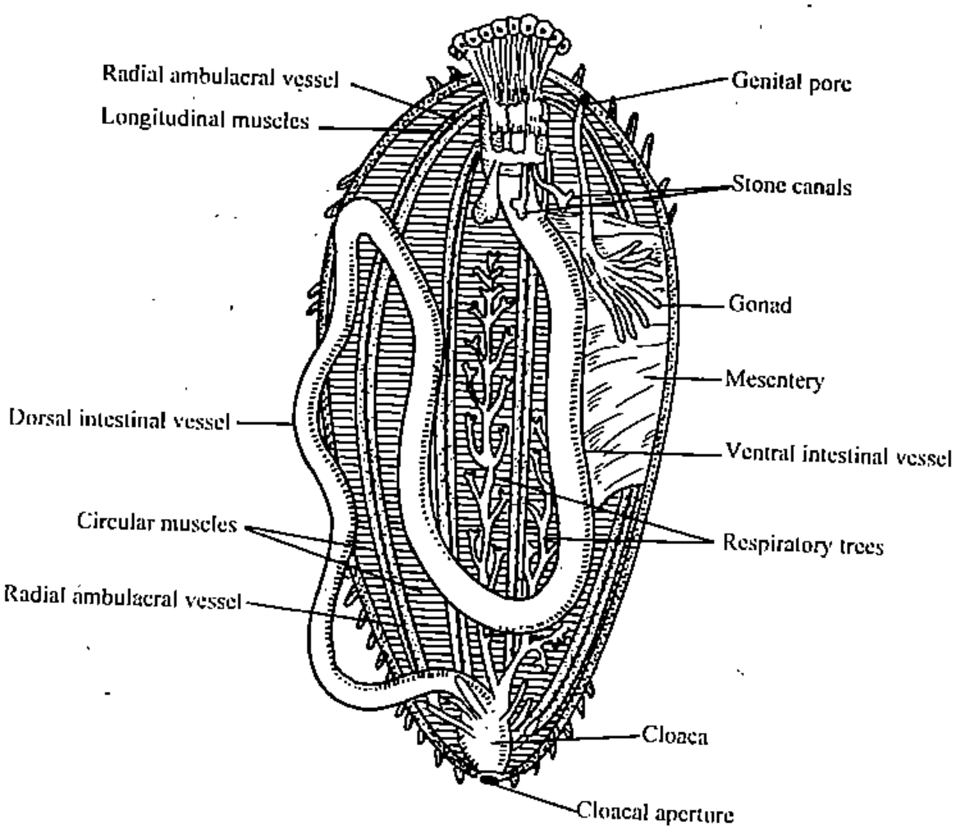



**Fig.9.21: Digestive system of holothurian.**

The pelmatozoan echinoderms, the crinoids, are suspension feeders. The alimentary canal consists of the mouth, a wide oesophagus, a spacious stomach with diverticula, a coiled ascending intestine opening outside by anus. During feeding, the arms and pinnules are outstretched and the tube feet are erect. The tube feet appear as small tentacles and bear mucus secreting papillae along their length. The food particles trapped in the podia are passed into the mouth by the ciliary currents.

## 9.2.5 FEEDING AND DIGESTION IN ARTHROPODS

Arthropods are known to lack cilia. Feeding in arthropods is carried out by the various appendages. Virtually every pair of appendages may be modified in one or other group of arthropods to aid in the feeding process. Whereas terrestrial arthropods in general are macrophagous and predaceous (there are many herbivores among insects), aquatic arthropods, mainly crustaceans have adapted themselves for filter feeding.

## Crustacea

Branchiopods (Anacostraca) provide a good example for filter feeding mechanism. The appendages are of foliaceous type(leaf-like) called phyllopodia and they beat metachronally. The inner edge of these appendages bears a series of endites, the most basal endite being larger than the others. The backwardly directed endites bear large setae which are also backwardly directed. The outer edge of the limb has several lobes. The most distal of these lobes is the exopodite while the basal ones are epipodite and protopodite.

The limbs perform different functions. They are locomotory, feeding and because of their delicate structure can also function as respiratory organs. The beating of limbs produces currents in surrounding water and brings in the food particles. In between the limbs present on one side, there is an interlimb space (Fig.9.22 and 9.23). The food materials are trapped on to the setae of endites which act as the filtering elements of the food capturing mechanism. The filtered food materials are taken to the mouth.

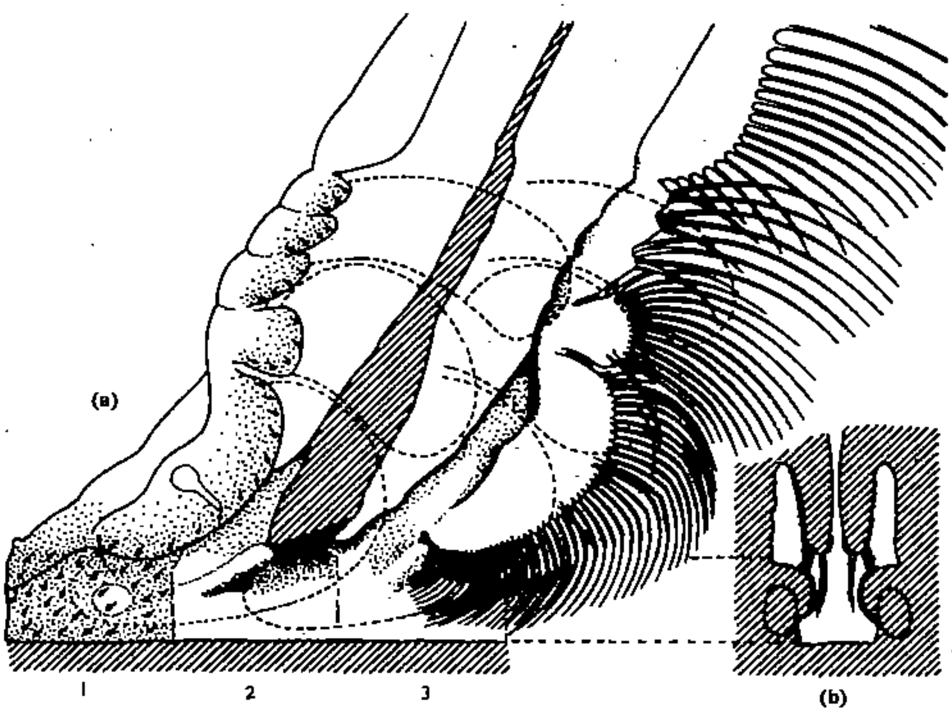



Fig.9.22: Median view of three consecutive limbs of a branchiopod to show interlimb space, setae and setules. In limb 1 the setae are removed. The setules are shown by stippling the area. In limb 2 the endites are removed to show the interlimb space and the channel into which it opens. Limb 3 shows endites with complete setae.

Copepods like *Calanus* resort to maxillary filter feeding. In these organisms feeding current is created by a swimming vortex.. The maxillary setae act as a filter and collect the food when the water passes through them. The setae on maxillular endites and maxillipedes remove the food from the maxillary setae and pass it onto the mouth.

Crustaceans like other arthropods have a ventral mouth that leads into almost a straight alimentary canal. The foregut is essentially enlarged stomach that harbours a triturating apparatus. Usually the apparatus is made up of chitinuous ridges, denticles and calcareous ossicles all located on the wall of the stomach. The length of the midgut varies in different groups of crustaceans and contain one to several pairs of caeca which increase the absorptive surface of the midgut. Hepatopancreas are spongy digestive glands composed of secretory tubules and ducts and are the source of proteinases and lipases. Both foregut and midgut are the sites of digestion. Absorption takes place across the midgut walls and the tubules Hepatopancreas also serves as a storage organ. The midgut leads into rectum that opens to the exterior by anus. Let us briefly look into the digestive system and nutrition of different groups of crustaceans.

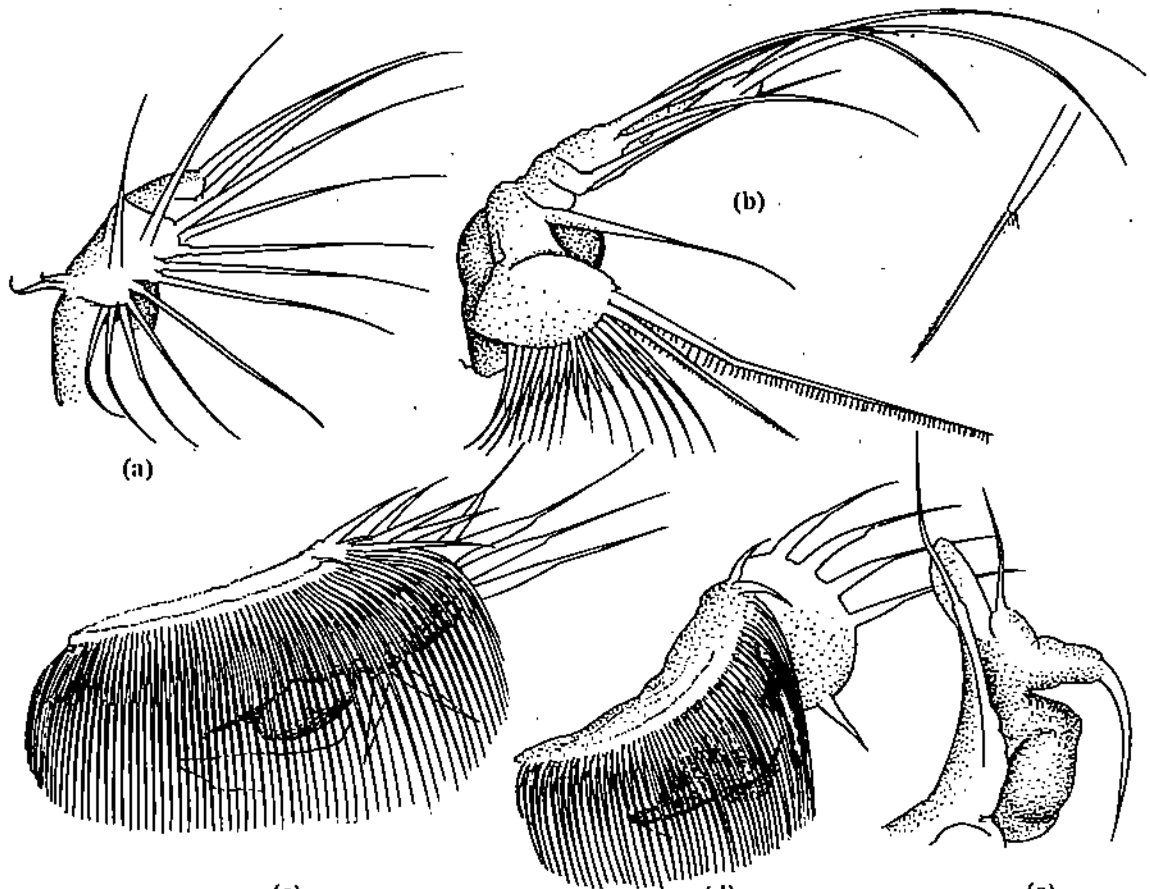



Fig.9.23: A to E: the first to fifth pair of trunk limbs of *Daphnia*; the gnathobase of second pair of limbs bears an elongate seta that assists in the removal of food particles from the filtering setae of 3rd and 4th pair of limbs.

In malacostracans the food is caught by chelipeds (the thoracic appendages) and is passed to the third maxillipedes which in turn push the food between the mouth parts. The mandibles and maxillae help in tearing the food into pieces before they are directed into the mouth. The foregut consists of an oesophagus, a cardiac stomach and a pyloric stomach all of which have chitinuous lining. Among the various decapod crustaceans the stomach is variously thickened to from ossicles or teeth which together form the gastric mill. The gastric mill together with the movement of stomach walls triturates the food. The pyloric stomach is divided into two portions, the dorsal one that leads directly into intestine and the ventral one, a bilobed gland filter which leads into hepatopancreas by two large ducts. The hepatopancreas is a large bilobed structure. Besides secreting the digestive enzymes, the hepatopancreas can also carry out intracellular digestion of particulate food, absorption of digested food materials, storage of nutrients, and vesicular packaging of indigestible wastes and their removal by exocytosis.

Decapods combine predatory feeding with scavenging. Large invertebrates like echinoderms and bivalves are predated upon by crabs and king crabs. Many fresh water and marine shrimps on the other hand are scavenging - detritus feeders. Some of the crabs feed by scraping the algae from rocks and some others feed on detritus from the surface of the sand. Fiddler crabs resort to filter feeding. This is also true of many burrowing shrimps, pea crabs, porcelain crabs and mole crabs. Wood boring marine isopod malacostracans feed on wood and their hepatopancreas secrete cellulase to digest the cellulose of wood.

Branchiopod crustaceans are suspension feeders and the food particles are collected by the setae of the trunk appendages. The collected food particles are transmitted to a midventral food groove where they become entangled with mucus and moved into mouth. In branchiopods, the oesophagus forms the foregut and it is the midgut that is enlarged to form the stomach. The intestine is coiled one to several times.

Ostracod crustaceans show a variety of feeding habits. They are either carnivores or herbivores; some of them are scavengers and still others are filter feeders. Plant food mostly consists of algae and the animal food includes other crustaceans, small snails and annelids.

Copepod crustaceans also have a range of feeding habits. Planktonic copepods are suspension feeders feeding on phytoplankton. Some of the planktonic forms are omnivores and predaceous as well. Bottom dwelling copepods feed on microorganisms and detritus attached to sand grains, algae or sea grasses.

Cirriped crustaceans are suspension feeders or predators. In suspension feeders, the beating of cirri create water currents and the food particles are trapped in the setae. The first pair of cirri scrape the food particles attached to the setae on the other cirri and transfer them to the mouth parts. Both mandibles and maxillae help to macerate the food. Stalked barnacles such as *Lepas* capture copepods, amphipods and other relatively large organisms and hence predaceous. Rhizocephalan cirripedes are parasitic and usually parasitise crabs.

## Insects

Among the terrestrial arthropods insects have developed a variety of adaptations in their mouth parts to suit their varied feeding habits. A detailed account of the mouth parts of insects is provided in unit 5 of this course. Briefly the mouth parts are the labrum, mandibles, the first and the second maxillae and these are variously modified to suit the type of feeding that a particular group of insects has specialised. Mouth parts of insects fall under two categories - the mandibulate type and suctorial type. Orthopterans, dictyopterans, coleopterans are some of the groups that have mandibulate type of mouth parts. Butterflies and mosquitoes are examples of insects with suctorial mouth parts. In mandibulate type (Fig 9.24), the mandibles are well developed and the maxillae remain

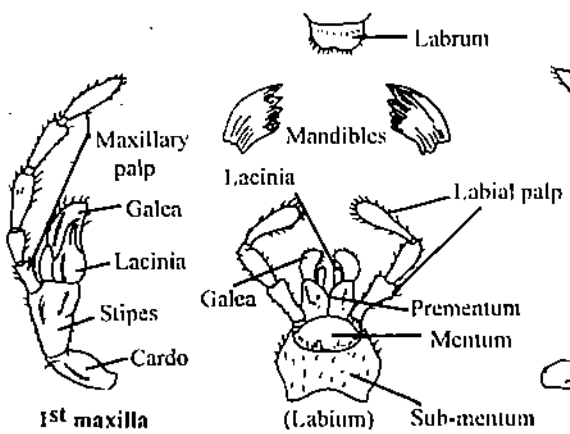



Fig:9.24 : Mandibulate type of mouth parts.

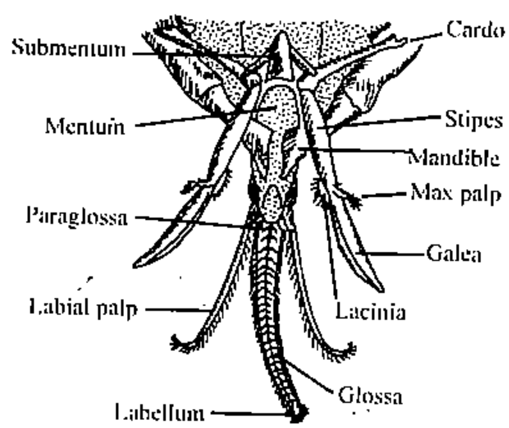
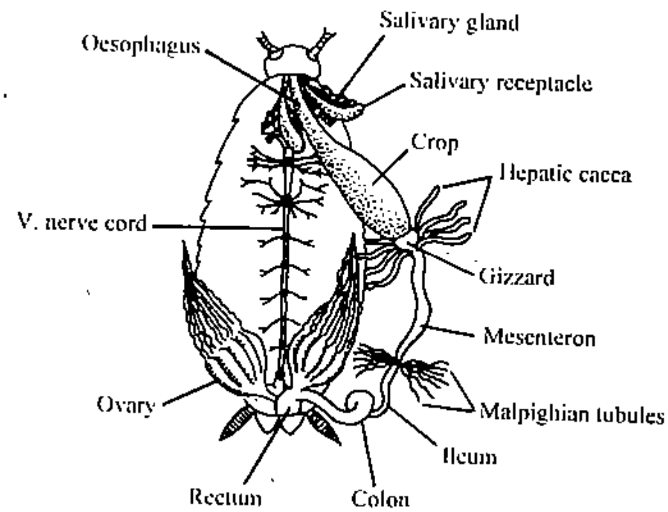



Fig.9.25: Suctorial type of mouth parts.

in their typical unmodified form. The mouth parts are adapted for cutting, chewing and crushing the food. In suctorial type (Fig. 9.25) the mandibles are more or less reduced and the maxillae are modified into stylets used as piercing organs. Labium also known as second maxillae may also be modified in different ways for piercing and sucking. The two broad types can be further subdivided into five categories: (a) biting type with toothed mandibles as is seen in cockroaches; (b) sucking type consisting of a proboscis which are modified maxillae as found in butterflies suited for obtaining nectar from flowers; (c) piercing and sucking type suited for piercing the tissues of animals and plants, such as sucking blood form animals and fluids from plants, as is found in mosquitoes and bugs; (d) biting and sucking type as is found in honey bees and (e) sponging and sucking type as is found in houseflies.

In general, alimentary canal of insects is divided into three regions - the stomdaeum or foregut, the mesenteron or midgut and proctodaeum or hindgut (Fig 9.26). The foregut arises as an anterior ectodermal invagination and the proctodaeum as a posterior invagination. The two regions are lined with chitin. The midgut is a endoderm derivative. The foregut consists of a short oesophagus, a sac like crop and a proventriculus or gizzard that may harbour a masticatory apparatus, specially in solid food feeders. Gizzard is well developed in cockroaches and in grasshoppers and is known as honey-stomach in honey bees. Fluid feeders may be provided with a reservoir that is usually attached with oesophagus as seen in Diptera, Lepidoptera and Hymenoptera. The midgut is often tubular and is the major site of digestion and absorption. The epithelium lining the midgut is formed of three types of cells. One type is secretory that secretes digestive enzymes ; the second type is generative that replaces the secretory cells that are destroyed during secretion; and a third type of cells known as goblet cells of uncertain function. In many insects the midgut lined by a membrane formed by loose chitin fibres known as peritrophic membrane. This membrane protects the midgut epithelium from abrasion and injury by contact with food particles. The Malpighian tubules located at the junction of the mid and hindgut, mark the beginning of hindgut. The hindgut shows three regions, a narrow ileum, a coiled colon and a broad rectum. Rectal glands are found connected with rectum in many insects. Both rectum and rectal glands play a role in resorption of water from faeces before it is ejected through anus.




9.26: Digestive system of an insect.

Many groups of insects have salivary glands and the glands assume varied form and structure. In Orthoptera the salivary glands are large structures and consist of four lobes and reservoir. In lepidopterans the salivary glands are tubular filaments. In hemipterous insects the glands are formed of four lobes and a reservoir. In hematophagous (blood sucking) insects such as mosquitoes, the saliva contains an anti-coagulant that facilitates free flow of blood into the crop. In honey bees, the salivary secretions serve several pruposes - inverting sugars, forming preservatives like formic acid and aiding in pollen digestion.

## Myriapods and Arachnids

Very briefly, you will study the digestive system of other terrestrial arthropods. Centipedes and millepedes, belonging to class Myriapoda have a typical arthropodan digestive system. In centipedes the alimentary canal consists of a short foregut, a very long midgut extending almost the entire length of the body and a short hindgut (Fig. 9.27). A pair of salivary glands open into the foregut. Most centipedes are predators and feed on a variety of small arthropods. Some of the chilopods are known to feed on small frogs, toads, snakes, birds and mice. Burrowing centipedes feed on earthworms, snails and nematodes. Mandibles, first maxillae, second maxillae and labium are the mouth parts (Fig 9.28).

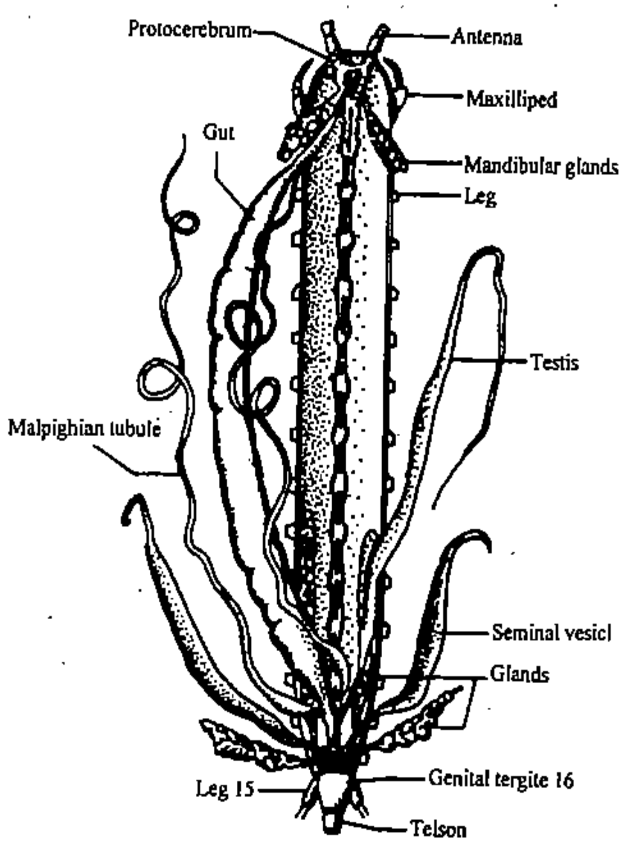



Fig.9.27: Digestive system of a centipede.

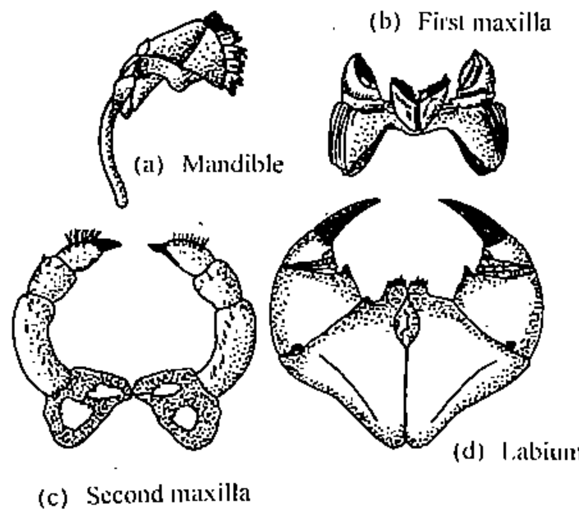



Fig. 9.28: Mouth pats of a centipede.

In millipedes the alimentary canal is almost very similar to those of centipedes. But unlike centipedes, the millipedes are herbivorous and feed on decaying vegetation. The mouth parts consist of besides a short seven segmented antennae, a mandible and a structure called gnathochilarium (Fig. 9.29). The mandibles are composed of a proximal cardo, a middle stipes and a distal mala mandibularis. The distal piece bears a large movable tooth and a masticatory plate provided with toothed ridges. The gnathochilarium resembles the labium of insects and is actually formed by the fusion of maxillae of two sides.

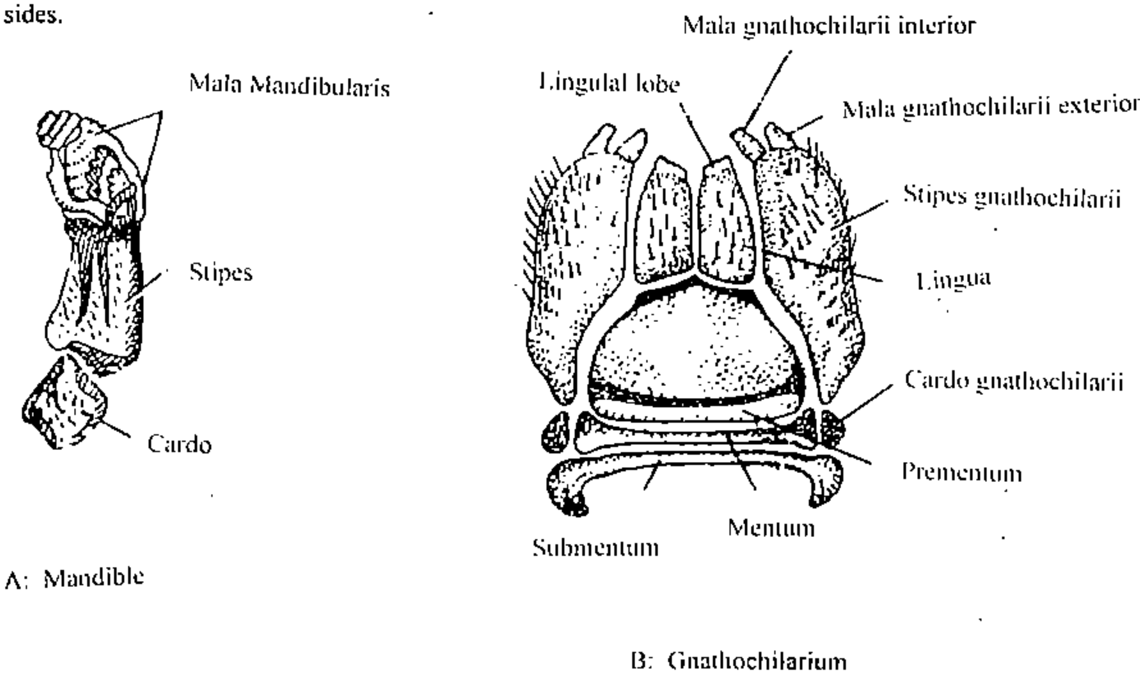



Fig.9.29: Gnathochilarium of a millepede.

Arachnids are generally carnivorous and predaceous. They feed on small arthropods. The prey is captured and killed by the cephalic appendages the chelicera and pedipalpi. Part of the digestion takes place outside the body of the animal. While the prey is held by chelicerae, digestive enzymes from the midgut are poured on the prey. Partially digested semisolid food is passed onto the oesophagus of foregut through mouth and pharynx. The food then reaches mesenteron which has a central tube and a number of lateral diverticula. All the diverticula are filled with partially digested food. Further digestion occurs in the midgut diverticula. The digested food is absorbed by the absorptive cells of the diverticula. The mesenteron extends throughout the length of the abdomen where in the last part of it is sclerotised and forms the hind gut. The hindgut opens out through anus.

## SAQ 4

Choose the correct answer from the alternatives provided.

1) Lamellibranchs are ciliary- mucus/rasping feeders.
2) In eulamellibranchs the gill filaments lack folds/are folded.
3) As the water passes through the gill filaments food is gathered by latero-frontal/frontal cilia.
4) The crystalline style is formed of mucoprotein/glycoprotein.
5) Fine/coarse cilia on the gill tracts deflect the large food particles.
6) Crystalline style releases carbohydrate/protein digesting enzymes.
7) In most gastropods, digestion is extra/intra cellular.
8) Herbivorous microphagous gastropods do have/do not have a crystalline style.
9) Actively swimming echinoderms are predaceous macrophagous/ciliary-mucous feeders.
10) Crustaceans are ciliary-mucous/filter feeders.

## 9.3 EXCRETION IN NON-CHORDATES

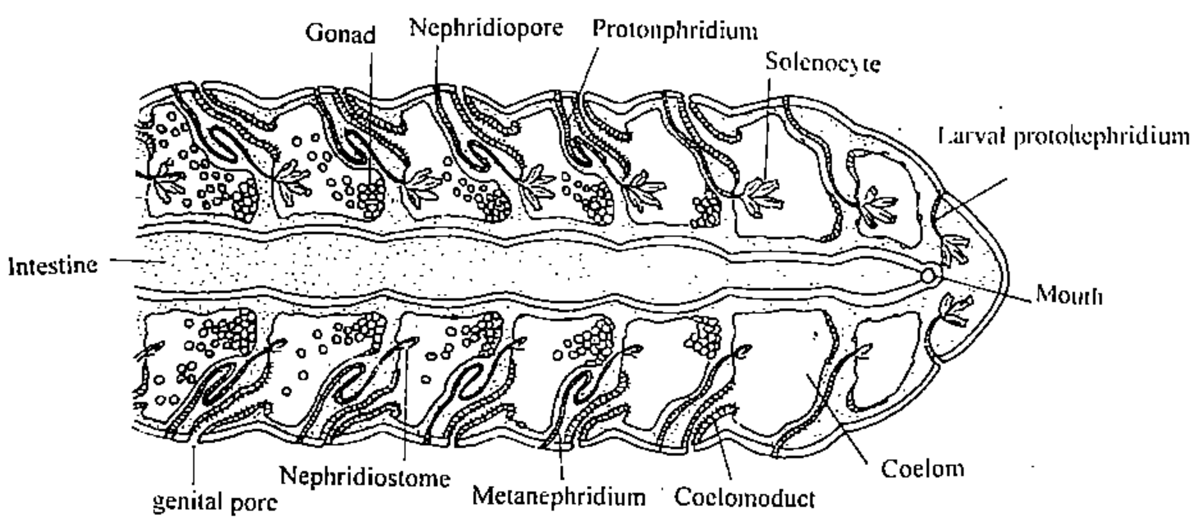



Fig.9.30: Longitudinal section of a primitive annelid showing protonephridia on the left and metanephridia on the right.

Excretion as defined under Introduction of this unit refers to removal of the waste products of metabolism - carbon dioxide and water released by the oxidation of energy rich compounds and the nitrogenous wastes released by the metabolism of proteins and nucleic acids. However, we will here limit ourselves to elimination of nitrogenous waste. In small ones, especially aquatic ones , simple diffusion from body surface plays an important role in elimination of nitrogenous wastes. Even in larger aquatic animals some diffusion takes place from body surface, but they have evolved specialised organs for excretion, which play the major role in elimination of nitrogenous waste material. However, it has to be remembered, that many of these organs serve primarily osmoregulatory function rather than excretory. Well defined excretory organs are seen from the pseudocoelomate animals onwards. Many groups of metazoans have nephridia as excretory organs. A nephridium develops from the ectoderm centripetally. The lumen of the nephridium is formed by the hollowing out of nephridial cells. Thus nephridia are intracellular. In primitive animals this lumen is closed internally but subsequently acquires an opening into the coelom. The opening is called nephridial funnel or nephrostome. Its opening to the outside is by nephridiopore (Fig.9.30).

## 9.3.1 PROTONEPHRIDIA AND METANEPHRIDIA

Nephridia occur in two major forms - the protonephridium and metanephridium. Protonephridia are found in flat worms. The protonephridial canals end blindly in structures called flame cells or solenocytes internally. Flame cells have central cavities that are continuous with the cavities of tubules and contain a bunch of cilia - the flame (Fig.9.31). Actually, the flame cell interdigitates with the first cell of the tubule, by means of finger shaped processes. In solenocytes, the cell lumen is prolonged into a delicate tube and the flame is reduced to a single flagellum. Flat worms generally have a pair of protonephridia. The protonephridial canals are much branched bearing flame cells at the end of branches. The flame cells are found scattered through out the parenchyma. The flame cells do the filtration, the filtered fluid is propelled by flagella. The nephridial epithelium carries out the functions of reabsorption and secretion. These physiological mechanisms are comparable with those carried out by a vertebrate kidney.

Very often there are another entirely different set of tubules, the coelomic ducts, connecting the coelom to the outside. These develop centrifugally, and are mesodermal derivatives. They are found as outgrowths of the wall of coelomic cavity. The tube is lined by a layer of cells and is hence not intracellular, but is intercellular. It opens into the coelom by a ciliated funnel. This funnel is called coelomostome. The primary function of the coelomoduct is to carry the germ cells to the outside. However, secondarily their structure and function may get obliterated.

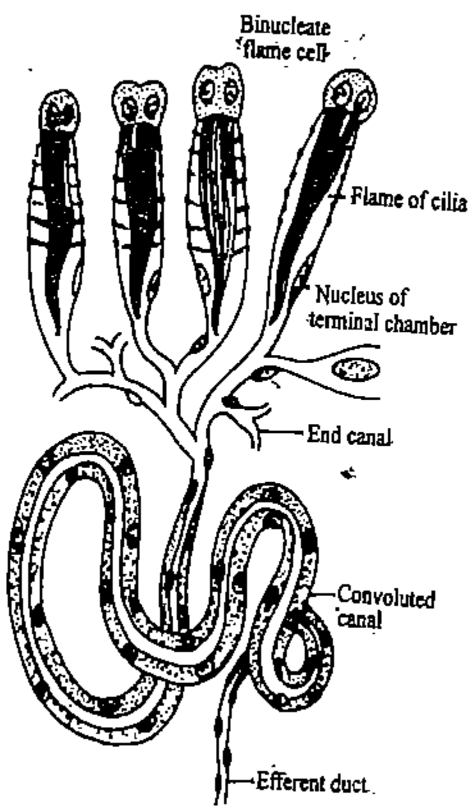



Fig.9.31: A single protonephridium of a flat worm.

In annelids, nephridia frequently bear ciliated funnels at the inner end and are then termed as metanephridia. Metanephridia are open at both ends. The nephrostome located in the coelom waft the waste materials by their cilia and pass them into nephridial tubes where they find their way to outside through the nephridiopores. However in trochophore larva of certain polyachetes possess a pair of simple typical protonephridia each with a flame cell bearing a single flagellum. But adults possess segmental metanephridia with open ciliated channels. In certain adult polychaetes such as *Nephtys* and *Phyllodoce* there are only protonephridia with solenocytes. Except in the polychaete family Capitellidae where there are separate nephridia and coelomoducts, in other families they become associated and form a compound organ called the nephromixium. The nephridium in a nephromixium may be a protonephridium or a metanephridium. In protronephromyxium (Fig.9.32a) the developing coelomoduct grows backwards along side the protonephridial canal and an open communication arises between the two at sexual maturity. In metanephromixium (Fig.9.32b), the nephridial component is a metanephridium (9.32c). In *Arenicola* the recombined structure forms a mixonephridium serving both excretory function as well as transportation of germ cells.

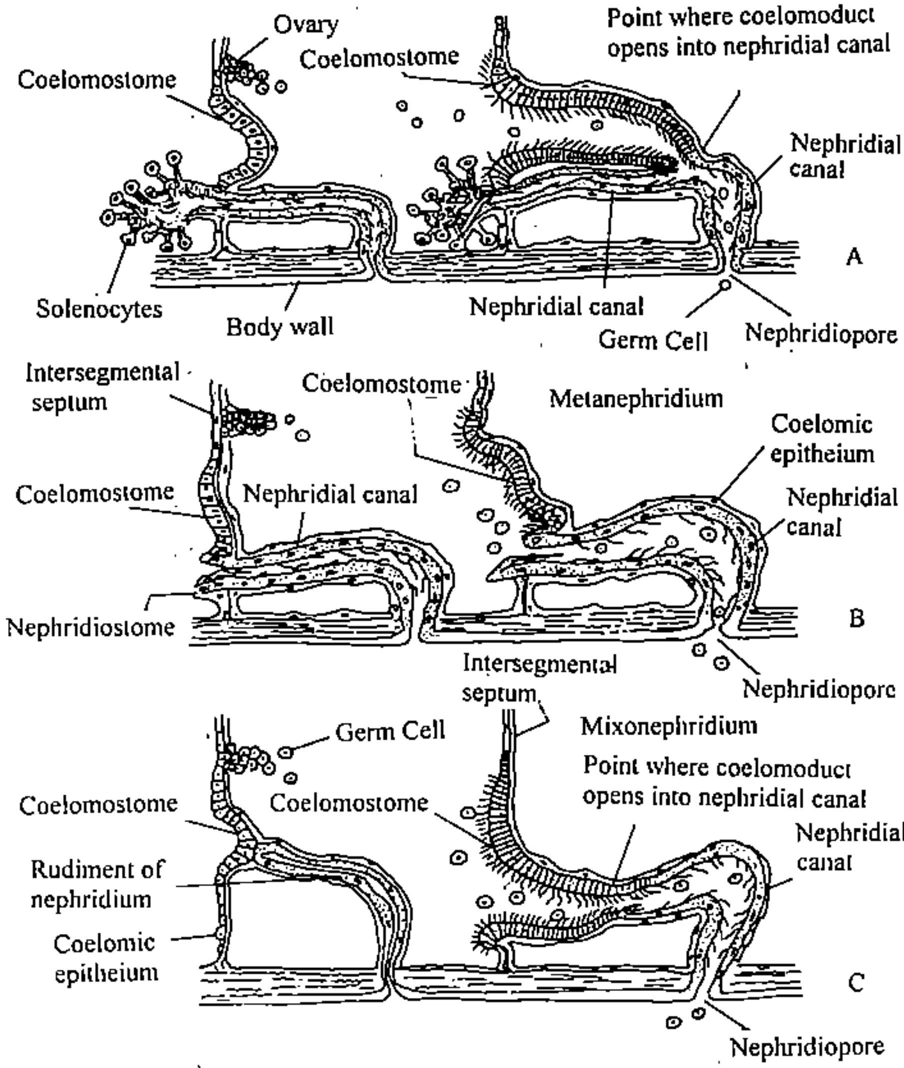
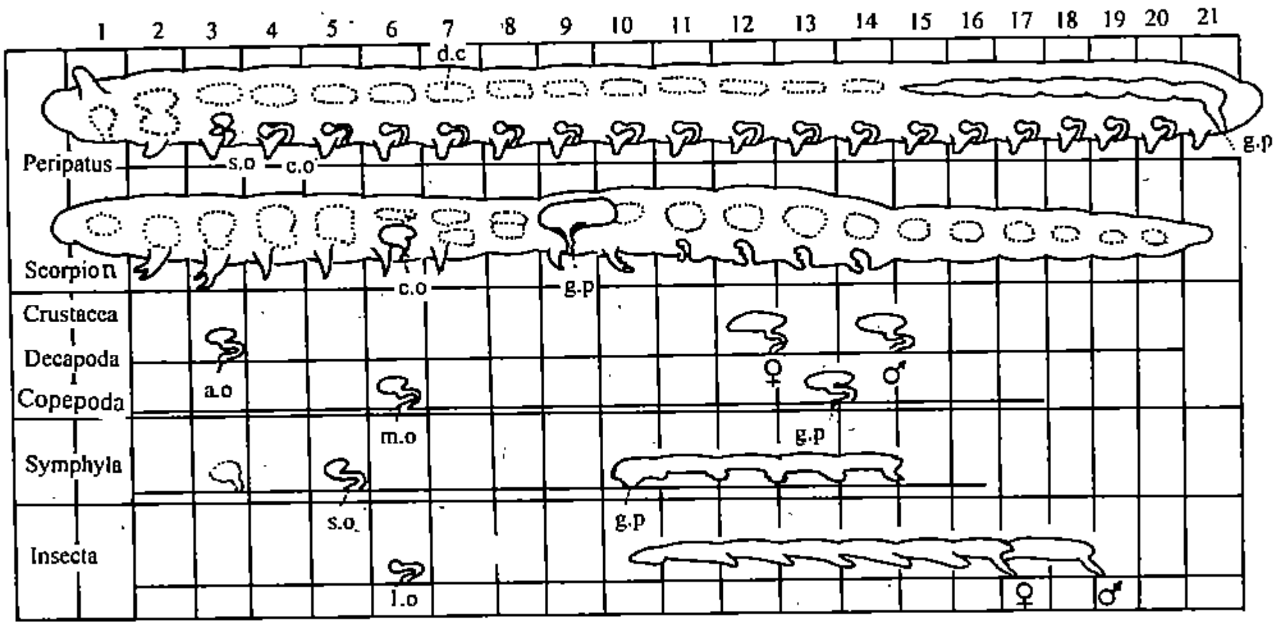



Fig.9.32: Nephridia in Polychaetes. (A) Protonephromixium (B) metanephromixium (C) Mixonephridium.

In oligochaetes the nephridia are all metanephridial type. The coelomoducts are also present, but are restricted to genital segments, one duct being associated with each gonad. A similar arrangement is seen in leeches as well.

## 9.3.2 COXAL GLANDS

In Onychophora (*Peripatus*) there is a pair of coxal glands, in almost all the segments (Fig.9.33a). Developmentally; in each segment a hollow follicle or somite arises and in the trunk region, they become divided into dorsal and ventrolateral portions. The ventrolateral portion grows into the appendages and its cavity forms the end sac of the coxal gland. The end sac opens by a ciliated canal, the coelomostome, into a coiled excretory canal. The terminal portion of the canal is enlarged to form a vesicle or bladder. Thus the coxal glands are derived from coelomoducts. In arthropods there is a similarity in the formation of coxal glands from coelomoducts and the formation of gonads and their ducts.




a.o; of coxal organ c.o; of excretory organ c.o; of lingual gland l.o; of maxillary organ
m.o; of salivary organ s.o; Dorsal coelom d.c; genital pore g.p; (both sexes indicated in Decapoda and Insecta)

**Fig 9.33: The excretory and genital coelomoducts in different arthropods. (a)*Peripatus* (b) scorpion (c) Crustacea (d) Symphyla (e) Insecta.**

Arachnids and crustaceans also posses similar coxal glands except that the numbers are greatly reduced (Fig.9.33b &c).

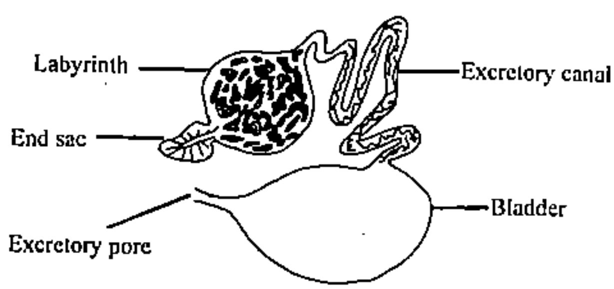



**Fig.9.34: Antennal gland of a crustacean.**

In crustaceans they are found in third and sixth segments and they are appropriately named depending on the site of their opening to outside. The one located at the base of the third segment opens at the base of the antenna, hence called **antennal gland** (Fig 9.34). The one located in the sixth segment opens at the base of the second maxilla, and is called **maxillary gland**. Antennal gland is present in the larval forms of Branchiopoda, Ostracoda, Copepoda, Branchiura, Cirripedia and lower Malacostraca but the adults of these groups have maxillary glands. The adult amphipod and decapod crustaceans have antennal glands. Mysidaceae, a primitive group of crustaceans have both antennal and maxillary glands functional.

Most arachnids have a pair of coxal glands opening in the sixth segment, opening at the base of third pair of walking legs. (Fig.9.35b). In *Limulus*, there are four pairs of coxal glands.

### 9.3.3 MALPIGHIAN TUBULES

Other arthropods such as insects and myriapods and arachnids have Malpighian tubules, the outgrowths of alimentary canal as excretory organs. Malpighian tubules are totally new structures, having no resemblance either to nephridia or coelomoducts. Generally, the Malpighian tubules are composed of single layered epithelium and are bathed in the blood of haemocoel. By the process of active secretion water passes into the lumen of Malpighian tubule together with nitrogenous wastes and dissolved salts. The secretion essentially occurs in the distal parts of the tubules. The proximal part of the tubule as well as the rectum are the sites of absorption. Most of the terrestrial arthropods excrete uric acid. The reabsorption of water results in the precipitation of urate crystals as nitrogenous waste, hence the animals are known as **uricotelic**. For an account of excretory products of invertebrates refer to Unit 4 of Block 1 of LSE-05 'Animal Physiology' course.

*Peripatus* which is also terrestrial lacks Malpighian tubules. Nevertheless it is uricotelic. The excretion of uric acid is achieved from the intestinal epithelium into the intestinal lumen. It is removed from the intestine within a peritrophic membrane which is sloughed off every 24 hours. There are also segmentally arranged coelomic excretory organs. The coelomoduct of *Peripatus* can be regarded as vestigial organs of its aquatic ancestry, with a much reduced activity.

### 9.3.4 COELOMODUCTS OF MOLLUSCS

In Mollusca, as in crustacea nephridia are absent. But certain of the larval pulmonates do possess protonephridia suggesting that they have been secondarily lost in molluscs. The excretory system is more or less similar in all the groups of molluscs. In molluscs it is assumed that the two coelomic cavities meet dorsally to enclose the heart and their walls proliferate into germ cells. Their cavities by further differentiation give rise to gonad anteriorly, pericardial canal centrally and gonoduct posteriorly. The last segment, in addition had an excretory function (Fig.9.35a). In Aplacophora the coelomoducts of adults consist of a pair of tubular structures, leading from the coelomic cavity to the outside and primitively constitute the genital ducts(Fig.9. 35b). But in other molluscs modifications have arisen in the following lines:

i) There is the development of certain degree of asymmetry.
ii) There is a separation of genital and excretory organs.

In Polyplacophora the coelomoducts split in the region of coelomostome and the gonadal cavities become closed off from pericardial coelom. The excretory coelom remains connected with pericardial coelom (Fig.9.35c). In gastropods there is a marked asymmetry in the coelomic complex. The left gonad disappears and the right gonad opens into coelomoduct that has lost its renal function and its connection with the pericardial coelom. The excretory organ is present only on one side(left kidney) and that is large and thick walled. In prosobranchs, the excretory opening is in the posterior part of mantle cavity and in pulmonates it opens outside the mantle cavity.

In lamellibranchs, though the complications of asymmetry in gastropods do not exist, the genital and renal ducts get separated. In the primitive group protobranchs, the entire coelomoduct has an excretory function. The gametes are discharged into renal organs

(Fig.9.35d). In filibranchs the coelomoduct is bent into a "U" shaped structure, the lower limb being glandular and the more distal upper limb forms a bladder (Fig.9.36e). The connection has shifted to the posterior end of the kidney. In eulamellibranchs, the two organs have developed separate openings (Fig.9.35f).

In cephalopods also the separation of genital and excretroy components of the coelomic complex has been achieved. The genital duct comes to run separately from the renopericardial canal and kidney (Fig.9.35g).

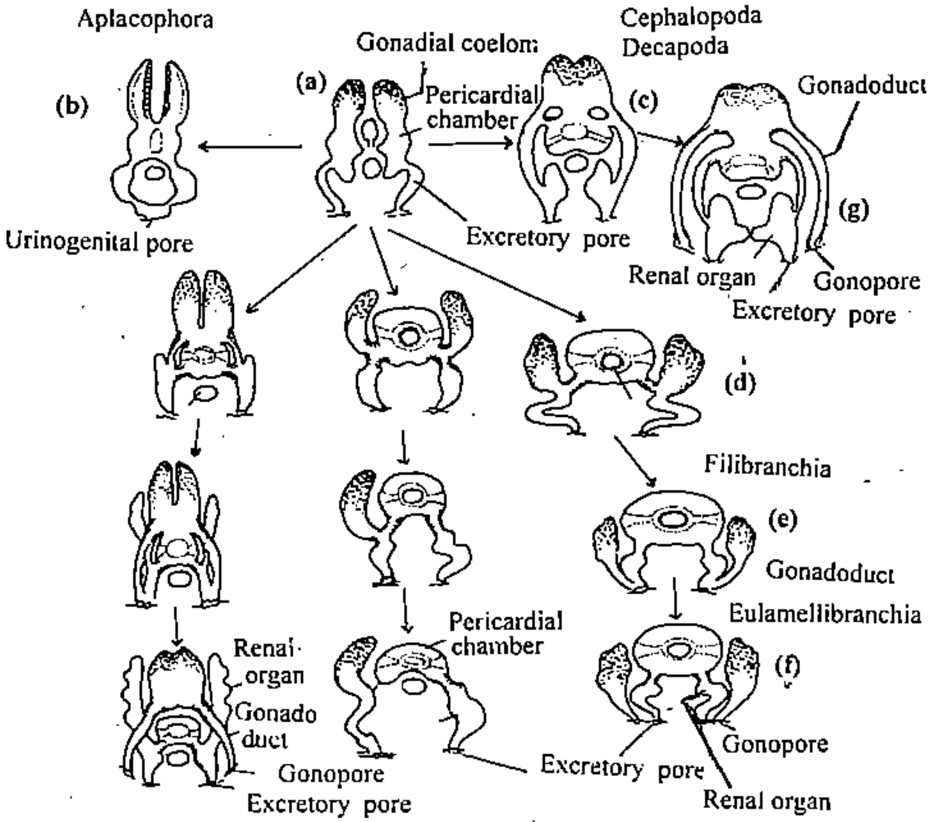



Fig. 9.35 : Coelom and coelomoducts in Mollusca: (a) primitive mollusc, (b) Aplacophora, (c) Polyplacophora, (d) protobranch, (e) filibranch, (f) eulamellibranch, (g) Cephalopod.

## SAQ 5

Match the following.

| | |
|---|---|
| a) Flatworms | 1) Malpighian tubules |
| b) Annelids | 2) metanephridia |
| c) Crustaceans | 3) coelomoducts(kidneys) |
| d) Insects | 4) coxal glands |
| e) Molluscs | 5) protonephridia |

## 9.4 OSMOREGULATION IN NON-CHORDATE METAZOANS

In unit 2 you have studied that in protozoans, particularly fresh water protozoans, contractile vacuoles play a significant role in the regulation of water content of the body. Fresh water organisms often face the problem of their body being flooded with water and have to constantly regulate the water content of their body. Marine animals, although, isotonic with the medium in which they live have to maintain an ionic composition of their body fluids that may be unique to them. Terrestrial organisms confront the problem of water conservation and have developed adaptations that prevent the water loss from the body. Essentially osmotic relationships of the organism have to be considered in relation to the ionic composition of body fluids. Ionic regulation could be defined as maintenance in body fluid, of concentrations of ions differing from those that would result from a passive equilibrium from the medium. In this section we shall briefly discuss the mechanisms of osmotic and ionic regulation of metazoan organisms adapted to living in different habitats.

### 9.4.1 OSMOREGULATION IN FRESHWATER METAZOANS

Freshwater and brackish water animals live in hypoosmotic(of lower osmotic pressure) environment and maintain a hyperosmotic (of higher osmotic pressure) condition in their body fluids. They may be able to tolerate only a narrow range of salinity of the medium in which they live. These are called stenohaline animals. If they tolerate a wide range of salinity they are known as euryhaline animals. Essentially their living environments are osmotically less concentrated than their body fluids. They face the problem of the water continuously entering into the body and leaching of salts from the body. You have already studied the role of contractile vacuole as water pumps in osmoregulation of freshwater protozoans in unit 2 of block 1 of this course. Such vacuoles are present in fresh water sponges as well. Protonephridia of freshwater flatworms, metanephridia of annelids and coxal glands of crustaceans are other such water pumps that are capable of removing large amounts of fluids from the body. In fact such organs have the primary function of water balance rather than excretion of nitrogenous wastes.

In some animals there are no special organs for the removal of water. *Hydra* is one such example. The regulation of both water and salt in *Hydra* is carried out by active transport of sodium. In the absence of calcium or sodium in the environment the osmoregulatory process breaks down in *Hydra*. The pumping in of sodium into the gut is followed by the passive flow of water along the osmotic gradient. The mesogloea functions like an extracellular fluid space. It is believed that two pumps may be operational in *Hydra*, one transporting Na into mesogloea and the second that transports it into gut. Water taken osmotically is expelled through the mouth. Active transport of sodium takes care of both osmotic and volume regulation. Thus there is an influx of water into the body through the external surface, and the excess water is removed through the gastrovascular cavity, through the mouth. Fluid in the gastrovascular cavity is hypoosmotic to tissue fluid. The gastrovascular cavity is thus supposed to act like big contractile vacuole

Ability to produce dilute urine has been demonstrated in animals belonging to more advanced phyla ( arthropods, earthworms and fresh water molluscs). Using the techniques of micropuncture and clearance of tubular fluid in the metanephric tubules, both filtration and active transport have been demonstrated. For instance, in the antennal gland of fresh water crayfish, the end sac functions as the site of filtration. Chloride is reabsorbed as the filtered urine passes through the long tubule resulting in conservation of salts and reabsorption of water (Fig. 9.36).

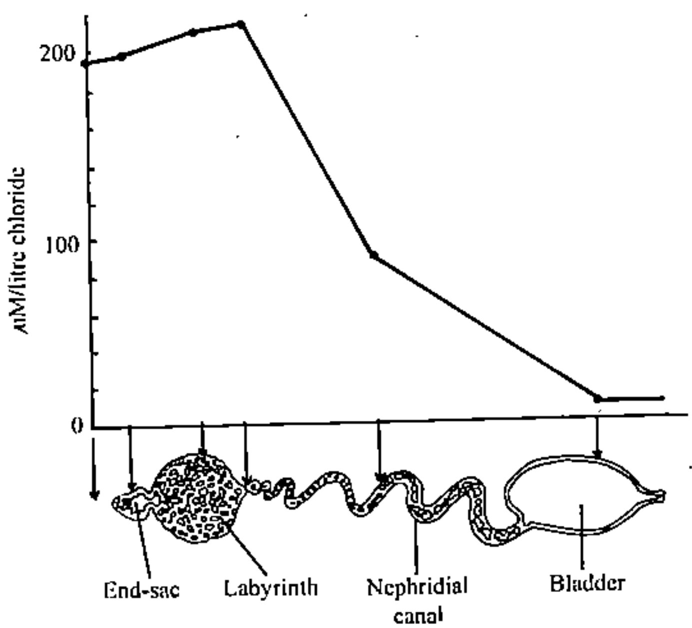



**Fig.9.36: Role of the different segments of coxal gland in the formation of hypoosmotic urine in the crayfish *Astacus*.**

Filtration in arthropods and molluscs is essentially carried out by the hydrostatic pressure of the blood. In arthropods, the wall of the coelomic sac is highly vascularised. In molluscs the heart passes through the filtration cavity or pericardial sac. There is filtration through the wall of the heart, into the pericardial cavity. From the pericardial cavity, filtrate passes through the nephrostome into the kidney. Generally the coelomic sac is located near the heart or near the region of high blood pressure.

The observed dilution of urine in the distal tubule and ureter could be due to the addition of water or to the reabsorption of salts. But the use of metabolic poisons that arrests the active uptake has clearly demonstrated that absorption of solutes is responsible for the excretion of hypoosmotic urine. It could be said that the capacity of excretory organs to form hypoosmotic urine and to trap ions from ambient fluid played a significant role in the colonisation of the fresh water environment.

## 9.4.2 OSMOREGULATION IN MARINE NON-CHORDATE METAZOANS

Studies on the osmotic pressure of body fluids of marine organisms have shown that their internal osmotic pressure is more or less similar to the sea water in which they live. Marine invertebrates are isotonic with the seawater in which they live, but the ionic composition of their body fluids may be markedly different from that of the normal sea water. For instance the mesogloea of the coelentrates has a high potassium and a low sulphate concentration as compared to the seawater in which they live. This is true of polychaets and echinoderms as well.

Marine and brackish water animals have isoosmotic or slightly hyperosmotic body fluid. Production of an isoosmotic or a slightly hyperosmotic urine may cause the loss of valuable electrolytes. Therefore, there is a continuous regulation of electrolytes of body fluids. Such regulation is achieved by several ways. Surface areas permeable to water and ions are generally reduced to a minimum. Water pumps in the form of contractile vacuoles and nephridial tubules are present. But the most important machinery that remains a part of every cell is the active transport. In certain organs such as gills of crustaceans, highly specialised tissues exploit the capacity of active transport of large amounts of salts.

In decapod crustaceans and cephalopods, ionic regulation may extend to every ion. For instance, in these organisms calcium and potassium are more concentrated in body fluids than in the external medium, whereas magnesium, sulphate and chloride are less concentrated. Reduction in anion concentration such as sulphate is compensated by an increase in sodium concentration. Thus in marine invertebrates including coelentrates, the internal medium has a specialised ionic composition quite distinct from that of external medium. Excretory organs play a role in ionic regulation.

## 9.4.3 WATER RELATIONS IN TERRESTRIAL ENVIRONMENT

Insects are the largest group of metazoans that have most successfully invaded the terrestrial environment. Besides, most arachnids, myriapods and isopod crustaceans do not depend on the aquatic environment for their survival. Terrestrial arthropods owe their success to life on land to the presence of an impermeable cuticle that prevents evaporation of water from the body. Their cuticle, a chitin-protein complex with a hydrophobic wax layer on the surface is the water-proofing structure.

The cuticle is an important structure that had made possible to a large extent the successful colonisation of land. Water loss through the spiracular openings is minimised by keeping the spiracles closed whenever the inspiration does not take place. The proximal region of Malpighian tubules and more importantly, the rectum play a significant role in water resorption expelling only dry faecal pellets with insoluble uric acid as nitrogenous waste. Pulmonate molluscs which have taken to terrestrial habitat have a calcareous shell that prevents desiccation of the soft inner parts of the body. Physiological adaptations such as aestivation help them to overcome adverse climatic conditions.

## SAQ 6

State whether the following statements are true or false.

1) Osmoconformers can have an ionic composition of their body fluids very different from that of the medium in which they live.
2) Euryhaline animals can tolerate only narrow ranges of salinities.
3) Marine animals excrete a hypo-osmotic urine.
4) Water resorption is more pronounced in fresh water metazoans than in marine forms.
5) Insects excrete dry pellets as urine.

## 9.5 SUMMARY

In this unit you have learnt:

- The metazoans have evolved a variety of feeding habits depending on the environment in which they live and availability of the type of food. They may be microphagous feeders or macrophagous feeders. If microphagous, they may be filter feeders or feeding on deposited food materials. Filter feeders may use ciliary-mucus feeding mechanism or make use of setae for gathering food.
- Sponges make use of the canal system for filter feeding of particulate food materials. Digestion is intracellular. Among coelenterates, the macrophagous and carnivorous feeders use the tentacles and the cnidoblasts present in them for capturing prey. Digestion is both intracellular and extracellular. Flatworms may digest food exclusively intracellularly as in *Polycelis* or exclusively extracellulary as in *Cycloporus.*
- Oligochaete annelids feed on dead organic matter. The intestine of these organisms secretes enzymes such as cellulase and chitinase . Among polychaetes free living forms are macrophagous and the sedentary forms are microphagous. Macrophagous feeders possess eversible proboscis for food capturing. Sedentary polychaetes resort to ciliary mucus -feeding. Sedentary forms possess a branchial crown of tentacles lined with pinnules which interlock and form a filtering device. Cilia are borne on the pinnules and direct the food into mouth. Tube dwelling polychaetes are efficient ciliary-mucous feeders. Annelids generally exhibit extracellular digestion.
- Among molluscs, lamellibranchs are ciliary-mucus feeders. Ciliated gills or lamella along with labial palps are food gathering devices. Coarse cilia reject the large food particles and fine cilia direct the movement of food towards the mouth. Digestion is mostly intracellular in lamellibranchs. A unique structure called crystalline style releases carbohydrate digesting enzymes. Some herbivorous particulate feeding gastropods also possess crystalline style. Both in gastropods and cephalopods digestion is extracellular.
- Arhropods lack cilia. Appendages modified for feeding aid in food gathering. Appendages are provided with setae that are used as filtering devices to collect suspended particulate food. The metachronal movement of thoracic appendages, the fringe of setae present in the endites, the inter-limb spaces, the midventral channel formed by the interlimb spaces and the maxillipedes and the maxillae of cephalic appendages are the structures involved in the filter feeding process of aquatic crustaceans. Insects, on the other hand, have developed specialised mouth parts for feeding as discussed in Unit 5 of Block 2 of this course.
- Metazoans have evolved a variety of 'excretory' structures. Many of these are however primarily osmoregulatory. Nephridia which are ectodermal derivatives are intracellular, formed by the hollowing out of the nephridial cells. Protonephridial canals that end blindly, carry solenocytes or flame cells secrete fluid into lumen and waft the materials towards nephridiopore. Metanephridia which are characteristic of annelids are closely associated with coelomoducts. Coelomoducts known as coxal glands are the excretory structures in many arthropods. In primitive arthropods, the coxal glands are present segmentally, but in higher arthropods they are present in one or two segments. Depending on their position they are variously named as antennary glands or maxillary glands. Insects have Malpighian tubules as excretory structures. The epithelial cell lined tubules secrete fluid into their lumen in the distal region and in the proximal segment there is reabsorption. Much of the water from the excretory material is resorbed both by the Malpighian tubule and

rectum and dry insoluble uric acid is excreted. Molluscs have coelomoducts as kidneys and they are closely associated with genital ducts. Marked asymmetry in the coelomic complex and gradual separation of excretory and genital structures are important features of molluscan coelomoducts.

- Regulation of water and ionic components of the body is the adaptation required for survival in aquatic environment. Fresh water organisms live in a hypo-osmotic environment and have to maintain hypertonic fluid in their body. They excrete a hypo-osmotic urine and their excretory system resorbs the vital ions required by the body. Marine organisms are more or less iso-osmotic with the medium in which they live; nevertheless the ionic composition of their body fluids is at variance with that of the medium. They resort to active uptake of ions to maintain the ionic composition of the body fluid. Terrestrial metazoans face the problem of water loss from their body and the problem has been solved by evolving a number of water conserving measures such as an impermeable integument, excretion of dry nitrogenous waste materials and keeping the respiratory apertures closed to minimise water loss through them.

## 9.6 TERMINAL QUESTIONS

1. Describe the structure of a cnidoblast and its functioning.

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2. Describe the mode of digestion in the flatworms *Polycelis* and *Cycloporus*.

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3. Describe the mechanism of ciliary -mucous feeding in sedentary polychaetes.

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4. Describe the structure of lamella in a lamellibranch and its function as a food gathering device.

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5. Describe the coelomoducts of different groups of molluscs.

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6. With suitable examples, describe how do the fresh water organisms maintain the water and ionic content of the body.

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## 9.7 ANSWERS

### Self-Assessment Questions

1) i) Macrophagy, ii) cilia, iii) suspension and filter, iv) sorting and rejecting, v) radula

2) i) T, ii) F, iii), T iv) F, v) F

3) 1 – c, 2 – a, 3 – f, 4 – b, 5 – d, 6 – e

4) 1. ciliary-mucous,
   2. are folded,
   3. Laterofrontal,
   4. Mucoprotein,
   5. Coarse,
   6. carbohydrate,
   7. Extracellular,
   8. have,
   9. Macrophagous predators,
   10. filter feeders

5) a – 5, b – 2, c – 4, d – 1, e – 3

6) 1 – F, 2 – F, 3 – F, 4 – T, 5 – T

**Terminal questions**

1. Refer to section 9.2.1
2. Refer to section 9.2.1
3. Refer to section 9.2.2
4. Refer to section 9.2.3
5. Refer to section 9.3.3

# UNIT 10 RESPIRATORY AND CIRCULATORY SYSTEMS

## Structure



## 10.1 INTRODUCTION

In the previous unit you have made a general and comparative assessment of different modes of nutrition, osmoregulation and excretion in various groups of non-chordates. In the present unit you will study what a respiratory system is and also examine the many types of organs that help in respiration, found in different groups of non-chordataes. In small animals passive diffusion will serve the purpose. On the other hand, when the animal becomes larger respiratory gases have to be transported between the surrounding medium and the area of metabolic activity, for which the circulatory system comes in handy. Thus you will see that from a simple type, a complex and highly developed system of respiration and circulation have evolved. The study is divided into two parts: the first part deals with respiration, and organs involved in the process of respiration and the respiratory pigments. The remaining part is devoted to the study of the types of circulatory systems found in the different phyla of non-chordates.

### Objectives

After studying this unit you will be able to:

- point out what respiration is,
- describe the role of respiratory organs in the process of respiration in different groups of non- chordates,
- discuss the importance of respiratory pigments in respiration,
- describe the structural organisation of the respiratory organs in various groups of non- chordates,
- distinguish between open and closed types circulatory system among non-chordates.

## 10.2 RESPIRATORY SYSTEM

Respiration is an essential physiological process in all living organisms by which they obtain energy for carrying out all the metabolic activities of the body. The term respiration has several meanings. In Latin, from which it has been derived, it means 'to breathe' or 'to exhale' and in this sense, respiration was initially applied to the exchange of gases between an organism and its environment. It meant the activities of breathing or their equivalent. As years rolled by, it became apparent that the fundamental exchanges occurred at the cellular level and consequently the term internal respiration was applied to this phase of gaseous exchange. The exchange of gases between the body surface and the environment then came to be called external respiration. This division is quite useful even today. Now a days however, respiration is frequently referred to the cellular processes involved in energy production that is the chemical processes occurring within the cell to liberate energy. We are here concerned with external respiration and transport of gases between tissues and the respiratory site.

From our point of view we may say that the characteristic feature of respiration is the intake of oxygen and the output of the carbon dioxide. The oxygen taken in is used in the oxidation of digested food in the cell to liberate energy. Carbon dioxide is produced as a consequence of oxidation of food materials. Its presence in the body is harmful, and hence it is removed from the body during this process.

In lower organisms such as protozoans, sponges, and platyhelminthes, oxygen is taken directly from the surrounding aquatic medium and carbon dioxide is given out directly into the surrounding medium. In larger animals, most of the cells are deprived of direct contact with the external environment because of their complex structure and larger size. Hence they require the help of respiratory and circulatory systems so as to facilitate exchange of gases and distribution of oxygen in all parts of the body. The process of respiration in these animals comprises the following phases.

i) External respiration is generally described as breathing. It involves organs which bring oxygen from the environment to the respiratory surface of the body. The system also serves the purpose of removing carbon dioxide from the body to the environment. The respiratory surface may often be within the body of the animal. The respiratory surface may be integument, gills, tracheae or lungs.

ii) The second phase of respiration comprises the transportation of oxygen from respiratory surface to the body tissues and carbon dioxide from the tissues to the respiratory surface. In higher animals the transportation of respiratory gases is often carried out through blood.

iii) During this phase oxygen is consumed by the cells and carbon dioxide is produced by them as a result of oxidative processes which liberate energy for physiological activities of the body. It is the sum of enzymatic reactions, both oxidative and non-oxidative processes, by which energy is made available to maintain the vital activities. This phase is internal respiration or tissue respiration.

## 10.2.1 RESPIRATORY ORGANS

These are the organs concerned with the gaseous exchange, i.e., intake of oxygen and output of carbon dioxide. They have usually greater rate of gas exchange per unit area than the general body surface. Thus respiratory organ may be a part or special region of the body or may be an organ particularly meant for this purpose such as lung.

In non-chordates various types of respiratory organs are found. These organs may differ in their structure but all are provided with a large surface of contact with the surrounding environment and are richly supplied with blood vessels and capillaries that ensure rapid gaseous exchange between the external environment and the blood. The external environment is usually water. Even when it is air, there is a thin film of water covering the respiratory surface and exchange of gases takes place through this aqueous film. The respiratory organs which work in water are gills; those which work in air, are lungs. They may project outwards (gills) or they may be invaginations (lungs). The kind of respiratory organs found in different phyla of non-chordates are as follows.

i) **General Body Surface**

In protozoans respiration takes place by diffusion. Oxygen diffuses into the cytoplasm through general body surface and carbon dioxide diffuses outwards. Sponges do not have special organs of respiration; they have a canal system which brings water to the interior of the body. Gases diffuse through the surface of the cells. Sponges prefer places where water is rich with oxygen. If kept in foul water or water with less oxygen content the sponges undergo reduction in size and ultimately die. Similar results are obtained if the dermal pores are clogged, which prevent water current. The oxygen consumption is

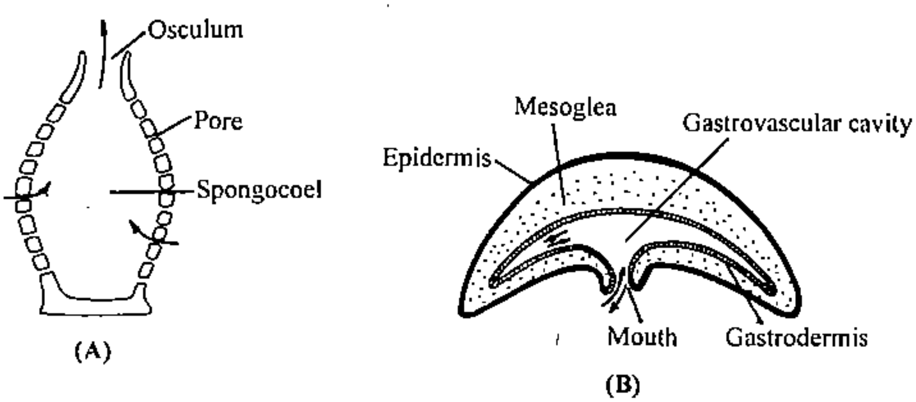



**Fig. 10.1 : Diagrammatic representations of the body form of a sponge and a Coelenterate. (A) radial section of an asconoid sponge and (B) radial section of a coelenterate medusa. Arrows in (A) and (B) indicate respiratory water currents through body cavity.**

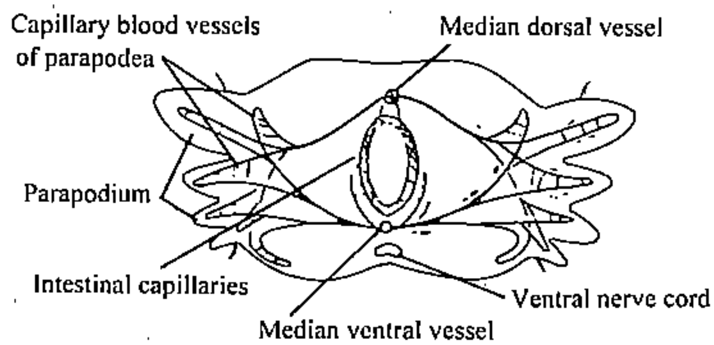



**Fig. 10.2: Diagrammatic section of Nereis to show the course of the main segmental blood vessels.**

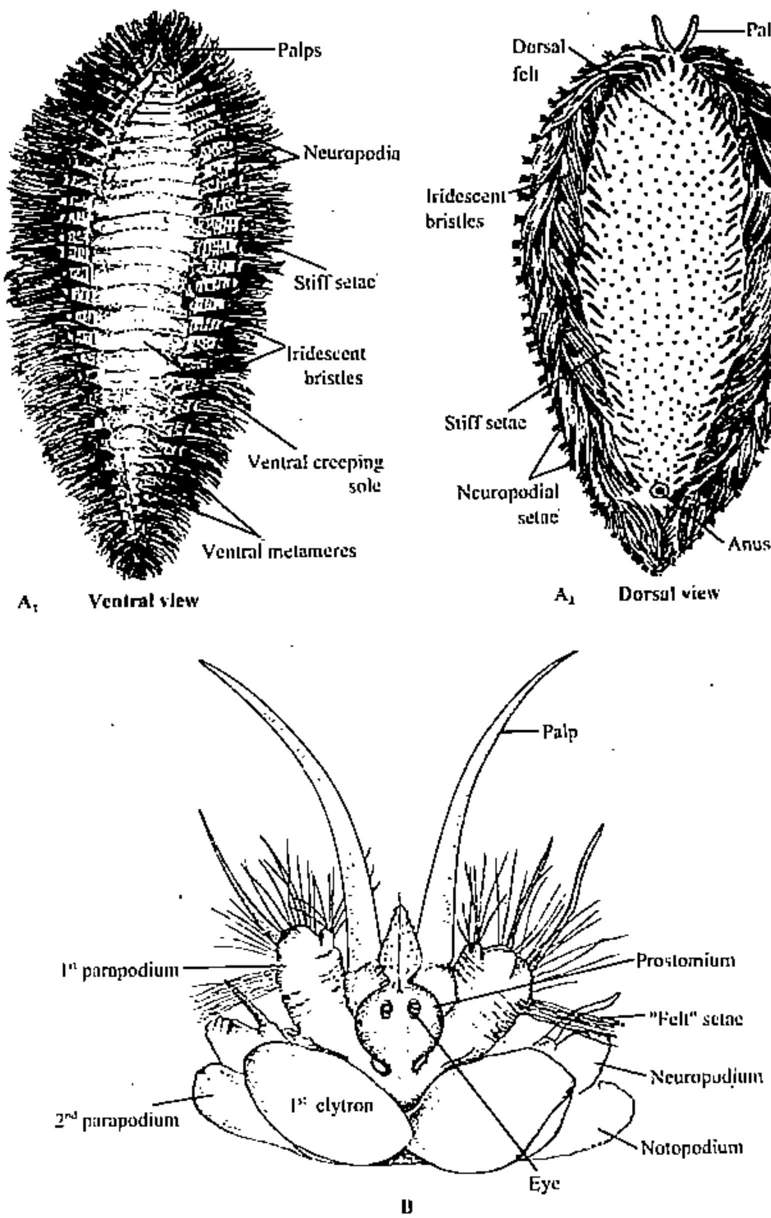



**Fig. 10.3: The sea mouse, Aphrodita aculeata. A1. Dorsal and A2. ventral view. The dorsal and lateral surfaces are covered by felt setae. B. Anterior end, including the first pair of dorsal scales. They live offshore where they burrow in soft bottom muds, leaving only their posterior ends exposed at the surface. The ventral surface is free of felt and forms a flat, muscular, creeping sole. They ventilate their burrow by elevating the ventral surface, which pumps surface water into the burrow and moves it anteriorly along the sole. The sole is then depressed, forcing the water posteriorly in a channel formed by the dorsum and its covering scales. Movement of the scales also helps create the exhaust flow.**

dependent upon the rate of water current (Fig. 10.1). Thus if the oscula are partially closed it is reduced, but this is compensated when the oscula are fully open. Also in coelenterates no definite organs of respiration are present. However, there is a water current through the gastrovascular cavity of these animals. So their epidermis and gastrodermis are necessarily in contact with water. Gaseous interchange necessary for respiration takes place by diffusion (10.1).

Free living flatworms are usually small and they respire by simple diffusion through body surface. Respiration of the helminth parasites is quite different. They usually live in an environment whose oxygen content is very low or nil as in the case of gut parasites. So they have no access to air or oxygen. They are anaerobic. Similarly most nematode parasites also resort to anaerobic respiration. Lactic acid is the end product in such anaerobes. Generally speaking, the amount of oxygen the endoparasites use depends upon its availability.

In annelids respiration takes place through the entire body surface which is enormously increased by thin flattened parapodia of many polychaetes (e.g. **Nereis**). Within the parapodia there is an extensive capillary network. The dorsal and ventral body walls are provided with numerous such networks of capillaries, which lie very close to the surface (Fig. 10.2). While passing through them, blood receives oxygen from the surrounding water and gives up carbon dioxide collected from the tissues. The oxygen carrying capacity of the blood of many annelids is increased by the presence of haemoglobin or other similar blood pigments. Usually these blood pigments are found in the plasma (fluid) instead of being contained within the cell. Gills are common among the polychaetes, but they vary greatly in both structure and location indicating that they have arisen independently within the class. Gills are never enclosed within the protective chambers. Many species which possess gills are already protected because they live in tubes and burrows. Gills are lacking in those polychaetes which are very small or which possess long, thread like bodies such as many burrowing Lumbrineridae, Arabellidae and Capitellidae. In the scale worms gas exchange is largely restricted to the dorsal body surface which is roofed over by the elytra. Cilia present on the dorsal surface create a current of water flowing posteriorly beneath the elytra. In felt covered sea mouse (**Aphrodita**) cilia are lacking (Fig. 10.3), but a dorsal water current is produced by the animal that tilts the elytra upward and then rapidly brings them down in sequence. Most commonly the gills are associated with parapodia and in many cases these gills are modified parts of the parapodium. The notopodium sometimes possesses a flattened branchial lobe, which acts as a gill as in case of nereids (Fig. 10.4). Generally, the dorsal

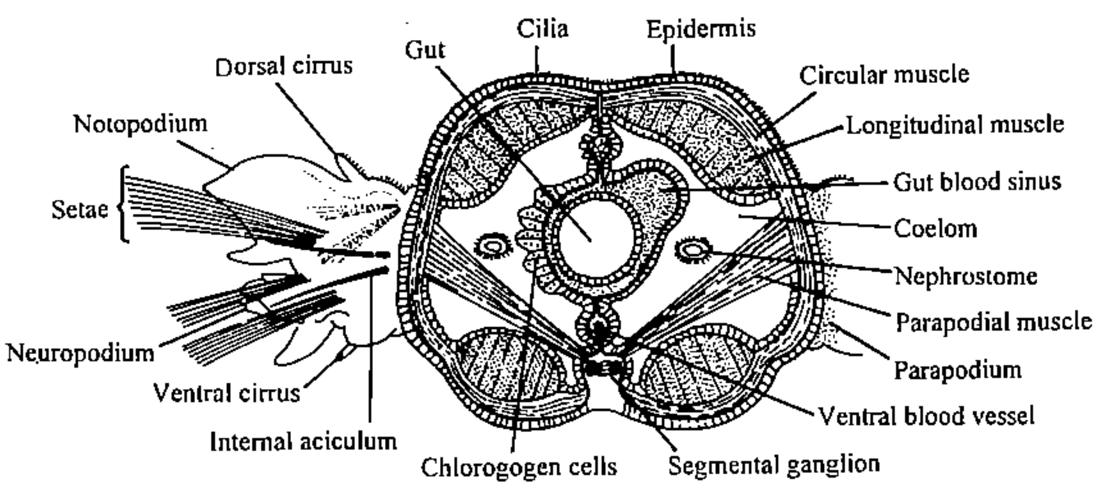



**Fig. 10.4 : Cross section of Polychaete trunk.**

cirrus of the parapodium is modified to serve as a gill (10.5) or the gills may arise from the base of the dorsal cirrus. Cirratulids have long, contractile, thread like gills (Fig. 10.6), each attached to the base of the notopodium.

The gills are not always assoiciated with parapodia. Many sedentary species have gills at the anterior ends near the opening of the tubes or burrows. For example, the gills of some terebellids such as **Amphitrite** (Fig. 10.7) are arborescent and are situated on the dorsal surface of the anterior segments. The bipinnate radioles composing the fans serve as sites of gas exchange in the fan worms sabellids (Sabella, Fig. 10.8) and serpulids. Ventilation may be provided by gill cilia or by gill contractions (Fig. 10.5). But many burrowing and

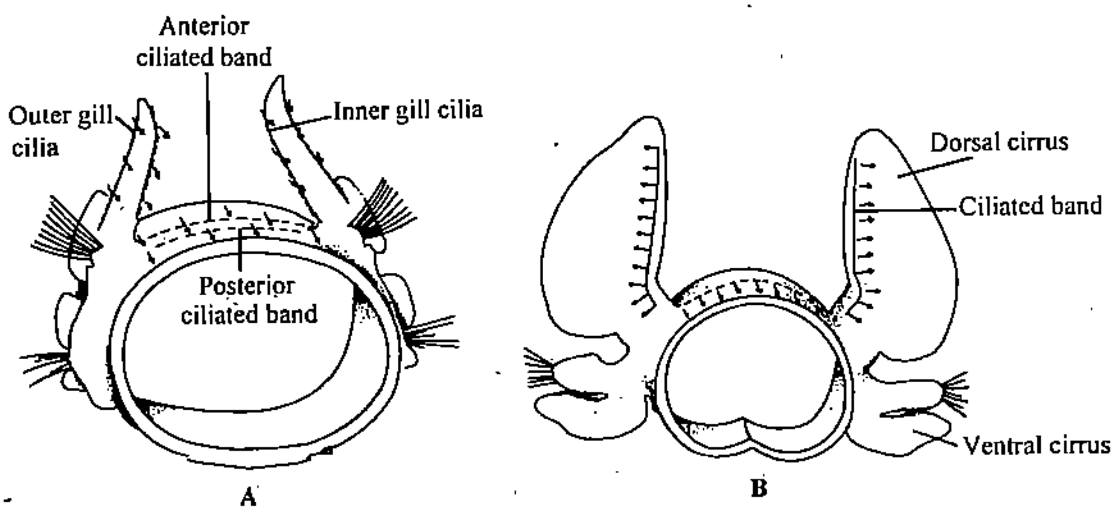



**Fig. 10.5 : Surface ciliation in two polychaetes Arrows indicate direction of water currents. Flows on trunk surface are directed posteriorly A. Scolelepis squamata B. Phyllodoce laminosa.**

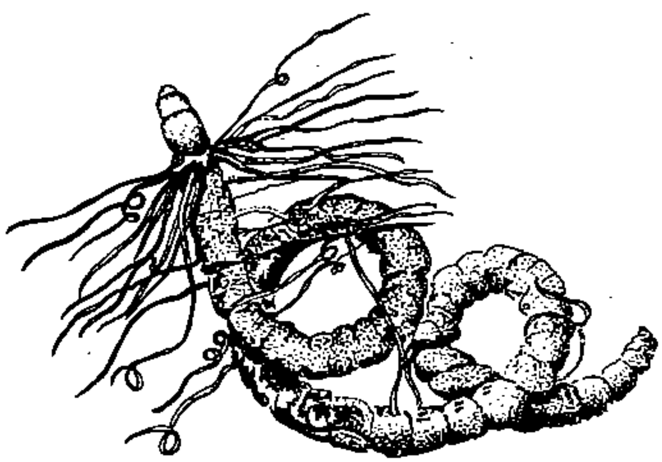


**Fig. 10.6 : *Cirratulus cirratus*, a polychaete with long, threadlike, dorsal cirri (gills).**

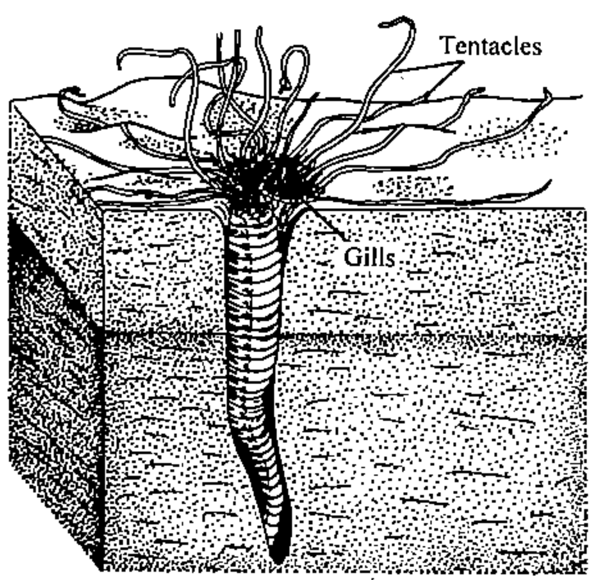



**Fig. 10.7 : *Amphitrite* at the aperture of its U-shaped burrow with tentacles outstretched over the substratum.**

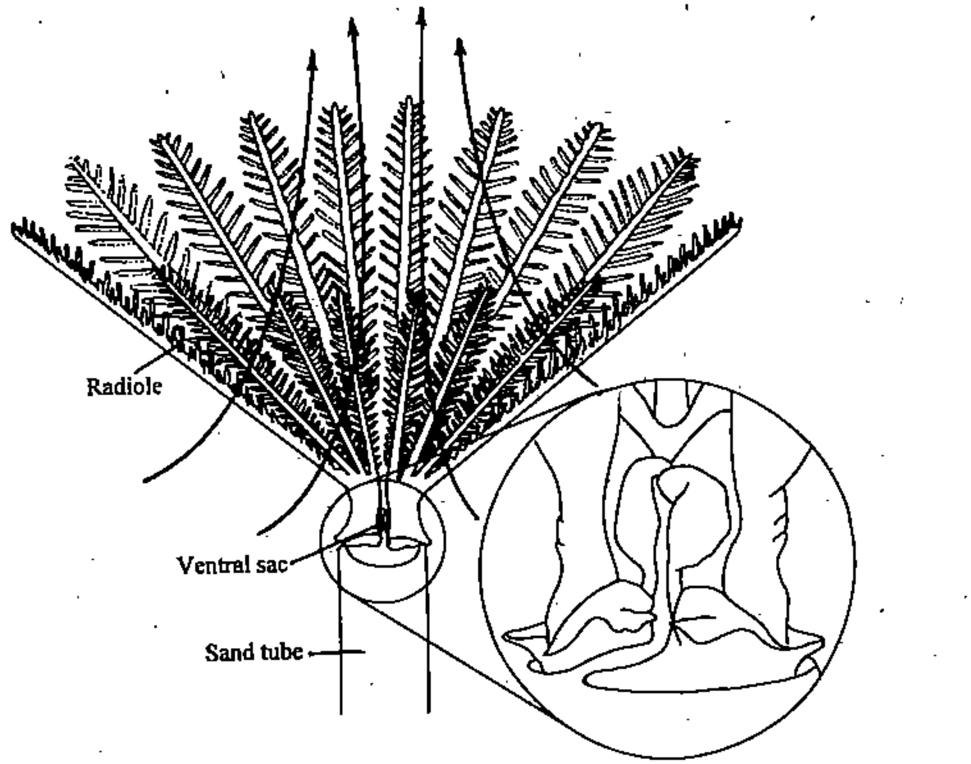



Fig. 10.8 : Anterior end of the fan worm, *Sabella*, showing the filter-feeding currents and tube building.

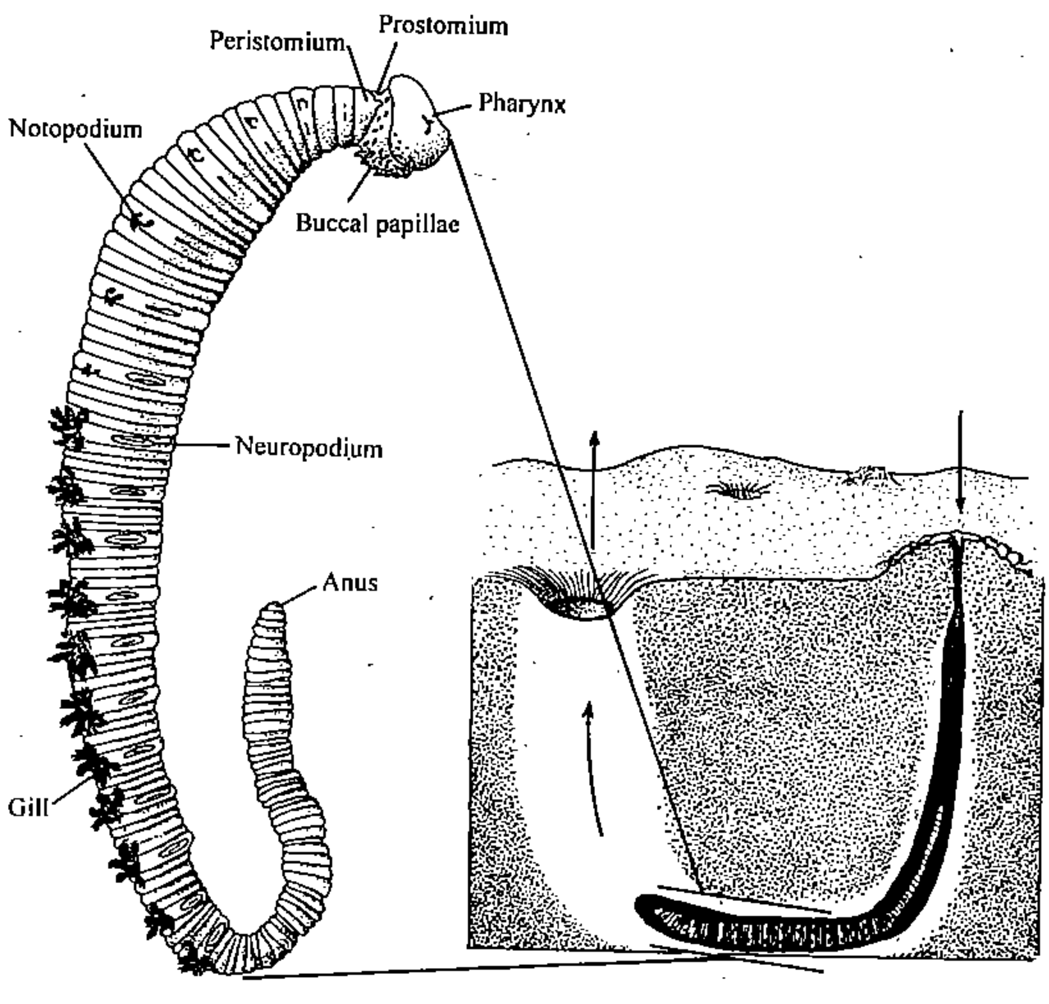



Fig. 10.9 : The lugworm, *Arenicola*, in its burrow. Arrows indicate the direction of water flow produced by the worm. The worm ingests the column of sand on the left, through which water is filtered. The pile of sand at the burrow opening is defecated castings.

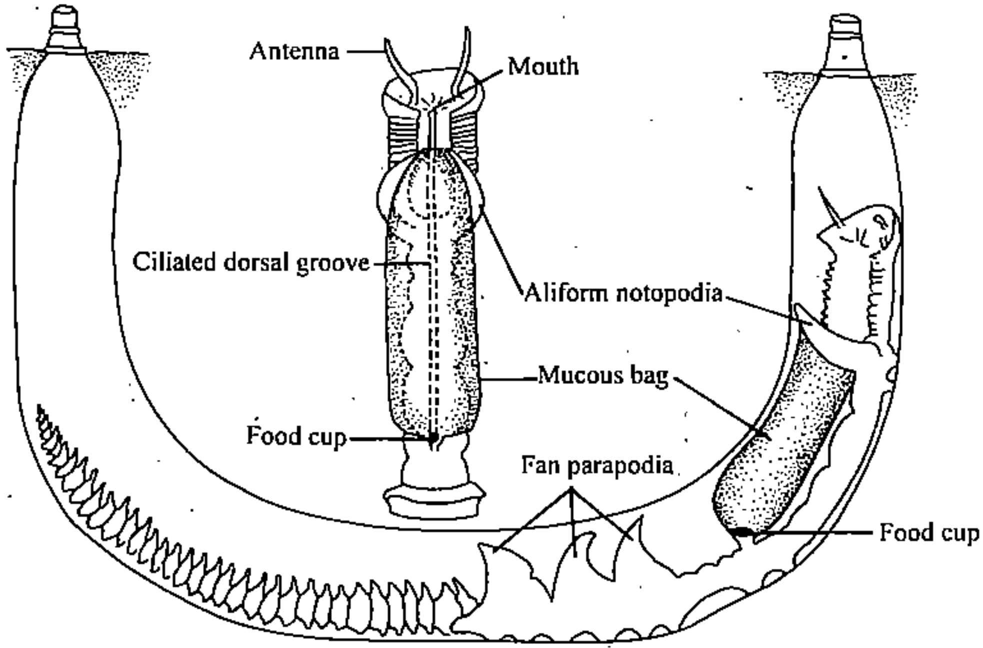



**Fig. 10.10 :** *Chaetopterus* during feeding. A, Anterior part of the body (dorsal view). B, Worm in tube (lateral view). Arrows indicate direction of water current through the tube.

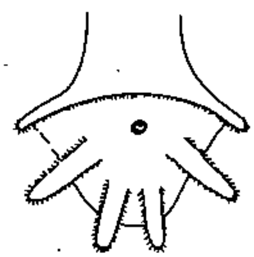


**Fig. 10.11 :** Posterior end of Dero showing circlet of gills around the anus.

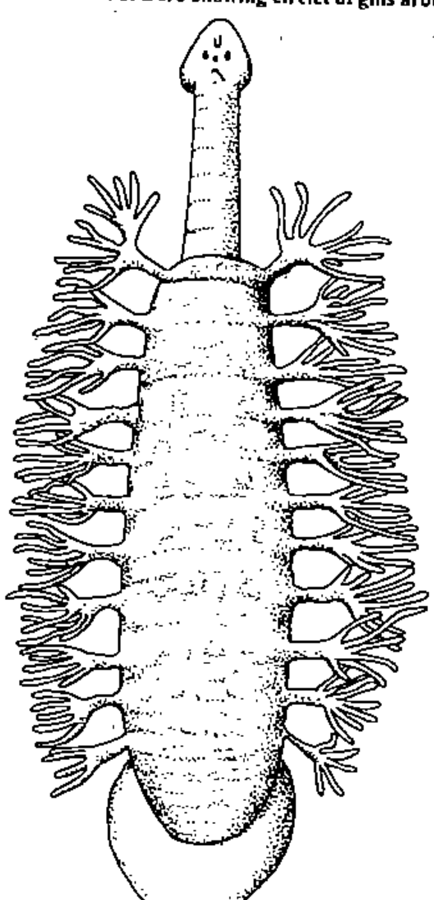


**Fig. 10.12 :** Fish leech (Piscicolidae). Ozobranchus showing lateral gills.

tube dwelling polychaetes drive water through their burrows or tubes by undulating or peristaltic contractions of the body e.g. **Arenicola** (Fig. 10.9), **Chaetopterus** (Fig. 10.10). Worms which ventilate by muscular activity typically exhibit a spontaneous ventilating rhythm in which a period of ventilation alternates with a period of rest. It is demonstrated that ventilation activity increases the worm's oxygen requirement as much as 15 fold, but there is approximately a 20-fold increase in oxygen uptake. Earthworms and leeches are also devoid of special respiratory organs. However, some aquatic oligochaetes such as **Dero**, (Fig. 10.11) and **Aulophorus** have gills at the posterior end of the body. The fish leech **Ozobranchus** (Fig. 10.12) has lateral gills. The skin which has rich blood supply acts as respiratory surface for the exchange of gases.

In echinodermata, there are finger like evaginations of the coelomic cavity called dermal papulae (dermal branchiae or branchial papulae) that serve as respiratory organs (Fig. 10.13). A major part of respiration takes place in echinoids, through ten branched gills

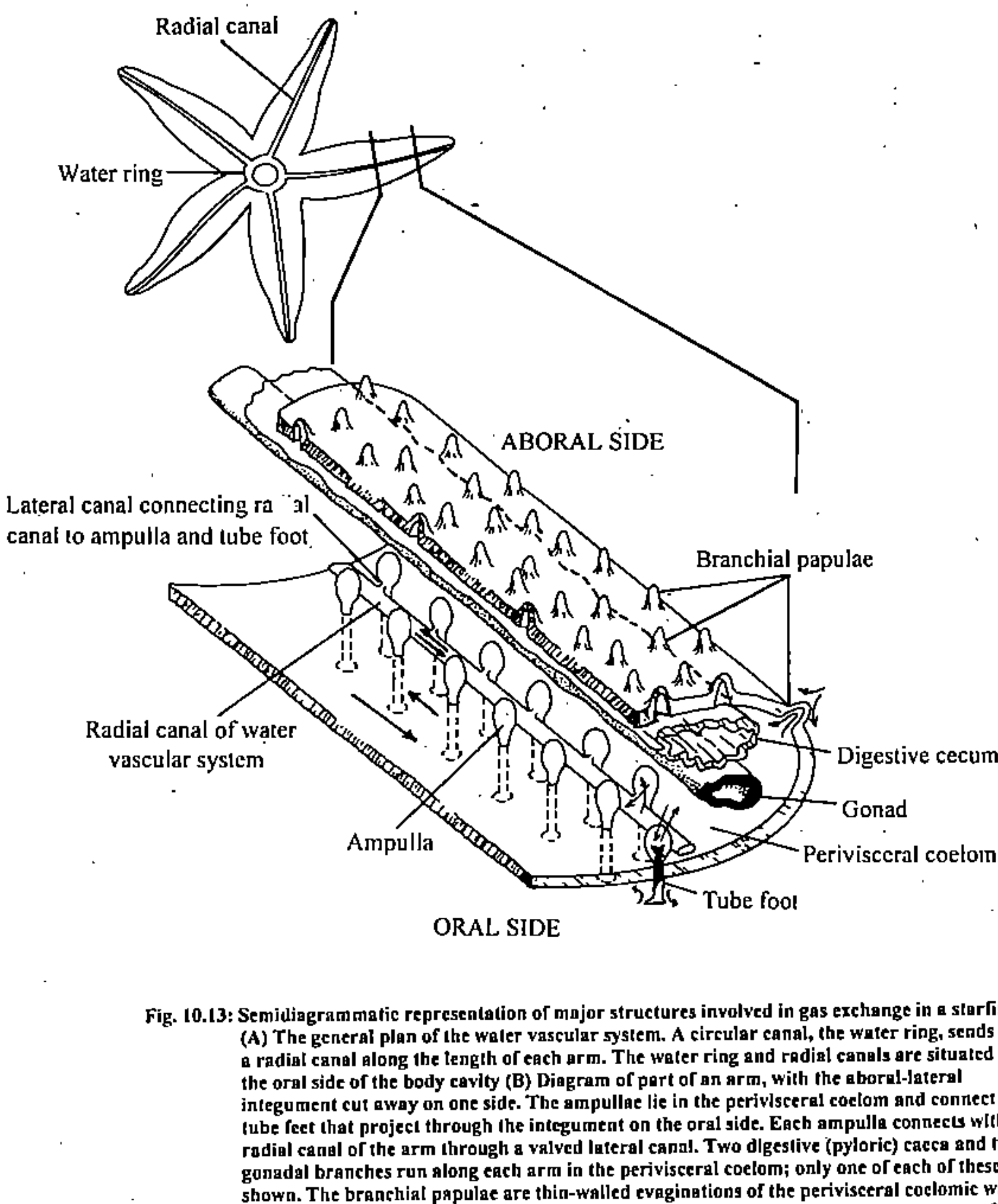



**Fig. 10.13: Semidiagrammatic representation of major structures involved in gas exchange in a starfish. (A) The general plan of the water vascular system. A circular canal, the water ring, sends out a radial canal along the length of each arm. The water ring and radial canals are situated on the oral side of the body cavity (B) Diagram of part of an arm, with the aboral-lateral integument cut away on one side. The ampullae lie in the perivisceral coelom and connect with tube feet that project through the integument on the oral side. Each ampulla connects with the radial canal of the arm through a valved lateral canal. Two digestive (pyloric) caeca and two gonadal branches run along each arm in the perivisceral coelom; only one of each of these is shown. The branchial papulae are thin-walled evaginations of the perivisceral coelomic wall and appear externally as minute, fingerlike projections. Solid arrows show movements of ambient water, water vascular fluid and coelomic fluid. Dashed arrows indicate diffusion of gases between the ampullar fluid and perivisceral coelomic fluid.**

situated in the area surrounding the mouth (Peristomial gills), one pair in each angle between the ambulacral plates (Fig. 10.14). The tube feet in echinoderms are also respiratory in function.

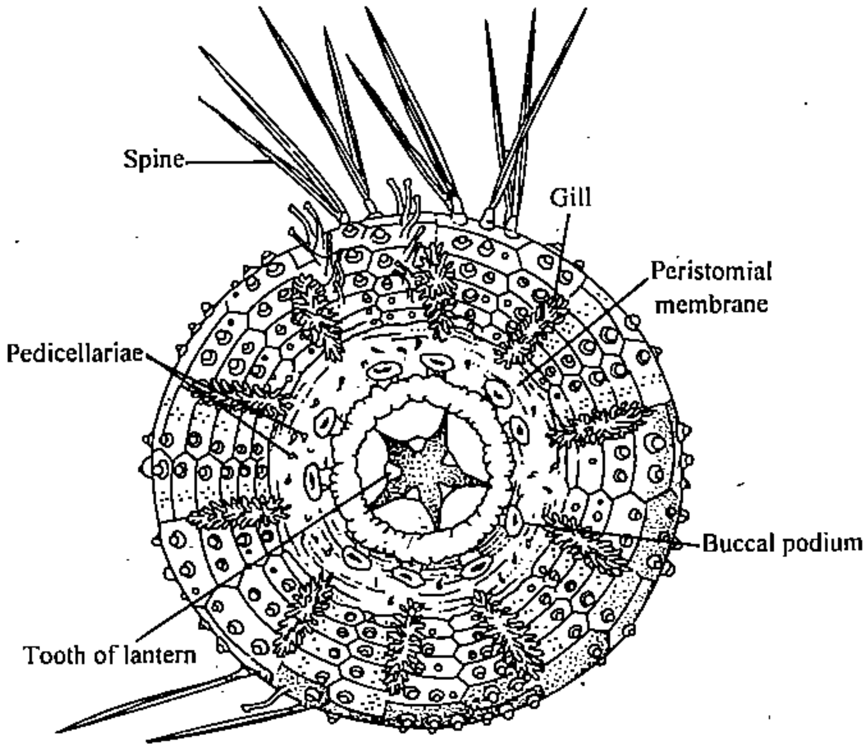
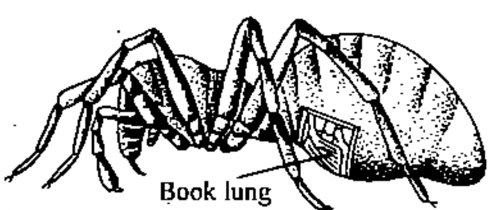


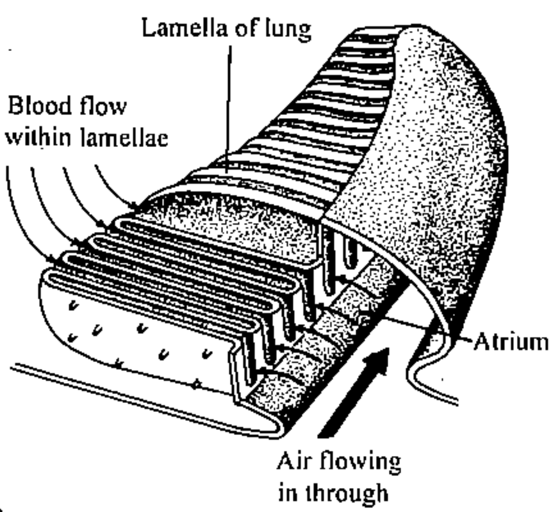

Fig. 10.14 : The regular urchin (*Arbacia punctulata*) Oral view showing the presence of gills.

### ii) Lungs

In arachnid arthropods like scorpion and spider. respiration takes place by means of book lungs (Fig. 10.15). There are four pairs of these structures in the scorpion, opening at the four pairs of slit like stigmata on the ventral sternum. Each book lung takes the form of a small hollow sac (pulmonary sac) filled with clusters of lamellae, 130 to 150 in number.




(a)




(b)

Fig. 10.15: The book lung of a spider is a type of diffusion lung. (a) Position of one member of the pair of book lungs within the abdomen of a spider. (b) Diagrammatic section through a book lung showing diffusion of gases or air flow between lamellae.

These lamellae are disposed like the leaves of a book. The leaves are borne on an axis. Each leaf is hollow and the blood to be oxygenated flows within the narrow slit like cavity, separated from the air by membranous walls. The spiracle opens into an atrial chamber. Each lung is enclosed in a pulmonary cavity. The lamellae contains respiratory air derived from the atrium and blood circulates in the spaces between the lamellae. It is here that excange of gases takes place through the thin walls of the lamellae. Air enters the lamellae by diffusion, but in some species the atrium is reported to produce a ventilating action by means of muscles.

### iii) Tracheae

Tracheal respiration is characteristic of insects. Onychophorans, arachnids, diplopods and chilopods also use tracheal system for respiration. In this type of respiration air is carried directly to the tissues without the intervention of blood. Tracheal system typically

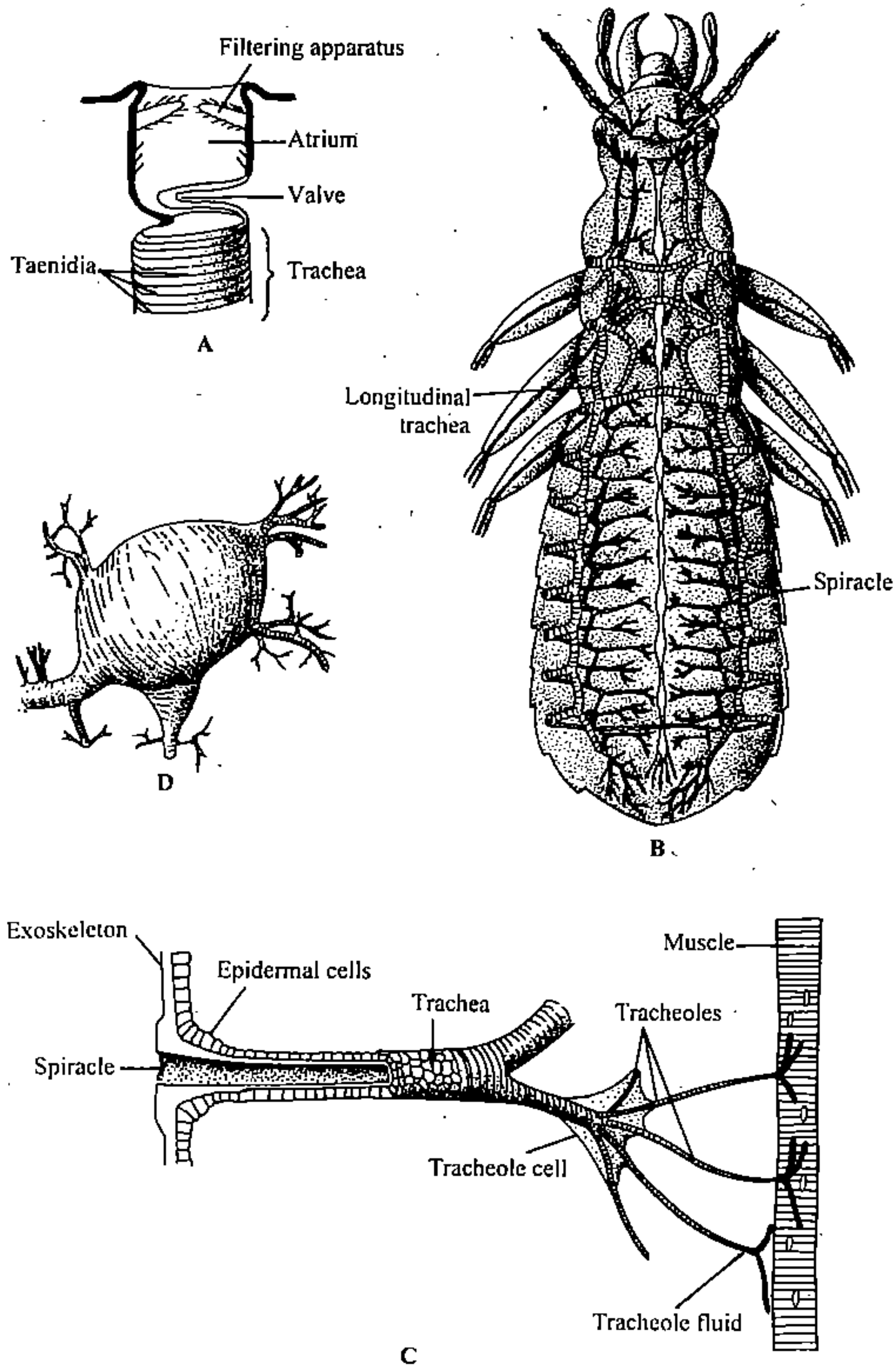



**Fig. 10.16 : A, A spiracle with atrium, filtering apparatus, and valve, B, A tracheal system of an insect, C, Diagram showing relationship of spiracle and tracheoles to tracheae, D, An air sac.**

consists of a large number of interconnected small tubes, the tracheae (Figs. 10.16). These open outside through minute pores called spiracles, which are located on either side of the body. Air is pumped into and out of tracheae through these spiracles by the ventilating movements of the body and gaseous exchange takes place directly in the individual cell. Single spiracle may serve for both inspiration and expiration; but usually there are numerous spiracles, some of them for inflow and others for outflow of the air.

The pattern of the internal tracheal system is variable but there exists a pair of longitudinal trunks with cross connections (Fig. 10.16). The tracheae are supported by thickened spiral rings of the cuticle, the **taenidia**. The rings resist compression (i.e., prevent collapse) but permit stretching of the tube. The tracheae divide and redivide to form minute branches called **tracheoles**. These ramify through the different tissues of the body. In some insects the tracheal tubes are dilated to form **air-sacs** (Fig. 10.16 D). A number of tracheoles may be formed by a single tracheole cell. In flight muscles of some insects, the tracheoles even push into the fibrils. The tracheole cuticle is not shed during molting as is the case of tracheae and after molting new tracheae are joined to old tracheoles.

Exchange of gases through the tracheae is known to occur primarily by diffusion. However, spiracles remain closed most of the time and exchange probably takes place as a result of both diffusion and ventilation. Studies have demonstrated that the spiracles open very briefly and not all at once in response to a localized reduction in hemocoelic pressure. The spiracle is literally sucked open and a "gulp" of air is taken in. The pressure drop results from intersegmental muscle contraction and is under the control of nervous system which in turn may be regulated by the oxygen/carbon dioxide tension of the blood. More spiracles are therefore open during flight compared with the insect at rest. Ventilating pressure gradients result from body movements, largely abdominal movements which bring about compression of the air sac and the longitudinal extension and contraction of trachea. Ventilation is facilitated by the sequence in which certain spiracles are opened and closed.

Gases are exchanged by diffusion down a concentration gradient. Tracheoles are permeable to liquids, and in most insects their tips are filled with fluid. This fluid seems to be involved in the final transport of oxygen. Some of the small insects such as collembolans and proturans which live in moist surroundings lack tracheae and gas exchange occurs over the general body surface. Some immature aquatic insects also lack tracheae, particularly during early stages of development. Tracheae are also usually present in adult insects which live in water. The adults merely utilize air from air bubbles or films held against the body surface by special "unwettable (hydrofuge) hairs. But the nymphs and larvae of certain groups may possess special adaptations for gas exchange in water.

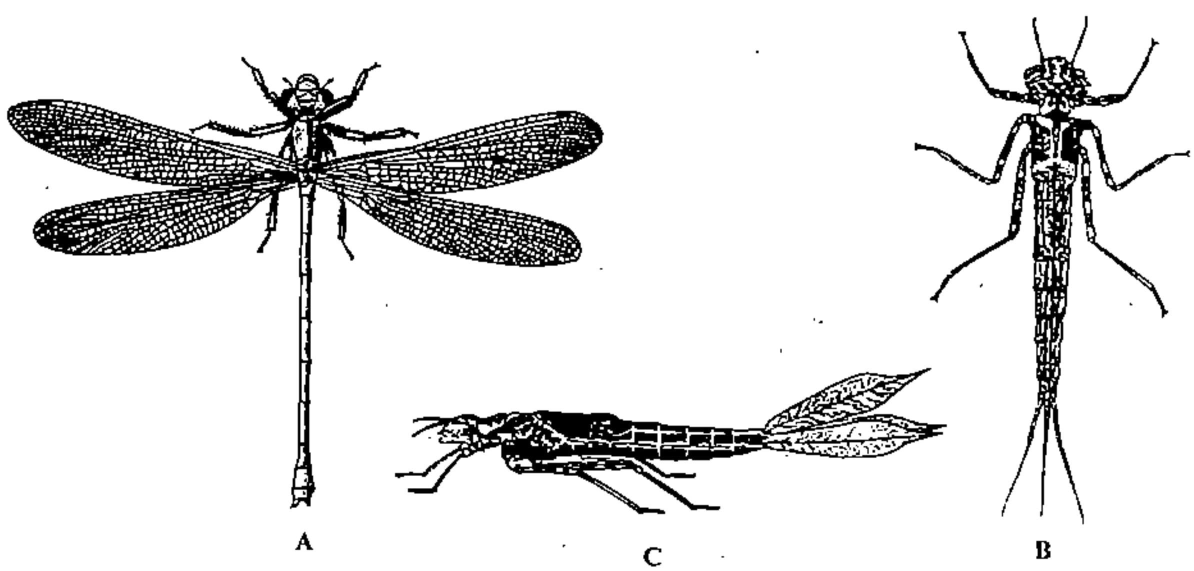



**Fig. 10.17 : A damselfly, *Ischneura cervula* (Coenagrionidae). (A) Adult male and (B,C) Nymph dorsal and lateral views.**

Damselfly nymphs and mayfly nymphs possess abdominal gills (Figs. 10.17 and 10.18). The gills are provided with closed tracheae and gas exchange occurs across the gill surface between the water and tracheae. Dragonfly nymphs pump water in and out of rectum, which contains rectal gills (Fig. 10.19) supplied with tracheae. Generally in immature insects gas exchange occurs across the general integument between the tracheae and water. Some larvae, such as those of mosquitoes, have a few functional spiracles associated with one or more breathing tubes. The larva rises to the surface periodically and obtains air through the tube.

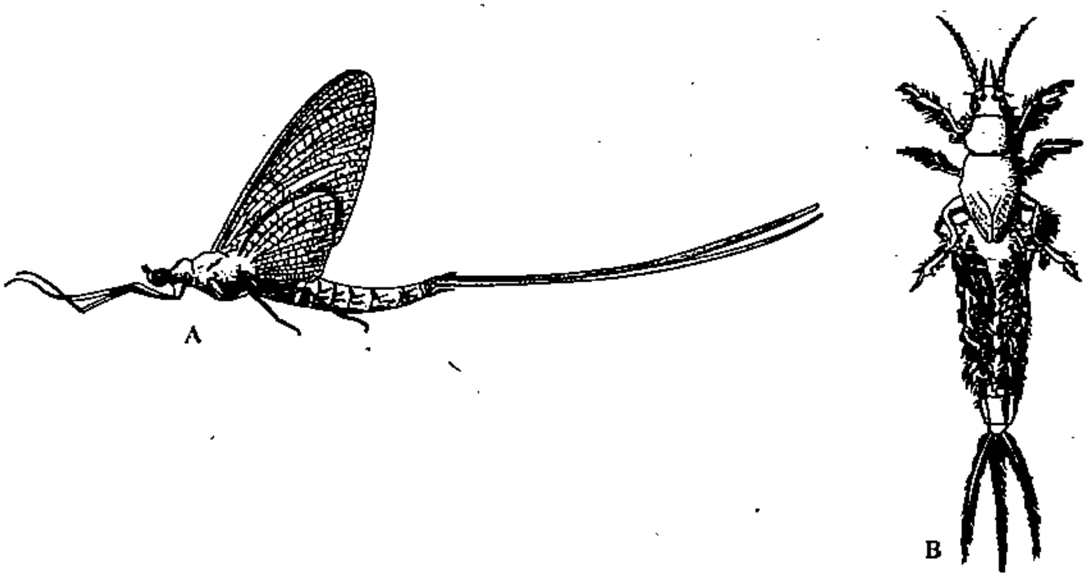



Fig. 10.18 : Mayfly*Hexagenia limbata* (Ephemeridae). (A) Adult and (B) Nymph.

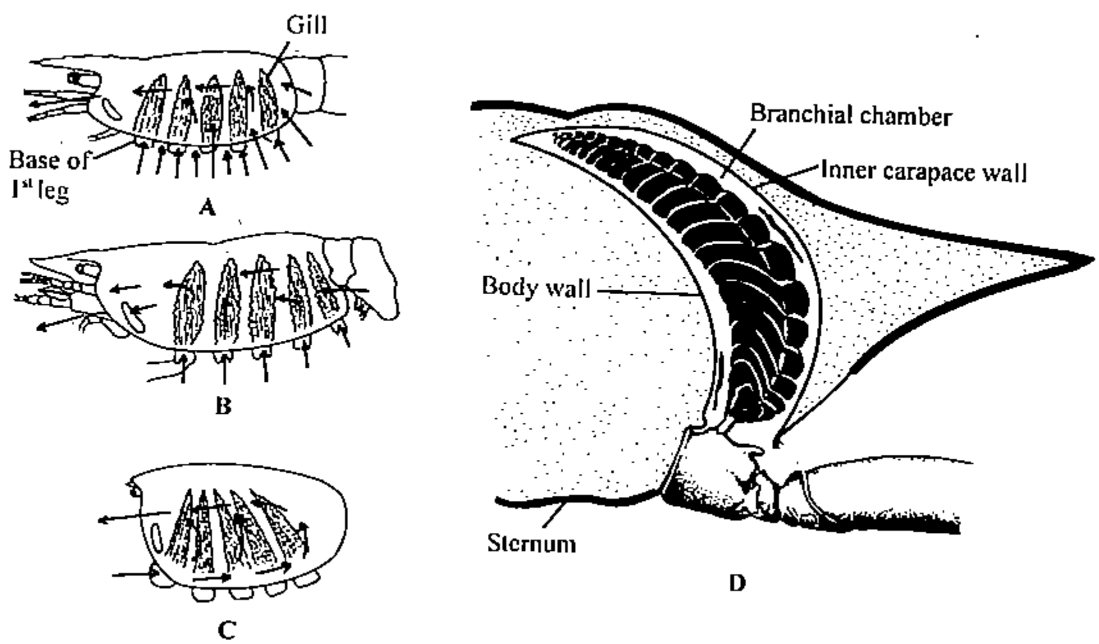



Fig. 10.19 : A-C, Paths of water circulation through the gill chamber of three decapods, showing progressive restriction of openings into the chamber. A. Shrimp, Water enters along entire ventral and posterior margins of the carapace. B. Crayfish. Water enters at the bases of the legs and at the posterior carapace margin, C. Crab. Water enters only at the base of the cheliped. D. Cross section through the gill chamber of a crab.

In **Onychophorans**, the organ of gas exchange is tracheae. The spiracles are minute openings and are present in large numbers all over the surface of the body between bands of tubercles. Each spiracle opens into a very short atrium, at the end of which arises a tuft of minute tracheae. Each trachea is a simple, straight tube and extends directly to the tissue that is supplying.

### iv) Gills

Gills are the specialised respiratory organs of many aquatic animals. They are found in molluscs and also in many crustaceans. Typically gills are filamentous structures richly supplied with blood. The gills found inside the body are referred to as internal gills whereas those found outside the body are referred to as external gills. Both are meant for respiration.

In crustaceans, gills are usually associated with appendages. They may however vary in form, origin and location.

In crayfish, lobster, crab etc, the gills are filamentous outgrowths from certain thoracic appendages, namely of epipodites and are enclosed in a chamber, covered by carapace (Fig. 10.19). These gills are usually ventilated by the paddle like movements of special appendages such as the scaphognathites. Many aquatic insects have gills. These are usually abdominal or caudal and are called tracheal gills. These occur in nymphs of Odonata, Trichoptera and in larvae of some beetles. These gills are supplied with fine tracheae instead of blood capillaries. The tracheal gills of the nymphs of the dragonfly **Aeschna** lie in the rectum (Fig. 10.20).


**Fig. 10.20 : Rectal gills of an insect.**

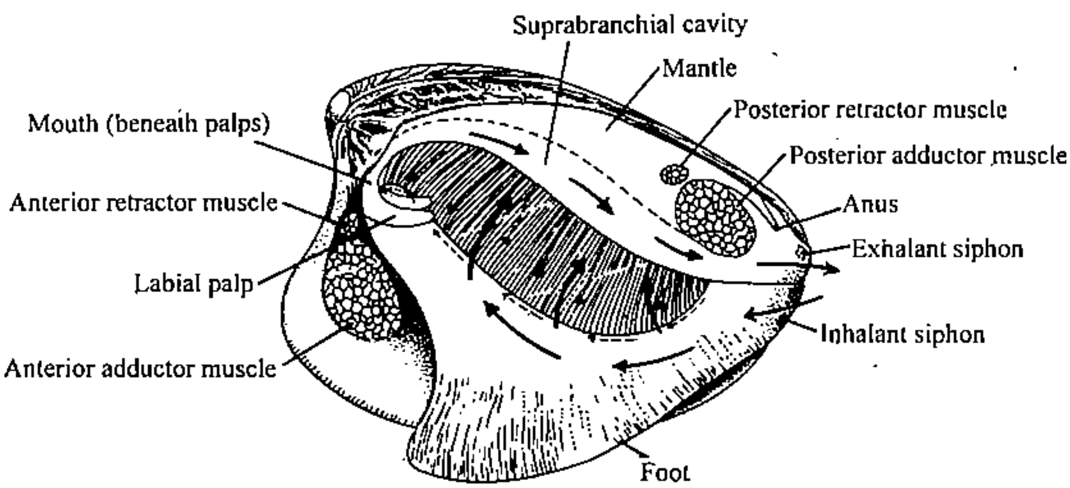



**Fig. 10.21: Gill structure and ventilation in eulamellibranch clams as exemplified by the freshwater mussel *Anodonta*. A specimen of *Anodonta* with the left shell removed (semidiagrammatic). One of the four gill lamellae suspended in the mantle cavity is shown. It has been sectioned longitudinally near its dorsal attachment with the body to reveal the water channels within.**

Molluscs possess a variety of gills (ctenidia). The lamellibranchs possess two pairs of ctenidia which show various modifications (Fig. 10.21). In chiton there are 6 to 80 gills in each pallial groove. In gastropods the gills are relatively simple paired, plume-shaped and are located in the mantle cavity (Fig. 10.22), but in cephalopods the gills are large and richly vascularised (Fig. 10.23).

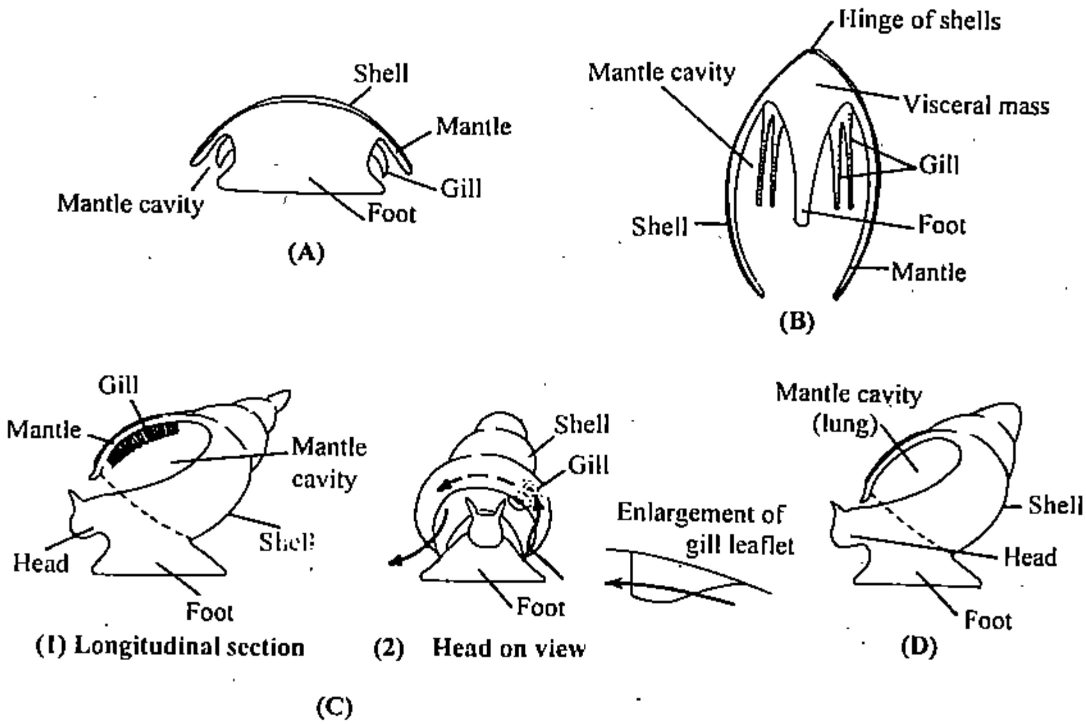



**Fig.10.22:** Schematic representations of the arrangement of the mantle, mantle cavity and gills in several groups of molluscs. (A) Transverse section of a chiton. (B) Transverse section of a lamellibranch clam. The mantle cavity is relatively capacious, and the gills are suspended in the cavity. (C) Diagrams of the condition in many prosobranch gastropods. There is only one gill, the left, and it has become modified and fused to the mantle assuming the form of many triangular gill leaflets that hang into the mantle cavity something like the pages of a book. (D) Longitudinal section of a terrestrial pulmonate gastropod. Gills are lacking and the walls of the mantle cavity have become richly vascularized, transforming the mantle cavity into an air-breathing lung. The mantle cavity opens to the outside only through a small porelike orifice. When the mantle cavity is ventilated, air passes both in and out through this pore.

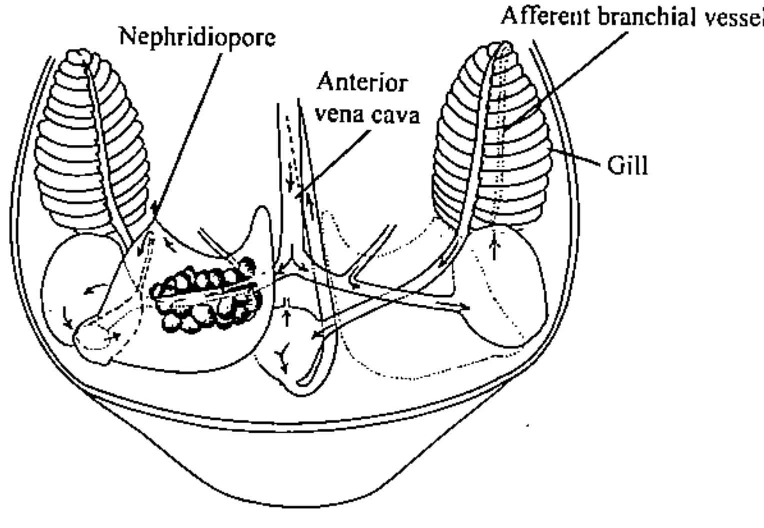



**Fig. 10.23:** Anatomy of Octopus showing gills.

Gaseous exchange is carried on by both mantle and the gills. The gills of most bivalves are highly modified for filter feeding. They are derived from the primitive ctenidia by lengthening of the filaments on each side of filamentous axis (Fig. 10.24). As the ends of long filaments became folded back towards the central axis; the ctenidial filaments took the shape of a long slender 'W'. The filaments lying beside each other became joined by ciliary junctions or tissue fusions, forming plate like lamellae with many vertical water tubes inside. Thus water enters the incurrent siphon, propelled by ciliary action, then enters the water tubes through pores between the filaments in the lamellae proceeds dorsally into a common suprabranchial chamber (Fig. 10.25) and then out of the excurrent aperture.

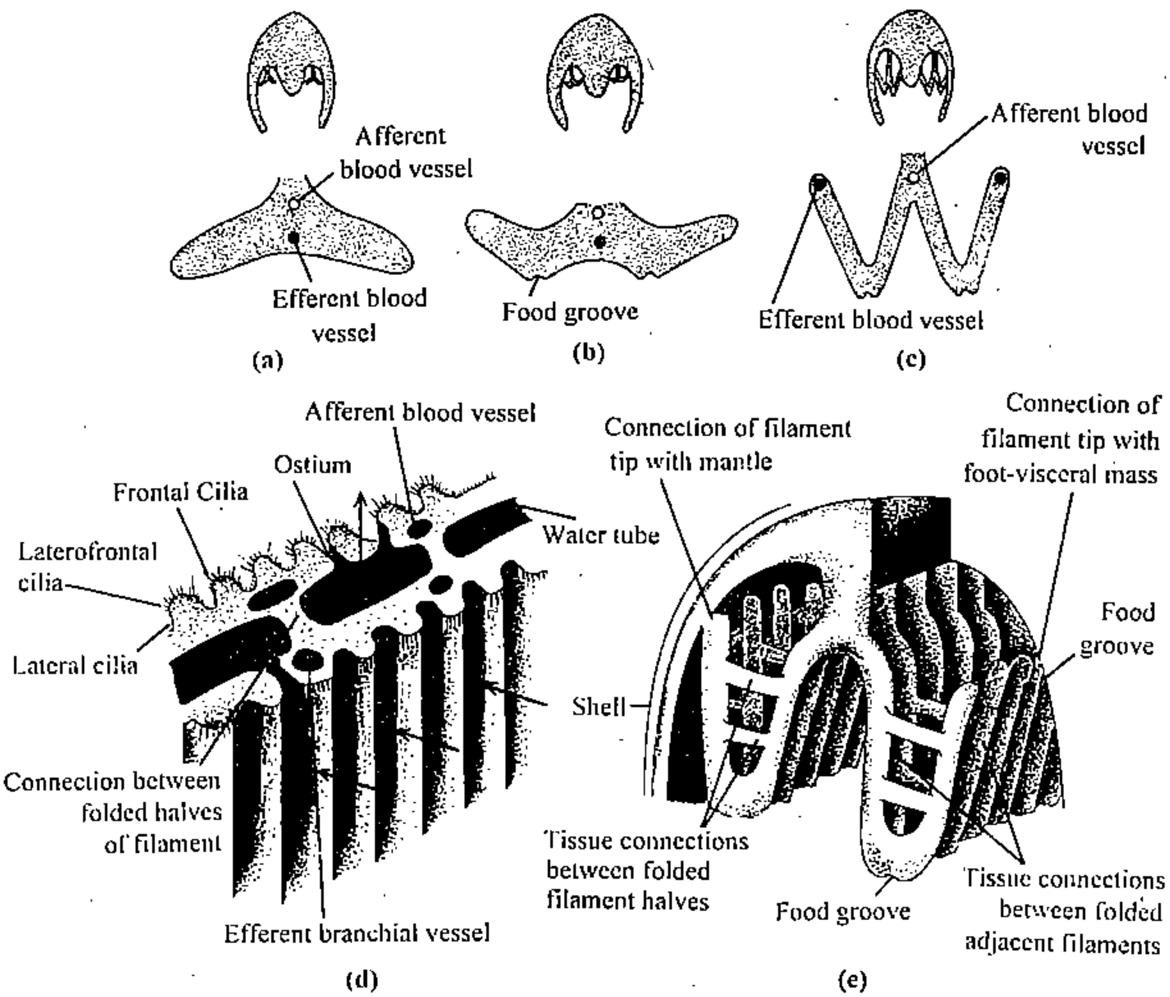



Fig. 10.24: Evolution of lamellibranch gills. (a) Primitive protobranch gill (position relative to foot-visceral mass and mantle indicated in cross section). (b) Development of food groove to produce the lamellibranch condition. (c) Folding of filaments at food groove to produce the lamellibranch condition. (d) Small section of lamellibranch gill; arrows show direction of water flow. (e) Tissue connections that provide support for the folded lamellibranch filaments.

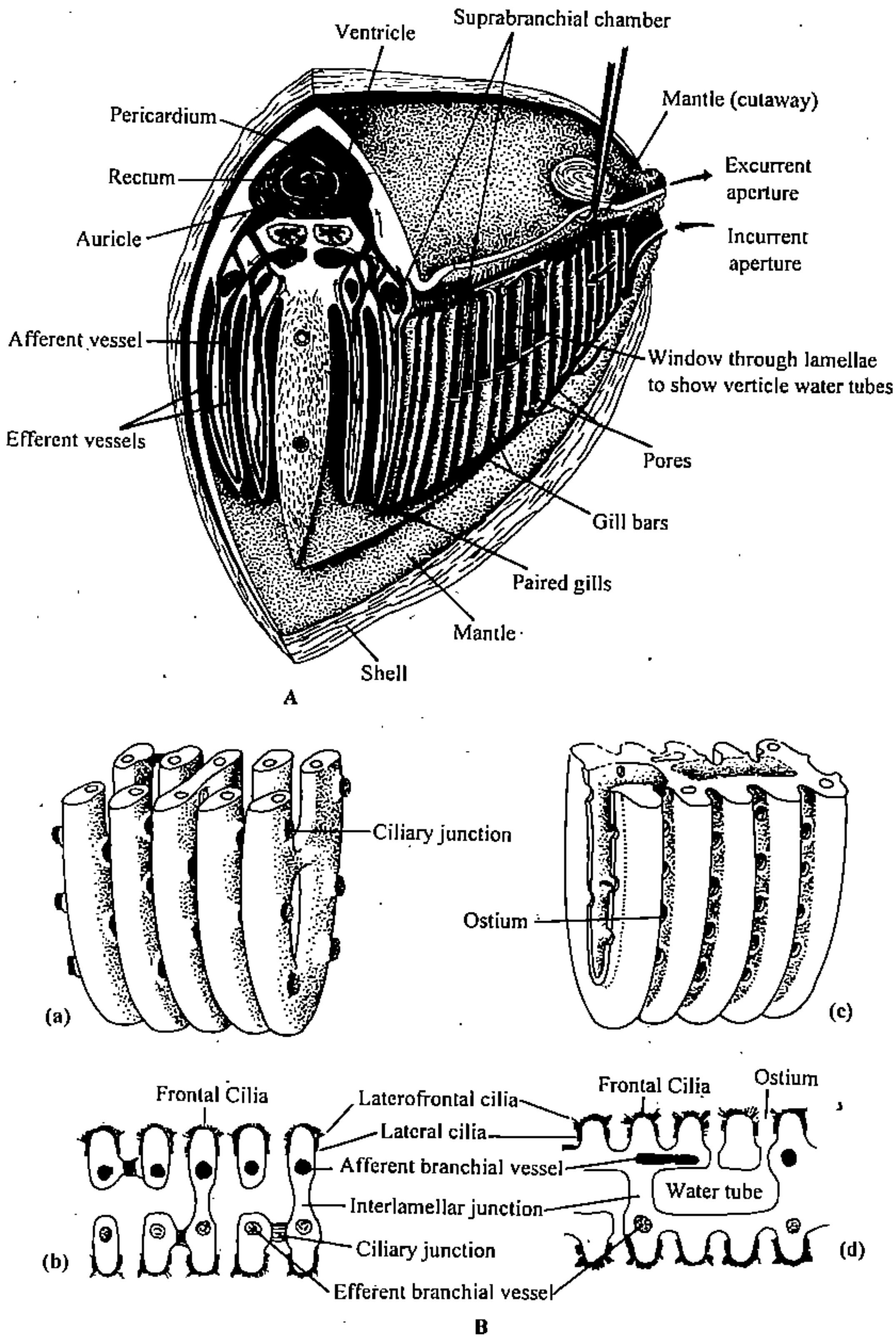



**Fig. 10.25 : A, Section through heart region of a freshwater clam to show relation of circulatory and respiratory systems. *Respiratory water currents*: water is drawn in by cilia, enters gill pores, and then passes up water tubes to suprabranchial chambers and out excurrent aperture. Blood in gills exchanges carbon dioxide for oxygen. *Blood circulation* : ventricle pumps blood forward to sinuses of foot and viscera, and posteriorly to mantle sinuses. Blood returns from mantle to auricles; it returns from viscera to the kidney, and then goes to the gills, and finally to the auricles. B, Filibranch gill. a, Five adjacent filaments (surface 3-D view). b, Frontal section. c-d, Eulamellibranch gill. c, Five fused, adjacent filaments (surface 3-D view). d, Frontal section.**

## 10.2.2 PROCESS OF RESPIRATION

Gaseous exchange, i.e. intake of oxygen and output of carbon dioxide, takes place at the respiratory surface because the surface is richly vascularised. The respiratory surface could be the general integument, a lung or a gill. As soon as the source of oxygen (atmospheric air or water containing dissolved oxygen) comes in contact with the respiratory surface as a result of various ventilating mechanisms, exchange of gases, takes place, e.g., oxygen is absorbed into the blood and carbon dioxide from the blood is released into the environment.

The exchange of gases takes place by simple diffusion, which is caused due to the partial pressure of the respiratory gases. Gases move from the medium with high partial pressure to the medium having low partial pressure. In the environment (air or water) the partial pressure of oxygen is comparatively higher than in the blood. Therefore, oxygen diffuses from the environment to the blood through the respiratory surface. Similarly the partial pressure of the carbon dioxide in the blood is higher than the immediate environment. So it diffuses outside from blood through the respiratory surface.

The partial pressure of any gas in gaseous mixture is proportional to its concentration in the mixture. For example, oxygen constituting approximately 21% of the air at a barometric pressure of 760 mm Hg exerts a partial pressure of about 160 mm Hg ($0.21 \times 760$). This is called the "oxygen tension" of air.

**Transport of Respiratory Gases**

In the more primitive animals, which are usually smaller, respiratory gases (Oxygen and Carbon dioxide) directly diffuse between the body and the environment. But in higher animals which are usually larger, respiratory gases are transported with the help of a circulatory system in which usually blood is the circulatory fluid.

Water normally dissolves only about 0.5 volumes per cent (i.e., 0.5 cc per 100 cc) oxygen. Carbon dioxide is soluble in water to a greater extent, but not more than 5 volumes per cent (i.e., 5 CC per 100 CC). Blood (plasma) in itself is normally a rather poor carrier of respiratory gases. It is capable of dissolving in it only as much as water or saline can. This will suffice for the purpose of small animals or even some larger but sedentary animals with very low metabolic activity. Larger non-chordates (and of course most chordates) with high metabolic activity usually have respiratory pigments. These pigments, also known as chromoproteins transport and store oxygen. In addition, these pigments (and some other substances) serve as buffers increasing the capacity of blood to carry carbon dioxide. Carbon dioxide can also combine with some chromoproteins to form carbamino-compounds, which may also play a small but significant role in transportation of carbon dioxide.

Thus you have seen blood itself is only a rather poor carrier of the respiratory gases, but very often in nonchordates it contains one of the respiratory pigments which acts as carrier of oxygen. These pigments take up oxygen when it is abundant and transporting it through blood readily parts with it to tissues where it is poor. Thus, respiratory proteins or chromoproteins play very important role in transport of respiratory gases, whereever they occur. However, respiratory pigments are by no means present in all invertebrates. In most insects and in many other arthropod groups for example, these are absent. When present, the nature of respiratory pigment varies in different animals. They may be found either in solution in blood plasma or in corpuscles. You will study now the various respiratory pigments found in different invertebrates, briefly.

## 10.2.3 RESPIRATORY PIGMENTS

Oxygen dissolves in blood and other body fluids in accordance with the physical laws. The amount of oxygen carried in solution per unit volume increases in proportion to the prevailing oxygen tension. However, at physiological tensions, the dissolved oxygen concentration of body fluid is never great. In animals which depend on the circulation of body fluids for oxygen transport, the capacity of the fluids to carry oxygen can be increased to well above that permitted by simple solution by the presence of specialized oxygen transport compounds. These compounds may be either dissolved in blood plasma or may be in the floating corpuscles in the circulating body fluid. These transport compounds undergo reversible, loose chemical combination with oxygen. Haemoglobin which is present universally among vertebrates is an example. Chemical combination of oxygen molecules with haemoglobin accounts for over 98% of the oxygen carried by the blood when leaving the lungs; less than 2% is in simple solution.

When we say that a compound undergoes reversible combination with oxygen, we mean that it tends to take up oxygen when exposed to high oxygen tensions and to release oxygen when oxygen tensions are low. The compounds in the body fluids of animals that function in this way fall into 4 groups: **haemoglobins, haemocyanins, haemerythrins** and **chlorocruorins.** All these compounds are collectively called the respiratory pigments or respiratory proteins; these are also sometimes called chromoproteins, because these are often coloured.

The process of combining with oxygen is termed **oxygenation**, whereas that of releasing oxygen is called **deoxygenation**. The prefixes oxy- and deoxy-, when appended to the name of a respiratory pigment, refer respectively to pigment that is combined or not combined with oxygen. For example, haemoglobin combined with oxygen is called oxyhaemoglobin (red), whereas haemoglobin devoid of bound oxygen is termed deoxyhaemoglobin (purple).

**Haemoglobins**

Haemoglibin is the best known of all respiratory pigments. The basic molecular unit of haemoglobin consists of a haem group (Fig. 10.26) bound to a protein or globin moiety. Haeme is a metalloporphyrin, to be more specific, ferrous protoporphyrin. This serves as the prosthetic (serving as a prefix) group, with which is linked the protein. Haemoglobins of different species differ in their chemical and physical properties. These differences are attributable to differences in their globin moieties. The molecular weight of each unit molecule is typically about 16000 - 17000. The four-unit haemoglobin of vertebrates thus have molecular weights of approximately 64000 - 68000. Relatively huge haemoglobin molecules are found in some non-chordates. For example, in numerous annelids including earthworms (eg. **Lumbricus**) and in the polychaete **Arenicola** the blood haemoglobin has a molecular weight of nearly 3 million. Such large molecules often contain around 100 or more oxygen-binding sites.

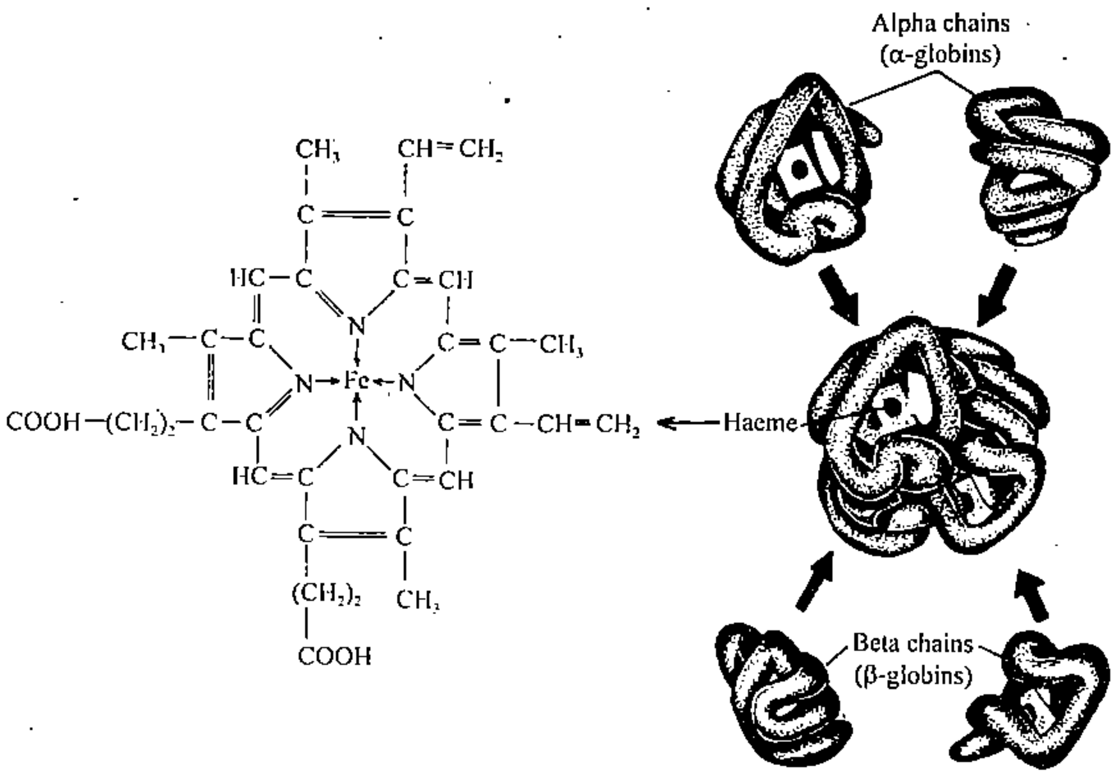



**Fig. 10.26 : When a protein consists of two of more polypeptide strands, as haemoglobin does, it is said to have a quaternary structure. Each of the four polypeptides in haemoglobin is joined to an iron-containing molecule, the haeme, but only two of the haemes can be seen in this view of the molecule.**

Haemoglobins are quite common in Annelida. In these, haemoglobins are usually dissolved in the blood.

They are, however, sometimes found even in tissues. Among arthropods, haemoglobins are found in a number of species of small branchiopod crustaceans (e.g., **Daphnia, Artemia**) and rarely in insects (larva of the midge, **Chironomus**). Here also it is usually in the dissolved form, in the blood. Among molluscs, haemoglobin is found dissolved in the blood of some planorbid snails and in the blood corpuscles of some bivalves.

**Chlorocruorins**

These pigments are found in four polychaete families: Sabellidae, Serpulidae, Ampharetidae and Chlorhaemidae. The pigment is found in plasma solution and bears close similarities to the extra-cellular haemoglobins so commonly found dissolved in the blood of annelids. Chlorocruorins are large molecules, with molecular weights nearly 3 million. In dilute solution chlorocruorins are greenish, but in concentrated solution, they are red.

**Haemerythrins**

The haemerythins are rather rare. They occur in some animals belonging to the minor phyla such as the sipunculid worms, some brachiopods, priapulids and in the polychaete **Magelona**. Haemerythrins are located intracellularly, usually in Cells of the coelomic fluid, or in blood cells as in **Magelona**. Despite their name, haemerythrins do not contain haee groups. They however, contain ferrous iron, bound directly to the protein. They have a molecular weights of about 75,000. These pigments are colourless when deoxygenated but turn reddish violet when oxygenated.

**Haemocyanins**

This pigment is found in some arthropods and molluscs. Haemocyanins do not contain haee groups. The metal they contain is copper, which is bound directly to the protein. Haemocyanins are found dissolved in the blood plasma and are always of large molecular size. Although colourless when deoxygenated, the oxygenated form is blue.

Among molluscs, haemocyanins are found in cephalopods, chitons and in many gastropods. Among arthropods they occur in malacostracan crustaceans (crabs, lobsters, shrimps, crayfish), horseshoe crabs, spiders and scorpions. The molluscan pigments have a molecular weights of 4-9 million.

**Functions of respiratory pigments**

As you have studied in the preceding sub-sections, the pigments are the carrier of oxygen. In the absence of respiratory pigments the blood can carry oxygen only in solution as in water or saline and the amount carried will be very low. All the pigments show great affinity towards oxygen with which they can combine at high partial pressure and dissociate at low partial pressure. Thus these pigments also show reversibility in their action.

(Under High Partial Pressure of oxygen)
Respiratory
organs

$$\text{Haemoglobin + oxygen} \rightleftharpoons \text{Oxyhaemoglobin}$$

Tissues
(Under low Partial Pressure of Oxygen)

Respiratory pigments found in tissues like muscles may also serve the function of storage of oxygen. In addition, they serve as buffers, increasing the capacity of blood to carry carbon dioxide.

## SAQ 1

(a) Tick mark (✓) the correct statement and put cross against the wrong ones.
   i) Respiration is a chemical activity taking place mainly in the nucleus of the cell, liberating energy.
   ii) In insects air is delivered directly to the tissues through the tracheal system.
   iii) Sponges prefer places where water is rich in oxygen.
   iv) Earthworms and most leeches are devoid of special respiratory organs.
   v) Gills are found in arthropods like scorpion and spider.
   vi) In echinoderms, tube-feet are not respiratory in function.

(b) Fill in the blanks with appropriate words from the text.
   (i) Gases diffuse from high ...................... to low partial pressure.

(ii) The quantity of oxygen carried by haemoglobin is affected by the partial pressure of ............................ in the blood plasma.
(iii) Respiratory pigments found dissolved in the blood plasma have usually ........................ molecular weight from those found within the cells.
(iv) Haemoglobin contains ......................... as the prosthetic group.
(v) Chlorocruorin is a pigment of ......................... colour found in ................................ annelids.

## 10.3 CIRCULATORY SYSTEM

In sponges, coelenterates and platyhelminths nutrients, respiratory gases and waste materials can easily diffuse through the intercellular spaces. However, in higher animals the circulatory system provides a medium through which oxygen and nutrients from the environment reach all the tissues of the body and carbon dioxide as well as nitrogenous waste materials are eliminated from the body into the external environment. The circulatory system consists of usually blood, the blood spaces and a series of tubes called vessels.

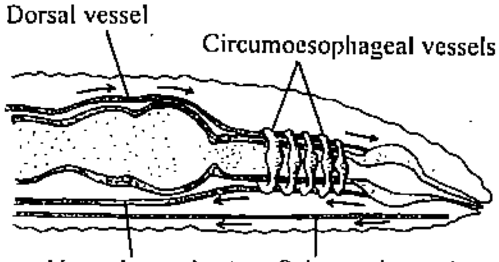
Circulatory systems can be divided into a number of components with similar functions. In addition to the ciruculating fluid, these consist of:

i) A main propulsive organ, usually a heart which forces blood around in the body,
ii) An arterial system which serves to distribute blood and as a pressure reservoir,
iii) Capillaries, or in some animals blood spaces, in which transfer of materials take place between blood and tissues, and
iv) The venous system that acts as a blood reservoir and as a system for returning blood to the heart.

One or more of the above component may be absent in various animals.

### 10.3.1 OPEN AND CLOSED TYPE OF CIRCULATORY SYSTEMS

There are two types of circulatory system found in higher metazoans. In one type the original blastocoel continues to be the main perivisceral space. Either there is no true coelom at all as in pseudocoelomates, or the coelom may be highly obliterated or reduced and restricted to gonads and excretory organs as in arthropods and most molluscs. In these animals there is no closed network of capillaries connecting the arteries and veins. The arterial blood flows into large spaces or sinuses (or into smaller spaces called lacunae), in which various tissues or organs are bathed by blood. From these spaces blood passes into large open veins or through ostia into the heart directly. This is called open type of circulatory system.



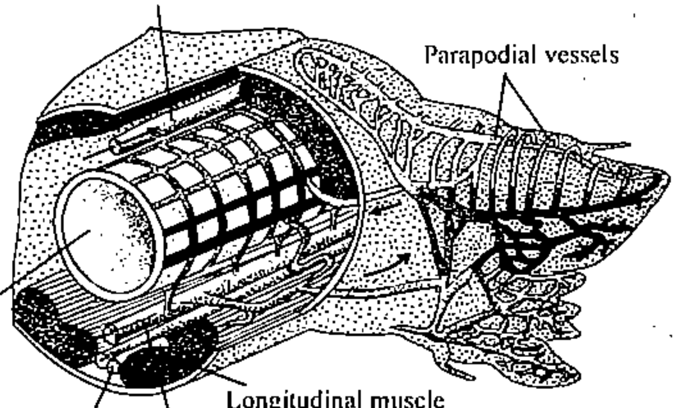
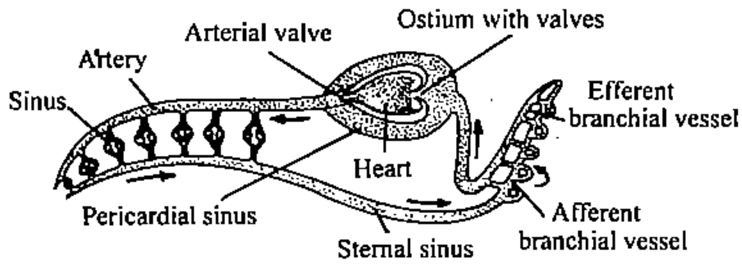




**Fig. 10.27 : The circulatory system of annelid worms. (a) A lateral view of the anterior part of the system in an earthworm. (b) Vascular system within a segment of Nereis. Arrows indicate the direction of blood flow.**

In the other type, a system of closed capillaries connect the smaller arteries with veins, fluid containing nutrients filter through the capillary walls into tissue spaces, from which cells in turn derive their nutrients. This is called closed type of circulatory system. This type of circulatory system is found in annelids, cephalopod molluscs and chordates (Fig. 10.27).

### a) Open Type

Many nonchordates have thus an open type of circulation - a system in which blood pumped by the heart empties via an artery into an open sinus filled with blood which lies between the ectodem and endoderm. The blood filled space is referred to as haemocoel, especialy in arthropods. The fluid contained within the haemocoel, referred to as haemolymph or blood, is not circulated through capillaries but bathes the tissue directly. Figures 10.28 show the organisation of the main vessels from two groups of non-chordates having open circulation, a cray fish and a bivalve mollusc.



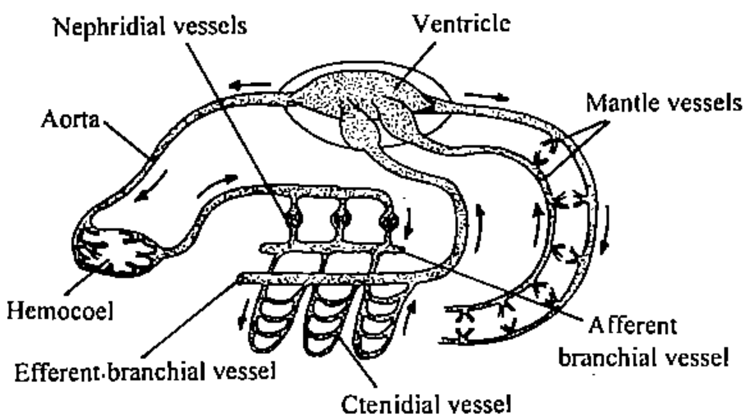




**Fig. 10.28: Invertebrate circulations (A) simplified diagram of the circulation in the crayfish, (B) Simplified diagram of the circulation in bivalve mollusc.**

In many animals the haemocoel is large and constitutes 20 - 40% of body volume. In contrast, chordates with a closed circulation have a blood volume of 5 - 10% of the total body volume. Open circulatory systems have low pressures, seldom exceeding 5 - 10 mm Hg..

Animals with an open circulation generally have only limited ability to alter the velocity and distribution of blood flow. As a result, in bivalve molluscs (Fig. 10.28 B) and other animals which have an open circulation and use blood for gas transport, change in oxygen uptake is slow and rate of oxygen transfer is low per unit weight. In other words, their metabolism is very low. Insects have, however, avoided this problem by evolving a tracheal system in which gas transport to tissues occurs direct through air filled tubes or tracheae (Fig. 10.29) that bypass the blood. Consequently, although insects have an open circulation, they have greater metabolic rate.

### b) Closed Type

Some non-chordates, such as cephalopods (octopuses, squids), earthworms, polychaetes and all vertebrates have a closed circulation, with blood flowing in a closed circuit of tubes from arteries to veins through capillaries. There is better separation of functions in closed circulatory system than in open system. In a closed circulation as shown in figures

10.30 the heart is the main propulsive organ, pumping blood into arterial system and maintaining a high blood pressure in arteries. The arterial system, in turn, acts as a

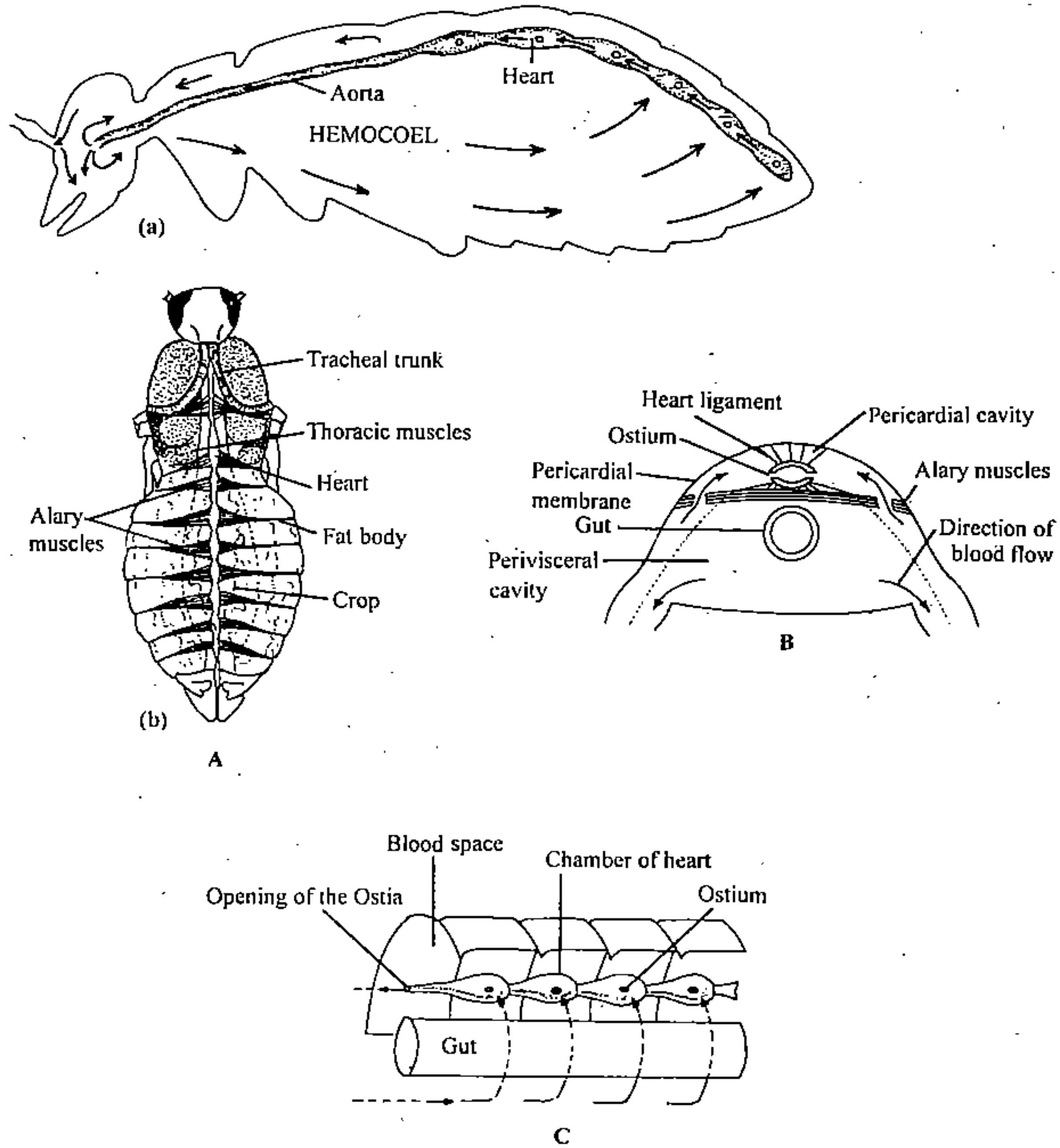
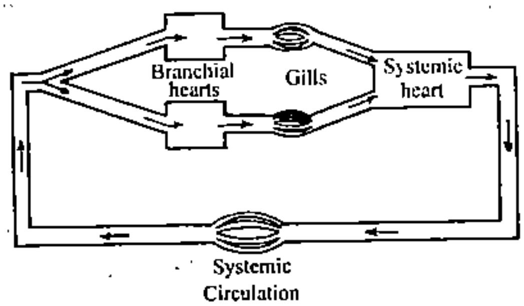



**Fig. 10.29: A, Ciculatory system a) lateral view of hypothetical insect indicating directional blood flow; b) dorsal view of heart . B, Schematic transverse section to show open blood vascular system of an insect. C. Blood is kept moving in the blood space by the heart. The heart sucks it out through the ostia in the sides and pumps it through the aortal opening front.**

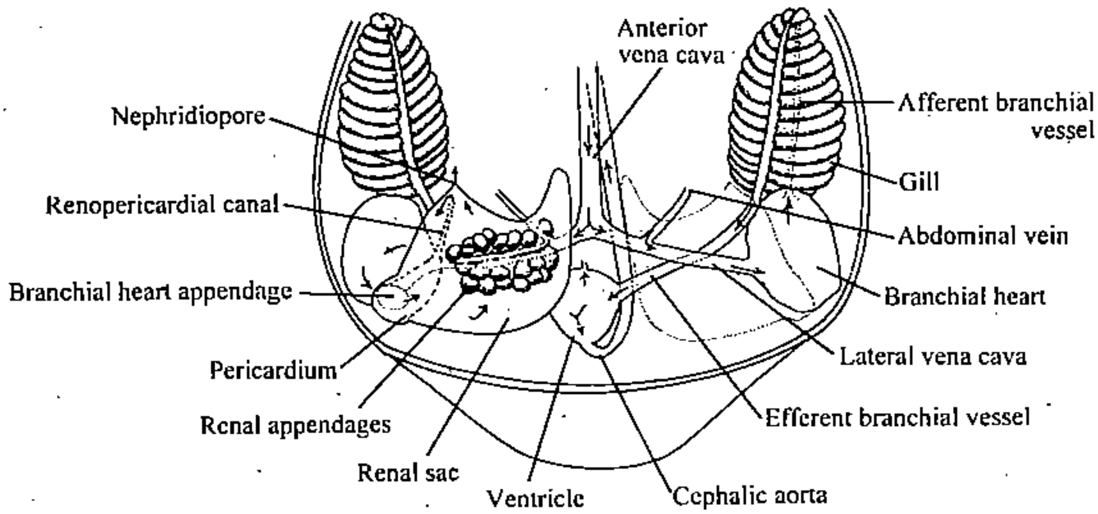
pressure reservoir forcing blood through the capillaries. The capillary walls are thin, thus allowing high rates of transfer of material between blood and tissues.

As shown in **Fig. 10.30 A** blood returning from the systemic circulation is directed to the gills. Much of the returning blood flows through the two lateral vena cava via the kidneys before arriving at the bases of the gills. Near the base of each gill is a bulbous accessory pulsatile organ, the branchial heart, which receives the systemic venous blood. This heart pumps the blood into an afferent branchial vessel, from which it passes through capillaries in the gill to the efferent branchial vessel and return to the systemic heart.

Physiologically the circulatory systems of cephalopods (squid and Octopus) resemble those of chordates far more than to those of the other molluscan groups. As for example, both cephalopods and chordates have closed circulatory systems; the blood volume of octopus is relatively small, about 6% of the body weight, well within the range of that of vertebrates but radically lower than in non-cephalopod molluscs.




A




B

**Fig. 10.30: A, Schematic representation of the circulatory plan in squids and octopuses. Stippled parts carry relatively deoxygenated blood. B, Circulatory systems of Octopus.**

## SAQ 2

Match the animals given in column A with the type of circulatory system found in them in column B.

| | A | B |
|---|---|---|
| i) | Helix | Open type |
| ii) | Octopus | |
| iii) | Squids | |
| iv) | Snails | Closed type |
| v) | Insects | |
| vi) | Crab | |
| vii) | Earthworm | |

## 10.4 SUMMARY

In the end you will try to recapitulate what you have studied in this unit.

- Respiration is an essential physiological process of living organisms by which they obtain energy for carrying out all the metabolic activities of the body. The term was initially applied to the exchange of gases (taking up oxygen and giving away carbon dioxide) between an organism and its environment. Sometimes, this process is now called external respiration as opposed to the chemical processes occurring within the cell to liberate energy, which is called internal respiration.
- In lower non-chordates such as protozoans, sponges and platyhelminths, oxygen is taken up directly from the air or from the aquatic medium surrounding them and carbon dioxide is given out directly to the surrounding medium.

- In arachnids like scorpions and spiders book lungs serve as respiratory organs whereas in insects, onychophorans, diplopods, and chilopods, tracheae are the respiratory organs.
- Gills are the respiratory organs of a number of aquatic animals like many polychaetes, molluscs and many crustaceans. These gills are typically filamentous structures richly supplied with blood. The gills found inside the body are referred to as internal gills whereas the ones found outside the body are referred to as external gills.
- To facilitate gaseous exchange i.e., intake of oxygen and output of carbon dioxide, the respiratory surface is richly supplied with blood vessels.
- Blood itself is a rather poor carrier of respiratory gases. But often it contains respiratory pigments such as haemoglobin, haemerythrin, haemocyanin and chlorocruorin. These respiratory pigments or chromoproteins act as the carrier of oxygen. They also serve as buffers increasing the capacity of blood to carry carbon dioxide.
- The circulatory system in higher animals ensures the exchange of substances between various tissues of the body on the one hand and the external environment on the other. It also transports various substances from one part of the body to the other.
- Many non-chordates like some crabs, snails, insects etc. are said to have an open type of circulation a system in which blood pumped by the heart empties via an artery into open sinus filled with blood. The various tissues and organs are bathed by blood in this sinus. There are no closed net work of capillaries connecting the arteries and veins in these animals.
- Some other non-chordates such as cephalopods (octopus and squid), annelids and all vertebrates have a closed circulation, with blood flowing in a continuous circuit of tubes from smaller arteries to veins through closed capillaries.

## 10.5 TERMINAL QUESTIONS

1. List the various organs found in non-chordates for respiration. Discuss the mode of respiration in scorpion.

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2. What is the purpose of respiration in animals? Explain briefly the mechanism of respiration in molluscs.

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3. Discuss briefly the mechanism involved in the transport of respiratory gases in multi-cellular animals.

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4. What do you mean by open and closed types of blood circulation?

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## 10.6 ANSWERS

### Self-Assessment Questions

1. a) i) false ii) true
   iii) true iv) true
   v) false vi) false

   b) i) partial pressure ii) oxygen
   iii) Higher iv) haeme
   v) green, polychaete

2. Open type (i), (iv), (v) and (vi)
   Closed type (ii), (iii) and (vii)

**Terminal Questions**

1. In non-chordates respiration takes place through various organ such as (i) general body surface, (ii) lungs, (iii) tracheae and, (iv) gills. In scorpions respiration takes place in book lungs. Each book-lung is a small hollow sac (pulmonary sac) filled with clusters of lamellae. The lamellae contain respiratory air derived from the atrium and blood circulates in the spaces between the lamellae. It is here that exchange of gases takes place through the thin walls of the lamellae. Air enters the lamellae through diffusion.
2. Respiration is an essential physiological activity of all living organisms for obtaining energy to carry out various metabolic activities of the body. In molluscs respiration takes place through gills.
3. Multicellular animals with high metabolic activity usually have respiratory pigments. These pigments are also called chromoproteins which transport and store oxygen. Besides, these pigments serve as buffers increasing the capacity of blood to carry carbon dioxide. Oxygen dissolves in blood and other body fluids in accordance with physical laws. The respiratory compounds in the body fluids of animals are of four types (i) haemoglobin, (ii) haemerythrin, (iii) haemocyanin and (iv)

chlorocruorins. The process of combining with oxygen is termed oxygenation whereas that of releasing oxygen is called deoxygenation.

4. There are two types of circulatory system found in higher metazoans. In open type the original blastocoel continues to be the main perivisceral space. There is neither true coelom at all as in pseudocoelomates or the coelom may be highly obliterated or reduced. In these animals there are no closed network of capillaries connecting the arteries and vein. Whereas in the other type, a system of closed capillaries connect the smaller arteries with veins, fluid containing nutrients filter through the capillary walls into tissue spaces from which cells in turn derive their nutrients. This is called closed type of circulatory system.

# UNIT 11 NERVOUS SYSTEM AND SENSE ORGANS

## Structure



## 11.1 INTRODUCTION

You have by now studied that non-chordates also carry out a variety of activities such as feeding, digestion, locomotion etc. For this purpose, they have corresponding organs and organ systems working in a coordinated way. Moreover, the environment of the animal, both internal and external, is never stable and the animal has to change its activities in relation to the changing environmental conditions. This includes escape from adverse climatic conditions or from a pursuing predator, catch food to overcome hunger, digest the food for energy requirements, excrete waste material, regulate the respiratory rate and so on. Towards this purpose, the concerned organs have to be coordinated in an efficient and purposeful manner. This is brought about mainly by the nervous system.

Necessarily, the animal has to perceive any change in the environment, compute the changes and ultimately translate these computations into requisite actions in a manner most profitable and adaptive to the animal. Towards this goal the nervous system has receptor components consisting of sense organs, coordinating centres in the central nervous system and the motor components controlling the motor elements. The system is connected throughout so to say, by cables of nerves through which messages or impulses flow as if on a telegraphic system. The receptor organs receive messages from the environment, which are transmitted to the central nervous system. The central nervous system is the decision centre, which sends requisite orders to the effector organs through motor neurons. Before you proceed to study this unit, you will have to go through the unit on physiology of the nervous system, to have a clear understanding of the working of the nervous system. In the present unit you will study essentially how the basic component of the nervous system, the neuron, has become specialised into sense organs, and how some of the neurons have got concentrated into central nervous system for effective control and coordination, during the process of evolution of non-chordates.

### Objectives

After reading this unit you should be able to:

- name the basic unit of the nervous system,
- differentiate the three structural types of neurons,
- describe the chief variants of mechanoreceptors of non-chordates and point out how they function,
- distinguish between olfactory receptors and contact chemoreceptors of insects,
- illustrate the parallelism in the structure of the cephalopod eye and vertebrate eye,
- elucidate what is nerve net and why it is supposed to be the primitive condition,

- describe how the central nervous system has originated and trace its evolution among non-chordate metazoans,
- explain what giant fibre is, and
- briefly point out how information processing takes place in the central nervous system.

## 11.2 ORGANISATION OF NERVOUS SYSTEM

Nervous systems are composed of nerve cells or neurons and glial cells. In the latter half of the 19th century it was strongly believed that nervous systems are composed of complex, continuous meshworks of cells and processes in protoplasmic continuity with each other. This theory was known as the reticular theory and it was strongly supported by Golgi's School. However, during early 20th century this theory was gradually superseded by the **neuron doctrine**. The champion of the neuron doctrine was Cajal, who demonstrated convincingly that neurons do not physically join or continue with one another but are closely apposed at synapses. The debate on continuity versus contiguity persisted until 1950s, when electron microscopy permitted resolution of cell membranes at neuronal endings, thereby demonstrating discontinuity of neurons. The neuron doctrine is the cornerstone of our understanding of nervous system. According to this doctrine, neurons are discrete cells forming the basic units of the nervous systems.

### 11.2.1 NERVE CELL : THE BASIC UNIT

The basic unit of the nervous system is the nerve cell or neuron. A neuron is to the nervous system what a brick is to the building. It has a cell body known as perikaryon and one or more processes known as neurites. You will see that, functionally, there are three types of neurons. Certain neurons are specialised for perceiving changes in the external or internal environment and transforming or transducing these stimuli into nerve impulses. We call them sensory neurons. Some neurones are specialised for receiving nerve impulses from other neurones and transmitting these impulses to effector organs like muscles or glands. These neurones are called motor neurones. Usually, intervening between sensory neurons and motor neurons are one or more association neurons. Association neurones receive impulses from sensory neurones and other association neurons. They also transmit impulses to other association neurons and motor neurons. Thus one or more association neurons may intervene between sensory neuron and motor neuron. However, sensory neuron may also transmit impulses direct to motor neuron.

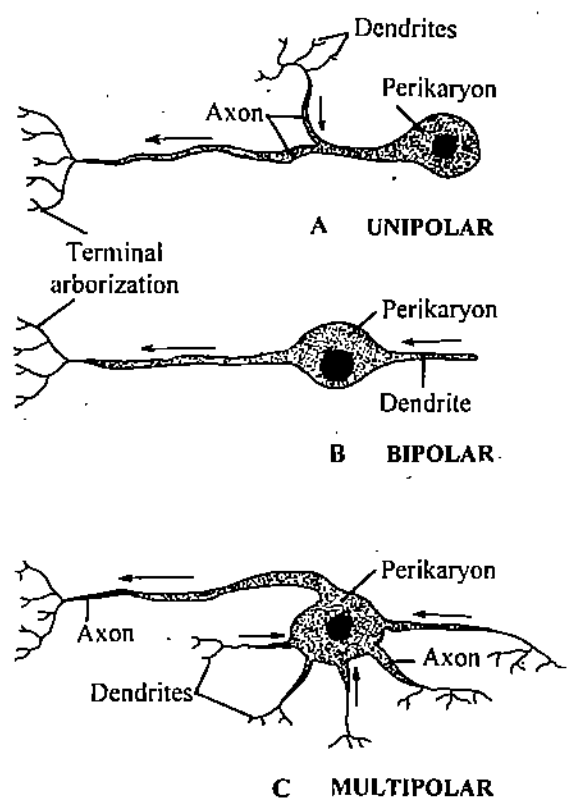


Fig. 11.1: Neurons found in the insect nervous system. Arrows indicate direction of impulse conduction.

You have studied above that neuron has usually one or more neurites. Of these, dendrites usually conduct impulses towards perikaryon. From the perikaryon, impulses are generally transmitted away, through the axon. So you will see that it is the direction of impulses travelling along a neurite which determines whether it is a dendrite or an axon.

Structurally, it is customary to categorise neurons into three: unipolar, bipolar and multipolar (Fig. 11.1). Unipolar neuron has only one neurite arising from the perikaryon and that is the axon. Dendrites join it as collaterals. By far most of the neurons of invertebrates belong to this category. They may be motor or association neurons. Bipolar neurons have two neurites, one being the dendrite and the other, the axon. Sensory neurons are bipolar.

Multipolar neurons have more than two processes connected with the perikaryon, one of which is the axon and the others are dendrites. These are association neurons. Most metazoan axons are surrounded by a thin sheath cell (Schwann cell) membrance. They, however, lack the so-called thick whorls of myelin sheath characteristic of many vertebrate axons (Fig. 11.2 A and B).

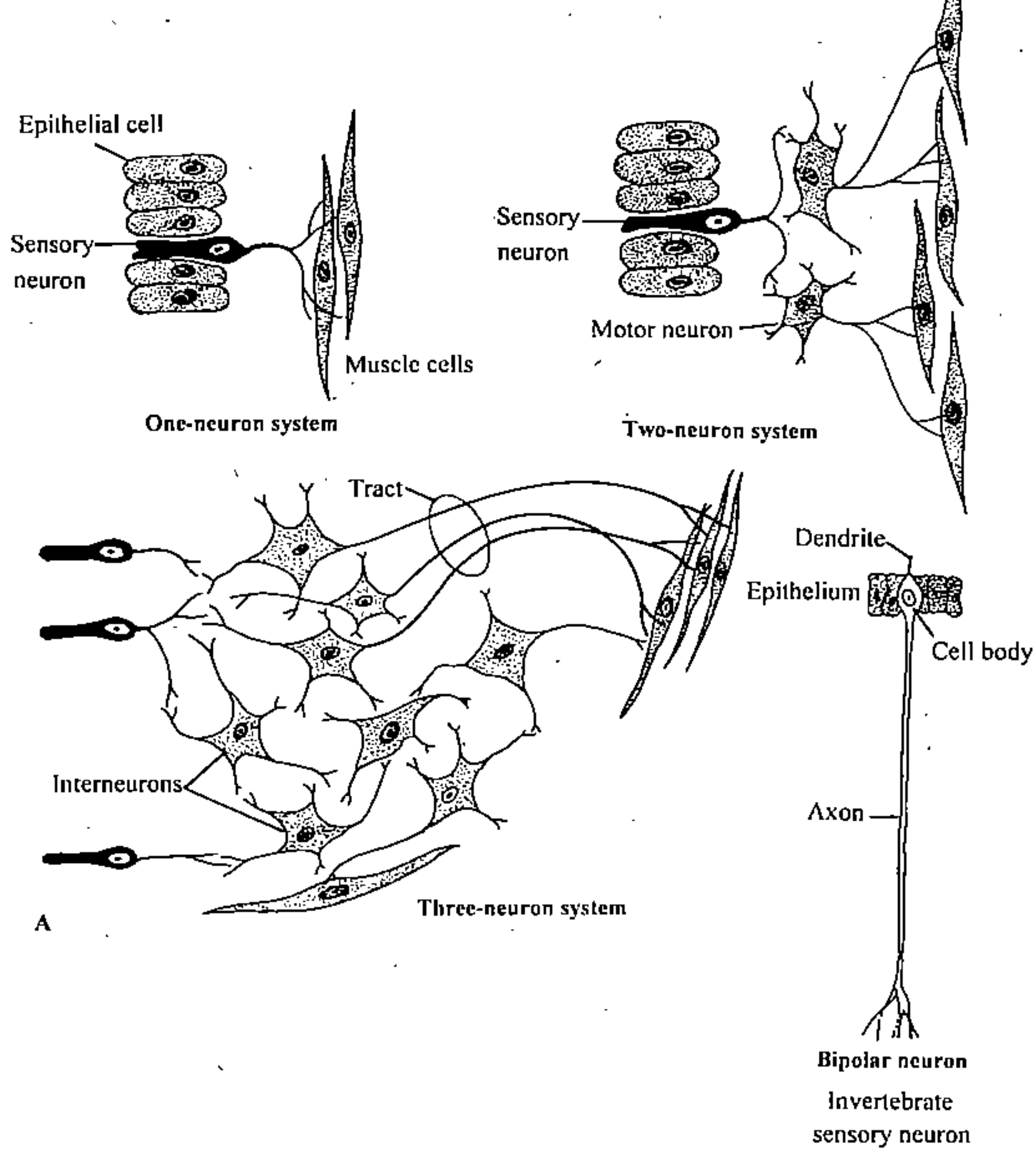


Fig. 11.2: A. Drawings of neuronal organizations found in cnidarians and insects.

## 11.2.2 NEUROGLIA

We may consider neuroglia as the connective tissue of the nervous system. It includes all elements of the nervous system other than neurons. You will see that neuroglia fills the space among the neurons and extends processes into the central region of the ganglia (neuropile). It also includes the covering of the ganglia (perineurium) with the outer, non-

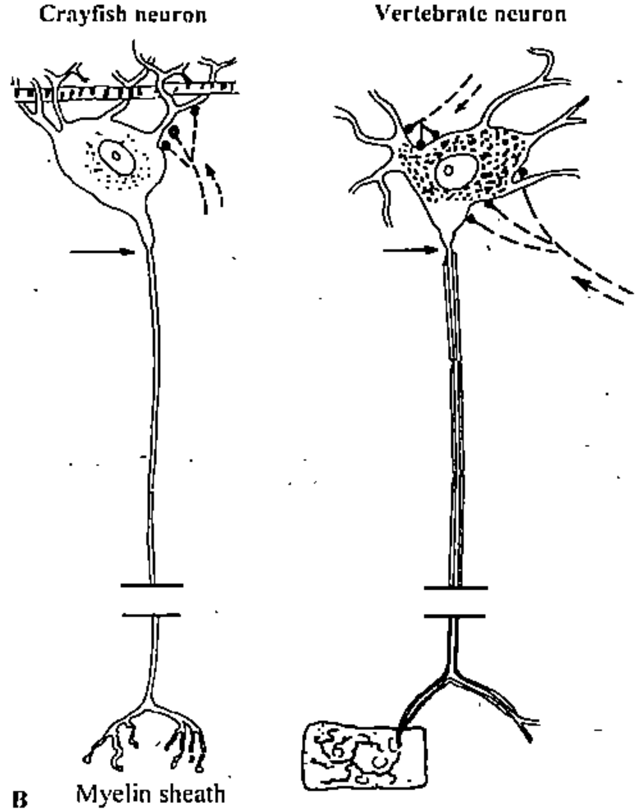


Fig. 11.2 B. Non-chordate neuron and a vertebrate neuron.

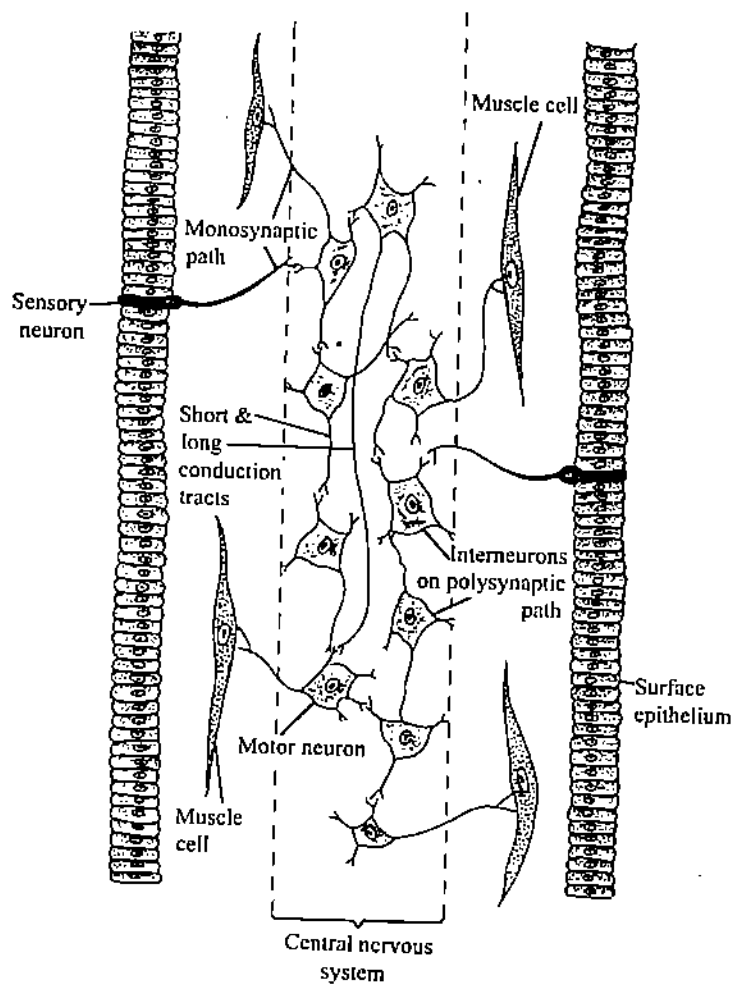


Fig.11.3: A drawing of the neuronal organization in a primitive worm with a central nervous system.

cellular, fibrous neurilemma or neural lamella. These coverings, though thin, extend along the nerves too. The Schwann cells too form part of the neuroglia.

### 11.2.3 GANGLIA

Among higher non-chordates with a central nervous system, you will see that the association neurons and motor neurons are concentrated in masses called ganglia, and the bipolar, sensory neurons are distributed peripherally in association with sense organs (Fig. 11.3). Invertebrate ganglia have a cellular rind or cortex and a central mass called neuropile (Fig. 11.4). The neuropile is made up of nerve fibre mass, criss crossing in all directions. Axons of sensory neurons terminate in the neuropile and those of motor neurons arise from it.

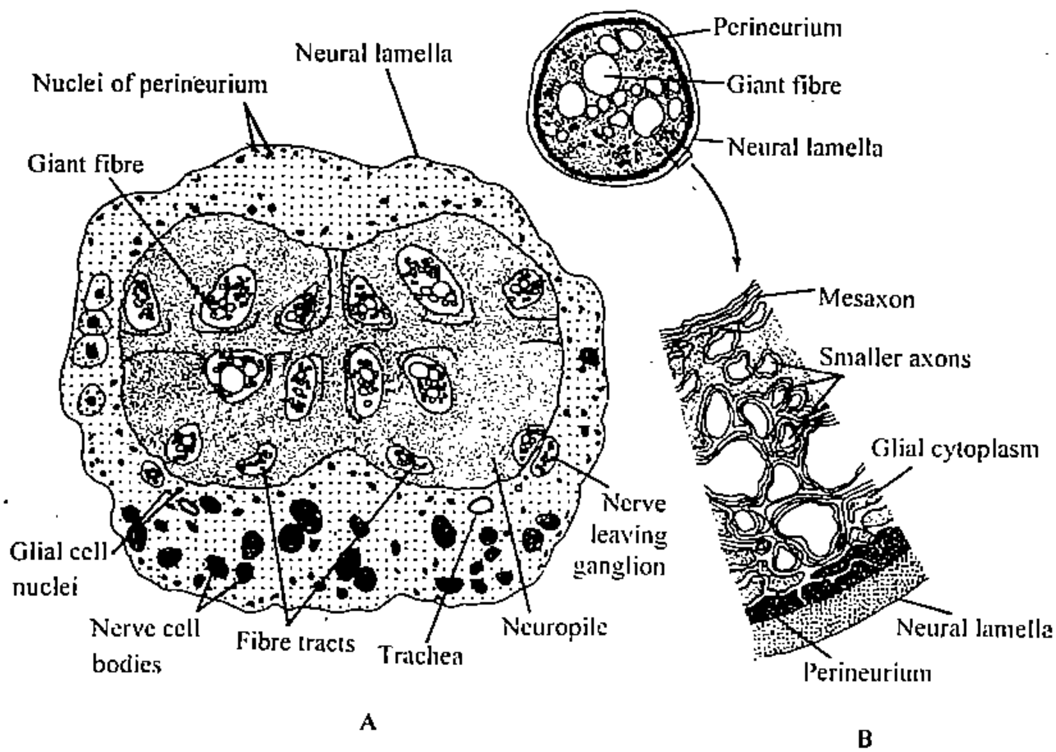


Fig.11.4: Cross sections through (A) abdominal ganglion and (B) interganglionic connective to show general structure.

### 11.2.4 NERVES

Because of the pattern of distribution of neurons as described above, there are bundles of nerve fibres, called nerves, connecting the central ganglia on the one hand, and sensory neurons or the effector organs on the other (Fig. 11.3). The nerves may contain sensory, motor or both types of fibres, and depending upon this the nerves may be sensory, motor or mixed respectively.

Similarly, there are connectives running between ganglia of the same side, and commissures between ganglia of the opposite side. They mostly contain association fibres.

### SAQ 1

Draw a diagram involving sensory, motor and association neurons to show possible pathways of transmission of an environmental stimulus resulting in motor action.

### SAQ 2

Given below are structural and distributional characteristics of sensory, motor and association neurons. Choose most appropriate structural and distributional characters.

| Type of neurons | I. Structural Characters | II. Distributional Characters |
|---|---|---|
| i) Sensory neurons | a) unipolar | A. Peripheral |

| | | |
|---|---|---|
| ii) Motor neurons | b) bipolar | B. Central (within ganglia) |
| iii) Association neurons | c) multipolar | |

## 11.3 PRIMITIVE NERVOUS SYSTEM: THE NERVE NET

A nervous system makes its appearance for the first time in the phylogeny among Cnidaria. In this group the nerve cells form an irregular nerve net or plexus (Fig. 11.5). In hydras we have a simple condition. The nerve net is made up of bipolar or tripolar and rarely multipolar neurons. The sensory nerve cells are distributed among the epithelial cells; they send their nerve fibres to the subepithelial nerve plexus. The plexus is situated beneath the epidermis. In hydroid polyps the plexus is concentrated around the mouth, suggesting the beginning of a centralised nervous system. Many cnidarians have more complicated nerve nets; for example they may have also a gastrodermal nerve net within the gastrodermis in addition to the epidermal nerve net as in sea anemones. A double nerve net in the same body layer is also common in some coelenterates. There is quite a lot of autonomy, in that, isolated parts of the animal behave as if parts of the body. There is no central controlling mechanism apparently because there is no distinct central nervous system. It is also poor in specific responses to particular stimuli. Transmission is unpolarised, in that impulse can be transmitted in either directions along the synapse unlike in higher animals. This happens because both terminals secrete transmitter substance. Thus the nerve plexus in this group shows diffuse, unpolarised transmission, autonomy of parts and scarcity of reflexes.

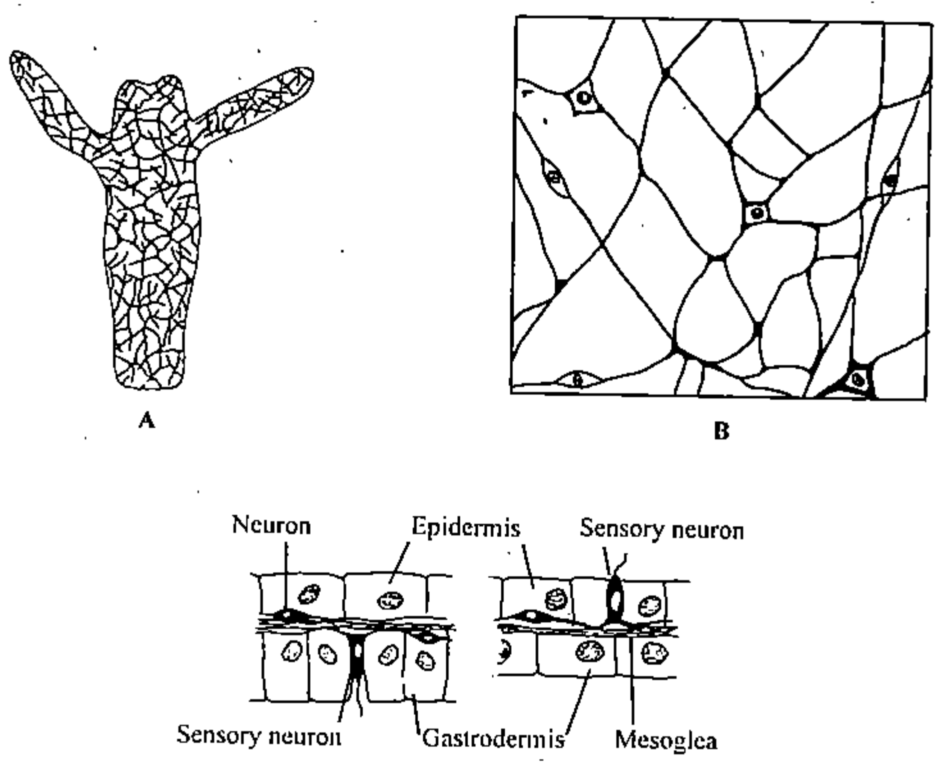


**Fig.11.5: A. The nerve net of *Hydra* and other cnidarians is the simplest organized nervous system. No central control organ and no definite neural pathways are present; B. Surface view of a cnidarian nerve net (details of synapses not shown); C. Body wall of *Hydra* showing nerve nets in both epidermis and gastrodermis. Sensory neurones are restricted to the gastrodermis in the column (left), and to the epidermis in the tentacles (right).**

Before studying the nervous system of echinoderms, you have to bear in mind the peculiar organization of these animals. Here also, the nervous system is primitive, retaining the nature of the network pattern beneath the surface epithelium. The epithelium itself is strewn with sensory cells. The network is however, concentrated into ganglionated nerve cords. These retain the general radiate pattern of the group. You will see three systems here:

(i) The oral or the ectoneural system beneath the oral epidermis, made up of a ring around the oesophagus and a ganglionated strand extending from this ring along each arm (Fig. 11.6). Each cord is made up of tracts of fibres. This is the main system in most echinoderms.

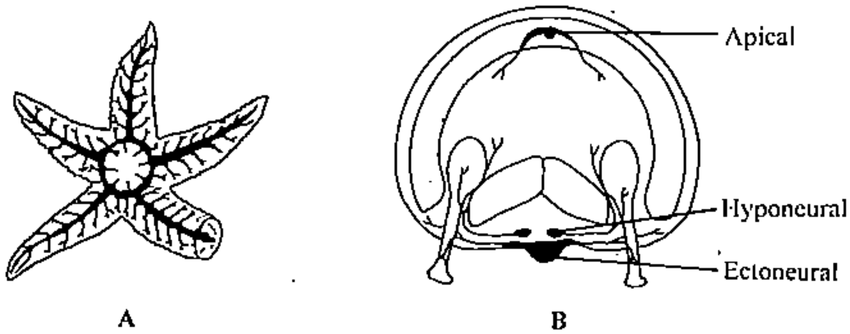


**Fig. 11.6: Sea star A. The nervous system consists of a central ring with major nerves radiating into each arm. B. Cross-section of the starfish arm. Nerve fibres from the ectoneural system terminate on the surface of the hyponeural system but there is little or no direct contact between the two systems.**

(ii) The deeper hyponeural system and

(iii) The aboral or apical system are weaker but organized on the same pattern as the ectoneural system. Thus it is simple in structure and with close relationship with the epidermis, lacking ganglia or brain. However, it has undergone certain amount of concentration, with circular and longitudinal cords. This marks the beginning of a central nervous system.

## SAQ 3

Given below are some characters of echinoderm nervous system. Point out advances (A) or similarities (S) of the system compared to that of coelenterates, by denoting respective alphabets against each character.

The system a) has close relation to epidermis; b) lack ganglia or brain; c) has undergone some amount of concentration with circular and longitudinal cords.

# 11.4 ADVANCED NERVOUS SYSTEMS:GENERAL TREND IN EVOLUTION

In higher groups of animals you will notice clear trends towards centralisation of the nervous system, to maximise efficiency. The diffuse peripheral network becomes less conspicuous or unrecognizable giving place to nerves made up of nerve fibres. The motor neurons and association neurons become mostly concentrated and centralised into masses known as ganglia. The increasing dominance of the association neurons which are the links in reflex pathways, makes possible more complex central pathways which form the structural basis of advances in integration. The sensory neurons become relegated to the periphery. This results in differentiation of functional tracts of neurites and nerves through which stimuli are brought to and carried out of the central nervous system. Thus better association or integration of afferent sensory stimuli with meaningful efferent motor outputs become possible, resulting in more intricate and efficient behavioural patterns. Perikarya become limited to the rind or cortex of the ganglia, the interior being made up of nerve fibre mass called neuropile in which conspicuous pathways or tracts already evident in the lower groups, become developed. The development of giant fibre system associated with the central nervous system further enhances the efficiency resulting in enhanced speed of propagation of impulse and hence efficiency of response to stimuli. With one end of the animal always directed forward during locomotion, an anterior end and bilateral symmetry become established. The anterior end becomes more important with most sensory organs becoming associated with this end. Naturally, the ganglia become better developed and more highly organised in this region, giving rise to the structurally and physiologically more complicated brain dominating over the whole organism. This is the direct result of cephalisation.

Now, we will discuss about the trend of development in the nervous system in different phyla of the invertebrates.

### 11.4.1 PLATYHELMINTHES

Among Platyhelminthes, you will see that turbellarians have a brain and three to five pairs of longitudinal nerve cords extending from the brain to the posterior end (Fig. 11.8). They are positioned along dorsal, lateral and ventral aspects. The cords are connected together by means of commissures. The commissures are in turn connected to a submuscular nerve plexus. The system is thus not only sunk deeper into the submuscular position, but it does not correspond to the real primitive plexus at all. The motor and association neurons are mostly confined to the brain and the cords all along their periphery surrounding the central neuropile. One pair of these longitudinal cords become conspicuous, the others tending to become weaker ultimately disappearing thus giving rise to the typical ladder like nervous system.

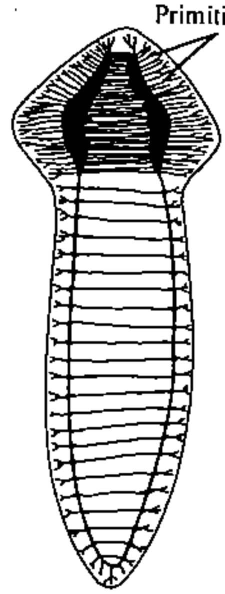


Fig. 11.7: Planarian flatworms have a ladder-type nervous system. Cerebral ganglia in the head region serve as a simple brain and, to some extent, control the rest of the nervous system.

With the development of the central nervous system, movements become more co-ordinated. Parts of the animal can maintain spontaneous movements and show co-ordination of responses in most species of this group, only if it contains portion of the nerve cord. The brain appears to have started exerting a dominating influence in this group.

### 11.4.2 ANNELIDS AND ARTHROPODS

From the ladder-like nervous system of Platyhelminthes is derived the metamerically arranged nervous system of annelids and arthropods (Fig. 11.8). Neurons become concentrated metamerically into ganglia, instead of being distributed throughout the periphery of the longitudinal cords. Anteriorly the cords continue as circumoesophageal connectives which end dorsally into a brain made up of cerebral ganglia. The two longitudinal ladder-like cords present in certain annelids and in some primitive crustaceans show a tendency to come closer together. Ultimately the metameric ganglia of the two cords fuse into a single ganglionic mass in each metamere. The two cords may even completely fuse together into a single cord having lost all indications of their double nature externally.

From each ganglion, varying number of paired nerves are given off. There may be further concentration by fusion of the ganglia in different groups of animals.

In **Polychaetes**, the brain is in the prostomium and may extend back through the anterior few body segments. The ventral nerve cord extends through the length of the body. The brain is better developed, with sensory centres, because of the presence of the well-developed sense organs like palps, antennae, eyes and nuchal organs. However, in leeches and earthworms lacking well developed sense organs on the head, the brain is less developed. In the leeches, there is the nerve ring and there are also two ventral nerve cords but each pair of ventral ganglia is fused. In oligochaetes also the brain is shifted a few segments posteriorly; the ventral nerve cords are however fused into a single nerve cord.

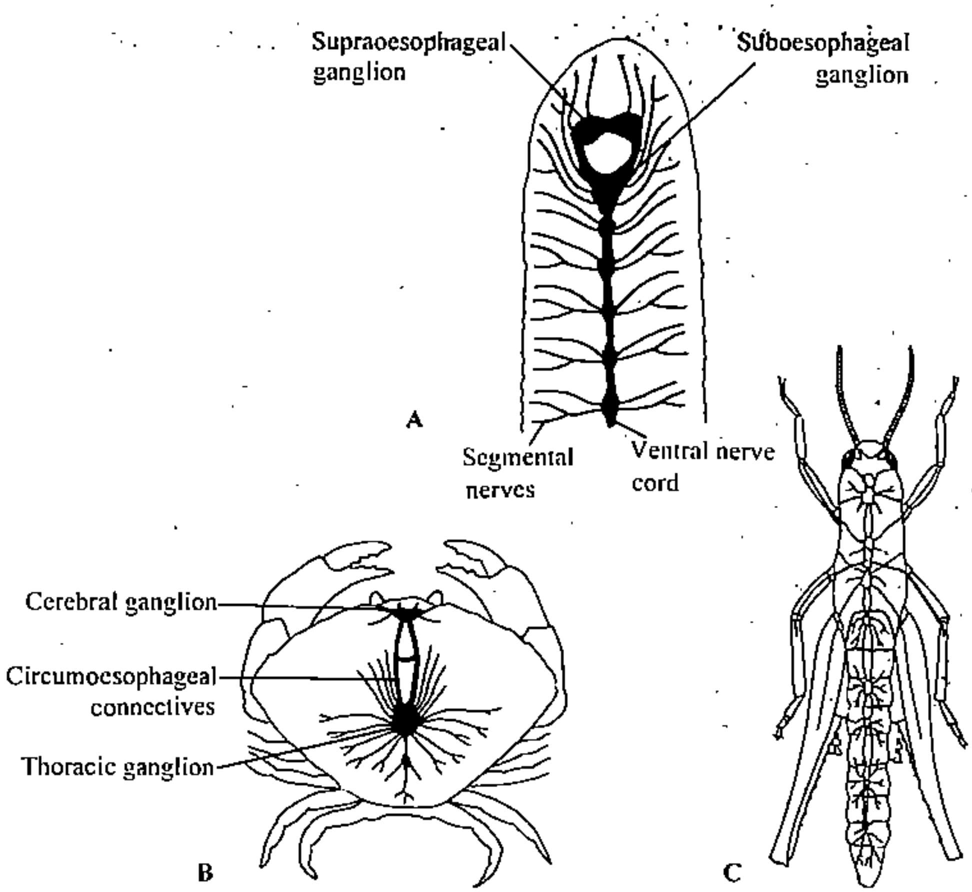


**Fig.11.8: A. The segmented ventral nerve cord in leeches is made up of well-differentiated ganglia, containing the cell bodies, and connectives composed of nerve fibres. The sub-oesophageal ganglion is derived from a number of segmental ganglia. B. Highly condensed central nervous system in a decapod crustacean. C. Nervous system of grasshopper.**

In arthropods there is a higher degree of cephalisation. The brain becomes comparatively larger with better developed sense organs on the head, like eyes and antennae. The brain has mostly three regions: the anterior protocerebrum, the middle deutocerebrum and the posterior tritocerebrum, with well developed sensory, motor and association centres.

### Motor Control

In annelids and arthropods in general, individual metameric ganglia of the ventral nerve cord are capable of initiating and maintaining locomotor movement in the concerned segment. The suboesophageal ganglion exerts a control over these; in fact it keeps the animal in hyperexcited condition. The brain on the other hand exerts a moderating influence on the suboesophageal ganglion and suppresses the concerned centres in the suboesophageal ganglion. Thus many of these animals show hyper excitability and an increased tendency for locomotion when their brain is removed. On the other hand, when their suboesophageal ganglion is removed, locomotion is considerably inhibited or even stopped.

## SAQ 4

What are the main trends in the evolution of the nervous system? Give four points.

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## 11.4.3 MOLLUSCS

You will see that the central nervous system of different molluscs has reached different degrees of development depending upon the adaptive radiation of this group. The molluscan nervous system shows conspicuous difference from that of annelids and arthropods in that it is not metamerically segmented. The primitive system is illustrated by that of **Chiton** (Fig. 11.9A). In this group, as in Platyhelminthes, though there is centralisation, there is very little concentration of nerve cells into ganglia. Even cerebral ganglia are lacking. But there is a nerve ring with longitudinal nerve cords consisting of pedal cords along foot and pallial cords innervating the mantle and the visceral mass, with transverse commissures forming ladderlike nervous system. The pair of buccal ganglia concerned with movement of radula are the only ganglia in these animals. Otherwise the nerve cells are scattered along the ring and cords.

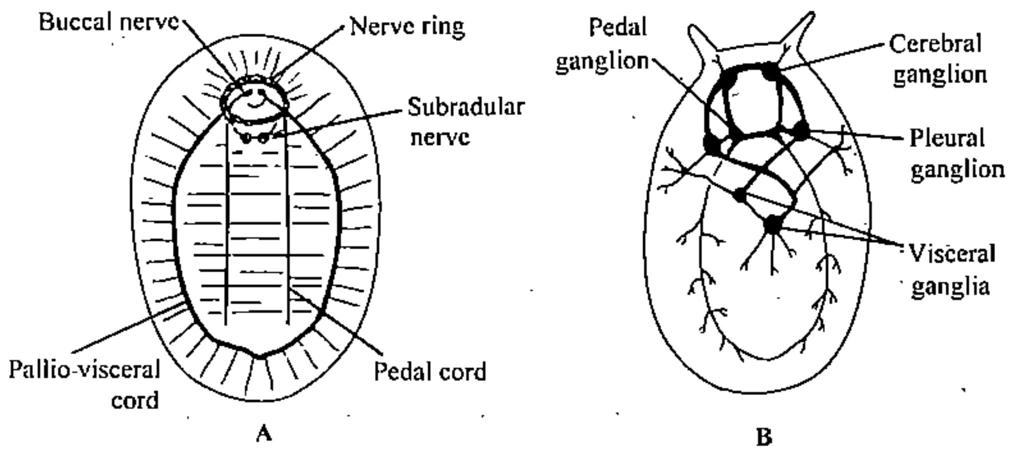
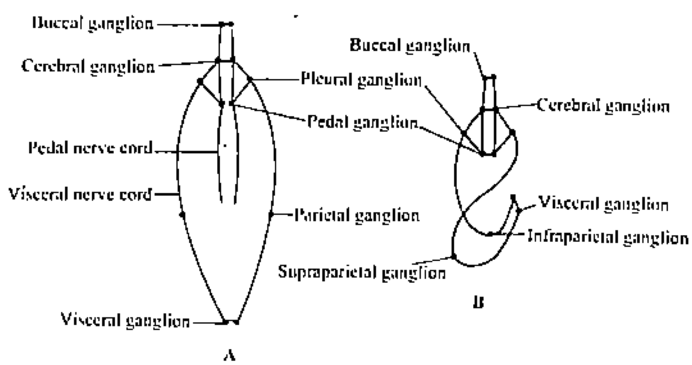
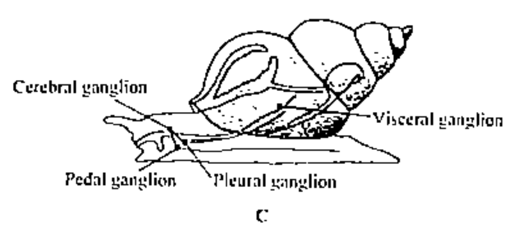



**Fig.11.9: A. Nervous system of Chiton, B. The mollusc, Patella, showing the principal ganglia and torsion of the visceral connectives.**

From this condition, the central nervous system has not increased very much in organization either in gastropods or bivalves, which are mostly rather inactive animals resorting to retreat in their shells. In gastropods (Fig. 11.11B) a pair of pleural ganglia



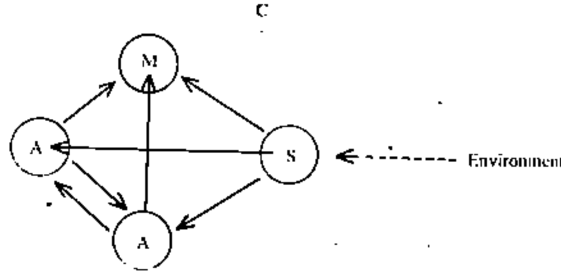




**Fig.11.10: A, Hypothetical pretorsion nervous system. B, Posttorsion nervous system. C, Lateral view of gastropod showing position of nervous system.**

appear at the anterior end of the pallial cords. The pallial cords form a visceral loop with a pair of parietal ganglia and visceral ganglia. Further concentration of nerve cells led to a pair of cerebral ganglia in the nerve ring and a pair of pedal ganglia, with pedal cords disappearing. The torsion of gastropods results in twisting of the visceral loop, the original left and right parietal ganglia becoming the subintestinal and supraintestinal ganglia (Fig. 11.10). Higher gastropods show an increasing trend in further concentration of the ganglia. Thus the subintestinal ganglion and the supraintestinal ganglion are drawn into the main nerve ring, resulting in shortening of the visceral loop. In **Opisthobranchia**, reversal of torsion (detorsion) leads to untwisting of the nerve loop.

The predatory and active swimming modes of life and locomotor dexterity of cephalopods have led to a high degree of cephalization among this group. The sharp sense of sight and touch has resulted in development of corresponding centres in the brain. The organization of the brain in cephalopod has attained perhaps an unparalleled level among invertebrates (Fig. 11.11). All of the ganglia characteristic of the molluscan central nervous system are concentrated and more or less fused into a brain encircling the oesophagus. As a result in *Octopus* for example about thirty lobes of the brain have been recognised, each with a layer of nerve cells and a central mass of neuropile, concerned with definite functions.

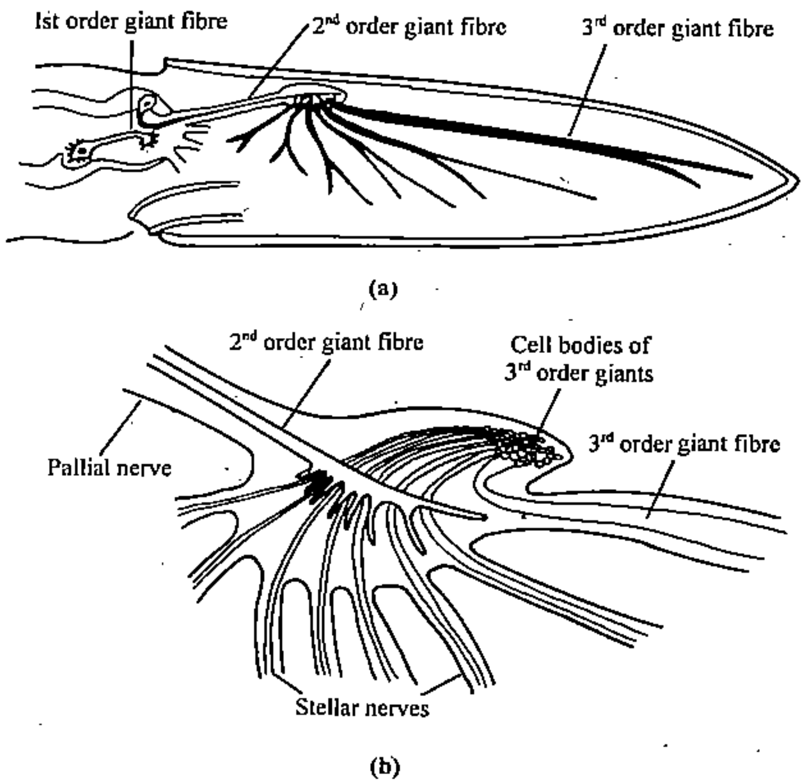



Fig. 11.11: (a) The giant fibre system of the squid *Loligo pealeii* and (b) the synapse in the stellate ganglion.

## 11.5 GIANT NERVE FIBRES

We now know that giant nerve fibres (Fig. 11.11) occur in the central nervous system of many polychaetes, oligochaetes, insects cephalopod etc. They are broader and longer than the other, ordinary nerve fibres which are about 2 μm or so only in diameter. In the squid, they may attain a diameter of 700 μm or even more. Their size makes them ideal material for electrophysiological studies, as recording electrodes can be inserted inside the axons and action potentials measured. They are of immense advantage to the animal because, with the increase in diameter of the axon, resistance for propagation of action potential is decreased, whereas velocity of propagation is increased. They conduct for longer distances with fewer or no synapses which also further facilitates conduction. On the whole they are pre-eminently suited for rapid conduction. These fibres are involved in escape reactions of the animal. The squid for example is rapidly propelled in water by expelling the water within the mantle cavity through the funnel, by rapid and simultaneous contraction of the muscles of the mantle innervated by the giant fibres using the principle of jet propulsion. The animal can escape from its enemies by this method within a fraction of a second.

## 11.6 INFORMATION PROCESSING

You have already seen that the sensory neuron transmits the information it receives, as an action potential along its axon. We call them an impulse. The intensity of the stimulus is transmitted along the nerve fibre by changing frequency. A stimulus of greater intensity will result in greater frequency of firing along the axon, one of lower intensity will have lower frequency. Let us see what happens when one of the first pair of legs of a cockroach is touched. Stimulation of the mechanorecepors of the first leg of a cockroach by touch will be carried by the axon to neurons in the first thoracic ganglion where it makes connection, in simplest case, through synapse, with a motor neuron directly. In more complicated cases, the motor neurone may be informed through one or more association neurons. These neurons may be receiving at the same time a number of other stimuli from a large number of presynaptic fibres. Some of them may be excitatory and some of them may be inhibitory, thus carrying opposing instructions. This type of connection also enables higher centres of the central nervous system to exert control over the action, so that, if inappropriate, it can withhold from exercising the reflex, like running away. Thus the postsynaptic cell receiving often contradictory messages, decides whether to fire or not, on the basis of all the instructions it receives. In case the neuron 'decides' to fire, the stimulus can result in the release of neurotransmitter at its terminals making the concerned muscle to contract, causing movement of the leg and the animal run away.

This kind of receptor-effector loop is the lowest level of information processing by central nervous system and is called a reflex. In lower animals this constitutes their entire behaviour. However, in higher animals especially in those like cephalopods and insects, with a well developed central nervous system, varying degrees of higher levels of control are exerted on the reflexes, with increasing hierarchy of the central nervous system exerting its influence. These animals have larger and complex type of brains by invertebrate standards; their large eyes and other sense organs feed a variety of stimuli into the brain. There are various motor centres in the central nervous system ultimately controlling activities through various motor centres. For example, thoracic ganglia of insects are under the control of suboesophageal ganglion; the suboesophageal ganglion in turn is under the control of the brain.

We must not forget that most animals have also the capacity of learning. Learning provides the animal with a record of information on which it can draw and act. The memory provides this information and the central nervous system can select the motor activity best suited for the animal's life.

## 11.7 RECEPTORS

In the previous sections you have studied how the nervous system is organised. Now you will study in detail, more about the receptors.

### 11.7.1 PROPERTIES OF RECEPTORS

The receptors collect information about the change in the environment such as temperature, illumination etc. In lower animals, sensory perception is mediated through undifferentiated nerve endings. These are their sense organs. However, the receptors or sense organs become more specialized and elaborate. Such elaborate sense organs are present even in Cnidaria, and they become more complicated in higher animals. You have already seen that sensory receptors convert one form of energy into another, electrical. So all receptors are transducers. Even one molecule of odour substance is often capable of evoking a small electrical disturbance in a chemoreceptor. This local current is usually the result of amplification too, and is propagated along the axon of the sensory receptor. The receptor is thus extremely sensitive to change in the environment. You have to also note that each sensory receptor responds to only one kind of stimulus. For example, chemoreceptors will respond to only chemical stimuli, but not to mechanical or light stimuli. Another important fact you have to bear in mind is that the frequency of nerve impulse increases with strength of the stimulus. In other words, information regarding intensity of the stimulus is transmitted by frequency code. Thus the code of information travels as impulse in axons of all receptors, be it mechanoreceptor, photoreceptor or chemoreceptor. But because each type of receptor is sensitive to one type of stimulus only and because these axons carry impulses to particular regions of the central nervous system, brain correctly interprets the information reaching it. Depending upon the type of stimulus, receptors may be divided into mechanoreceptors, chemoreceptors and photoreceptors.

## SAQ 5

1. A moth : (Write "Yes" or "no" against each capacity)
   a) sees a flower;
   b) hears the sound produced by a bat;
   c) smells its mate.

2. Do you think:
   i) the three pieces of information will reach the brain of the moth as electrical impulse? (Yes/No)
   ii) the moth will recognize the three objects above, even if the nerves concerned are severed from the brain? (Yes/No)
   iii) the moth will recognize the three objects above correctly, even if the nerves concerned are connected to the brain improperly (for example, optic nerves to antennal centre; antennal nerves to optic centre, and auditory nerve to optic centre) ? (Yes/No)

### Mechanoreceptors

Mechanoreceptors include those receptors involved in perception of touch, pressure, tension, hearing, vibration, gravity, muscle tension etc. These would appear to us at first sight as rather heterogeneous assemblage of sensations, but the basic mechanism involved in the perception of all these is the same: they are all sensitive to contact with objects and are mechanically deformed temporarily by all the above stimuli. In the simplest case, they involve free nerve endings on the body surface. But often mechanoreceptors are more complex.

A mechanoreceptor of wide occurrence in the nonchordate metazoans is the **statocyst** (Fig. 11.12). It is primarily an organ concerned with perception of gravitational force and is a balancing organ found in almost all phyla, including coelenterates. It consists essentially of a particle of calcium carbonate called statolith. The statolith is carried in a vesicle lined by a layer of sense cells which have hair-like processes. The statolith rests on the sense cells. The vesicle is of course filled with a fluid. The animal can appreciate the direction of gravity or tilt, from the sense cells on which the statolith comes to rest.

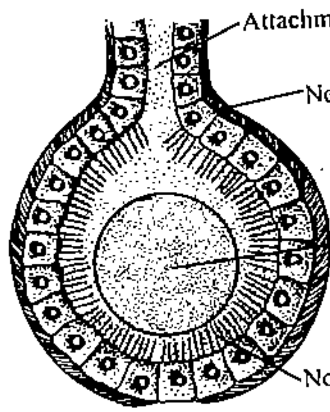



Fig.11.12: Gravitation and equilibrium receptors. A. A statocyst of a mollusc.

In insects, as in other arthropods, since the body surface is covered by a rigid cuticle, mechanical sensation should be transmitted through cuticle to the sense cell situated within the body. In the **trichoid sensillum**, for example, a bristle or seta is articulated in a socket. The tip of a sensory cell is attached to the base of the seta (Fig. 11.13). The movement of the seta generates an impulse in the sensory cell.

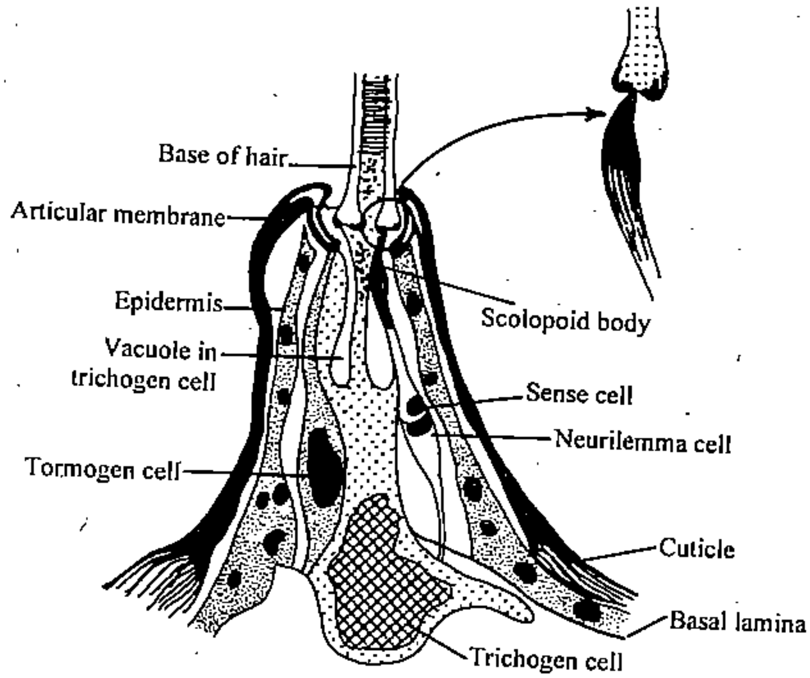



**Fig.11.13: Simple trichoid sensillum.**

On the other hand, in the case of **campaniform sensillum** of insects (Fig. 11.14) there is no projecting hair. It consists of a small elliptical, thin, dome like, arched, cuticular area with a thickening or rib along its long axis. To the middle of this is attached the sense cell. The campaniform sensilla are distributed widely in insects, especially at the base of wings and on legs, in groups. Mechanical deformities of the cuticle cause slight bulging of the roof of the sensillum outward pulling the hair and stimulating it.

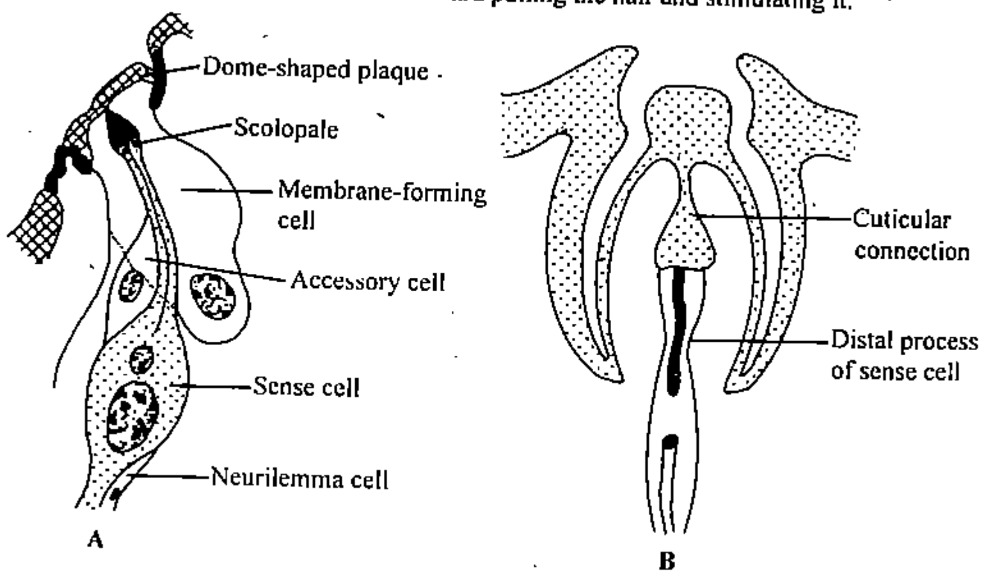



**Fig.11.14: (A) Campaniform sensillum and (B) section through tip of campaniform sensillum to show stiffening rod of cuticle running along cuticular plate present in some species.**

**Stretch receptors** (Fig. 11.15) capable of perception of muscle tension or stretch are distributed in the connective tissue associated with muscles of many groups of animals. This consists of a multipolar neuron with free nerve endings embedded in the fibrous connective tissue. Stretch of the muscle is capable of stimulating this receptor.

Many insects have a fine membrance or tympanum stretched across a cavity with air on both sides. In the locust (Fig. 11.16), for example, a pair of such tympanal organs are present in the first abdominal segment, the inner side of the membrance held over the air sac of the tracheal system. Against the inner side of the tympanum are held a group of mechanoreceptors. Sound waves between 500-11,000 c/s causing vibration of tympanum can generate impulses in the tympanal membrane. You will be surprised to know that many insects like moths are even sensitive to ultrasound which we cannot perceive.

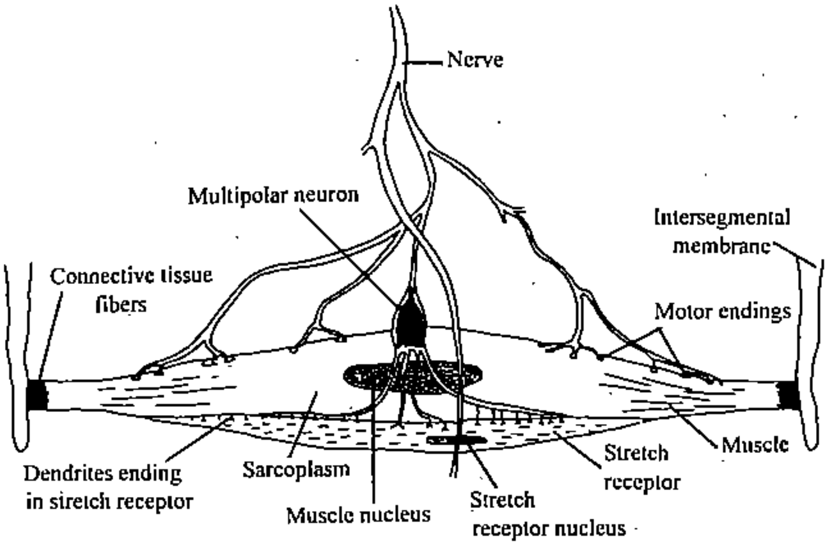
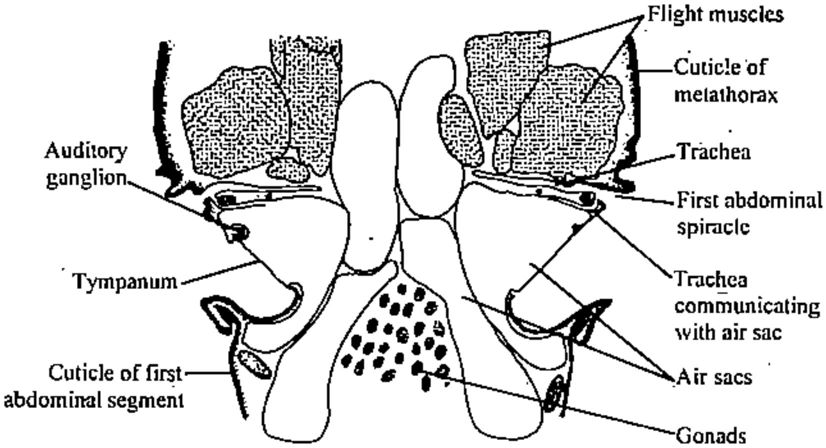
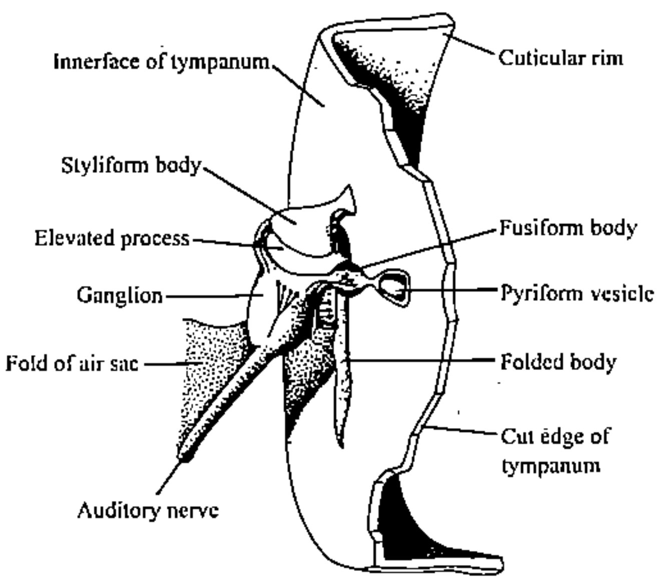



**Fig.11.15: Stretch receptor of male mosquito.**




A




B

**Fig.11.16:** A. Diagrammatic horizontal section through the base of the abdomen of *Locusta*, showing the positions of the tympanic membranes, the air-sacs and the associated spiracles. B. Diagram to show the method of attachment of the auditory ganglion to the inner surface of the tympanum of *Locusta*. The folded body, styliform body and elevated process are cuticular structures. The orientations of the scolopidia are indicated by the arrows.

## SAQ 6

The following are apparently different types of sensations:

1) Sound
2) Touch
3) Gravity
4) Muscle tension

Examine whether it is correct to club the coresponding receptors together as mechanoreceptors? Why?

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(Yes/No)

### Chemoreceptors

These are receptors involved in perception of chemical stimuli. You will see that there are three types of chemoreceptors among metazoans:

i) those concerned with general chemical sense perceived by undifferentiated nerve endings or unspecified receptors. These are distributed all over the surface of the body and are common among lower animals such as cnidarians, worms and molluscs. This is the most primitive type of chemoreceptor and results in escape reaction of the animal.

ii) Chemotactile sense perceived by contact chemoreceptors involving contact with molecules in dilute solution; they are usually present in large numbers in special regions of the body. In mammals these are situated on the tongue and we call the sensation taste or gustation. But in **Octopus** they are concentrated around the rim of the suckers, and in insects they are present on mouthparts and in flies, they are found in abundance also on tarsal segment of foot. So one may say that the fly "tastes with their feet" (Fig. 11.17).

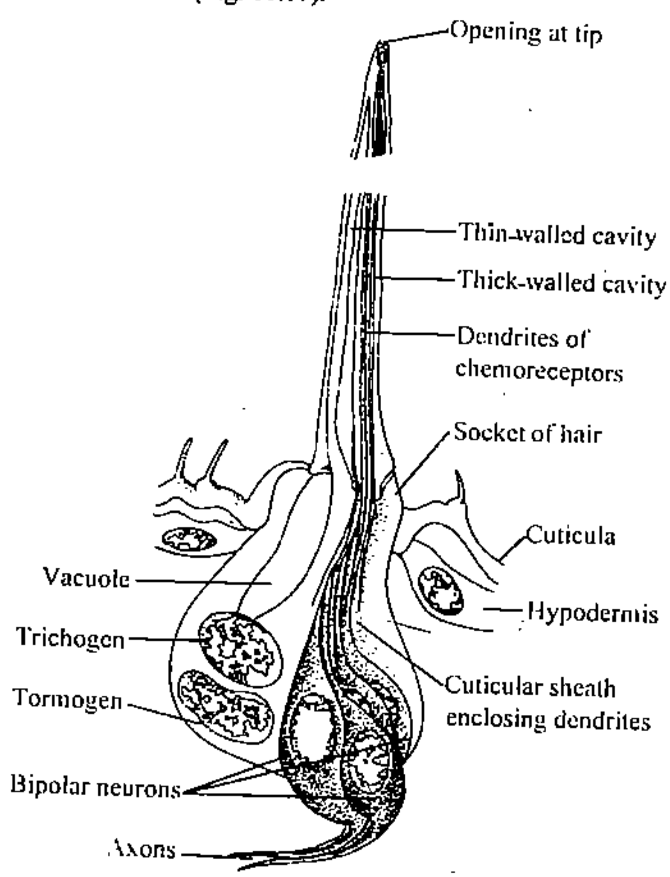


**Fig.11.17: Chemosensory hair (taste receptor) from the mouthparts of an insect.**

iii) Olfaction involves distant chemical sense and is the most sensitive type of chemical sense. Olfactory receptors are capable of perceiving molecules of extremely low concentration in air and we usually call it smell. They are distributed in high density on the antennae of insects. The combined electrical recordings of the antennal nerve produced by the odours on the olfactory receptors of the antennae are termed electroantennograms. Certain insects can recognize their mates even at a distance of a couple of kilometers, from the odour (pheromone) molecules they emit.

You can easily distinguish chemoreceptors structurally with comparative ease among arthropods, especially insects, as they are associated with well differentiated cuticular outgrowths, usually setae, bristles or peg like structures. In them **Olfactory receptors** (Fig. 11.18) often have many sense cells; their dendrites highly branch and end close beneath the surface of the peg in association with large number of tiny pores, in a liquid. The odour molecules from air are dissolved in the liquid, and on capture by the dendrites, set in an impulse in them. Contact chemoreceptors in insects have however a smaller number of sense cells associated with the bristle and their dendrites do not branch but terminate at the tip of the hair in association with a pore. Chemoreceptors play an important role in the life of animals, such as finding food, recognition of mate, selection of oviposition site etc.

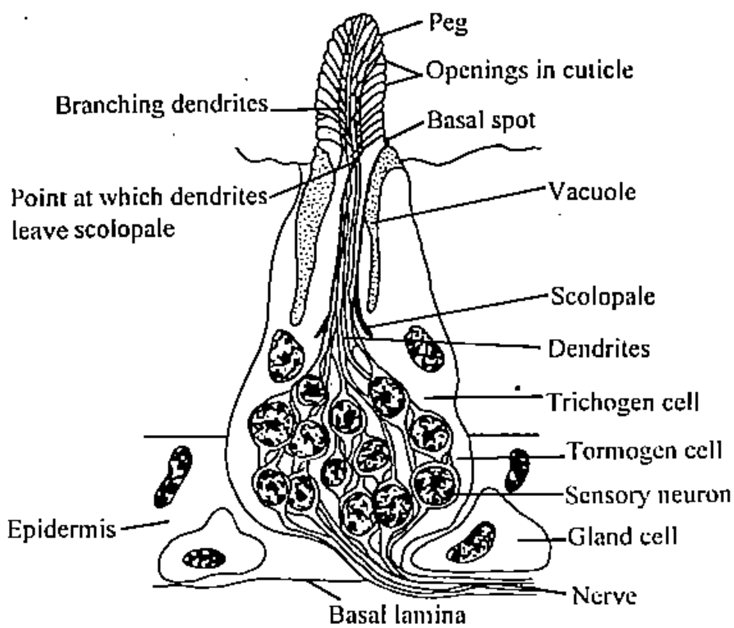


**Fig.11.18: Diagram of a peg-shaped insect olfactory sensillum in longitudinal section.**

## SAQ 7

How would you distinguish between the contact chemoreceptors and olfactory receptors of an insect, structurally?

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## Photoreceptors

Photoreceptors are involved in absorption of light by photosensitive pigments. The chemical change involved generates the impulse concerned in the nerve cells. The pigments involved are carotenoid derivatives consisting of retinine (vitamin A aldehyde) combined with a protein (opsin). Rhodopsin is one of the common pigments.

Simple eyes are very common; highly differentiated compound eyes have evolved in many arthropods, and well differentiated camera type eyes, comparable to vertebrate eyes occur in cephalopods. You will see among many non-chordates a variety of eyes ranging between these extremes.

Simplest eyes in Platyhelminthes and annelids are in the form of pigment spots consisting of sensory cells associated with pigment cells (Fig. 11.19). They serve differentiation of light from darkness. In many polychaetes they reach higher level of organization. The cup may often secrete a lens. The cephalopod eye (Fig. 11.20) is the result of highest elaboration of vesicular eye. The eye in **Octopus** in fact reaches the structural complexity of that of vertebrate eye, resembling it in considerable details. However, the cephalopod retina is direct type with sensory ends of the receptor cells directed towards the source of light whereas the retina of vertebrate eye is inverted with the sensory ends turned away from the source of light.

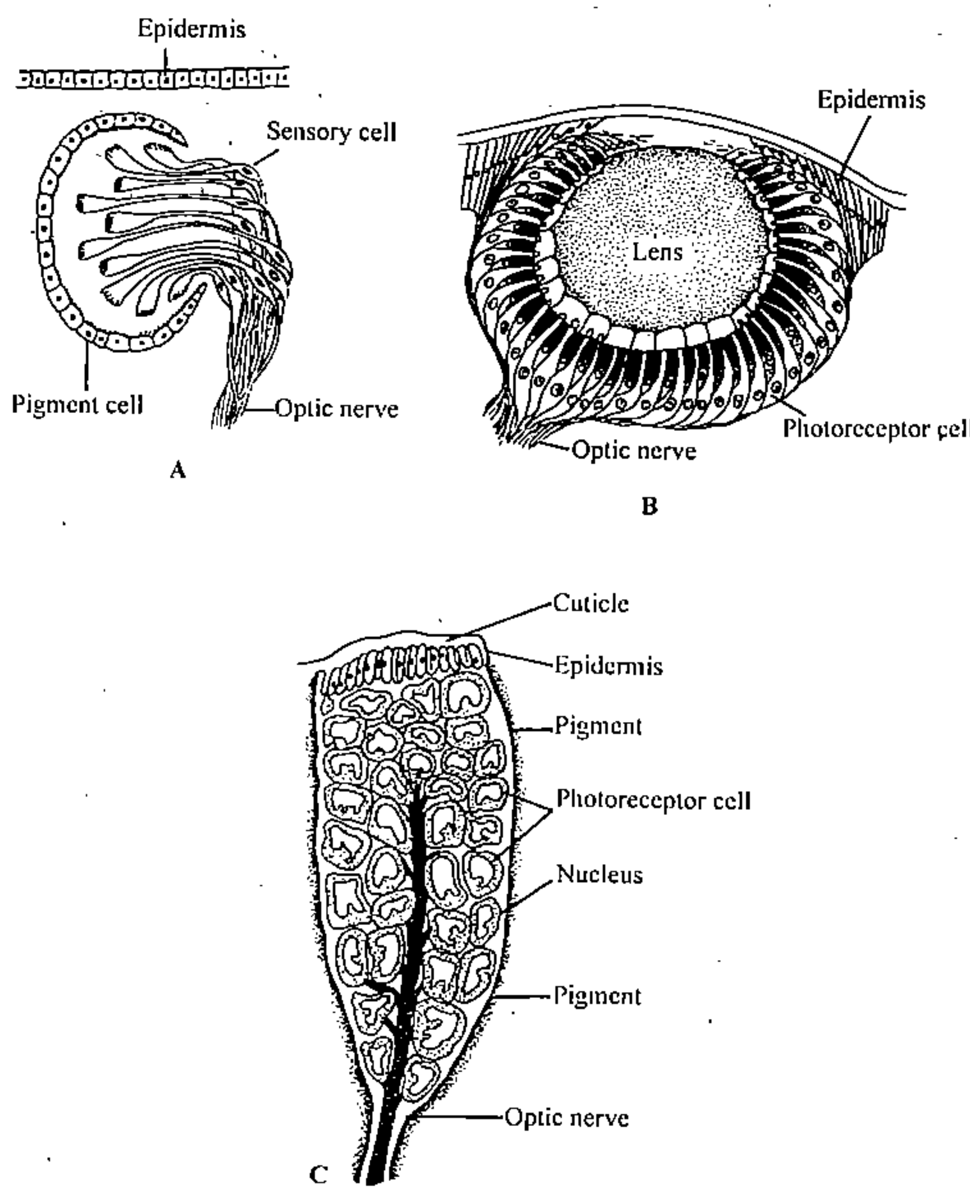


**Fig.11.19: Simple invertebrate eyes. A. Ocellus of planarian worm. B. Eye of a polychaete worm. C. Eye-cup with sensory neurons in the leech.**

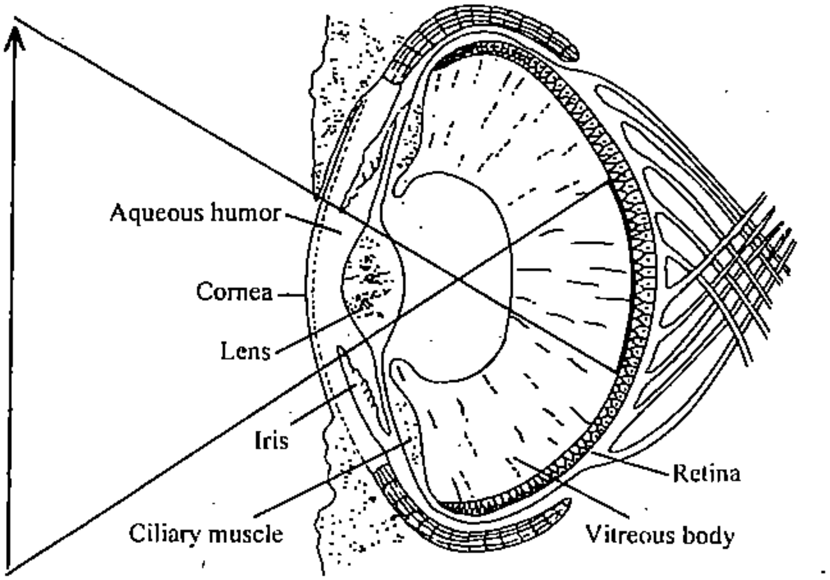


**Fig.11.20: The octopus has a pair of large image-forming eyes. Each eye is a camera-like eye in which the receptive ends of the retinal cells are directed toward the light source.**

We find among arthropods simple eyes like the median eye of nauplius larva, dorsal ocelli of insects, stemmata of many insect larvae and ultimately highly advanced compound eyes of many insects and crustaceans. The **compound eye** (Fig. 11.21) is made up of large number of units called ommatidia. Often you may be able to recognize hexagonal patterns on the surface of the compound eye; each of these represents an ommatidium. Each ommatidium consists of a dioptric (optic) unit and a sensory unit. The dioptric unit consists of: (i) a biconvex, colourless cuticular lens secreted by a pair of corneagen cells. When secretion of the lens is completed, the corneagen cells are pushed apart and are converted into primary pigment cells. (ii) A crystalline cone secreted by four Semper cells. These two lenses determine the focal length of the ommatidium. The sensory components consist of eight receptor (retinula) cells arranged around an axis.

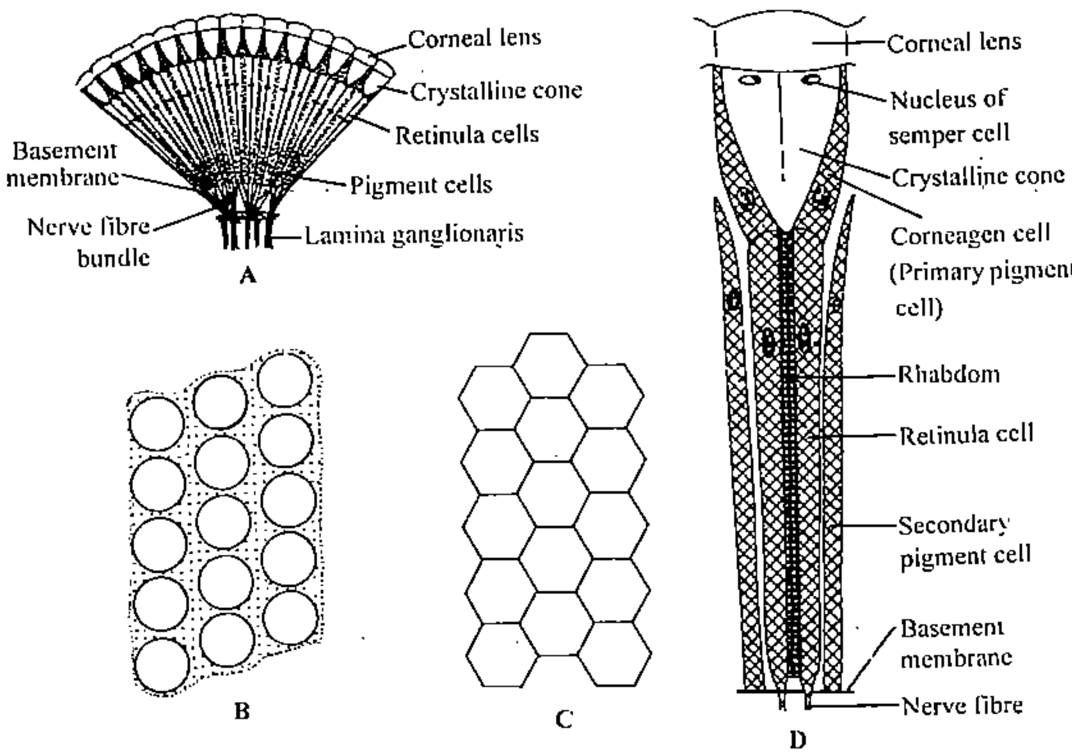


**Fig.11.21: Diagrams illustrating the structure of the compound eye. A. Section through part of an eye showing the arrangement of ommatidia. B. Surface view of part of the eye of an aphid, which consists of a small number of ommatidia, showing the facets well separated by unmodified cuticle. C. Surface view of part of the eye of a syrphid, which consists of a large number of ommatidia with the facets crowded together. D. Detail of a single ommatidium.**

Each retinula cell forms an inner fibrillar rhabdomere. The rhabdomeres of the eight retinula cells together form the rhabdome. From the base of the retinula cells arise a nerve fibre. The visual pigment is situated in the rhabdomere and hence the rhabdomeres are comparable to the rods and cones of vertebrate retina. Photostimulation of rhabdomere results in nerve impulse which is transmitted along the nerve fibre. There are also a few secondary pigment cells which isolate each ommatidium from its neighbours. You have to bear in mind that, unlike photopigment distributed in rhabdomes, the pigment granules in the primary and secondary pigment cells are not photopigment but serve to cut off light entering one ommatidium into the adjacent ommatidium. The nerve fibres of the rtinula cells enter the optic lobe. The electrical recordings of the response of the eye is called electroretinogram.

There are two types of compound eyes: (i) the **apposition** eyes and (ii) **superposition** eyes. The apposition eye is characteristic of diurnal species. The receptor cells are highly elongated, extending distally as far as the crystalline cone. The image formed by the eye as a whole is a mosaic of areas (Fig. 11.22 A). Nocturnal insects have superposition eyes (Fig. 11.22 B). In them the retinal cells are widely separated from the crystalline cone; each receptor cell is stimulated by light entering through a number of ommatidial lenses. This type of eye is suited for vision in dim light. The over-lapping images, however, give poor resolution. The pigment of the primary and secondary pigment cells move in strong light to screen retinal cells so that they can be stimulated only by light entering along the ommatidial axis. The eye is then called light adapted, protecting it from light of high intensity. In dim light, pigment moves to expose the retinal cells, which can now be reached by light from a wider source. Now the eye is called dark adapted.

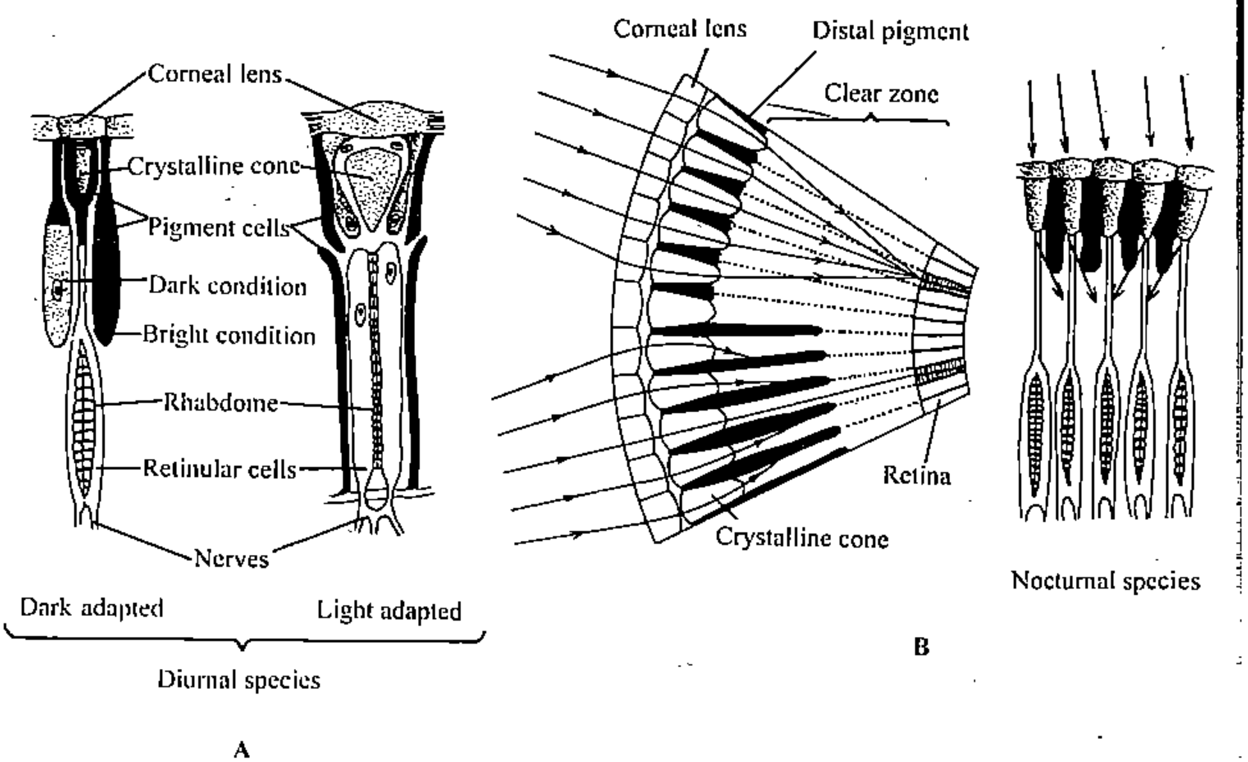


Fig.11.22: A. Insect ommatidia, showing a diurnal type (left) and a nocturnal type (right). In the diurnal type, the pigment is shown in two positions: adapted for very dark conditions on the left side, and for relatively bright conditions on the right. B. Nocturnal type of eye adapted for dark conditions, showing how light can be concentrated upon one rhabdome from several lenses. If the pigment moved downward, light from peripheral lenses would be screened out.

## SAQ 8

Which of the following cells of the compound eye contains photosensitive pigment?

a) Primary pigment cell
b) Secondary pigment cell
c) Retinula cell
d) Rhabdomere

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## 11.8 SUMMARY

After reading this unit you have learnt that

- The nervous system is made up essentially of nerve cells called neurons. They are sensory, motor or association neurons, and may be unipolar, bipolar or multipolar.
- A nervous system is present from Cnidaria onwards. In Cnidaria, it is in the form of a subepithelial nerve net, with very little centralisation.
- During evolution of the metazoa, clear trends in the development and evolution of a central nervous system are visible. These consist of: 1) Disappearance of subepithelial nerve net, giving place to a central nervous system where motor and association neurons are grouped together. 2) Initially, the central nervous system is in the form of thickened nerve cords with uniformly distributed nerve cells along the periphery of the cords. 3) Subsequently the cells become clustered together into ganglia with commissures and connectives. 4) Finally, with cephalisation, the brain has evolved which has assumed gradually greater importance and better organization.
- Giant fibres have evolved in many groups of non- chordate metazoans to facilitate rapidity of conduction of impulses. They are involved in escape reactions of animals.
- Receptors are sensory neurons. They perceive various kinds of stimuli and transform them into electrical impulses. Different types of receptors are specialised for perception of different kinds of stimuli. Accordingly, they are mechanoreceptors, chemoreceptors or photoreceptors.
- Receptors may be scattered throughout as individual cells; they usually tend to get concentrated as for examples in eyes, statocysts etc. which frequently occur among animals.

## 11.9 TERMINAL QUESTIONS

1. How would you identify a neuron, structurally?

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2. What is neuroglia?

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3. Mention the three major types of receptors; what are their functions?

4. What is the basic difference between the cephalopod eye and vertebrate eye? Cite one important difference.

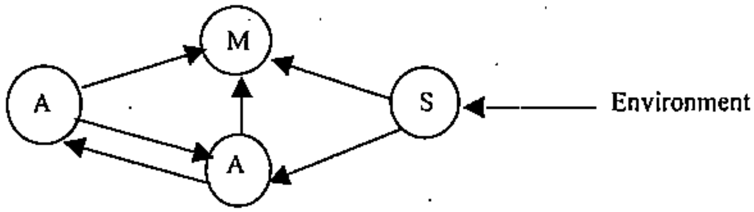
5. Why do you consider epithelial nerve net as the primitive type of nervous system?

6. Why do you consider the cephalopod brain as highly evolved? Give one good reason.

## 11.10 ANSWERS

### Self-Assessment Questions

1.




2.

| | I | II |
|---|---|---|
| i) | b | A |
| ii) | a | B |
| iii) | c | B |

3. a) S
   b) S
   c) A

4.

i) The peripheral, subepidermal nerve net disappears; the nervous system becoming mainly submuscular, with nerves.
ii) While sensory neurons are retained at the periphery, the association neurons and motor neurons become concentrated into central nervous system;
iii) The neurons become further concentrated into ganglia, connected together by connectives and commissures;
iv) With cephalisation, the brain develops, which becomes more and more important with evolution.

5.

1) a) Yes
   b) No
   c) Yes

2) i) Yes
   ii) No
   iii) No

6.

Yes. Because all the four types of sensation produce their effect by bringing about temporary deformation of the receptors concerned.

7.

| | *Contact chemoreceptors* | *Olfactory receptors* |
|---|---|---|
| 1. | Have smaller number of sense cells associated with them | have larger number of sense cells. |
| 2. | Dendrites do not branch | dendrites highly branch |
| 3. | Single pore at the tip of the sensillum | numerous pores all over the sensillum |

8.

c) retinular cell. (note: though rhabdomere contains pigment, it is not a cell. It is only part of the retinular cell).

**Terminal Questions**

1. Neuron has a cell body called perikaryon and one or more processes called neurites.
2. Neuroglia is the connective tissue of the nervous system, filling the space among the neurons. It also includes Schawann cells, covering the neurites, it includes the perineurium and the neural lamella covering the ganglia as also the nerve sheath.
3. Mechanoreceptors: sensations of touch, gravity, sound, tension.
   Chemoreceptors: taste, odour.
   Photoreceptors: vision, sensation of light.
4. In the cephalopod eye, the receptor cells of retina are directed towards the source of light, in the vertebrate eye they are directed away from the source of light.
5. The epithelial nerve net is found among the most primitive metazoans, where this is the only type of nervous system. It is not found among higher animals.
6. Various centres (association, motor and sensory) of the brain are highly developed and localised in large and distinct lobes of the brain.

# UNIT 12 ENDOCRINE SYSTEM

Structure



## 12.1 INTRODUCTION

In the previous unit you have learnt that the nervous system brings about integration and co-ordination of various activities of the animal. The afferent stimuli from various sense organs are brought to the brain, which is the coordinating centre. From the brain appropriate efferent stimuli are transmitted to various motor or effector organs resulting in coordinated motor activities of the animal. You have seen that these stimuli travel through a closed system of circuits comparable to telegraphic cables, called nerve fibres, in the form of electrical disturbances. There are indeed many minute gaps in between the connections where neurotransmitters make and break the circuits between gaps. In the present unit, you will learn that there is another equally important system, which also serves transmission of messages form one part of the body to another, bringing about integration and coordination of various activities of the animal. This is the endocrine system. The endocrine system brings about communication through chemical substances called hormones produced by endocrine glands. The hormones are transported to their target tissues or organs by the blood stream. The nervous system and the endocrine system form an integral part of the coordinating system of the animal. In fact the two systems are closely associated with each other and the branch of study of the two closely-knit interacting systems is known as neuroendocrinology. Before you begin the study of endocrine system, you may quickly review what you have studied under nervous system.

### Objectives

After studying this unit you should be able to:

- describe the differences between the neural and hormonal integration,
- explain the concept of neurosecretion,
- distinguish between an ordinary neuron and a neurosecretory cell,
- name the major endocrine structures in annelids, molluscs, insects and crustaceans,
- describe the process of hormonal control of moulting and metamorphosis in insects,
- elucidate the mechanism of hormonal control of colour change in crustaceans, and
- discuss the importance of hormones in the life of non-chordates.

## 12.2 ENDOCRINE VERSUS NEURAL INTEGRATION

A question that might come across your mind is, " what is the need for two types of integrative mechanisms, the neural and the endocrine"? Each of these systems has specific properties and functions and therefore confers specific adaptations to the animal. In the previous unit you have learnt that the nervous system responds rapidly to the various stimuli. So, when a rapid action is called for, nervous system will be more effective. On the other hand, in functions controlled by endocrine system hormone concentration is built up gradually, and only when the titres reach a threshold level, the function of the cell or tissue or organ is carried out.

Essentially hormone concentration is built up gradually, the specific function is carried out and then the hormone is metabolised and broken down slowly. As a result, the effect of the hormone is sustained and continued for a long duration. Thus when rapid responses are required, such as the escaping from a predator, the animal resorts to neural mechanism; but when a slow but sustained effect is called for, for instance, during the growth of the animal or the development of the oocyte, the hormonal mechanism takes over.

## SAQ 1

Some activities exhibited by non-chordates are given below. Try to assess whether the type of regulation involved is neural (N) or endocrine (E).

i) A prawn changes colour pattern of its body to suit its surroundings.
ii) Yolk deposition taking place in the eggs of cockroach.
iii) A resting moth flies away to escape from a lizard.
iv) A honeybee visiting flowers.
v) A snail retracting into its shell, in response to fouling of the water in which it lives.
vi) Transformation of a caterpillar into a butterfly.

## 12.3 ENDOCRINE ORGANS

Endocrine organs, as described earlier are those organs or tissues, which release chemical substances directly into blood stream. Unlike exocrine glands they do not have ducts to carry their secretion, and are hence considered ductless glands. Table 12.1 lists the endocrine glands of the higher invertebrate groups, the secretions they produce and the functions of the secretions. Among non-chordates neurosecretory cells (NSCs) form an important constituent of the endocrine system. These are nerve cells specialised for hormone production. So they combine neural and endocrine properties. Apart from this, endocrine glands may arise from the nervous system, by complete modification. Corpus cardiacum of insects is one such gland. Many non-chordates have also epithelial endocrine glands derived from embryonic ectoderm, mesoderm or endoderm layers. The optic glands of cephalopod molluscs, androgenic glands and Y-organs of crustaceans, and the corpus allatum and prothoracic glands of insects are some examples. You will be studying these structures and their functions in detail. But before we proceed further, let us look into the concept of neurosecretion a little more elaborately, since neurosecretion plays an important role in regulating metabolic and reproductive functions in non-chordates.

### 12.3.1 NEUROSECRETORY CELLS AND NEUROSECRETION

We have earlier said that the neurosecretory cells are an important component of the non-chordate endocrine system. Of course, they are also present in chordates. But unlike chordates, among non-chordates there are fewer epithelial endocrine glands, and so they have to depend more heavily on neurosecretory cells for chemical coordination.

Berta Scharrer and Ernst Scharrer are considered progenitors of the concept of neurosecretion. Put in a simple way, it is the concept of neurones taking to secretary activity and producing hormones. We can easily locate and identify these NSCs in histological sections of the brain or ganglia, because they contain plenty of stainable material or colloids, unlike ordinary neurones, which do not contain any stainable colloids. We believe that these colloids are carrier substances for hormones. Very often we can prove the presence of such hormonal principles in such cells by experimental means. Unlike the neurosecretory neurones, the ordinary neurones do not contain or secrete any hormones. Though they release neurotransmitters at synapse and neuromuscular junctions, these are not released into blood and are short lived; unlike the hormones secreted by NSCs. In the live brain of certain insects, in dissections, we can easily see the NSCs as tiny bluish white specks through the brain sheath, using a binocular dissection microscope.

The neurosecretory material containing the hormone is produced mainly in the cell body, and is transported through the axons to the finger-like axon terminals (Fig 12.1). If we follow these axons, we see that these axonal endings often form swellings in association with blood spaces at a distance from the neuronal cell bodies. The secretory material is stored at the swellings and hormones are released from them into blood stream. Such organs seen in association with blood spaces and containing the swollen nerve endings of NSCs are called **neurohaemal organs**. You will see that there are neurohaemal organs in some non-chordates. Sinus gland in crustaceans and corpus cardiacum in insects are examples of neurohaemal organs. Vertebrates also have their own neurohaemal organs - the neural lobe of pituitary is one such neurohaemal organ.

**Table 12.1 :**

| Animal Group | Endocrine gland | Some of the hormones isolated | Some of the functions |
|---|---|---|---|
| Annelida | Brain NSC | | Stimulates growth and regeneration |
| | Infracerebral gland | | Inhibits sexual maturation and epitoky |
| Mollusca<br>i) Cephalopoda | Optic gland | | Stimulates male and female gonads |
| ii) Gastropoda | NSC of brain | | Growth hormone stimulates body growth. |
| | Lateral lobe | | Growth retarding hormone inhibits body growth and stimulates egg production. |
| | Dorsal bodies | | Stimulate development of male and female phases of reproductive cycle. |
| Arthropoda<br>i) Crustacea | X-organ - sinus gland system; Other NSC;Post-commissural organs | Red pigment concentrating hormone | Colour change; moult inhibition; inhibition of ovarian maturation |
| | Pericardial organs | | Regulates heart beat. |
| | Y-organ | Ecdydone | Stimulates moult |
| | Androgenic gland | | Stimulates spermatogenesis and development of male secondary characters |
| ii) Insecta | Pars intercerebralis NSCs | Prothoracotropic hormone | Stimulates prothoracic glands to produce ecdysone. |
| | Prothoracic glands | Ecdysone | Stimulates moulting. |
| | Corpus allatum | Juvenile hormone | Regulates metamorphosis by retaining juvenile characters. Stimulates oocyte growth and vitellogenesis. |
| | Corpus cardiacum | Adipokinetic hormone | Stimulates fat metabolism. |

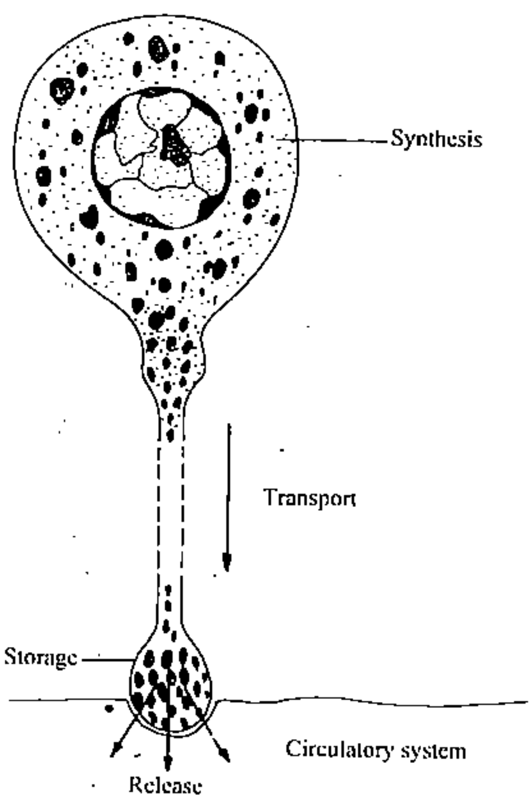



**Fig.12.1 : The concept of neurosecretion.**

Scientists have isolated hormones from neurosecretory systems. These are mostly peptides, both in non-chordates and chordates. They contain a few amino acids and hence we call them oligopeptides.

An example is the prothoracicotropic hormone produced by the brain NSCs of insects. Red pigment concentrating hormone of crustaceans is another example. However, as the material available from non-chordates is very little, isolation and identification of hormones from non-chordates has been very difficult. But presence of hormonal material in their neurosecretion has been demonstrated by experimental means in many non-chordates and their functions are also known.

Before we proceed to the next section on neurosecretory systems of non-chordates, you may answer the following SAQs.

## SAQ 2

Which of the following statements are true?

i) All neurones are neurosecretory because they all secrete transmitter substances.
ii) All neurones containing stainable colloids are neurosecretory.
iii) Neurones, which secrete hormones, are neurosecretory.
iv) Neurosecretory cells are those cells associated with neruohaemal organs.

## 12.3.2 NEUROSECRETORY SYSTEMS

Almost all groups of multicellular animals have been investigated to find out if neurosecretory cells are present in them. Such investigations have shown that these cells are located either in brain or ganglia. However, discrete neurosecretory systems made of neurosecretory cells with their axonal tracts and axon termini forming neurohaemal organs have been found among non-chordates only in certain groups. These systems are best known among arthropods, especially in insects and crustaceans.

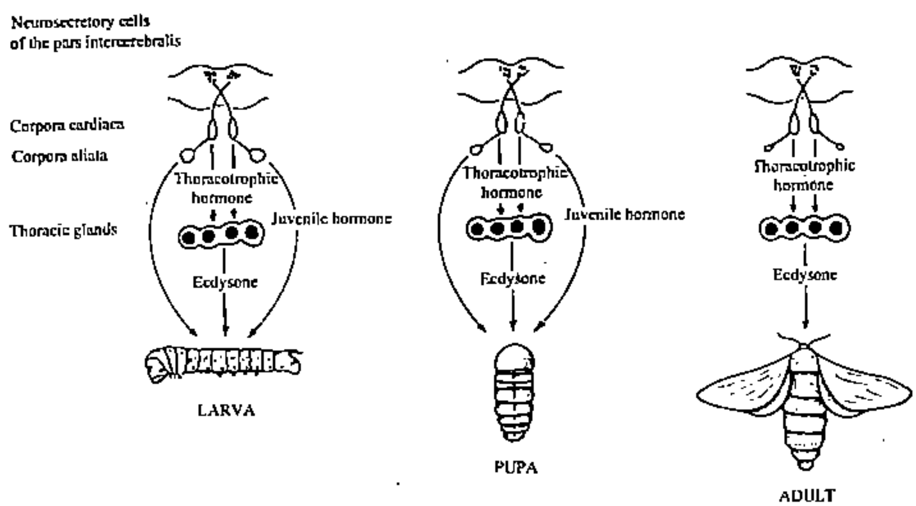



**Fig.12.2 : Brain neurosecretory cell – corpus cardiacum –corpus allatum system of a generalised insect.**

Among insects (Fig. 12.2) we can see conspicuous groups of NSCs in the median region of the protocerebrum of the brain, known as **pars intercerebralis,** on either side of the median line. If we follow their axonal tracts we can see that they cross each other in the brain and emerge out of the brain as corpus cardiacum nerves (**nervi corporis cardiaci**). These nerves enter the corpus cardiacum situated just behind the brain. Thereafter their neurosecretory fibre terminations branch and rebranch, ending close to aortal wall. The neurosecretory material elaborated in the NSCs of the brain are transported and stored at these axonal endings. At the time of necessity the hormone is released from these structures into the aortal blood. So we can call the corpora cardiaca as neurohaemal organs. Frequently we can also see other well-defined neurosecretory systems in association with ventral ganglia, forming the perisympathetic system in many insects (Fig 12.3).

Among crustaceans (Fig.12.4) we can see a tightly clustered group of NSCs situated on the margin of optic ganglia. These constitute the **X-organs.** Some authors describe more than one X-organ on each side, in crustaceans. The neurosecretory axons from x-organ traverse the eye stalk ganglia and converge to neurohaemal organ, which is called the sinus gland. It is a white iridescent structure on the surface of the optic ganglion. As the

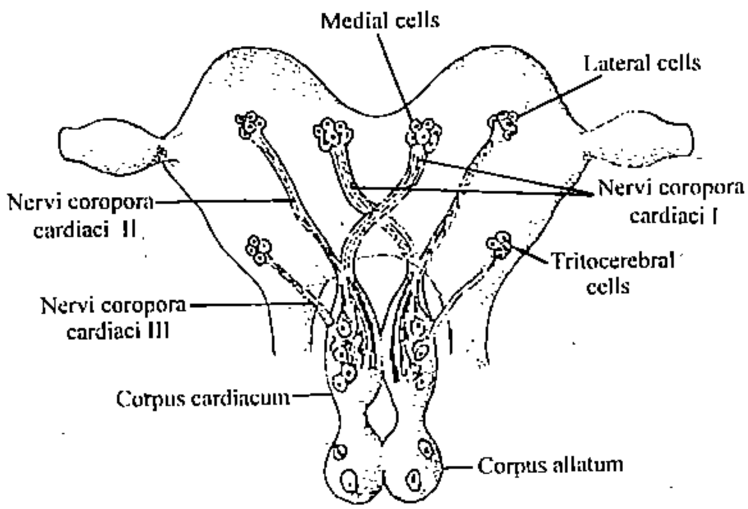
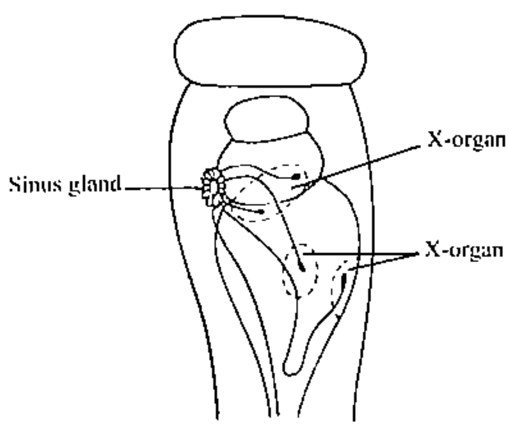



**Fig.12.3 : Brain neurosecretory cell – corpus cardiacum –perisympathetic system of a generalised insect. Neurosecretory cells of the ventral ganglia are also shown.**

name indicates, the sinus gland is situated close to a blood sinus. This is the most common picture in the crustaceans that have been studied. Usually there are no NSCs in the sinus glands.




*Gecarcinus lateralis*

**Fig. 12.4 : X-organ - sinus gland system of a crustacean.**

In crustaceans we can commonly see other neurosecretory systems also (Fig.12.5). For example, the post-commissural organs are found attached to the circumoesophageal connectives. These are also the neurohaemal organs. Their neruosecretory cell bodies appear to be situated in the brain. So also, the pericardial organs floating in the pericardial sinus of crustaceans are neurohaemal organs. Most of their neurosecretory cells are situated in the thoracic ganglia.

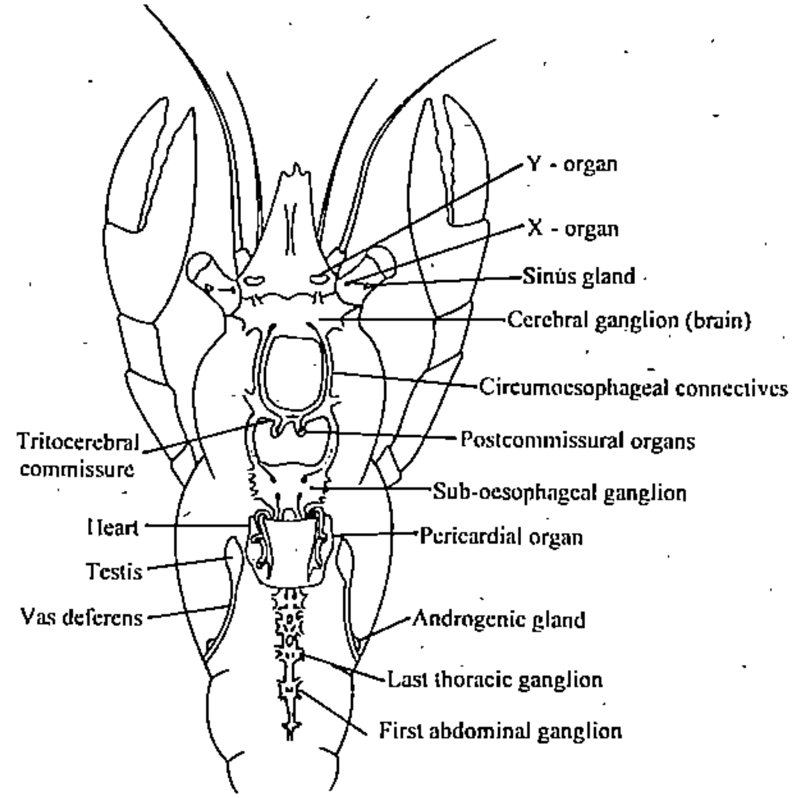



**Fig.12.5: The endocrine organs of a generalised crustacean. Except the androgenic gland and the male reproductive system, other glands are common for female also.**

In millipedes and centipedes also we can see cerebral NSCs leading to a neurohaemal organ, the cerebral glands on each side (Fig.12.6). In some millipedes, in addition, there is another neurosecretory system with NSCs usually in the tritocerebrum and connective body as the neurohaemal organ. The connective body is situated close to the post oral connectives where it joins the circumoral commissure.

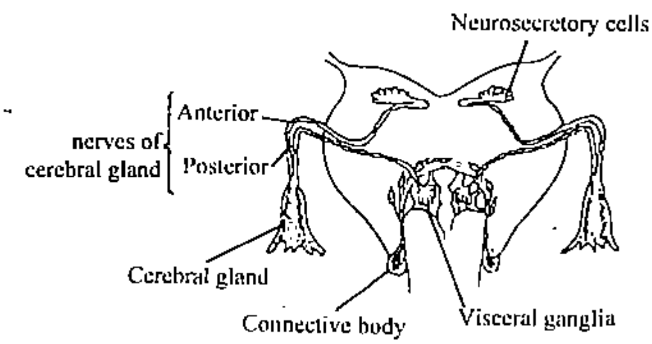



**Fig.12.6 : Neurosecretory system of a millepede.**

## 12.3.3 OTHER ENDOCRINE ORGANS

**Corpus cardiacum:** We earlier mentioned that corpus cardiacum (pl. corpora cardiaca) is a neurohaemal organ in insects. It is gland of neural origin. They are considered as transformed ganglia. Apart from these, we will discuss in the ensuing section a number of other endocrine glands. Most of them are, however, of epithelial origin. The corpora cardiaca are situated close behind the brain dorsally, on either side of the dorsal aorta or remain in close association with it. They appear as a white bluish organ in dissections and so we can easily locate them under dissection microscope. Though they are neurohaemal organs in insects as they contain fibre terminations of NSCs situated in the pars intercerebralis of the brain, they have their own cells too (Fig.12.2). That is, they contain intrinsic cells. which synthesise hormones different from the ones produced by the NSCs of the pars intercerebralis. So they have a dual function. They are the neruohaemal organs as well as endocrine glands in their own right. They receive usually two or sometimes three nerves from the brain in front and are connected to the corpora allata (sl. corpus allatum) behind, by allatal nerves. In some insects there may be also ordinary nonsecretory neurones in the corpora cardiaca.

**Corpus allatum** : The corpus allatum is located in the neck region of insects(Fig 12.2). It is usually a rounded, solid and translucent structure. Nerves to corpus cardiacum in front connect it. The allatum is densely packed with small nuclei with little cytoplasm around them. It produces juvenile hormone. The juvenile hormone is a straight chain terpenoid (a type of lipid) compound of 16 to 19 carbon atoms.

**Prothoracic gland:** The prothoracic glands (Fig.12.7) are usually made up of loose strings of cells situated in the prothorax of immature insects. They produce the steroid hormone ecdysone. These glands undergo degeneration in the adult.

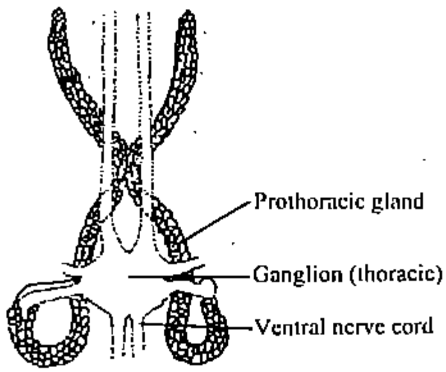



**Fig.12.7: Prothoracic glands of an insect.**

**The Y-organs**: The Y organs Fig.12.5) are a pair of endocrine glands in crustaceans. We see them either in the antennary or in the second maxillary segment. They produce the moulting hormone ecdysone in crustaceans.

**The androgenic glands**: The androgenic glands (Fig 12.5) are the endocrine glands found only in male crustaceans. They are attached to the hinder end of the vasa deferentia and their hormone is thought to be a peptide or protein.

**The optic glands**: The optic glands of cephalopod molluscs (Fig.12.8) are the endocrine glands found in the optic stalk, internal to the eye and are well innervated. However, the gland is not part of the neurosecretory system.

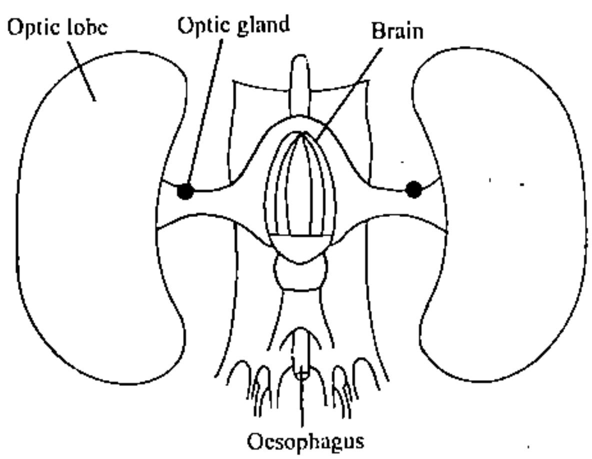



**Fig.12.8 : Optic glands of the cephalopod mollusc Octopus.**

Among the gastropod molluscs (Fig.12.9) as for example in the fresh water snail *Lymnea stagnalis, there* are structures called the **dorsal bodies** and the **lateral lobe** containing follicle glands; both of them are associated with the brain. They are important structures in these molluscs.

In polychaete annelids, there is an infracerebral gland close to the brain. This endocrine gland has a complex structure.

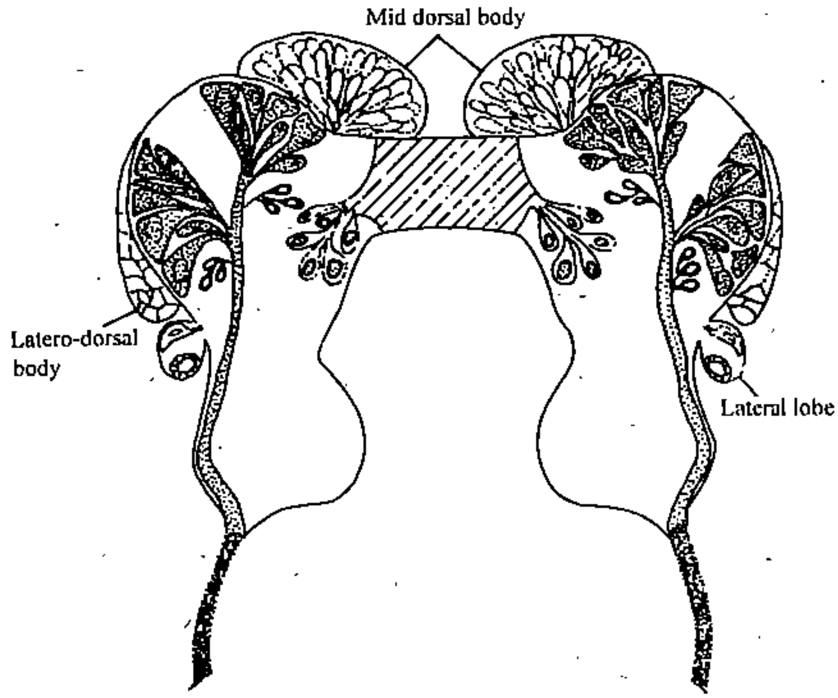



**Fig.12.9 : Endocrine system of a gastropod, *Lymnea stagnalis* showing Median and Lateral Dorsal bodies as well as Lateral lobes. Also shown are the brain neurosecretory cells.**

## SAQ 3

Indicate which of the following statements are true or false.

i) Neurosecretory cells usually secrete steroid hormones.
ii) Neurosecretory cells usually secrete peptide or protein hormone.
iii) Prothoracic glands secrete steroid hormone.
iv) Juvenile hormone is a straight chain lipid.
v) Androgenic glands secrete a lipid hormone.

## 12.4 HORMONES IN GROWTH AND REPRODUCTION

The growth and reproduction of higher invertebrates are known to be regulated by the endocrine secretions. The regulatory mechanisms have been well demonstrated in annelids, arthropods (specially in crustaceans and insects) and molluscs. We shall briefly study the hormonal regulation of growth and reproduction in chosen non-chordate groups.

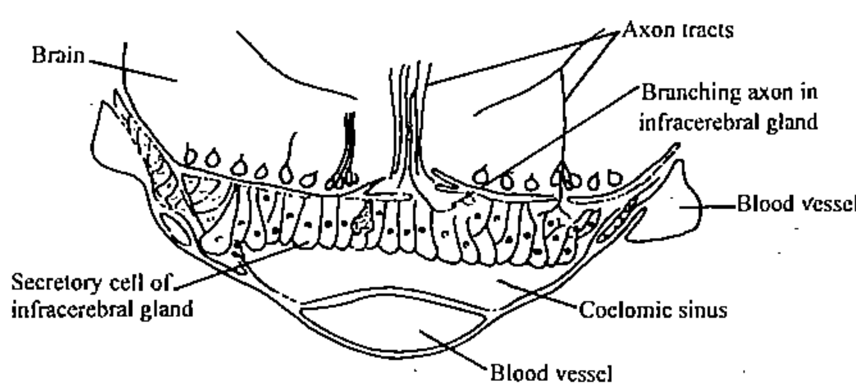



**Fig.12.10 : Infracerebral glands of a polychaete annelid.**

## Annelids

Studies on polychaetes have shown that the endocrine glands play a key role in growth and reproduction. In addition to the brain neurosecretory cells, we see that in annelids there is an infracerebral gland (Fig.12.10). This is situated in close association with the brain immediately beneath or behind it. The infracerebral gland has its own secretory cells. In addition, the neurosecretory cells of the brain have their fibre terminations in the brain, close to the infracerebral gland, or even passing into the gland. *Nereis* and *Nephthys* are examples.

The polychaetes are capable of rapid growth when young, with proliferation of new segments. They are also capable of extensive regeneration. However growth rate and regenerative ability decline with age. An interesting phenomenon in polychaetes is epitoky. This takes place during sexual maturation in some nereids. Sexual maturation in them is accompanied by changes in certain regions of the body. The changes include enlargement of parapodia and development of modified chaeta. The animal is transformed into heteronereid phase (Fig.12.11), adapted for rapid swimming and sexual swarming.

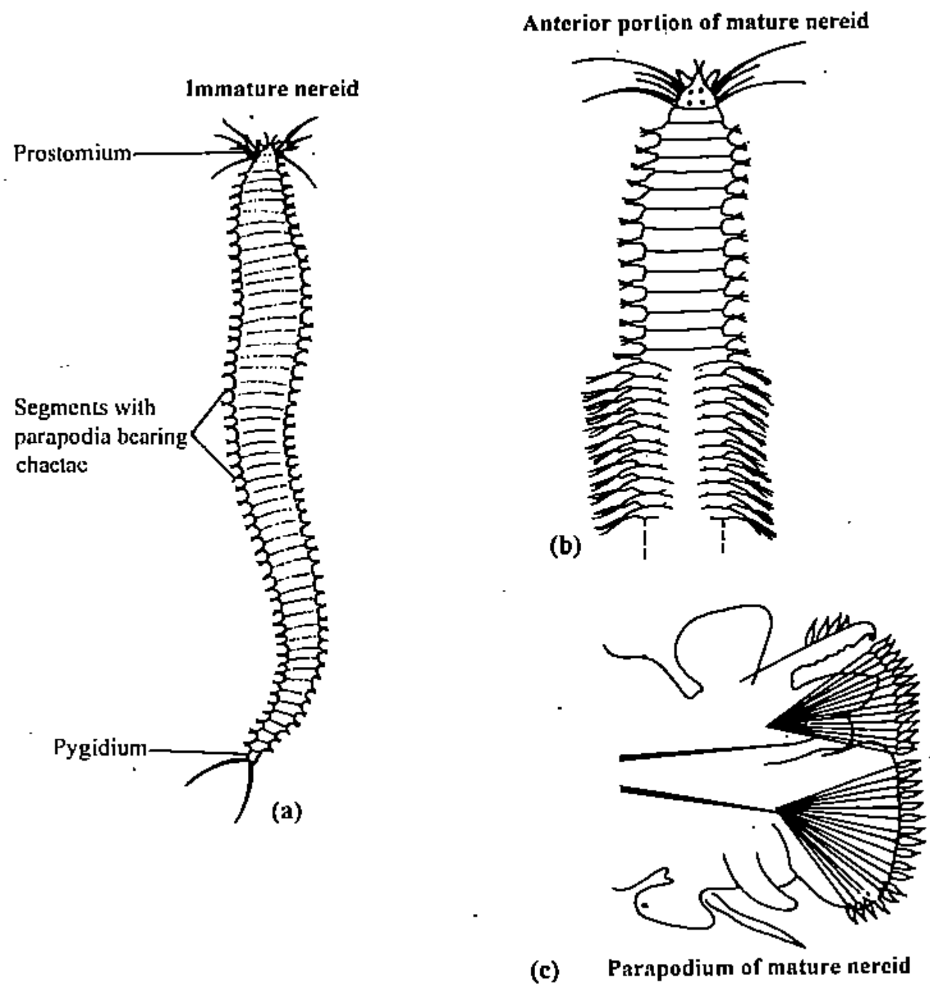



Fig.12.11 : Changes undergone by the immature nereid during transformation into heteroneried worm.

In polychaetes growth, regeneration as well as sexual maturation accompanied by epitoky are all controlled by a hormone of the brain-infracerebral gland complex. This hormone is required for growth and regeneration, and is secreted in large quantities at the early stage of the animal's life, which is the growing stage. However, the same hormone appears to inhibit sexual maturation and epitoky. So sexual maturation does not take place at this stage. When growth period terminates the hormone secretion drops and the animals become sexually mature.

Moonlight synchronises swarming in these worms. In moonlit nights we can see these mature worms swarming in the sea in large number and they shed their germinal products (sperm and ova) more or less simultaneously. This brings about successful fertilisation.

### Molluscus

We know fairly well about the endocrine mechanism of growth and reproduction in the freshwater snail *Lymnea stagnalis*. This is a gastropod, and like other gastropods, *Lymnea* is protandric hermaphrodite. That means, in these groups of animals, male gonads mature first and this is followed by the maturation of the female gonad. The dorsal bodies produce hormones, which promote development of both male and female phases of reproductive organs. In the female phase these glands produce pronounced effects. They stimulate maturation, yolk deposition in the eggs, ovulation and oviposition. They also stimulate growth and differentiation of the female accessory sex organs. In this animal, certain groups of neruosecretory cells of the cerebral ganglia produce a hormone (growth hormone) which stimulates growth and differentiation of the female accessory sex organs. In this animal, certain groups of neurosecretory cells of the cerebral ganglia produce a hormone (growth hormone) which stimulates growth of the body. On the other hand the lateral lobes attached to the brain produces a growth-retarding hormone. This hormone not only retards growth of the body but also causes an increase in egg production.

The optic glands of the cephalopod mollusc *Octopus* control reproduction in the male and female. The glands secrete a gonadotropic hormone at the onset of sexual maturity. This stimulates development of the genital ducts and maturation of germ cells.

### Crustaceans

Arthropods have a tough and often hard exoskeleton made up of cuticle composed of chitin and protein. The cuticle imposes restrictions on the growth of the animal. Unless the cuticle is shed, growth is not possible to any extent. The periodic shedding of cuticle is known as moulting. So, moulting is closely related to growth in arthropods. In crustaceans, two hormones control the moulting process. The Y-organ produces the moulting hormone, the ecdysone, a steroid. Under the influence of ecdysone the animal moults. So it is a moult-inducing hormone having a positive influence on moulting. However, moulting in crustaceans is also under the inhibitory control of another hormone produced by the X-organ and released at the sinus gland. This hormone has a negative influence on moulting. If the inhibitory hormone concentration in the blood dominates, the animal moults. It is the balance between the two hormones that determines moulting in crustaceans. However, it is not certain whether the inhibitory hormone acts on the Y organ decreasing the release of moulting hormone ecdysone or it acts directly at the level of the epidermal cells where ecdysone also acts. Anyway, the effect is same. You will see that in many animals, two or more hormones of antagonistic effects may control very often one function, the balance determining the result.

Reproduction in crstaceans is also under hormonal control. The X-organ-sinus gland complex is involved here also. It is easy to remove the X-organ-sinus gland system of crustaceans, which are situated in the eyestalk. Removal of the eyestalk, known as eyestalk ablation, would result in the removal of the endocrine structures. Removal of the eyestalk from the adult female crustacean results in the acceleration of yolk deposition in the oocytes; size and width of the ovaries will therefore increase. Sometimes it results in precocious egg-laying too. Injection of an extract of the eyestalks of the adult females into an eyestalk-ablated animal will reverse the trend. Such types of experiments led to the conclusion that in normal animals ovarian growth is inhibited by a neurosecretory hormone from the eye stalk, namely, X-organ-sinus gland complex. When the hormone is absent, the ovaries start growing, depositing yolk in the oocytes. Even though a number of other hormones controlling ovarian and testis activity have been postulated, sufficient evidence to prove their existence is lacking. An exception is the androgenic gland hormone of some crustaceans.

The androgenic glands are normally present only in the male crustaceans and are necessary for production of sperms by testes. These glands stimulate spermatogenesis in the male. Even though it is normally absent in the female, you can implant the androgenic gland into a female and watch the effects. Implantation of the androgenic gland in the female can convert the ovaries into testes. The ovaries ultimately produce sperms. The androgenic gland hormone is required for the differentiation of male secondary sex characters also. You have studied the phenonmenon of testicular feminisation in crabs occurs due to parasitisation by *Sacculina*. The parasite causes the degeneration of the androgenic gland. In the absence of the androgenic gland hormone responsible for maintenance of maleness, the sex reversal takes place.

**Insects**

In insects hormones regulate moulting and metamorphosis. The larvae or nymphs that hatch out of the eggs undergo regular moulting which is followed by growth, as in crustaceans and ultimately they become adults. The change in form from larva to adult is known as metamorphosis. In insects like cockroach, grasshopper etc., (hemimetabolous insects), the change in form is gradual. However in some other insects like moths, butterflies, houseflies etc., (holometabolous insects), the change is more conspicuous during the later period of the life history and the adult which emerges from the pupa is quite different. As in crustaceans, the hormone which brings about moulting in these animals is also ecdysone but in insects it is secreted by prothoracic glands.

How is metamorphosis in insects brought about? In insects the hormone that is responsible for preventing the animal from metamorphosing is juvenile hormone secreted by the corpus allatum. In fact, as the name implies, juvenile hormone keeps the insect juvenile. So in effect it inhibits metamorphosis. We have already seen that the prothoracic glands in immature insects secrete ecdysone. This hormone causes the insect to moult. As long as the larva moults in the presence of high titres of juvenile hormone, it moults into another larva (Fig.12.12). If the moult takes place when the titres of JH are low in the blood, it results in a pupa. Finally when there is no JH circulating in the blood, the pupa moults into adult. Thus the concentration of JH in blood determines the type of resulting individual. It is also known that JH causes the repression of those genes, which are responsible for adult differentiation.

Karel Slama, an insect endocrinologist from Czechoslovakia while working in the laboratory of Carroll Williams in United States found that the bugs he brought from his country were not undergoing normal metamorphosis. Many of them did not reach adulthood and died as nymphs. Since it was a laboratory working with hormones, they suspected a possible contamination of juvenile hormone (that prevents metamorphosis) and care was taken to avoid any such possible contamination. Everything, right from a glass-dropper was kept clean; but the problem persisted and the insects did not complete the metamorphosis. Slama then undertook the laborious task of screening all the materials in the laboratory for the possible cause of disruption of metamorphosis in the bugs. Much to his surprise he found that the filter papers that were used to line the petri dishes in which the bugs were reared were the cause for the problem. An analysis of the filter paper showed that they contained juvenile hormone like substances (JH analogues) in it. Slama and Williams called the substance the 'paper factor'. But how did the paper come to possess juvenile hormone activity? In fact the JH activity was traced to the trees from the pulp of which the paper was made. Subsequently, a number of trees were screened for JH activity and the activity was found in several of them. Here is an instance of plants having evolved a certain defense mechanism from the possible attack by the insects. The JH analogues would not allow the insects which feed on the trees which possess such analogues to moult into adults and the insects die as juveniles, thus saving the trees from the subsequent attack of insects.

Yet another type of an interesting defense mechanism which plants have evolved relates to the presence of anti-juvenile hormone substances in them. The anti-JH substances have the property of suppressing the juvenile hormone secretion. If an insect nymph or larva feeds on a plant, which possesses anti-JH substance in it, the substance causes the inhibition of the corpus allatum of the insect, thereby causing the lowering of the juvenile hormone titres in the blood. Under such circumstances, the insect, instead of undergoing a normal metamorphosis, undergoes an abnormal or precocious metamorphosis. Such a metamorphosis results in abnormally developed insects called adultoids, which die without reproducing. And the substances in plants, which cause a precocious metamorphosis of insects, have been termed as precocenes.

Let us now examine the hormonal control of reproduction in insects. While studying the mechanism of metamorphosis in insects, we have seen that adult differentiation takes place when there is no JH in blood stream. Essentially at the time of pupal adult moult the corpus allatum is inactive. Once the adult emerges, the corpus allatum becomes once again active and produces JH. In female insects the JH has been shown to function as a gonadotropic hormone. Under the influence of the JH, the fat body of certain insects synthesise yolk protein precursors, the vitellogenins, which are subsequently released into the haemolymph. Also JH is shown to promote the uptake of vitellogenins from the haemolymph by the developing oocytes. Inside the oocytes the vitellogenins are transformed into vitellins, the yolk proteins. Besides regulating the oocyte development and vitellogenin synthesis and uptake, JH has been shown to promote oviposition as well. Besides JH, the neurosecretory substances produced from the neurosecretory cells of the pars intercerebralis region of the brain are shown to regulate the oocyte development and oviposition in locusts and grasshoppers.

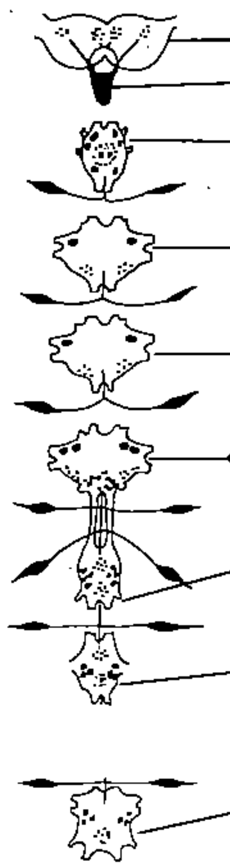



**Fig.12.12 : Hormonal mechanism of moulting and metamorphosis in insects.**

In mosquitoes such as *Aedes*, ecdysone is shown to be the gonadotropic hormone. Ovary has been shown to be the source of ecdysone that promotes viltellogenenin synthesis. In hymenopterans such as honey bee, an interaction between JH and ecdysone promotes vitellogenin synthesis. While the JH primes the fatbody for vitellogenin synthesis, the synthesis *per se* depends on ecdysone. Thus insects exhibit a variety of mechanisms of hormonal regulation of yolk protein synthesis and a generalised mechanism does not prevail.

Spermatogenesis, the formation of mature sperm from the primordial spermatogonial cells has not been shown to be under hormonal control. But in many insects JH has been shown to regulate the synthesis of the male accessory gland substances. These substances, mainly proteins, are transferred to females as a part of the seminal fluid at the time of mating. They are known to perform a variety of functions, such as the formation of spermatophores, inhibition of receptivity of once mated females, enhancing their fecundity and acting as oviposition stimulants. In certain grasshoppers, they were also shown to contribute to the yolk formation in females.



## 12.5 HORMONES CONTROLLING OTHER FUNCTIONS

Crustaceans exhibit pronounced capacity for physiological colour changes. It is known that the colour changing mechanisms in Crustacea are regulated by hormones. The animals have a variety of chromatophores containing different pigments: the melanophores usually contain black pigments.

Many crustaceans are brilliantly coloured animals and they have the capacity to change their body colour. Body colour is often due to coloured pigments present within certain cells. The cells concerned are called chromatophores. Colour change may be (1) either due to synthesis of new pigments or destruction of existing pigments. In other words it is due to a quanititative change in the pigments of the body. This type of colour change called morphological colour change is very slow, taking considerably long time to accomplish. (2) However, animals can also change their colour without recourse to synthesis or destruction of pigments. That is, there is no change in the quantity of pigments present. This involves movement of already existing pigment granules within the chromatophjores. When the pigment granules within the chromatophores are concentrated at a point, the cells appear pale or blanch; when the pigment granules are dispersed throughout the cell, it appears brightly coloured. This type of colour change is called physiological colour change, and is comparatively more rapid than morphological colour change.

Colour change is of immense advantage to the animal. By adapting its colour to the surroundings, it can escape from its enemies; it serves to attract opposite sexes when the colouration is sexually dimorphic; sometimes the colour change may be useful to the animal to adjust to the environmental temperature.

Similarly red, orange, yellow and white chromatophores are also present in these animals. These chromatophores are controlled by a number of hormones. The source of these hormones may be the neurosecretory cells of the X-organ –sinus gland complex or the isolated scattered neurosecretory cells of the brain or of the thoracic ganglia or the post-commissural organs. Some of these hormones have been isolated, purified and their structure elucidated and they have even been synthesised. The red pigment concentrating hormone of *Pandalus borealis* has thus been found to be an octapeptide, a peptide conatining eight amino acids. Under its influence red pigment in the chromatophores concentrates and the cells appear pale. So the animal which earlier appeared red will now appear pale.

How can the opposite effect be produced? The red pigment, which is now in a concentrated condition, will disperse, usually under the influence of a red pigment dispersing hormone. The chromatophores will now assume red colour and the animal becomes red. Sometimes even the very disappearance of the red pigment concentrating hormone from the blood stream may result in dispersal of the pigments. In that case also the chromatophores will appear red and the animal too will appear red.
We have now seen that non-chordates too have endocrine glands. In annelids, molluscs, crustaceans and insects, growth and reproduction are under hormonal control. In insects they also control metamorphosis. In crustaceans the hormones bring about colour change. Besides these functions, a variety of other functions are also under hormonal control in them. Crustaceans and more so, insects, have been studied extensively from this point of view. The metabolism of carbohydrates and fats are known to be regulated by hormones in insects. Adipokinetic hormone in insects is known to regulate the fat metabolism in insects. Similarly hyperglycemic and hypoglycemic factors from brain and corpus cardiacum have been shown to regulate carbohydrate metabolism. Prothoracic glands, which secrete ecdysone, are themselves under the control of a hormone from the brain neurosecretory cells. A number of other hormones controlling a variety of functions in non-chordates are already known. Also there is accumulated evidence to show that there is the possibility of the existence of yet unidentified

hormones in non-chordates. In short, we may say that hormones play a very important part in integration of a multitude of physiological activities in non-chordates.

## SAQ 4

Correlate the following endocrine organs given under A with their direct positive functions given under B.

| A | B |
|---|---|
| 1. Prothoracic glands | a) moulting |
| 2. Y-organ | b) development of gonads |
| 3. Optic gland | c) colour change |
| 4. Androgenic gland | d) regeneration |
| 5. Post-commissural organs | e) prothoracic gland stimulation |
| 6. Pars intercerebralis NSCs | f) male sex characters |
| 7. Brain-infracerebral complex | |

## 12.6 SUMMARY

- In this unit you have studied the various endocrine glands of non-chordates, the hormones they release and the functions they discharge. The glands are either neurosecretory, neural or epithelial in nature.
- Neurosecretory cells are important constituents of the multicellular non-chordate endocrine system as they have fewer epithelial endocrine glands. The neurosecretory cell is a neurone specialised for hormone production.
- Corpus cardiacum and sinus gland are the main neurohaemal organs of insects and crustaceans respectively. Corpus cardiacum is also a neural endocrine gland. Corpus allatum, prothoracic glands, Y-organs, androgenic glands and optic glands are some of the epithelial endocrine glands.
- The endocrine glands play important role in annelids, molluscs, crustaceans and insects, in coordinating and controlling growth, reproduction, colour change and metabolism.

## 12.7 TERMINAL QUESTIONS

1. Give two differences between neural and endocrine coordination.

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2. Give two important characters of neurosecretory cells.

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3. What is a neurohaemal organ? Name two neuro-haemal organs in non-chordates.

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4. Explain how moulting and metamorphosis are controlled by hormones in insects.

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5. Compile a table showing the main endocrine glands of non-chordates you have studied, the hormones they produce and the functions they discharge.

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## 12.8 ANSWERS

### Self-Assessment Questions

1) i) – E, ii) – E, iii) – N, iv) – N, v) – N, vi) – E

2) i) – F, ii) – F, iii) – T, iv) – F

3) i) – F, ii) – T, iii) – T, iv) – T, v) – F

4) i) – a, ii) – a, iii) – b, iv) – f, v) – c, vi) – e, vii) – d

### Terminal Questions

1) Neural coordination is (a) rapid and (b) momentary whereas hormonal coordination is (a) slow and (b) sustained.
2) Neurosecretory cells are (a) neurones (b)which produce hormones.
3) Neurohaemal organs are organs containing fingerlike, highly branched, fibre terminations of neurosecretory cells, situated close to blood sinuses, and store neurosecretory material and release hormones into blood on requirement. (a) Pars intercerebralis NSC –corpus cardiacum system (b)X-organ-sinus gland system.
4) Prothroracic glands secrete ecdysone. When the concentration of ecdysone reaches a certain level, moulting results. Corpus allatum secretes juvenile hormone. When

moulting takes place in the presence of high concentrations of juvenile hormone another larval-larval transformation takes place; when moulting occurs in the presence of relatively low concentrations of JH, the larval-pupal transformation occurs. Finally When the corpus allatum is totally inactivated and no JH secretion occurs, then the pupal-adult transformation occurs. Thus the metamorphosis is controlled by the titres of JH in blood.

# UNIT 13 REPRODUCTION IN NON-CHORDATES

## Structure



## 13.1 INTRODUCTION

In previous units you studied the body systems and life processes of non-chordates which are essential for keeping an individual organism alive and enabling it to function normally. There you noted that although each of these systems performed the same overall common function, yet it differed considerably in the different phyla of the non-chordates and even in the sub-groups of the same phylum. These differences are evidently correlated with mainly two things – the structural organisation of the organisms and, the environment which they occupied. The same is true about the differences in the reproductive patterns. Since reproduction also is a significant phenomenon of life enabling a species to continue generation after generation, it is logical to find that the non-chordates have evolved no less diverse methods of reproduction. Such methods range from simple splitting into two, to very complicated methods of sexual reproduction, parthenogenesis, etc. You will learn that asexual reproduction, combined with sexual reproduction has evolved complicated life cycles and several larval forms that are entirely different from the adult forms. This unit is designed to make you familiar with such varied types of reproduction among the non-chordates.

### Objectives

After studying this unit you will be able to:

- illustrate the various types of asexual reproduction in non-chordates giving examples,
- define regeneration and describe how it is contributory to asexual reproduction,
- describe sexual reproduction and its importance,
- cite examples of hermaphroditism and relate the phenomenon with the conditions of life of the hermaphrodites,
- describe the phenomenon of parthenogenesis, its significance and its various types in the non-chordates,
- explain the importance of alternation of generations in some phyla of non-chordates
- differentiate between direct and indirect life cycles and
- describe some of the important larval forms found in invertebrates.

## 13.2 ASEXUAL REPRODUCTION

Reproduction may be considered as production of true copies. Most of the animals which are quite familiar to us produce male and female gametes (sperms and eggs). These gametes unite together to form a zygote that subsequently develops into an adult, which is a copy of the parents. This kind of reproduction is called **sexual reproduction**. There are also a large number of animals, particularly among non-chordates, which reproduce from body parts other than gametes. This does not involve sex or sex-cells or meiotic division. It basically involves both growth and regeneration of missing parts. Such reproduction is categorised as **asexual reproduction** and it is very common among coelenterates, plananians, polychaetes and oligochaetes. Asexual reproduction is also called **vegetative reproduction**; this is because it involves some body part or any special unit produced by it, not related to the gamete-producing organs (ovaries and testes). In fact, asexual reproduction is the most primitive one – the first organisms that evolved on the earth were protistans and they probably just divided into two – the simplest form of asexual reproduction. Even today, this is the most common type of reproduction among protistans.

**Main forms of asexual reproduction**

The following are the main types of asexual reproduction.

Binary fission
Multiple fission
Fragmentation
Budding
Strobilation
Formation of special units (or bodies)

### 13.2.1 BINARY FISSION

Binary fission is a process in which an organism divides mitotically into two equal individuals which are normally identical to each other. This process is widespread in protozoans. *Amoeba, Euglena* and *Paramecium* are the most familiar examples. All the three are freshwater forms. *Amoeba* (Fig. 13.1) is an irregularly shaped unicelluar organism. When full grown and when the conditions are favourable it slows down its movements and produces short fine radial pseudopodia. The contractile vacuole stops functioning and may disappear. The nucleus elongates, becomes dumb-bell shaped and undergoes mitotic division. The cell constricts in the middle to finally divide into two smaller daughter amoebae each possessing one daughter nucleus (Fig. 13.1). Subsequently, the pseudopodia become normal and a new contractile vacuole is formed in each. The entire process of fission in *Amoeba* may take about 30 minutes at moderately warm temperature. *Amoeba* thus divides regularly, almost every 24 hours.

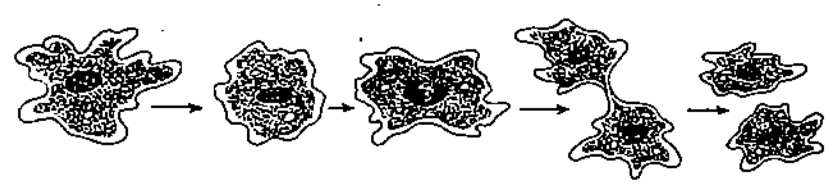


**Fig. 13.1 : Binary fission in freshwater amoeba.**

*Euglena*, a freshwater flagellate, divides longitudinally (longitudinal binary fission). The kind of division in it is said to be **symmetrogenic**, that is, producing symmetrical or mirror-image daughter cells (Fig. 13.2). The centrioles first divide into two and the nucleus then begins to divide. Each centriole produces a new basal body and a new flagellum. The contractile vacuole also divides into two. As mitosis (nuclear division) reaches completion the cytopharynx (gullet) also begins to divide and finally when the organelles have duplicated the anterior end starts dividing as a fork, which deepens posteriorly to ultimately produce two daughter *Euglena*.

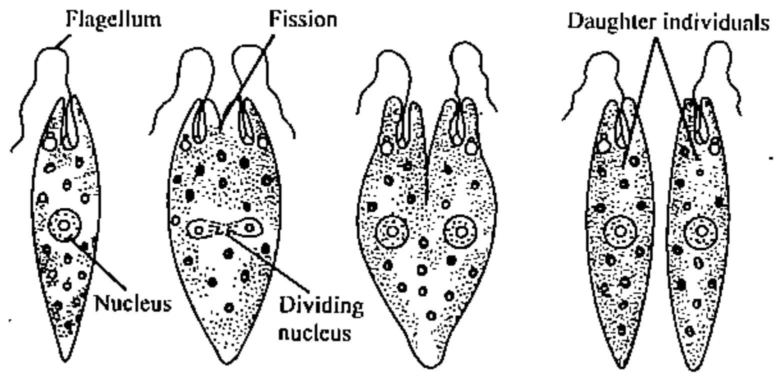



Fig. 13.2 : Binary fission in *Euglena.*

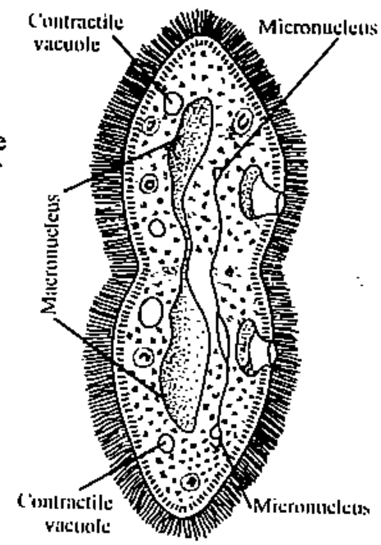



Fig. 13.3 : Transverse binary fission in *Paramecium.*

*Paramecium* (Fig. 13.3) divides transversely into an anterior half and a posterior half. The fission here is called **homothetogenic**, meaning looking like the letter "θ" i.e., "theta" of greek alphabet. The macronucleus divides amitotically and the micronucleus divides mitotically. A second cytopharynx is produced by the posterior half. Two new contractile vacuoles are formed one going to each half. In the meanwhile a constriction is formed at the middle which deepens to finally separate the two independent daughter paramecia. The entire process of binary fission in *Paramecium* may take about two hours. According to one estimate as many as 600 generations can be produced in a single year. It may be seen that all the progeny thus produced from a single original parent as a result of binary fission either in *Amoeba, Euglena* or in *Paramecium* have the same genetic composition. They are identical in all respects. The term *clone* is used to refer to such a population.

**Plasmotomy** is a variant form of fission found in some multinucleate protozoans like *Opalina* (Fig. 13.4), a ciliate that lives as a commensal in frog's rectum. In this kind of asexual reproduction the multinucleate protozoan divides into two or more parts without any nuclear division and the existing nuclei are distributed among the new individuals. The new, still multinucleate, daughter opalinas produce more nuclei as they grow.

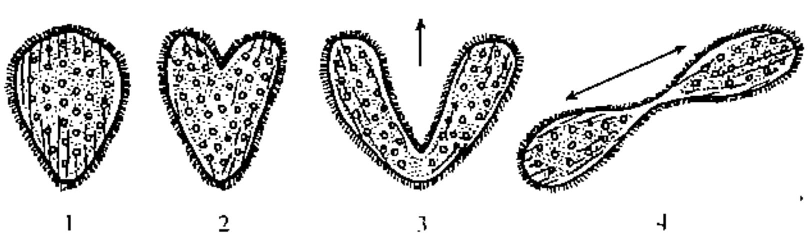



Fig. 13.4 : Multinucleate *Opalina* which reproduces asexually by plasmotomy. Opalines usually divide longitudinally, between the rows of cilia.

## 13.2.2 MULTIPLE FISSION

Multiple fission is a variation of fission in which the parent divides mitotically into a number of smaller units, which are the daughter individuals simultaneously. The nucleus in this case divides very fast, repeatedly. Subsequently the cytoplasm surrounding each daughter nucleus begins to form separate units leading to formation of small uninucleate, masses. These units become independent. This method of reproduction is also known as **schizogony and** it occurs typically in Sporozoa and some Sarcodina. Schizogony is also known as **sporogony** if it is associated with production of sporozoites after formation of zygote. A very good example of multiple fission is seen in *Plasmodium* where sporozoites are introduced by the mosquito in the human host and where they enter the liver to undergo several schizogonous cycles (pre-erythrocytic schizogony). The merozoites liberated from liver enter erythrocytes to undergo another cycle of schizogony in which the schizont inside the human RBC undergoes multiple fission to produce merozoites (refer to Unit 2 of this Course). Can you visualise here that the parasite is exploiting the food resource to very rapidly multiply its numbers? That is one very significant advantage of asexual reproduction.

In addition to the different types of fissions described above, a modified type of fission in the form of budding occurs in suctorians. The adults bud off one or more smaller daughter cells. When buds are given off from the outer surface, it is known as external budding. When budding takes place inside a chamber, buds arising from the wall of the chamber it is called internal budding (Fig. 13.5). The buds, when released, possess ciliated bands and they swim around. But they soon attach to the substratum and become adults.

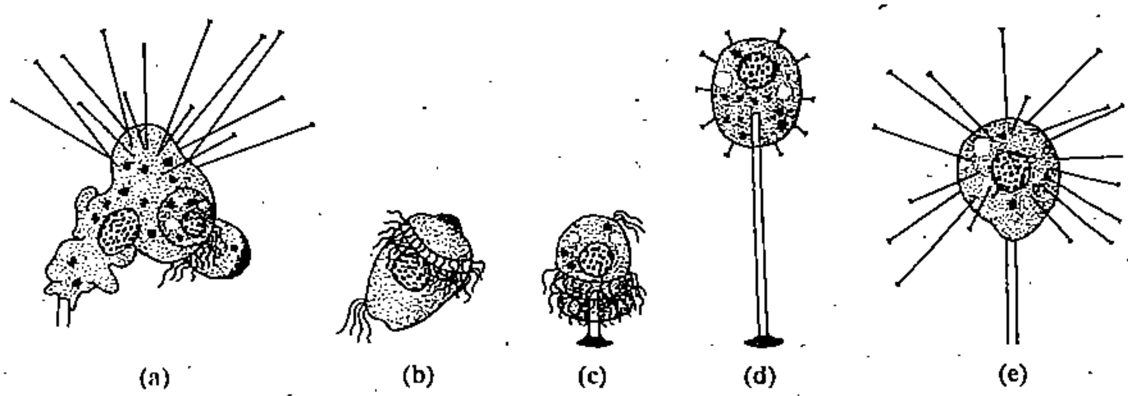



Fig. 13.5 : Suctorian budding in *Tokophrya lemnarum.* The bud escapes from an internal pouch through a narrow pore (a) and swims away. (b) It attaches to the substratum to produce a stalk. (c) The cilia are lost and tentacles appear. (d-e)

### 13.2.3 FRAGMENTATION

Fragmentation is a phenomenon in which a parent animal spontaneously (on its own accord) splits into two or more fragments. Each one of such fragments then regenerates the missing parts to form a new individual. This method is reported in certain sea-anemones and some worms. Sea anemones sometimes break off part or whole of their pedal disc while the main body moves away (pedal laceration). The pedal disc may put out lobes which pinch off and regenerate into small sea anemones. Sometimes a sea anemone leaves behind its pedal disc alongwith a few mesenteries at the site of attachment, in such cases the part left behind regenerates into a new sea anemone and the other main part regenerates the missing pedal disc. Fragmentation may be considered as a type of fission. Moreover longitudinal and transverse fission occurs as a normal method of asexual reproduction in many sea anemones.

Spontaneous separation is beautifully illustrated in certain freshwater planarians (Platyhelminthes, Class Turbellaria). A common example is *Dugesia.* The fission occurs when the animal has grown to the maximum size. The fission plane usually forms behind the pharynx.

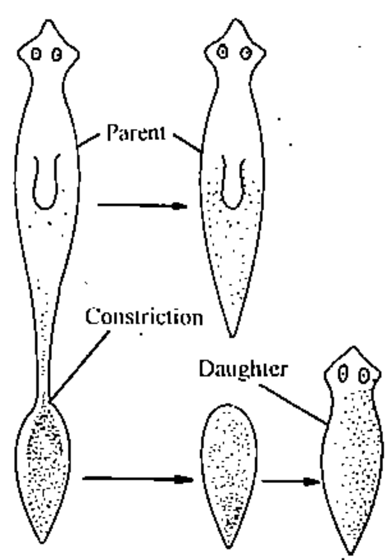



Fig. 13.6 : A planarian reproducing asexually by fragmentation.

At that time the hind part of the animal is firmly attached to the substratum and the front part continues to move forward until the worm breaks at the constriction into an anterior and a posterior segment (Fig. 13.6). Each segment next regenerates the missing parts to form a new small worm. In some planarians such as *Microstomum*, chains of individuals may be formed as a result of repeated fission. When these individuals develop and attain a certain degree of differentiation, they separate from the chain. (Fig. 13.7).

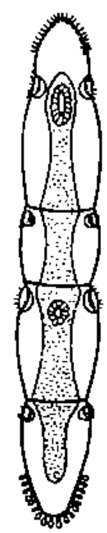


Fig. 13.7 : *Microstomum* with a chain of zooids.

### 13.2.4 BUDDING

In reproduction by budding, small groups of cells form buds in some part or parts of the parent animal. The bud grows, differentiates and ultimately forms a new adult individual. This adult may either remain attached to the parent as in colonial forms (sponges and many coelenterates) or may separate from it to form an independent individual, as in *Hydra*. Fig. 13.8 shows budding in the common freshwater hydra. It first starts as a simple bulging of the ectoderm. Then both ecto- and endoderms project outward in the form of a bud. Thereafter, the coelenteron also extends into this little protuberance. The bud begins to grow in size, the tentacles start forming and a mouth appears. When the bud practically assumes the shape of a miniature hydra a constriction appears at its base which gradually narrows to a small point and finally the little bud hydra separates off to settle somewhere else as an independent hydra.

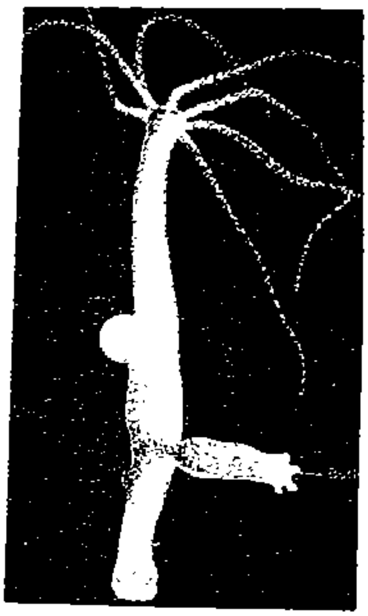


Fig. 13.8 : Budding in Hydra.

Asexual reproduction by budding is quite common in many other cnidarians also. It is prevalent both in the polypoid stages (as in hydra) as well as in medusoid forms (jellyfishes). Budding at times takes the form of stolons that grow along the ground from which are budded upright stems; this is quite common in colonial cnidarians.

**How budding and fission are similar and how these are different.**

Both budding and fission are similar in at least one way in that the young ones produced by these processes are the result of direct splitting off from the body of the parent. But the two are also clearly different in many respects. These differences are listed in the Table 13.1 given below.

Table 13.1 : Differences between budding and fission.

| S.No. | BUDDING | FISSION |
|---|---|---|
| 1. | The parent individual persists after the daughter individual has budded off. | The parent individual loses its identity after splitting into two or more daughter individuals. |
| 2. | Bud starts as a trace and slowly grows to an appropriate size before it pinches off but it is still smaller than the parent | The daughter individuals (whether two or more) are identical in structure but all are smaller in size than the parent. Later they grow to attain their normal dimensions. |
| 3. | Budding is rather slow and gradual. | Fission is rapid and instantaneous. |

## 13.2.5 STROBILATION

Strobilation is a kind of asexual reproduction in which successive segments are separated off from the body one after another. It is well illustrated in some jellyfishes (Scyphozoa) and in tapeworms. In the life-history of *Aurelia*, a scyphozoan, the planula larva develops into a hydra-like stage called hydratuba or scyphistoma. From the stolon, the scyphistomae may produce new scyphistomae. After a certain period of life this scyphistoma undergoes transverse division producing buds of medusae. This gives it a kind of pattern of a pile of saucers arranged one above the other. In this pile, the youngest (smallest) saucer lies towards the base and the oldest and the largest one at the free end. This "pile of saucers" stage is called the **strobila**. The transverse discs or young medusae buds separate one after another from the strobila, each resulting in a kind of larva (called ephyra) which gradually metamorphoses to become the adult *Aurelia* (Fig. 13.9, also refer to Fig. 14.7 of Block 2 of this course).

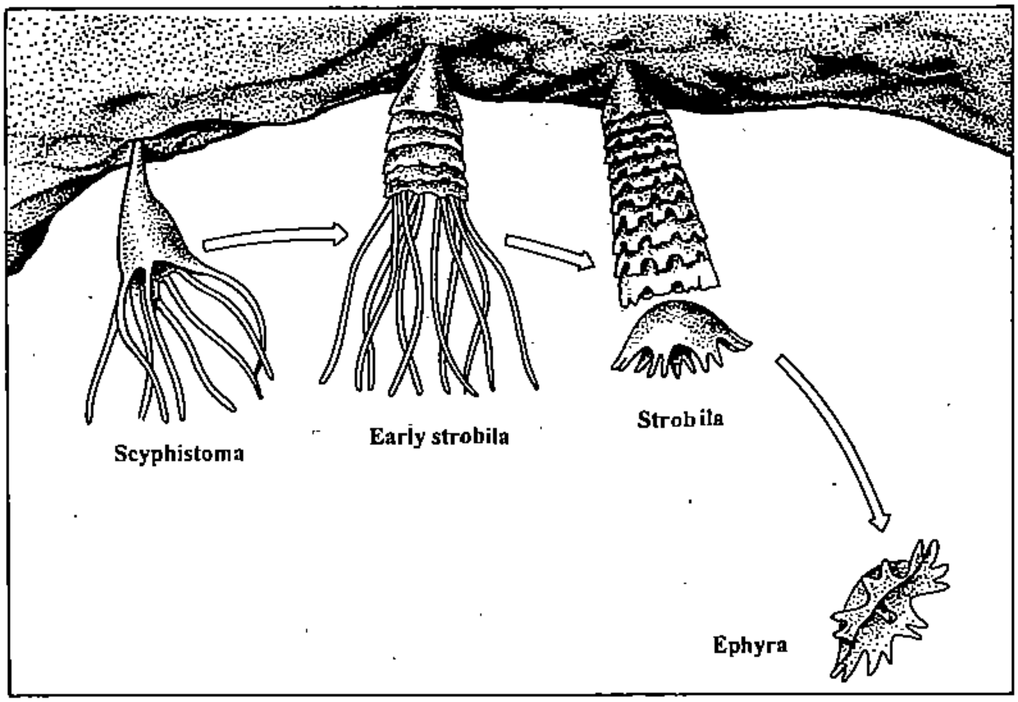



**Fig. 13.9 : Strobilation of the scyphistoma of *Aurelia*.**

A situation somewhat similar to the above also occurs in the tapeworms. New segments (proglottides) are continuously demarcated off from the neck by a sort of transverse fission; Here also, it is the oldest proglottid at the free end which breaks off and the process keeps on repeating (Fig. 13.10).

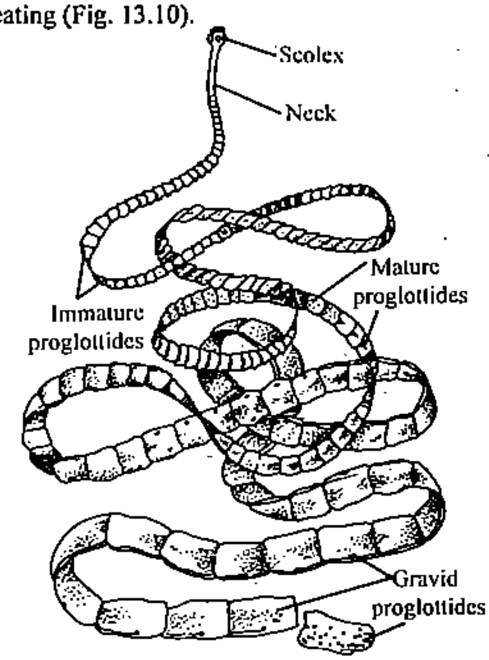



**Fig. 13.10 : Strobilation in tapeworm.**

### 13.2.5 FORMATION OF SPECIAL REPRODUCTIVE UNITS – THE GEMMULES

All freshwater sponges (Spongillidae) and some marine species, under dry conditions or low temperature produce asexual bodies called **gemmules**. These are formed before the onset of the adverse conditions. The parent sponge disintegrates, leaving behind, the gemmules, which can withstand drought and winter. In spring, when temperature begins to get warmer the gemmules undergo development and each of them produces a new sponge.

**Formation of gemmules**

During the formation of gemmules, masses of food – laden amoebocytes called archeocytes feed on other cells and lay down yolk within them. They get surrounded by spongiocytes (another kind of amoebocytes). The latter secrete a two layered hard covering. A tiny pore, the **micropyle**, is left as a small opening in this protective shell. Thereafter, some scleroblasts (spicule-producing cells) come to lie between the two layers of the shell and produce spicules (Fig. 13.11). The gemmules are now completed. The parent sponge may now disintegrate leaving behind the gemmulus. On revival of favourable conditions, the gemmules start development. The centrally located archeocytes emerge out through the micropyle as a mass which undergoes cell division and differentiation to produce a new sponge.

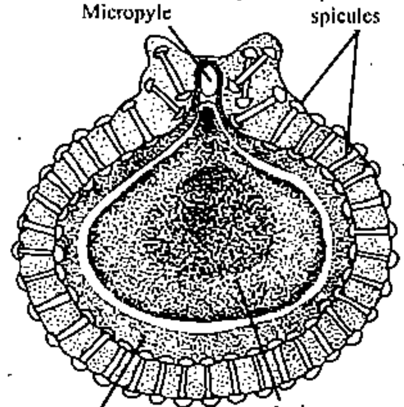



**Fig. 13.11: Section of Gemmule of *Spongilla*. Throughout dormancy which may last for several years, the cells of the inner mass retain the ultrastructure of active cells. Within 24 hours of favourable conditions arising, the membrane below the pore is digested by enzymes and cells start to escape out.**

**SAQ 1**

I. Match the modes of asexual reproduction with the appropriate examples.

| Mode of reproduction | Example |
|---|---|
| 1. Binary fission | (a) *Hydra* |
| 2. Fragmentation | (b) *Aurelia* |
| 3. Plasmotomy | (c) *Plasmodium* |
| 4. Budding | (d) Planaria |
| 5. Multiple fission | (e) *Opalina* |
| 6. Gemmule formation | (f) *Paramecium* |
| 7. Strobilation | (g) *Spongilla* |

II. Tick (✓) mark the correct statements.

i) The most primitive mode of reproduction in animals is by binary fission.
ii) Multiple fission and cell division are one and the same.
iii) Asexual reproduction by fragmentation depends on power to regenerate.
iv) Budding is a slow and gradual process.
v) Asexual reproduction by gemmules is a regular method found in all sponges.

## 13.3 REGENERATION LEADING TO ASEXUAL REPRODUCTION

Regeneration is defined as the replacement of the lost parts of the body of an organism. This capacity is present in almost all organisms but in many cases, especially in most higher vertebrates and some non-chordates, this capacity is limited only to replacement of cells, but not to organs or major parts of organs. But regenerative capacity in many non-chordates, especially the lower forms, is tremendous and can lead to the formation of a completely new individual from any broken bit or the fraction of the parent's body, and in this manner it almost becomes yet another method of asexual reproduction.

Regeneration as a process leading to asexual reproduction can occur in two situations:

1. Animals *naturally fragmenting* (spontaneous separation) followed by regeneration of the missing parts in each fragment.
2. Animals *accidentally cut* or *broken* into pieces by injury followed by regeneration in each bit to produce as many complete individuals.

### 13.3.1 FRAGMENTATION AND REGENERATION

Both the situations mentioned above i.e., whether occurring naturally or accidentally, can in general, be categorised as fragmentation. Of these, the first one, of natural or innate fragmentation followed by regeneration producing complete individuals has already been

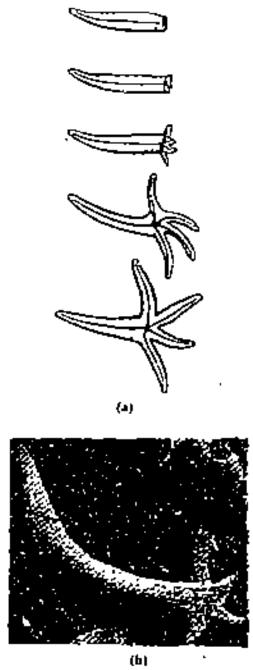



**Fig. 13.12 : Regeneration in starfish *Linckia* leading to asexual reproduction (a). A single arm regenerates the central disc as well as the remaining four arms (b).**

covered in the previous sections. We shall here describe the second manner in which accidentally produced body fragments regenerate all the missing parts to produce complete individuals.

Regenerative capacity is fairly well-developed and extensive in echinoderms, but to a different degree in different groups and species. Though echinoids or sea urchins are poorly endowed with regenerative power, star fishes (asteriods), brittle stars (ophiuroids) and sea lilies (crinoids) have extensive capacity to regenerate. Most of these, especially many star fishes and brittle stars, not only regenerate lost arms or part of the central disc, but even an arm can regenerate a whole animal, including the other arms and the central disc. Some starfishes eg., *Linckia* are able to cast off their arm, which will regenerate into a starfish (Fig. 13.13). A number of starfishes and some crinoids (eg. *Ophiactis*) even normaly reproduce asexually. This involves division of central disc so that the animal divides into two. This is known as fissiparity. The two halves will regenerate the missing half. Certain holothurians (sea cucumbers) are unique in showing what is called evisceration. On encountering any immediate danger of some intruder or enemy these can throw out the large masses of "tubules of cuvier" attached to respiratory trees, or some times even almost all of their viscera through their cloaca and regenerate them later. In some species evisceration is a normal seasonal phenomenon.

Spontaneous fragmentation of the body followed by regeneration of the body parts to form a new individual is a common form of asexual reproduction in polychaetes. In many syllids the point in the septa where the segment will fragment is predetermined and is different from other septa. In such species fragmentation and regeneration are highly organised and each fragment can develop into a complete individual. In some cases the original somite remains large and a head and tail regenerate at each end. These break off and the tail portion grows a new head, while the head grows a new tail.

### 13.3.2 AUTOTOMY AND REGENERATION

Shedding of body parts in self-defense to divert the attention of the predator-enemy or in any other emergency is a kind of autotomy (*auto*: self, *tomy*: cutting). The most familiar example of autotomy is a breaking off of the tail in the common house lizard among the chordates, but the phenomenon is far more common among the non-chordates. You have already seen that this occurs is many echinoderms. The star fishes and brittle stars can cast off their arms which can regenerate into whole animals. A very interesting case of autotomy followed by regeneration is found in a polychaete annelid worm called *Chaetopterus*.

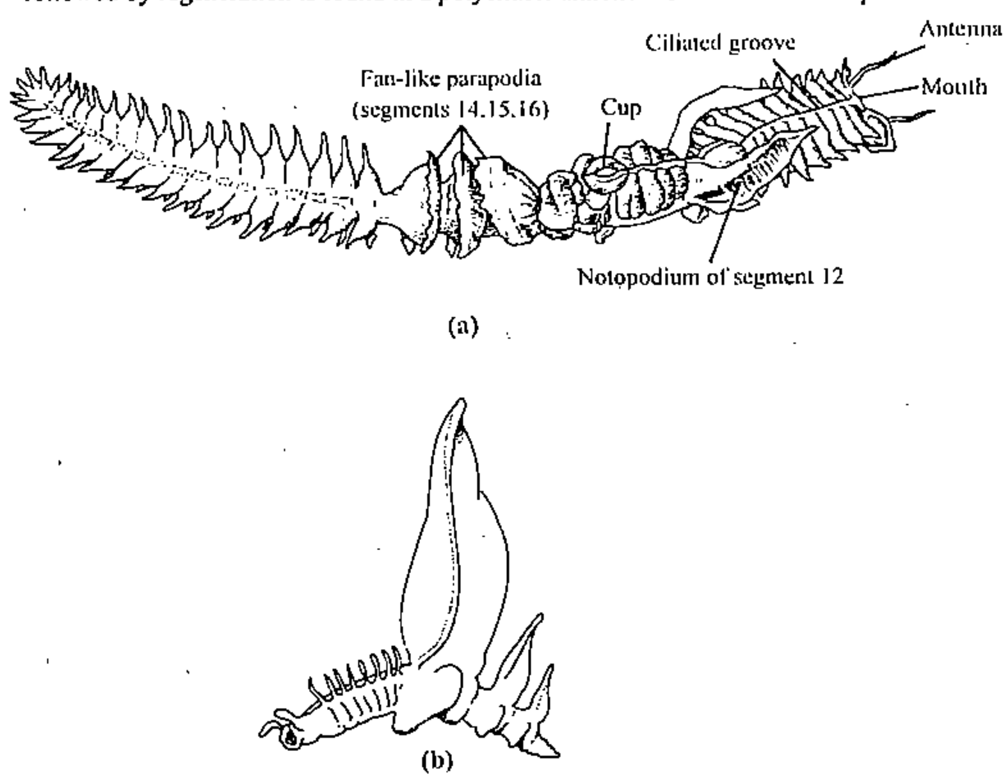



**Fig. 13.13 : A tube-dwelling annelid Chaetopterus (a). It can regenerate the lost front end of the body, as well as the entire worm from a single isolated body segment in the figure from a single fan segment (b).**

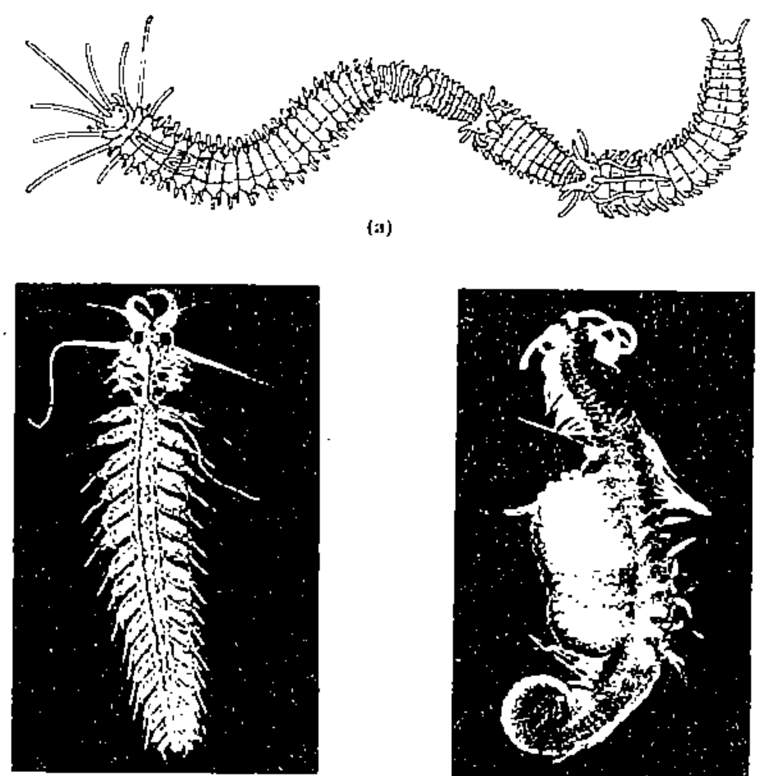
It lives permanently inside a U-shaped parchment tube in the muddy bottom in shallow sea water (Fig. 13.13 a). If the anterior end of this worm is pulled by a predator a constriction between 12th and 13th segments breaks the body into two pieces. The worm loses its head region to enemy while the remaining hind portion is left behind in the U-tube. This hind portion contains the gonads and regenerates the front part required for normal feeding activity. *Chaetopterus* has been found to have a remarkable power of regenerating a complete worm from a single isolated body segment i.e., segment 14 (Fig. 13.13 b).

## 13.3.3 EPITOKY

This is a highly specialised form of asexual reproduction where an asexual worm known as "atoke" buds off a sexual form. Certain polychaete annelids occur in two distinct phases – a non-reproductive (asexual) and a reproductive (sexual) phases. *Nereis irrorata* is a simple example. This worm is a bottom dweller in shallow sea. In the non-breeding phase it lives mostly hiding among rocks and crevices or inside tubular formations to creep out only at night for feeding. During breeding season, it undergoes marked structural changes in both males and females. The body gets differentiated into an anterior half and a posterior half - **heteronereis** (Fig. 13.14). The anterior half called **atoke** remains almost unchanged while the posterior half called **epitoke** undergoes a few radical changes. The changes in the **epitoke** primarily include (i) the parapodia, which get enlarged to become oar-like for efficient swimming and (ii) the gonads, confined only to this region, grow profusely and the gametes fill the body cavity. At certain fixed nights, determined by environmental factors such as the moonlight in a particular month of the year, the posterior sexual parts (epitokes) of the worms get detached and swim around. Large number of such male and female epitokes produce a dense swarm on surface of the sea during these night.

Fig. 13.14: Heteronereis, male showing the atoke and epitoke regions.

These epitokes then burst and disintegrate releasing sex cells in the sea where they undergo fertilization. The non-swarming body parts (atokes) regenerate the lost segments to repeat the process once again the next year. The term swarming is used here to emphasize the fact that the rising of the epitokes to the surface of the sea is collective constituting sometimes even millions of such individuals, both males and females, together. When they all burst to release the sex cells, the chances of fertilization are very high.



(a)

(b) (c)

Fig. 13.15: a) *Autolytus* budding off a chain of epitoke, budding occurs in both males and females. Producing (b) male or (c) female epitoke.

There are numerous variations in epitoky. For example in *Syllis vittata* the epitoke develops the head and a pair of eyes even before fragmentation from the atoke, and similarly, the atoke begins to grow the hind part before the epitoke has separated.

In the polychaete worm *Autolytus* the asexual worm developed from the ovum gives rise by a process of constrictions and posterior proliferations to new (one or more) zooids which may remain connected in a string before getting separated. The sexual zooids later develop into mature male and females (Fig. 13.15).

*Syllis ramosa* is another peculiar polychaete annelid that lives inside the cavities of certain deep sea sponges. The annelid produces lateral buds repeatedly from various segments. Thus it presents the appearance of a branching colony (Fig. 13.16). The individuals produced by such budding get separated. They are sexual zooids.

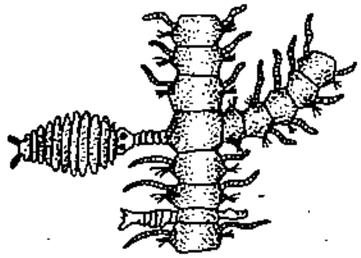


Fig. 13.16: Syllis showing branching individuals, budding off from parapodia.

Amongst poriferans any piece cut away from the main body of a sponge can grow into a complete sponge, but the process is fairly slow and months or even years may elapse before full size is reached. Some sponges reproduce asexually by constriction of branches and their falling off, which regenerate into new sponges. Sponges can even regenerate from masses of isolated cells. When a sponge is squeezed through fine silk cloth it gets broken up into isolated cells or cell-clumps. Through random amoebid movements of the amoebocytes the isolated cells form aggregates. These are the reunition masses. These rearrange and ultimately grow into new sponges.

*Hydra* and many other Cnidarians like *Tubularia, Obelia,* and even sea-anemones, if cut into pieces, can regenerate producing new individuals. For example, if *Hydra* is cut into three equal pieces, the piece with tentacles regenerates the pedal disc; the basal piece regenerates the oral disc along with the tentacles; the middle piece regenerates the oral disc from its apical end and the pedal disc from its proximal end. (Fig. 13.17).

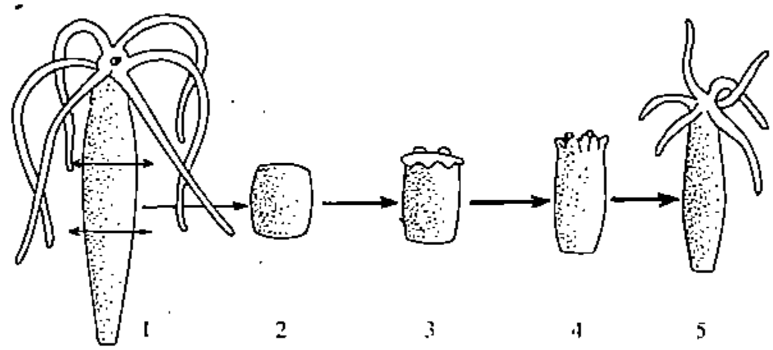



Fig. 13.17 : Regeneration in *Hydra* cut into pieces.

Planarians ( Phylum Platyhelminthes) exhibit remarkable property of regeneration. When cut into half, the missing half will regrow in each piece to produce a complete planarian. Many interesting experiments have been performed on regeneration in planarians. A two headed planarian can be produced by splitting only the head and two-tailed specimen can be produced by splitting the tail only (Fig. 13.18).

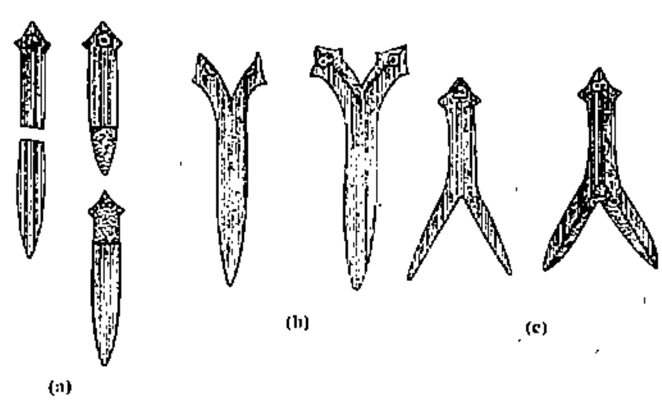



Fig. 13.18: Regeneration in a planarian.

### 13.3.4 POLARITY IN REGENERATION

A distinct polarity or gradient exists in planarians (and in other animals). It means that in any piece or segment of the body, its anterior end (head end) represents one pole and the posterior end (tail end) represents the other pole. Regeneration is normally correlated with this polarity. In any excised piece the cut surface towards the head end produces a new head and the cut surface towards the hind end produces a tail.

In the remaining non-chordate phyla (i.e. Aschelminthes, Arthropoda and Mollusca) regeneration of missing parts is minimal, and asexual reproduction involving regeneration is almost non-existant.

## 13.4 ASEXUAL REPRODUCTION – ITS PREVALENCE AND SIGNIFICANCE

Having studied the various aspects of asexual reproduction in the non-chordates we can now make a few generalisations.

**A.** ***Prevalence of asexual reproduction***

1. Asexual reproduction is far more prevalent in the lower animal phyla than in the higher ones.
2. Asexual reproduction is largely associated with the regenerative capacity.
3. Lower animals with relatively less differentiated cells and tissues possess higher regenerative power than the higher animals and thus contribute to asexual reproduction.
4. In higher animals regenerative capacity in largely restricted to organ replacement (In chordates it is even less and is limited to tissue regeneration).

**B.** ***Significance of asexual reproduction***

Asexual reproduction is advantageous to the species in many ways:

1. Asexual mode of reproduction is a surer method of reproduction, it normally does not involve chance or risk factors which are usually inherent in the sexual method.
2. Asexual reproduction, specially by fission and budding, is a method of rapid increase in numbers and thus leads to a faster growth of population.
3. Animals reproducing asexually are able to take maximum advantage of favourable environment by rapid multiplication.
4. Asexual reproduction by formation of gemmules in certain sponges is a means to tide over unfavourable conditions.

## SAQ 2

I. Fill in the blanks in the following sentences:

1. In starfishes even a single separated arm can regrow a complete ........................... as well as the remaining four ........................
2. Evisceration followed by regeneration of the lost viscera is frequently found in ....................
3. Sponges can regenerate from masses of isolated cells often termed as .......................... masses.
4. A two headed planarian can be produced by ......................... the head longitudinally.
5. Production of ..................... in sponges is a method to tide over conditions of drought or cold.

II. Give one main reason why asexual reproduction is more prevalent in lower non-chordates than in the higher ones.

..........................................................................................................

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## 13.5 SEXUAL REPRODUCTION

All metazoans, whether or not capable of propagating asexually, produce special cells called **gametes**. The gametes maybe either male gametes (sperms) or female gametes (ova). Syngamy follows during which a sperm fertilizes an ovum producing a zygote. The zygote develops and ultimately produces an adult. During syngamy, there is doubling of chromosomes; the zygote and its derivative cells are diploid. To avoid repeated doubling of chromosomes, there is meiosis or reduction division during the production of gametes. In this process chromosome number is reduced to half (haploid number). The cycle is repeated, and the chromosome number is maintained, (refer to sexual reproduction in the courses LSE-05 and LSE-06)

### 13.5.1 THE GAMETES AND SIGNIFICANCE OF SEXUAL REPRODUCTION

If chromosome number is thus maintained constant in a species as a result of sexual reproduction, then what is the use of this process involving syngamy and subsequent meiosis? The answer is, that there is mixing of maternal and paternal chromosomes in the zygote. This, together with recombination between homologous chromosomes taking place during meiosis, gives ample opportunity for genetic variation of the individuals produced. On this genetic variation, selection can work and evolution can proceed.

It must be clearly noted here that sexual reproduction is a fundamental property of protozoans as well, though there are important differences between the two group as we shall see when we proceed further in this section.

Following are some general characteristics of gametes:

1. The gametes of opposite sexes are usually unequal in size – the ones which are generally larger are the eggs or the female gametes, and the others that are smaller are called the **spermatozoa** (or sperms) or just the male gametes.
2. The female gametes are generally laden with food material, the yolk, while the male gametes are **without** food reserve.
3. The female gametes are usually nonmotile or immobile (cannot move about actively) while the male ones are motile.
4. Both the kinds of gametes possess half the quantity of the genetic material (DNA), i.e. half the number of chromosomes of the parent. This is expressed by saying that the gametes are **haploid** (n) possessing only one out of each pair of chromosomes of the species, whereas the parents which produced them are **diploid** (2n).
5. The gametes usually cannot develop singly. Instead, they must undergo syngamy involving **fertilization** in which the male and the female gametes fuse together to form the zygote.
6. The **zygote** is still a single cell which has to undergo a process of cell division and cell differentiation to gradually acquire the adult form and structure.
7. The sex cells or gametes which fertilize to produce a new individual usually come from different parents (males and females). This provides for the combination of genes from the two parents, and the offspring, due to such chance combinations of genes, may be better equipped (adapted) for life.

### 13.5.2 THE TWO SEXES AND SEXUAL DIMORPHISM

**The two sexes - male and female** : In most animals, each species has two types of individuals the male, producing male gametes or sperms and the female producing ova or eggs. However, in many animals, especially many non-chordates, both types of gametes are produced in the same individual. Such individuals are called **hermaphrodites** (recall from LSE-05 Unit 14). You will read more about them in section 13.6. Apart from producing different types of gametes, usually the males and the females can be distinguished by other characters. This is called **sexual dimorphism**. Sometimes sexual dimorphism may be very conspicous, sometime the differences may not be very pronounced. But practically all animals above the level of Cnidaria show varying degrees of sexual dimorphism. Some examples are:

1. The blood fluke of the genus *Schistosoma*, for example, *Schistosoma haematobium* (Phylum Platyhelminthes, Class Trematoda) is a parasite in human blood vessels. The male is large and thick: it bears a long canal along its ventral surface, which is formed by the body folds. The female is also long but thin and is firmly held inside the male's ventral canal – gynaecophoric canal (Fig. 13.19).

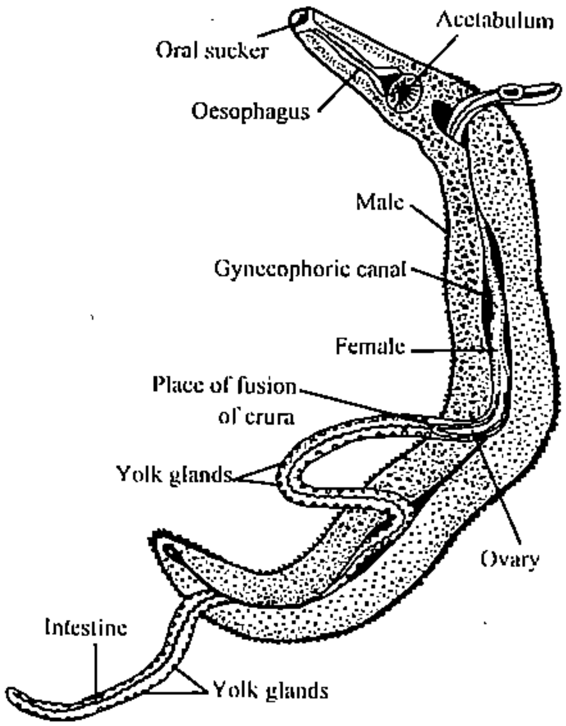



**Fig. 13.19 :** ***Schistosoma haematobium*****, the male holding the female inside the gynaecophoric canal.**

2. *Ascaris lumbricoides* (Phylum Nematoda or Nemathelminthes) is a fairly common intestinal parasite of humans; males are smaller than the females and can be readily distinguished by their curved posterior end looking like a hook (Fig. 13.20a).

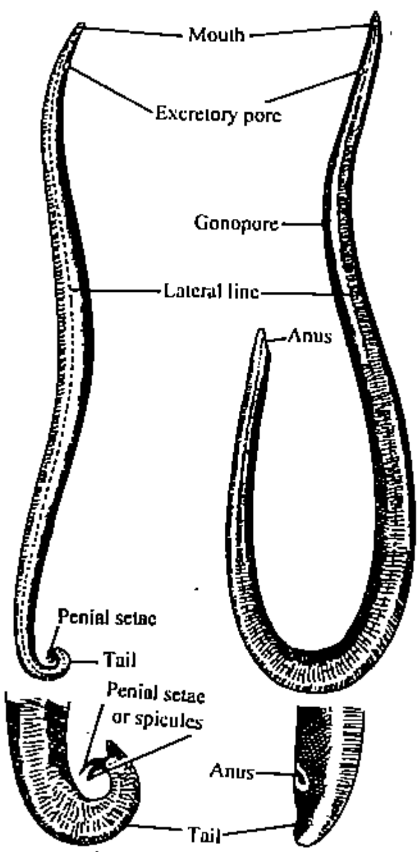



**Fig. 13.20 :** ***Ascaris lumbricoides*****. (a) – Male, (b) – Female.**

In female, the posterior end is straight (Fig. 13.20b). In males a pair of needle like chitinous structures called **penial setae** project out from the transverse anus which also serves as the reproductive aperture.

3. *Bonellia* is a member of a group of marine worms allied to annelids. It shows very marked sex dimorphism. Its female has an ovoid body about 5 cm or more long, usually lodged in crevices of rocks. A highly extensible long proboscis, which may be about a meter long, projects from the main body. The male is a dwarf about 0.5mm long. It is ciliated all over and has no proboscis. While still young and immature it enters the body of the female, and after attaining sexual maturity it lives permanently inside the uterus or coelom of its female partner. There are also considerable differences in the structure of the male.

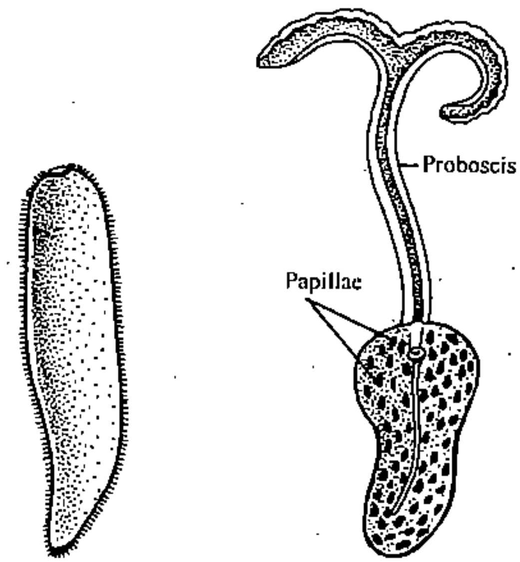



**Fig. 13.21 : *Bonellia*. Male, tiny microscopic (0.5mm long), with most internal organs other than those related to reproduction, degenerate. Female is large (5 cm long) which harbours its male partner inside the uterus or coelom.**

4. The crayfish *Palaemon* shows the following sex differences.
   i) The male is smaller than the female.
   ii) The second pair of chelate legs in males are much longer and are more densely covered by spines and setae.
   iii) The second abdominal appendage in males has an extra process called appendix masculina.

5. Insects : Most insects show sex differences, especially with regard to external genitalia. The common cockroach is easy to collect and examine. The male cockroach *Periplaneta americana* bears a pair of anal styles projecting behind the ninth sternum. These are missing in the female. The female has a much enlarged (boat-shaped) VII sternum, largely concealing the sterna of the VIII & IX segments forming a genital pouch (Fig. 13.22 a).

   In mosquitoes the antennae of the males are more hairy and densely plumose (Fig. 13.22 b). In Bombyx male, it is pectinate (comb-like) (Fig. 13.22 c) and in some other male moths (eg. *Saturnia*) it is bipectinate.

   Many dipterans have much larger eyes (holoptic) almost touching each other in males, while they are smaller and clearly separated in the females.

6. Among molluscs, a cephalopod *Argonauta*, popularly called the paper nautilus, shows conspicuous sexual dimorphism. The male is small just about 2 cm and has no shell, whereas the female is about 8 times larger and possesses a thin transparent shell (Fig. 13.23).

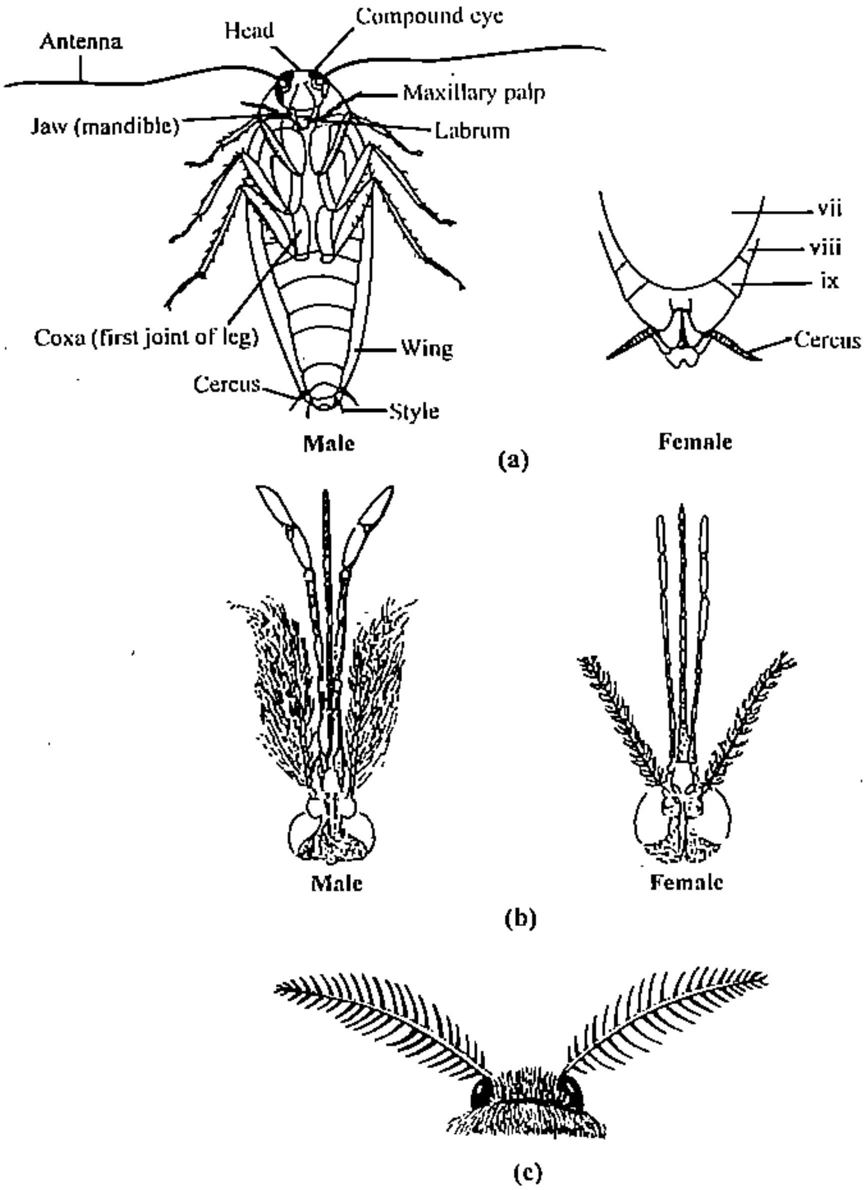



Fig. 13.22 : ***Periplaneta americana.*** **(a) – Ventral view of the male, distinguished by a pair of anal styles projecting behind IX sternum. Ventral view of the tip of the female showing enlarged VII sternum and no anal styles. (b) – Antennae of male and female mosquito. (c) – Antennae of Bombyx.**

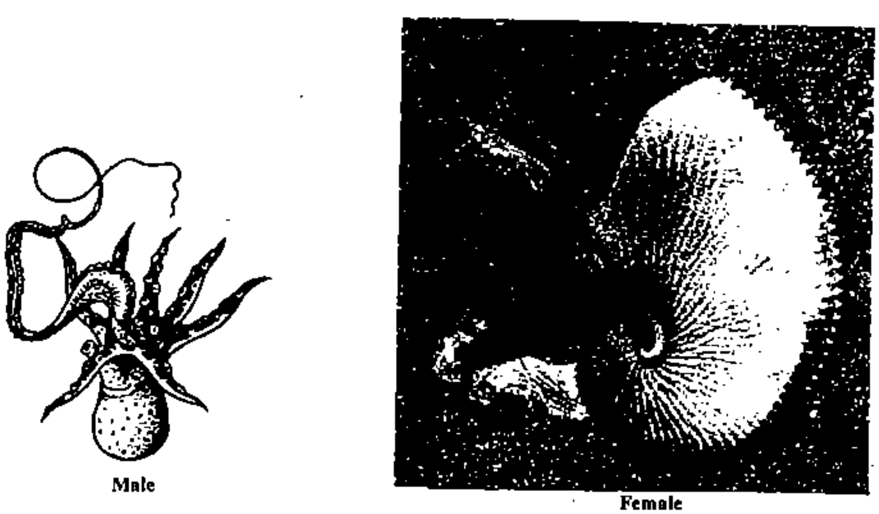



Fig. 13.23 : ***Argonauta*****, female and male.**

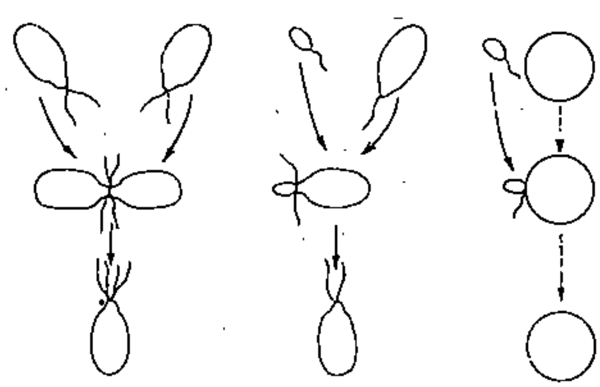
## 13.5.3 PATTERNS OF SEXUAL REPRODUCTION

Highly diverse non-chordates varying from Protozoa to Echinodermata, show numerous patterns of sexual reproduction, the major types are:

I. **Syngamy** – Sperm fuses with the egg. This results in both the union of the paternal nucleus with the maternal one (**karyogamy**), as well as the fusion of the cytoplasms of the two gametes (**plasmogamy**). Syngamy leads to fertilisation producing a zygote which develops into a new individuals.

Depending upon the size and shape of the gametes involved, syngamy can be subdivided into three types (Fig. 13.24).

i) **Isogamy** : The gametes are morphologically similar although they may differ in their physiological and biochemical properties. For example, the gametes produced from the male and female gametocytes of *Monocystis*.
ii) **Anisogamy** : The gametes differ in size and structure and are collectively known as anisogametes. Of these, the smaller ones are usually more numerous and motile. They are called the male gametes (or the micro-gametes as in protozoans and the sperms as in metazoans). The fusion of micro – and macrogametes is known as anisogamy. It is frequently found in protozoans as in *Plasmodium* and *Vorticella*. In higher phyla the term **fertilisation** is used instead of anisogamy.
iii) **Oogamy** : In oogamy one gametes type is always motile and usually small (the sperm) and the other is always non-motile and large (the egg). All metazoans exhibit oogamy. The eggs of most fully terrestrial non-chordates such as insects have shelled eggs. The shell bears a minute pore (micropyle) for allowing the entry of sperms for fertilization.



(a) (b) (c)

**Fig. 13.24 : The three patterns of fertilisation. (a) Gametes may be of the same size and motility (isogamy) (b) of different sizes but with motility (anisogamy) or (c) of different sizes and one being motile (oogamy).**

II. **Conjugation** – Conjugation is a temporary union between two individuals of the same species, during which the original macronucleus disintegrates, a new macronucleus is built from micronucleus, and the conjugants exchange nuclear material. The male nucleus of one moves over to the opposite individual and fuses with its stationary female nucleus. The process is reciprocal and the conjugants separate. This is followed by fission of the conjugants. *Paramecium* is a good example. You can refer to Fig. 2.12 subsection 2.3.7 of Block-1 for a detailed description of conjugation. Conjugation in such cases provides a kind of rejuvenation. Repeated asexual reproduction by fission through some 350 or more generations leads to onset of senility and weakens the race that may otherwise die out.

III. **Autogamy** – It is known to occur in many ciliate protozoans including *Paramecium*. Autogamy involves same nuclear behaviour as in conjugation, but it takes place in a single individuals. Therefore, there is no exchange of micronuclear material between two individuals (Fig. 13.25), as only a single individual is involved.

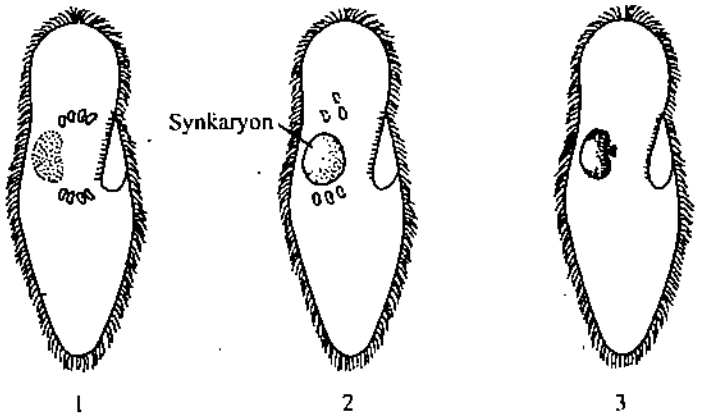



**Fig.13.25: Autogamy in *Paramecium*. The macronucleus degenerates and micronucleus undergoes meiosis to form 8 or more nuclei (1). Two of these nuclei fuse together to form a zygote nucleus (2). The others degenerate. The synkaryon divides to form a new micronucleus and macronucleus (3).**

## 13.5.4 THE REPRODUCTIVE ORGANS

In most metazoans, gonads are well-defined. Testes and ovaries take up different shapes and anatomical dispositions. In cases of certain hermaphrodites (see section 13.6) the same reproductive tissue from one part may produce sperms and from another part the ova.

In sponges, gonads are poorly defined. Sperms and eggs arise from choanocytes and archeocytes which are transformed into spermatogonia. Sperms leave the sponge through water currents. They enter choanocytes of other sponges which transport the sperms to the egg. Thus fertilisation occurs *in situ* by the intervention of choanocytes.

In cnidarians, testes and ovaries are distinct. In some species of *Hydra* both tests and ovaries may be formed in the same individual (monoecious, bisexual) or in different individuals but in most species they are found in different individuals (dioecious unisexual).

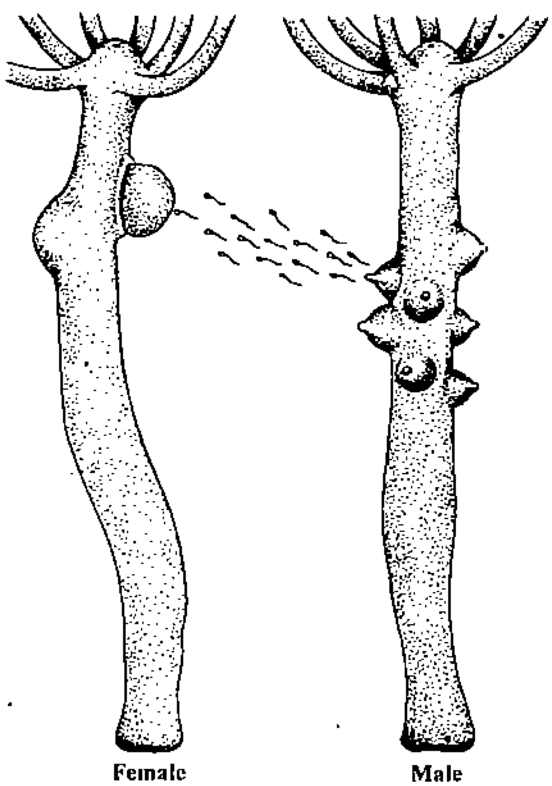



**Fig.13.26: Sexual reproduction in Hydra. Sperms from male *Hydra* testes fertilise the single ovum of female *Hydra*.**

A single ovum produced in the ovary (Fig. 13.26) is fertilised *in situ* by the sperms usually coming from a different hydra. In colonial cnidarians the gonads are formed on the medusae from interstitial cells beneath the radial canals. They are formed in the epidermis of sub-umbrella. Fertilization is usually external, in water (refer unit 4, Block – 2, Fig. 4.14).

In almost all higher non-chordates there are three kinds of structures associated with reproductive systems – the gonads (testes or ovaries), the gonoducts (vasa deferentia or oviducts) and the copulatory apparatus. A few examples of male and female reproductive organs in some non-chordates are shown in Fig. 13.27 to 13.32.

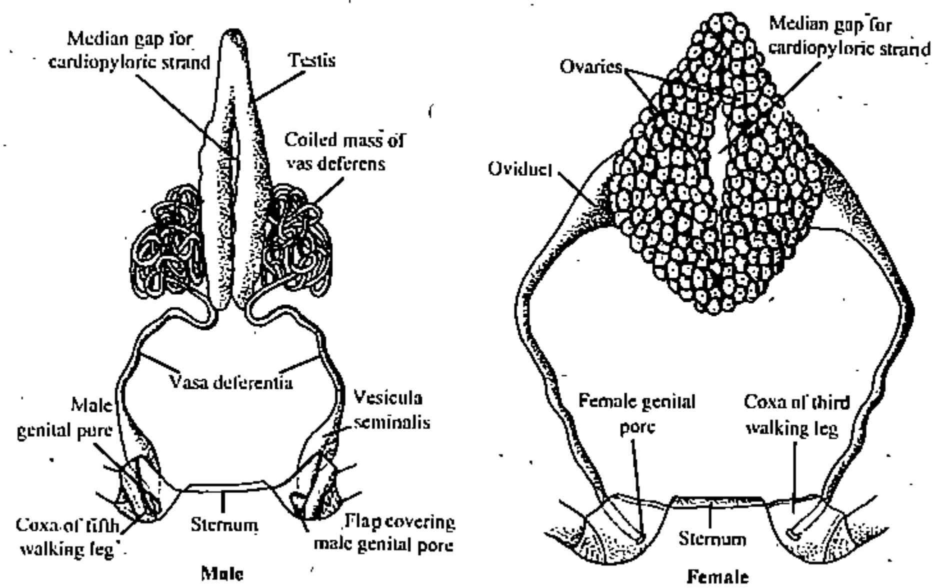



**Fig. 13.27: *Paleomon* (prawn), male and female reproductive systems.**

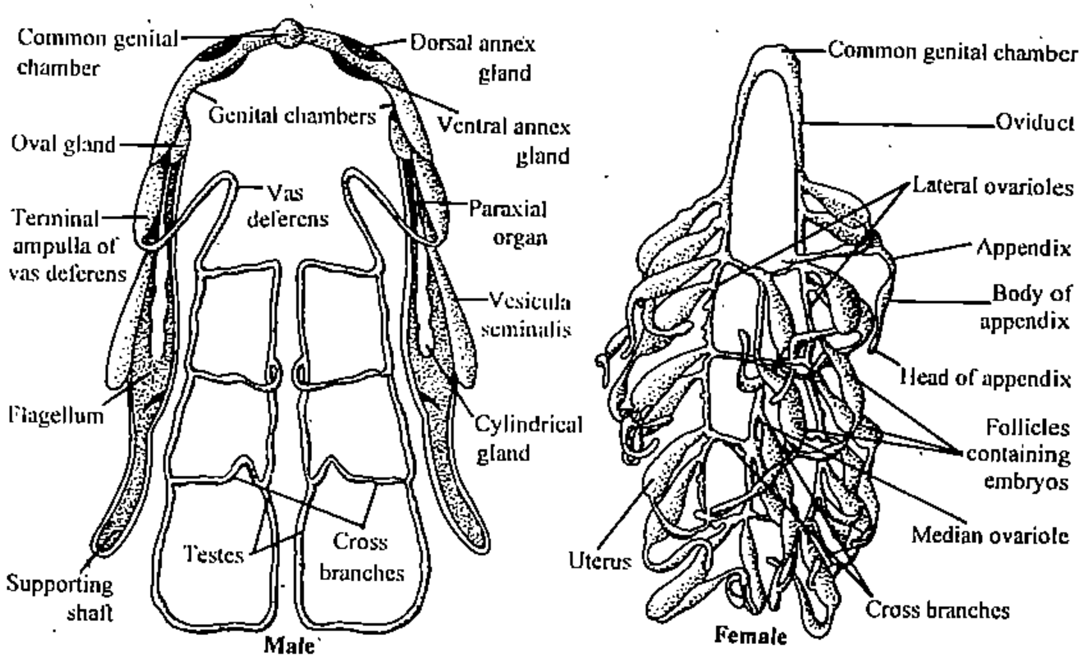



**Fig. 13.28 : Scorpion, male and female reproductive organs.**

### 13.5.5 Accessory sex glands

Species that fertilise their eggs internally usually have accessory sex glands that are indispensable for some key aspects of their reproductive physiology. For example, coating of eggs with protective and nutritive substances; transport of sperm in a liquid suspension or in encapsulated form, and for storage of sperm in the females in special chamber, and for supply of nutrition to sperms.

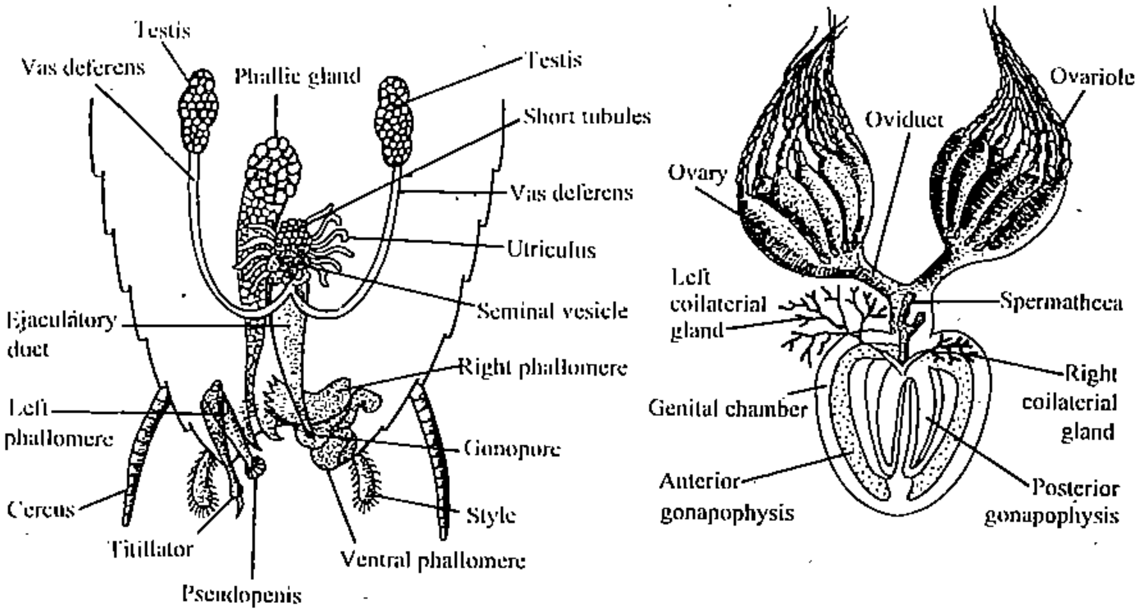



**Fig. 13.29 : Cockroach, male and female organs.**

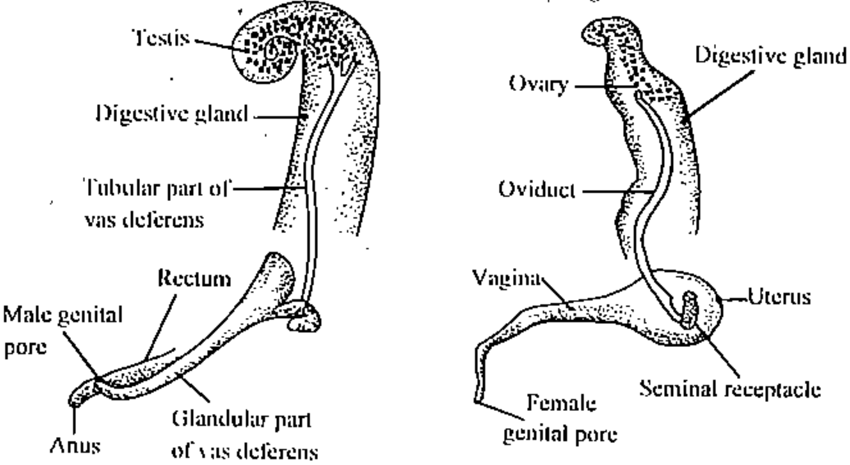



**Fig. 13.30 : Pulmonate snail reproductive organ organs.**

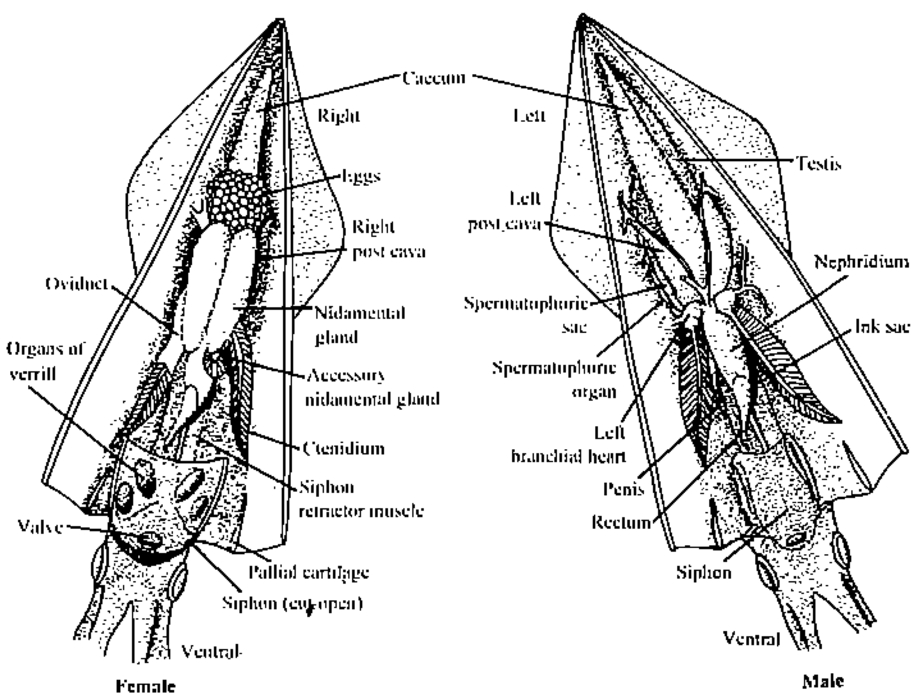



**Fig. 13.31: Cephalopod reproductive organs.**

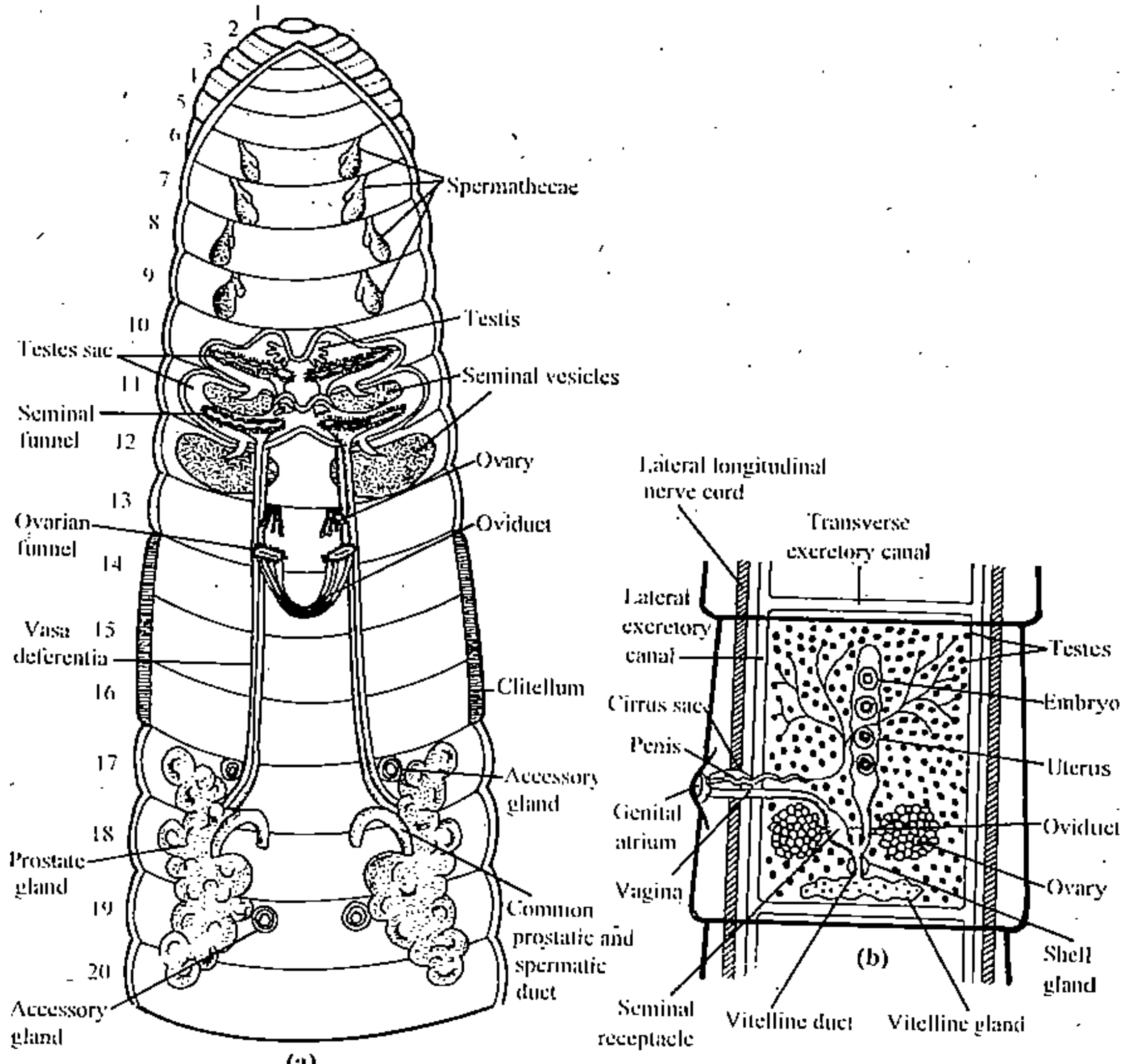



Fig. 13.32: (a) Earthworm,reproductive organs (Hermaphrodite). (b) Tapeworm, a mature proglotid showing both male and female reproductive organs. (Hermaphrodite).

These accessory glands are distributed generally along or in the genital ducts and some in the gonads. Many of them may be outside the genital system but pour their secretion into the genital duct.

As a rule, accessory sex glands are either absent or reduced in groups that shed their gametes into the surrounding water (Cnidaria and Echinodermata). On the other hand they are well developed in internally fertilizing groups. (eg. Platyhelminthes, Mollusca, Annelida, Arthropoda).

### 13.5.6 Mating and fertilisation

In all animals sperms are motile and must move and seek the eggs to fertilise them. For this an aqueous environment is necessary. This requirement of a liquid medium has led to two basic mating patterns.

1. **External fertilisation** – mating partners come in close proximity in water and simultaneously shed their eggs and sperms in water.
2. **Internal fertilisation** – mating partners come into physical contact and copulate, wherein the male transfers the sperms directly into the reproductive ducts of the female. The ova coming down the ducts get fertilised. Internal fertilisation is characteristic of terrestrial animals, but also occurs in several aquatic forms. Internal fertilisation usually leads to development of an intromittent organ or penis in the male partner. A variety of such copulatory organs are found in non-chordates, such as the cirrus in certain worms, complex phallus (penis) of cockroach etc.

In several non-chordates there are spermathecae for storing sperms received during mating. As the eggs pass down the ducts sperms are released from the spermathaca to fertilise them. Honey bee queen mates just once when it receives enough sperms to fertilise the many thousands of eggs she is going to lay in 4-5 years of reproductive life.

**Spermatophores**

Many non-chordates do not release free sperms during copulation. They have a mechanism to bundle and enclose a number of sperms in a sheath usually made of gelatinous material. Such bodies are called spermatophores. Most insects, the centipedes and certain molluscs produce spermatophores. Male centipede emits a spermatophore and places it on a web already made. The female picks up the spermatophore and takes it into her genital opening. In many male cephalopods such as *Loligo* and *Argonauta* one of the arms gets specialised for the transfer of spermatophore into the females. Such an arm is called **hectocotylised** arm. The spermatophore, after having been deposited in the female, finally releases the sperms which move into the female ducts or the spermatheca.

## 13.5.7 Ovipary, Vivipary and Ovovivipary

In all cases of external and in some cases of internal fertilisation, development of the fertilised egg (zygote) takes place outside the mother's body. The egg is laid either in water or in soil, on plants, or inside the body of their hosts in case of certain parasites. All such animals or called **oviparous** (laying eggs).

Some exceptional cases of non-chordates showing, **vivipary** i.e., giving birth to young ones nourished by the genital tracts of the female, are found in some insects such as tsetse fly (*Glossina*).

A third condition is that of **ovovivipary**. In this case, after fertilisation the zygote is retained in the female reproductive system without any direct connection with the maternal tissues for providing nourishment. Here it undergoes development. Ultimately the eggs hatch still inside the female and the young ones are "born". This happens for example in certain flies.

## SAQ 3

1. List any *three* significant differences between eggs and sperms.

   ..........................................................................................

   ..........................................................................................

   ..........................................................................................

   ..........................................................................................

2. Match the features in column I with the animals in column II.

| Column I Features | Column II Animal |
|---|---|
| (1) Anal styles | (a) *Ascaris* (male) |
| (2) Curved tail end | (b) *Schistosoma* (male) |
| (3) Shell | (c) Mosquito (male) |
| (4) Gynaecophoric canal | (d) Cockroach (male) |
| (5) Plumose antennae | (e) *Argonauta* (female) |

3. Name one example from non-chordate animals for each of the following:-
   i) Epitoky
   ii) Isogamy
   iii) Hectocotylized arm
   iv) Viviparous condition.

   ..........................................................................................

   ..........................................................................................

   ..........................................................................................

   ..........................................................................................

## 13.6 HERMAPHRODITISM

You would have fully appreciated now that sexual reproduction is definitely the more advanced type of reproduction. It provides for combination of genes from different genetic stocks and imparts the potentiality of greater adaptation to the environment and evolution. The involved sex cells (gametes) i.e., the eggs and sperms come from different individuals, namely the female and the male. Species having separate sexes are called dioecious (di = two, oikos = house) such species are also called unisexual – composed of individuals of any one sex. But a different condition pervails in many non-chordates in which both types of organs (testes and ovaries) are found in the same individual. This condition is called **bisexualism** or more popularly **hermaphroditism**, and such individuals are termed **monoecious** (*mono*: single, *oikos*; house). The term hermaphrodite comes from Greek mythology in which Hermaphroditos the son of Hermes and Aphrodite possessed both male and female sex characters.

Hermaphroditism is common in non-chordate groups. In the most incipient form we can see it even in the ciliate protozoans such as *Paramecium*. From the account of conjugation of *Paramacium*, it is clear that it has both a male and a female pronucleus. Thus each *Paramecium* serves as a male and a female.

In *Paramecium* during **autogamy**, the same micronuclear changes as seen during conjugation occur in the single individual. But here as there is no second individual involved, it is comparable to self-fertilisation.

Among metazoa, hermaphroditism is the rule in flatworms, (Platyhelminthes), pulmonat among gastropods, earthworms and leeches (Annelida) etc. In addition, hermaphroditisim occurs among other animals also, as in some bivalve molluscs.

**Kinds of hermaphroditism**

Depending on the timing of maturity of the gonads, hermaphroditism can be of two types:-

1. **Simultaneous hermaphroditism.** Both male and female gonads mature at the same time. Some common examples are liver flukes (Trematoda), tapeworms (Cestoda) earthworms, leeches, pulmonate gastropods etc.
2. **Protandrous hermaphroditism.** (gk *protos*: first, *andr*: man/male). Male gonads mature first. This condition is common in some molluscs like limpets and slipper shells (*Crepidula*).

**Copulation and fertilisation in hermaphrodites**

Copulation among hermaphrodites is common. The flatworms possess a cirrus and penis that is inserted into the uterine vaginal opening of the other worm. After copulation, the sperms are stored in a seminal receptacle. In earthworms (Refer to Fig. 5.11 in Block 2 of this course), the genital papillae help in mating, the sperms released from the male genital pore of one earthworm are received and stored in seminal receptacles (spermathecae) of the other earthworm. Sperm transfer is thus mutual.

Similarly cross fertilisation is probably the rule in tapeworms when there are adjacent individuals inside the hosts gut, but self fertilisation between two different proglottids of the same tapeworm is also known to occur.

Majority of hermaphrodites tend to be protandrous i.e. male gonads maturing first, and this is a condition to ensure cross fertilisation. In protandrous hermaphrodites the gonads (testes and ovaries) may be **separate organs** and they mature at different times. In some rare cases as in certain gastropod molluscs there is a single gonad called **ovotestis** which produces both eggs and sperms. But the gonad first produces sperms and later the egg.

### SAQ 4

Mention whether the following statements are **True** or **False**.

i) Earthworm may be termed bisexual, hermaphrodite or monoecious.
ii) Autogamy in *Paramecium* is a kind of cross fertilisation.
iii) In most hermaphrodites the female gonads mature first.

## 3.7 PARTHENOGENESIS

arthenogenesis means development from a female gamete (egg) alone, without :rtilisation. Among non-chordates this condition is found in several groups such as, ›me crustaceans and a number of insects including aphids (plant lice), thrips, ants, ɔneybees etc.

here are different types of parthenogenesis.

**Obligatory parthenogenesis.** It is found in certain insects and some branchiopods (Crustacea). Here males are unknown and parthenogenesis is the only way of reproducing.

**Facultative parthenogenesis.** In this case ova can develop into adults whether fertilised or not. The fresh water flea *Daphnia*, for example, may produce eggs developing parthenogenetically into females for several generations. Some times males may appear. Then fertilised eggs are produced. Some insects like the aphids (plant lice) have a complicated pattern of reproduction. In them parthenogenesis occurs alternately with sexual phase.

The queen of the honey-bee (*Apis* sp.) may lay unfertilised and fertilised eggs. The fertilised eggs give rise to females (workers and queens) and the unfertilised ones to males (drones).

**Arrhenotoky.** In this case the haploid egg does not undergo fertilization and gives rise only to male.

**Thelytoky.** The unfertilised eggs give rise to only females.

**rtificial parthenogenesis**

ı several cases, the eggs that normally develop only after fertilisation, can be ‹perimentally induced to develop parthogenetically by certain treatments. This is 'tificial parthenogenesis. For example, sea urchin eggs develop parthenogenetically if ıey are subjected to certain temperatures, electric shocks, ultraviolet light, ether, alcohol, ctic acid, mechanical stimuli like pricks etc.

### AQ 5

Name the following:-

i) The kind of parthenogenesis in certain species that may or may not occur, depending on environmental conditions.

ii) The kind of parthenogenesis that leads to the production of males only.

....................................................................................................

....................................................................................................

Name any three non-chordates in which parthenogeneis is very common.

....................................................................................................

....................................................................................................

## 3.8 ALTERNATION OF GENERATIONS

ıe term alternation of generations (metagenesis) in animals refers to a phenomenon in eir life-histories, in which asexual and sexual generations alternate with each other. ›me well-known examples are given below:

**·otozoa**

A foraminiferan *Elphidium* (=*Polystomella*) found in shallow sea water occurs in two forms – macrospheric and microspheric. Both forms have a many chambered shell (Fig. 13.33). The macrospheric form has a larger proloculum or initial chamber and a large nucleus. The microspheric from has a smaller proloculum and numerous small nuclei. The macrospheric individual represents the sexual phase and produces flagellated anisogametes (haploid). Pairs of these anisogametes fuse to form a zygote, which begins life with a small initial chamber but slowly grows a multichambered shell and its single nucleus divides several times to produce numerous small nuclei. This is an **agamont**. The full grown microspheric form then undergoes cytoplasmic divisions (asexual reproduction) and the resulting single-nucleated "**amoebulae**" or spores are liberated. Each of these establishes the initial macrospheric chamber and subsequently grows into the macrospheric form. Thus here, there is an alternation of macrospheric (sexual) phase with microspheric (asexual) phase.

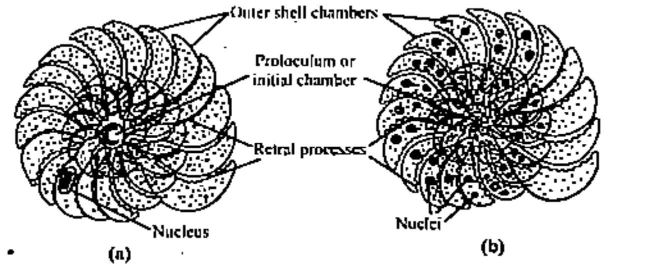



**Fig.13.33 : *Elphidium*. (a) macrospheric and (b) microspheric forms.**

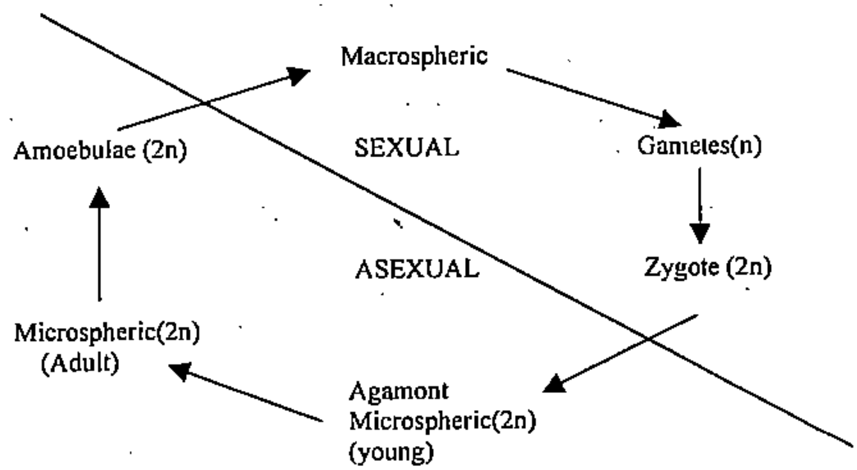



**Fig.13.34: *Elphidium*, schematic life-history indicating alternation of sexual with asexual generation.**

2. Malarial parasite *Plasmodium* (Refer to Unit-2 Block-1) carries out its sexual cycle inside the female mosquito starting with the micro- and macrogametes received from human host. These then fuse together to produce the zygote. The latter grows and undergoes sporogony (an asexual cycle) to produce sporozoites. The sporozoites are released into human host through mosquito bite. These sporozoites first undergo schizogony in liver cells to produce merozoites. Next these may undergo another schizogony inside the red blood cells. In this way, the sexual cycle in the mosquito is followed by two kinds of asexual cycles in human host.

**Cnidaria**

The mature medusoid jellyfishes such as *Aurelia* are the sexual stages. Sperms and eggs produced in the different (male and female) individuals are released in water, which then fuse to form a zygote. The latter develops into a fixed polypoid scyphistoma which undergoes several transverse fission to produce ephyras by the process called strobilation (see page 10), a kind of asexual reproduction. Thus the sexual generation of the adult jellyfish is alternated with an asexual generation i.e., scyphistoma. You would recall from unit 7 of this course that alternation of generation is quite common among hydrozoans, in which the highly branching sedentary colonies like those of *Obelia* are asexual generations. They give off medusae which are sexual generations. The medusae give rise to the colonies and vice versa, alternating with one another.

## SAQ 6

Fill in the blanks:-

i) In *Elphidium* the macrospheric individuals represent the .................. phase whereas the microspheric ones represent ............. phase.

ii) In *Plasmodium* sporogony is followed by ......................

iii) Strobilating ..................... represents the asexual phase in the life-history of *Aurelia*.

# 13.9 REPRODUCTION, LIFE CYCLES AND LARVAL FORMS

You are well aware by now that meiosis in metazoans takes place only during the formation of haploid gametes. The diploid condition is restored with the formation of zygote after fertilisation. However, from earlier sections you can see that a new diploid individual is not always formed through sexual reproduction alone. Offspring of invertebrates can also be formed without recombination of genetic material. Asexual reproduction combined with the capacity for sexual reproduction leads to complex patterns of life cycles.

What pattern of reproduction, is followed by a species (i.e. whether asexual, sexual or through parthenogenesis), depends on the environment it lives in.

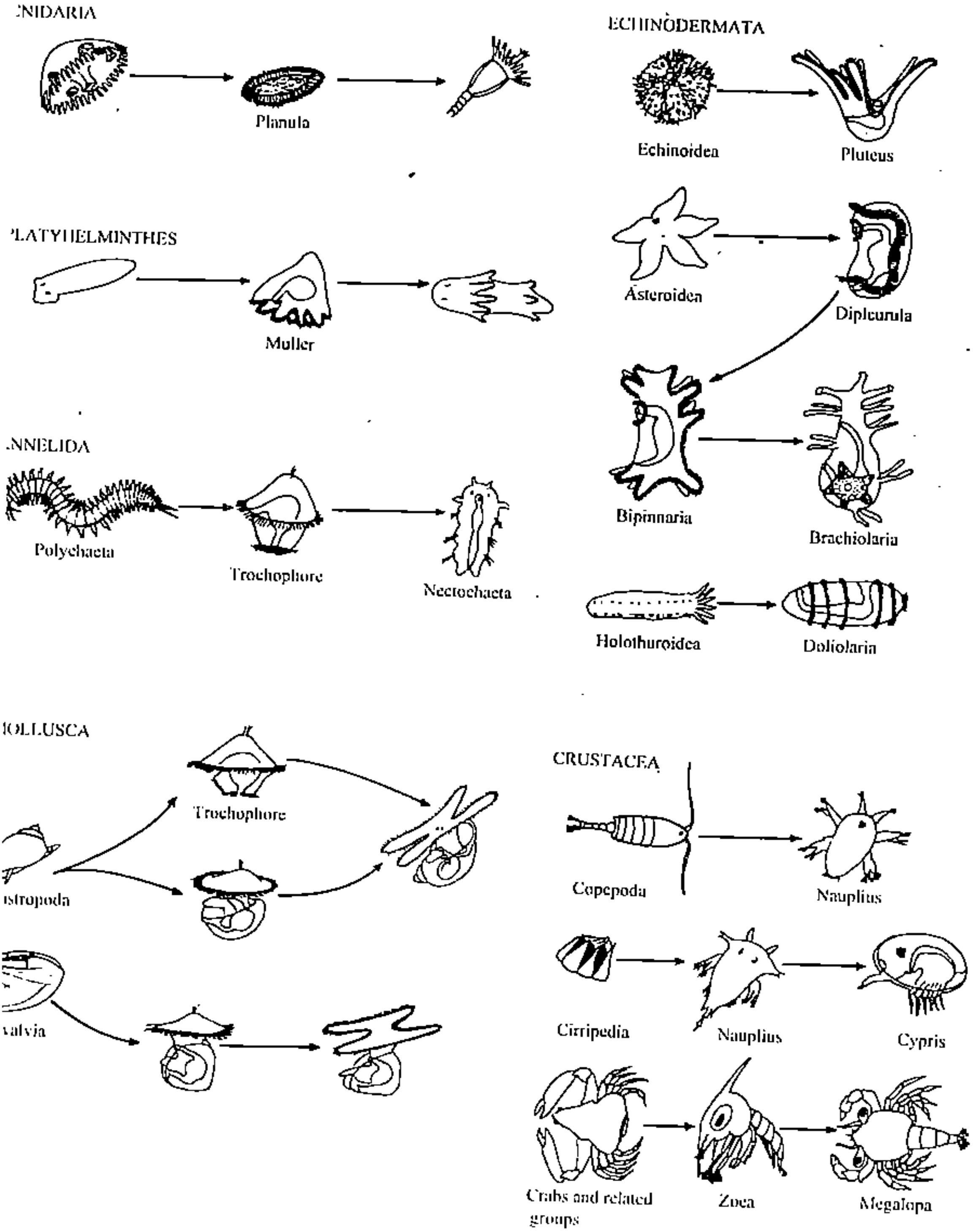



**Fig 13.35: Characteristic larval stages of major marine invertebrate groups along with their adult forms. Note that the adult forms are drawn to a much smaller scale than the larval forms.**

For example, marine invertebrates discharge their gametes into the surrounding mediun where fertilisation may take place but freshwater and terrestrial invertebrates do not do so. Externally fertilised gametes of invertebrates usually have little yolk or stored sourc of nutrition and develop into motile independent post-embryonic stage called the **larva**, which is typically tiny and very different from the adult. The larvae may feed on an external source of nutrition and are independent from their parents. They are usually th means of wide dispersal for the species. Larvae never reproduce sexually, and often it i impossible to establish the sex into which the larvae will grow as is the case with most caterpillars of insects. After a period of time the larva settles down and undergoes metamorphosis to attain adult form and life style. Such a life cycle with larval forms is said to be **indirect** and is found in a majority of marine invertebrate species and platyhelminths, annelids and arthropods. The major disadvantage of such a life cycle is the high mortality of the planktonic eggs, embryos and larvae. Many marine invertebrat have overcome this by depositing their eggs in protective envelopes and the hatching occurs at larval stage (see Fig. 13.35). The larvae may be long lived, feeding on diatom and other minute organisms may be planktonic permiting adequate dispersal. The majority of invertebrate phyla have external fertilisation and pelagic larvae. They exhib a pelagic benthic life cycle. This condition of having pelagic larvae is considered to be primitive trait.

Other species have dispensed with larvae altogether. The entire development takes plac inside the protective egg envelope and the young hatch as miniature adults. Fewer eggs are deposited by such species and they contain large amounts of yolk. Such a developmental pattern is called **direct development** and is characteristic of many mari and most freshwater and terrestrial invertebrates. However, amongst terrestrial invertebrates, most insects have a larval stage during development. Some important lar forms have been described below.

### Larval forms

#### Porifera

In the majority of sponges the larval stage develops within the body of the parent. The larva is usually at the blastula stage of development. Figure 13.36 shows two kinds of poriferan larval stages, amphiblastula and stereoblastula in which monociliated cells cover the outer surface except the posterior pole. The interior of the larva commonly contains most of the cell types found in the adult except choanocytes. The larva breaks out of the parents' body wall and has a brief free swimming existance.

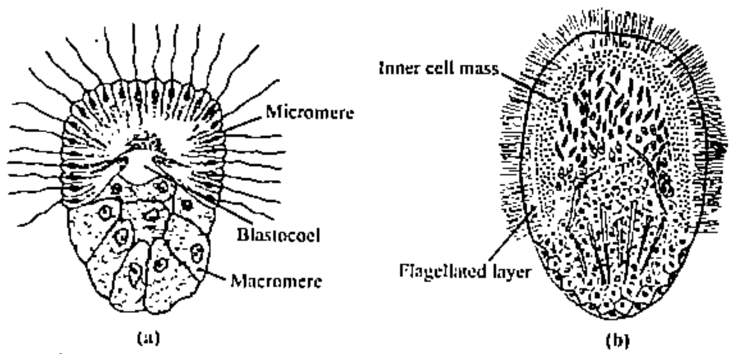



**Fig. 13.36: (a) amphiblastula of *Sycon* showing flagellated miromeres and non-flagellated macromeres. (b) Demospongian larva – stereoblastula.**

#### Cnidaria

The common larval stage found in cnidarians is the **planula** which forms following gastrulation. The planula is elongated and radially symmetrical with anterior and posterior ends. The surface is covered by ciliated cells. A mouth may be present sometimes at the posterior end of the larva and the larva attaches by its anterior end. The planula may settle down to form a polypoid scyphistoma that ultimately forms the medusa. In most hydrozoans the planula forms the actinula larva that transforms into the medusa.

#### Platyhelminthes

Development in parasitic platyhelminthes is generally complicated with several free swimming (Fig. 13.31) to parasitic larval forms. The progression is from miracidium to

›orocyst to redia and cercaria. You can refer to Unit 4 of Block 2 of this course for life istories and larval forms of parasitic platyhelminths.

### olychaete and Mollusca

he polychaete have a trochophore larva. A typical trochorphore larva is top shaped earing a tuft of cilia at the apical end and a band or girdle of cilia called the prototroch ·hich rings the body about one third to one half the distance from the apical tuft. It is the wimming organ and collects suspended food particles. The gut is a complete tube and nouth opens posterior to prototroch. Trochophore larva is characteristic of polychaetes nd molluscs (Fig. 13.35).

### chinodermata

lmost all larvae of echinoderms are planktonic (Fig. 13.35). Unlike the adults the larvae o not show pentamerous symmetry and do not have tube feet. They move by bands of ilia over the body and its projections. After a time of planktonic life a rudimentary keleton begins to form and the larvae sink to the bottom to develop the adult shape and orm.

### rthropoda

ome of the planktonic larvae of crustaceans are shown in Fig. 13.35. The larvae of rustaceans occupy different niches from their parents and there is no competition for ood among the larvae and adult forms.

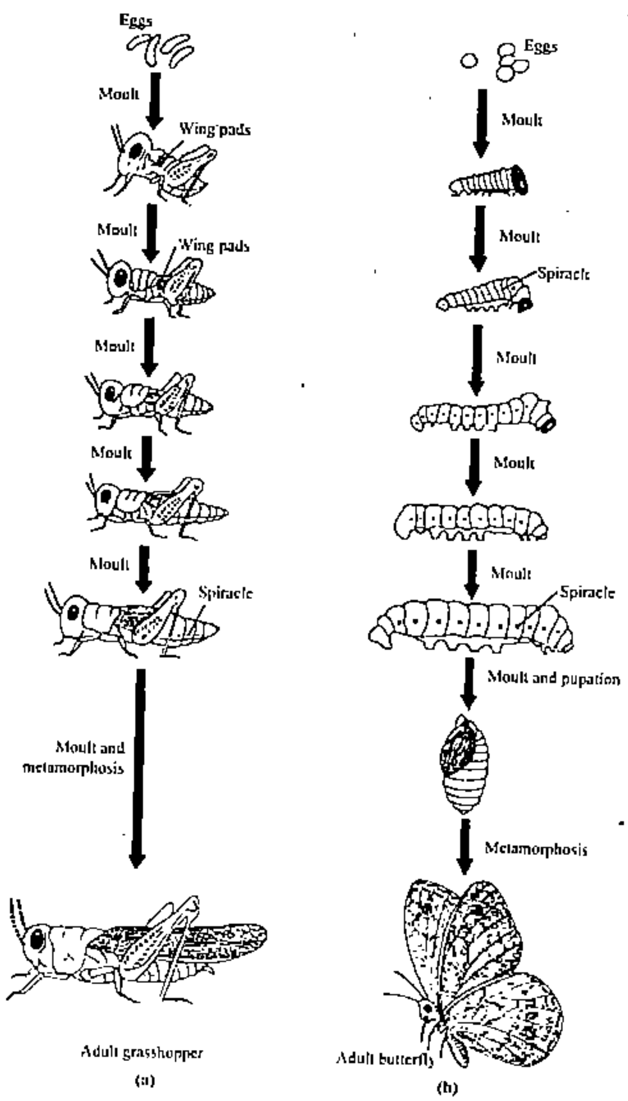



Fig. 13.37 : Life cycle of insects. a) exopterygota, b) endopterygota.

In the life cycles of insects we see that larval and adult stages have different patterns of activities. Insects grow through a series of moults or instars. The simplest life history is one in which there is a gradual transition from embryonic to adult condition and both larva and adult exploit the same food resource. These are the exopterygote insects and their larvae have externally visible wing pads although, only the adults have functional wings and the period of inactivity between the final moult and adult is not much longer than that between the larval moults. This simple life cycle is seen in grasshopper (Fig. 13.37 a).

More than 80% of living species of insects including Coleoptera (beetles), Lepidoptera (butterflies and moths), Hymenoptera (wasps, bees and ants), Diptera (flies) are endopterygotes. Their larvae include caterpillars, grubs and maggots. They never have externally visible wing pads and are very different from the adult (Fig. 13.37 b) in form and diet. There is a resting stage called pupa which may last from a few hours to many months before the adult emerges from the final moult.

Thus we see that the different types of life cycles demonstrate the diverse sets of reproductive strategies found among invertebrates. Sexual reproduction is the dominant way of reproduction and often alternates with asexual reproduction in complex life cycles seen in many cnidarians, flatworms, annelids, small crustaceans and some insects.

## 13.10 SUMMARY

In this Unit you have learnt that:

- Reproduction ensures continuation of a species, generation after generation. Non-chordates with their diverse body organisation and different ways of life present equally diverse modes of reproduction. The most primitive and simplest of these is binary fission, i.e., just a kind of cell division. Some protozoans divide transversely and some longitudinally. Multiple fission in which the parent cell divides simultaneously to produce numerous daughter individuals is also a kind of asexual reproduction. Some animals undergo spontaneous fragmentation, each fragment regenerating the missing part to make a full animal as in certain sea anemones and some worms. Asexual reproduction commonly occurs by budding as in hydra and some other cnidarians. Some non-chordates such as certain sponges reproduce asexually by formation of gemmules under unfavorable conditions.

- Regeneration is a very common phenomenon that in many non-chordates leads to the formation of new individuals. It is thus closely associated with asexual reproduction. Regeneration of missing parts following natural fragmentation or accidental breaking leading to forming of new individuals is very common. Most organisms exhibit polarity in regeneration. Some non-chordates resort to autotomy primarily in self defence, and regeneration may lead to reproduction.

- Sexual reproduction involves production of gametes that are usually distinguished as the smaller, motile spermatozoa and the larger non-motile eggs. Gametes are produced through meiosis, and fertilization restores the normal chromosome number. The greatest advantage of sexual reproduction is the consequent mixing of genes that lead to better adaptation and to evolution. Very often the two sexes are distinctly different exhibiting sexual dimorphism. Sexual reproduction takes up various patterns such as isogamy, anisogamy, conjugation, autogamy etc. The reproductive organs include the gonads, gonoducts, accessory glands and certain structures that facilitate copulation. Patterns of gonadal shape and disposition varies considerably. Some non-chordates shed gametes in water (external fertilization), in some cases sperms are released in the form of a spermatophore. The fertilised eggs may be released (ovipary) or sometimes retained inside the female (vivipary, or ovovivipary) till development is partial or full, before being released.

- Many non-chordates, specially sluggish and parasitic forms are hermaphrodites. Hermaphroditism can either be simultaneous or protandrous. Many non-chordates reproduce parthenogenetically.

Asexual reproduction in many cases may lead to a generation of sexual individuals. Often there may be an alternation of sexual and asexual generation in the life history of animals. This is called alternation of generations or metagenesis.

Asexual reproduction combined with sexual reproduction leads to complex patterns of life cycles. What pattern of reproduction is followed by an organism depends on its environment. Marine invertebrates often have external fertilisation and one or more larval stages very different from the adult. Such life cycles are called indirect. Other species have dispensed with larval stages and have direct development. Life cycles in insects have different patterns of development involving a series of molts or instars.

## 3.11 TERMINAL QUESTIONS

. List any six methods of asexual reproduction in non-chordates and write not more than two lines about each.

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. What are the advantages of asexual reproduction to the animals that practice it?

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. Give any three examples of conspicuous sexual dimorphism in non-chordates.

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. What is the advantage of sexual reproduction?

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. Describe the adaptive value of hermaphroditism.

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. Differentiate between:-

i) Obligatory and facultative parthenogenesis

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ii) Arrhenotoky and thelytoky.

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7. Write briefly about the alternation of generations in malarial parasite.

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8. Give an important difference between the role of insect larvae and marine invertebrate larvae in the life cycle of the species.

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## 13.12 ANSWERS

### Self Assessment Questions

1. I. 1-f, 2-d, 3-e, 4-a, 5-c, 6-g, 7-b
   II. Correct ones – (i), (iii) and (iv)

2. I. i) Central disc, arms
   ii) Holothurians (sea cucumbers)
   iii) Reunition
   iv) Splitting/incising
   v) Gemmules
   II. Asexual reproduction is largely associated with regenerative capacity which is stronger in lower animals in which the cells and tissues are less differentiated and specialised.

3. 1. Eggs are (i) nonmotile, (ii) larger, and (iii) usually laden with food material
   2. 1-(d), 2-(a), 3-(e), 4-(b), 5-(c)
   3. i) Heteronereis/*Nereis*
   ii) *Monocystis*
   iii) *Loligo*/*Argonauta*
   iv) *Glossina* (tsetse fly)

4. 1. i) True, ii) False, iii) False, iv) True.

5. 1. i) Facultative
   ii) Arrchenotoky
   2. Aphids, honey bee, wasp, thrips, daphnia (fresh water flea)

6. i) sexual; asexual
   ii) schizogomy
   iii) scyphistoma

**Terminal Questions**

1. Six methods of asexual reproduction – Binary fission, multiple fission, fragmentation, budding, strobiliation, formation of special bodies like gemmules. Binary fission usually takes place in protozoans. These divides into two longitudinally or transversely; in multiple fission the animal divides into more than two. In fragmentation, a metazoan splits into two or more parts each of which regenerates the missing part. *Budding* is a kind of outgrowth that break off from the parent to grow into an adult. Strobilation is a serial budding/cutting off of segments from the parent. Special units like Gemmules are formed to tide over unfavourbale environmental conditions.
2. Advantages of asexual reproduction – rapid multiplication accompanied by surer and quicker exploitation of favourable environment.
3. *Blood flukes* – Male large and thick, with gynaecophoric canal to hold the long thin female.
   *Ascaris* – Male smaller with a curved tail and carrying a pair of penial setae.
   *Bonellia* – Microscopic male living parasitically inside the nephridium of several times larger female.
4. Advantage of sexual reproduction. Gametes from opposite sexes combine resulting in mixing of genetic characteristics of male and female parents. This enables the progeny to be better adaptated to changes in the environment. Sexual reproduction tends to revitalise the population.
5. Hermaphroditism usually expresses itself in sessile, sluggish and parasitic species that may otherwise have poor chances of meeting other individuals (opposite sexes). With hermaphroditism, any two individuals would serve the purpose of reproduction.
6. i) *Obligatory* parthenogenesis is a condition where parthenogenesis, is the sole method of reproduction; *facultative* parthenogenesis is one in which the eggs, may develop parthenogenetically or by fertilisation.
7. Malarial parasite shows two generations – (1) schizogony either in human RBCs or liver cells or in both; (2) gamogony in mosquito. The sporozoites released into the human body enter the liver cells first (pre-erythrocytic); the cryptomerozoites released from liver cells enter RBCs ro carry out erythrocytic schizogony. These merozoites may repeat the erythrocytic cycle, several times before they are taken in by the mosquito. Inside the mosquito gamogony (sexual cycle) takes place. The zygote subsequently passes through gamogony or sexual phase inside mosquito.
8. In case of insects, the adult is mobile and can disperse to greater distances than their larvae, while in case of marine invertebrates the larvae are the main dispersal stages as they are planktonic. The adult mollusc or echinoderm is relatively slow moving or sedentary.

# GLOSSARY

**Aerobic respiration** : Respiration involving the use of oxygen.
**Afferent blood vessels** : Blood vessels which carry deoxygenated blood to the respirator surface i.e., the gills.
**Afferent nerve:** A nerve which carries impulses from the receptor to the central nervous system.
**Aorta:** The main artery springing from the heart and leading blood away from the heart.
**Arteriole:** It is a fine artery formed after repeated branching of main artery.
**Autotrophy** : Capability of organisms to synthesise organic nutrients from simple inorganic substances. All green plants are autotrophs.
**Axon:** It is one of the protoplasmic processes of a neuron which conducts impulses away from the cell body.
**Capillary:** A tube of very small diameter. In the circulatory system, capillaries connect the ends of the smallest arteries (arterioles) to those of smallest veins (venules).
**Combplate** One of the plates of fused cilia that are arranged in rows for ctenophore locomotion.
**Dendrite:** The process of a neuron which conducts impulses towards the cell body.
**Diffusion:** It is a process in which molecules of gas or substance are transported from high concentration to low concentration.
**Epipod, epipodite** A lateral process on the protopod of a crustacean appendage, often modified as a gill.
**Exopod,exopodite** Lateral branch of a biramous crustacean appendage.
**Exopterygote** Insect in which the wing buds develop externally during nymphal instar, has hemimetabolous metamorphosis.
**Extracellular digestion** : Occurrence of digestion in the cavity of digestive system, the cavity being lined by cells. The digestive enzymes are secreted into the cavity by the secretory cells.
**Flagellum** Whiplike organ of locomotion.
**Ganglion:** A collection of nerve cell bodies.
**Haematophagous feeders** : Animals which feed on the blood vertebrates, especially mammals.
**Haemoglobin:** An iron containing respiratory pigment concerned with the tramsports of oxygen by the blood.
**Halter** In diptera, small club shaped structure on each side of the metathorax representing the hindwings, believed to be sense organs for balancing, also called balancer.
**Heterotrophy** : Refers to the dependency of organisms on other organisms for their nutritional requirements. Heterotrophs can not syntehsise food on their own.
**Hypertonic** : Refers to a situation where the body fluid of an organism has a higher osmotic pressure than the medium in which it lives.
**Hypotonic** : Refers to a situation where the body fluid of an organism has a lower osmotic pressure than the medium in which an it lives.
**Intracellular digestion** : Occurrence of digestion within specified cells of the digestive system; theses cells secrete the necessary enzymes for digestion.
**Macrophagous feeders** : Organisms which feed on large food particles.
**Maxilla** : One of the head appendages in arthropods.
**Maxilliped** : One of the pairs of head appendages located just posterior to the maxilla in crustaceans, a thorasic appendage which has become incorporated into the feeding mouth parts.
**Microphagous feeders** : Organisms which feed on microscopic food particles.
**Nematocysts** : Stinging cells found in cnidarians and used for defense, capturing prey and for anchorage.
**Nerve:** A bundle of nerve fibres.
**Nerve fibre:** It is an elongated protoplasmic process of nerve cell.
**Neurilemma (Neural lamella):** It is the outermost covering of the nerve fibre.
**Neurohaemal organ** : A vascular structure which temporarily stores hormonal substances secreted by neurosecretory cells before they are released into blood.
**Notopodium** : Lobe of parapodium nearer the dorsal side in polychaete annelids.
**Parapodium** : One of the paired lateral processes on each side of most segments in polychaete annelids, variously modified for locomotion, respiration or feeding.
**Pedipalps** : Second pair of appendages of arachnids.
**Plasma:** It is a fluid part of the blood which is distinct from the blood cells corpuscles.

'leopod : One of the swimming appendages on the abdomen of a crustacean.

'espiration: A chemical activity taking place within the protoplasm of the cell and esults in liberation of energy.

aprozoic feeders : Animals which feed on dead and decaying organic materials.

'ricotelic : Refers to organisms that excrete uric acid as main excretory product of ietabolism.

'ropod : Posteriormost apppendage of many crustaceans.

'ein: The blood vessel which transports blood towards the heart from the capillaries.

## Further Readings


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Uttar Pradesh
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# UGZY -01
# ANIMAL DIVERSITY-I

Block

# 4

## ADAPTATION AND BEHAVIOURAL PATTERN

# BLOCK 4 ADAPTATION AND BEHAVIOURAL PATTERN

In the previous block you have studied about the comparative forms and functions of non-chordates. You have learnt that despite differences in the level of organisation all animals, simple or complex, are capable of performing necessary bodily functions. Of these one is locomotion. You have noted how from a simple type, complex and highly developed systems of respiration and circulation have evolved. You have learnt that animals perceive any change in their external and internal environment, compute the change, and ultimately translate these computations into requisite actions in a manner most profitable and adaptive to the animal through a system of nerves and sense organs. Besides you have studied the endocrine system that brings about communication through chemical substances called hormones produced by endocrine glands. In the previous block you have also noted that non-chordates have evolved diverse methods of reproduction ranging from simple splitting into two to very complicated methods of sexual reproduction, parthenogenesis etc. This last Block of Animal Diversity – I course (LSE-09) comprises 4 units dealing with various aspects of adaptation and behavioural patterns.

In unit 14 of this block you will study that often organisms belonging to different groups adapt themselves to similar environments and look and act alike. This is called adaptive convergence, whereas the condition, in which animals belonging to same or closely related groups occupy different habitats and acquire different functional adaptations, is called adaptive divergence or adaptive radiation. This unit will explain how adaptive radiations have evolved in different non-chordate groups.

Unit 15 deals with the patterns of animal gestures and movements in response to internal and external stimuli in their environment. You will learn that behavioural activities occurring in non-chordates with clockwork precision at regular intervals are called biorhythm. The unit describes about various taxes and kineses, rhythms, social organisations, courtship and communication behaviour and the behaviour and adaptations of parasites in non-chordates.

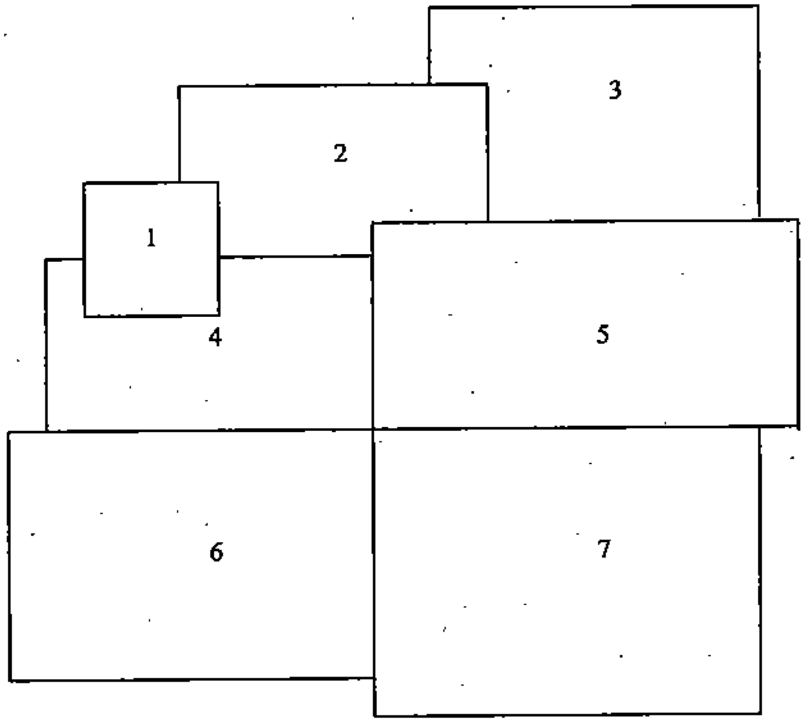
In unit 16 you will learn about some non-chordates that cause diseases in the host, both plants and animals including humans. You will study that some non-chordates are, however, indirectly harmful as they transmit various parasites or pathogens from one host to the other thereby, spreading dreadful diseases. Also we will discuss major species of protozoans, platyhelminthes, nematodes and arthropods that are harmful to human health or economy.

Unit 17 describes two categories of non-chordates that are useful to man. You will study that some non-chordates are directly beneficial to mankind in the form of food, or the food gathered by them is used for human consumption. They give us useful produce, medicine and are objects of beauty and decoration. Whereas, some of non-chordates benefit us indirectly in the field of agriculture and as scavengers in cleaning the environment.

## Objectives

After having read this block you should be able to:

- list the adaptive radiations that enable the organism to face the vagaries of ever changing environment,
- explain the behavioural patterns and their adaptive values in non-chordates,
- describe important harmful non-chordates of medico-veterinary and agricultural importance,
- become familiar with the variety of ways in which non-chordates benefit humans directly or indirectly.




1. Tropical centipede

2. Stink bug

3. *Morpho menelaus* – The wing scales reflect interference colours. Tilting the wings produces a sequence of colours.

4. Brown recluse spider

5. *Tealia piscivora* – The colour is due to free or esterified carotenoids

6. *Agriolimax columbianus* – Yellow banana slug.

7. *Dasychalina cycanthina* – sub tidal sponge.

# UNIT 14 ADAPTIVE RADIATIONS

## Structure



## 14.1 INTRODUCTION

You have read in our course on Taxonomy and Evolution (LSE-07) that living organisms are products of evolution. In simple words evolution may be defined as 'descent with change'. Here change is the basic factor. Evolution may be in the nature of the environment or in the form and function of the organism. The nature of the environment has a strong bearing on the form and function of the organism. You will see in Section 1.3 of this course (Unit 1, Block1) that the organisms always tend to establish harmony with their environment. This process, called adaptation, enables the organism to face the vagaries of the everchanging environment. Adaptation actually sums up the whole result of evolution.

You might have noticed that when organisms belonging to different groups come to occupy similar environment, they develop striking similarities in structure and behaviour, giving a false impression of closer relationship. For example, fishes and whales which belong actually to different classes (Pisces and Mammalia, respectively) are found in similar habitat i.e., they are both aquatic. They look so alike that for a layman both are 'fishes'. This condition where organisms belonging to different groups adapt themselves to the same environment and look and act alike, is called *adaptive convergence*.

On the other hand, there are situations where organisms belonging to the same or closely related groups may occupy different environments due to which they develop varied adaptations. It gives rise to diverse evolutionary lines. You know that house- lizard, snake, tortoise and crocodile belong to the same class, Reptilia. But they look so different from each other that one may be tempted to place them in separate classes. This situation in which animals belonging to same or closely related groups occupy different habitats and acquire different functional adaptations, is called *adaptive divergence* or *adaptive radiation*. In this unit you will study how adaptive radiations have evolved in different non-chordate groups.

### Objectives

After studying this unit you should be able to:

- distinguish between solitary and colonial forms of animals and explain the needs for the evolution of true colonies in lower non-chordate groups,
- differentiate between adaptive convergence and adaptive divergence or adaptive radiation and identify the different ways in which adaptive radiations have occurred in Annelida, Arthropoda and Mollusca,
- describe the structure of insect wing and explain the mechanism of flight in insects,
- describe the meaning, process and significance of migration in insects.

## 14.2 SOLITARY AND COLONIAL FORMS

Animals may lead their lives either as individuals or in groups. When they exist as individuals, they are called solitary, but if they live in organised colonies, we name then colonial. Colonies are a form of intraspecific association in which the interests of an individual are subordinate to those of the whole group. In true colonies the individuals are organically connected together by living matter or through material secreted by them. The degree and extent of closeness among individuals in a colony may vary considerably. True colonies are found only in primitive groups with simple organisation, such as protozoans and coelenterates. In sponges it is difficult to ascertain whether the branched animal is an individual or a colony. Colonial forms mostly reproduce asexually. Actually the colony results due to the failure of the individuals to separate. Each individual in a colony is called a zooid.

### 14.2.1 Colonial Forms among Protozoans

Many well known colonial forms occur among protozoans. Simplest colony formation is seen in **Choanoflagellates**, which have a collar around the base of the flagellum (hence the name). There are a few zooids in a colony as for example, in *Codosiga* (Fig. 14.1 a). Each zooid leads an independent life though remaining attached to a common stalk. The volvocales form more complex colonies. For example, *Gonium* forms plate like colonies of 4-16 individuals; *Pandorina* forms spherical colony of 16 individuals; *Eudorina* is a spherical colony of 32 zooids arranged on the surface, *Pleodorina* has 128 zooids. An advanced form of colony is seen in *Volvox*, which is a plant-like mastigophore, or phytoflagellate. In this colony thousands of individuals remain embedded (Fig. 14.1 b) on the surface of a spherical jelly-like substance secreted by the zooids. Here also each zooid leads an independent existence except for a co-ordinated flagellar movement which helps in swimming. There is also connection among zooids by protoplasmic threads (Fig. 14.1). It is of interest to know that these colonies always swim with a particular side forward i.e., they possess polarity, an attribute of fundamental importance for colonial existence. In *Volvox* and *Pleodorina* some sort of division of labour is also noticed. The anterior zooids do not reproduce while those elsewhere are reproductive some of which become

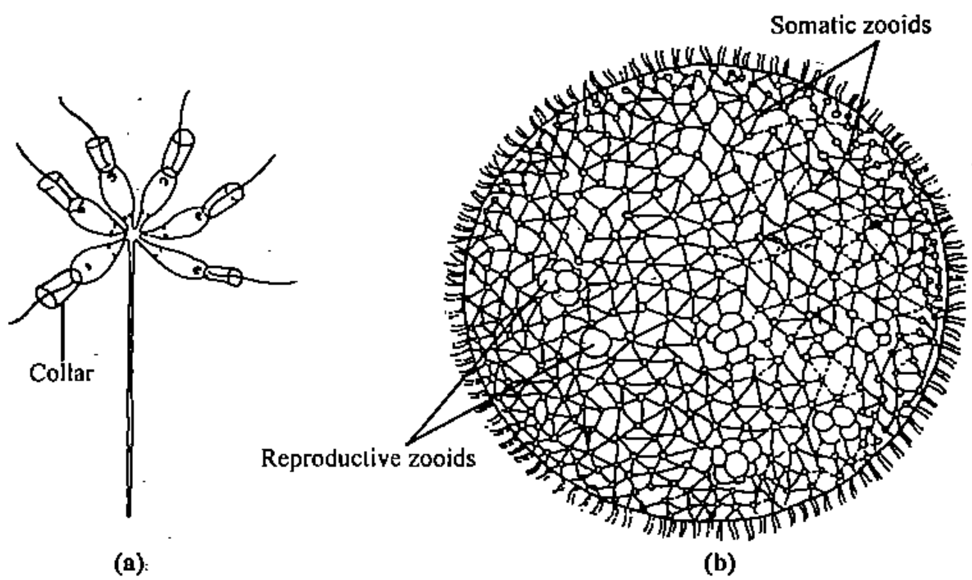



**Fig. 14.1: a) Choanoflagellates : the simplest protozoan colony *codosiga* b) *Volvox*: an advanced colony.**

Many ciliates like *Epistylis* and *Zoothamnium* also form colonies. Each of these colonies has bell-shaped zooids united by their stalks (Fig. 14.2 a and b) to a common stem. In *Epistylis* all zooids are alike while *Zoothamnium* shows polymorphism in zooid structure. There are four types of zooids in the colony (Fig. 14.2 b) a single terminal macrozooid which transforms into macro- conjugant; median axillary microzooids that can become migratory ciliospores; terminal branch microzooids which can form microconjugants and vegetative microzooids that can transform either into ciliospores or microconjugants.

Now let us examine the advantages of the colonial life in protozoans. Most of the protozoan colonies are **autotrophic** i.e. they obtain their food in a plant-like manner by photosynthesis. Therefore no apparent nutritive advantage is provided by the colonial way of existence. Then what are the benefits? We can observe following advantages:

1. Association of individuals in a jelly-like ground substance, especially when interconnected by protoplasmic strands, facilitates transmission of nutrients.
2. Combined flagellar activity of many zooids gives locomotory advantage.
3. Most of the colonies being spherical, minimum surface area for a given volume of sphere is exposed to the surrounding water, due to which the resistance offered by water is least.
4. In colonies of ciliates the group association provides protection and more efficient exploitation of food-supplies.

Before we pass on to colonial life in metazoans, let us see what you have learnt so far.

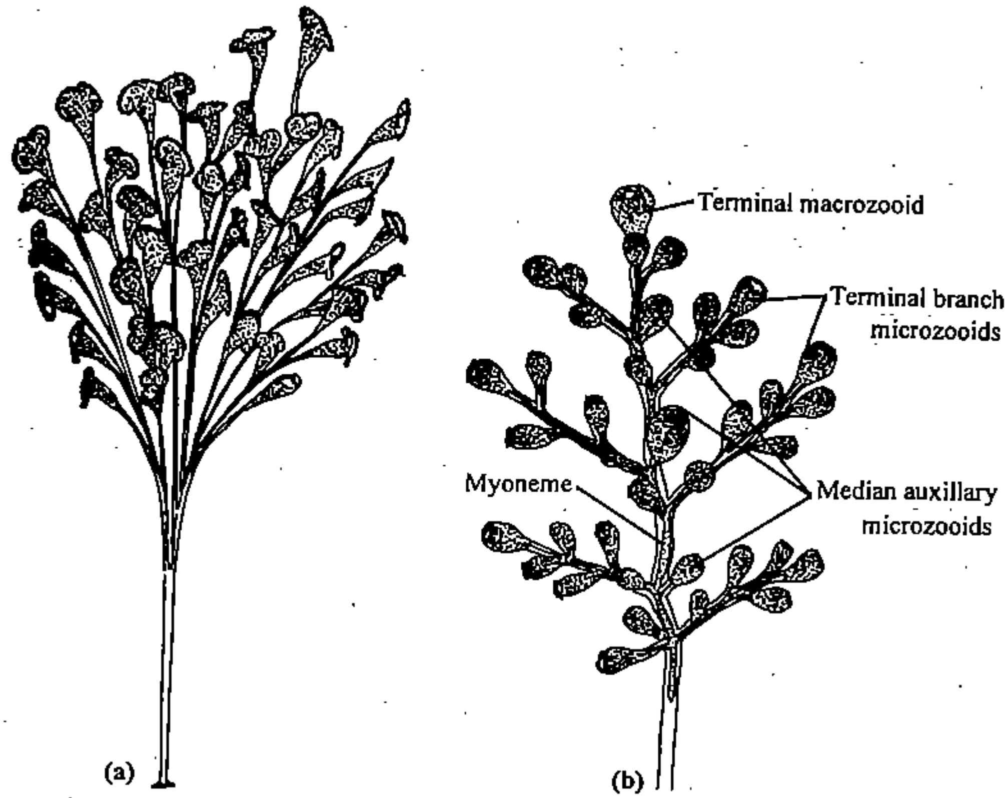



Fig. 14.2: a) *Epistylis* : Colony having similar zooids, b) *Zoothamnium* : a polymorphic protozoan colony.

## SAQ 1

i) Fill in the blanks using the correct word given in parenthesis below: (environment, different, alike, adaptive convergence, adaptive divergence)

a) The condition where organisms belonging to widely different phylogenetic groups adapt themselves to the same ............................. and look and act alike is called ......................................

b) When animals belonging to phylogenetically closely related groups occupy different habitats and acquire different adaptive modification, it is called ........................ ..........................

ii) Indicate whether the following statements are true (T) or false (F):

a) In true colonies zooids are not organically connected with each other.
b) True colonies are found only in organisms with comparatively simple organisation.
c) Colonies in *Carchesium* show polymorphism.
d) Colonial life provides nutritive advantage in all colonial forms.

### 14.2.2 Colonial Forms in Metazoans

Among metazoans, true colonial forms are met with in coelenterates, though the term 'colony' is often used in relation to sponges and insects also. In sponges the 'colony' is arbitrarily defined on the basis of the number of oscula. One osculum-one-individual is the rule. However, this definition is more a matter of convenience. In insects the word 'colony' is employed to denote the complex societies that are formed by them, as in the case of honey bees, ants, termites etc. But these social groups do not strictly fall within the definition of the term colony.

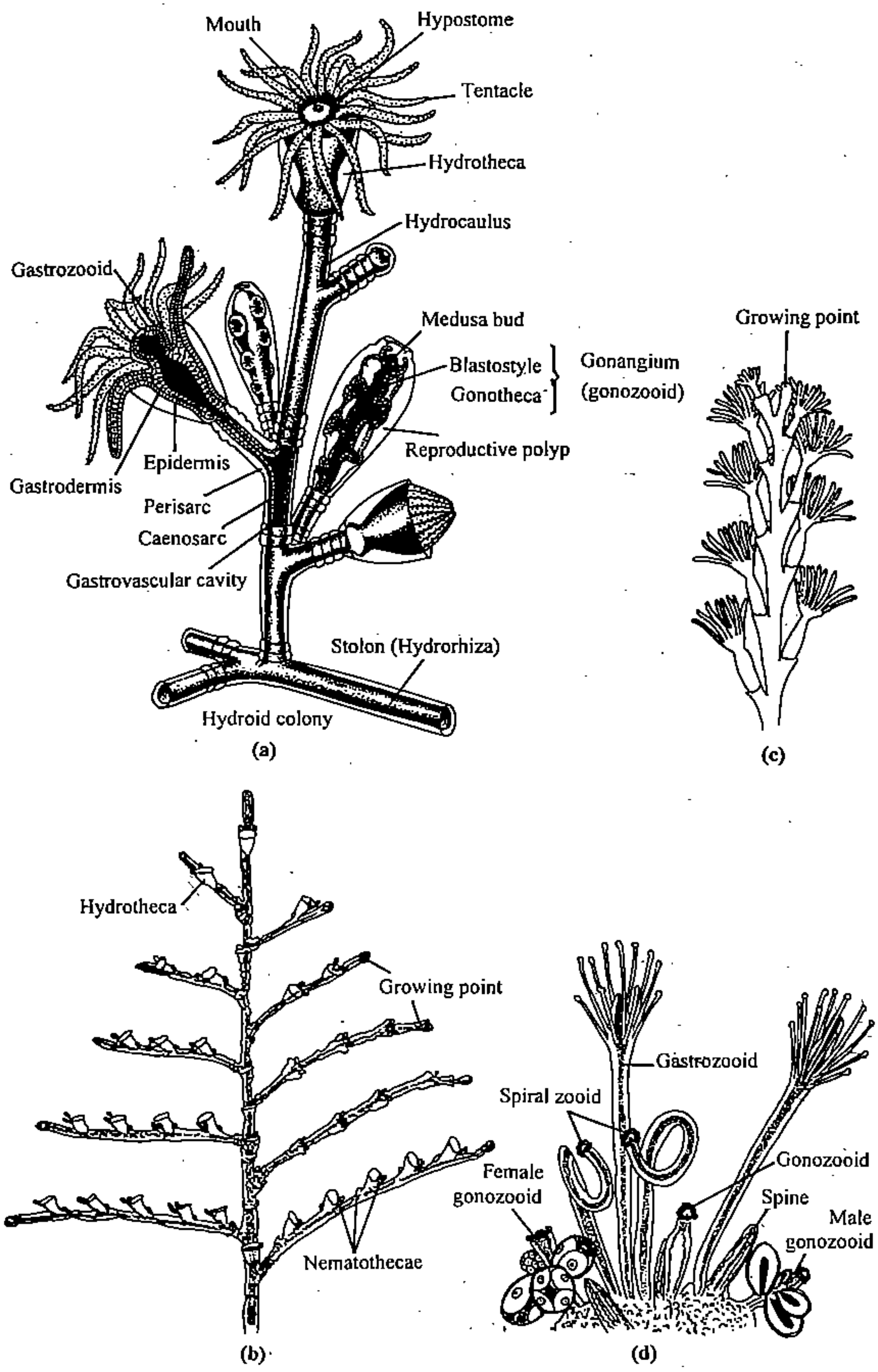



**Fig. 14.3 : a)** *Obelia*, **the hydroid colony (monopodial colony). (b)** *Plumularia* **colony showing monopodial growth. (c) Sympodial growth of** *Halecium* **colony. (d)** *Hydractinia* **colony where polyps grow directly from the mat of stolons.**

## Coelenterate Colonies

Members of the class Hydrozoa and Anthozoa form true colonies. Zooids with well-defined individuality are present in a colony, the shape and pattern of which varies from species to species. Floating colonies are formed by siphonophores. In the case of sedentary hydrozoan colonies, the colonies are attached to the substratum by living thread-like horizontal stolon or hydrorhiza (Fig. 14.3 a). From the stolon arise vertical branching stems called hydrocauli. Each hydrocaulus gives off lateral branches, which in their own turn bear branches of the third order. Zooids are borne on these branches (Fig. 14.3 a).

The branches and zooids in a colony are connected by a living coenosarc, over which a non-living horny perisarc is present. The coelenteron continues throughout. A zooid is cylindrical or umbrella-shaped, diploblastic structure with a body cavity or coelenteron opening to the exterior by a *mouth* situated on hypostome. A circlet of tentacles is usually present around the hypostome. In some cases the perisarc forms a cup like or capsule-like covering, variously named hydrotheca or gonotheca, around the zooids. The zooids covered with theca are called thecate; those without a thecal covering are naked ones or athecate.

The growth of the hydrocaulus is of two types viz. monopodial and sympodial (Fig. 14.3 b and 14.3 c). In the former the main axis maintains a single line of growth i.e., each branch ends in a permanent terminal zooid which is oldest of that branch. Below the base of this terminal zooid is the zone of growth. This zone lengthens the branch. The growth zone may also give rise to lateral buds, which may elongate in their turn. In the sympodial growth the primary polyp does not continue to elongate. But it produces lateral polyp. This also stops growth, but produces lateral buds again. Here the terminal polyp is the youngest. The main axis is formed by the combined hydrocauli of many polyps (eg. *Halecium*). In some forms like *Hydractinia* (Fig. 14.3 d) zooids arise directly from the stolon in an irregular fashion.

Polymorphism is another characteristic feature of coelenterate colony. The zooids exist in many forms and show division of labour. Usually some zooids are concerned with feeding; these are called **gastrozooids**. The **blastozooids** or gonozooids undertake reproduction, budding off medusae which are another type of zooids, while **dactylozooids** are meant for protection.

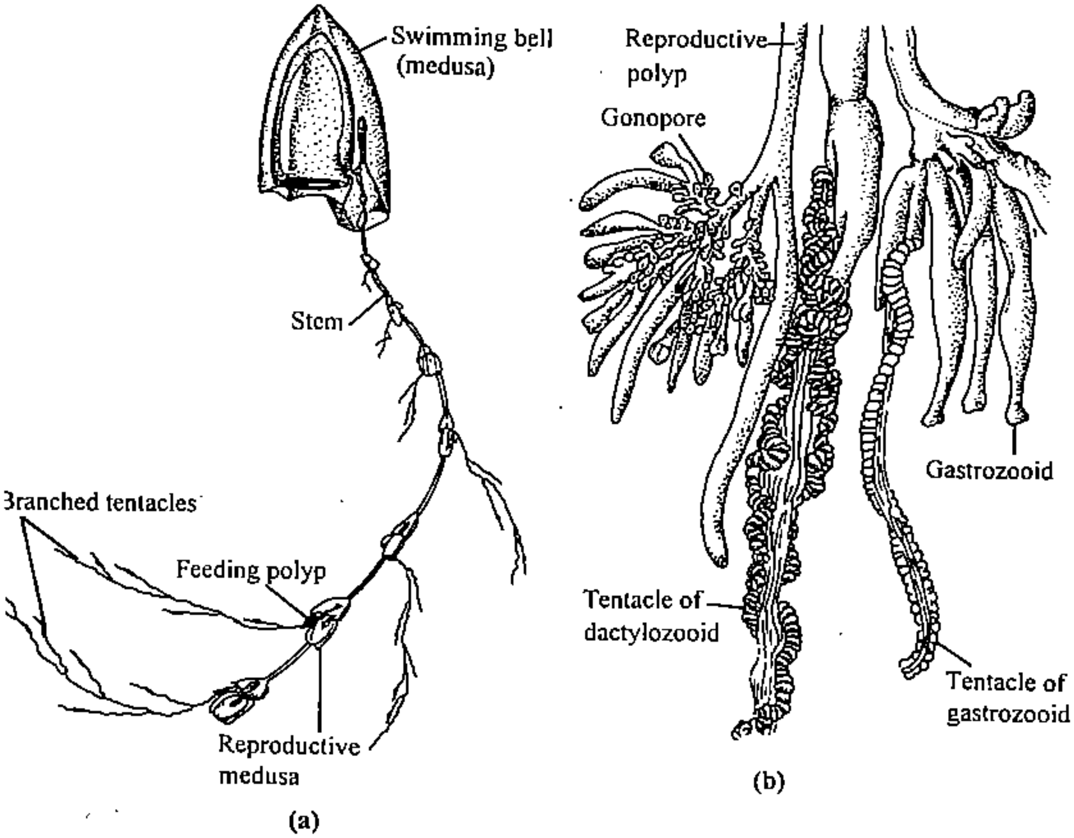



**Fig. 14.4 : a) A typical submergent siphonophore *Muggiaea*; b) Part of another siphonophore *Physalia* colony showing the zooid polymorphism.**

The saucer-shaped zooids called medusae produce gametes and reproduce sexually. You may recall here the siphonophores and other hydrozoan colonies which you have already studied in previous unit. Siphonophora shows extreme case of polymorphism, for example, *Muggiaea* and *Physalia* (Fig. 14.4). The group includes pelagic zooids. The colony comprises gastrozooids, dactylozooids and gonozooids. The medusae remain attached to the parents and modify to form gonophores (reproductive zooids), nectophores (locomotory zooids) and gas- filled pneumatophores (floating zooids).

In one of the previous units dealing with coelenterates you have studied in detail, corals and coral reefs. You may recall that section here. The Hydrocorallina (the hydrocorals; eg. *Stylaster*, *Millepora*) (Fig. 14.5) are colonial, polypoid, hydroid corals which may attain considerable size contributing to coral formation. Their skeleton is calcareous, internal and epidermal. Though not accompanied by polymorphism, many anthozoans are also Colonial, eg. *Palythoa*.

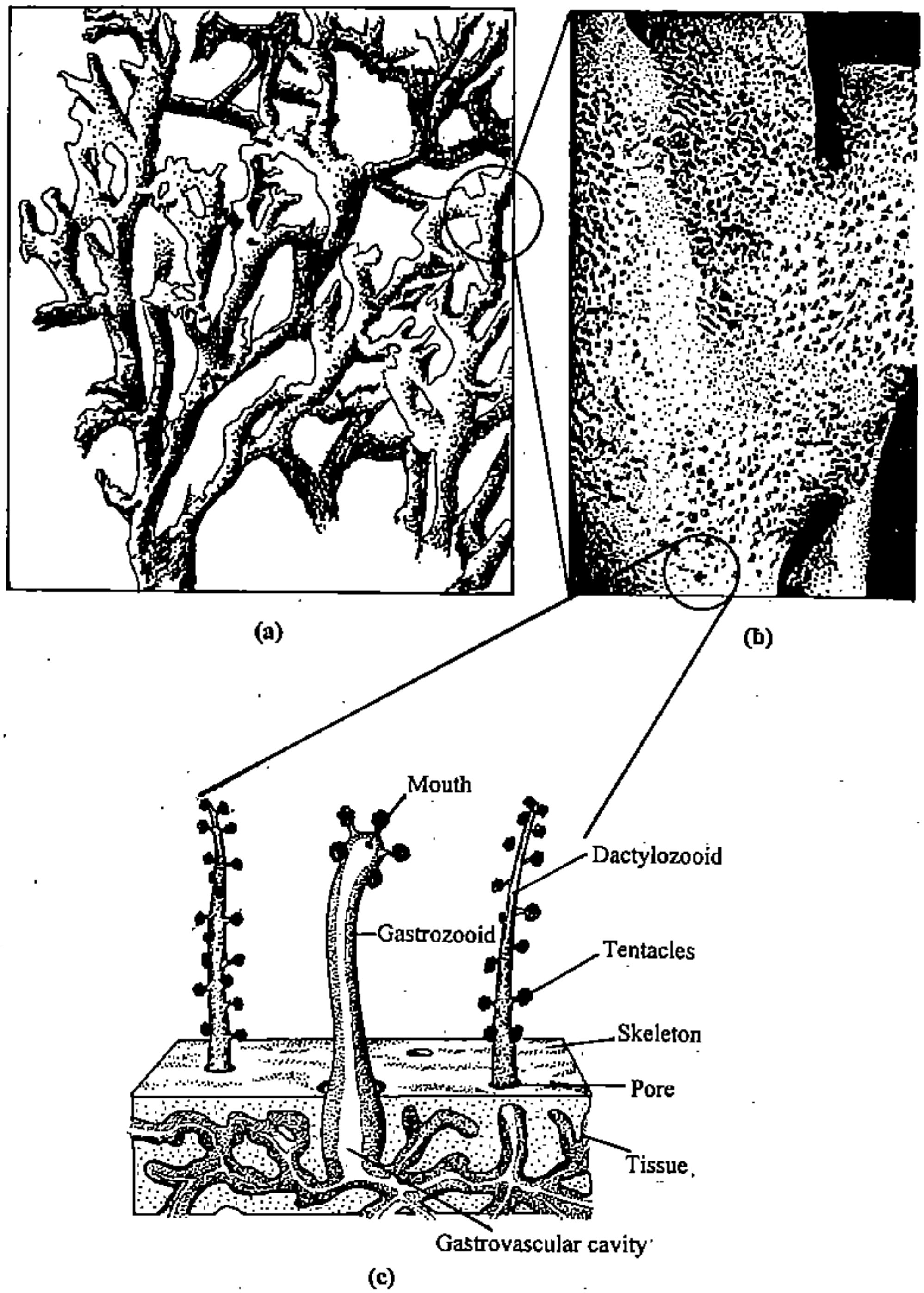



**Fig. 14.5 : Hydrocoral *Millepora*; a) The colony, b) part of the colony magnified showing the pores, c) polyps of *Millepora* emerging from the pores in the skeleton.**

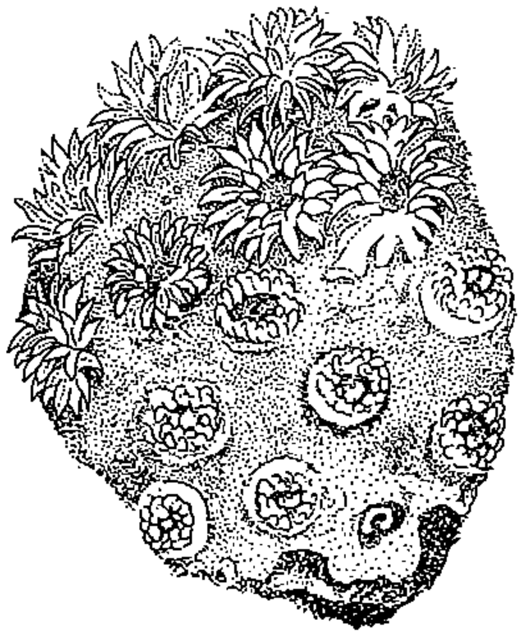


Fig. 14.6 : Part of the coral colony showing contracted and expanded polyps.

Many true corals, though not all, are also colonial. Conspicuous among the colonial anthozoans are in fact many coral formers. The colony-forming scleractinian corals or stony corals, also known as hexacorals and madreporerial corals (Fig. 14.6), include *Astrangia*, *Montastrea* and the brain coral. Here the polyps are interconnected by horizontal connections. The skeleton is epidermal and external (Fig. 14.7). There are solitary corals also among them, like *Fungia* (Fig. 14.8). The colony-forming octocorals (alcyonarians) among anthozoans include the common sea pens, sea rods, sea pansies, sea fans, whip coral, pipe corals etc. (Fig. 14.9). The ameobocytes secrete their skeleton which supports the colony. The skeleton of these octocorals is therefore internal and is part of the tissue.

From this account you will see that corals have developed from different groups of coelenterates. This is convergence in their adaptation.

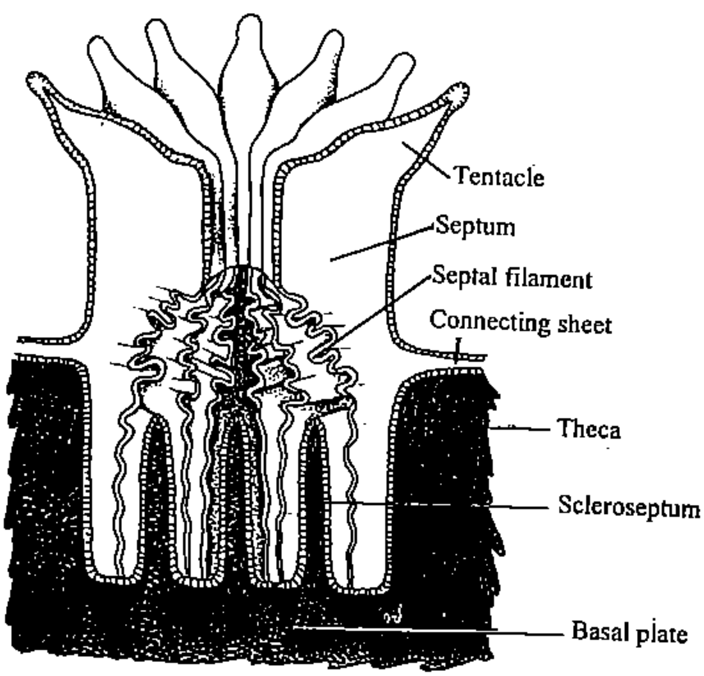



Fig. 14.7: Vertical section of the coral polyp in its theca.

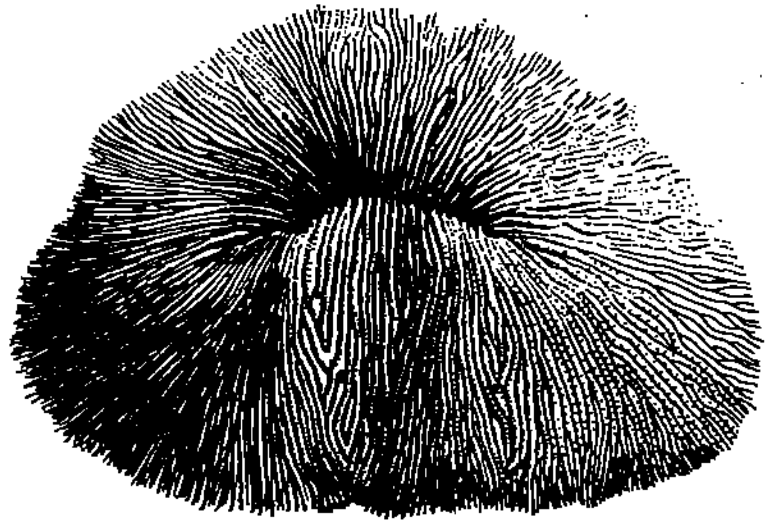


Fig. 14.8: *Fungia*.

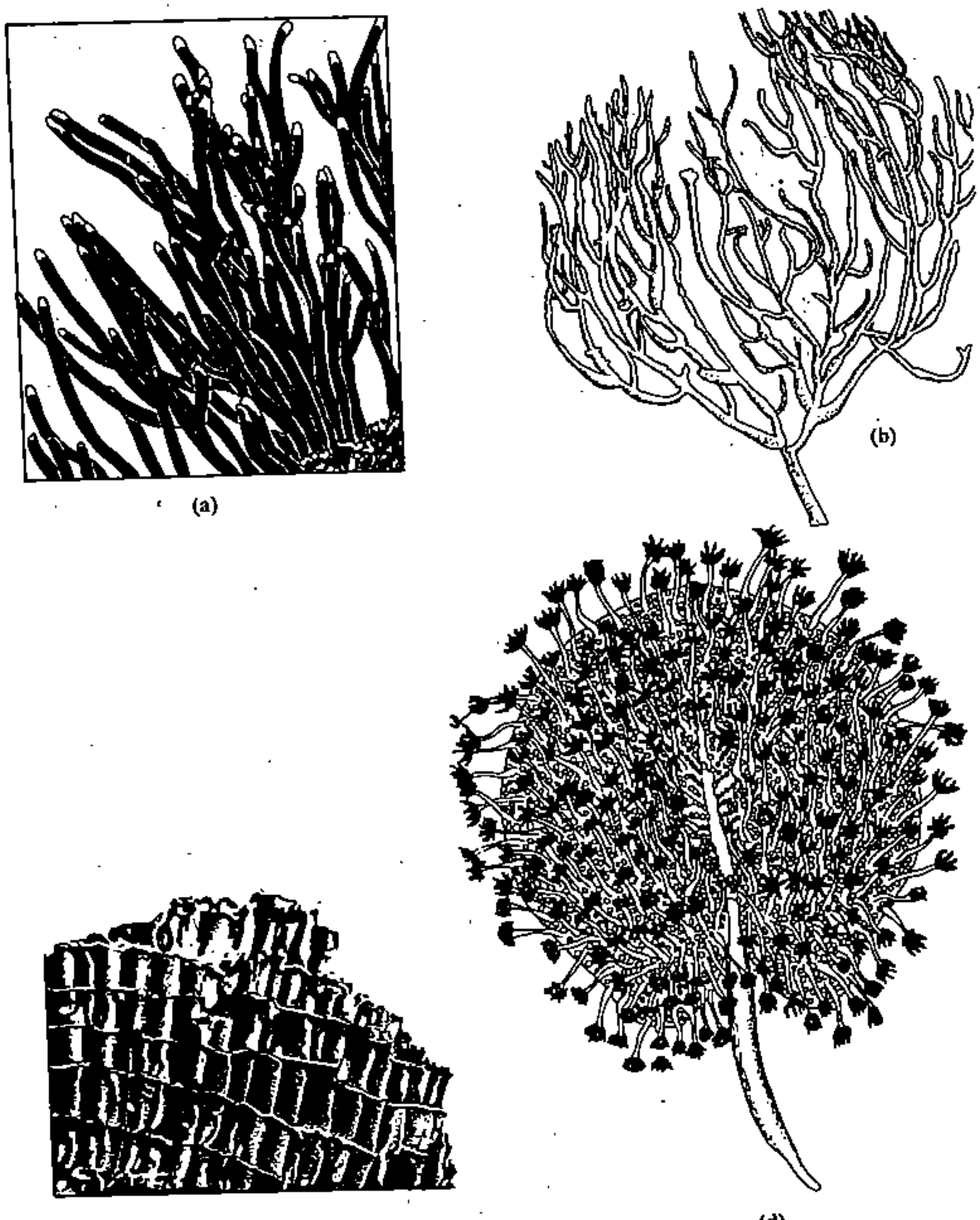



Fig. 14.9: a) Sea rods; b) Sea fan; c) Organ-pipe coral; d) Sea pansy.

Thus the benefit of colonial life is also clear: competition for survival among individuals is replaced by co-operation. This provides distinct nutritive, protective and reproductive advantages to them.

## SAQ 2

i) Match the words in list A with those in list B.

| List A | | List B | |
|---|---|---|---|
| 1) | Dactylozooid | a. | Feeding |
| 2) | Gastrozooid | b. | Floating |
| 3) | Pneumatophore | c. | Protection |
| 4) | Medusa | d. | Sexual Reproduction |

ii) Fill in the blanks in the following statements on the basis of what you have studied in subsection 14.2.2.

The growth of the hydrocaulus is of two types viz., .................................... or ..................................... In the former each branch ends in an oldest terminal zooid, below the base of which is the zone of growth that lengthens the branch and gives rise to buds.

# 14.3 ADAPTIVE RADIATIONS

In the beginning of this unit, you have studied that when the animals belonging to the same or closely related groups adapt for different modes of life, they are said to show adaptive divergence or adaptive radiation. This concept was known to early zoologists like Lamarck and Darwin. Lamarck called it embranchment and Darwin called it divergence. The idea was, however, concretized in the form of a law by Osborn, the law of adaptive radiation. Though Osborn postulated the law of adaptive radiation on the basis of his studies on mammals, it applies equally well to other animal groups, whether non-chordates or chordates. There is always a brief period in the history of all animal groups when the rate of evolution is very rapid. It results in the emergence of many new major lines of evolution or adaptation. Further evolution of each of these lines is comparatively slow. This process of breaking up of the parent stock into diverse lines which continue their own evolution is adative radiation.

Two fundamental needs of the organisms are mainly responsible for adaptive radiation. These are need for food and need for safety. A major factor in the animal evolution has been their habit of food gathering. Two basic ways of this habit may be recognised. There were animals which would just wait for the food to come their way. Secondly, some animals would actively seek the food and go after it. The former acquired sedentary habits and radial symmetry. Radial symmetry would allow the fixed animals access to food in all directions. These animals evolved a special feeding device called filter-feeding. On the contrary, a typical food- seeker has to resort to movement for food gathering. They would go after the food. This gave rise to antero-posterior polarity, cephalisation, and bilateral symmetry. The anterior end may have developed into a distinct head, the seat of mouth-parts, sense organs and brain. (see earlier unit).

The second major factor in animal evolution has been the need for safety from the hostile abiotic and biotic components of the environment. All this has also led to exploitation of new habitats and acquisition of appropriate adaptations to suit the new surroundings. These modifications may have been in the habits, morphology and physiology of the animals. The evolutionary history of various lines or animal groups show that functional adaptations in different groups are different. Therefore you will find different lines of adaptive radiations in different groups of animals.

## 14.3.1 Adaptive Radiation in Annelida

Phylum Annelida includes three classes; Polychaeta, Oligochaeta and Hirudinea. Of these, the Polychaeta do not have clitellum; the Oligochaeta and Hirudinaria are clitellate. Now you should recollect the classification and characters of Annelida which you have studied in Unit 4, Block 1 of this course. The early annelids are supposed to have been marine worms burrowing in the bottom, in sand and mud on the shore.

Polychaetes comprise the marine species which continued their life in the sea diversifying into various niches there; Oligochaeta include the line which led to the fresh water forms and to the earth worms; Hirudinea includes the leeches which arose from some fresh water oligochaetes.

### Adaptive Radiation in Polychaeta

Having evolved from some small, annelid worm-like creatures adapted for burrowing and crawling life in oceans, the group diverged into two main branches on the basis of their food habits; a group of active food seekers and another line of sedentary animals. The former actively sought after the food either scavenging or preying upon it whereas the latter gave rise mainly to burrowing or tubicolous forms. In this section we will discuss the polychaete groups adapted to various modes of locomotion, habitation and nutrition.

**Errant Polychaetes:** Worms such as nereids or hesionids are rapid crawling worms that crawl beneath stones and shells in rock and coral crevices and among algae and sessile animals. In these worms the head is well developed having one to four pairs of eyes, upto five antennae and a pair of palps (Fig. 14.10).

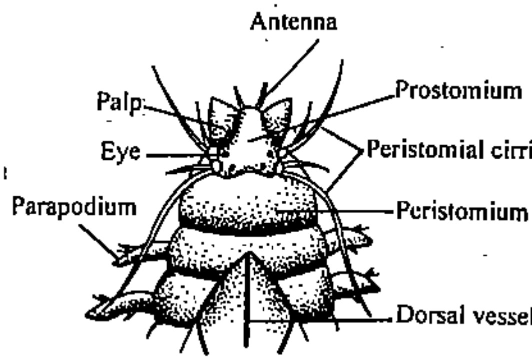



**Fig. 14.10: The head region of the polychaete *Nereis*.**

These worms have large parapodia that help in crawling. Many of these polychaetes are carnivores and feed on small vertebrates including other polychaetes. Food habits like scavenging, algae eating and detritus feeding have also evolved in some of these polychaetes. The pharynx of the errant polychaetes is muscular and eversible and possess teeth or jaws which vary in number in different families (Fig. 14.11).

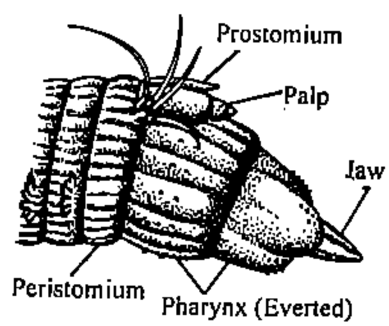



**Fig. 14.11: The head of the polychaete *Nereis* with everted pharynx (lateral view) the jaw is open when pharynx is everted and closed when pharynx is retracted.**

**Pelagic Polychaetes:** Certain families of polychaetes are adapted to life in oceans and thus are pelagic or planktonic. In these worms head is well developed and parapodia are large that are used as paddles to aid in swimming. Like other planktonic animals these polychaetes are pale or transparent. These worms are generally carnivores, e.g. *Rhynchonerella angelina* (Fig. 14.12), *Tomopteris renata*.

**Gallery Dwellers:** These polychaetes are adapted to live in burrows made of sand or mud. The gallery dwellers make extensive burrow system or galleries that open to the surface at many points (Fig. 14.13a). These burrows are lined by the mucus secreted by the worms that prevent the collapsing of burrows. The prostomium of these worms can be a simple lobe or of conical shape and lack the eyes and other sensory organs (Fig. 14.13 b).

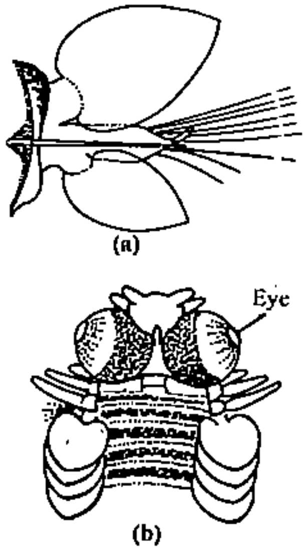



Fig. 14.12: Pelagic polychaete *Rhynchonerella angelina* (a) and its parapodium (b).

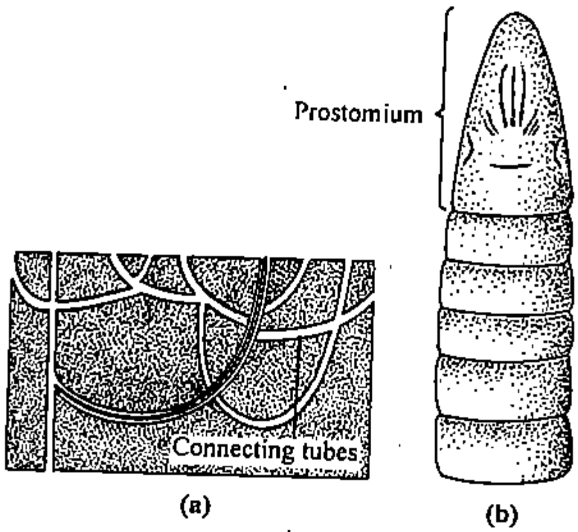



Fig. 14.13: a) Burrow system of a gallery dweller worm *Glycera alba* showing the worm lying in wait for the prey. b) Anterior end of the gallery dweller *Drilonereis* showing the conical prostomium that lacks eyes and sensory appendages.

The worms usually move in the burrows by peristaltic movements, and the parapodia are reduced and help to anchor the segments by gripping the walls of the burrow. The septa and circular muscles are well developed. However, some of the gallery dwellers may crawl with the help of parapodia. They may be carnivorous or non- selective deposit feeders and consume the substratum through which the burrows are made.

*Glycera*, is the best studied gallery dwelling polychaete and is also used as fishing bait. These worms lie in wait in the gallery system and when the prey moves across the surface creating pressure waves, the worm moves to a nearby opening. Blood worms have a long proboscis that is shot out with explosive force to seize the prey (Fig. 14.14).

**Sedentary Burrowers:** Certain polychaetes make simple burrows that have only one or two openings to the outside (Fig. 14.15 b). These worms move about very little when the move, they also go by peristaltic contractions only. Parapodium is reduced to hook like setae that help in gripping the burrow wall. The prostomium is devoid of most of the sensory structures. However, special feeding appendages may be present. Some of the sedentary burrowers are nonselective deposit feeders while others are selective deposit feeders. L-ug worms (*Arenicola*) (Fig. 14.15 a) nonselective deposit feeders, live in L-shaped burrows and ingest the sand at the bottom with an eversible pharynx. At fixed intervals the worm comes out of its burrow and defecates at the surface as a casting. After this the worm resumes feeding and ventilating. Ventilation occurs because peristaltic contractions bring in the water current.

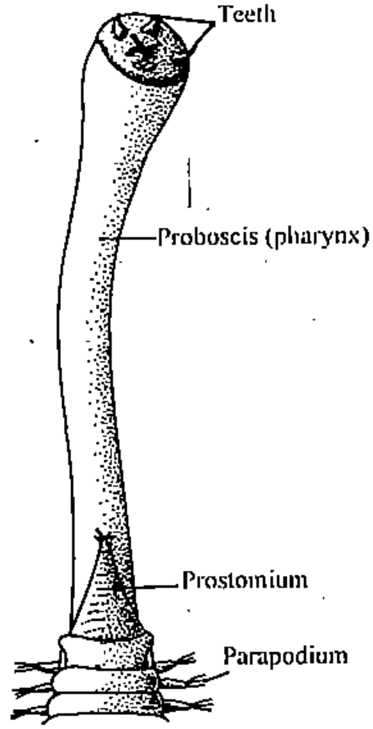



**Fig. 14.14: Anterior end of *Glycera* showing the everted pharynx.**

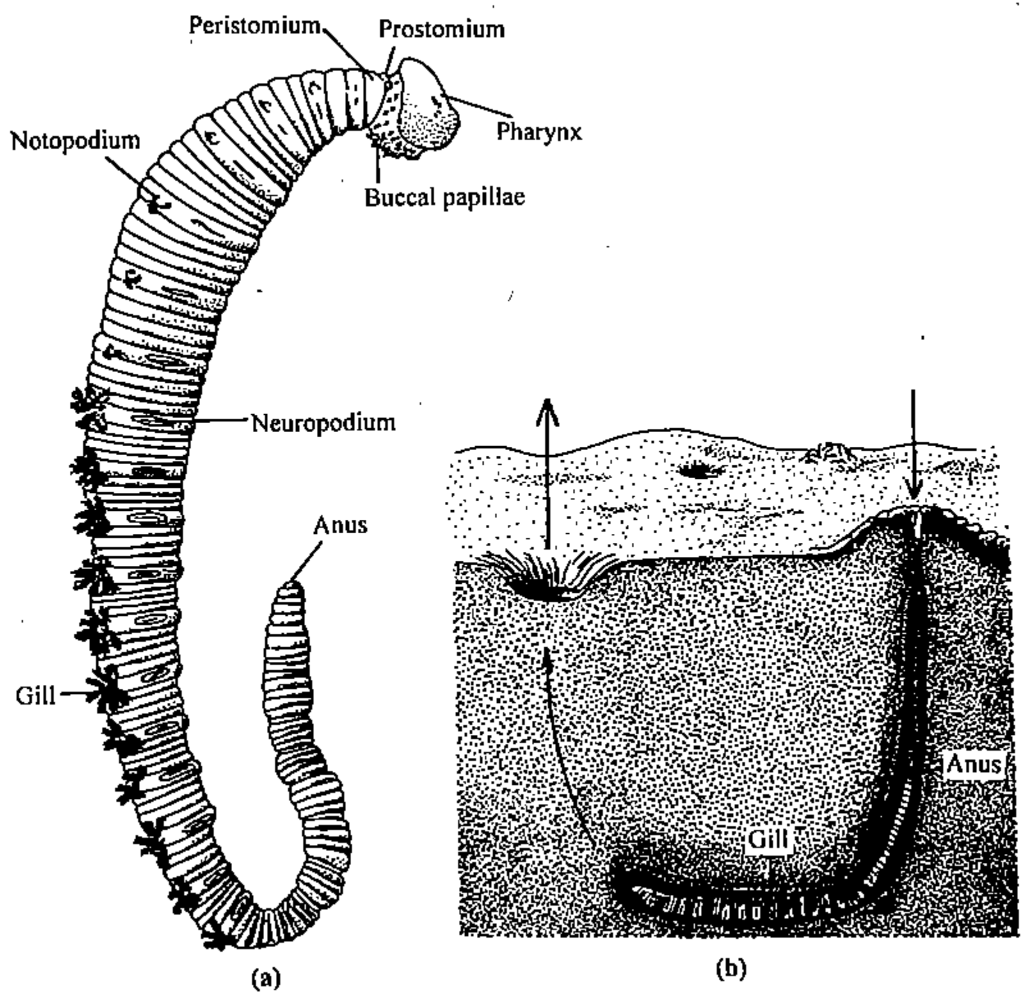



**Fig. 14.15: The L ug worm (*Arenicola*) with its pharynx everted (a). Worm in the burrow (b)**

In selective deposit feeders there is no eversible pharynx. Instead they have special head structures that pick up the organic matter from the surrounding sand grains. For example *Amphitrite* has a great mass of long tentacles that spread over the surface from the opening of the burrow (Fig. 14.16). The detritus material adheres to the mucus on the tentacles and is then passed on to the mouth in a ciliated tentacular gutter with the help of tentacular contraction.

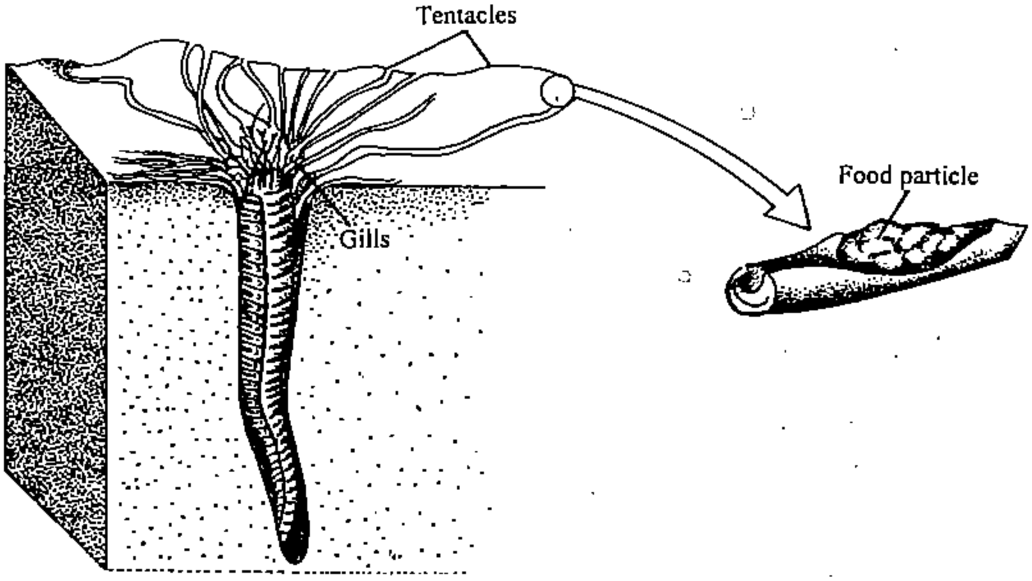



**Fig. 14.16:** ***Amphitrite*** **in its burrow with outstretched tentacles on the surface. Also shown is the food particles trapped in the tentacles that are rolled up to form a ciliary gutter.**

**Tube-Dwelling Polychaetes:** Tube dwelling is more widespread habit among the polychaetes as compared to other animal groups. The worms can make the tubes in the sand or in firm and exposed substrates such as algae, rock, coral or shell. The tube may be completely made up of hardened material secreted by the worm or composed of foreign material cemented together. Thus, a tube will remain intact when dug out of the sand.

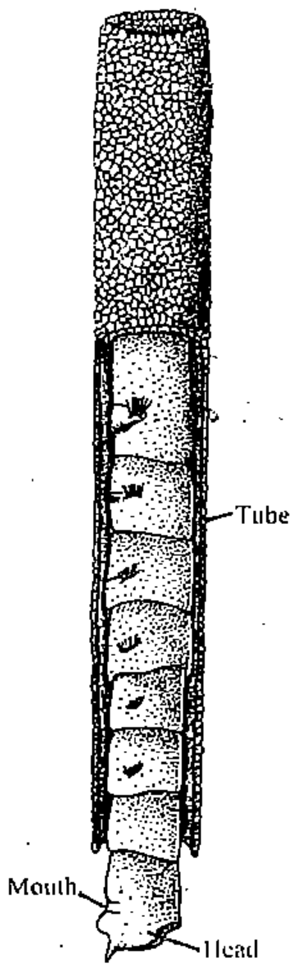



**Fig. 14.17: Bamboo worm that lives upside down in the tube.**

Tube dweller (tubicolous) polychaetes show structural diversity that is correlated with their different modes of feeding. Majority of the tube-dwellers are sedentary and move about within the tube lazily with the help of peristaltic contractions. They lack sensory structures, although feeding appendages may be present. Parapodia are reduced to ridges with hooked setae for gripping. Infact these adaptations are similar to those for sedentary burrowers as these two habitations are similar to some extent. Some families contain both burrow dwelling and tubicolous species.

The nonselective deposit feeders like bamboo worms (*Clymenella, Axiothella*) live in sand grain tube by keeping their head down and ingest the substratum at the bottom of the tube with the help of eversible pharynx (Fig. 14.17). Periodically the worm comes back to the surface and defecates.

Filter feeding is another mode of nutrition that has evolved in several families of sedentary and tube dwelling polychaetes. One kind of filter feeding is seen in fan worms or feather duster worms, where the prostomium palps have developed to form a funnel - shaped or spiral crown consisting of pinnate processes called radioles, for example in *Sabella* (Fig. 14.18). During feeding the particles are first trapped in the mucus of the radioles surface and then passed on to the mouth with the help of cilia. When the worm pulls back its anterior end into the free end of the tube, the radioles are rolled and closed up together.

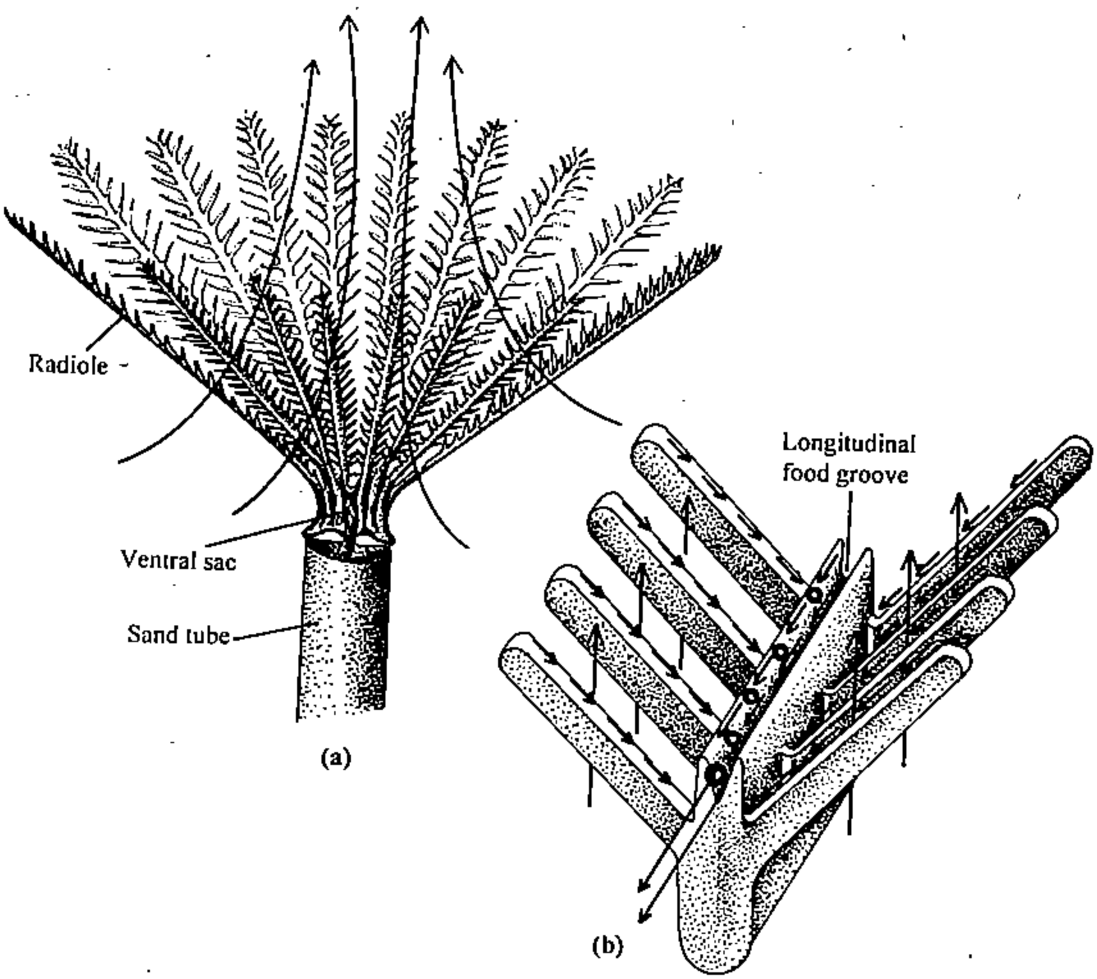



**Fig. 14.18: Filter feeding in fanworm *Sabella* (a) Water current passing through radioles. (b) Water current and ciliary tract over a part of radiole.**

*Chaetopterus* exhibits another mode of filter feeding. It feeds by filtering water through a mucus bag. These worms live in U- shaped tube made by secreted parchment like material (Fig. 14.19). In the middle of the body of the worm there are three piston like or 'fan' like parapodia that drive water through the tube. A pair of long winglike anterior notopodia secrete a film of mucus that is rolled up into bag like shape with the help of cilia. The water current driven in the tube passes through these mucus films. Periodically the mucus secretion is stopped and the mucus bag containing trapped food is rolled up into a ball which is passed along the ciliated groove to the mouth.

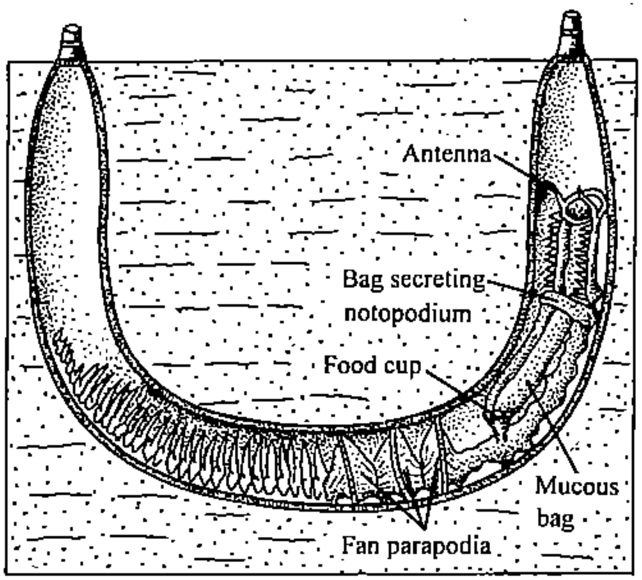



Fig. 14.19: *Chaetopterus* in its tube (lateral view).

Till now you have studied about the adaptations in annelida. Try the following SAQ before we proceed further.

## SAQ 3

i) Mark (✓) the correct alternatives in the following statements :

a) Law of adaptive radiation was postulated by *Lamarck/Osborn*.
b) Adaptive divergence was called 'embranchment' by *Darwin/Lamarck*.
c) Worms with well developed head having eyes, antennae and a pair of palp are *gallery dweller polychaetes/errant polychaetes*.
d) Large parapodia in polychaetes that are used as paddles are adaptations to life in *oceans/sand and mud*.

## SAQ 4

i) State whether the following statements are true (T) or false (F).

a) Sedentary burrower Polychaetes are essentially carnivores.
b) Filter-feeding is mostly found in sedentary tube-dwelling polychaeta.
c) Polychaets are mainly fresh water animals.
d) Sedentary and tube-dwelling polychaetes mostly lack well-developed sensory organs.

ii) Name the two fundamental needs responsible for adaptive radiation.

a) ....................................,
b) ....................................

### Adaptive Radiation in Clitellate Annelida

Polychaeta, being aquatic, lay their eggs in water and most of them develop through a *trochophore* larval stage. Aquatic environment offers many advantages: animals require less energy expenditure for supporting their body weight, water acts as a cushioned envelope providing protection from jerks and strains, temperature gradient in water is least and it provides an ideal medium for egg-laying and development. These advantages are available to marine as well as fresh-water forms. However, fresh water habitats have one big drawback. These are not permanent like marine habitats. They may dry up during some part of the year. Therefore the fresh water forms and terrestrial ones face a two fold problem to different extent. One, they are denied the benefits of permanent and continuous access to the aquatic medium and secondly, they are exposed to the risk of desiccation. This problem has been solved by clitellate annelids successfully. Let us examine how.

The clitellum-bearing Annelida, the Oligochaeta and Hirudinea, mostly inhabit fresh water and terrestrial habitats. They have no larval stage and the development is direct. Glandular cells of some of their body segments become active during breeding season and form a conspicuous belt-like **clitellum** (Fig. 14.20) which produces a cocoon. Eggs are laid and develop within these cocoons. The clitellum may be permanent (as in earthworms) or temporary (as in leeches). These annelids are hermaphrodites, though reciprocal copulation in earthworms is well known. The clitellates are devoid of antennae, palpi or parapodia.

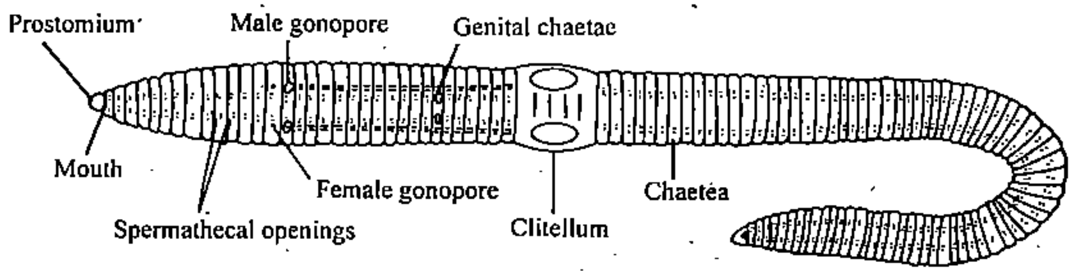



**Fig. 14.20: Earthworm showing clitellum**

Oligochaeta appear to have evolved directly from the marine annelids, independently of polycheates. Some species of tubulificids and enchytraeids especially from littoral and intertidal zones and estuaries have been reported from marine waters.

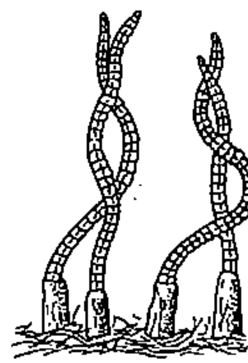



**Fig. 14.21: *Tubifex* that lives head down in long tubes. The posterior end waves about in water to facilitate gas exchange.**

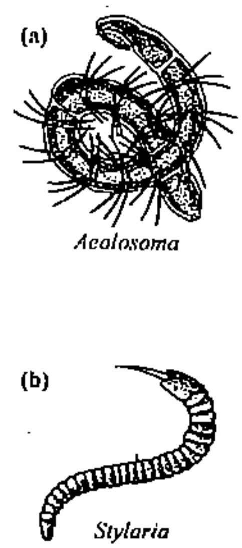



**Fig. 14.22: (a) *Aeolosoma* - the cilia around the mouth sweep in the food particles. (b) *Stylaria* - prostomium drawn out into long snout.**

*Tubifex* (Fig. 14.21) and *Limnodrilus* are reported to thrive well in sewage-polluted waters. *Tubifex* which lives in stagnant water in mud, builds tubes. It projects posterior part of its body from the tube and waves it about in water facilitating gas exchange. Some like *Aeolosoma* and *Stylaria* (Fig. 14.22) are fresh water forms. Aulophorus constructs tubes in mud and debris. Aquatic forms like *Dero* (Fig. 14.23) and *Aulophorus* have finger like gills at the posterior end. *Branchiura* and *Branchiodrilus* have filamentous gills on the body. Aquatic forms are generally small; but they have longer setae. Some like enchytraeids are transitional between aquatic and terrestrial habitat; and live in marshes. These include lumbricids, megascolecids and moniligastrids. Earthworms are burrowing animals and are known to increase land fertility.

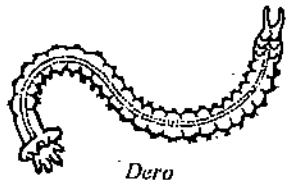



**Fig. 14.23:** *Dero* has ciliated anal gills.

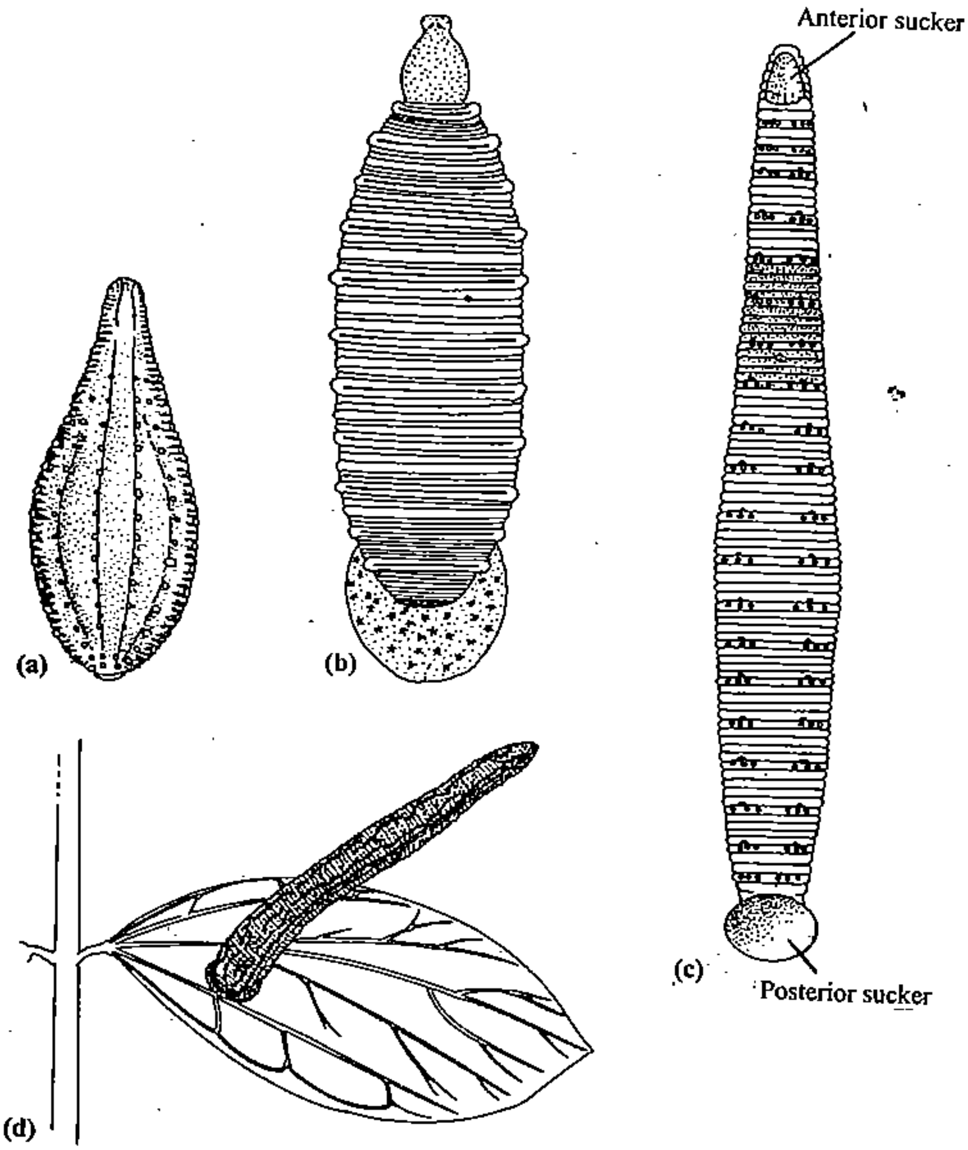



**Fig. 14.24:** a) Glossiphoniid leech *Glossiphonia complanata*; b) piscicolid leech *Cystobranchus*; c) hirudinid leech *Hirudo medicinalis*; d) haemadipsid leech *Haemadipsa*.

**Hirudinea** includes leeches. Many of the leeches are ectoparasites of vertebrates [glossiphoniids, piscicolids, hirudinids, haemadipsids (Fig. 14.24)]. The parasitic adaptations of the leeches are: presence of sucking pharynx and a post-anal sucker, provision for the secretion of mucus layer over the body by the skin glands to prevent dehydration, secretion of an anticoagulant **hirudin** to facilitate feeding on blood, and provision of food storage in the spacious crop. One full meal by a leech may last it for about four months. Leeches and oligochaetes have a common ancestry. Leeches are mostly fresh water animals. However, some have become adapted to terrestrial life (*Haemadipsa*). Some have also become secondarily adapted to marine habitat.

## SAQ 5

i) Indicate whether the following statements are correct or not.

a) All members of the phylum Annelida develop through a larval stage called trochophore.
b) Clitellum is a well developed permanant structure in earthworms.
c) The skin of leeches contains gland cells which secrete a mucus layer over the body which prevents desiccation.
d) *Tubifex* is very comfortable in ponds polluted with sewage.

## 14.3.2 Adaptive Radiation in Arthropoda

Biologically Arthropoda is the most successful group in terms of numerical strength, adaptive diversity and extent of territorial distribution. They are supposed to be polyphyletic in origin, with a number of (three or four) independent lines of evolution. There is also a tendency among them for reduction of number of segments by fusion or loss. Arthropoda, literally meaning **joint- footed** (Gr. arthros = joint; podos = foot), is represented by horse-shoe crabs (Subclass Xiphosura), prawn, lobsters, crabs (Subphylum Crustacea), spiders and scorpions (class Arachnida), centipedes (class Chilopoda), millipedes (class Diplopoda) and insects (Class Insecta). Formerly *Peripatus* (Onychophora) also used to be included in this phylum. Arthropods have certainly evolved from marine Annelida by acquiring an armour of chitin over the body and paired appendages on almost all body segments. The armour not only provided support and protection to the animal but also prevented entry of excess water and salts in the body in aquatic forms and desiccation in terrestrial ones. But it interfered with smooth gas exchange through the body surface and hampered growth. The adaptive radiation in Arthropoda is mainly related to the evolution of suitable respiratory mechanism, appropriate limb modifications and flight.

### Respiration

The annelids respire by the general body surface or by gills. In Arthropoda while gills are retained by aquatic forms, terrestrial members of the group have evolved **book-lungs** (scorpions) and **tracheae** (centipedes, milipedes and insects). Xiphosura and Crustacea are almost exclusively aquatic. They evolved in water and remained there. There are also some water-dwelling arthropods, which had actually invaded land and acquired terrestrial adaptations. They re-entered aquatic medium and made it a second home. This includes many adult insects (water-bugs, water-beetles, etc), which respire by tracheae while living in water. Thus, aquatic respiration in Arthropoda may be by gills (usually called branchial respiration) or by tracheae (tracheal respiration).

### Aquatic Respiration by Gills

In Xiphosura, Crustacea and many larval insects respiration takes place by gills. A gill is a vascular outgrowth of the bodywall. It remains bathed in water and gaseous exchange occurs on its surface. In *Limulus* (Xiphosura) five pairs of **book-gills** are present on the ventral surface (Fig. 14.25). These are flat, lamellate abdominal appendages. Each gill supports about 150 gill lamellae arranged in a manner which gives it an appearance of the leaves of a book, hence the name.

In Crustacea the gills or branchiae are arranged as lateral extensions along the central axis. Gills may be of three types: **Phyllobranchs** are simple, leaf-like lobes set on either side of a main axis (Fig. 14.26 a), **Triochobranchs** have filaments arranged around a central axis (Fig. 14.26 b) and dendrobranchs are modified phyllobranchs with each lateral lobe being subdivided (Fig. 14.26 c). Gills have a supply of haemocoelomic channels. A continuous supply of water is maintained in the gill chamber. This ensures proper gas exchange.

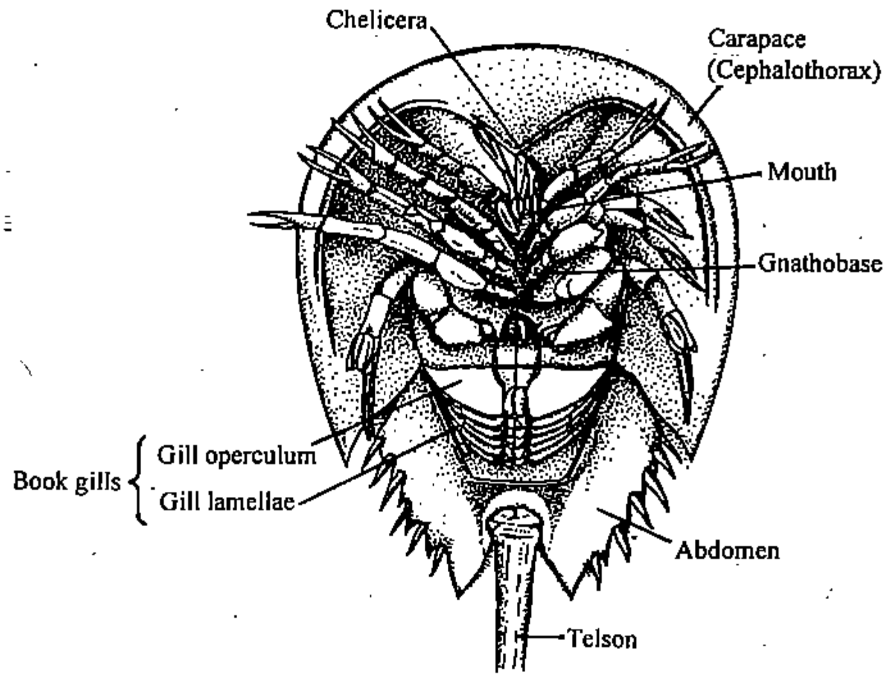



**Fig. 14.25: Ventral view of horseshoe crab *Limulus polyphemus*.**

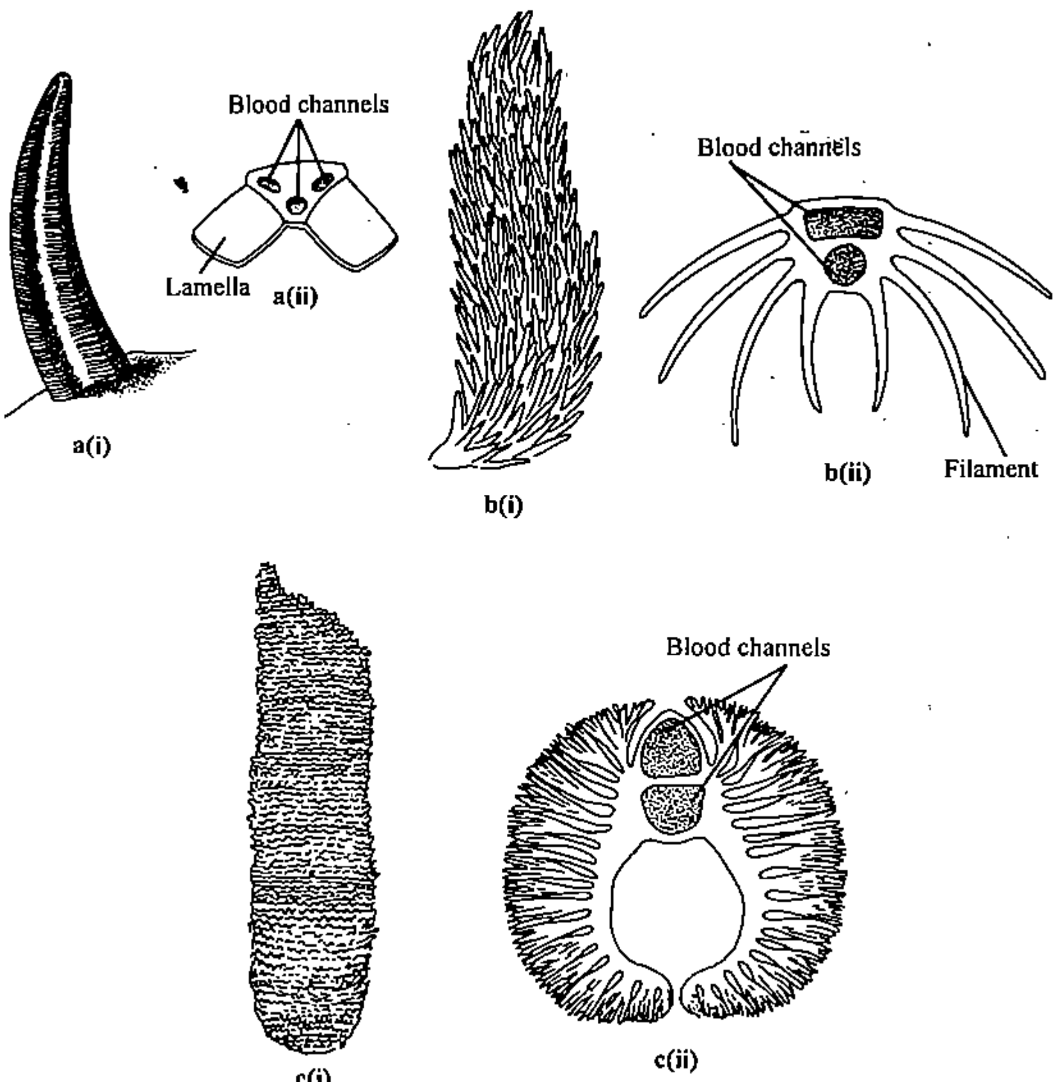



**Fig. 14.26: Gill types in crustaceans. a) Phyllobranch, b) Triochobranch, c) Dendrobranch, (i) Lateral view (ii) Transverse view.**

### Aquatic Respiration in Insects

Two modes of aquatic respiration in insects are recognised. In one, the insects obtain oxygen dissolved in water. This may be affected either through the general body surface or by means of different types of gills. **Tracheal gills** of the aquatic larvae of mayfly, stonefly and caddisfly are the lateral outgrowths of the bodywall and contain tracheal branches. **Rectal gills** are present in the rectum of Odonata larvae. The stonefly larvae (Fig. 14.27) possess **tracheal gills** on various regions of the body and *anal gills* on each side of the anus. The **blood-gills** of some dipteran larvae are blood-filled out-growths of the bodywall. The blood of **Chironomus** larvae is red due to haemoglobin, giving the name blood-worm to the larvae.

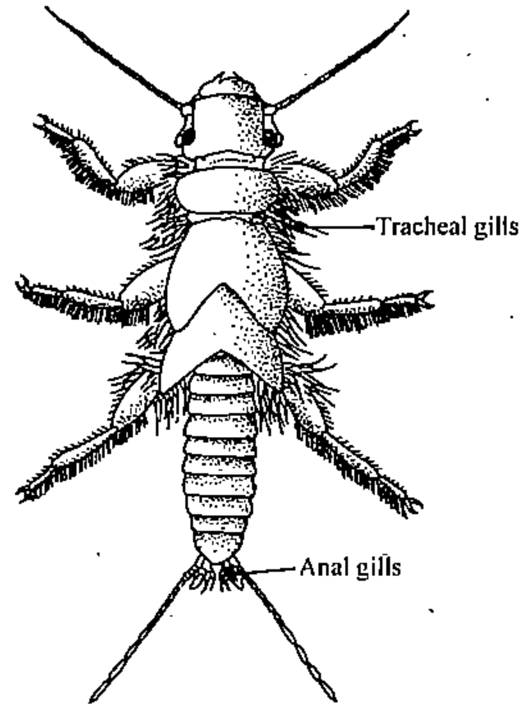



**Fig. 14.27: Stonefly larva showing tracheal and anal gills.**

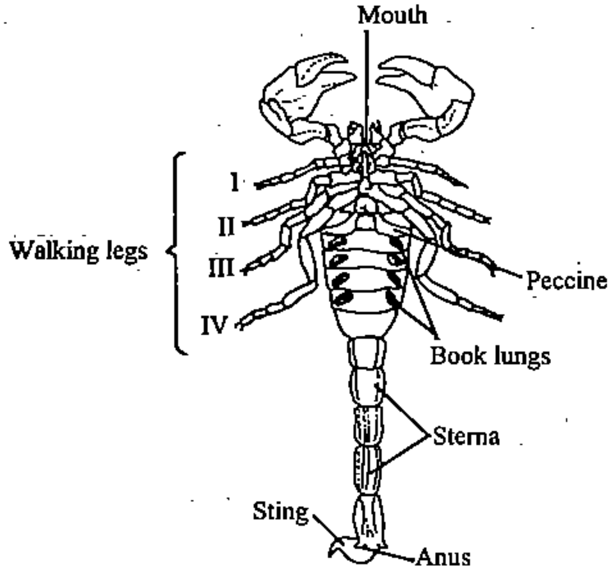
There are some insects which live in water but still breathe air. They have devised modifications to obtain supply of fresh air at periodic intervals. We will discuss more about these forms when we deal with respiration in terrestrial insects.

### Respiration in Terrestrial Arthropoda

In land-dwelling Arthropoda respiration is effected either by **book-lungs** (Arachnida) or by **tracheae** (Myriapoda and Insecta). The book-lungs seem to have been modified from the **book-gills** of the ancestral arachnids, the Merostomata. Scorpions possess four pairs of book-lungs, one inside each mesosomatic segments 3-6 (Fig. 14.28 a). A book-lung has a ventral atrial **chamber** and a dorsal **pulmonary chamber** (Fig. 14.28 b). The former opens to the exterior by **stigma** (plural-stigmata) and the latter contains about 150 vertically placed lamellae giving the whole structure an appearance of the leaves of a book that explains the nomenclature. In spiders the respiratory organs may be either primary book-lungs or some modified structures such as **tube- trachea** and **sieve-trachea**.

### Respiration by Tracheae

In most animals, except small and simple integument-breathers, oxygen is supplied to the different body parts through blood stream. Blood and air come in contact either in the gills or in the lungs. However, the land arthropods like Myriapoda and Insecta evolved an entirely unique system for oxygen transport in the body. In their case a series of pores, called **spiracles** are present on either side of the thorax and abdomen. These pores lead into a network of branching tubules, the **tracheae** (Fig. 14.29), which ramify throughout the body. Finer branches of tracheae called **tracheoles** reach out almost every cell. Air enters the trachea via spiracles and directly reaches the tissues. Thus, blood does not carry respiratory gases in them.



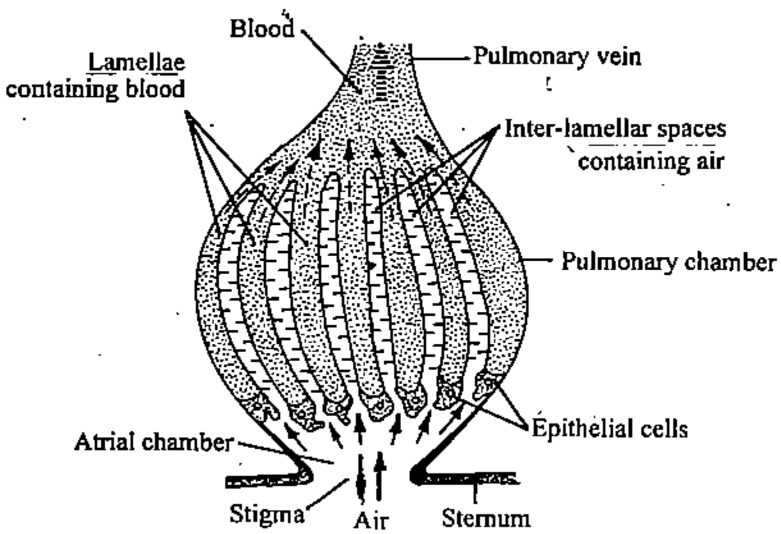




**Fig. 14.28: Ventral surface of scorpion showing spiracle of book-lungs (a). Vertical section of a book lung (b).**

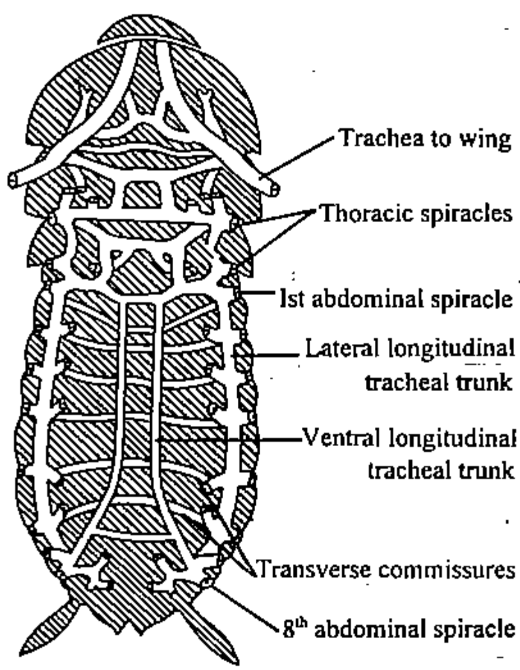



**Fig. 14.29: Tracheal system in insects (Dorsal view).**

While talking about respiration in aquatic insects it was mentioned that some insects live in water but breathe air. Let us now see how they do that. The tracheal system in such air-breathers is little altered and the spiracles are open. But these insects acquire various modifications to renew the supply of fresh air. The Odonata and mosquito larvae periodically come to the water surface to take in fresh one. In many water-bugs and water beetles there are tufts of water-proof (hydrofuge) hairs on different parts of the body. The air trapped among these hairs is used for breathing. In the water-beetle *Dytiscus* the air is enclosed between body and the forewings (elytra). The adults of water-bug Nepa or the larvae of *Eristalis* (Diptera) possess a long respiratory siphon (Fig. 14.30), which remains in contact with the air.

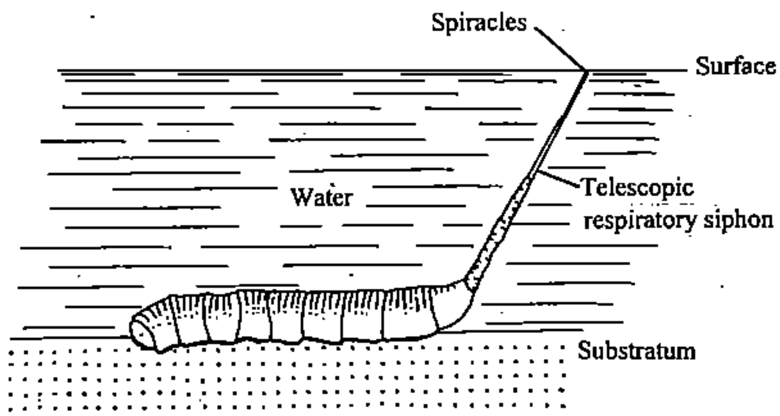



**Fig. 14.30: Respiratory siphon in *Eristalis* larva.**

## SAQ 6

i) On the basis of what you have read in subsection 14.3.2 supply the missing words in the following sentences.

   a) In scorpions the respiratory organs are ......................................, of which there are .......................................... pairs.
   b) Respiratory organs of *Limulus* are ..........................................
   c) In Crustacea three types of gills are found. These are .........................................., .......................................... and ..........................................
   d) Rectal gills are present in the aquatic larvae of ..........................................
   e) The adults of the water-bug, .......................................... has a long respiratory siphon.

### Modifications of Limbs

You may recall here what you have already studied under "Animal Diversity" on arthropod appendages. The appendages in Arthropoda have undergone three major functional modifications: (a) as sense organs, (b) as mouth parts, and (c) as locomotor organs. Out of these, maximum adaptive divergence is shown by the locomotor organs and mouth parts. Locomotor organs are modified in most of the arthropod groups. On the whole, primitive groups have more appendages. The locomotor appendages tend to become reduced in number as they become specialised and modified for various functions. This increases their maneuverability as well as speed. Two distinct lines of adaptations are recognised: aquatic and terrestrial. On the contrary, mouth parts show highest adaptive divergence only in insects, the details of which you have already studied in Unit 4, Block 1 of this course. Therefore, we will presently discuss the modifications of locomotor appendages only.

### Locomotion in Aquatic Arthropoda

The aquatic arthropods are mostly adapted for crawling or walking on the substratum and for swimming. The horse-shoe crab *Limulus* is a coastal dweller. Its locomotion is effected by walking on sand or mud bottoms. For this it has five pairs of walking legs. The fifth pair of walking legs is specially modified for removing the mud while burrowing. The distal lamellae of this pair spread and can push against the floor to prevent sinking in the loose mud.

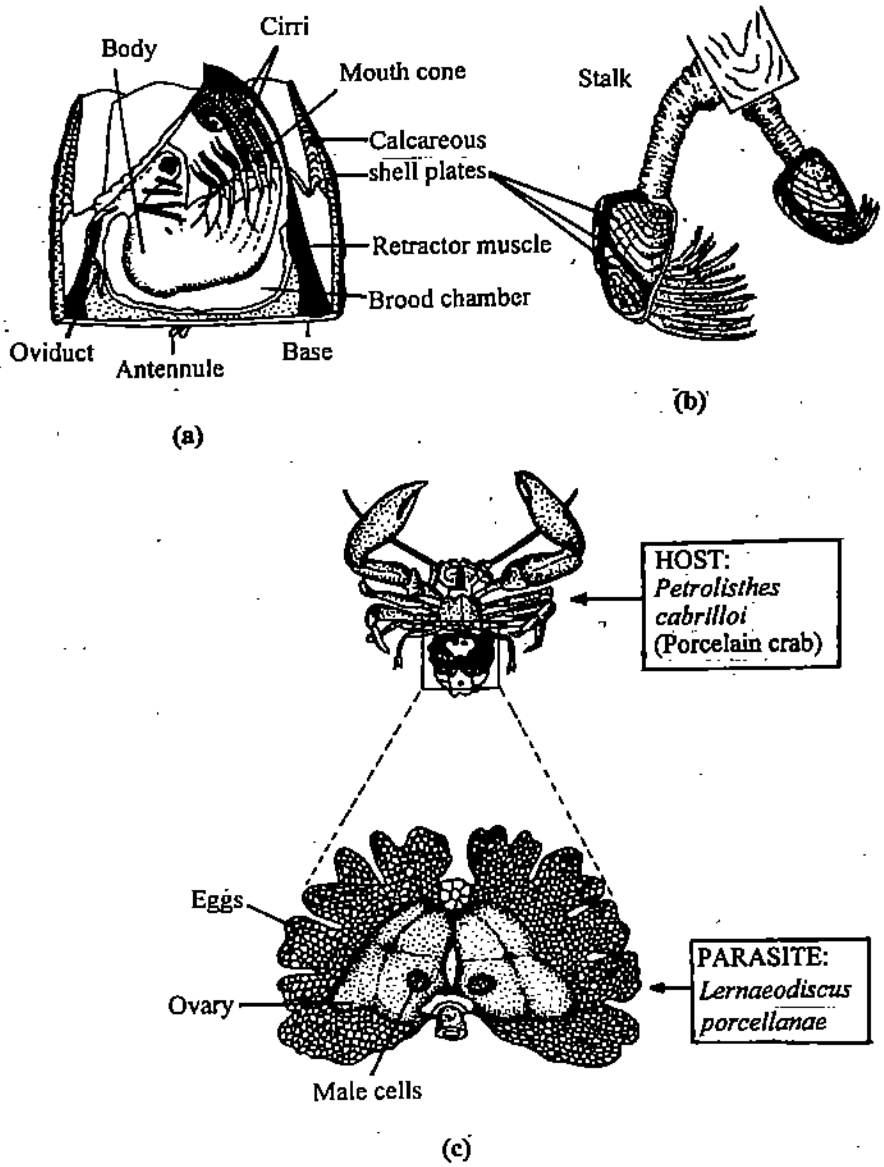



**Fig. 14.31: a) Balanus a sessile barnacle; b) Lepas, a stalked barnacle. Barnacles, the marine animals belong to order Thoracica of subclass Cirripedia, that are usually enclosed in a shell of calcareous plates. In these arthropods head is reduced, abdomen is absent and the thoracic legs are long and many jointed cirri with hair like setae c) *Lernaeodiscus porcellanae*, the rhizocephalan barnacle, parasitic on the porcelein crab.**

Most Crustacea, except the sessile and parasitic cirripedes (Fig. 14.31), are active swimmers. Their thoracic and abdominal appendages are adapted for swimming. These are oar-like and are usually provided with fringed setae which increase surface area of the swimming organs. In Branchiopoda (small fresh-water crustaceans) all appendages are adapted for swimming and respiration (Fig. 14.32).

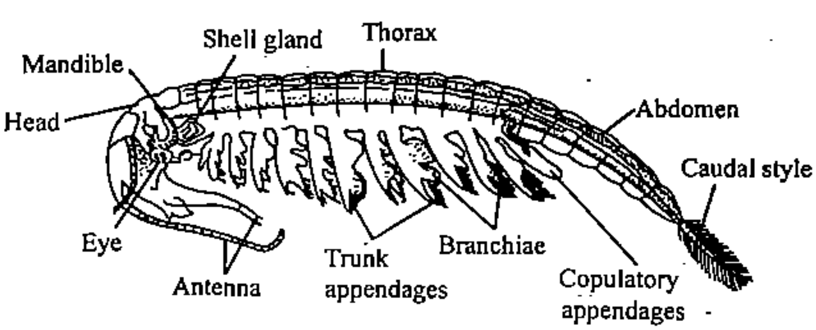



**Fig. 14.32: Branchiopoda: appendages used for swimming and respiration**

The water fleas swim by strong second antennae. The free living tiny copepods also use mainly their second antennae for swimming (Fig. 14.33 a). Most crustaceans have become crawlers, though they can also swim and burrow. Whereas many parasitic copepods (Fig. 14.33 b) have become highly modified for parasitic mode of life, the prawns, lobsters, crabs and many others possess well-formed swimming and walking appendages. The walking in prawns and lobsters is effected by five pairs of walking legs, which are the posterior thoracic appendages (Fig. 14.34 a). For swimming, these animals have six pairs of abdominal appendages, named **pleopods** and **uropod** (Fig. 14.34 b). The crabs have abandoned swimming and are adapted for walking. Consequently they have their abdomen shortended, abdominal appendages absent and five pairs of thoracic legs developed for walking.

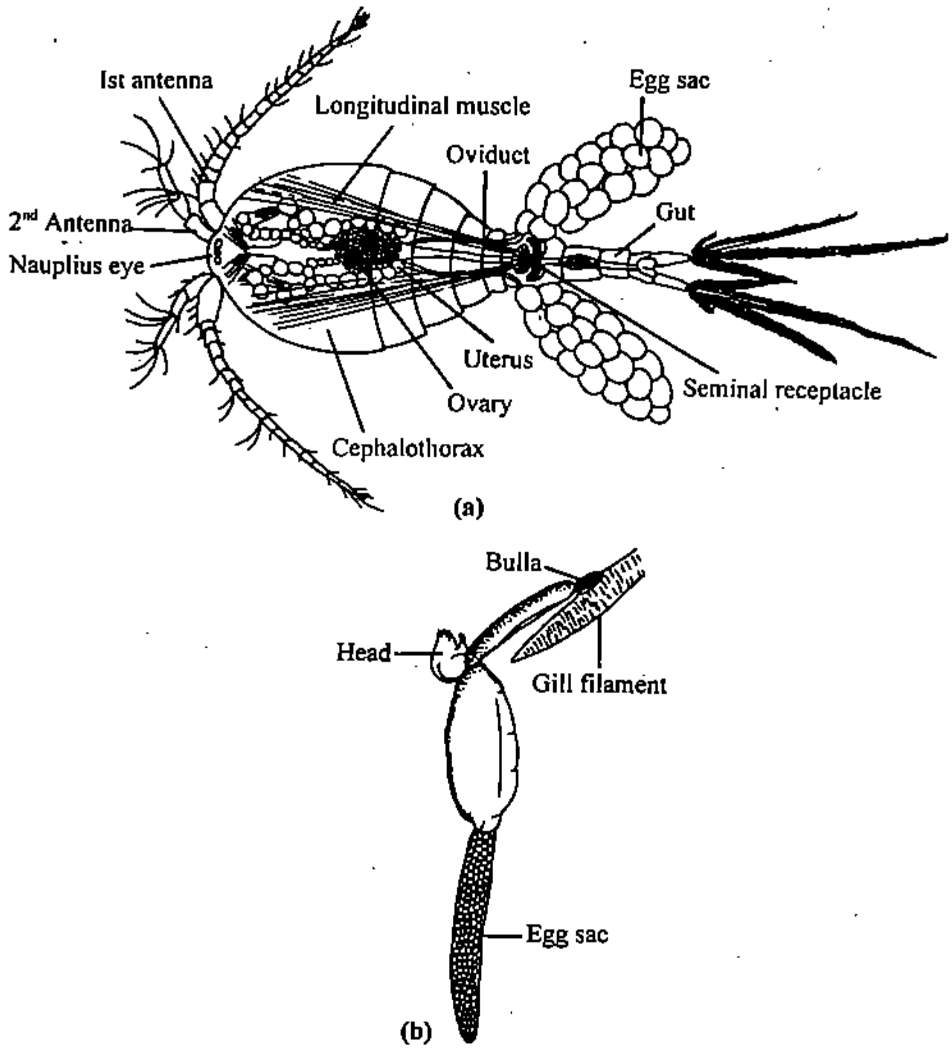



**Fig. 14.33: a) A copepod *Macrocyclops albidus*; b) *Salmincola salmonea* a parasitic cepepod. The mature female is attached to the gill of European salmon.**

Crustaceans have exploited all types of aquatic niches thus exhibiting high degree of adaptive radiations. They are the dominant arthropod group in marine environment and also share dominance of fresh water habitat with insects. Invasion of terrestrial environment is, however, much limited. The most diverse class is Malacostraca and the most abundant group is Copepoda. Both these groups include planktonic suspension feeders and numerous scavengers. Copepods also include parasites of both vertebrates and invertebrates. Cirripedes includes sessile and parasitic crustaceans. Parasitic copepods exhibit varying degree of modifications as compared to the free living ones. In most parasitic copepods the adults are parasitic exhibiting free swimming larval stages. Parasitic cirripedes also show modifications as compared to free living ones. Their body is saccular and the mantle is devoid of calcareous plates. There is also the absence of appendages and segmentation.

In aquatic insects swimming is effected by variously modified legs (Fig. 14.35 a). In many larval forms hairy bristles help in swimming e.g. rudder-bristles on the ninth abdominal segment of mosquito larvae (Fig. 14.35 b).

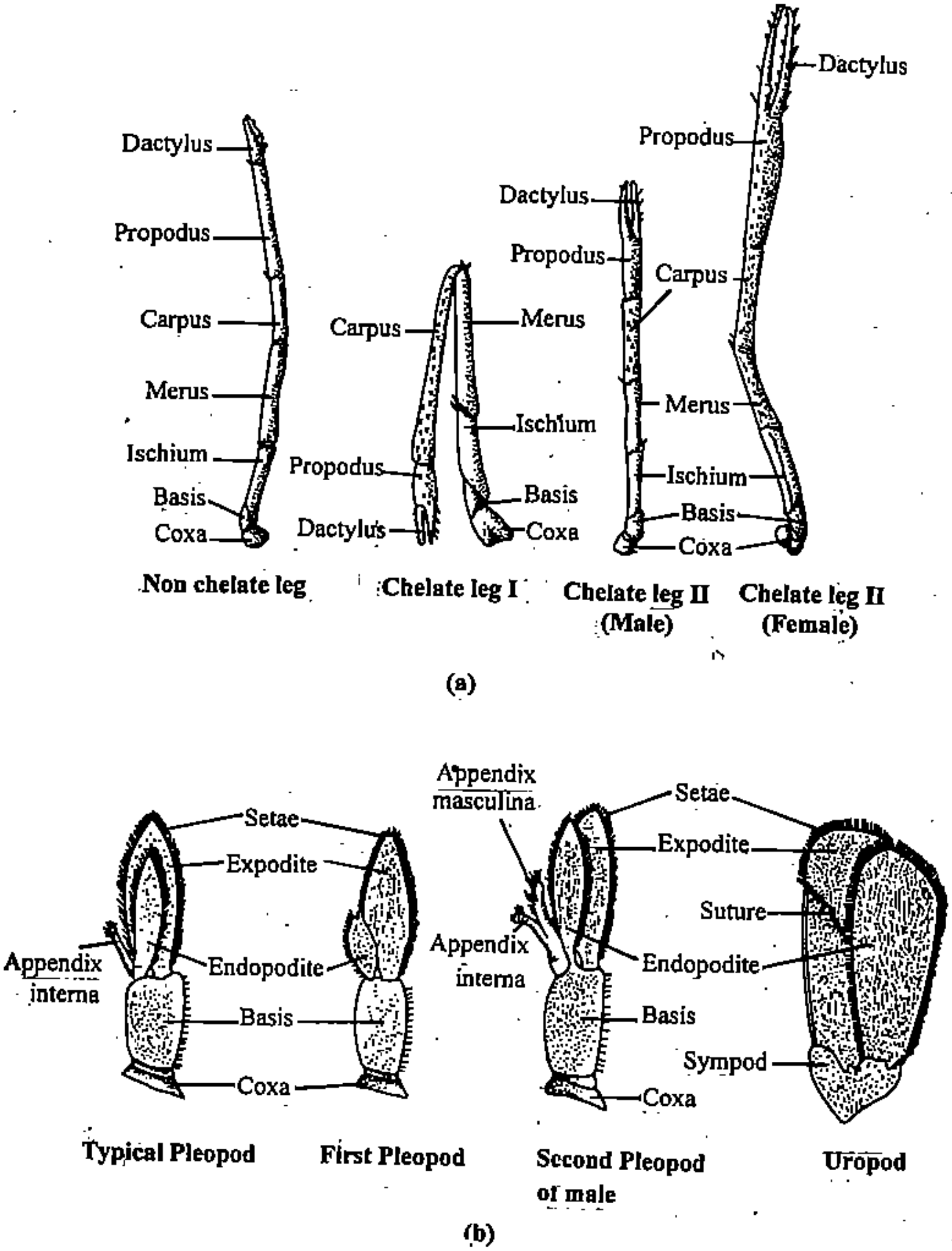



Fig. 14.34: Walking legs of prawn (a) Swimming appendages of prawn (b).

## Locomotion in Terrestrial Arthropoda

In most adult terrestrial arthropods well developed walking legs are present, which are adapted to the needs of their habitats. Their number and structure are variable. Scorpions possess four pairs of walking legs (Fig. 14.28 a) meant for running fast. In spiders also four pairs of walking legs are present and all of them are used in walking. These arthropods can move very rapidly for short periods.

Centipedes and millipedes are adapted for living in soil and among litter and in crevices among stones, logs and bark. Centipedes have one pair of legs per segment while in millipedes there are two pairs per diplosegment. Unlike other arthropods these legs are short and stumpy. They are adapted for crawling, swift walking and running. Millipedes can also effectively push into soil.

Adult insects, as a rule, possess three pairs of legs and are appropriately called **hexapoda**, i.e, *six-footed*. An insect leg is attached to the thoracic wall by means of a ring-shaped coxa. Besides coxa it has five more segments viz. **trochanter, femur, tibia, tarsus and pretarsus**, (Fig. 14.36). The tarsus may have three to five sub segments called **tarsomeres**. The insect legs not only serve the function of locomotion but also undertake other roles like jumping (hind-legs in grasshopper, Fig. 14.37 a), **swimming** (hind-legs in *Gyrinus*, Fig. 14.35 a), **digging** (fore-legs in mole-cricket, Fig. 14.37 b), **grasping** (fore-legs in praying- mantis, Fig. 14.37 c) and **grooming** (toilet-organ in the hind- legs of honey-bees, Fig. 14.37 d).

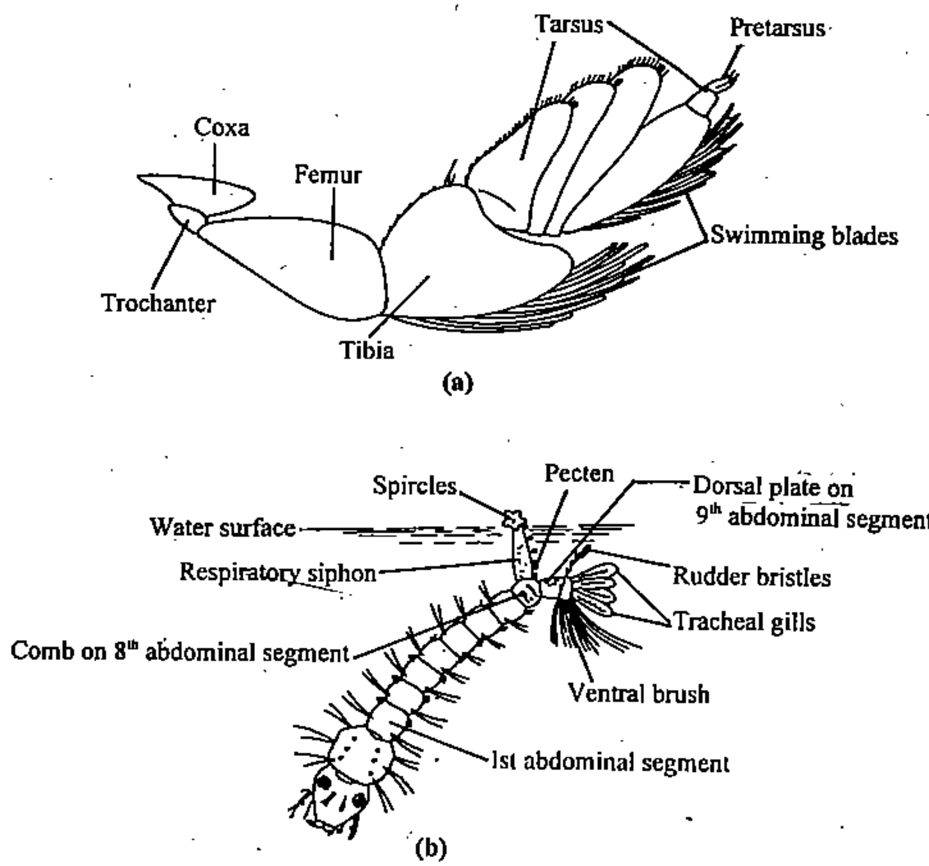



**Fig. 14.35: An insect leg adapted for swimming (a); Rudder- bristles of mosquito larva (b).**

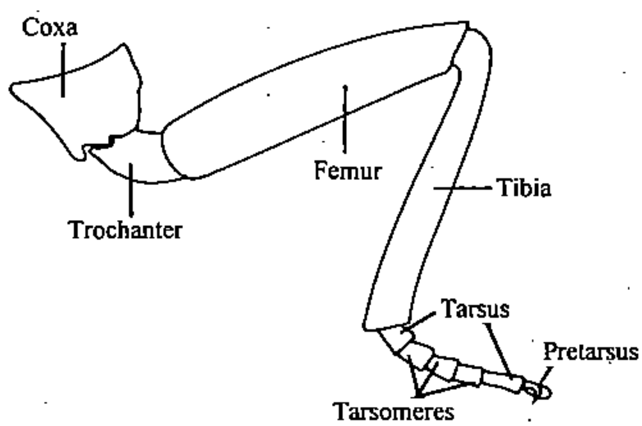



**Fig. 14.36: Insect leg adapted to different functions.**

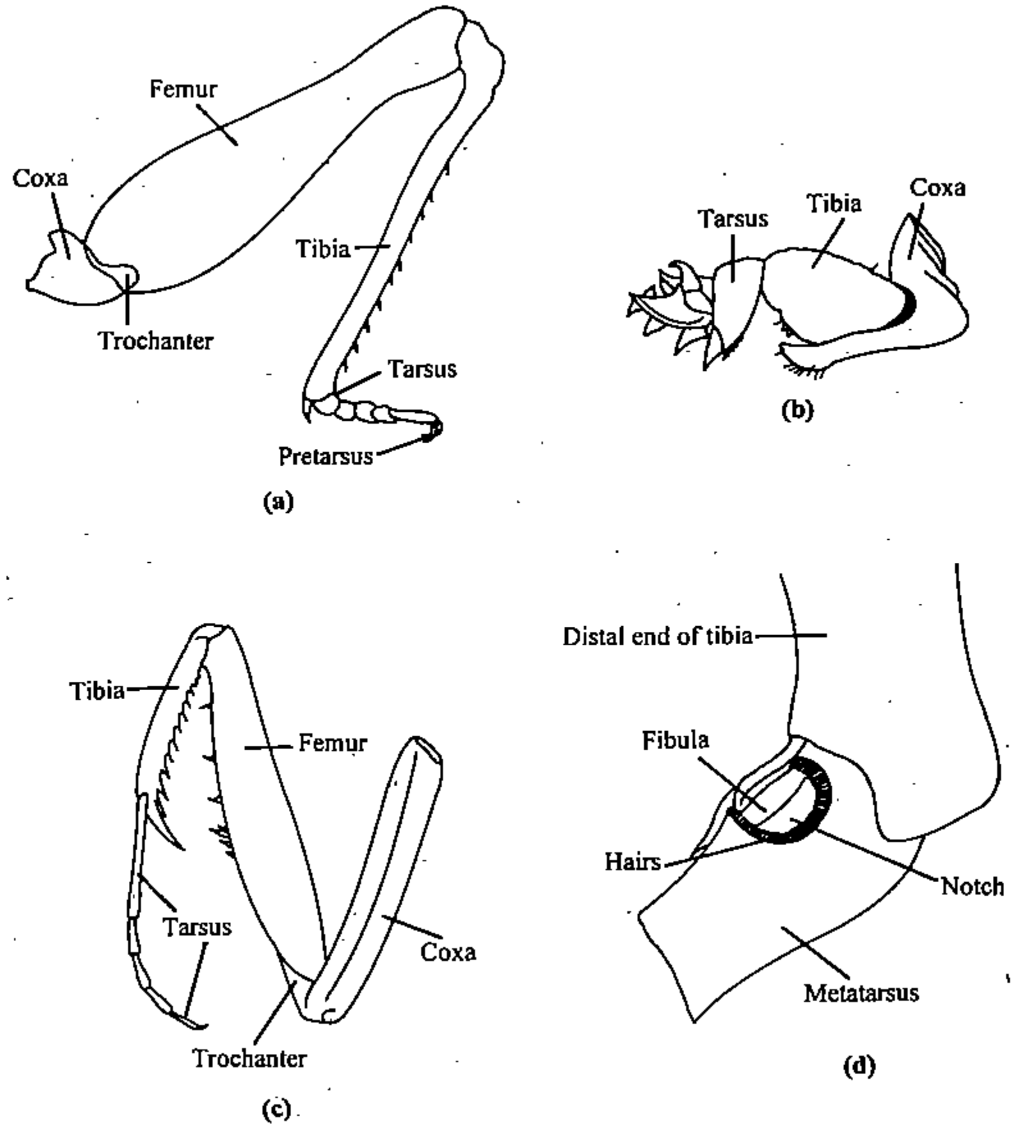



**Fig. 14.37: Insect legs adapted for a) jumping; b) digging; c) grasping; d) toilet organ of honey bee for grooming.**

**Insect Wings:** The outstanding success of insects as terrestrial animal is, to a great extent, on account of their ability to fly. For this purpose most of them usually bear two pairs of wings on their thoracic segments. We will discuss the wing structure and the mechanism of flight, in insects in section 14.4.

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## SAQ 7

i) Indicate whether the following statements are correct or incorrect.

a) Mouth parts in Arthropoda are modified segmental appendages.
b) In prawns and lobsters walking is effected by abdominal appendages.
c) In aquatic insects swimming is brought about by six pairs of abdominal appendages.
d) The hind-legs in grasshoppers are adapted for jumping.
e) In centipedes two pairs of legs are present in each segment.
f) Rudder-bristles in mosquito larvae are used for respiration.

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### 14.3.3 Adaptive Radiation in Mollusca

Presence of shell, mantle, radula and foot distinguishes mollusca from the other animal phyla. Present-day molluscans are represented by forms like *Neopilina* (Monoplacophora), chitons (Polyplacophora), *Dentalium* (Scaphopoda), snails and slugs (Gastropoda), mussels and oysters (Pelecypoda), and squids and octopuses (Cephalopoda). Respiration in aquatic forms takes place by means of gills and in terrestrial molluscs by lung. The adaptive modifications in Mollusca are chiefly reflected in the shell, foot and respiratory apparatus. You have already studied extensively the structure and types of molluscan shell in Unit 4 Block 1 and the various modifications of the foot in Unit 7, Block 11 of this course. You may recall those portions here. We will now discuss the structural modifications of respiratory mechanism in Mollusca in the following paragraphs.

**Respiration in Mollusca**

Molluscs are mostly marine. Some gastropods and pelecypods are found in fresh-water while the pulmonate gastropods occur on land. Aquatic molluscs employ gills or **ctenidia** (singular- ctenidium) for respiration. The terrestrial forms, on the other hand, breathe by means of the **pulmonary chamber**, usually referred to as the 'lung'. In some molluscs exchange of respiratory gases takes place through the general body surface. Thus we have branchial, pulmonary and cutaneous respiration in Mollusca.

**Branchial or ctenidial respiration** occurs in aquatic molluscs. Formed as an outgrowth of the bodywall the ctenidia are present in the **mantle cavity**. In all molluscan groups the basic structural plan of the ctenidium is the same. A gill has a horizontal **main axis**, which remains attached to the body. The axis possesses on one or both sides a row of **delicate, flexible respiratory lamellae** (singular-lamella) with their surface covered with ciliated epithelium (Fig. 14.38). When the lamellae are present on one side only, the gill is called **monopectinate** and if the lamellae are present on both sides, **bipectinate**. The ciliary movement drives a continous flow of water over the richly vascular gills, which receive deoxygenated blood through inlet veins or **afferent branchial** veins. The gills return oxygenated blood through outlet or **efferent branchial** veins. The direction of flow of water current over the gills is always opposite to the direction of blood-flow within the gills (Fig. 14.38 c). This countercurrent flow ensures maximum and efficient gas exchange.

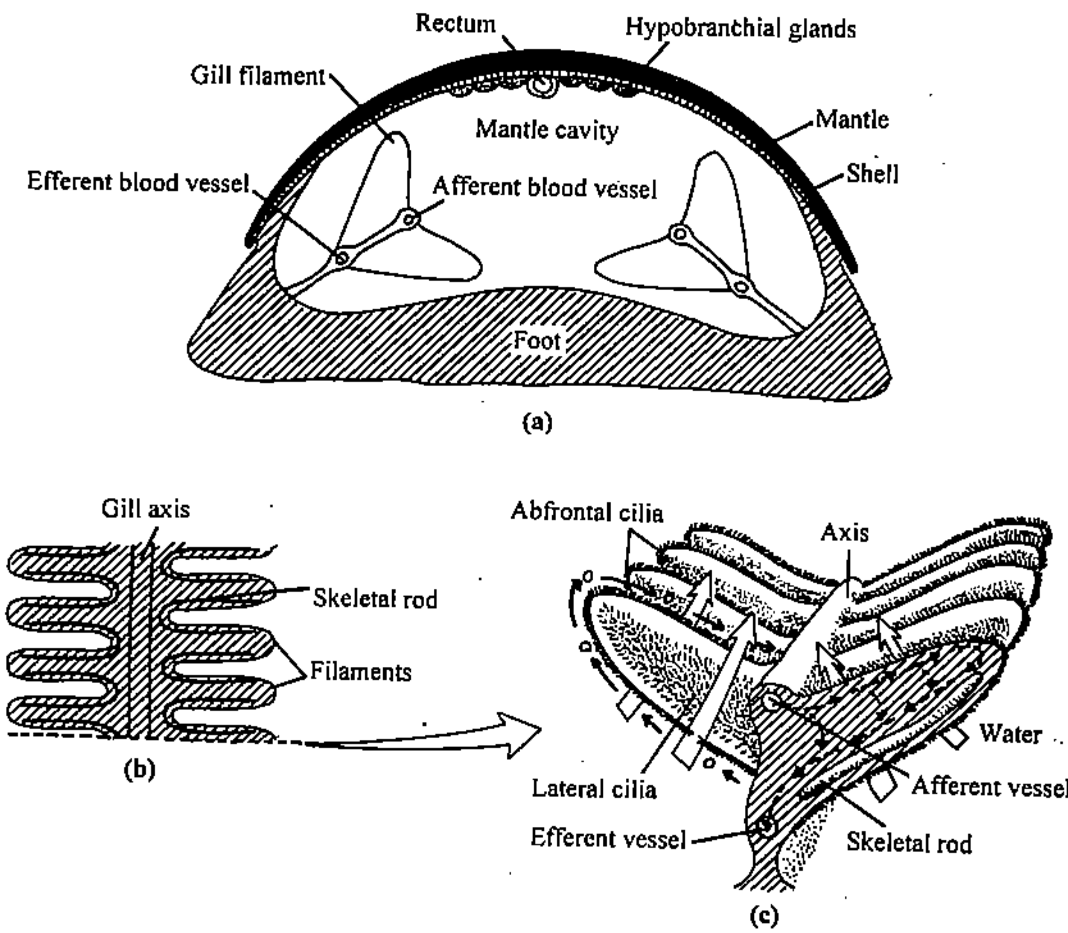
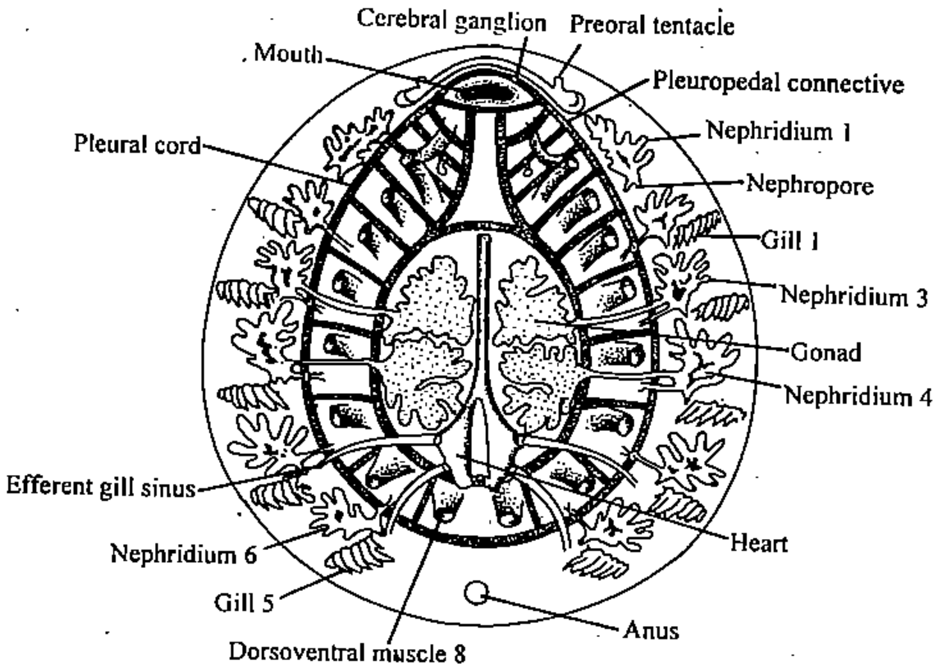
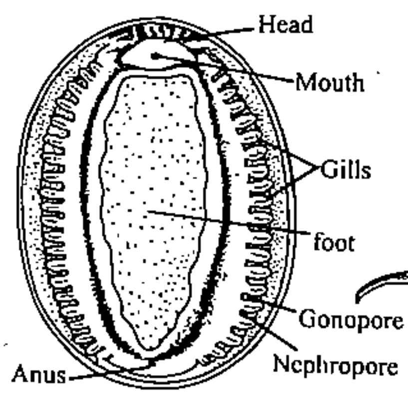



**Fig. 14.38: Transverse sections through the body of a mollusc at the level of mantle cavity a). Frontal section through the gill showing gill lamellae b). Transverse section through current and blood flow c). the gill lamellae showing directions of water current.**

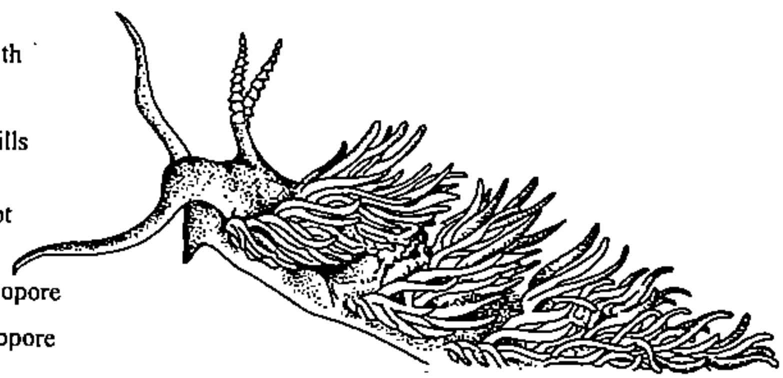
The **ctenidial arrangment** differs in different classes of Mollusca. In Pelecypoda the gills subserve not only respiration but help in feeding also. In Monoplacophora there are five pairs of monopectinate gills with finger-like lamellae (Fig. 14.39 a). The position of the gills in this class shows segmental nature of the Mollusca, which otherwise is not apparent in other classes. In Polyplacophora the chitons have six to eighty bipectinate gills arranged in a row within the two mantle cavities (Fig. 14.39 b). While in the Aplacophora (Solenogastres) the gills are reduced or absent.




(a)




(b)



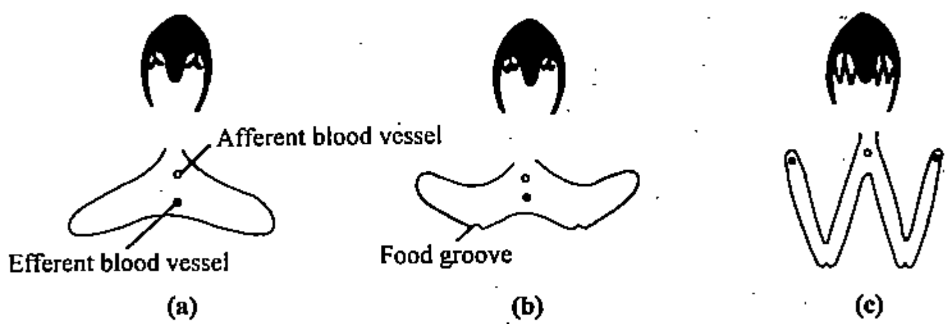
(c)

**Fig. 14.39: Molluscan gill - a) Monoplacophora (*Neopilina*); b) *Chiton*; c) Sea slug (*Aeolis*).**

Gastropoda has three subclasses : Prosobranchia, Opisthobranchia and Pulmonata. In Prosobranchia the gills are shifted in front along with the mantle cavity due to torsion and there may be one monopectinate gill (as in *Pila*) or two bipectinate gills (as in *Haliotis*). In **Opisthobranchia** the mantle cavity and the organs it contains shift to the right side due to detorsion (see earlier unit for torsion). Forms like **Aplysia** (sea-hare) possess one ctenidium on the right side while **Doris** and **Aeolis** (Nudibranchia) have altogether lost true gills. Instead, they have acquired secondary gills which are present either around the anus or on the lateral edge of the mantle or in rows on dorsal body surface (Fig. 14.39 c). In pulmonates, gills are absent. Mantle cavity is on the right side. This becomes a vascularised "lung" for air breathing.

**Pulmonary Respiration:** In terrestrial gastropods the mantle cavity is transformed into a **pulmonary chamber or lung**, the roof of which is richly supplied with blood vessels. The evolution of the pulmonary sac is a land adaptation. Alternate muscular contraction and relaxation of the mantle floor causes the air to enter in and pass out of the pulmonary sac through a small aperture guarded by a valve. The exchange of gases occurs through the mantle wall. In some forms the pulmonary sac may also help in aquatic respiration.

The gills in Pelecypoda have a complex structure. Besides breathing, they also help in collecting food and serve as a brood-pouch. There is one pair of bipectinate gills in the mantle cavity, one on either side of the body. These extend from the anterior to the postrior end of the animal. On either side of the axis in each gill, long filaments extend ventrally and then bend upward like a hairpin (there being two "hair pins" on each side) (Fig. 14.40). There is an ascending and a descending limb in each "hairpin". These filaments may hang freely or the adjacent ones may be joined by inter filamentar junctions forming a gill-plate or demibranch. There are two gill plates on each side, an outer and an inner one. Each gill-plate has two lamellae each made of an ascending and a descending limb. The outer and the inner lamellae are joined together by interlamellar junctions (Fig. 14.40). The gill-plates divide the mantle cavity into an upper **suprabranchial** and a lower **infrabranchial chamber.** The former opens to the exterior by excurrent (exhalant) or dorsal siphon which drains the water out. The infrabranchial chamber has an incurrent (inhalant) or ventral siphon through which the water enters the mantle cavity. The action of the cilia present on the gills maintains a continuous water current over their surface in the mantle cavity, where exchange of gases take place.



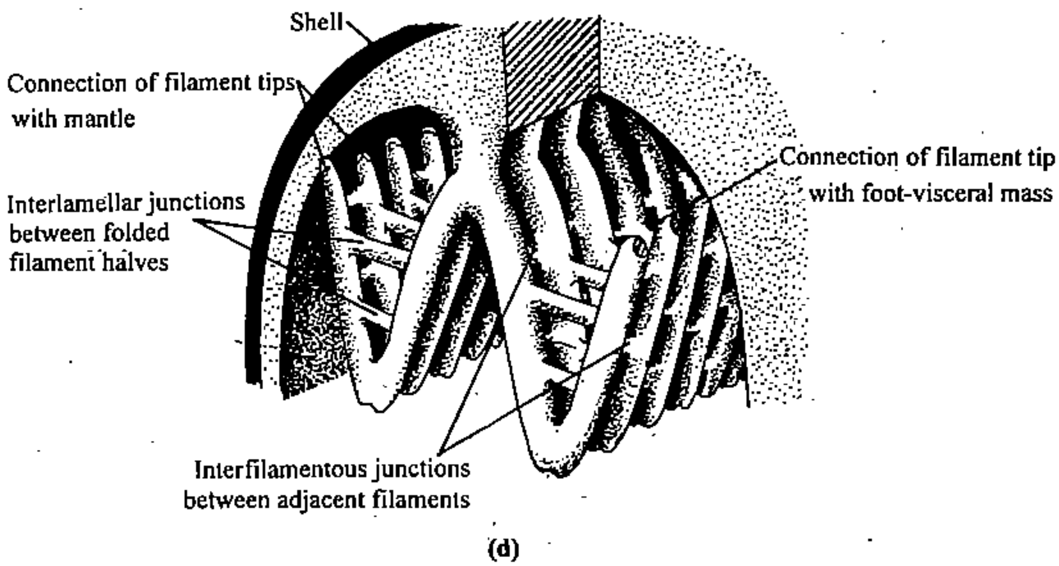




**Fig. 14.40: Evolution of Lamellibranch gills in Pelecypods. a) Primitive protobranch gill b) Food groove development to create lamellibranch condition. c) At food groove the filaments fold to form lamellibranchs conditions. d) Lamellibranch gills with tissue junctions providing support to the folded filaments.**

### Filter Feeding

Pelecypods are sedentary feeders and wait for the food to come their way. The constant inflow of water through the incurrent siphon into the mantle cavity brings in food particles which include micro-organisms and organic debris. When water enters the mantle cavity the heavier particles sink down and are expelled. The lighter food particles pass over the outer surface of the gill lamellae where they get entangled in mucus secreted by the gills. The mucus-mixed food particles pass into food grooves on the ventral edges of the gills, which take these towards the mouth. Near the mouth the labial palps further sort out the particles according to their nature. Smaller digestible particles are taken to the mouth while larger indigestible ones are thrown out of the mantle cavity.

**Cephalopods** have simple bipectinate gills situated on either side of the anus. The leaf-like lamellae are arranged in a linear row on the axis. There are no cilia on the gill surface and the flow of water is regulated by the muscular mantle, funnel and the inlet-valves. There are two gills in the cuttlefish, squids and octopuses and four in nautiloids.

**Cutaneous Respiration**

In Scaphopoda, Aplacophora and parasitic or terrestrial Opisthobranchia respiration occurs through the moist integument of the mantle cavity or through the general body surface. It is called cutaneous respiration.

## SAQ 8

i) Fill in the blanks in the following sentences using words given in the parenthesis below:

(deoxygenated, efferent branchial, ctenidia, afferent branchial, oxygenated, flow, drives, vascularised)

a) Formed as an outgrowth of the bodywall, the .................................. are present in the mantle cavity.

b) The ciliary movement drives a continuous flow of water over the richly .................................. gills, which receive .................................. blood through inlet veins or .................................. veins and return .................................. blood through outlet veins or .................................. veins.

ii) Indicate whether the following statements are true (T) or false (F).

a) In Pelecypoda gills also serve food capture.
b) There is one monopectinate gill in *Pila.*
c) *Aeolis* and *Doris* do not possess true gills.
d) The gill surface in Cephalopoda is ciliated.
e) Pulmonary chamber is found only in aquatic Mollusca.
f) In Opisthobranchia the gills are anteriorly placed.

## 14.4 FLIGHT IN INSECTS

Insects are unique among non-chordates to have evolved the ability to fly. For this purpose most adult insects possess one or two pairs of wings on their thoracic segments. The wings form an important basis of insect classification. There are chiefly two types of insects : winged and wingless. Wingless insects may be primarily wingless or secondarily wingless. In the former (primarily wingless insects) the wings have not evolved. The primarily wingless insects include silverfish and springtails. Secondarily wingless insects lost the wings during their evolution from winged insects. The ants, lice and fleas fall in the category which has secondarily lost wings. The dragonflies, butterflies, houseflies, mosquitoes, bugs, beetles etc. are winged insects. The wings of insects evolved as lateral outgrowths of the body.

**Structure of Wings**

The wing (Fig. 14.41) arises as dorso-lateral outgrowths of the bodywall on mesothorax and metathorax. It is a thin membrane and is supported by a system of tubular veins. The membrane actually consists of two layers of closely apposed integument. The veins are the heavily sclerotised regions where the two layers remain separate. The veins have branches of nerves and trachae. Blood circulates through the veins in the wing.

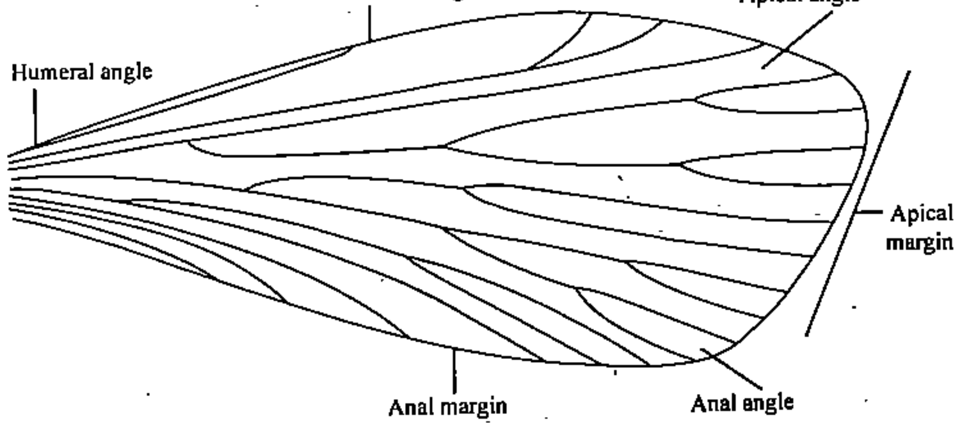



Fig. 14.41: Wing of an Insect.

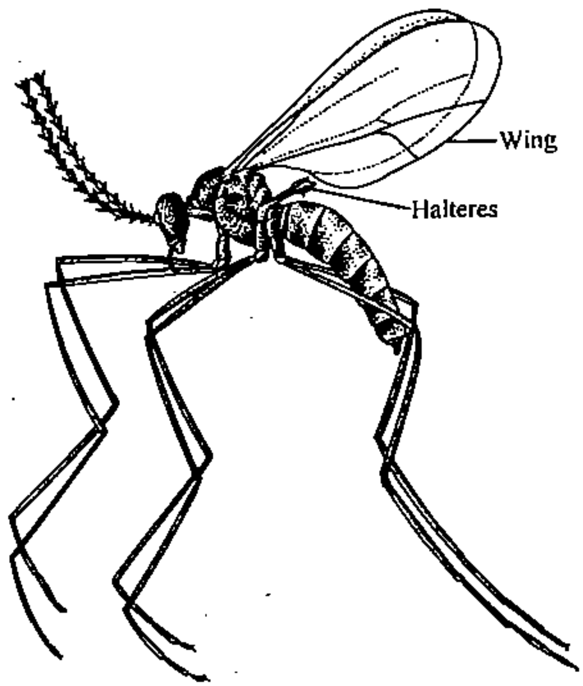



Fig. 14.42: A gall gnat showing wings and halteres. Halteres are responsible for equilibrium during the flight.

The forewings sometimes become hardened serving to protect the hindwings, as in the beetles. In the dipterans (eg. housefly and gnat) the hind wings have become modified into a sense organ called haltere (Fig. 14.42).

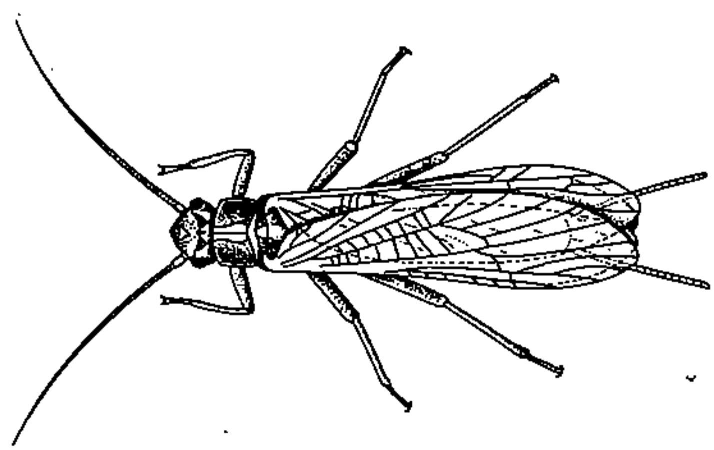


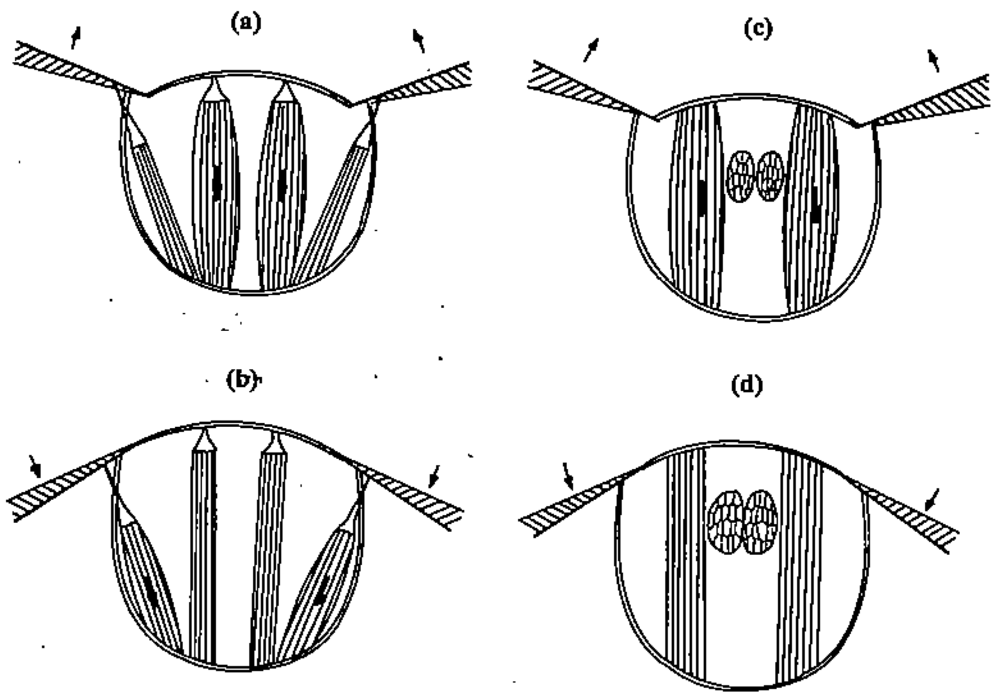
Fig. 14.43: Stonefly showing the wings folded at rest.

In most insects however the two wings on each side are membranous and can be folded at rest (Fig. 14.43). They are coupled to function as a single wing functionally. This increases their efficiency during flight.

**Wing movement**

Flight in insects is the result of co-ordinated wing beats. These movements are highly complex, involving various components like elevation (upward movement), depression (downward movement), and forward as well as backward movements. These wing movements are produced mainly by (1) muscles directly inserted into the wing base (direct flight muscles); (2) distortions of thorax brought about by muscles which are not directly associated with wings (indirect flight muscles) (Fig. 14.44 a-d); (3) elasticity of wing hinge. Once the muscles have moved the wings in a particular unstable position, the elasticity movements result in bringing the wings automatically into the stable position, with great force. This is known as "click" mechanism. Presence of a protein called "resilin" with considerable elastic property, in the hinge joints of insects, enables insects to bring about this "click" movement.

Insects thus fly with a wing beat frequency of 4-20/second as in butterflies or 190/second in honeybees and house flies. Some small dipterans may show a wing beat frequency of 1000/second.




Direct flight muscles of locusts and dragon flies — Indirect flight muscles of flies and midges

**Fig. 14.44: (a) and (b) Flight muscles of insects such as dragonflies and locust where upward stroke is by indirect muscles and downward stroke is by direct muscles. (c) and (d) Flight muscles of insects like bees where both upstroke and downstroke are by indirect muscles.**

## Flight

The wing movements are very complicated. The whole mechanism of flight may be described in simple words as follows : The various wing movements create a low air pressure zone above and a high pressure zone below the wings due to which the body of the insect lifts above in the air. Similarly the wing twisting creates an area of low air pressure ahead and high air pressure behind the insect. This provides a forward thrust to the body. Many insects can remain stationary during flight. In their case wing movements create only lift and no thrust. Steering during flight is effected by shifting the centre of gravity or by altered wing- beats.

**SAQ 9**

i) Mark the correct alternative in the following statements.

a) The insects in which wings have not evolved at all, are called primarily/ secondarily wingless insects.
b) Dragonflies are winged/wingless insects.

ii) Match the words in list I with those in list II.

| | List I | | List II |
|---|---|---|---|
| 1. | Silverfish | a. | Secondarily wingless |
| 2. | Ants | b. | Primarily wingless |
| 3. | Haltere | c. | Modified hind wings |
| 4. | Resilin | d. | Help the click movement |

## 14.5 MIGRATION IN INSECTS

In insects mainly two types of flight activity occurs. Trivial flight serves routine activities such as feeding and mating while during migration flight activity dominates. Migration is essentially dispersal. Whenever in a partciular habitat any environmental factor hinders feeding or breeding activity, the insects fly out to explore new pastures for food and reproduction. This is what we call migration. In the adult life of many insects there is a particular phase when this activity predominates. It is called the **migratory phase** and varies from a few hours as in many insects, to many days (as in some Coleoptera and Lepidoptera). In migration usually the animals move out from the feeding ground at the end of that activity in search of breeding ground and after breeding, they come back to the old habitat.

Since the main aim of migration is dispersal, females invariably participate in it, while males may or may not do so. In the locust, *Schistocerca* both sexes are included in migratory flights, but in the bug, *Eurygaster* males as well as females migrate from breeding to feeding grounds but only the females return to the breeding ground. In *Rhyacionia*, a lepidopteran, females are fertilized before they start migration to the breeding ground. The males do not migrate.

**Direction of Migration**

Direction of migration is mainly influenced by the wind-speed and direction of the wind. Wind speed increases as one moves higher in the air. The speed of insects in flight in relation to air is called air-speed. Wind-speed is comparatively lower closer to the ground. This forms what is called **boundary layer**. Air speed is greater than the wind speed at the boundary layer. However at higher levels, wind speed exceeds air speed. The insect can determine the direction and course of migration on its own in the boundary layer. For example, the moth *Ascia monuste* in Florida (US) flies 1 to 4 m above ground level. It can easily proceed against a wind current of 10 km/hour velocity. The direction of migration in this moth is determined by availability of flowers in the area. In other insects, factors responsible for determining the direction of migration may include position of the sun, landmarks such as roads, coastline etc. In the boundary layer the migration may be initiated by a number of factors but ultimately the position of the sun, pattern of the polarized light in the sky and the visual landmarks decide the migratory path.

Migration outside the boundary layer is seen in many insects. Sometimes those insects which usually migrate in the boundary layer, are seen flying above the boundry layer.

*Ascia monuste* has been reported flying at a height of 1500 m and above in Argentina. At higher altitude the insects fly in the direction of the wind current. Denser swarms of locusts at higher levels, in higher wind-speeds, fly in the direction of the wind. Aphids with a low air speed (0.6 m/second) find it difficult to fly against wind currents or to migrate within the boundary layer. They ascend up in the air due to positive phototactic reaction to ultra violet rays, and are then carried to long distances by wind currents. Many other insects such as dragonflies, beetles, butterflies and moths also move down-wind (in the direction of wind) at higher levels. Once the insects are carried to higher altitudes by higher wind currents (convection current) these carry the insects over long distance in a shorter duration. It is observed that swarms of locust *Schistocerca* cover a distance of 1200 km within 24 hours at 700 m above ground at a wind-speed of 45 km/hour.

**Return Migration**

Some insects show to and fro migratory movements. The monarch butterfly, *Danaus plexippus* in the United State migrates in autumn from the north where winter temperature becomes too low and food scarce, to the south where temperature is moderate and food supply plenty. In February these insects start return migration northward. This sentence is not fitting properly. Such two way migration by the same individuals is exhibited by *Agrotis infusa* (Lepidoptera) in Australia and *Hippodamia convergens* (Coleoptera) as well as a number of other insects.

**Locust Migration**

Locusts exhibit mass migration or swarms. The swarms of the desert locust, *Schistocerca gregaria* may cover an area of 10 to 250 square km. You may be surprised to know that a swarm spread over about 20 square km may contain about 100 crore individuals. The swarms may cover a distance of up to 100 km a day.

Locusts form two types of swarms viz. **stratiform** and **cumuliform**. In the former the locusts fly flat in the form of the thin layer within few meters above the ground and there may be 1 to 10 individuals per cubic meter. In cumuliform swarms locusts fly in a tower-like column extending up to 1000 m above the ground, with a low density of only 0.001 to 0.1 individual per cubic metre. The stratiform swarms are formed in the absence of convective currents to take them up while the cumuliform ones occur when there is convection current.

An interesting aspect of locust swarms is that all individuals in a swarm do not face forward. Their heads face in different directions. This is called **random orientation.** However, the locusts at the edge of the swarm face towards the body of other locusts. This helps to maintain the integrity of the swarm.

**Beginning and End of Migration**

Let us now examine the cause of migration. Migration is often initiated not by the actual onset of adverse environmental conditions. For example, in the monarch butterfly, the southward migration begins before the onset of cold conditions in the north, and locust swarms leave their habitats while plenty of food is still available. This shows that migration is an evolved adaptation in these cases and does not result from adverse environmental stimuli as such. Migration begins even before the onset of adverse conditions. This may be called **spontaneous migration**. On the contrary, in some cases migration may be stimulated by some physiological or behavioural phenomena which put the insect into a state of readiness to migrate. This type may be called **facultative migration**. Photoperiod, temperature and food supply are some such factors. Once the insects are kept in a state of readiness to migrate, the actual take off may be stimulated by another set of factors, like light of a particular intensity, wind speed, temperature etc. Similarly, it is not the physical exhaustion which brings migration to an end, but different wave-lengths of light being reflected by leaves (as in aphids), smell of salt-marshes (as in *Ascia*) and odour from host trees (as in beetle Melolontha) etc. may be responsible for the termination of migration.

**Significance of Migration**

Migration enables the species to cope with the changes in the location of its habitats. It is more common in those insects which occupy temporary habitats. For example, many species of Odonata, which live in permanent streams do not migrate whereas more than half of those living in temporary pools do so. The temporary nature of habitats may be due to changes in temperature, humidity, rainfall, etc. Migration is a way of over coming the adverse environmental conditions.

## SAQ 10

i) Indicate whether the following statements are true (T) or false (F).

a) Trivial flight serves feeding and mating.
b) In the locust *Schistocerca*, only males are included in migratory flights.
c) Boundary layer of the air is near the ground and within this layer the air-speed is greater than the wind-speed.
d) Monarch butterfly, *Danais plexippus* in the US migrates in winter from south to north.
e) At higher altitudes in the air the insects fly downwind i.e. in the direction of the wind.
f) Spontaneous migration is initiated by one or the other environmental factor.
g) Physical exhaustion of the insect brings migration to an end.
h) Migration is common in those insects which live in temporary habitats.

## 14.6 SUMMARY

In this unit you have learnt that:

- Animals which lead their lives as individuals are called solitary and those living in organised groups are known as colonial. True colonies in which individuals or zooids are organically connected by living matter, are present in protozoans and coelenterates. Polymorphism and division of labour are some of the important features of colonial life.
- If the animals of the same or closely related groups adapt for different modes of life, they are said to show adaptive radiation or adaptive divergence.
- The basic needs of animals viz. food and safety, lead to adaptive radiation. Among non-chordates Annelida, Arthropoda and Mollusca exhibit clear adaptive radiation.
- Adaptive radiation is chiefly reflected in method of feeding and exploitation of different habitats in Annelida, respiratory modifications and limb modifications in Arthropoda as well as modifications of shell, foot and respiratory apparatus in Mollusca.
- Wings are unique acquisitions of insects. Formed as dorso- lateral outgrowths of the body wall, these are moved by direct and indirect flight muscles as well as by elasticity of the thorax, of flight muslces and of wing hinge. They impart capability of flight to the insects.
- Two types of flight activity are shown by the insects. Trivial flight for routine activities like feeding mating etc., and migration for dispersal. Migration is common in many species of insects and may be either spontaneous or facultative.

## 14.7 TERMINAL QUESTIONS

1. Differentiate between adaptive convergence and adaptive divergence. Write the answer in two or three lines in your own words.

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2. Name three flagella-bearing Protozoa which form advanced colonies. Does any of these show polarity and if yes, explain why you think so.

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3. Define polymorphism. Why do you say that Siphonophora colony is polymorphic?

4. Mark the correct alternative in the following statements:

   a) The animals which would wait for the food to come their way, acquired radial/bilateral symmetry.
   b) Filter-feeding has evolved in sedentary/active food- seekers.
   c) Eversion of proboscis affects feeding in predatory/parasitic Polychaeta.
   d) Earthworms lack/possess antennae and palpi.
   e) One full meal by a leech may last for four hours/months.

5. Give two advantages and two disadvantages of the hard and tough body cover in Arthropoda.

6. Match the words in the List A with the most appropriate ones in the List B.

| | **List A** | | **List B** |
|---|---|---|---|
| 1. | Branchiae | a. | Dipteran larvae |
| 2. | Tracheae | b. | Stonefly larvae |
| 3. | Anal (tracheal) gills | c. | Insects |
| 4. | Blood-gills | d. | Crustacea |

7. Molluscans are believed to have evolved from annelidan ancestors, though they show no trace of segmentation. Give two grounds on the basis of which their ancestry may be linked with Annelida.

8. Indicate whether the following statements are correct or incorrect.

   a) Migration in insects is meant for feeding only.
   b) In a stratiform swarm locusts fly in a column at about 1000 m above ground.
   c) In random orientation all individuals in a locust swarm face forward.
   d) The course and direction of the insect migration is determined by the position of the sun alone.

## 14.8 ANSWERS

### Self Assessment Questions

1. i) (a) environment, adaptive convergence.
   (b) adaptive divergence.

   ii) (a) F, (b) T, (c) F, (d) F

2. i) (1) c, (2) a, (3) b, (4) d.
   ii) monopodial, sympodial, permanent.

3. i) Osborn, ii) Lamarck, iii) errant polychaetes, (iv) oceans

4. i) (a) F, (b) T, (c) F, (d) T.

ii) (a) food, (b) safety.

5. i) and ii) incorrect, iii) and iv) correct.

6. i) booklungs, four, ii) book-gills, iii) Phyllo-branch, trichobranch and dendrobranch, iv) Odonata, v) *Nepa*.

7. i) Correct, ii) and iii) incorrect, iv) Correct, v) and vi) incorrect.

8. i) (a) ctenidia, (c) vascularised, deoxygenated, afferent branchial, Oxygenated, efferent branchial.
   ii) (a) T, (b) T, (c) T, (d) F, (e) F, (f) F.

9. i) (a) primarily, (b) winged,
   ii) 1 - b; 2 - a; 3 - c; 4 - d

10. i) a) T, b) F, c) T, d) F, e) T, f) F, g) F, h) T.

## Terminal Questions

1. In adaptive convergence animals of unrelated groups adapt for the same habitat while in adaptive divergence those belonging to same or closely related groups adapt for different habitats.
2. *Volvox*, *Pleodorina* and *Pandorina* form advanced colonies among flagella-bearing protozoans. All of them show polarity because they swim always with a particular side facing forward.
3. Polymorphism is the occurrence of zooids or individuals in a colony in many forms, which exhibit division of labour. Siphonophora colony consists of gastrozooids for feeding, dactylozooids for protection, and three types of other zooids - gonozooids concerned with reproduction, nectophores for locomotion and gas-filled pneumatophores for floating.
4. Correct alternatives are : (a) radial, (b) sedentary, (c) predatory, (d) lack, (e) months.
5. **Advantages:**
   1) Provides support and protection,
   2) Prevents desiccation,

   **Disadvantages:**
   1) Hampers growth
   2) Hinders smooth gaseous exchange through general body surface.
6. (1) e, (2) d, (3) b, (4) a.
7. The two grounds are :
   1) A trochophore larval stage occurs in Polychaeta among Annelida as well as in Mollusca.
   2) The arrangement of paired gills in *Neopilina* (Monoplacophora) points to the segmental nature of Mollusca.
8. All statements are incorrect.

# UNIT 15 BEHAVIORAL PATTERNS

## Structure



## 15.1 INTRODUCTION

Behavioural patterns of animals are the patterns of their gestures and movements in response to stimuli in their environment. Behaviour patterns are purposeful and may be for procurement of food, finding mate, for locating convenient and sheltered site, or communication with animals belonging to the same species or to different species.

When an animal moves its body in response to a stimulus, the movements are termed **taxes and kineses**. Behavioural activities occurring with clock work precision at regular intervals are called **biorhythms**. Elaborate ritualistic behaviour patterns are associated with **courtship** and **mating**, communication with members of one's own species as well with other species. Certain groups of animals live in groups to form societies and exhibit **social behaviour**. They also possess special means of **communication** with members of their own species. Some communication signals are for self defence. In this Unit you shall learn about the various taxes and kineses, rhythms, social organisations, courtship and communication behaviour and the behaviour of parasites, with reference to non chordates.

### Objectives

After studying this Unit you shall be able to:

- distinguish between taxis, kinesis,
- explain endogenous and exogenous biological rhythms,
- describe different types of communication methods in non-chordates,
- illustrate how non-chordates attract their partners and mates,
- describe the caste system, division of labour and advantages of living in social groups,
- distinguish between different types of parasites, and
- discuss parasitic adaptations.

## 15.2 TAXIS AND KINESIS

Animals are characterised by great mobility. Stimuli from the environment direct these movements. These movements may be either taxis or kinesis.

### 15.2.1 Taxis

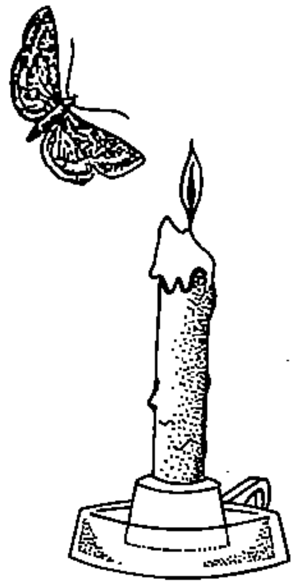

Fig. 15.1: A moth flying towards a source of light is an example of taxis.

Taxis (plu Taxes) is a directional movement, either toward or away from a source of stimulation. The animal is oriented along a line that runs through the source of stimulation and the long axis of the animal's body. Taxis is termed **positive** if the movement of the animal is towards the stimulus and **negative**, if away from it. Taxis is a behavioural response that cannot be modified by learning. A moth flying towards light (Fig. 15.1) is a classical example of taxis. So is the migration of an earthworm to the surface of soil after a heavy rain. [Taxes are easily demonstrable in animal - like protists such as *Amoeba* and *Paramecium* (Fig. 15.2).]

Taxes are classified according to the nature of stimulus. Table 15.1 shows the various types of taxes - thermotaxis, phototaxis, thigmotaxis, rheotaxis, galvanotaxis and geotaxis.

**Table 15.1: Different kinds of Taxes.**

| Nature of Stimulus | Name of Taxis | Type of taxis (positive + or negative –) | Examples |
|---|---|---|---|
| Temperature | Thermotaxis | + or – | Animals thrive in different ranges of temperature. Optimum range 20-25°C, cold blooded animals avoid temperatures above and below the range of temperature that they can tolerate. |
| Light | Phototaxis | + | *Hydra*, *Musca* (housefly), *Ranatra* (an aquatic insect) move towards light. |
| | | – | Earthworms, mosquitoes, cockroaches, woodlice move away from light. |
| Mechanical | Thigmotaxis | + | Contact with food causes positive taxis in most animals. |
| | | – | Contact with barriers brings about avoidance reaction. |
| Chemicals | Chemotaxis | + | Odour from chemical ingredients of food orient house flies towards it, also *Hydra*; |
| | | – | Mosquitoes avoid mosquito repellents Animals show negative response to injurious chemicals. |
| Water and wind currents | Rheotaxis | + | Moths and butterflies fly into wind current. |
| | | – | *Planaria*, the free living flatworm moves against water current. |
| Electric current | Galvanotaxis | + | *Hydra* reacts to weak currents of electricity, it bends towards the anode. |
| Gravity | Geotaxis | + | Cnidarian larva planula swims towards sea bed. |
| | | – | Ephyra larvae of jelly fish swim away from sea bed. Drosophilids (fruit fly) fly up against gravity to dry parts of a jar. |

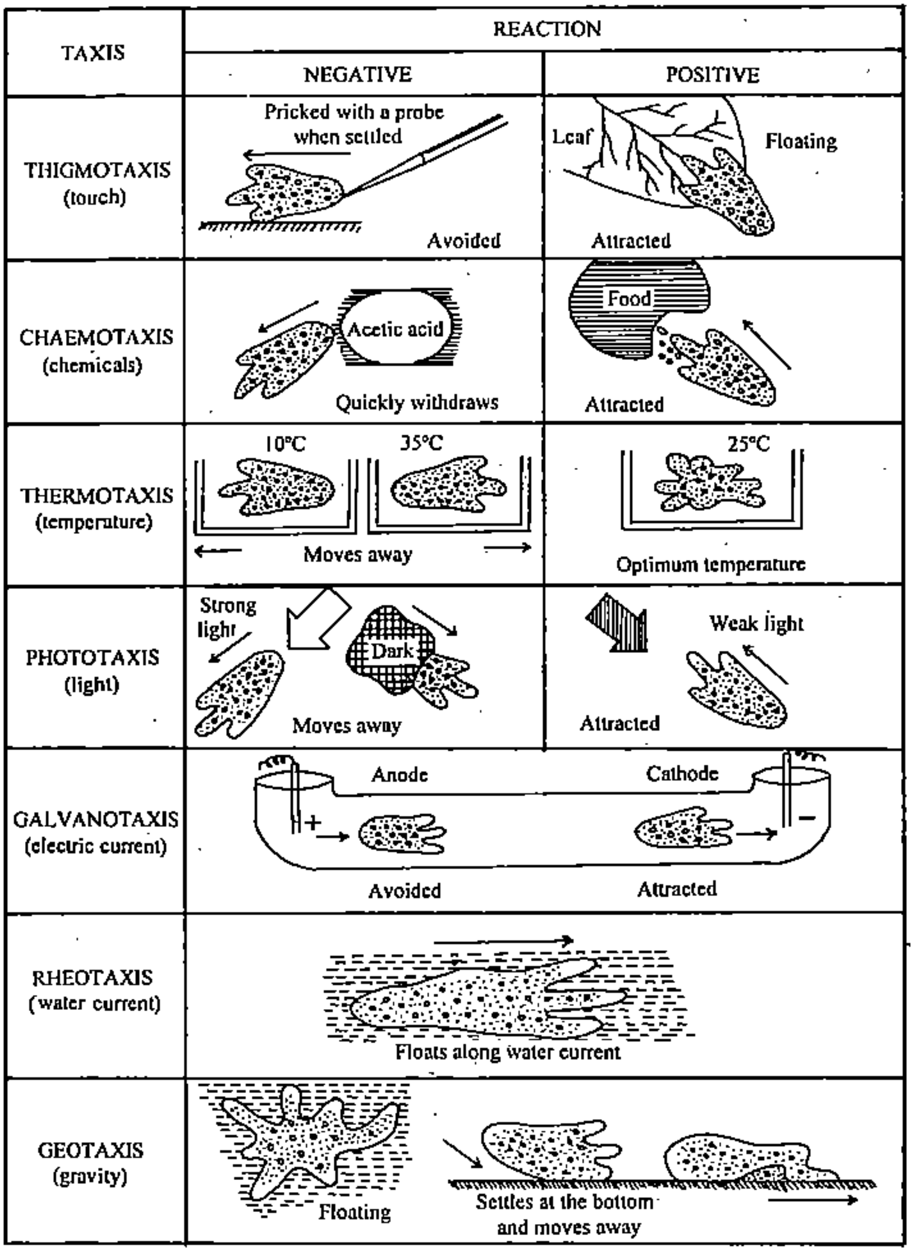


**Fig. 15.2: Reaction to various stimuli in *Amoeba*, arrows indicate the direction of movement.**

## 15.2.2 Kinesis

Kinesis is a **non-directional** movement. Here the animal's body is not oriented with respect to the source of stimulation, but the **rate of speed of movement** changes with the intensity of the stimulus. *Hydra* moves its tentacles at random in search of food but if food is kept close to tentacles, they are moved faster.

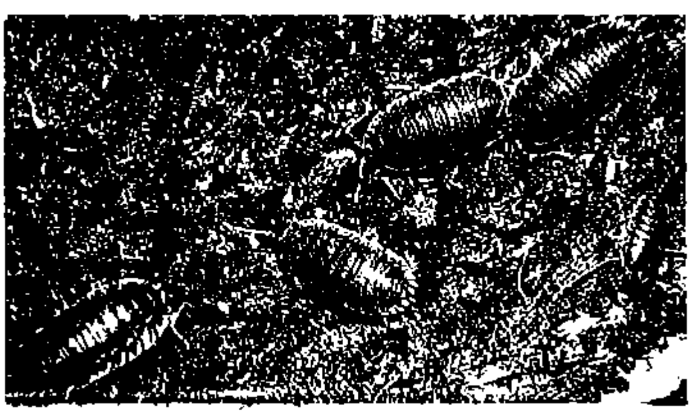

**Fig. 15.3: Kinesis in Woodlice.**

If the woodlice *Porcellio scaber* are given a choice between humid and dry areas, they tend to collect in humid areas gradually. This is due to their non-directional movement. In other words, they do not seek out humid areas, but movement is random. What happens here, is that their movement increases on dry areas but their movement decreases when they occupy humid areas. The random movement with speed is an attempt to find out optimal conditions. Once they reach humid areas, their speed slows down and they settle there (Fig. 15.3).

## SAQ 1

1. What is taxis?

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 ...........................................................................................

2. What is kinesis?

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 ...........................................................................................

3. What are the terms used for the following taxes
 (i) movement towards light.

 ...........................................................................................

 (ii) movement away from electric current.

 ...........................................................................................

 (iii) movement in response to gravity.

 ...........................................................................................

# 15.3 BIOLOGICAL RHYTHMS

Many behavioral activities are carried out by animals at regular intervals of time. Most animals are active during the day and rest at night (**diurnal** animals), while some animals such as cockroaches are active during the dark hours of the night and rest during the day (**nocturnal** animals). Similar behavioral activities occurring with cyclical regularity constitute **biorhythms**.

Some biological activities which show rhythmic oscillations are feeding, mating, egg laying, emergence from pupa (in case of insects) and migratory behaviour. The rhythmic activities are co-ordinated with the cycles of nature such as day and night cycles, annual seasons, lunar cycle of one moon-rise to the next. This kind of rhythmic activity is to avoid adverse environmental factors and to fully make use of favourable factors. For example, it will be beneficial for bees and other diurnal insects like butterflies, to be active during the day when the flowers they visit open so that they can collect nectar and pollen. Thus organisms have evolved their own rhythms which co-ordinate their activities with environmental rhythms. Daily rhythms such as feeding, drinking and sleep follow a cycle of approximately twenty four hours and are termed **circadian rhythms** (Latin circa: approximately; diem, day). Many littoral shore animals become active when the tide leaves them exposed. This is **tidal rhythm** eg. fiddler crab emerges from its burrow to feed at low tide. Certain intertidal snails release eggs at very high tides which occur once in two months. The palolo worm and some other polychaete annelids show **lunar rhythm**. They rise to the surface of the sea to spawn (lay eggs) during certain phases of the moon. Certain animals show courtship behaviour, mate and reproduce once a year (**circa annual rhythm**). Many animals migrate to and from breeding grounds twice a year. Many insects or their stages go into a state of dormancy or **diapause** during winter when the climate is not congenial. For example, eggs of the mosquito *Aedes*, larvae of flesh fly (*Sacrophaga*) and certain dragonfly nymphs show diapause in winter. Thus biorhythms are behavioural activities performed at regular intervals.

### 15.3.1 Control of Biorhythms

Certain activities require an external stimulus to maintain them at regular intervals. These rhythmic activities are termed **exogenous rhythms**. A major external factor regulating rhythmic activities is **photoperiod** or relative length of day (or light hours) and night (or dark hours). Temperature and humidity are other such factors which may control rhythms in animals. The palolo worm swarms and mates once a year, on the first day of the last lunar quarter of the year. Lunar cycle is the exogenous factor triggering this activity.

However an internal biological clock exists in almost all eukaryotes which can detect the passage of time even if the environmental cues are absent. Behavioral activities controlled by the biological clock within an organism are termed **endogenous rhythms**. Behaviour of many terrestrial insects appears to be controlled by endogenous rhythms related to photoperiods. *Drosophila* always emerge from pupae at dawn. Insects generally have an inbuilt biological clock. Circadian or diurnal rhythms are the most common of these biorhythms and they are controlled by endogenous biological clocks.

How would you distinguish whether the rhythm exhibited by an animal is exogenous or endogenous? For example, cockroaches are nocturnal, they begin their activity by the onset of night, and stop their activity before daybreak. Is this rhythm exogenous (i.e. controlled by outside darkness in this case) or by its own internal clock? An easy way to find it out, is to transfer cockroaches to continuous darkness or to continuous light. You will then see that irrespective of whether they are under conditions of constant dark or constant light conditions, they will exhibit a periodicity or rhythm of approximately 24 hrs. This indicates an endogenous rhythm, independent of external light/dark conditions.

## 15.3.2 Biological Clock

Biological clocks are internal mechanisms that provide a means of measuring time. These internal clocks are set to cyclic events in nature such as day and night, temperature changes during the seasons, high and low tides (in case of marine organisms) etc. Animals accordingly show feeding behaviour and other activities, sleep and rest or migrate (in case of migratory animals), controlled by the internal clock. A biological clock is therefore a necessity for most organisms.

**Entrainment and free running of biological clock**

Biological clock is autonomous and does not vary in its time keeping property. However, if the environmental cycle is changed as happens when animals travel long distances during migration or are transported for experimental purposes to a different continent, the internal clock sets into phase with the external clock prevailing in the new place. The biological clock is then said to be **entrained**. Entrainment is like setting a clock to correct time so that it does not give wrong signals at wrong times. In other words, entrainment is setting of the biological clock in phase with the environmental cycle. Once the biological clock is set, it continues to run on set time for a while even if environmental conditions are suddenly changed. As time passes, biological clock resets or entrains and gets into phase with the new set of environmental conditions.

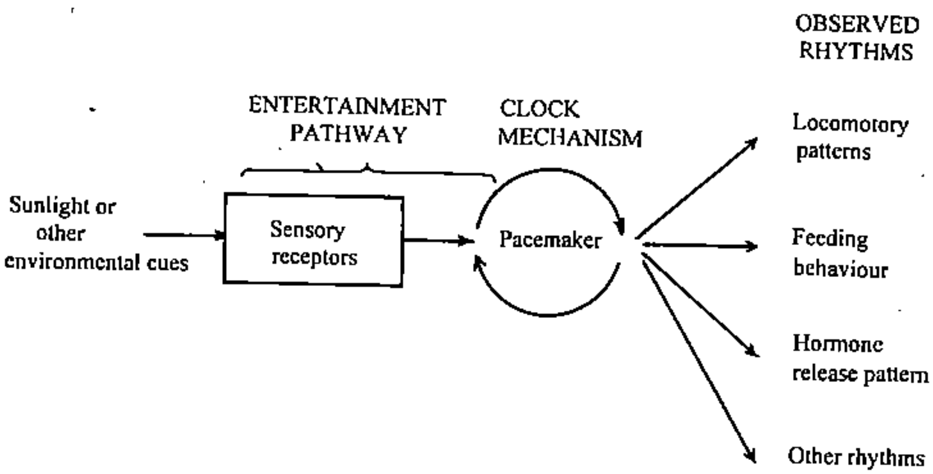


**Fig. 15.4: A master clock may, in some species, act as a pacemaker to regulate the many other clocks that control the circadian rhythm of the organism.**

If animals are isolated from environmental influences then the cycle does not stick to a 24 hour rhythm. For example cockroaches are nocturnal, but if they are kept in constant darkness their rhythmic activities continue but instead of an exact 24 hour cycle, they may exhibit a slightly different cycle of say 23.8 hour. This property of the cycle becoming slightly shorter or longer than the exact 24 hour schedule is referred to as **free running of the biological clock**. Free running period is the internal clock's repetitive cycle when an animal is isolated from environmental cycle and kept under constant conditions.

### Zeitgeber

The environmental stimulus which entrains a biological clock is called **Zeitgeber** (from German: Zeit - time; geber - giver). Light, temperature and tides are important Zeitgebers. Several environmental factors have been shown to act as Zeitgebers (Fig. 15.4).

### Where is the biological clock located?

Researchers have tried to locate the biological clock in the nervous system. But what generates the rhythms is as yet unknown. From some experiments on cockroaches and the fruit fly, it is believed that the rhythm originates in the optic lobes of the brain. Optic lobes, therefore, form the pacemaker of biological clock (Fig. 15.5) in these organisms.

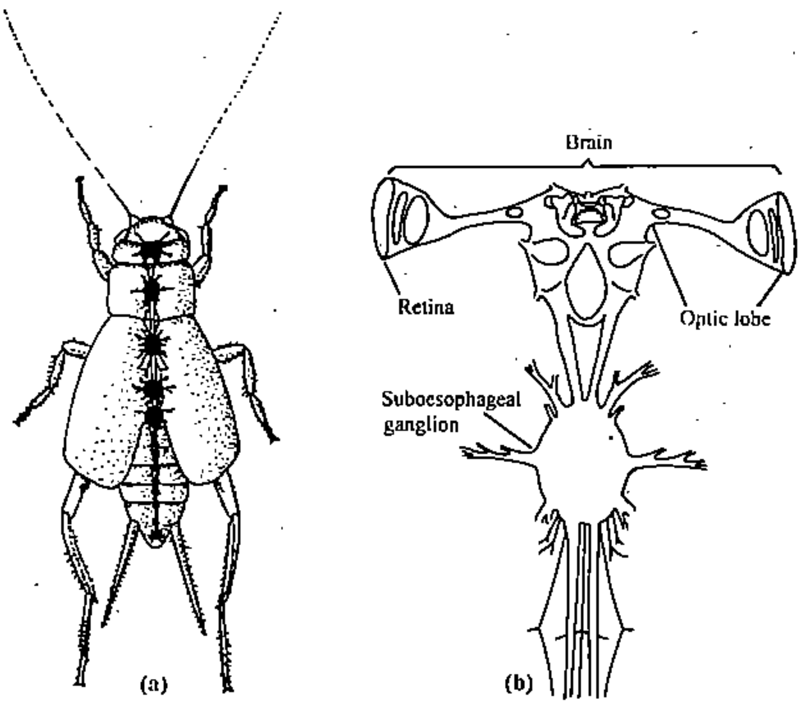


**Fig. 15.5: Nervous system in cricket. Visual information is relayed to the optic lobes of the brain. If the optic lobes are surgically disconnected from the rest of the brain, the cricket loses its ability to maintain its circadian rhythm.**

### Nature of biological clock

The nature of biological clock seems to be **biochemical.** This biochemical mechanism neither slows down in cold weather nor speeds up during warm days, inspite of the fact that in cold blooded or poikilothermic animals, biochemical activities double with each rise in 10° C. Internal clocks are little affected with changing temperature conditions. Thus biological clocks are said to be temperature compensated.

### Characteristics of the Biological Clock

1. Biorhythm or biological clock has repeating units called cycles of activity and rest, sleep and wakefulness etc.
2. Each cycle takes a particular time period.
3. It shows peaks and troughs a phase of peak activity followed by a phase of low activity.
4. Rhythms are said to be temperature compensated. That is, rhythm (or biological clock) keeps the same time irrespective of a rise or fall in temperature outside.
5. Metabolic inhibitors do not affect biological clocks or biorhythms.

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## SAQ 2

1 Define biorhythm.

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2. Match the terms in Column I with words or statements in Column II.

| Column I | Column II |
|---|---|
| i) Circadian rhythm | a. light hours |
| ii) Photoperiod | b. rhythm under constant darkness |
| iii) Zeitgeber | c. marine invertebrates. |
| iv) Lunar rhythm | d. environmental stimuli that set the biological clock. |
| v) Free running | e. 24 hour cycle of earth's rotation. |

3. What is the difference between exogenous and endogenous rhythm?

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4. What does entrainment of the biological clock mean?

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5. Which organ system, seems to control the biological clock?

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## 15.4 COMMUNICATION BEHAVIOUR

Animals need to interact with their conspecifics (members of the same species) as well as animals of other species. Interaction requires effective means of communication. Various means of communication among animals have thus evolved. Communication behaviour is highly developed in animals that exhibit social behaviour. Though there are many definitions for communication for our purposes the following definition of communication between two organisms can be acceptable.

**An action on part of one individual organism which alters the pattern of behaviour in another organism is known as biological communication.** The action is in the form of a signal from one animal to another and the sender of the signal usually benefits from the response of the receiver.

Human beings usually communicate through language made of words. Words can be rearranged in infinite ways to construct numerous messages. Language of animals, other than humans is in the form of **signals**. These mutually recognisable signals may be visual, auditory, tactile or chemical. Signals are exchanged between individuals and these influence the behaviour of each other. One signal may convey one or more messages.

### Types of Signals and Their Purposes

Signals for communication may be of four types.

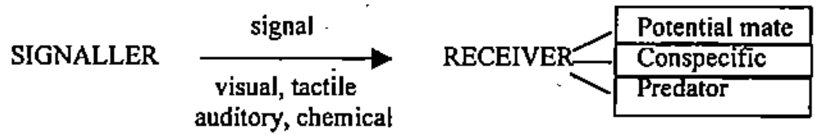
1. **Visual** - Which can be recognised by seeing.
2. **Mechanical** - Which are recognisable through the tactile sense.
3. **Auditory** - These are sound signals of various frequencies which convey different messages.
4. **Chemical** - Signals are due to secretions. The secretions include pheromones.

Signals are used to communicate various messages. The messages may be regarding

i) availability of food.
ii) need for defence from predators
iii) availability of mating partners.

An animal may utilise a channel of communication for more than one purpose. For example, many spiders respond to captured prey through web vibrations. Through web vibration they also communicate with prospective mates. Jumping spiders use visual signals to stalk and capture prey. They utilise these signals for courtship also. All signals of display are behaviour patterns established through evolution to become effective for communication. This is called **ritualisation.** Through ritualisation, simple movements or traits become more intense, conspicuous and precise and their original undifferentiated function acquires a signal value.

Communication behaviour often occurs in regular sequences. These sequences become stereotyped and then they are termed **fixed action patterns.** Most stereotyped signals are for courtship and territoriality.




Meaning of Signal
1. Sender ready to mate
2. Sender anxious, predator in sight.
3. Prey or food in vicinity
4. Predator beware, sender is harmful
5. Sender's territory, tresspassers flee

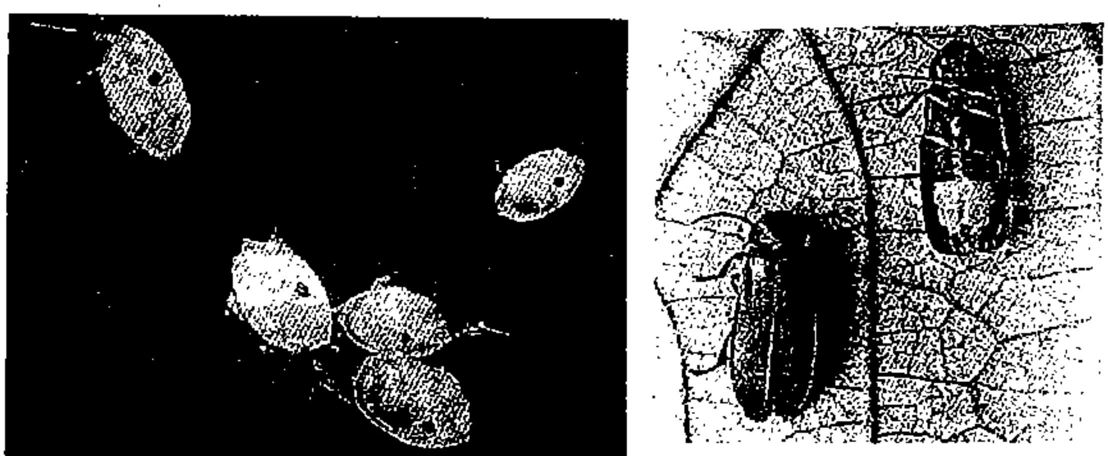
### 15.4.1 Visual Signals

The **posture of the body** and the **colour patterns of the animal** are the two major visual signals among invertebrates. In general molluscs and arthropods have well developed eyes. Their efficient eyes and well developed nervous systems are able to discriminate visual signals. Hence these animals communicate a lot through visual signals. Many of these animals can distinguish shapes and movements.
In nocturnal animals and deep sea inhabitants, communication by visual signals is limited to flashes of light or **bioluminiscence** (Fig. 15.6 A,B).

Visual signals are mainly used for

i. frightening the predator
ii. luring the prey and
iii. for attracting a mate

The advantage of visual signals is that if the receiver can see the signal, the sender can be located immediately. But visual signals cannot be used at night except for bioluminiscence. They cannot pass many physical barriers unlike auditory and chemical signals. Another great disadvantage is that the sender can easily be detected by its predator.



(a) (b)

**Fig. 15.6: Bioluminiscent invertebrates: a) *Cypridina* (crustacean), b) Firefly is actually a beetle. The white abdominal segments with photocyts are supplied oxygen by the abundant trachioles. The oxygen oxidises the luciferin +ATP in the presense of Mg ions and enzyme luiciferase.**

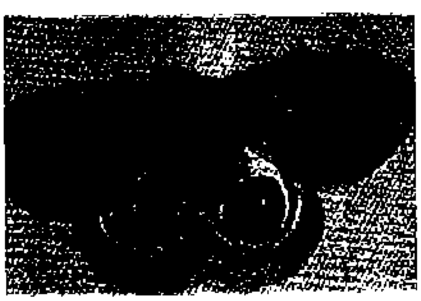


**Fig. 15.7: Moth with eyespots on wings.**

There are various examples of communication through visual signals among the invertebrates, which have been listed for your knowledge you may observe and add more examples to this list.

1. To startle the predator, some moths the eye like spots on the hind wings (Fig. 15.7).
2. The large coloured eye spots on the caterpillar of the swallow tail butterfly gives it the appearance of a snake head (Fig. 15.8) which scares the predator.
3. The ant *Crematogaster* adopts an alarm and defence posture by curving its abdomen upwards which warns and sends alarm signals to the predator, of its toxic sting (Fig. 15.9).

Fig. 15.8: Snake head caterpillar.

Fig. 15.9: *Crematogaster* adopts alarm and defence posture.

Fig. 15.10: Larva and adult monarch butterfly showing aposematic colouration warning predators of the presence of cardiac glucosides in their bodies.

4. The monarch butterfly *Danaus* and its caterpillar are brightly coloured. The bright colouration keeps predators away as they associate bright colours with the presence of toxic cardiac glycosides (Fig. 15.10).

5. The reef squid *Sepioteuthis sepioidea* manipulates its chromatophores to exhibit colour patterns which, along with the body posture and position of tentacles, alarms the predator.

6. The crustacean *Cypridina* (Fig. 15.6 a) comes to feed at night and releases bioluminescent substances (luciferin) into water. The bioluminescence attracts the prey.

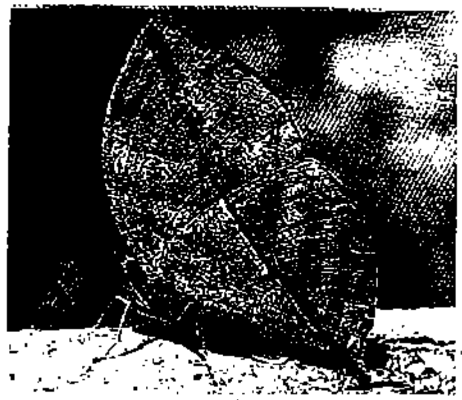
7. Female of the polychaete *Odontosyllis* emits green light continuously during their mating period. Circles of light attract male worms. They in turn respond by emitting intermittent flashes of light. Eggs and sperms are deposited in water, resulting in fertilisation.

8. The male and female fireflies of the genus *Photinus* (15.6b) have bioluminescent organs. They emit flashes of light. These serve as visual signals for mating.

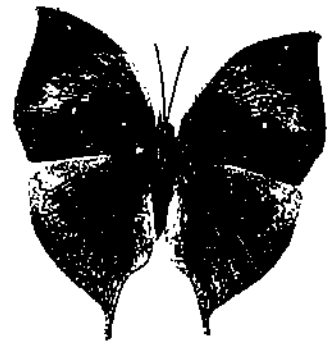
### Deceit in visual communication

Colouration and mimicry are antipredatory behavioural patterns. *Kallima* the dead leaf butterfly, which resembles (mimics) a dry leaf when it rests folding its wings (Fig. 15.11), is an example of mimicry for it mimics a leaf in this case.

The leaf insect, is green in colour and shaped like a leaf; the spotted leaf katydid resembles the leaves on which it feeds; the stick insect resembles the twig on which it rests (Fig. 15.12 a and b). There are many other examples of mimicry. These insects convey visually that they are inedible or inanimate. The deceiving visual signals protect these insects from the predator.



(a)



(b)

Fig. 15.11: a) *Kallima* looks like a dry leaf when it folds up its wings (1) Note the fine lines on its wings suggesting the veins of a leaf, b) a preserved specimen of *kallima* with its wings open.

(a)

(b)

Fig. 15.12: a) The spotted leaf katydid is exactly like the leaf on which it rests, b) Stick insect can hardly be noticed. Note the spines on the body of the insect that resemble the spines on the plant on which it rests.

Some bioluminescent fireflies even deceive the prey (species of fireflies belonging to another genus) through visual signals. For example, the predatory female of the firefly *Photuris* answers the courtship flashes of light given by the males of the firefly *Photinus* species. If the *Photuris* female succeeds in attracting male of the species, she grabs him, kills and eats him.

## 15.4.2 Mechanical Signals

Mechanical signals of communication include the tactile signals in which communication is through touch and auditory or acoustic signals in which sound is generated through movement of wings or special stridulatory organs.

A good example of tactile signal is the food begging behaviour of the larvae of the *Formica* ant. When touched by an adult worker ant's mouthparts or antennae, the larva tries to make contact with the head and mouthparts of the worker by tapping its mouth parts with the mandible of the worker as though begging for food. The worker, immediately regurgitates a food droplet and offers it to the larva. When an adult *Formica* ant taps another worker with its antennae, the signal is to stop moving about.

Auditory Signals from the sender reach the receiver through airborne sound waves. Special sound producing organs and organs of hearing are common among insects. Sound signals are efficient means of advertising the presence of the signaller. They may thus be used as (i) courtship songs; warning devices, advertising territorial claims. Sound can pass round corners and a great deal of information can be sent by modifying frequencies of sound produced. The disadvantage of sound signals is that they can easily be exploited by predators. For example the male cricket sings to lure the female into his burrow. But the predator receives the sound of his song, locates and preys upon the cricket.

Among invertebrates, insects as a class have very effective sound communication system. Everyone is familiar with the buzz of the bee, chirps of crickets, loud noise of cicadas, and buzzing of mosquitoes at night. In insects sound is usually generated by frictional methods, rubbing specialised surfaces of two parts of the body, like thorax, abdomen, wings and legs. This is called stridulation. Sound reception is by hair like mechanoreceptors distributed in connection with the tympanal organs.

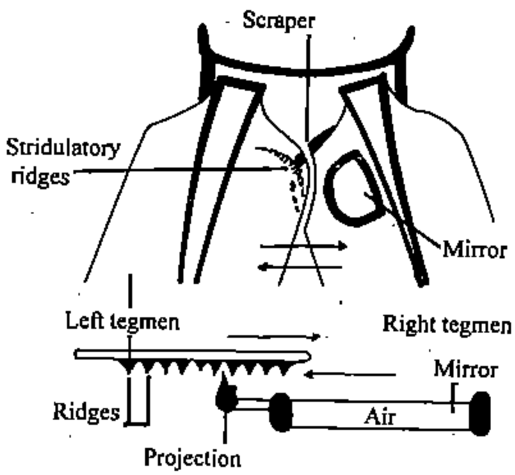



Fig. 15.13: Stridulatory organs of cricket.

Courtship singing is a daily programme with male crickets and begins in the evening. Wings are moved so that a ridge on the edge of one elytrn (forewing) forming the "scraper" moves across the toothed files on the underside of the other elytron (forewing) like a bow across the strings of a violin creating various patterns of sound (Fig. 15.13). Song patterns are specific for a species as also specific in their meaning. The commonest song is the calling song to beckon and guide the sexually receptive females into their burrows. Once the couple meet, a **courtship** song ensues. After mating, the male sings a **triumphal** song.

The courtship movements and songs of *Drosophila* are likewise, characteristic. The male touches the female and extends its wings. It then moves the body and makes a characteristic sound which the female of the same species alone can recognise by its antennae. If the female is not ready for mating, it generates a buzz with its wings and the male turns away.

## 15.4.3 Chemical Signals

Certain chemical compounds are secreted by animals which act as signals for olfaction (smell). These serve to communicate with other members of the same species or with other species. Chemical signals serve a variety of purposes. Some of these, especially in moths, act as sex attractants. In social insects, chemical signalling is very well developed and is used for various purposes.

Chemical signals diffuse through the environment and the speed and direction by which the scent of chemicals disperses depends on the wind. But the advantage lies in the fact that a small moth may not be seen or heard at long distance. But the species specific scent of the chemical molecule can be detected by the mate several kilometers away. Chemical signals are persistent and continue to signal even when the sender moves away. They are effective even in the dark, can pass round obstacles and disperse over great distances. Such chemicals released as signals for commmunication are called **pheromones**.

Pheromones are chemicals which are released by one organism and produce a response in conspicifics (members of the same species). Pheromone communication has been discovered in unicellular organisms as well as in nearly all animal groups. Many kinds of chemicals act as pheromones and many types of signals can be conveyed by pheromones. Pheromones generally act as **releasers**, (signalling pheromones) stimulating the recipient to show a very specific but transitory type of behaviour. Sex phenomenes of insects generally belong to this category. Some pheromones act as **primers** and evoke slower but longer lasting physiological responses from the receiver. An example is the chemical in the "queen substance" that inhibits ovary development in the worker honey bees.

**Communication in social insects by pheromones.**

Trail marking pheromones are used by some insects to find mates, communicate information on the location and quantity of food and to ensure that migrating groups retain their integrity. Amongst social insects, for example in ants, trail marking pheromones are deposited on the ground as foraging workers return to recruit other workers to a food source (see Fig. 15.23). Most trails fade away soon unless reinforced continuously. The chemical nature of relatively few trail marking pheromones is known. In termites and some ants they appear to be long chain acids, alcohols, aldehydes or hydrocarbons.

Pheromones also help in recognition of members of the social group in insects. Alarm pheromones warn members of a species about foreign intruders. If termites from another nest enter a colony of termites, soldier members release an alarm pheromone which attracts other soldier termites who chase away foreigners.

The nature of alarm pheromones is varied but specific for each group. In honeybees, the pheromone is released from the stingshaft that is buried inside the invader. This attracts other bees to attack.

In a honey bee colony, the queen secretes the "queen substance", by the mandibular glands. It has two components oxydecanoic acid and 9 - hydroxy decanoic acid, which act synergistically on the gonad development within the workers and their construction of special cells in which larvae would develop as queens. These primer pheromones inhibit the workers from raising a new queen and also inhibit the development of ovaries in workers.

**Sex attractants or sex pheromones in moths**

Virgin female silk moths have special pheromone glands whose secretions act as chemical sex attractants. Males "smell" these chemicals with their large bushy antennae with numerous sensory hairs functioning as olfactory receptors. These receptors are highly sensitive to Bombykol, the pheromone produced by the female silk moth. The female rests at a place and releases her pheromone, a little bombykol, which travels downwind and reaches the male antennae. Immediately the male gets stimulated and flies upwind to find the female. He moves randomly till he is close to the female flying towards her by the smell of bombykol, finds her and mates with her. This is clearly then a releaser pheromone.

In the gypsy moth, a similar releaser pheromone, gyplure is involved in bringing the two sexes together.

### 15.4.4 Communication Among Honey Bees – The Dance Language

The Austrian ethologist Karl von Frisch received Nobel prize for his research on communication in honey bees.

The honey bee, *Apis* exhibits social behaviour. Worker bees collect enormous quantity of pollen and nectar to feed the the colony mates. This is accomplished through co-operative effort whereby the worker bee who discovers a rich source of pollen and nectar, comes back to the hive and communicates the information regarding the source through specific dancing patterns, to the other workers. For instance, when a forager bee finds a garden of flowers fairly close to the hive, say within a distance of 50 meters, it performs the **round** dance (Fig. 15.14 a) at the hive. In the round dance, the bee turns in alternate circles to the left and right. The bee penetrates the hive and runs in a circular fashion excitedly. Other workers follow this worker bee. The dancing bee ultimately regurgitates the nectar. From the taste and the scent picked up from the dancing bee, other worker bees locate the food source.

If the food source is beyond 50 meters from the hive, the bee performs the **waggle dance**. This is a modified round dance, which incorporates in it a straight run. During the straight run, the worker waggles (moves) its abdomen from side to side. Greater the distance to the foraging site, longer is the straight run component in the waggle dance (Fig. 15.14 b). The waggle dance thus indicates the distance and direction of a nectar source.

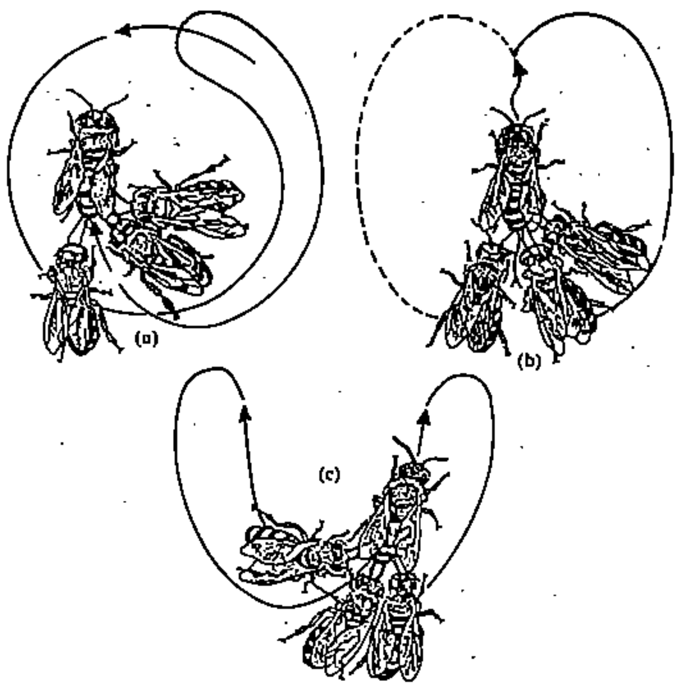



**Fig. 15.14: Honey bee workers dance in different patterns to communicate the distance of the food from the hive to the workers.**

**Sickle Dance** is also another modification of the round dance, and is performed by the Italian bee. She moves to make a flattened figure of eight, when the source is at intermediate distance from the hive. The opening of the sickle faces the source of food (Fig. 15.14 c). A dancer is always followed by her hivemates.

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## SAQ 3

1. Define biological communication.

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2. What is ritualisation?

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3. What do 'fixed action patterns' mean?

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4. Name any two purposes for which
   a) visual signals are used.
   b) auditory signals are used.

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5. What is stridulation?

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6. Which head appendage of the insect generally has sex pheromone receptors.

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7. What is the significance of (a) round dance (b) waggle dance in honey bees.

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## 15.5 COURTSHIP BEHAVIOUR

Specialised behavioural patterns of animals for attracting the opposite sex for reproductive purposes is termed **courtship behaviour**. These behavioural patterns may be in the form of display of bright colouration or accessory morphological structures, or in the form of offering nuptial gifts, or making specific gestures in front of the opposite sex. Courtship behaviour culminates in mating unless the prospective mate refuses to be satisfied with the courtship behaviour.

It is usually the male which shows various kinds of elaborate courtship behaviour, sometimes strange, to attract the female. The female rarely shows courtship behaviour, but responds to his overtures. Choice of mate seems to be her privilege. Interactions between sexes cease with copulation.

### 15.5.1 Need for Courtship Behaviour

Courtship behaviour serves the following purposes.

1. **Synchronisation and orientation of sexual partners.**

For successful fertilisation, sperms and ova have to be discharged by the two sexes at the same time. The male and female of the same species have to be properly oriented. The courtship behaviour of the male attracts the sexually mature female ultimately culminating in fertilisation or insemination.

2. **Persuasion**

The male exhibits courtship behaviour patterns and the female examines and decides about the fitness of its mate based on these patterns. More often than not the behaviour of the male persuades her to accept him as the mate.

3. **Mating with conspecifics**

Courtship patterns are species specific. The female of a particular species can recognise the courtship behaviour of a male belonging to her own species. This ensures mating between members of the same species.

4. **Reproductive isolation**

As a consequence of specificity of courtship behaviour, mating with members of another species (interspecific mating) is prevented. Courtship is thus a means of reproductive isolation. Courtship patterns that prevent interspecific breeding and hybrid formation is termed **ethological isolation.**

### 15.5.2 Sex Differences in Courtship Behaviour

The behavioural patterns of males to woo females are diverse and often strange. No less strange is the choosiness that females exhibit. Why males take the initiative to court females and why females sometimes reject males following his courtship may be attributed to the difference in the investment of either parent in the offspring in terms of time and energy. Such differences in the reproductive tactics of male and female may have helped to create a kind of natural selection termed **sexual selection.** Sexual selection occurs when individuals vary in their ability to (a) compete with others for mates or (b) to attract members of the opposite sex. Sexual selection involves.

1. competition to gain access to mates, often but not always among males. (intrasexual competition) Males compete with other males of the species for a mate. This probably led to the evolution of aggressive behaviour which males at times show.
2. competition to choose the best possible mates mostly among females (intersexual selection)

Mate preference exhibited by females probably resulted from practical value of:

i) what kind of genes the male has to offer, and
ii) if the chosen mate is of any other value.

The theory of sexual selection was first suggested by Charles Darwin (1871). He recognised that the reproductive success depended on the ability of individuals of one sex to locate the opposite sex, fight with other conspecific members of its own sex and win over a mate. Competition for mates among the individuals of one sex was thought to be responsible for the evolution of the characteristic features of that sex, including the behavioural mechanisms involved in selection of mate.

It is now known that reproductive success or ability to produce large number of viable offspring is more variable with males than females. This is due to difference in contribution of reproductive resources by male and female to the zygote and hence to the developing embryo i.e., parental investment of the male in the offspring is less than that of the female.

**In case of females parental investment is more because:**

(i) the female gamete, egg, is larger than sperm, the male gamete,
(ii) generally only a few eggs are liberated by the ovary at a time,
(iii) egg contains nutritive substance such as yolk for the developing embryo,
(iv) females, in many cases, spend extra time after mating for parental care.

**All these activities take time energy and materials and consequently limit the number of young that can be produced. On the contrary:**

(i) males release, larger number of sperms,
(ii) sperms are much smaller than ova,
(iii) males contribute only their genes through sperms, but no nutrients,
(iv) in most invertebrate species, males do not do anything beyond transfer of sperms to the female.

Sexual selection should produce different degrees of variation in reproductive success of males and females. Some males may mate with several females while some males may fail altogether. Females need only to mate once or twice for they can receive all the sperms from one or two males to fertilise the relatively few eggs they produce. Thus reproductive output of males will depend on how many females it can inseminate and hence vary among males. Females, on the other hand will produce more or less the same number of offspring.

Females, the choosy sex, prefer certain attributes in males which leads to **mate selection**. The preference differs in different species. Some of these attributes are:

- large size,
- visual, mechanical and chemical signals or display by the male,
- offer of nuptial gifts from the male,
- superior fighting ability and aggressive behaviour of male,
- ability of the male to guard the mate,
- attempt of a male to become socially dominant.

In certain species, males force the female into copulation.

Let us now examine some examples of male courtship behaviour patterns used for attracting conspecific females.

### 15.5.3 Visual, Mechanical and Chemical Displays

The crab *Uca* waves an enlarged chela (Fig. 15.15) to attract the female. Horns and snouts of certain male beetles have a similar effect. Male crickets and locusts stridulate to produce species specific sounds. The sounds differ in frequency and may mean mating receptivity. victory etc. (see subsection 15.4.2 – for auditory signals).


Fig. 15.15 : Male fiddler crab had enlarged chela used to attract females.

In scorpions, both male and female, indulge in a courtship dance during the monsoon (Fig. 15.16). The male and female face each other, raise the post abdominal part high into air, then move in circles. The male holds the pedipalpi (clawed appendages on the cephalothorax) of the female with his own pedipalpi and both intertwine with post abdomen above them. Then they walk forward and backward and in rings. While moving in a ring, male retreats and drags the female along. The courtship play may last for hours or even days. The male digs a burrow. Both enter and mate. The male scorpion deposits a spermatophore and moves the female so that her genital area is above the spermatophore. Sperms enter through the female genital opening. The female eats up the male after mating!

Fig. 15.16: Courtship dance of scorpions.

In some spiders, the female sits at the centre of its web. The male approaches the web and plucks a thread of the web at a specific frequency. The female reduces her natural aggressive form. But if the male, by chance, tries to attract the female of another species, it is killed.

Pheromones also act as sex attractants (see section 15.4.3). The pheromone is released by eversible glands at the tip of the abdomen of unfertilised adult female moth. Antennae of male moths have olfactory receptors for these pheromones, and they fly towards the female in a definite species specific pattern and mate. Male of butterfly *Danaus gilippus* brushes, pheromone laden 'hairpencils' everted from the tip of his abdomen on the female. The female is stimulated to mate.

### 15.5.4 Nuptial Gifts

Gifts offered by males to court females may either be in the form of (a) food or (b) spermatophore. The female black-tipped hangingfly (*Hylobittacus apicalis*) chooses for mating, the male which offers a large edible nutritional gift. The gift is a dead insect (Fig. 15.17). If unpalatable lady bird beetles are offered as gifts, the female rejects the male. Duration of mating depends on size and quality of the prey which is gifted by the male. If the gift is small, female unhooks itself from the male to give up mating without accepting sperms.

Among katydids, relatives of grasshoppers the male offers "spermatophore" (a packet of sperms). The spermatophore is rich in protein and after copulation, the female feeds on it. If the male offers a small spermatophore, the female does not permit entry of sperm into her spermatheca (sperm storage organ of female).

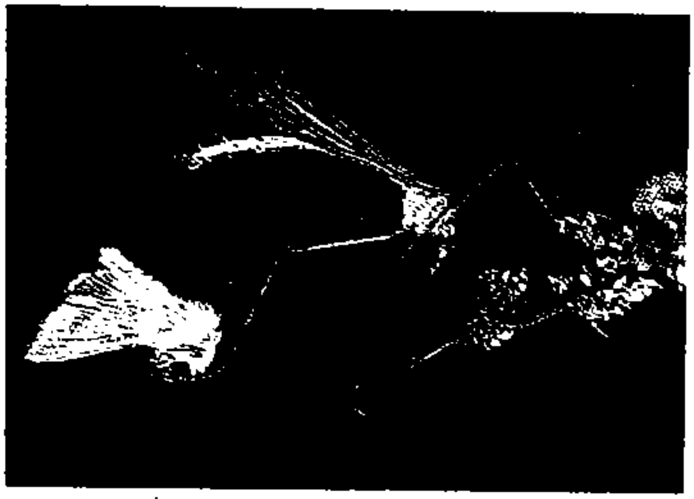

Fig. 15.17: Male hanging fly carrying captured prey as nuptial gift for the mate.

In the Mormon cricket, *Anabrus simplex* the male attaches a two-part spermatophore to the mate's genital opening during copulation (Fig. 15.18). The male separates after copulation and the female feeds on one part of the spermatophore the spermatophylax leaving the other part containing the sperms in place. Larger the spermatophore, longer she feeds and more time elapses with more sperms entering the female spermatheca from the sperm ampulla. When the first part is eaten she eats up whatever is left of the second part the ampulla.

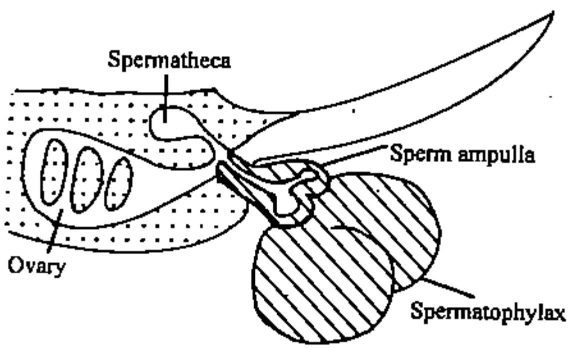


Fig. 15.18: Diagram of the posterior part of a female katydid showing male spermatphore after mating. The spermatophore is made up of the ampulla containing the sperm and the spermatophylax containing nutritional material.

The male balloon fly (*Hilara sartor*), an empid fly constructs silken balloons as nuptial gifts (Fig. 15.19). A group of balloon carrying males display collectively to visiting females. The female selects one balloon carrying male and accepts the balloon as a precondition to mating.

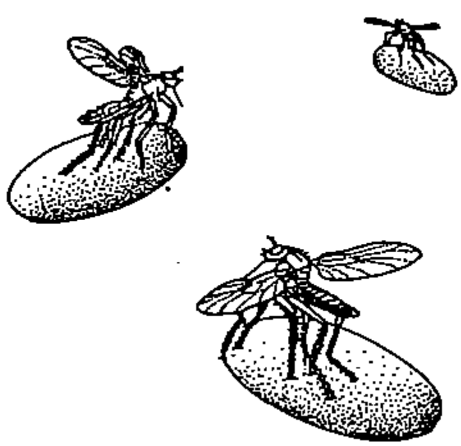

Fig. 15.19: Males of emphids. Carrying silken balloons for mates.

### 15.5.5 Sperm Competition and Mate Guarding

Sperm competition and mate guarding is particularly important in insects, because female insects can store sperms in an organ called spermatheca and use the sperm later. Copulation by one male does not exclude successful copulation by other rival males. An interesting example of sperm competition is seen in damsel fly *Calopteryx maculata*. Some males defend a territory of one to three meter long stretch of the bank of a stream, from which they drive away all other males. Females come to lay eggs on underwater vegetation, the male courts her and mates with her before she oviposits. The male has specialised claspers at the tip of his abdomen to grasp her. He bends the abdomen to form a loop so that sperms are transferred to the penis. The receptive female swings her abdomen and places her genitals on the penis. The penis is inserted by the rhythmic movement of the abdomen. If there are sperms of another male stored in the spermatheca, they are brushed out of the spermatheca before fresh sperms are deposited by the penis. He then releases her but guards her while she lays eggs in his territory. If the male cannot guard her, she flies away to another territory to mate with another male who repeats the performance.

### 15.5.6 Alternative Tactics of Mate Competition

Not all males of a species compete for mates in the same way. In many species the males often adopt alternative means of mating. For example, the scorpionfly *Panorpa* employs three tactics for mating. (1) Some males defend dead insects which attract receptive females that feed upon them. (2) Others secrete salivary material on leaves and wait for females to come and consume them. (3) Still others, the smaller males, do not give any gifts to the female but force her into copulation.

Not only scorpionflies but males of other insect species also force females to copulate. The assaulting males especially pounce on females while they are laying eggs. Some species may have the potential to behave in any of the available ways depending on the prevailing conditions.

**Mate choice by males**

Uptill now we have examined examples where mate competition occurs between males and mate choices by females. If and when parental investment is made by males rather than females, the role of the sexes can get reversed. In high density population of Mormon crickets, where the food becomes scarce, when a male gathers enough resources to produce a spermatophore, he climbs up a bush and begins to sing. Hungry females are attracted and when more than one female arrives they compete to copulate. The male accepts only that female that is significantly heavier than the rejected females. Such sex role reversals are rare and show that when parental investment is greater by the male then competition for mate arises amongst the females.

### 15.5.7 Rejection and Deceit in Courtship

Females of certain species have specific signals for rejection of the mate. The female ground beetle *Plerostichus lucublandus* sprays the rejected male with toxic liquid and the male may be in coma for a long time.

Female butterfly *Colias* is unreceptive during egg laying and if courted, flies very high when the males run away, she descends and oviposits in peace.

Deceit in courtship is shown by some males of the hangingfly *Hylobittacus*. A male without a nuptial gift poses as a female, takes a gift from another male which mistakes him for a female and gives the gift to a female.

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## SAQ 4

1. What is courtship behaviour?

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2. What is the major difference between the courtship tactics of a male and female?

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3. What are some of the nuptial gifts offered to the females by males?

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## 15.6 SOCIAL ORGANISATION IN INSECTS

The term social organisation refers to populations or groups and not to individuals and defines how members of a species interact with each other. Social organisation among non-chordates is best examplified in insects. Insects such as ants, wasps, honey bees and termites survive through cooperative hiving. A number of individuals live as a society or colony. Work such as, building the abode, procuring food, cleaning etc., are divided among members of the society. Thus when a number of individuals of a species co-operate and live together sharing the duties of life they are said to exhibit social behaviour.

### 15.6.1 Advantages and Disadvantages of Social Behaviour

Social life has several benefits. A collective defence strategy can easily drive away predators. The young ones can be better looked after and protected in a colony of individuals. Social life has its disadvantages too. The following table (Table 15.2) shows some major advantages and disadvantages of sociality.

**Table 15.2: Benefits and cost of social organisations**

| ADVANTAGES | DISADVANTAGES |
|---|---|
| 1. **Defence from predators**<br>(i) One member detects predator, can warn and save other members.<br>(ii) A joint attack can easily repel the enemy.<br>(iii) The sight of a colony of prey individuals has a better chance of scaring the predator. | 1. **Competition within the group**<br>Members of the society may compete amongst themselves for food, nest material, nest site and mate. |
| 2. **Collection of food**<br>(i) Food resources may be spotted by one member and others are led to the food source. This saves energy expended on searching foraging grounds.<br>(ii) gathered food is shared by the young, the aged, the infirm apart from others. | 2. **Risk of epidemic and parasites**<br>Increased risk of infection by contagious diseases and parasites. |
| 3. **Care of offspring**<br>Improved care of offspring through communal feeding and protection from enemies. | 3. **Exploitation of parental care by conspecifics**<br>The lazy members may leave the care of their progeny to others. |
| 4. **Defence of occupied territory**<br>Intruders from other groups of the same species looking for the same habitat and food are driven away through a joint effort. | 4. **Risk of loss of one's progeny**<br>Increased risk of progeny being killed by conspecifics. |

### 15.6.2 Characteristics of Social Insects

You have already read about polymorphism in highly organised insect societies of termites (Isoptera); ant and bees (Hymenoptera), in Block - I, Unit- 7 of this course. In these societies we find such remarkable adaptation to social life that they are not called just social but eusocial insects.

All truly eusocial insects possess three traits.

(1) many individuals of the same species cooperate in caring for the young;
(2) there is division of labour with sterile individuals working on behalf of fecund (fertile) individuals;
(3) there is an overlap of at least two generations in life stages capable of contributing to colony labour, so that offsprings assist parents during some period of life.

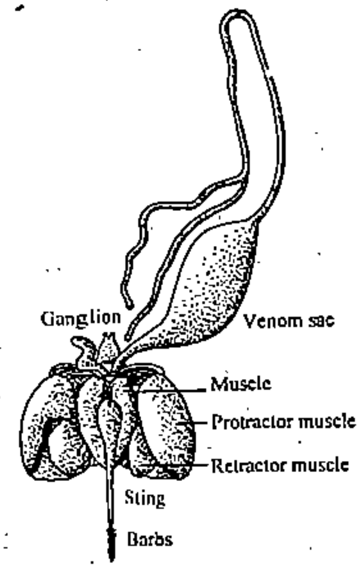


**Fig. 15.20: Sting apparatus of the honey bee. The barbs of the sting get lodged in the victim's flesh. As a result the sting apparatus tears out of the bee's body and she dies. The muscles left back with the apparatus continue to contract, pumping more venom into the victim.**

You would recall that these societies are divided into castes, such as soldiers, workers and reproductives which are morphologically different from one another and each has a separate role to perform in the colony. Eusocial insects show cooperation and altruism in an incredible manner. They build elaborate nests where temperature and humidity are kept constant. Group foraging allows sharing and harvesting of widely spread food resources. Communication involved in foraging and maintaing the colony structure are complex and the nest or hive is fiercely protected as in the case of honeybees. When the honeybee worker stings, she leaves her sting along with the poison gland and a set of contracting muscles behind as she pulls away. As a result she continues to pump poison in the victim even though she herself dies. Fig. 15.20 shows the sting apparatus which consists of the muscles, pheromones that attract other guard bees and venom sac. The evolution of nonreproductive castes showing a readiness for self sacrifice is intriguing. In the following subsections we describe some interesting social organisations in insects.

## 15.6.3 Social Wasps

Among wasps eusocial behaviour is limited almost entirely to family Vespidae. The paper wasp *Polistes*, with its painful sting is a familiar example.

These wasps build small open nests beneath roofs of houses, barns, garages and other outhouses. They build annual colonies. The colony consists of three castes: the queens (fertile females); the workers (nonfertile females) and drones (males). Reproductive females (queen) emerge from cells of their papery nest late in the breeding season, mate and hibernate in winter. In spring, these females emerge and construct either alone (foundress) or with co-operation of other similar queens (auxiliary queens) a nest. The foundress queen lays eggs and rears the first group of her larvae on macerated insects. All of these become workers. These workers thereafter, maintain the nest. They add new cells to the nest, look after the queen henceforth, forage and bring food (Fig. 15.21). The foundress remains in the nest thereafter, and lays eggs. The colony now grows rapidly as more and more workers emerge. At the end of summer, some new queens and a number of males emerge. These leave the nest, mate and hibernate. After winter they build new nests. The old queen and the old workers die and the original colony disappears.

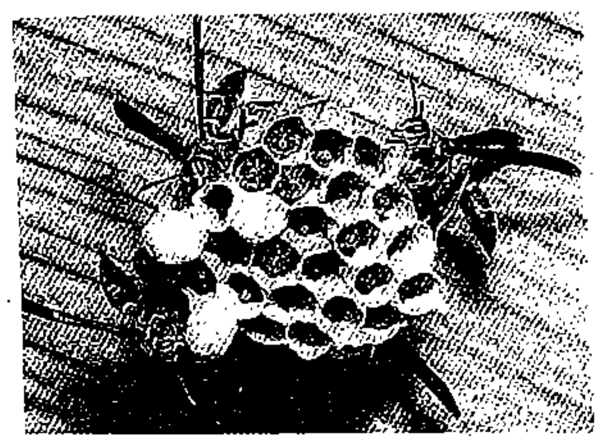

**Fig. 15.21: A social wasp *Polistes*. One of the adults shown is the queen the others are workers that assist in building the nest and caring for the young i.e. the larvae inside the cells.**

## 15.6.4 Ants

The ants belong to the family Formicidae (*Order Hymenoptera*). Common ants are the small black *Monomorium* and the large black *Camponotus*. *Formica*, *Lasius* are other genera. They build nests in cavities in plants, in the soil, or under stones or logs. The tropical ant *Oecophylla smarsedina* weaves leaves of trees into a nest with threads of silk.

All ants are social and polymorphic You have already learnt in unit-7, Block 1 of this course that there are mainly three castes. (1) wingless and sterile females are either soldiers having huge head and well developed mandibles, or ordinary workers. (2) winged fertile females which lay eggs (queens) and (3) winged fertile males which are short lived and die after mating.

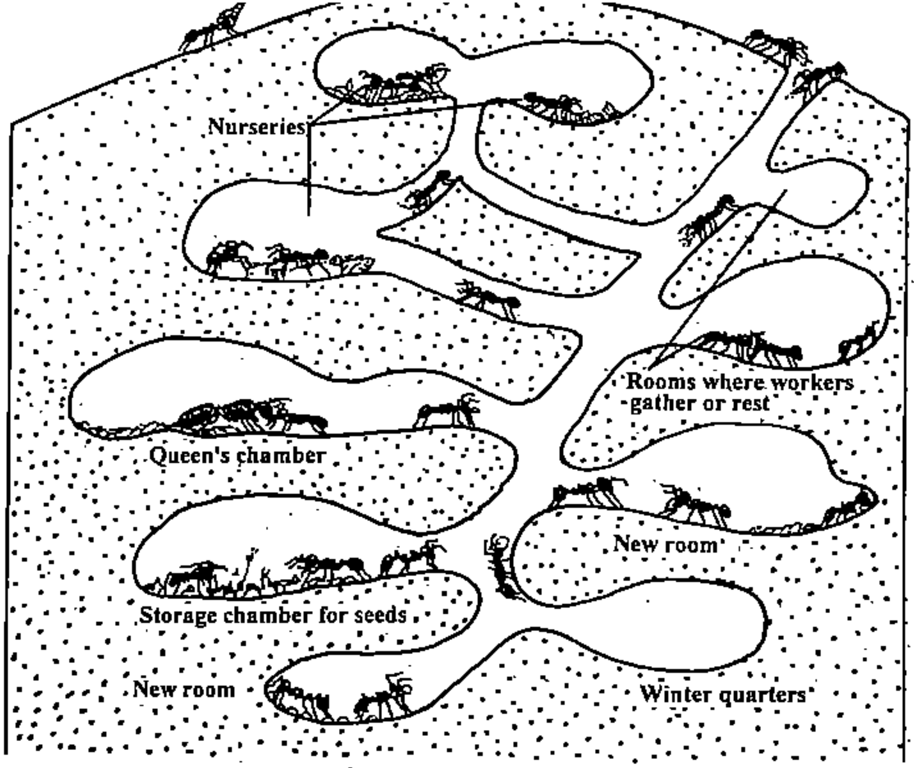


Fig. 15.22: An underground harvester ant colony. The nest consists of various chambers and connecting tunnels. One chamber houses the queen. There are several nurseries where workers take care of the young. Harvester ants also have storage chambers for seeds.

The underground nests of ants are called formicaria (Fig. 15.22). After mating in air, females dealate (drop their wings) build a new nest and lay eggs in cells or chambers. Initially the queen performs all the work also. But once the initial clutch of eggs hatch into workers they take up the work of the colony. Then the queen is free to concentrate on egg laying and growing.

Ants have glands for secreting trail laying pheromones (Fig. 15.23). These pheromones help in communication and troops of ants can be seen marching along the trails laid. Certain ants also have beetles and other insects living in their nests as guests. Some ants even cultivate fungus garden.

Fig. 15.23: Fire ant worker laying a trail by releasing pheromone along its extended sting. The sting is touched to the ground periodically.

### 15.6.4 Honey Bees

Honey bees belong to family Apidae (Order Hymenoptera). There are three common species of honey bees in our country namely the giant bee *Apis dorsata*, the little bee *Apis florea* and the Indian honey bee *Apis indica*. Honey bees are socially very well organised. About 10000 to 16000 individuals may live in a honey comb. Recall from Unit 7 of this course that each colony has only one queen - the fertile female, about 500 to 1000 males (drones) and the rest are sterile, female workers. The queen, the drones and workers are all winged. The functions of the colony are divided among these three castes. The queen is the mother of the colony. She remains in the live except during nuptial flight when she mates with a drone in air.

The workers build the honey comb with wax which is secreted by wax glands on the abdomen. They collect nectar from flowers, for which their mouth parts are suited. Pollen is an important part of the food of the larvae and adult bees. The legs of the workers are modified for collection of pollen. The hind legs (Fig. 15.24) have tibia fringed with long, curved hairs and these forms the pollen brush. The space enclosed by the hairs form the pollen baskets. The legs have spurs and bristles to clean antennae and pollen sticking to body. The workers have a sting at the abdominal tip into which leads a poison gland (see Fig. 15.20). The queen has a very well developed sting to drive away rival queens. Drones do not have sting.

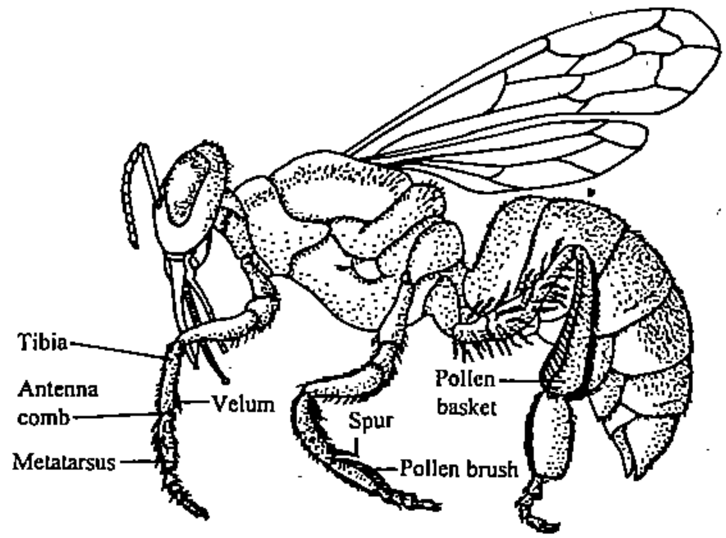


**Fig. 15.24: Legs of honeybee workers that are especially modified for collecting pollen. The hind leg has long hair forming a pollen basket. The joint between tibia and metatarsus of front leg is modified as an antenna cleaner.**

### 15.6.5 Termites

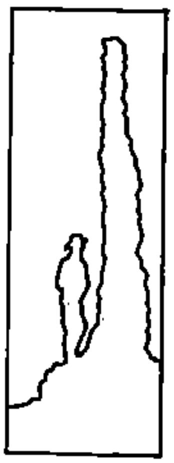

**Fig. 15.25 : Termite mounds are elaborate constructions. The nests of Aftrican termites *Macrotermes bellicosus* can reach skyscraper proportions. The nests have rock hard water tight walls of earth and plant material bound together with the saliva and excreta. The walls help to insulate the nest from extremes of temperatures.**

All termites are social insects, and belong to the primitive order Isoptera. They are popularly called white ants. Examples are *Kalotermes flavicollis* and *Reticulitermes lucifugus, Miacrocerotermies* sp. The immense damage done to wooden components of houses and furniture by termites is well known. Termites are also polymorphic (refer to page 164-165 of unit 7 of this course for a detailed description of termite castes) and live in communities leading a social life, in galleries. Most termite species live in soil inside mounds of earth known as termitaria (Fig. 15.25). Termites feed on wood which they digest with the help of symbiotic flagellate protozoans in their intestine. Some termites have fungal beds or gardens in their nests specially prepared by workers..

### SAQ 5

i) Name the different castes found in
   (a) honey bee
   (b) termites.

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ii). What is meant by eusocial insects?

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## 15.7 PARASITISM

In the earlier section you learnt how eusocial insects show cooperative behaviour and often go to suicidal lengths to protect their colony from invaders. In this section we shall learn about another behaviour - parasitism - that is the other end of the spectrum. While social behaviour is an intraspecific behaviour, parasitism is a regular and close interspecific association in which one of the animals, the parasite is benefitted especially nutritionally. The parasite in other words, lives at the expense of the host. The parasite is usually smaller and weaker. It lives within or on the surface of body of the larger and stronger host. The parasite gets its food from the host.

Parasitism evolved separately in many major groups of animals. Platyhelminthes, Nemathelminthes, and Arthropoda are the main non-chordate groups that show examples of parasitic behaviour.

### 15.7.1 Types of Parasites

Parasites may be classified into the following types. **Ectoparasites** are those that attach to the surface of the host (eg. leech on cattle).

**Endoparasites** live inside the body of the host. eg. Round worm (*Ascaris*) and tape worm (*Taenia*) live inside the human intestine.

**Facultative parasites** may live without a host.

**Obligatory parasites** spend at least part of their life in the host to complete their life cycle eg., *Taenia*. They cannot complete their life history without the host.

Apart from Platyhelminthes and Nemathelminthes, parasitic species are common among Arthropoda (many among crustaceans, arachnids & insects). You would come across more examples of arthropod parasites from relevant sections, in the next unit Harmful and Beneficial Non-chordates.

### 15.7.2 Effects of Parasitism on Parasites

Majority of Platyhelminthes and Nemathelminthes lead a parasitic life. The greater the degree of parasitism, the more is their departure from normal morphology and physiology. All these deviations, however, are adaptations to a parasitic life. You may recall here the adaptations discussed in the relevant units in the course.

The main parasitic adaptations are:

1. **Loss of surface epidermis** and its replacement by a tegument which plays an important role in the physiology of the parasite, is a common feature among parasitic platyhelminths. In nematodes, the cuticle is impervious. There are shells around eggs and cyst walls around larvae, for protection.
2. **Presence of organs of adhesion** to fix to the host. Hooks, claws, various types of suckers and in certain cases adhesive secretions. Consequent on the development of adhesive organs **there is loss of motility.** Parasites remain firmly attached to hosts.
3. **Loss of sense organs:** Progressive parasitism is accompanied by corresponding loss of sense organs and a concomitant degeneration of nervous system.
4. **Simplification and eventual loss of digestive system** : Parasites depend on hosts for food. In tapeworms there is a complete loss of digestive system but flukes possess a mouth, a suctorial pharynx and a blindly ending intestine. Tapeworms absorb wholly digested food of the host, through the tegument.
5. **Reproductive system** of parasites is highly complex. They show excessive capacity for egg production. Tapeworms show multiplication of sex organs along the strobila (proglottides of the body) for further augmentation of egg production. Many parasites are hermaphrodites to ensure fertilisation.
6. **Life cycle of parasites is complicated.** Flukes have stages of life cycle passing through one to three intermediate hosts. To suit this, the parasites often have a number of larval stages. These often show polyembryony giving the animal a further reproductive advantage, resulting in multiplication.

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## SAQ 6

1. Define parasitism.

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2. What are the usual organs of attachment of parasites?

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3. Why is the digestive system of parasites incomplete or lost?

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## 15.8 SUMMARY

In this unit you have studied:

- Taxis and kinesis involve movements in response to environmental stimuli. Taxis is a directional movement of the organism. Taxis can be classified according to stimuli into:
  - phototaxis in response to light
  - thermotaxis in response to temperature
  - thigmotaxis in response to mechanical contact
  - chemotaxis in response to chemicals
  - rheotaxis in response to wind and water currents
  - galvanotaxis in response to electric currents
  - geotaxis in response to gravity.
- Kinesis is a non-directional movement.
- Biorhythms are behavioural activities performed at regular intervals. Daily rhythms in which activities follow approximately twenty four hour cycle are circadian rythms. Activities regulated by tides in marine animals are termed tidal rhythims while those controlled by phases of moon are lunar rhythms. Rhythms shown once a year are called circaannual rhythms. Biorhythms are exogenous when rhythmic activity is controlled by external stimuli such as by photoperiod. Endogenous biorhythms are regulated by an inbuilt biological clock.
- Biological clocks are internal mechanisms which can measure time. They are set to cyclical events such as day and night. In case of change in the environmental cycle that is, such as when kept in continous darkness, the timing of biological clock changes slightly and this is termed free running of the clock. If the organism moves to a different photoperiod such as when animals travel from one part of the world to another, the biological clock sets to new environmental conditions and this is termed entrainment. Stimulus which sets the time of biological clock is called *Zeitgeber*.
- Animals communicate with each other through signals. Various signals are visual, mechanical, auditory, chemical etc. and indicate availability of food, predator around mate etc. When communication signals occur in regular stereotyped sequences they are fixed action patterns.
- Some visual signals such as changes in body posture or specific colour patterns lure prey or mate, or frighten or warn the predator. Tactile signals are employed by ants where touch makes the ant regurgitate food for consumption by the larva. Auditory signals are common among insects. Pheromones play an important role in chemical communication. Honey bees employ "dance language" for communication among the members of the hive.
- Courtship behaviour helps to attract the opposite sex of the same species for mating and reproduction. Courtship behaviour brings about synchronisation of mating activity and proper orientation of the mates. Courtship behaviour is usually initiated by the male and the female has the privilege of choosing the mate. Courtship behaviour patterns include visual displays, production of sex attracting pheromones, nuptial gifts.
- Ants, termites, wasps and bees are some examples of social insects. All these four groups show polymorphic castes with division of labour. The castes are broadly similar among all these. But there are some basic differences also between hymenopteran groups (bees, ants and wasps) on the one hand and isopterans (termites) on the other. The most important of these is that the worker caste in hymenopterans consists of adult females only, whereas in termites (isopterans) the workers consist of both adult males and females. The immatures also contribute to work of the colony. The advantages of social life are:
  - collective defence from intruders and predators;
  - co-operative collection and sharing of food;
  - community care of young and sick.

  The disadvantages are competition within the social group; risk of epidemics and parasites; and exploitation of parental care by conspecifies.
- Parasitism is a regular and close interspecific association in which the parasite is benefitted at the expense of the host. Advantages of parasitism are: parasite gets ready supply of food; shelter and other metabolites without any effort. Disadvantages are that the parasite has to produce large number of eggs so that at least a few will find a host. Once it finds a host it depends on the host for its life.

- Adaptations to parasitism are:
  - presence of impervious cuticle, cyst or shell,
  - presence of hooks or suckers for attachment to host; loss of motility,
  - loss of sense organs and poorly developed nervous system,
  - simple digestive system or its absence altogether, accompanied by development of a special tegument for absorption of predigested food in the environment,
  - well developed complex reproductive system,
  - capable of producing enormous number of eggs, and
  - hermaphroditism,
  - life cycle complicated with many larval stages accompanied with polyembryony in each stage.

## 15.9 TERMINAL QUESTIONS

1. Enumerate the different types of biorhythms and explain with examples.

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   ......................................................................................................

2. Write a short paragraph on "biological clock".

   ......................................................................................................

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3. With two examples each, explain the different types of signals used for communication among invertebrates.

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4. Elucidate how insects employ pheromones in communication.

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5. What does mate selection mean?

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6. What is the significance of courtship display in animals.

   ......................................................................................................

7. What is social behaviour? Enumerate its merits and demerits?

   ......................................................................................................

## 15.10 ANSWERS

### Self-Assessment Questions

1. i) Taxis is directional movement in response to a stimulus.
   ii) Kinesis is non-directional movement in response to a stimulus.
   iii) (i) positive phototxis; (ii) negative galvanotaxis; (iii) geotaxis.
2. i) Behavioural activities performed at regular intervals.
   ii) i - e; ii - a; iii - d; iv - c; v - b.
   iii) In exogenous rhythm, an external stimulus triggers the behavioural pattern of an animal at regular intervals. In endogenous rhythm, an internal biological clock triggers activities of an organism at regular intervals.
   iv) Setting the biological clock in phase with the environmental cycle.
   v) Nervous system.
3. i) Action/signal of an individual which alters the pattern of behaviour of another individual.
   ii) Behaviour patterns for communication established through evolution.
   iii) Stereotyped sequences occurring at regular intervals.
   iv) a. frightening predator/luring prey/attracting mate.
   b. courtship/alarm.
   v) Sound made by rubbing surfaces against one another.
   vi) antennae

vii) a. to inform the workers that source of food is close by (within 50 mefers from the hive).

b. to inform fellow worker bees that source of food is far beyond 50 meters from the hive.

4. i) Specialised behavioural patterns in animals for attracting the opposite sex for reproductive purposes.

ii) Male exhibits visual displays, offers nuptial gifts, or fights with conspecifics to attract female. Female chooses to accept or reject him.

iii) Food/spermatophores/silk balloons.

5. a) Honey bee - Queen (fertile female), workers (sterile females), drones (fertile males)

Termites

1) King and queen (Primary reproductives)
2) Supplementary reproductives (males and females)
3) Workers (sterile males and females)
4) Soldiers (sterile males and females)

b) Insects with highly developed and defined castes.

6. i) Close and regular interspecific association in which one of the organisms derives nourishment from the other.

ii) Hooks, suckers, adhesive secretions.

iii) parasites absorb food which is already digested by host.

## Terminal Questions

1. Refer Sub-sections 15.3.1
2. Refer Sections 15.3
3. Refer Sub-sections 15.4.3
4. Refer Sub-sections 15.4.3
5. Refer Sub-section 15.5.2
6. Refer Sub-section 15.5.1
7. i) A number of individuals of a species living together co-operatively sharing the duties of life.

   ii) Collective means of defence from predators/intruders; cooperative collection and sharing of food; care of young.

   iii) competition within group; risk of loss of progeny; proneness to epidemics/ parasites.

## Credits

Figs. 15.3; 15.12 b from The Illustrated Encyclopaedia of Animals (Exeter Books).

Figs. 15.6a and b; 15.7; 15.11; 15.12a from Living Invertebrates, Pearse and Buchsbaum (Blackwell Scientific Publication).

Fig. 15.8a from The Unity and Diversity of Life, Starr and Taggart (Wadsworth Publishing Company Inc.).

Fig. 15.10a and b from Biology, Arms and Camp (CBS College Publishing) 3rd Edition.

Fig. 15.15 from Animal Behaviour (Time Life Series).

Fig. 15.21 from Animal Behaviour John Alcock.

# UNIT 16 HARMFUL NON CHORDATES

## Structure



## 16.1 INTRODUCTION

In Blocks 1 and 2 you would have got a fairly good background about the diversity that exists within the Animal Kingdom. You have learnt about various groups of protozoans and metazoans and also the characteristic features that differentiate them. The units of Block 3 have given you the basic idea about their structural organisation and the functions of the various structures. Most of these animals have a free existence, whereas some form various types of associations with other living beings. Their association or dependence on other organisms can be for shelter, transport or for acquiring food. Sometimes the dependence may be deeper or more intimate. Parasitism is one such association. It may be defined as a regular and close association in which the parasite lives on or inside the body of the host, deriving nourishment from it but not necessarily destroying it. In Unit 4 Block 2 you have already learnt about some of these parasites. Many of these parasites are unable to survive independently on their own in nature. These parasites share or rob resources of their host, thereby debilitating it. Parasites may inflict injuries to the host by causing destruction of the tissues, which may result in disease on the host. In extreme cases even death of the host occurs due to release of toxic metabolites by the parasite.

Thus some non-chordate parasites directly cause diseases in the host, which may be plants and animals including man. Some non-chordates called vectors are however, indirectly harmful as they transmit various parasites or pathogenic agents from one host to the other. These vectors are thus responsible for the spread of several dreadful diseases. Let us, in this unit study from the point of view of humans some animals among the non-chordates which are harmful in one way or the other to them, and therefore are important from medical, veterinary or agricultural point of view.

When we look into the various non-chordate groups, it emerges that major species harmful to human health and/or economy come under the protozoans (animal protists), platyhelminths, nematodes and arthropods. Of these the protozoans have already been dealt with in a previous unit. In the present unit we will study some selected members from the Phyla Platyhelminthes, Nemathelminthes and Arthropoda. We will also discuss how these parasites or vectors complete their life cycle and the way they affect their hosts. This knowledge will also give us an idea as to how their propagation and spread in nature could be brought under control.

### Objectives

After studying this unit you should be able to:

- name a few important helminth parasites of medico - veterinary and agricultural importance.

- describe the ways in which these helminth parasites complete their life cycle and are transmitted from one host to another,
- give examples of some important arthropods which act as vectors or as pathogens of plants, animals and man,
- identify the ways in which the propagation and transmission of the parasites can be checked.

## 16.2 PARASITIC PLATYHELMINTHES

Before attempting to study this unit, you will do well to go through the relevant sections of this course which deal with classifications (Refer to Block 2 of this course– sections 4.6 and 4.7 of Unit 4 and section 5.3 of Unit 5). In Phylum Platyhelminthes the classes Monogenea, Trematoda and Cestoide (Cestoda) are parasitic during the whole or part of their life cycle. The turbellarians are free living. The trematode and cestode species are of veterinary importance and are also cause of concern in human health. Monogeneans are ectoparasitic usually on lower vertebrates, especially on fish.

### 16.2.1 Class Monogenea

Most Monogeneans are ectoparasites especially on fish. A few flukes are also found in the urinary bladder of various aquatic vertebrates.

The monogenetic flukes are small, less than 1 mm to 2 mm. They are (Fig. 16.1) circular to spindle shaped and dorsoventraly flattened. Their body is composed of a head, trunk and haptor (opisthaptor). The head lacks an oral sucker but has adhesive glands (head organs). A complex well developed opisthaptor is present at the posterior end which helps the flukes to cling tenaciously to their host and to withstand the flow of water over the gills and skin of the host.

The opisthaptor of Monogeneans vary in different species and may bear hooks, suckers and clamps, often in combination with each other. They may also have adhesive secretions.

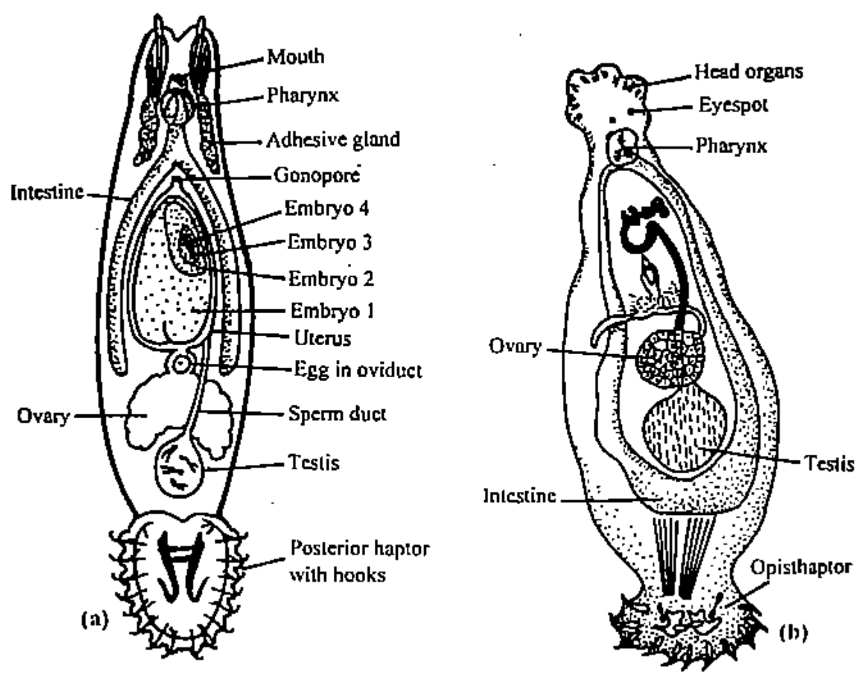



**Fig. 16.1: Some ectoparasitic monogeneans. (a) *Gyrodactylus*, a fish parasite is a serious pest in fish ponds and hatcheries where fishes are crowded. (b) *Dactylogyrus vastator* is ectoparasitic on gills of fresh water fishes and is a serious pest in fish hatcheries.**

There is no intermediate host in monogeneans and one egg gives rise to only one adult worm, hence the name monogenea – 'one generation'. The egg hatches into a free swimming ciliated larva-the oncomiracidium-that attaches to the host with its opisthaptor, and metamorphoses rapidly into an adult.

**Damage:** The monogeneans become serious pathogens only in the case of fish farming where their hosts the fish are crowded together. *Dactylogyrus* is an ectoparasite in gills of various fresh water fishes. It can become a serious problem in fish hatcheries.

## 16.2.2 Class Trematoda

The class Trematoda consists of flukes. The majority of these flukes are a few millimeter in length (Fig. 16.2). They are all parasites. Some are ectoparasitic living on the surface of their hosts while others are endoparasitic, found within the host body. The class Trematoda, includes the Digenea, a large, economically and medically important taxon.

Digenean parasites produces infection in higher animals, including man. They are common parasites of all classes of vertebrates. Some species particularly those inhabiting the liver, lungs or blood are serious pathogens of humans and livestock in which they cause debilitating diseases.

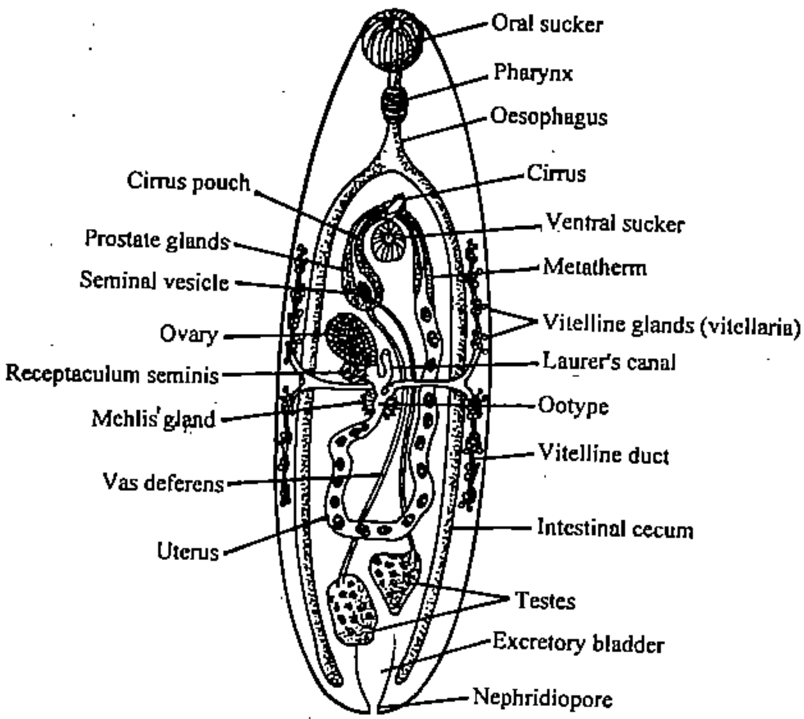



**Fig. 16.2: Diagram of a generalized trematode.**

### Life cycle

Almost all digenetic trematodes are endoparasitic in the vertebrates. The vertebrates are the primary or definitive hosts of the parasites as the sexual reproduction of the parasite takes place in the vertebrate host. Digeneans usually have an invertebrate as their first intermediate host. Thus digeneans have involved or complicated life histories with at least two generations and two hosts.Hence the name 'Digenea' meaning having two generations. In such a complicated life cycle there may be two or more intermediate hosts that are infected by the larval stages of the parasite before the life cycle is completed. The final larval stage locates in the definitive host in which the parasite undergoes sexual reproduction.

Majority of the digenean trematodes are located in the digestive tract of their final (definitive) hosts. Some species however live in bile ducts, a few in the lungs and still others in the portal venous blood.

A gastropod snail (mollusc) usually acts as the first intermediate host for larval development of the parasite. Some species may even need a second (fish, crab or other crustaceans) or even a third (amphibian, reptile or mammal) intermediate host. The digeneans, after successfully invading the first intermediate host, undergo two rounds of asexual division which greatly increase their numbers and so also their chances to complete the life cycle.

Definitive or primary hosts are those in which the parasite reproduces.

The life cycles of digeneans as mentioned before vary, depending upon the species. The life cycle of the liver fluke *Fasciola* has been taken as an example in this unit.

## LIVER FLUKE (*Fasciola*)

The cosmopolitan liver fluke of the ruminants sheep, goat and cattle is *Fasciola hepatica* (Fig. 16.3). It causes in them a serious disease, known as liver rot. The Indian species is *Fasciola indica*. The adult liver fluke lives in the bile passages of the liver of the host where in case of heavy infections it causes extensive damage and necrosis of liver. Heavy infection also interferes with the normal flow of bile which results in obstructive jaundice (Also refer to unit 4.6.2 of this course for the life cycle).

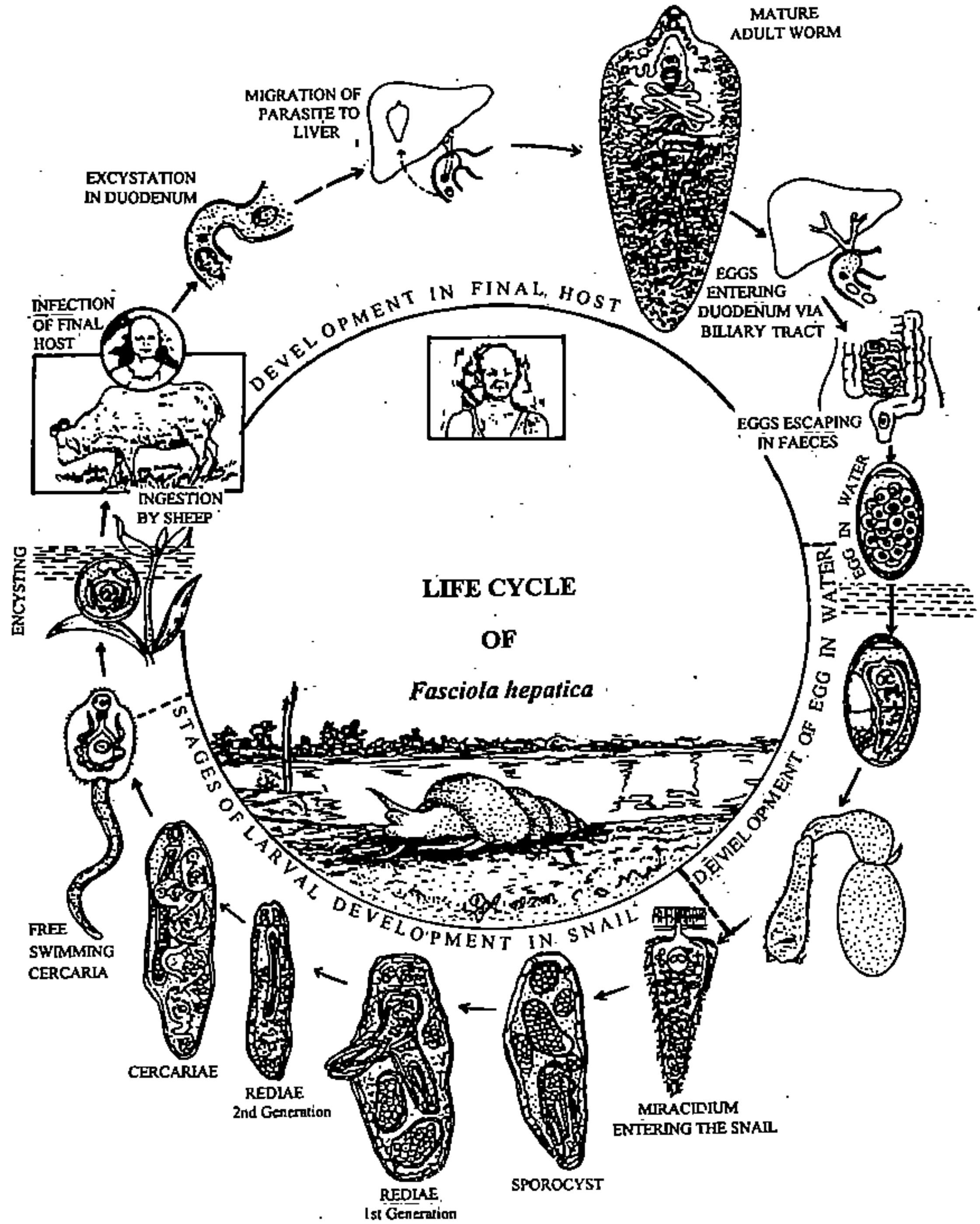


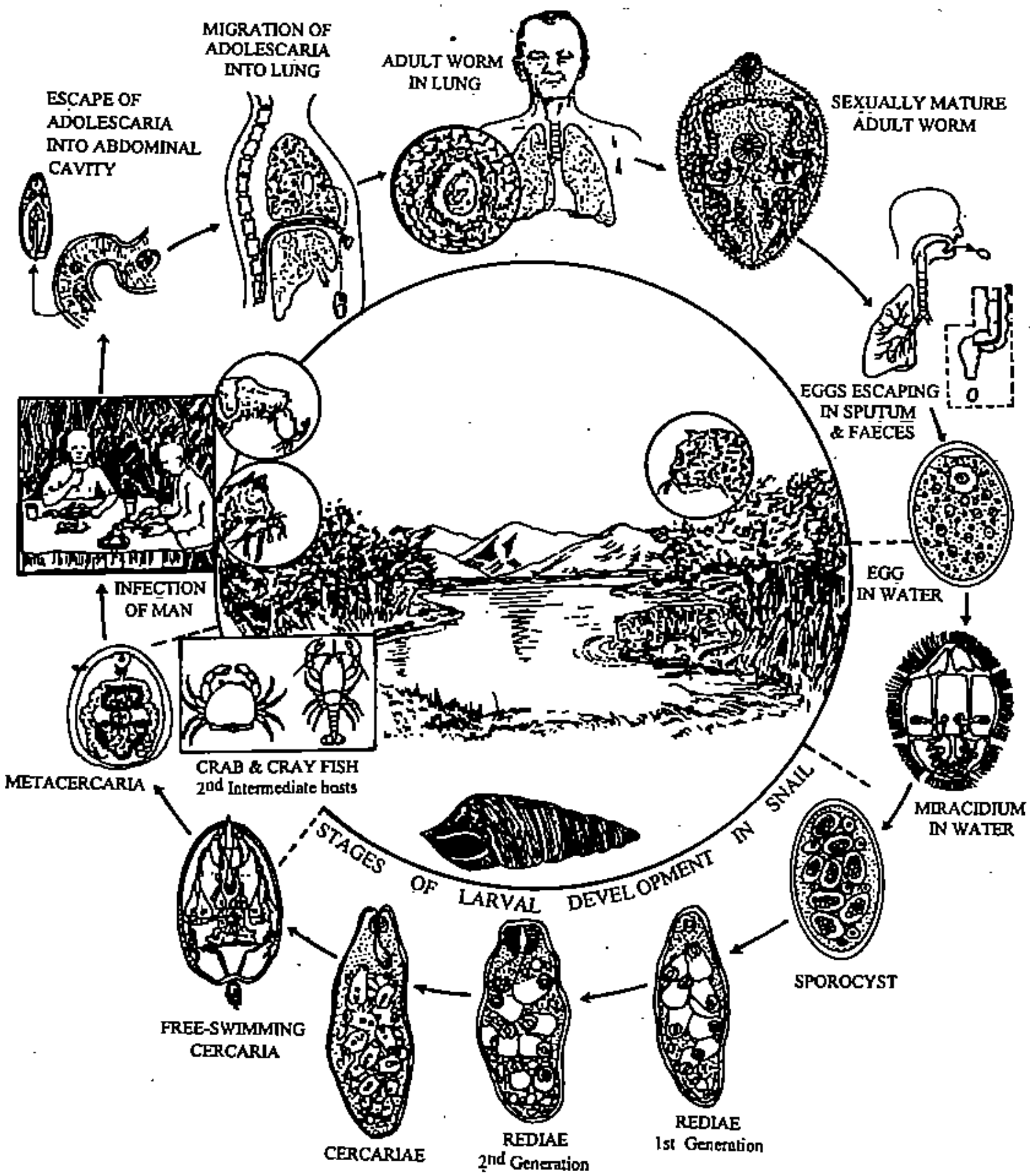

Fig. 16.3: The life cycle of *Fasciola hepatica*, a liver fluke of sheep, goats, and cattle.

The Chinese liver fluke *Clonorchis* (*Opisthorchis*) *sinensis* is the liver fluke commonly found in China, Southern Asia and Japan.

## LUNG FLUKES (*Paragonimus*)

Species of genus *Paragonimus* (Fig. 16.4) occur as lung parasite in humans and in many species of carnivorous mammals. The species *P. westermani*, a human parasite, is widely distributed in the Far East Africa and South America. In India, it has been frequently reported from West Bengal, Assam and South Indian States. Life cycle of *P. westermani* has two intermediate hosts; a snail is the first intermediate host, while a fresh water crayfish or crab is the second intermediate host.

Lung fluke infection can best be controlled by the eradication of the host species of snails and by only eating crabs and cray fish after cooking them well.




**LIFE CYCLE OF *Paragonimus westermani***

Fig. 16.4: Life cycle of *Paragonimus westermani*.

## BLOOD FLUKES (*Schistosoma*)

Blood flukes cause the human disease **schistosomiasis**. The three important species of this genus are *Schistosoma haematobium*, *Schistosoma mansoni* and *Schistosoma japonicum* (Fig. 16.5) which are serious parasites of humans (Refer also to unit 4.6.2 of this course).

Schistosomes have a life span of 20-30 years. The adult *Schistosoma* lives in humans and may be 2 cm long and 1 mm in width. The blood flukes differ from most other flukes in being dioecious (Fig. 16.5). The male and female flukes, though separate individuals, are permanently paired. The male is shorter, broader and heavier. It has a large ventral groove, called the **gynecophoric canal** which is posterior to the ventral sucker into which is lodged the more slender and longer female. Depending on the species the schistosomes inhabit blood venules of different organs of the body and have specific intermediate snail hosts.

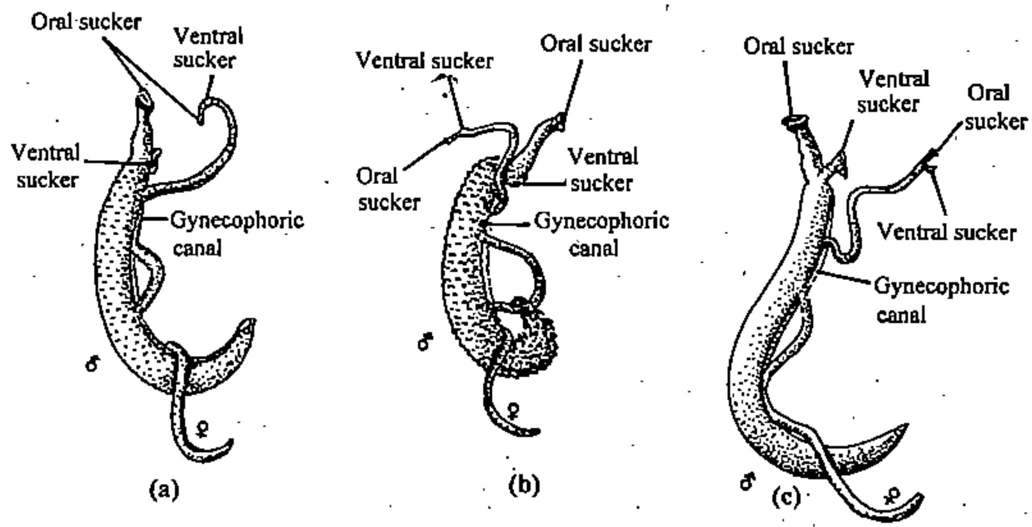



**Fig. 16.5: Important schistosomes of man. (A)** ***Schistosoma haematobium.*** **(B)** ***S. mansoni.*** **(C)** ***S. japonicum.***

*Schistosomia mansoni* is widely distributed in Africa, the Northern parts of South America and the West Indies. *S. mansoni* adults live primarily in the venules draining the large intestine of the human host. Their principal intermediate snail hosts are species of *Biomphalaria.*

*Schistosoma haematobium* occurs in the Middle East and parts of Africa. The adults of *S. haematobium* are lodged in the venule of the urinary bladder of the human host. Their principal intermediate snail hosts belong to the genera *Bulinus* and *Physopsis.*

*S. japonicum* is mostly found in Japan and other Far East countries. Adults of *S. japonicum* mostly lodge in the venules of small intestine of the human host. Their main intermediate snail hosts are species of *Oncomelania.*

The life cycle of blood flukes is generally similar in all species. In this unit we will study the life cycle of *Schistosoma mansoni.*

***Life Cycle of Schistosomia mansoni***

The adult male and female couple live in humans and feed on blood in the venules of the large intestine. The female deposits the eggs in the small intestinal venules. Using its spine the egg breaks through into the lumen of the intestine and is excreted outside. When released from the host each egg contains a fully developed ciliated miracidium (miracidia – plural). The eggs on coming in contact with water hatch and the miracidia escape into the water. The miracidia seek out and penetrate the specific intermediate host, a fresh water snail. Within the intermediate host the miracidia transforms into a sporocyst. This sporocysts produces, a brood of second-generation sporocysts. These daughter sporocysts directly produce cercariae, without going through redia stage. The cercariae come out of the snail host and swim about in water with their forked tail. On coming in contact with the human host they penetrate the skin, enter the cutaneous blood vessels, and transform into a juvenile or schistosomula. The schistosomulae migrate via blood circulation through lungs, into liver and finally to their final destination i.e. to the venules of the large intestine.

During penetration through the skin, the cercariae cause local dermatitis reaction at the site of entrance. During their growth phase in the portal system of the liver, the parasites liberate toxic metabolites causing fever and enlargement of liver and spleen of the human hosts. The eggs, while being extruded from the blood capillaries, cause extensive damage. Tissue reactions occur around the eggs remaining in tissues like liver, resulting in the formation of nodules which may gradually become irreversibly calcified, thus damaging the organ. Blood circulation in liver may also be obstructed by these parasites which may cause cirrhosis, interfering with the proper functioning of the organ.

## SAQ 1

a) Fill in the blanks with appropriate words.

i) The free swimming, ciliated larva of blood flukes is called ……………………

ii) The scientific name of the cosmopolitan liver fluke of ruminants is ............................................................

iii) The scientific name of Chinese liver fluke is ................................ ..........................................

iv) *Paragominus* a parasite of human lodges in their ..................................

v) The second intermediate host of lung fluke is either a ............................ or a ........................................

vi) The principal intermediate snail host of *Schistosoma haematobium* belongs to the genus ....................................

b) Indicate whether following statements are true (T) or false (F).

i) Digenean fluke have only one host. ☐

ii) The lung fluke does not occur in India. ☐

iii) *Schistosoma mansoni* is found mostly in the venules of large intestine. ☐

iv) The intermediate host of *Fasciola hepatica* is a snail. ☐

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### 16.2.3 Class Cestoda

All cestodes are called tapeworms. Adults of all tape worms are endoparasites in the gut of vertebrates. One of the intermediate hosts is usually a non-chordate. The young stages live in various tissues of non-chordates and also of vertebrates. Several species of cestodes occur in man and animals of economic importance of which the two most important economically are *Taenia solium* and *Taenia (Taeniarhynchus) saginatus* (Refer to Unit 4.6.2 of this course also).

**THE PIG TAPEWORM (*Taenia Solium*) and THE BEEF TAPE WORM *Taenia Saginatus***

*Taenia solium* and *Taenia saginatus* are cosmopolitan species of tapeworms occurring in man. The intermediate host for *Taenia solium* as you will recall is pig, as a result of which it is also called pork or pig tape worm. The intermediate host for *Taenia saginatus* however is cattle and hence it is called the beef-tape worm (Fig. 16.6).

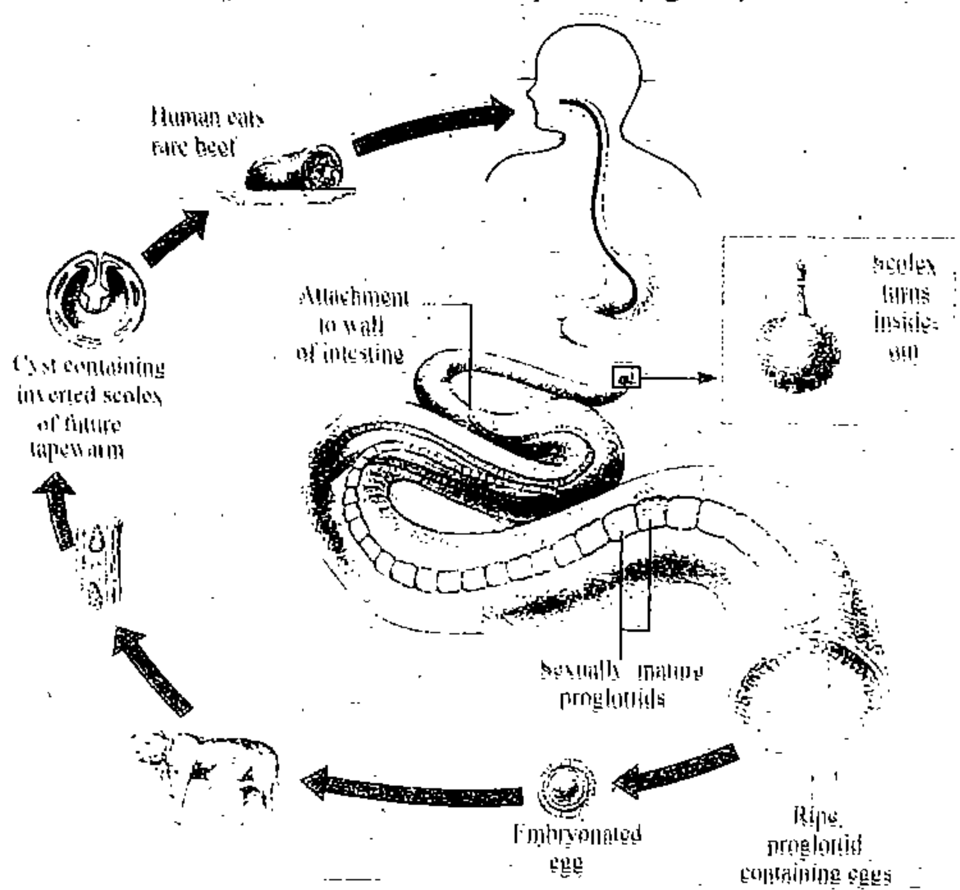



**Fig. 16.6: Life cycle of *Taenia saginatus* (beef tape worm)**

Heavy parasitic infections in humans causes digestive problems, diarrhoea, weight loss, abdominal pain, often blockage of the intestinal lumen and reactions to toxic wastes of the worm. Proper cooking of meat and better hygienic practices would prevent Taenia infection.

**DWARF TAPE WORM (*Hymenolepis Nana*)**

*Hymenolepis nana* is another tape worm of humans. Its development is usually direct without any intermediate host. The eggs pass out and when ingested by another human host hatch in the duodenum releasing oncospheres or the hexacanth embryos.

**THE FISH TAPEWORM (*Diphyllobothrium Latum*)**

The adult *Diphyllobothrium latum* is found in the intestine of man, dog, cat and other mammals. The immature stages occur in copepods (crustacean) and fish which are its intermediate hosts.

**THE DOG TAPEWORM (*Echinococcus Granulosus*)**

One of the most serious larval cestode infection in man is caused by *Echinococcus granulosus* (Refer Unit 4 of this course also). The adult parasite is minute being only 3 to 6 mm long. It lives in the small intestine of canines which are the main host. The parasite has a scolex and strobila consisting of 3 or 4 segments. The larval stages occur in a number of mammals such as sheep, cattle, horses or even humans, all of which serve as intermediate hosts. Thus humans serve as an intermediate host in this case and are infected from dogs due to their association with them.

The eggs ingested by intermediate host lodge in the intestine of the host and liberate the onchospheres or hexacanths. The hexacanth leave the intestine and makes its way to various organs such as lungs, liver, kidney, heart, brain or even bone via circulation. In these organs the onchosphere develops into a larval form called **hydatid cyst**. The hydatid cyst which is the bladder worm, contains a single or unilocular chamber within which numerous daughter cyst or bladder worms develop or bud off. Each of these in turn has many scolices within it (Each scolex will produce a worm when eaten by a canine host). In course of time the hydatid cyst may grow to a very large size, of more than 15 cm in diameter. Depending on its size and location, the cyst in the intermediate host may cause varying degree of damage. Rupture of a cyst in human may cause toxic reactions (fever, vomiting, shock, even sudden death). If the hydatid grows in a critical site such a heart or central nervous system, serious symptoms occur. Hydatid cysts may remain alive and viable for many years after the initiation of the infection and in humans their surgical removal is the only way out. Adequate personal hygiene of man and also of the pet dogs along with their proper care are the suggested control measures against hydatid infection.

## SAQ 2

Fill in the blanks with appropriate words.

i. Cestodes are commonly called ................................

ii. ............................. .......................... is the beef tape worm.

iii. ............................. .......................... is the pork tape worm.

iv. .............................. is a human tape worm usually with direct development.

v. ............................ is a fish tape worm that you have studied in this unit.

vi. In humans, the onchosphere of the dog tape worm develops into a larval form called ............................... cyst.

## 16.3 PARASITIC NEMATHEHELMINTHES

### 16.3.1 Class Nematoda

Many nematodes are parasitic in plants or animals (food crops, domestic animals and humans). You may go through the earlier unit 4 subsection 4.7 of this course for an account of this group, which gives you an idea about their classification and organisation. The size of nematodes varies greatly, from being microscopic to even a metre or so long. Most species of plant parasitic nematodes range from 0.3 mm - 5 mm in length. Many are even smaller. Most free-living nematodes are much larger. Animal parasites show a vast range from less than 5 mm to a metre.

The buccal cavity has usually teeth or cutting plates. The buccal cavity of plant parasitic (phytoparsites) nematodes have usually a spear or stylet, instead (Fig. 16.7). The sexes in nematodes are nearly always separate (i.e. dioecious) and readily distinguishable externally (sexual dimorphism).

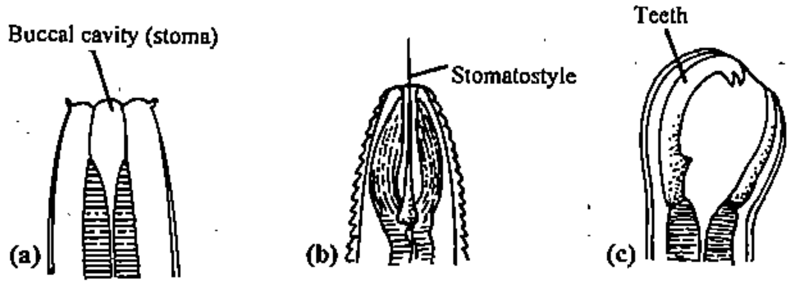



**Fig. 16.7: Nematode buccal cavities (a) Free living bacteriovore, *Rhabditis* (b) the plant root parasite, *Criconemoides*. (c) The intestinal parasite, *Ancylostoma*.**

## 16.3.2 Plant Parasitic Nematodes

Plant parasitic nematodes or phytoparasitic nematodes cause extensive damage to cultivated plants, resulting in heavy losses. Most cultivated plants are affected. The damage may be caused directly, or indirectly when the parasitic phytonematodes transmit plant viruses or allow other pathogens to gain entry into the plant through damaged areas created by these nematodes. All the plant parasitic nematodes possess a sharp, pointed, protrusible buccal stylet or spear (Fig. 16.7 b). This is used to puncture plant cells. The parasitic nematode suck the cell sap from the punctured cells. The nematode also injects saliva into plant cell while feeding. This saliva is toxic to plants and causes many symptoms in the infected plants.

The life cycle of plant parasitic nematodes (Fig. 16.8) is simple. The adult female lay 200-500 eggs. The first stage larva or juvenile moults within the egg to form the second stage larva or juvenile which comes out of the egg into the soil and then enters the root of the host plant and starts feeding. Three more moults follow giving rise to the adult with fully developed reproductive system. In some plant parasitic nematodes like Meloidogyne species and Heterodera species, only the female is parasitic, while the male develops from the second stage juvenile into a free living adult that lives in the soil.

The phytoparasitic nematodes spread from one plot to another through percolating water or through soil which is transported from place to place. Flood water also causes extensive spreading. Contaminated seed material is also an important source of spread of these nematodes.

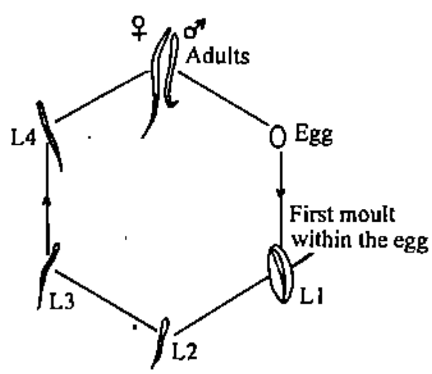



**Fig. 16.8: Generalized life cycle of a plant parasitic nematode showing the four larval stages - L1, L2, L3, L4.**

### Symptoms on Plants due to attack by some Phytoparasitic Nematode

The nematode *Aphelenchoides* damages the buds and shoot tips and causes distortion of stem and crinkling of foliage. The juveniles of *Anguina* cause damage of leaves and wheat grains. *Ditylenchus* is responsible for extensive rot of potato tuber and onion bulbs. *Pratylenchus* and *Radopholus* cause root lesions as well as root rot in chillies, coffee, corn, cotton, rice, pineapple, wheat, banana, coconut, sweetpotato, tomato etc. The female of *Meloidogyne* is parasitic (Fig. 16. 9 a) and causes formation of root galls or knots in the roots of many plants specially the solenaceous plants. Meloidogyne species affect chillies, tomato, brinjal, carrot, cotton and a number of other useful crops. *Heterodera* species (Fig. 16.9 b) are the root cyst nematodes and occur in colder climates. The female of *Heterodera* forms resistant cysts full of eggs. *Heterodera* species damage potato, sugarbeet, oats, wheat, cabbage tobacco etc.

Some specific symptoms due to nematode infestation are poor crop growth, winter injury, wilting of trees, loss of seedling, stunting of plant, patchiness in leaves and growth and discoloured foliage in a crop.

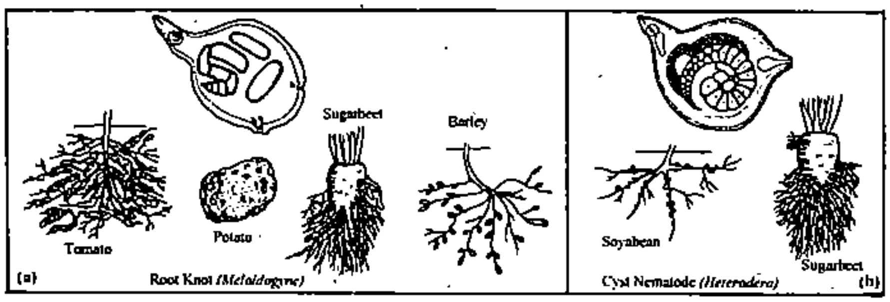



**Fig. 16.9: Some important plant parasitic nematodes and the damage they cause (a) Meloidogyne species (b) Heterodera species.**

## 16.3.3 Animal Parasitic Nematodes

Just like plant nearly all vertebrate and invertebrate animals are parasitized by nematodes.

### ASCARIOD NEMATODES

A number of these nematodes are very important pathogens of humans and domestic animals of which *Ascaris lumbricoides* the common human round worm is an important pest. It is found more commonly in children than in adults (Refer to unit 4 of course for more details about this nematode).

### THE PIN WORM (*Entorobius vermicularis*)

The pin worm, *Enterobius vermicularis*, is most common among children (see unit 4). Adult worms are about 10 mm and live in the caecum of large intestine. The adult female deposits eggs at the anal region. This causes intense itching in the perianal region. While scratching, the finger tips of the children get contaminated with the eggs. These eggs get into the mouth of children when they suck their finger and so are swallowed. In the intestine the eggs hatch and develop into adult worms in 3-4 weeks. The parasites however except for intense itching cause comparatively little disease symptoms.

### THE HOOK WORM (*Ancylostoma duodenale* and *Necator americanus*)

The common hookworms of man, *Ancylostoma duodenale* (common in the old world) and *Necator americanus*, occur widely in the developing nations of the tropics and in the temperate regions of the world. The mouth region of these parasites is usually provided with cutting plates, hooks teeth or a combination of these structures for attaching to the gut wall of the host. Adult worms live attached to the mucosal wall of the intestine.

Female lays several thousand eggs per day, which escape via faeces. The larvae on hatching come out of the eggs in the soil. In about a week's time they become infective juveniles and gain entry into the human host by penetrating the skin of their feet. These larvae then travel through circulating blood to reach the lungs, into the air passages, the trachea, to the epiglottis and when swallowed, enter the gut. In the intestine the juveniles become firmly attached to the mucosal wall and feed on blood and abraded tissue, for which their hooks, cutting plates and teeth are useful. Within a week's time they develop into full adults reaching about 10 mm in length. Hookworm infections cause mechanical damage to the intestinal wall and loss of blood resulting in anaemia. Infected persons show stunted growth.

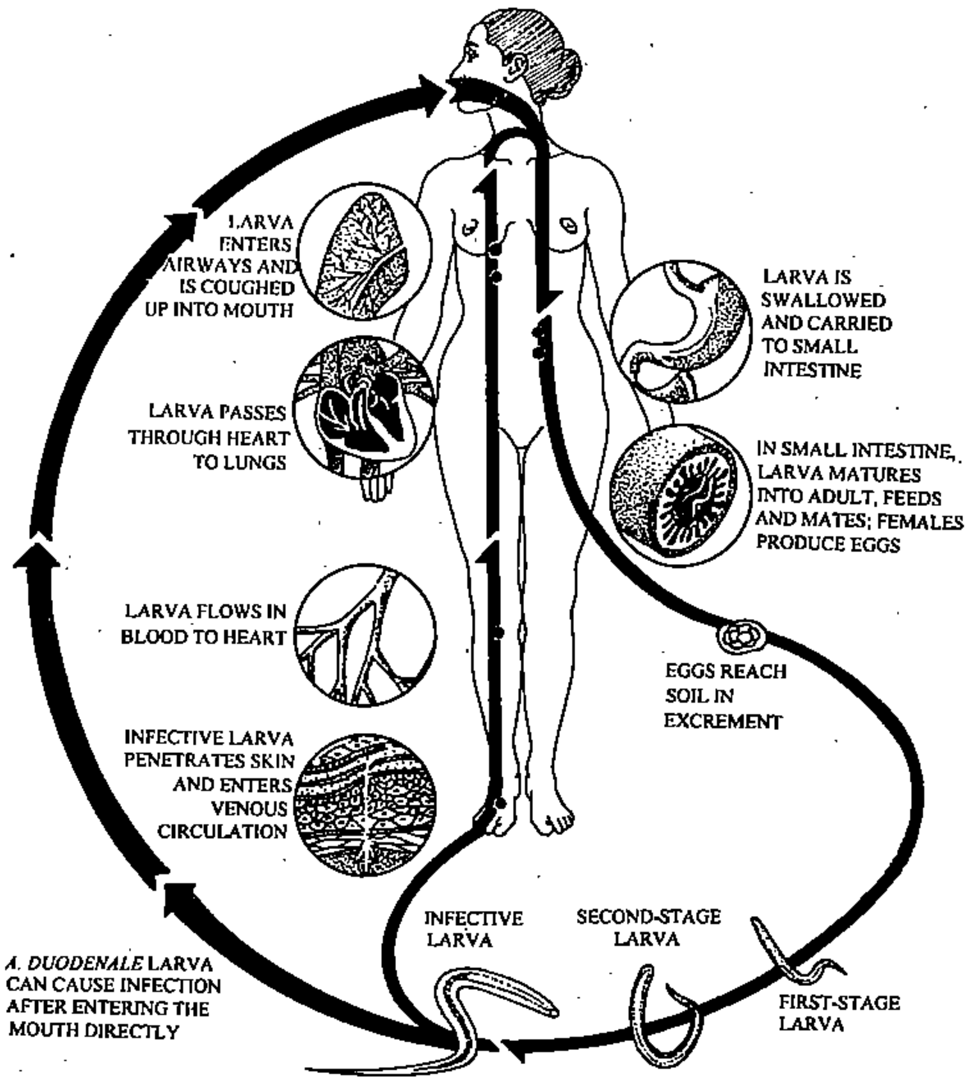



**Fig. 16.10: A generalized life cycle of hookworm.**

## THE WHIPWORM (*Trichuris trichiura*)

Whip worms or *Trichuris* are parasites in the alimentary tracts of vertebrates, especially human beings, dogs, cats, cattle and other mammals. They are relatively small in size. *Trichuris trichiura* is parasitic in humans. The adult is about 4 cm long and lives in the large intestine.

The life cycle is similar to that of the pinworm. The eggs are ingested by the host along with contaminated food and hatch into larvae which pass into the caecum of the large intestine and develop into adult worms in about 3 months. In the case of heavy infection, the worms cause diarrhoea and dysentery. (Refer also unit 4 of LSE-09).

## THE TRICHINA WORM (*Trichinella Spiralis*)

*Trichinella spiralis* is a minute (about 3 mm long) nematode found in rats, pigs and human. In humans it causes the disease **'trichinosis'** which is prevalent in most countries of the world. Both larvae and adults are present in the same host. However, infection requires another host. Adult worms (Fig. 16.11) live in the mucosa of the small intestine. They do not have much effect on the host then. The adult female bores through the intestine into a spiral lymph space and gives birth to about a thousand juveniles at a time. The juveniles enter the blood stream and are carried throughout the body where they may be found in almost any tissue or body space. Eventually they penetrate the skeletal muscles and encyst there. The cyst walls gradually calcify. The skeletal muscle cells of the host undergo extensive changes and serve to nourish the juveniles. There is no further development till these cysts are ingested by a new host. When humans ingest pig meat containing the juveniles the cysts break down and the juveniles escape in the intestine where they mature. Humans are usually infected due to eating poorly cooked pork.

Heavy infection may be fatal leading to trichinosis and even death. Severe pain and inflammation as well as toxic damage occur when the juvenile encyst in muscles. They cause degeneration of muscle tissue.

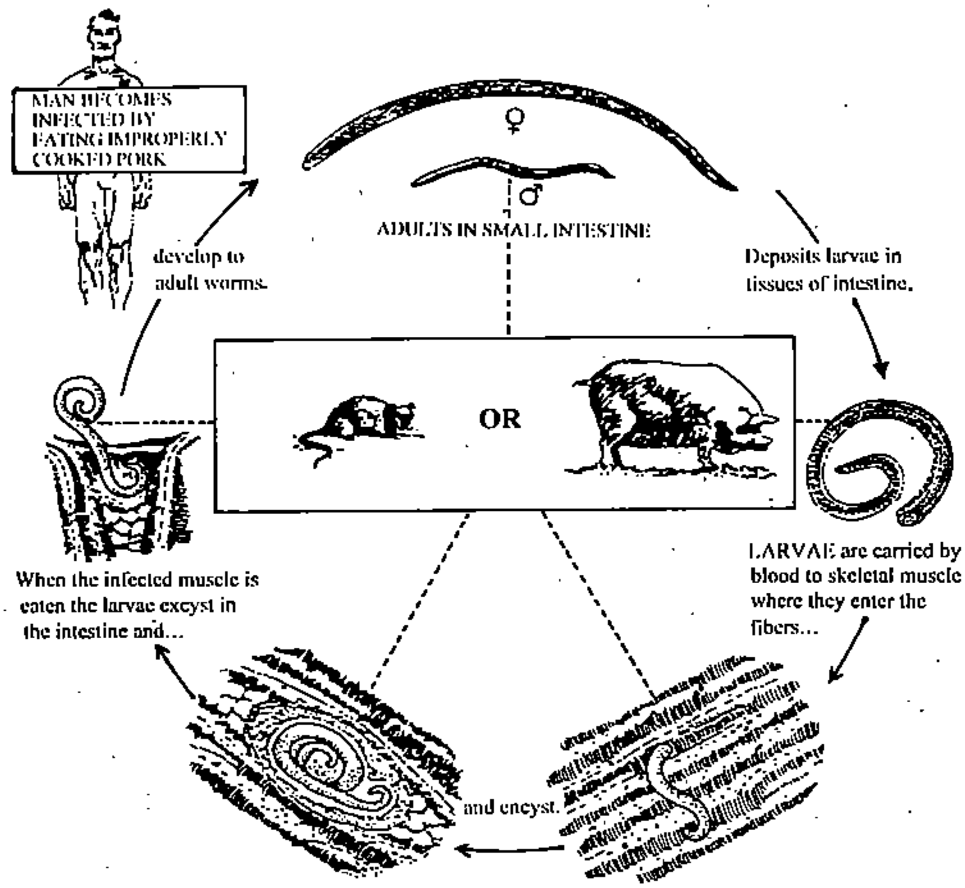



Fig. 16.11: Life cycle of *Trichinella spiralis*.

## FILARIAL NEMATODES

Several species of filarial nematodes are parasites of humans and cause diseases. These are thread-like worms and inhabit the lymph glands and lymphatic vessels. The female gives birth to juveniles called microfilariae. The life cycle of these nematodes require an arthropod intermediate host such as certain species of fleas, flies or mosquitoes.

## FILARIASIS WORM (*Wuchererla Bancrofti* and *Brugia Malayi*)

About 250 million people in tropical countries are infected with *Wuchereria bancrofti* (40-90 mm long; 1-24 mm broad) or *Brugia malayi* both of which have certain species of mosquitoes as their intermediate host. These nematodes are responsible for causing the disease **'filariasis'**, and in extreme cases, **'elephantiasis'**.

The life cycles of both *Wuchereria bancrofti* and *Brugia malayi* are similar. Adults live in th lymphatic ducts. The larvae or microfilariae are liberated in the blood and lymphatic system. They show nocturnal periodicity i.e., they move to the peripheral blood vessels at night.

Certain specific mosquito species (refer to subsection 16.4.2 of this unit) act as intermediate hosts. When these bite the infected human host, the microfilariae enter the mosquito with the host's blood. Development within the intermediate host involves migration of the microfilariae through the gut to the thoracic muscles and then into the proboscis. From the proboscis the microfilariae are introduced back into the primary host, when the mosquito bites a another human.

In severe filarial infections the blocking of the lymph vessels by large number of worms causes serious lymphatic inflammation marked by pain and fever. In chronic (long term) infection, increase of connective tissue (fibrosis of infected areas) may cause irrevesible massive enlargement and deformites of lower extremities such as legs, arms and sometimes scrotum (vulva and breast are rarely affected). Such enlargement is called '**elephantiasis**' and can only be corrected by surgery. Fortunately extreme cases of elephantiasis are now rare.

In India this disease is very damaging and is prevalent in Eastern Uttar Pradesh, Bihar, West Bengal, Orissa and Eastern coastal regions of India.

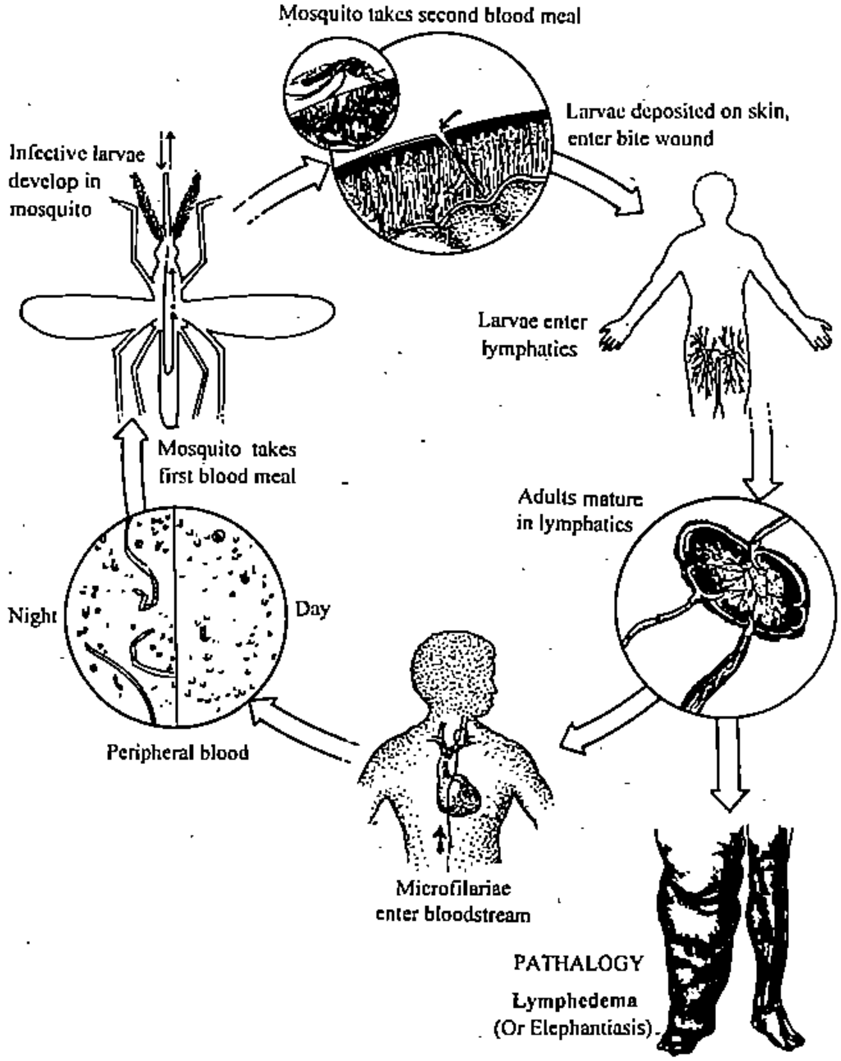



Fig. 16.12: Life cycle of *Wuchereria bancrofti*.

## RIVER BLINDNESS WORM (*Onchocerca Volvulus*)

Onchocerca volvulus is another filarial nematode, which causes the disease known as river blindness or onchocerciasis in humans. This disease affects more than 30 million people in parts of Africa, Arabia, Central America and South America. It causes severe itching and damage to the eye and ultimately leads to blindness. The intermediate host is the black fly *Simulium*.

## THE GUINEA WORM (*Dracunculus medinensis*)

*Dracunculus medinensis*, the 'Guinea Worm' is a thread like nematode. It is a common parasite of humans throughout Africa, the Middle East, Pakistan, and parts of India, particularly Rajasthan and Gujarat. The female is about 1 mm in diameter and upto 120 cm in length.

The gravid female, after a period of development in the body cavity and connective tissue of the human host migrates to the subcutaneous tissue and produces a painful blister that bursts to form an ulcerated opening. If the ulcerated area of the host comes in contact with water, the active first stage juvenile larvae are discharged into the water. The juveniles are ingested by a fresh water copepod crustacean *Cyclops* which acts as the vector. In the *Cyclops* the juvenile mouths twice to form the infective stage. The infective juvenile re-enters the human host through infected drinking water. The nematode juveniles are released from the ingested cyclops, in the human gut. These juveniles then penetrate the intestinal wall to reach subcutaneous tissues which is their final destination. Here the juvenile moults twice and becomes an adult.

Intense allergic reactions occur, characteristically when the gravid female migrates to the skin tissue. The worms can be removed surgically

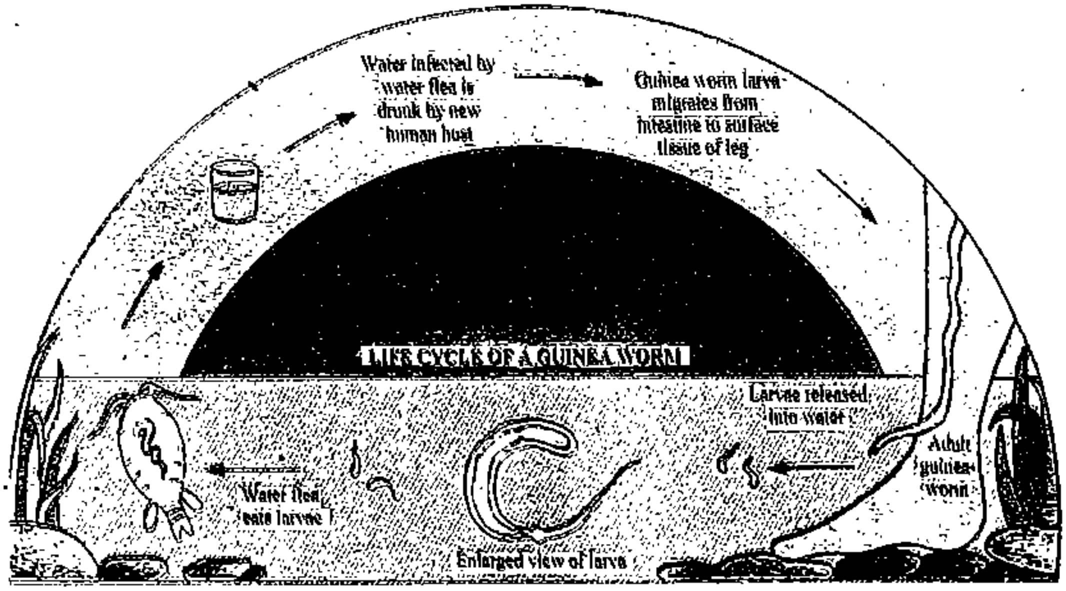



Fig. 16.13: Life cycle of the Guinea worm, *Dracunculus medenensis*.

## SAQ 3

Match items listed in column A with those listed in column B:

| Column A | Column B |
|---|---|
| 1. *Fasciola* | i. whip worm |
| 2. *Clonorchis sinensis* | ii. Chinese liver fluke |
| 3. *Schistosoma* | iii. Hookworm |
| 4. *Paragonimus* | iv. Blood fluke |
| 5. *Taenia solium* | v. Dog tapeworm |
| 6. *Echinococcus* | vi. Pig tapeworm |
| 7. *Ascaris lumbricoides* | vii. *Cyclops* |
| 8. *Ancylostoma* | viii. Elephantiasis |
| 9. *Dracunculus* | ix. Sheep liver fluke |
| 10. *Wuchereria* | x. Common human roundworm |
| 11. *Trichuris* | xi. Lung fluke |
| 12. *Heterodera* | xii. root-knot nematode |
| 13. *Meloidogyne* | xiii. plant cyst nematodes |

## 16.4 INJURIOUS AND HARMFUL ARTHROPODS

As you have studied in section 5.3 of unit 5 Block II, the Phylum Arthropoda constitutes the largest assemblage of species in the animal kingdom. Many of these are prominent source of diseases of man, domesticated animals and cultivated plants, and cause extensive injury to them. Some also transmit pathogens, like viruses, bacteria, fungi and protozoans.

### 16.4.1 Arachnids of Medical, Veterinary and Agricultural Importance

The economically important orders of this class are (I) Scorpiones (Scorpions) (II) Araneae (spiders) and (III) Acarina (ticks and mites). Refer to unit 5 of this course where distinguishing features of the taxa mentioned here are already given at the level of order.

**(I) SCORPIONS**

The scorpions possess 'sting'. The venom of the sting of most scorpions produces only localised reaction (Refer Fig. 5.42 of unit 5 of this course).

### (II) SPIDERS

Spiders are predaceous and carnivorous. They generally feed on insects and are helpful to human, and are only rarely dangerous to them (Refer Fig. 5.46 of unit 5 of LSE-9). However some venomous spiders (Fig. 16.14) are harmful to humans.

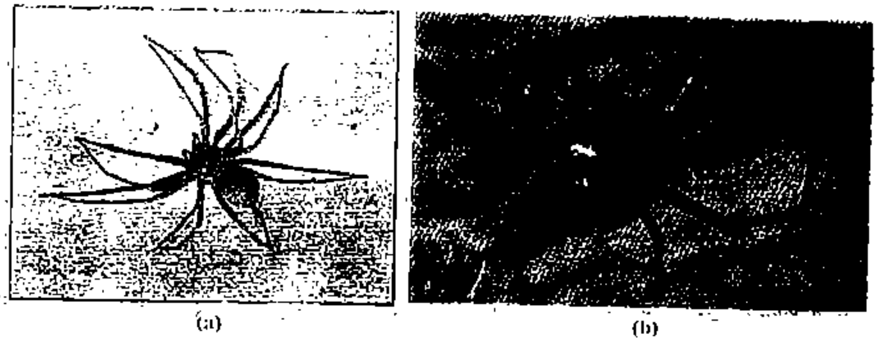



**Fig. 16.14: Venomous spiders (a) Brown recluse spider *Loxosceles reclusa* (b) Female black widow *Latrodectus mactaus*. The red hour glass marking on the under side of the abdomen is a distinguishing feature of the species.**

### (III) ACARINA

Acarina comprise mites and ticks. Many of these are parasitic on man, his domestic animals and crops or are vectors. Many others are destructive to food and other useful products. Most mites are 1 mm or less. Ticks are larger than mites. Some species of ticks reach 3 cm in length (Refer Fig. 5.52 of Unit 5).

**Plant Mites**

The plant mites belong mostly to two families: Tetranychidae and Eriophyidae. Tetranychid mites are known as spider mites (Fig. 16.15 a). Their body is unsegmented (not divided into cephalothorax and abdomen) and has four pairs of legs. Eriophyid mites (Fig. 16.15 b) have vermiform body distinctly divisible into a cephalothorax and a long, tapering abdomen, and two pairs of legs which are situated near the anterior end of the body.

Plant mites damage plants in the following ways:-

1. They suck plant material. This results in loss of vitality of plants.
2. They cause severe deformities such as galls in plants.
3. Some mites transmit virus diseases.

*Tetranychus cinnabarinus* (= *T telarius*) the red spider mite (Fig. 16.15 a) is an important example of phytophagous mite which attacks cotton, castor, citrus, brinjal, pumpkin, chow-chow, grapevine, papaya, mulberry, jute, tea etc.

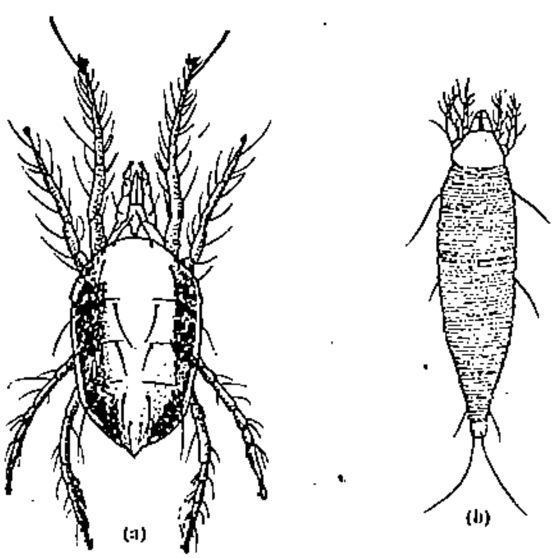



**Fig. 16.15: (a) Tetranychid mites: The red spider mite, *Tetranychus cinnabarinus* ( = *T. telarius*) (b) Eriophid mite : a minute plant parasitic gall mite *Eriophys*.**

## MITES AND TICKS OF VETERINARY AND MEDICAL IMPORTANCE

### CHICKEN MITE (*Dermanyssus gallinae*)

These (Fig. 16.16) suck the blood of fowls, through their sharp piercing mouth parts. When the number of chicken mite increases, egg-laying as well as weight gain in fowls is affected.

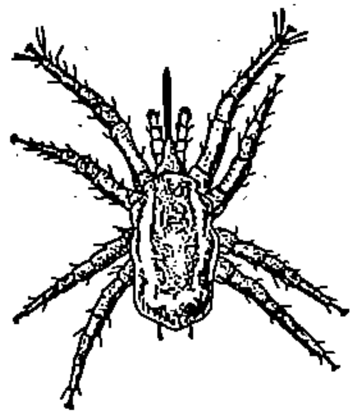


**Fig. 16.16: The chicken mite (*Dermanyssus gallinae*) nymph before gorging on blood.**

### SHEEP SCAB MITE (*Psoroptes*)

The sheep scab mite, *Psoroptes* (Fig. 16.17) infests the skin of sheep, goats and cattle. The attack results in loss of wool.

**Fig. 16.17: The female of sheep scab mite (*Psoroptes equii ovis*).**

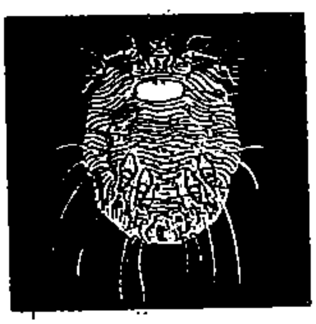


**Fig. 16.18: Mange or itch mite, *Sarcoptes scabiei*.**

### ITCH MITE (*Sarcoptes scabiei*)

The human itch mite (*Sarcoptes scabiei*) (Fig. 16.18) is responsible for human scabies. It lives in cutaneous burrows of the skin, where eggs are laid and development takes place. The burrowing and feeding of mites cause extreme itching which is the chief symptom of the disease. The mites spread through contact of the patient or his clothings.

### CHIGGERS

Chiggers are the parasitic larval stages of the mites of the family Trombiculidae eg. *Eutrombicula* and *Trombicula*. They attack poultry, ground resting birds, and mammals, including man. Their attack results in scattered red blotches on skin accompanied by intense itching.

### TICKS

All ticks are parasites of vertebrates. They feed for days or weeks through the skin of their hosts. They cause local inflammatory damage and itching. They serve also as vectors of diseases caused by many viruses, ricketsiae, bacteria and protozoa.

### CATTLE TICK (*Boophilus*)

Cattle Ticks (Fig. 16.19) feed on cattle, sucking their blood. They transmits 'Texas fever', as they serve as the vector of the organism responsible for the fever which is the protozoan parasite, *Babesia*.

Fig. 16.19: Cattle tick *Boophilus microplus*.

## SAQ 4

a) State whether true or false.

(i) All spiders are predacesus and carnivorous.

(ii) Spiders belong to the Order Araneae.

(iii) The main distinguishing feature between ticks and mites is the difference in the thickness of their cuticle.

(b) Match the items listed in **Column A** with those in **Column B.**

| | Column A | | Column B |
|---|---|---|---|
| i) | *Tetranychus* | (a) | Attacks a number of important vegetables |
| ii) | *Sarcoptes scabiei* | (b) | Texas fever |
| iii) | *Boophilus microplus* | (c) | itch mites |
| iv) | *Psoroptes equi ovis* | (d) | poultry mite |
| v) | *Dermanyssus* | (e) | sheep scab mite |

(c) Fill in the blanks with appropriate choices.

(i) The cattle ticks belong to the genus ................................ .
(ii) The parasitic protozoan responsible for Texas fever is the ................................ .
(iii) Tetranychid mites are known as ................................ mites.

### 16.4.2 Insects of Medical Importance

Many insects transmit diseases in humans and domesticated animals. Others cause much damage to crops, stored products and forests. A number of them serve as vectors of viruses and other microorganisms which produce diseases in plants.

**Mosquitoes**

Mosquitoes (Order Diptera) have a world wide distribution. They mostly affect warm blooded animals like birds and mammals, including humans.

The most important mosquitoes which affect man belong to the genera *Anopheles*, *Culex*, *Aedes* and *Mansonia* (Fig. 16.20). *Anopheles* species are vectors of a malaria parasite *Plasmodium*. The main malarial vectors in India are *Anopheles culicifacies*, and *Anophelese stephensi*. *Culex fatigans* is the chief intermediate host of the filarial nematode (*Wuchereria bancrofti*) which causes filariasis. Encephalitis viruses are transmitted by *Culex tarsalis*. *Mansonia* transmits the filarial nematode *Brugia malayi*. Certain species of genus *Aedes* spread yellow fever and dengue.

The male and female mosquitoes can easily be identified (Fig. 16.20). The males are smaller than females and do not feed on blood and their palpi are more prominent. The antennae of the females have whorls of short hairs but in males the antennae have many long hairs giving them a feathery or plumose appearance. The females also have specially elongated and modified mouthparts suitable for piercing and sucking human blood.

Mosquitoes develop in water (Refer to Fig. 16.20) which contains microscopic plants and animals that serve as food for the larvae. The eggs are laid on water or in places where water is likely to collect. The eggs of *Culex* are laid singly or in minute rafts or masses while those of anophiline mosquitoes are laid singly and have floats. Mosquitoes have four larval instars ("wrigglers").

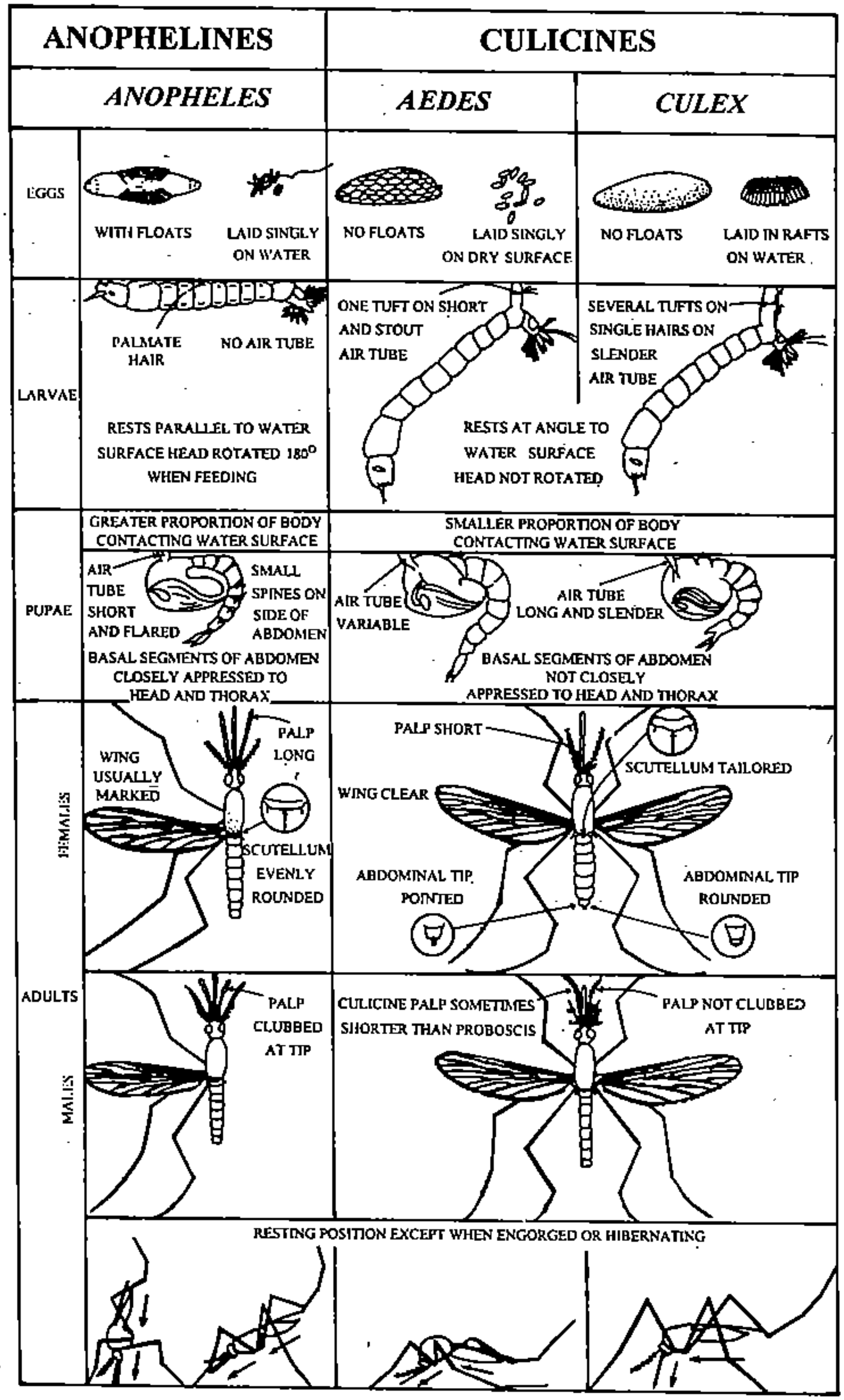



**Fig. 16.20: Diagrammatic representation of the principal characters separating the various stages in the life cycle of anopheline and culicine mosquitoes.**

Most mosquito larvae must come to the surface to breathe atmospheric air through spiracles which are often situated at the tip of an air tube called siphon. *Mansonia* larvae have specialised siphon which is capable of being inserted into roots or stems of aquatic plants from where oxygen for larval respiration is obtained. Larvae of anopheline mosquitoes however do not have siphons though they posses spiracles. They have also anal gills.

The full grown larvae change to the non-feeding but actively swimming pupae or "tumblers". They are comma shaped. Their cephalothorax has dorsally a pair of respiratory "trumpets".

The principal characters enabling one to distinguish differences between the anopheline and culicine mosquitoes and their developing stages are given in Table 16.1.

**Table 16.1: Principal characters distinguishing anopheline and culicine mosquitoes**

| Stage | Anophelinae | Culicinae |
|---|---|---|
| Eggs | Laid singly, possess floats | Laid singly or in egg rafts or masses. Never possess floats |
| Larvae | Never have a siphon. Lie parallel to water surface | All larvae have a short or long siphon. Subtend an angle from the water surface. |
| Pupae | Breathing trumpets short and broad apically. | Breathing trumpets long and tubular. |
| Adults (both sexes) | Rest at an angle to the surface. | Rest with the bodies more or less parallel to the surface. |

## SAQ 5

Fill in the blanks.

i) The four most important mosquitoes that affect humans belong to the genera ........................ ........................ ..................... and ...................

ii) ...................................... is the chief intermediate host of the filarial nematode *Wurcheria bancrofti.*

iii) ............................. species are vectors of malarial parasite *Plasmodium* species.

iv) The mosquito larvae are called ...................................... .

v) The *Mansonia* species transmit the filarial nematode ............................... .

vi) Male and female mosquitoes can be easily identified by their size, mouth parts, ............................... and ................................ .

vii) The mosquito .................................. transmits encephalitis virus.

viii) Dengue virus and yellow fever are transmitted by the mosquito species belonging to the genus ................................ .

### THE COMMON HOUSE FLY (Order -Diptera)

House flies are cosmopolitan in distribution. Though *Musca domestica* (Fig. 16.21) is world wide in distribution, in India, *Musca vicina* and *Musca nebulo* are more common.

Houseflies transmit a large number of diseases in man, through contamination of food. Some of the diseases they cause are typhoid fever, cholera, poliomyelitis, diarrhoea and dysentery. They also act as carriers of eggs of a number of worms (helminths).

Adult female lays eggs on decaying organic matter. The larva emerging from the egg is called a maggot.

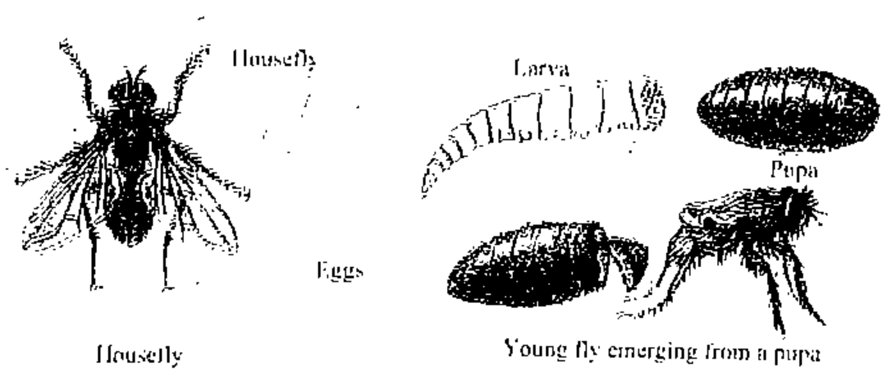



**Fig. 16.21: Life stages of the house fly, *Musca domestica*.**

### BED BUGS (Order - Hemiptera)

These are *Cimex* species. Bed bugs (Fig. 16.22) are nocturnal in habit. They are flattened dorsoventrally and their wings are reduced to inconspicuous pads. The adults as well as nymphs suck blood of man, other mammals and poultry. The two common species that parasitise humans are *Cimex lectularius* and *C. hemipterus*.

Fig. 16.22: Common bed bug.

### FLEAS (Order - Siphonoptera)

The human flea *Pulex irritans* (Fig. 16.23) and the rat flea or the oriental flea *Xenopsylla cheopis* are the common species. They suck blood and act as transmitters of a bacterium which causes bubonic plague.

Adult fleas are laterally compressed, wingless, with piecing and sucking type of mouth parts. Their posterior pair of legs are adapted for jumping.

Fig. 16.23: Female human flea, *Pulex irritans*.

### Human Lice (Order - Anoplura)

Three species of lice usually infect man. 1. Body louse - *Pediculus humanus corporis* (Fig. 16.24 a). 2. Head louse, *Pediculus humanus capitis*. 3. Pubic louse – or crab louse *Phthirus pubis* (Fig. 16.24 b). The head and body lice are vectors of relapsing fever, epidemic typhus fever and trench fever.

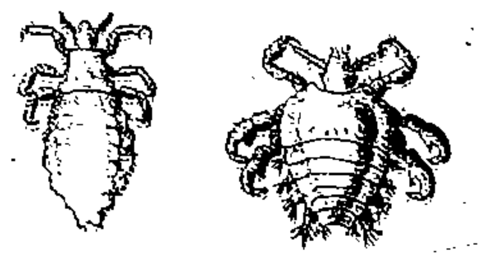


Fig. 16.24: Human lice (a) body louse is one of the most dangerous parasite. It is a carrier of epidemic typhus. (b) pubic louse *Phthirus pubis* lives on areas of the body with widely spaced coarse hair. For this reason its main location is the pubic area.

### Sand Fly (Order - Diptera)

Sand fly (Fig. 16.25) are responsible for spreading several diseases. *Phlebotomus argentipes* is the Indian species, responsible for spreading 'Kala Azar', oriental sore and phlebotomus fever. They are vectors of *Leishmania donovani* which causes Kala-azar and *Leishmania tropica* which causes Oriental sore, as well as of a virus which is the causative agent of phlebotomous fever.

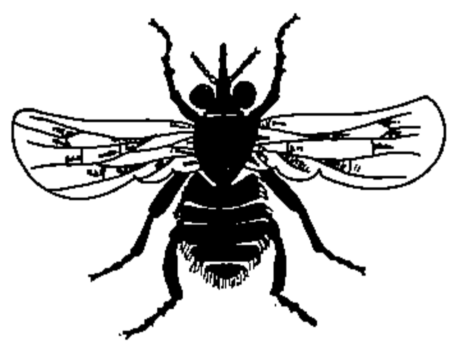


Fig. 16.25: Sand fly.

## SAQ 6

Match the following items listed in Column A with those listed in Column B.

| | Column A | | Column B |
|---|---|---|---|
| i. | *Musca domestica* | (a) | Flea |
| ii. | *Cimex* | (b) | Trench fever |
| iii. | *Pulex irritans* | (c) | Common house fly |
| iv. | *Pediculus humanus* | (d) | Bed bug |

## 16.4.3 Insects as Household Pests

**ANTS (Order - Hymenoptera)**

Ants are social insects (see unit 7 of this course). Some common Indian species are *Monomorium indicum*, and *Componotus compressus* (the large black ant known as the carpenter ant (Fig. 16.26 a and b) and *Dorylus labiatus* (the small red house ant). All these are house hold pests as their worker ants feed on a variety of material including the food we eat, seeds, fruits and nectar.

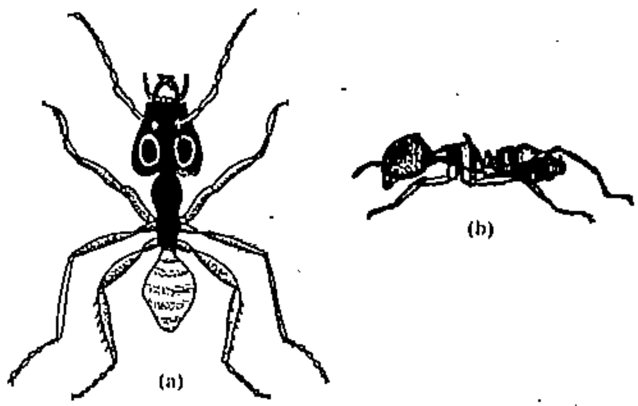



**Fig. 16.26: Ants (a) *Monomorium indicum* (b) worker of the *Camponotus compressus*.**

**TERMITES (Order - Isoptera)**

They are pests causing heavy damage to wood in all its forms, and to a number of house hold goods (Refer to unit 7 of this course for greater detail).

**SILVER FISH (Order - Thysanura)**

These are small, primitive, wingless insects, commonly found among books. Examples are: *Lepisma* (Fig. 16.27), and *Ctenolepisma*. These cause damage to a variety of materials on which they feed such as starched clothes, binding of books, etc.

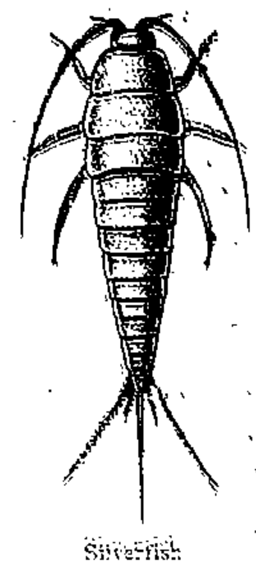


**Fig. 16.27: Silver fish.**

**COCKROACHES (Order - Orthoptera)**

Cockroaches (*Periplaneta americana* (Fig. 16.28), and *Blatta orientalis*) are very familiar. Both adults and nymphs cause damage, feeding on many kinds of materials like binding or leaves of books, and various food products in kitchens.

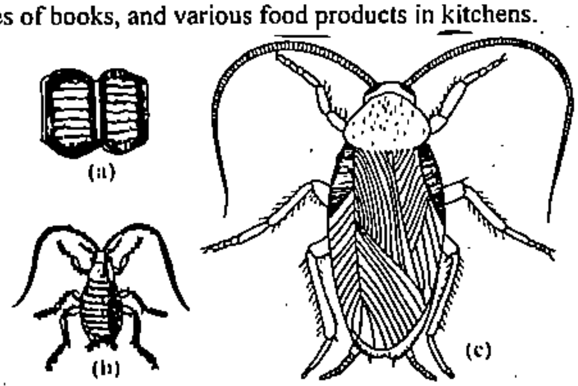



**Fig. 16.28: *Periplaneta americana* (a) Egg case with two longitudinal rows of eggs. (b) Second instar nymph. (c) Adult.**

The fertilized female lays about 30 eggs in a capsule or case called ootheca which is carried by the female for a few days before being deposited. The eggs hatch into nymphs which mature into adults (Fig. 16.28).

## 16.4.4 Insects of Veterinary Importance

### STABLE FLY (Order - Diptera)

The stable fly (*Stomoyxs calcitrans*) attacks mules, horses and other animals as well as man. It (Fig. 16.29) resembles the house fly but is smaller. Both males and females suck blook. Animal attacked by these flies lose weight, and their milk yield is reduced.

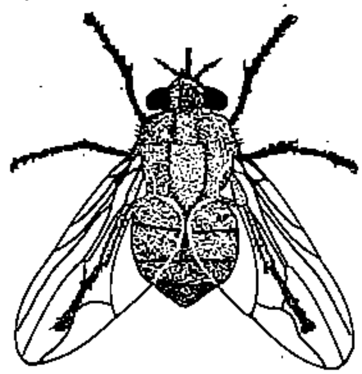


Fig. 16.29: Adult of the stable fly, *Stomoxys calcitrans*.

### HORSE FLY (Order - Diptera)

The horse flies (*Tabanus striatus*) resemble house flies but are larger and stouter. The females attack horses, cattles, dogs, humans, deer etc. They pierce the skin and suck blood. Blood continues to ooze from the wound even after the fly leaves the animal.

### OX WARBLE FLY (Order - Diptera)

The common cattle grub is the larval stage of the fly *Hypoderma lineatum* (Fig. 16.30). The maggots of these flies form tumour or cyst under the skin of the back of cattle. Each tumour contains a maggot. It emerges when mature and falls to the ground and pupates. Adult emerges from pupa. Eggs are glued to hair near hoof of the host and hatched maggots penetrate skin.

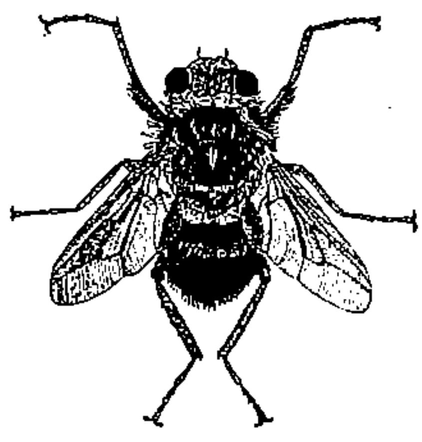


Fig. 16.30: Adult female fly of the common cattle grub, *Hypoderma lineatum*.

### BLOW FLY (Order - Diptera)

*Lucilia serenissima* is an example of blow fly. It is small, metallic blue or green in colour. Other blow flies are *Calliphora* and *Phormia*. Only larvae feed on livestock. Wounds attract female blow fly which lay eggs in them.

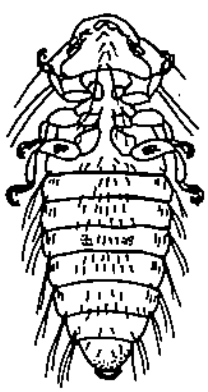


Fig. 16.31: The shaft louse *Menopon gallinae*.

### SHAFT LOUSE (Order - Mallophaga)

Shaft louse (*Menopon gallinae*) (Fig. 16.31) mainly infests chickens. The shaft louse feeds by nibbling or chewing dry skin scales, feathers or scabs on the skin of the host.

The irritation results in a nervous condition of the bird like sleeplessness, loss of appetite.

**CHICKEN FLEA (Order - Siphonoptera)**

The chicken flea *Echidnophaga gallinaceus* attacks chickens, and other poultry. Young fowls infested by chicken flea are often killed. Furthermore egg-laying and growth is severely affected in infested poultry.

## SAQ 7

Indicate which of the following statements are true (T) or False (F).

i) The common cattle grub forms tumours on the back skin of the host. ☐

ii) Only larvae of blow flies feed on the necrotic tissue of the host. ☐

iii) The horse flies (*Tabanus*) attack only horses. ☐

iv) The milk yield of cattle attacked by stable fly is often reduced. ☐

v) The common name of *Lepisma* and *Ctenolepisma* is ox warble fly. ☐

vi) The female of cockroach lays about 30 eggs in a capsule called ootheca. ☐

## 16.4.5 Insects of Agricultural Importance

Insects attack a large number of trees, vegetable, fruit and ornamental plants. Different parts of trees and plants may be attacked.

**Types of Losses of Agriculture**

Losses of agriculture by insects may be due to (1) direct losses to the plants (2) indirect losses.

**1. Direct losses are due to:**

i) Leaf eaters or defoliators - Such insects posses biting, and chewing type of mouth parts for eating leaves and often cause serious damage to the crop. Examples include grasshoppers, locusts, beetles, weevils and larval stages of caterpillars of moths and butterflies.

ii) Leaf miners - Insects of this group lodge in between upper and lower epidermis of leaves and devour their green parts eg. citrus leaf miner.

iii) Leaf rollers - Caterpillars of insects, feeding on leaves also cause the leaves to roll up which later shrivel and fall off eg. cotton leaf roller.

iv) Stem and root borers – Caterpillars of insects bore though the stems and roots of various plants, often seriously damaging them. As a result affected plants dry up and become stunted in growth - e.g. sugarcane stem borer and rice stem borer.

v) Sap suckers - Such insects pierce and suck cell sap of plants. They cause serious injury to the plants when present in large numbers e.g. rice gandhy bug, mustard aphis etc.

vi) Bark and wood feeders - This group consists primarily of caterpillars, beetles and weevils which tunnel between bark and wood of shrubs and trees e.g. bark eating caterpillar.

vii) Fruit destroyers - Insects of this group attack fruits, making them inedible for human consumption and unfit for seed purposes e.g. fruit flies.

viii) Seed feeders or storage insects - Much damage is caused to stored food material and grains by certain insects like rice weevil.

**2. Indirect losses to plants**

Most leaf hoppers and aphids indirectly damage host plants by secreting honey dew on their leaves which result in the development of sooty moulds. This retards the development and growth of the plants. Several sap suckers also indirectly transmit fungal, bacterial and viral diseases (called blight, mould, wilt) while feeding on plants. Beetles transmit bacterial wilt on cucurbits, leaf hoppers, aphids and fulgorids transmit viral diseases of tobacco, potato, peach etc.

Some insects restrict their attack to one species of plants and are called **monophagous.** Others attack and feed on a few related plant species and are called **oligophagous.** While many others attack a considerable number of host species and are called **polyphagous.**

In this section we will discuss two or three agricultural pests each of (1) Paddy, (2) Wheat, (3) Sugarcane, (4) Coconut, (5) Oilseeds, (6) Cotton, (7) Pulses, (8) Potato, (9) Vegetables, (10) Fruit, (11) Stored grains, (12) Teak trees.

To make this study easier we will first briefly study the polyphagous insects like termites, desert locusts and hairy caterpillars which attack a large number of plants. We will then describe two or three important pests of the above listed plants which may be monophagous, oligophagous or polyphagous.

## A. SOME POLYPHAGOUS PESTS

**Termites (Order - Isoptera)**

Termites have already been covered previously both in this unit (sub section 16.4.2) as well as in unit 7 of this course. The important crop damaging subterranean termite species are *Microtermes obesi* and *Odontotermes obesus*. Termites are polyphagous. They destroy wood and attack a large number of crops likes paddy, wheat, sugarcane, barley, cotton, groundnut, jowar, bajra, maize, chillies, brinjal, guava, lemon, mango, coconut stored grains, fruit trees, forest trees etc. The attacked plants show drying up of leaves and damaged buds.

**LOCUSTS (Order - Orthoptera)**

Locusts are grasshopper species which multiply rapidly when conditions are favourable. They form swarms and migrate from place to place travelling long distances and destroying vegetation on their way.

There are three species of locusts that occur in India.

1. *Schistocera gregaria* (desert locust)
2. *Locusta migratoria* (migratory locust)
3. *Patanga succinata* (Bombay locust)

Locusts are polyphagous and attack most plants. The locust have mainly two phases (1) Solitary (2) gregarious (Fig. 16.32).

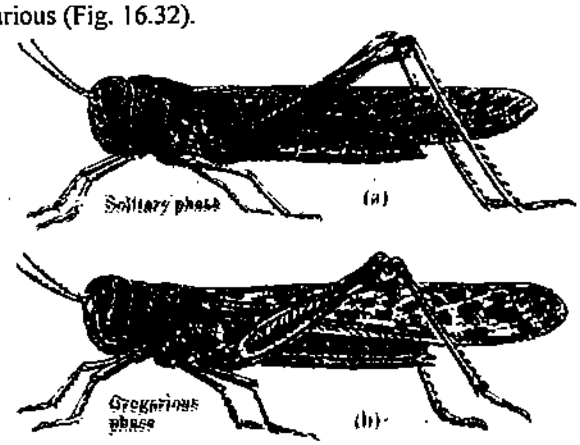
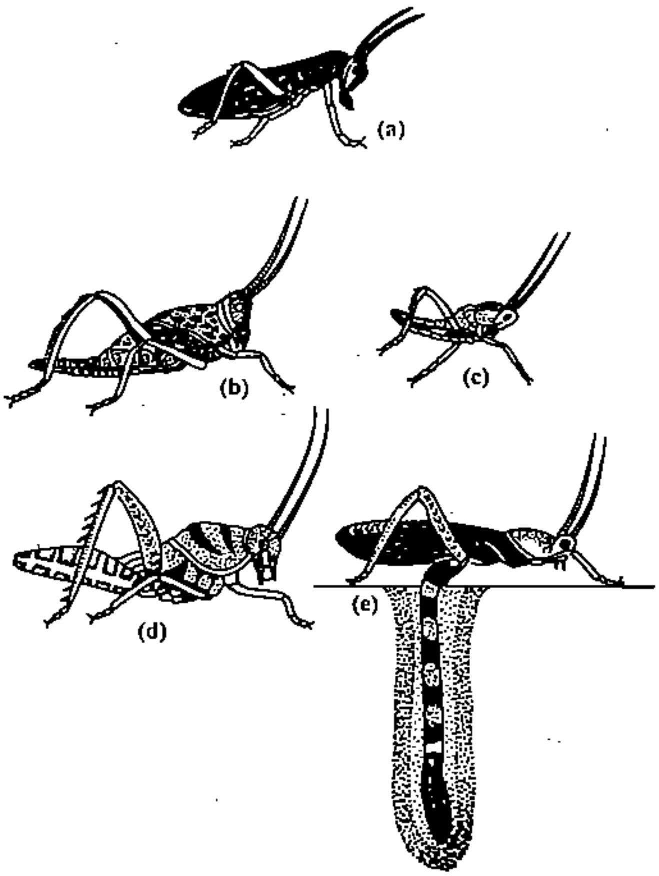



**Fig. 16.32: Locusts of the two phases are of different colours.**

In solitary phase the locusts are dispersed, leading solitary and sedentary life. They breed in desert area which in India are in Rajasthan, parts of Saurashtra and Baroda, Kutch and Hissar and some districts in Punjab.

In the gregarious phase, the locusts are more active and crowded. They form swarms and migrate long distances. The desert locust is the most destructive. It has a wide range of activity extending from Southern Portugal, Gibralter, North West, East and North East – Africa to Arabia, Israel, Northern Russia, Iraq, Iran, Turkey, Afghanistan, Pakistan and India.

he desert locusts copulate just after attaining maturity. The female lays 50-100 eggs in .undy soil in a compact cluster (Fig. 16.33).




ig. 16.33: *Schistocarca gregaria* – (a & b) nymphs of solitary phase.; (c & d) Nymphs of gragarious phase. (e) Female locust laying eggs.

## :ATTER PILLARS OF MOTHS (Order - Lepidoptera)

.arvae of moths and butterflies are called caterpillars. Many of these are polyphagous :specially, so the hairy caterpillars.

:he more important hairy caterpillar pests are:

. *Amsacta moorei* - Red Hairy caterpillar
:. *Diacrisia obliqua* - Bihar Hairy caterpillar

\ll these caterpillars are polyphagous attacking a variety of food plants. They are poradic pests and occur in large numbers during certain seasons.

## [HE RED HAIRY CATERPILLAR (*Amsacta moorei*)

[he red hairy caterpillar (Fig. 16.34) is a voracious feeder of leaves devouring almost any ;reen matter. The pest occurs regularly but assume epidemic proportion in certain years. ts main host plants are groundnut, cowpea, other pulses, cotton, maize, bajra, sun hemp :tc.

[he adult moth is medium sized and lays 800-1000 eggs in batches in her lifetime, on the ınderside of the leaf and even on the soil. The caterpillars feed on whatever green plant naterial is available and move from plant to plant devouring all that is their path. The 'ully grown red caterpillar pupates in the soil into a cocoon made of larval hairs. The noth emerges from the cocoon to start the next generation.

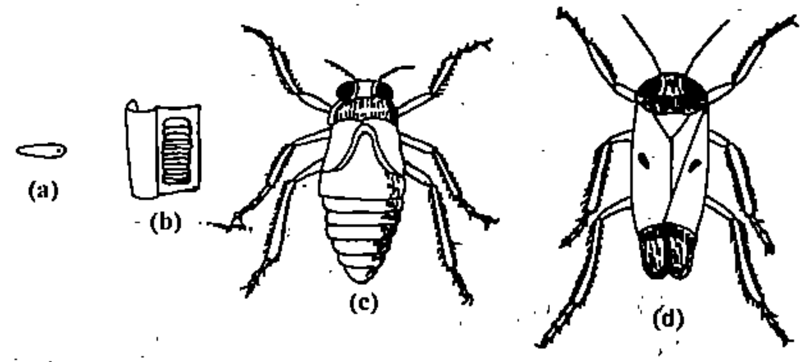



Fig. 16.38: *Nephotettix virescens*. , (a) Egg, (b) Eggs arranged in a row, (c) Nymph (d) Adult.

## RICE SWARMING CATERPILLAR (*Spodoptera mauritia*) Order - Lepidoptera

The caterpillars of *Spodoptera mauritia* (Fig. 16.39) when present in large numbers, cause severe damage to crop. They move in bands (and so are called swarming caterpillars), feeding voraciously and leaving behind leafless plants. The fully grown caterpillar pupates in the soil. The adult emerges from the pupa.

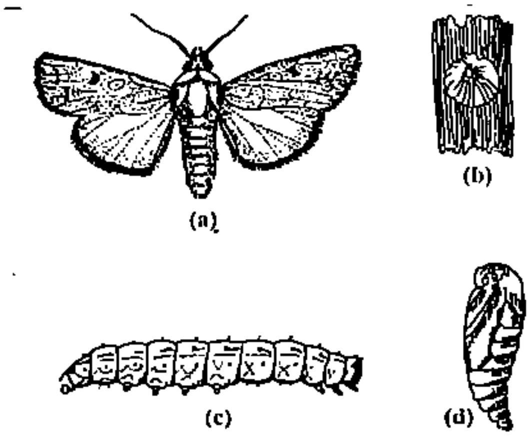



Fig. 16.39: Life history of *Spodoptera mauritia* (a) adult (b) egg- (c) larva (d) pupa.

## THE RICE STEM BORER (*Scirpophaga incertulas*), Order- Lepidoptera

The cater pillar of the rice stem borer *Sciropophaga* (*Tryporyza*) *incertulas* (Fig. 16.40). bores into the stem near the roots causing 'dead heart' or drying of central shoot which comes off easily when pulled. When plants are attacked at flowering stage, the panicles (ear head) dry up causing white ear heads.

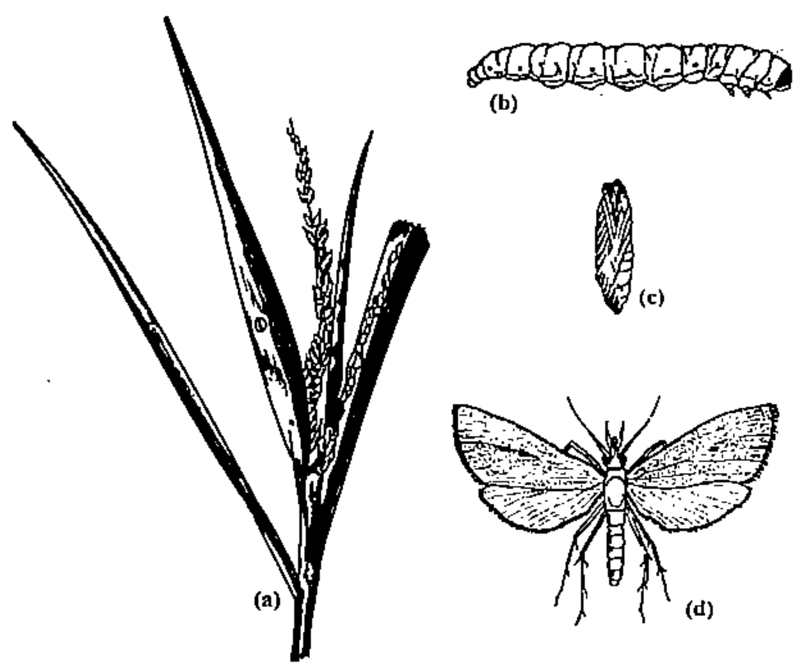



Fig. 16.40: Life cycle of the rice stem borer *Sciropophaga incertulas*. (a) a infested plant with egg; (b) larva; (c) pupa; (d) adult .

## PADDY ARMY WORM (*Mythimna separata*), Order - Lepidoptera



The caterpillar of *Mythimna separata* (Fig. 16.41) is the destructive stage. It feeds voraciously on the leaves and cuts the stem and unripe ears. The final larval stage cuts off rice panicle from peduncle, hence the term 'ear cutting'. It is this stage of caterpillar which causes maximum loss to crops. The fully grown caterpillar enters the soil, constructs an earthern chamber and pupates within it.

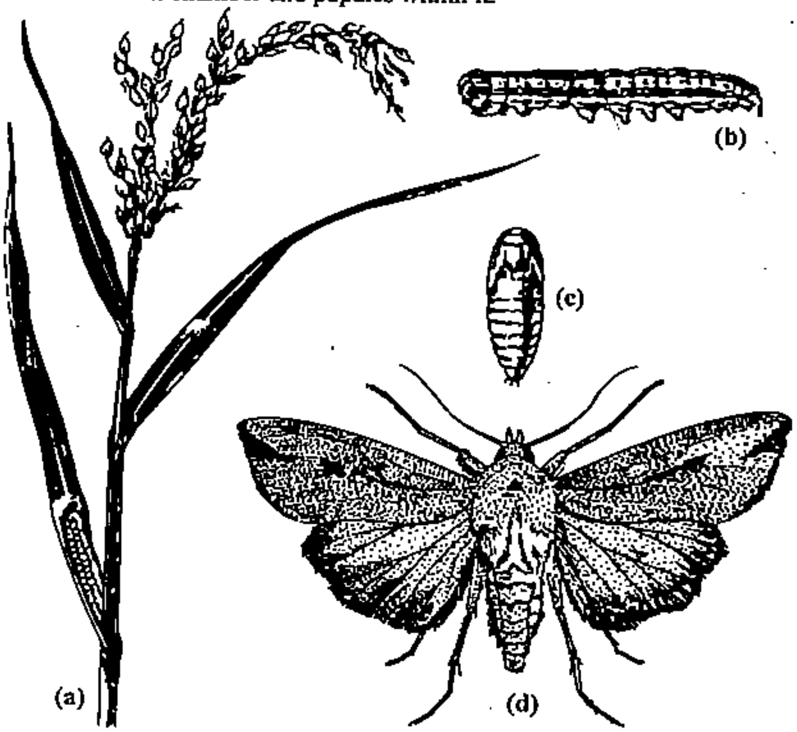



Fig. 16.41: Life Stages of *Mythimna separata* (a) eggs; (b) caterpillar; (c) pupa; (d) adult.

## RICE EARHEAD BUG (*Leptocorisa varicornis*), Order - Hemiptera

Both adult and nymph of *Leptocorisa varicornis* (Fig. 16.42) suck the sap of peduncle, tender stem and grains which are at the milky stage as a result of which they become chaffy.

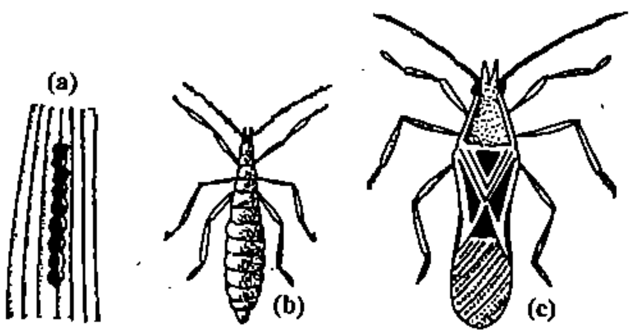



Fig. 16.42: Life history of *Leptocorisa varicornis*. (a) eggs; (b) nymph; (c) adult.

## PESTS OF WHEAT

Wheat is also attacked by a large number of pests.

**Some important pests include:**

1. *Agrostis ipsilon* - Cutworm
2. *Sesamia inferens* - Pink stem borer

## CUT WORM (*Agrostis ipsilon*), Order - Lepidoptera

The larval stage of *Agrostis ipsilon* (Fig. 16.43) damages the standing crops by cutting the tender plants at just above the soil surface. These larvae make earthern chambers underground and pupate within them. The moth emerges from the pupa at night.

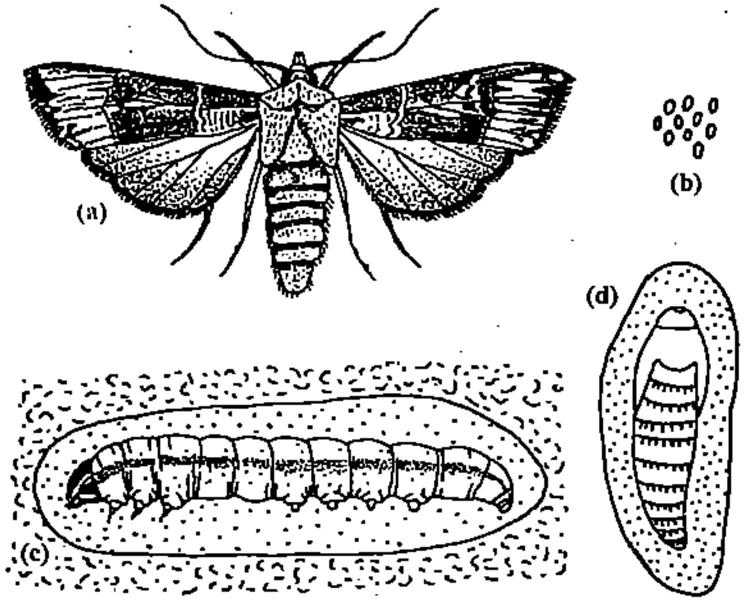



Fig. 16.43: Life stages of *Agrostis ipsilon*. (a) adult (b) eggs (c) larva (d) pupa.

**PINK STEM BORER (*Sesamia inferens*), Order - Lepidoptera**

Caterpillars of *Sesamia inferens* (Fig. 16.44) produce dead hearts similar to the rice stem borer.


Fig. 16.44: *Sesamia inferens* (a) Adult (b) Larva.

**PESTS OF SUGARCANE**

**The main destructive pests of sugarcane are:**

1. *Chilo infuscatellus* - The Shoot borer
2. *Pyrilla perpusilla* - Leaf hopper
3. *Sesamia inferens* - **Refer to pests of wheat of this unit**
4. ***Hieroglyphus nigrorepletus*** - **Grass hoppers - Refer to pest of paddy in this unit.**
5. ***Mythimna separata*** **– Paddy army worm - Refer to pests of paddy in this unit.**

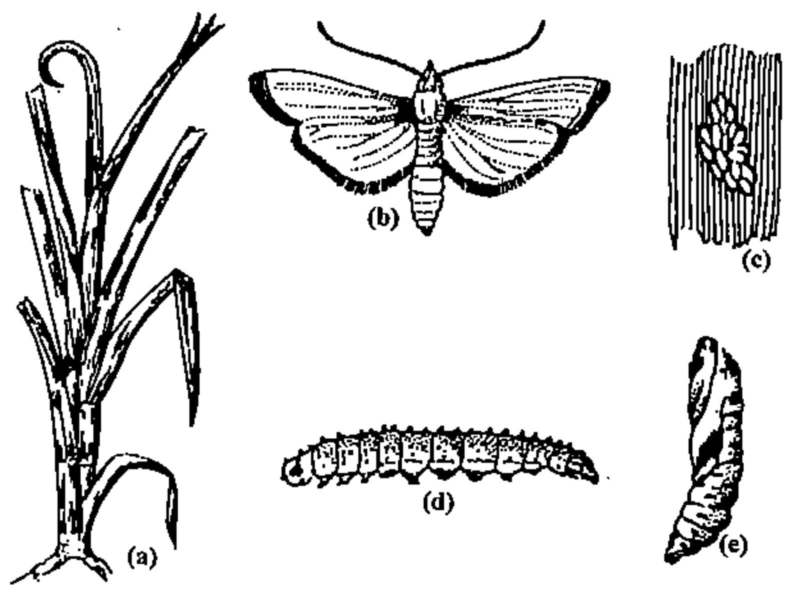



Fig. 16.45: Life history of *Chilo infuscatellus*. (a) Infested plant (b) adult (c) eggs (d) larva (caterpillar) (e) pupa.

## SUGARCANE SHOOT BORER (*Chilo infuscatellus*), Order-Lepidoptera

The caterpillars of *Chilo infuscatellus* (Fig. 16.45) bore into the stem and feed inside the soft tissues causing "dead heart". The adult moth lays eggs in clusters of 8-10 in rows on underside of leaves. The hatched caterpillars enter the stem just above ground level. Fully grown caterpillar pupate within the shoot or stem from which fully grown moth emerges.

## SUGAR CANE LEAF HOPPER (*Pyrilla perpusilla*), Order - Hemiptera

Both adult and nymph of *Pyrilla perpusilla* (Fig. 16.46) suck the cell sap of the leaves of sugar cane. Consequently the leaves turn yellow and dry up. The adult and nymph also secrete honey dew on the foliage. The honey dew attracts harmful fungi resulting in growth of black sooty mould due to which the rate of photosynthesis in the attacked plants is retarded, causing loss in sugar content of sugarcane.

The head of the adult insect is prolonged anteriorly into a snout-like structure called rostrum. The female has a pair of anal tufts which produces waxy filaments.

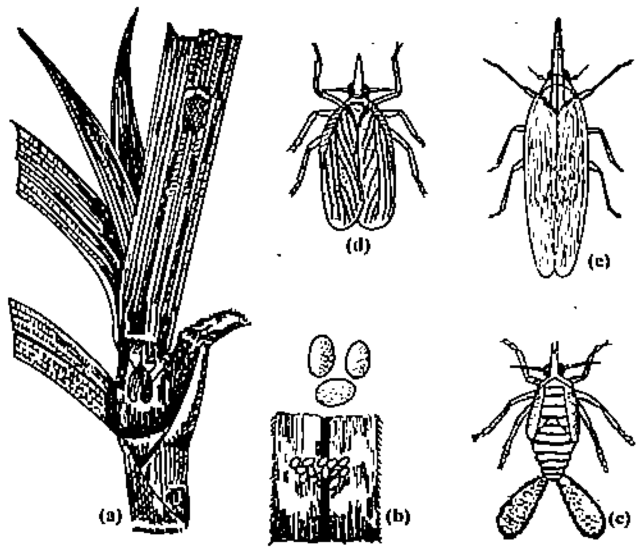



Fig. 16.46: Life history of *Pyrilla perpusilla*. (a) infested sugarcane plant (b) eggs (c) nymph (d) male (e) female.

## PESTS OF COTTON

Cotton suffers severely due to many insect pests. Some of these are:

- *Earias vitella* (*Earias fabia*) - Spotted boll worms
- *Dysdercus koenigii* - Red cotton bug
- ***Amsacta* spp. - Red hairy caterpillars - Refer to polyphagous pests of this unit.**
- ***Diacrisia obliqua* - Bihar hairy caterpillar - Refer to polyphagous pests of this unit.**
- ***Mythimna separata* - Cut worm - Refer to paddy pests of this unit.**

## SPOTTED BOLL WORM (*Earias vitella*), Order - Lepidoptera

The caterpillar of spotted boll worm (*Earias vitella = E. fabia*) (Fig. 16.47) bores into the growing shoots of cotton plants when the plants are 6 weeks old, causing the plants to droop and wither. Later when the flower buds and cotton bolls appear they are also attacked by the caterpillars and are consequently damaged. Due to this the bolls are shed.

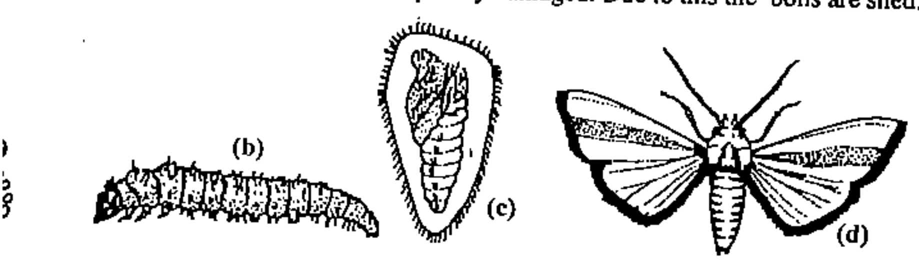



Fig. 16.47: Life history of *Earis vitella*. (a) eggs (b) larva (c) pupa (d) adult.

## RED COTTON BUG (*Dysdercus koenigii*), Order - Hemiptera

Both the adults and nymphs of *Dysdercus koenigii* (Fig. 16.48) damage the host plant as well as the bolls by sucking their sap.

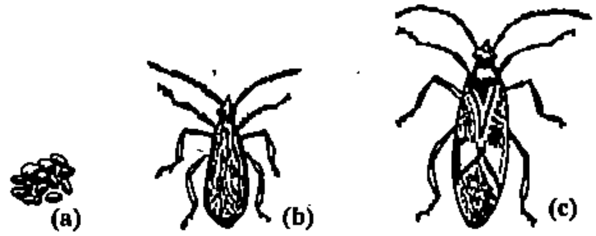



Fig. 16.48: Life history of *Dysdercus koenigii*. (a) eggs (b)nymph (c) adult.

## PESTS OF OIL SEEDS

Oil is excracted from the seeds of several types of plants like castor, ground nut and coconut palm. All these are often attached by insect pests.

## PESTS OF CASTOR PLANT

The following are some important pests of castor.

1. *Achaea janata* - Castor semilooper
2. ***Amsacta moorei*** **- Red hairy caterpillar - Refer to polyphagous pests in this unit.**

## CASTOR SEMILOOPER (*Achaea janata*), Order - Lepidoptera

The caterpillars of *Achaea Janata* (Fig. 16.49) feed voraciously on leaves and when they attain full growth, they pupate in the soil. Adult emerges from the pupa.


Fig. 16.49: Life history of *Achaea janata* (a) full grown semi looper caterpillar (b) Adult

## PESTS OF GROUNDNUT CROP

**Some important pests of Groundnut are:**

1. *Aphis craccivora* - Groundnut aphid
2. ***Amsacta moorei*** **- Red hairy caterpillar - Refer to polyphagous pests in this unit.**
3. ***Diacrisia obliqua*** **- Bihar hairy caterpillar - Refer to polyphagous pests in this uni**
4. ***Agrotis*** **spp. - Cut worm - Refer to wheat pests in this unit**
5. ***Heliothis armigera*** **- Gram pod borer - Refer to pests of pulses later in this unit.**

## GROUNDNUT APHID (*Aphis craccivora*), Order - Hemiptera

Large number of adults (Fig. 16.50) and nymphs of *Aphis craccivora* may be observed on tender shoots sucking the cell sap. Consequently the shoots dry up. These aphids act also a vector for "rosette disease" in groundnut. Population of these pests on plants increase very rapidly. Infestation on the groundnut crop usually occurs 4-6 weeks after sowing.

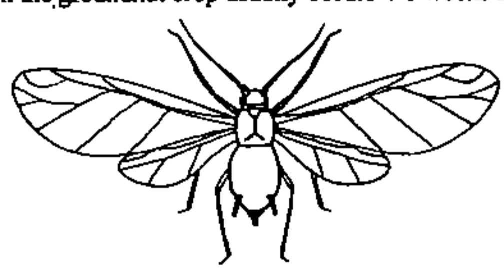


Fig. 16.50: Adult of *Aphis craccivora*.

## PESTS OF COCONUT PALM

**Some pests of Coconut Palm are:**

1. *Rhynchophorus ferrugineus* - Red palm weevil

2. *Oryctes rhinoceros* - Rhinoceros beetle
3. *Opisina arenosella* (=*Nephantis serinopa*) - The black headed caterpillar

### THE RED PALM WEEVIL (*Rhyncophorus ferrugineus*), Order - Coleoptera

The adult weevil (Fig. 16.51) is about 35 mm and is cylindrical and reddish brown. The damage is caused by the grubs of the weevil which bore into soft tissues of the trunk of the palm and feed inside. When attack is severe the central shoot wilts and the palm dies. The female makes small holes in the soft tissues of the host and lays eggs in the hole. The apodous, (without eggs) soft whitish grubs with red head, feed on soft tissues resulting in the formation of tunnels inside tree trunk.

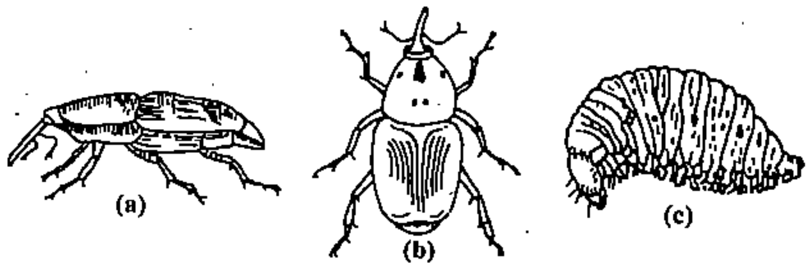



Fig. 16.51: *Rhynchophorus ferrugineus* – (a) adult (b) grub (c) cocoon.

### THE RHINOCEROS BEETLE (*Oryctes rhinoceros*), Order - Coleoptera

The adult rhinocerous beetle (Fig. 16.52) is responsible for most of the damage in the plants. They bore into unopened, folded tender leaves and petioles, chewing up tissues, leaving fibrous mass in the burrow. Attacked trees becomes stunted and the growing points are destroyed. This beetle is one of the major pests of coconut palms.

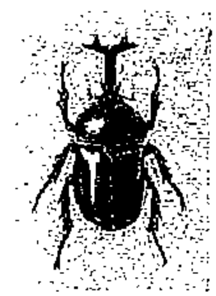


Fig. 16.52: Adult beetle of *Oryctes rhinoceros.*

The adult beetle measures about 5 cm and has a stout cylindrical, reddish brown black body. Its head is provided with a pointed horn projecting dorsally. The horn is longer in the females.

The female lays 100-150 eggs in decaying organic matter or in manure pits. The grubs feed on decaying matter. The grub pupates in a cocoon in the soil at a depth of 30 cm. Adult beetles emerge from the cocoon and fly towards host tree and start feeding on it thus damaging it. Life span of adult is about 200 days.

### THE BLACK HEADED CATERPILLAR (*Opisina arenosella*), Order - Lepidoptera

The black headed caterpillar of *Opisina arenosella* (=Nephantis serinopa) (Fig. 16.53) feeds on the undersurface of leaflets scraping off the green matter. The leaves consequently dry up. In case of severe attack the whole plantation gives a burnt up appearance.

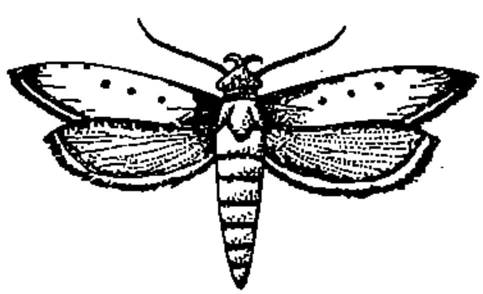


Fig. 16.53: Adult of *Opisina arenosella* (=*Nephantis serinopa*)

### PESTS OF PULSES

The pulses attacked by the pests are green gram (moong), black gram (urd), Bengal gram (chana), Pea (matar) and pigeon pea (arhar) etc.

**Some important pests of pulses include:**

1. *Helicoverpa* (*Heliothis*) *armigera* - Gram pod borer.
2. *Aphis craccivora* - **Aphid - Refer to pests of groundnut crop in this unit.**
3. *Amsacta moorei* - **Red hairy caterpillar - Refer to polyphagous pests in this unit.**

4. *Diacrisia obliqua* - **Bihar hairy caterpillar - Refer to polyphagous pests in this unit.**

## GRAM POD BORER (*Helicoverpa armigera*), Order - Lepidoptera

The catter pillar of gram pod borer, *Helicoverpa* (=Heliothis) *armigera* (Fig. 16.54) is a polyphagous pest of pulses attacking many pulses (red gram, Bengal gram, soybean, green gram, black gram and pea) and other important crops including safflower, chillies, sorghum, groundnut, tomato, cotton etc.

The caterpillars are voracious feeders and damage young pods, foliage and developing grains by boring into them and feeding on them thus reducing yield. In America it causes maximum destruction to cotton, hence it is called "American cotton boll worm".

The adult females lay eggs singly on tender parts of plants. These eggs release young caterpillars which start feeding voraciously, initially attacking the leaves and then the pods. The caterpillars when fully grown pupate in the soil. The adult moth emerges from the pupa and lays eggs on leaves.

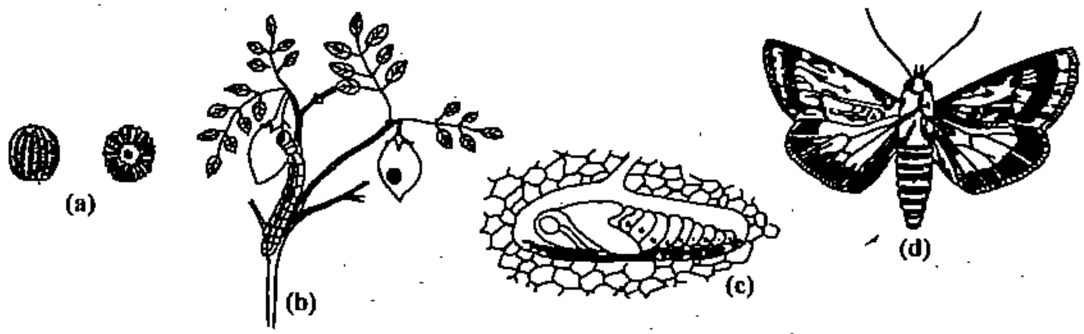



**Fig. 16.54: Life history of Gram pod borer *Helicoverpa (=Heliothis) armigera* (a) eggs (b)infested plant (c) pupa below soil (d) adult.**

## PESTS OF VEGETABLES

### Pests of Potato and Brinjal

The fruits leaves and often entire plants of vegetables like brinjal, potato, okra, cabbage, cauliflower etc. are attacked by a large number of insect pests some of which are given here.

### Some pests of Potato and Brinjal

1. *Leucinodes orbonalis* - The shoot and fruit borer
2. *Epilancha vigintioctopunctata* - Spotted leaf beetle
3. *Agrostis ipsilon* - **Cut worm - Refer to pests of wheat in this unit.**
4. *Helicoverpa armigera* - **Gram pod borer - Refer pests of pulses in this unit.**
5. *Myzus perisicae* – **Refer pests of mustard in the unit.**

## THE SHOOT AND FRUIT BORER (*Leucinodes orbonalis*), Order – Lepidoptera

*Leucinodes orbonalis* (Fig. 16.55) is a polyphagous pest on a large number of solanaceous plants including potato and brinjal. The caterpillar produces damage by boring into the tender shoots of young plants. The growing point wilts, drooping shoots appear, which ultimately wither and die. The caterpillar also bores into flower and fruits.

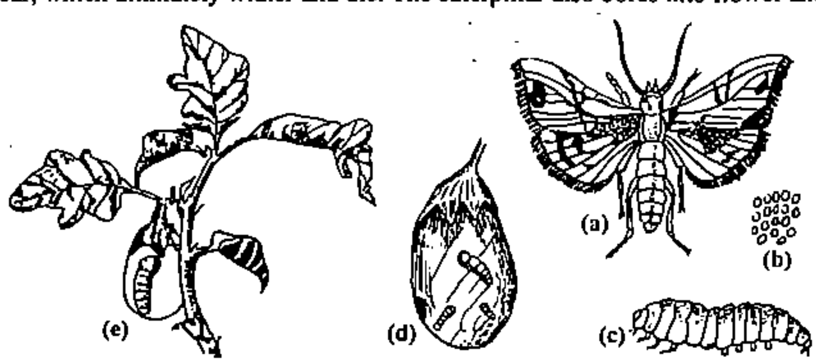



**Fig. 16.55: Life cycle of *Leucinodes orbonalis*. (a) adult (b) egg (c) larva (d) pupa in brinjal fruit (e) infested plant**

## SPOTTED LEAF BEETLE (*Epilachna vigintioctopunctata*), Order - Coleoptera

*Epilachna vigintioctopunctata* is also a polyphagous pest of solanceous plants. The adult and the grubs both feed on potato, brinjal, tomato and other solanaceous plants. It is however a very serious pest of potato and brinjal.

The adults and grub both are destructive stages which scrape and feed on the green chlorophyll and sketelonize the leaves which then get gives a characterisitic lace like appearance. These leaves dry up later. The adult of *E. vigintioctopunctata* (Fig. 16.56) is dotted at several places on the elytra.

**Fig. 16.56: Spotted leaf beetle (*Epilachna vigintioctopunctata*).**

## PESTS OF LADY'S FINGER (OKRA)

**Some pests of lady finger or okra are:**

1. ***Earias vitella*** **- Spotted boll worms – Refer to pests of cotton in this unit.**
2. ***Helicoverpa armigera*** **- Gram pod borer – Refer to pests of pulses in this unit.**
3. ***Dysdercus koenigii*** **- The red cotton bug – Refer to pests of cotton in this unit.**

## PEST OF CUCURBITACEOUS VEGETABLES

Cucurbitaceous vegetables include the various gourds.

**One important pest of cucurbitaceous vegetables is:**

1. *Dacus cucurbitae* - Fruit fly

## FRUIT FLY (*Dacus cucurbitae*), Order - Diptera

The fruit fly (*Dacus cucurbitae*) (Fig. 16.57) is the most important pest of cucurbitaceous vegetables. The attacked plants include bottle gourd, bitter gourd, pumpkin, water melon, musk melon, cucumber etc. Damage is caused by larvae called maggots which feed on the pulp of fruits. The infested fruit starts rotting. The female lay eggs into flowers and tender fruits. The maggots which hatch from the eggs feed on the pulp of fruits. The fully grown maggots pupate in soil. Adult flies emerge from the pupa.

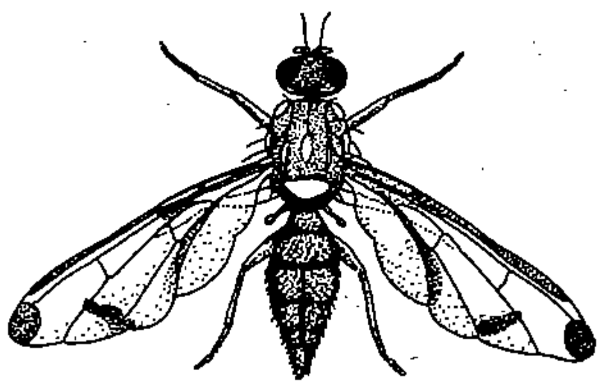


**Fig. 16.57: Adult male of *Dacus cucurbitae (Melonfly)*.**

## PESTS OF CRUCIFEROUS VEGETABLES

Cruciferous vegetables include cabbage, cauliflower, knol-khol, beet root, radish, turnip etc. **Some of their pests are:**

1. *Plutella xylostella* - The diamond back moth
2. *Trichoplusia ni* - The cabbage green semilooper
3. *Lipaphis erysimi* and *Myzus persicae* – Aphids
4. ***Agrostis ipsilon*** **- The cutworm - Refer to wheat pests in this unit.**

## DIAMOND BACK MOTH (*Plutella xylostella*), Order - Lepidoptera

The damage is caused by the small caterpillar of the moth *Plutella xylostella* (Fig. 16.58). The cater pillar feeds on the underside of the leaves cutting several holes. Caterpillars hinder healthy growth of plants due to which yield is considerably reduced.

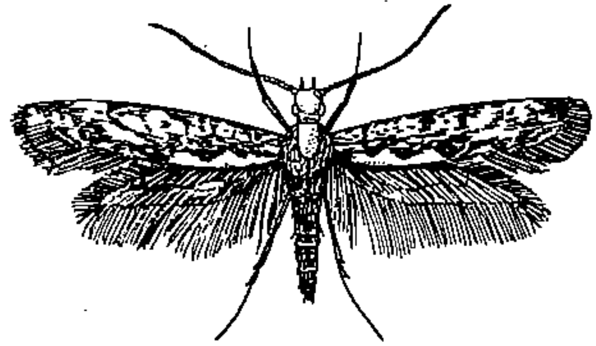


Fig. 16.58: The diamondback moth, *Plutella xylostella*.

## CABBAGE GREEN SEMI LOOPER (*Trichoplusia ni*), Order - Lepidoptera

The caterpillar of *Trichoplusia ni* (Fig. 16.59) is the pest. This pest in addition to attacking cabbage also attacks lettuce, spinach, beet, pea, celery, parsley, potato, tomato, carnation, nastursium etc.

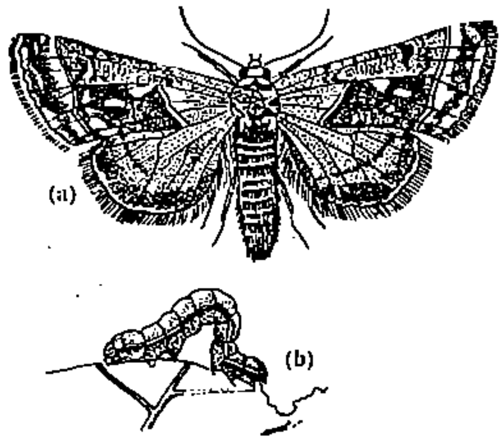



Fig. 16.59: *Trichoplusia ni* (a) adult (b) cater pillar.

## MUSTARD APHID (*Liaphis erysimi*) and POTATO APHID (*Myzus persicae*), Order - Hemiptera

The adults and nymphs of both *(Liaphis erysimi)* (Fig. 16.60 a) *and Myzus perisicae* (Fig. 16.60 b) suck the sap from the host plant. The main plants attacked by mustard aphids include mustard, cabbage, raddish and cruciferous plants. The potato aphid (Fig. 16.55 b) attacks mustard as well as potato, bean, lady's finger, tomato etc.

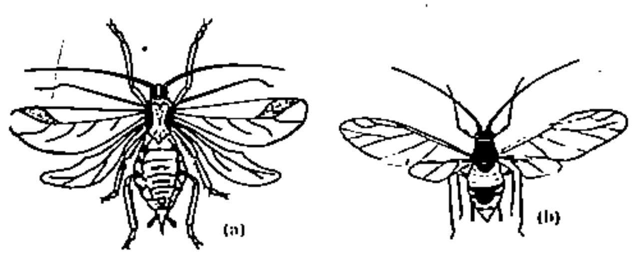



Fig. 16.60: Aphids. (a) Mustard aphid (*Liaphus erysimi*) (b) Potato aphid *Myzus persicae*.

## PESTS OF FRUIT CROPS

Fruit trees are also attached by a large variety of insect pests of which only a few are given here.

## PESTS OF MANGO

Some important pests of Mango are:

1.. *Amritodus ( Ideocerus) atkinsoni* - Mango hoppers
2. *Dacus dorsalis* - Fruit fly

## MANGO HOPPERS (*Amritodus atkinsoni*), Order - Hemiptera

Both adults and nymphs of the hoppers (Fig. 16.61) are serious pests of mango. They suck cell sap from new shoots, inflorescence, buds and flowers. When infestation is severe the entire inflorescence and even tiny fruits wither. Tiny fruits and flower buds are shed resulting in heavy crop loss due to poor fruit setting. The hoppers also secrete honey-dew on which a black sooty mould develops.

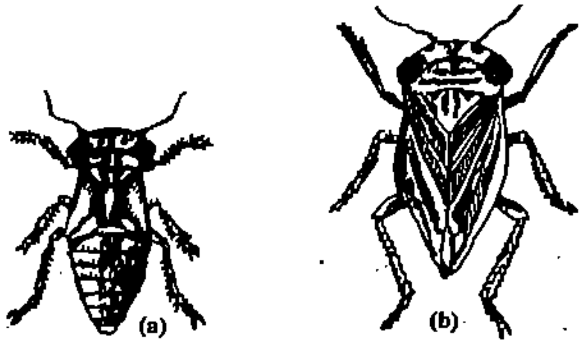



Fig. 16.61: *Amritodus (Idiocerus) atkinsoni.* (a) adult (b) nymph.

**FRUIT FLY (*Dacus dorsalis*) Order - Diptera**

*Dacus dorsalis* (Fig. 16.62)It is a polyphagous pest on mango, guava, banana, citrus, apricot, apple, pomegranate, locat, plum, peach, pear and a number of other fruits and vegetables too.

The damage is mainly caused by maggots of the adult fruit fly which feed on the pulp of fruits, causing the fruits to rot and fall off.

Fig. 16.62: Adult of fruit fly *Dacus dorsalis.*

**PEST OF CITRUS**

**An important pest of citrus is:**

*Papilio demoleus* - The lemon butterfly

**LEMON OR CITRUS BUTTERFLY (*Papilio demoleus*) Order – Lepidoptera**

The Lemon butterfly (Fig. 16.63) is one of the important pests of citrus. Damage is caused by the caterpillar which feeds on fresh leaves and terminal shoots of the citrus plant. When infestation is severe the plant becomes unfit for fruit bearing.

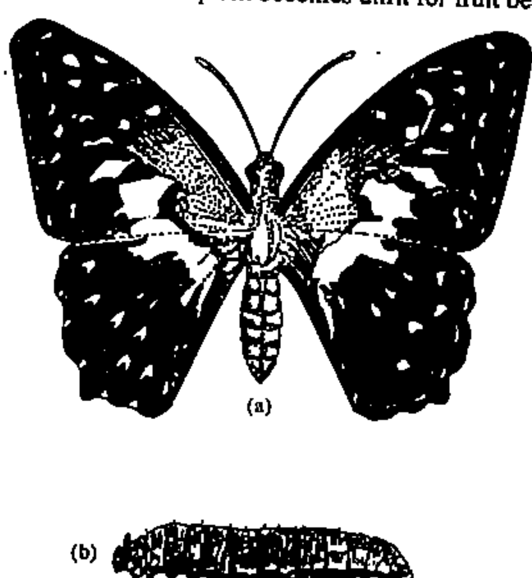



Fig. 16.63: Citrus butterfly *(Papilio demoleus)* (a) adult (b) larva

## PESTS OF STORED GRAINS

Stored grains are damaged by a large number of insect pests.

## PESTS OF ORDER COLEOPTERA

Some pests belonging to order Coleoptera which attack stored grains are only listed here alongwith their figures (Fig. 16.64):

1. *Sitophilus oryzae* - Rice weevil, (Fig. 16.64 a)
2. *Tribolium castaneum* - Red flour beetle, (Fig. 16.64 b)
3. *Callosobruchus chinensis* - The pulse beetle, (Fig. 16.64 c)
4. *Rhizopertha dominica* - The gram borer or paddy borer beetle, (Fig. 16.64 d)
5. *Trogoderma granarium* - The khapra beetle, (Fig. 16.64 e)

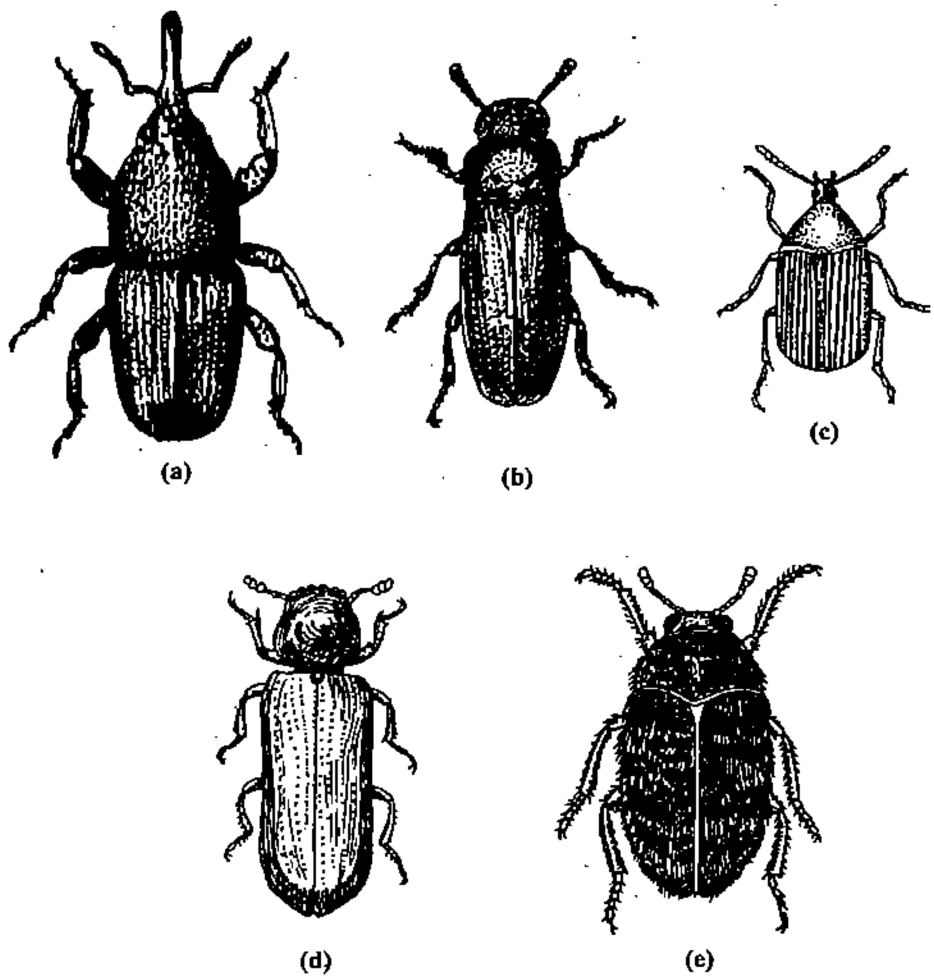
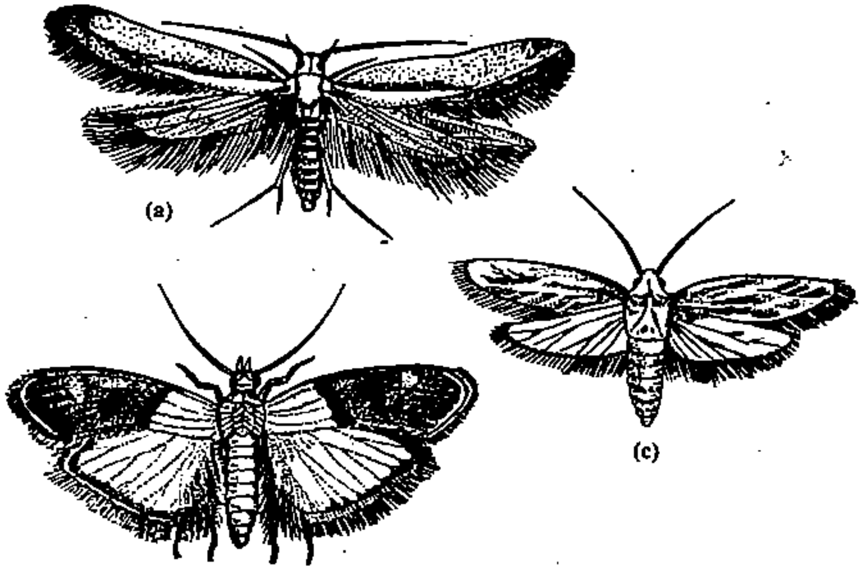



Fig. 16.64: Some Coleopteran pests of stored grains. (a) Rice weevil (*sitophilus oryzae*) (b) Red flour beetle (Tribolium castaneum) (c) Pulse beetle (*Callosobruchus chinensis*) (d) Gram borer or paddy borer beetle (*Rhizopertha dominica*) (e) Khapra beetle (*Trogoderma granarium*).

## PESTS OF ORDER LEPIDOPTERA

The stored grains are also damaged by several lepidoptera species. A few major pests belonging to the order lepidoptera are also only listed here along with their figures (Fig. 16.65).

1. *Sitotroga cerealella* - Angoumois gram moth, (Fig. 16.65 a)
2. *Plodia interpunctella* - Indian meal moth, (Fig. 16.65 b)
3. *Corcyra cephalonica* - The rice moth, (Fig. 16.65 c)



(a) (b) (c)

**Fig. 16.65: Some Lepidopteran pests of stored grains. (a) Angoumois grain moth (*Sitotroga cerealella*). (b) Indian meal moth (*Plodia interpunctella*). (c) Rice moth (*Corcyra cephalonica*).**

## PESTS OF TREES

A number of insects are pests on trees. One of the most commercially important of these tree, is teak, which yields much valuable timber:

## PESTS OF TEAK TREE

**An most important pest of teak tree is the:**

1. *Hyblaea puera* - Teak defoliator

## TEAK DEFOLIATOR (*Hyblaea puera*) Order - Lepidoptera

The caterpillars of the adult moth *Hyblaea puera* (Fig. 16.66) feed on the tender leaves and skeletonize the older ones, causing extensive defoliation.

(a) (b)

**Fig. 16.66: *Hyblaea puera*. a) larva; (b) adult moth.**

## SAQ 8

Match the insect in Column A with the crop it damages listed in Column B.

| Column A | Column B |
|---|---|
| i) *Nephantis serinopa* | a) Cotton |
| ii) *Chilo infuscatellus* | b) Wheat |
| iii) *Agrostis ipsilon* | c) Castor |
| iv) *Helicoverpa armigera* | d) Cabbage |
| v) *Epilachna vigintioc topuanctata* | e) Pulse |
| vi) *Earias vitella* | f) Ground nut |
| vii) *Nephotettix virescens* | g) Coconut |
| viii) *Achaea janata* | h) Brinjal |
| ix) *Trichoplusia ni* | i) Rice |
| x) *Aphis craccivora* | j) Sugarcane |
| xi) *Dacus dorsalis* | k) Citrus |
| xii) *Papilio demoleus* | l) Mango |
| xiii) *Tribolium castaneum* | m) Teak |
| xiv) *Hyblaea puera* | n) Wheat grain |

PREVENTION AND CONTROL OF ARTHROPOD PESTS

In modern times, large number of insecticides are available to bring down the population of arthropod pests to reasonable levels. However, none of them totally eliminate any pest. So there will be pest build up again, and insecticides will have to be thus repeatedly employed. Most of these insecticides are poisonous not only to man and domestic animals, but to beneficial arthropods like honey bee as well. So pesticide application has to be avoided as far as possible or at least kept to the minimum level. This can be done by resorting to suitable preventive measures which prevent build up of pest.

There are several preventive methods which we can employ against many arthropod pests. This however, depends upon a thorough knowledge of the biology of the pest. We will here discuss some of these preventive measures.

1. Most of the house-hold pests and those of veterinary and medical importance, breed and multiply in unhygienic conditions. So keeping our home and the surroundings clean and hygienic is important to prevent buildup of pests like mosquitoes, houseflies and other related flies, bedbugs, cockroaches, lice, fleas etc. It is to be especially noted that many species of mosquitoes breed in stagnant and foul water or where there are chances of such water accumulating. This should be avoided. Larivorous fish like *Gambusia* and *Aplochilus* should be grown in stagnant water bodies like wells, tanks, ponds etc. as they will devour the mosquito larvae. Application of crude oil (spraying) on foul/stagnant water bodies will also result in elimination of many types of mosquito larvae, as this process will prevent them from breathing. Similarly, house flies and many related flies breed in decaying matter, which therefore should be properly disposed off and prevented from accumulating.
2. Sanitation methods can also be used in agriculture to prevent build up of pests in the field. Pest-free seeds should be employed for sowing. After harvesting the stubble should be burned so that the different stages of the pests in the stubble will be destroyed. The field should also be ploughed thoroughly so that egg masses and pupae of those pests in the soil are brought above soil in the open where birds can easily eat and destroy. Since many pests are polyphagous they will migrate after harvesting to weeds in the field which are also their hosts. So keeping the field free of weeds, removing the weeds from time to time, will facilitate prevention of pest build up.
3. Some pests (either adults or other stages) are fairly large, as is the case with the red palm weevil and rhinoceros beetle. These can be hand picked, or mechanically scooped out from their holes or burrows in tender palm shoot by inserting sharp hooked or barbed wire for pulling them out and destroying.
4. The build up stored products pests can be prevented by drying grain and similar products before storage, as this will kill their sensitive stage. Periodical drying may be needed to prevent further build up of storage pests.
5. Borer attack can be brought down by removing the "drooping" and "wilted" shoots or stem (which are tell-tale symptoms of the borer inside) from plants and burning them promptly.
6. Many night flying insects, especially moths and beetles, are attracted to light during night. So light traps can be set in fields and the pests trapped and destroyed.
7. Many insects are attracted to food and so mixing insecticides with their food (poison baits) can be used to attract and kill them. Cockroaches and many moths can thus be easily attracted and killed by this method.

These are some of the many methods available to us, and by judiciously resorting to such tactics, pest build up can be prevented to a certain extent.

## 16.5 SUMMARY

In this unit you have studied some harmful non-chordates. They may be harmful in many ways. They may cause direct or indirect injury to man, his domestic animals or to economically important plants or to their products. They may be parasites and cause diseases in plants or animals including man, or they may serve only as tools in transmitting some disease agents. Platyhelminthes, Nemathelminthes and Arthropods are the major non-chordate groups which have many harmful species.

- Platyhelminthes include animal parasites belonging to the classes Monogenea, Trematoda and Cestoda. Many of these are serious pathogens causing disease in man and animals. Monogeneans are ectoparasites of lower vertebrates, especially of fish. They are often quite damaging in fish hatcheries. Parasitic trematodes are exclusively parasitic on or in vertebrates. Among them, *Fasciola* and *Clonorchis* are important liver parasites. *Paragonimus* is a lung fluke and the species of *Schistosoma* occur as blood parasites. All trematodes complete their life cycle in two or more hosts. Their larval stages develop in a snail which acts as a intermediate host. Additional intermediate hosts like fish or crab may be involved in the life cycle of some trematodes. Cercarial or the metacercarial stage is the infective stage though which the final host gets infected.
- Cestodes, like trematodes, are exclusively parasitic and have usually an indirect life cycle. Tapeworms of the genera *Taenia*, *Hymenolopis* and *Diphyllobothrium* are common intestinal parasites of man. While it is the adult which is the main parasite and causes injury to the hosts, larval stages of some species may also be seriously harmful. Infection by the bladder worm of cysticercus of *Taenia solium* and hydatid cyst of *Echinococcus granulosus* (the dog tapeworm) may be dangerous.
- The animals of class Nemathelminthes are called round worms or nematodes. A large number of nematode species (roundworms) are parasitic on either plants or animals. They all have the same basic pattern of life cycle - adult worm, the egg and 4 successive larval stages each following moulting. Nematode pests of plants are called phytoparasites. Some nematodes act both as vectors of viruses and bacteria as well as pathogens of plants. *Meloidogyne* the root knot nematode which produces galls in root and *Heterodera*, the cyst nematode, are major parasites of plants.
- Animal nematode parasites lodge in the intestine or other systems in the body of their host. The common roundworm (*Ascaris*), the trichina worm (*Trichinella*) the whipworm (*Trichuris*), the pinworm (*Enterobius*), the filarial worms (*Wurchereria* and *Brugia*), the river blindness worm (*Onchocerca*); the Guinea worm (*Dracunculus*) and the hookworm (*Ancyclostoma* and *Necator*) are important nematode parasites of man. Ascaris, whipworm, pinworm and hookworm occur as parasites of the digestive tract of humans who contract the infection by ingesting contaminated food or water containing infective eggs or through penetration of skin by infective larvae present in the soil. The filarial worms (*Wuchereria* and *Brugia*) have in their development, a microfilaria stage which occurs in the blood stream. Mosquitoes spread the filaria infection. The Medina worm or Guinea worm (*Dracunulus*) occurs in the subcutaneous tissue of man and produces blisters which burst releasing the infective juveniles. Cyclops infected with the larvae of the worm spread the infection.
- Many species of arthropods are harmful as they serve as carriers of disease agents for man, e.g., typhoid, plague, cholera, yellow fever, etc. Arthropods serve as biological vectors for many helminth parasites, and are essential as intermediate host for the completion of the parasite's life cycle. These include mosquitoes, flies, bugs, beetles, copepods and ticks. Many arthropods are directly harmful to man as they themselves cause injury or disease. Species of scorpions, spiders, ticks, mites, beetles, lice, flea and flies cause localised injuries to man while termites, cockroaches, silverfish and ants cause indirect damage to man. Several species of flies, lice and flea are important parasites of domestic animals.
- Many insect pests are found on a wide variety of plants. Several of these cause damage to the plant directly, while others are indirectly damaging as they transmit pathogenic micro- organisms. Mites, termites, locusts, several species of beetles and moths are important insect pests of various economically important plants, trees and grains.

## 16.6 TERMINAL QUESTIONS

1. List the three important species of Schistosomes of man and describe the life cycle of any one.

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2. Describe the life cycle of the dog tape worm. Explain how the larval forms of this tapeworms could be harmful to man.

3. Mention the nematodes parasitising different organs in the human body. Describe the diseases caused by any three important nematodes and thir mode of their infection.

4. Write a brief account of arthropods as pathogens and as vectors of human diseases.

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## 16.7 ANSWERS

### Self-Assessment Questions

1. a (i) miracidium; (ii) *Fasciola hepatica*; (iii) *Chlornorchis (Opisthorchis) sinensis*; (iv) lung; (v) Cray fish, Crab; (vi) *Bulinus, Physopsis*
   b (i) False; (ii) False; (iii) True; (iv) True.

2. (i) tapeworm; (ii) *Taenia saginatus*; (iii) *Taenia solium*; (iv) *Hymenolepis nana* (v) *Diphyllobothrium latum*; (vi) hydatid.

3. 1,9; 2,2; 3,4; 4,11; 5,6; 6,5; 7,10; 8,3; 9,7; 10,8; 11,1; 12,13; 13,12.

4. (a) (i) True; (ii) True; (iii) True; (iv) False
   (b) i a; ii c; iii b; iv e; v d;
   (c) (i) *Boophilus* (ii) *Babesia* (iii) red spider;

5. (i) *Anophelese, Culex, Aedes, Mansonia* (ii) *Culex fatigans* (iii) *Anophelese* (iv) *wrigglers*, (v) *Brugia malayi* vi) antennae and palpi (vii) *Culex tarsalis* (viii) *Aedes*

6. (i) c; (ii) d; (iii) g; (iv) a; (v) b;

7. (i) True; (ii) True; (iii) False; (iv) True; (v) False; (vi) False;

8. (i) g; (ii) j; (iii) b; (iv) e; (v) h; (vi) a; (vii) i; (viii) c; (ix) d; (x) f; (xi) l; (xii) h; (xiii) n; (xiv) m.

### Terminal Questions

1. Refer to Blood Flukes in subsection 16.2.2.
2. Refer to *Echinococcus granulosus* in subsection 16.2.2.
3. *Ascaris*, *Enterobius*, *Ancyclostoma*, *Necator* and *Trichuris* occur in the digestive tract; larvae of *Trichinella* remain encysted in the skeletal muscles; *Wuchereria* inhabits the lymph ducts while its microfilariae occur in the blood; *Dracunculus* occurs in the subcutaneous tissue in the gravid stage. *Trichinosis* is caused by *Trichinella* larvae. This infection results in severe muscular pain. Infection occurs

when man ingests infected pork. *Wuchereria bancrofti* is responsible for elephantiasis, a disease in which the limbs (arms and legs) become abnormally swollen and deformed. Mosquitoes serve as the vector and transmit the infection. *Dracunculus medinensis* causes blisters with acute pain. Larvae of the worm get into *Cyclops* present in water bodies and man acquires the infection on drinking cyclops-contaminated water.

4. Refer to section 16.4 for giving examples of disease causing arthropods and also of those which serve as vectors by referring to section 16.4.

# UNIT 17 BENEFICIAL NON-CHORDATES

## Structure



## 17.1 INTRODUCTION

In Unit-16 you have studied the harmful non-chordates and have seen that some of the worst disease-producers and food-destroyers are non-chordates. In this Unit you will realise that some non-chordates are beneficial to man.

It is not the intention here to point out how they constitute significant links in the natural cycles including the food chains, or how they serve as research material in the hands of scientists but we will make a survey as to how some of these we find extremely useful in a variety of other ways.

This unit will familiarise you with the variety of ways in which non-chordates are of benefit to man, directly and indirectly.

### Objectives

After studying this unit you will be able to :

- categorise the ways in which the non-chordates are beneficial to humans,
- describe the usefulness of non-chordates as sources of food,
- list the various industrial products of non-chordates and briefly describe the manner in which these are produced by them,
- cite examples of non-chordates that have been used as sources of medicines and as objects of decoration,
- point out how they are useful in agriculture.

## 17.2 BROAD CATEGORISATION OF BENEFICIAL NATURE OF NON-CHORDATES

Many non-chordates are beneficial to humans in numerous ways. This beneficial nature can be either direct or indirect. The direct usefulness may include their utilization as food or as a source of products that fulfil human needs. The indirect benefits are the result of their activites which in turn contribute to human welfare. The list below aims to classify broadly how the non-chordates are useful to humans.

A. Directly beneficial
   1. Used as food
   2. The food they gather is used as food for human consumption.
   3. They produce useful substances
   4. Used in medicine
   5. Used as objects of beauty and decoration

B. Indirectly beneficial
   1. Useful in agriculture
   2. They clean the environment and thus serve as scavengers.

We shall now examine each of the above points in detail and survey the contributions of different non-chordates to human welfare.

## 17.3 NON-CHORDATES USED AS FOOD

Among non-chordates only arthropods and molluscs contain edible species.

### 17.3.1 Phylum Arthropoda as Source of Food

Though some primitive tribes are known to eat insects like termites and grasshoppers, well-recognised edible species are limited to crustaceans.

**CRUSTACEANS**

Though many crustaceans are edible, only the larger ones are of commercial significance. Most shrimps are small and are hence not of much commercial value. But prawns, lobsters and crabs are larger and are hence exploited commercially. All these come under order Decapoda. These are of great food value and are an important source of earning especially foreign exchange. The main export products are frozen prawns, canned prawns, dried prawns, prawn pickles, frozen crab meat and canned crab meat.

**1. Prawns and Shrimps**

Prawns and shrimps have cylindrical or compressed body and the abdomen is large with a peculiar bend (Fig. 17.1). The carapace has a well developed rostrum. Thoracic legs are slender, anterior ones being chelate. These swim in water.

Prawns are considered a delicacy throughout the world. There are various species of prawns that inhabit the sea, freshwater reservoirs, rivers and estuaries. The following are some important species of prawns that are commercially exploited:

*Penaeus indicus* (Indian prawn) found in coastal regions only; *Penaeus monodon* and *Metapenaeus monoceros* (Giant tiger prawn) found in fresh as well as salt waters; *Macrobrachium malcomsonii* : inhabit fresh and brackish water; *Macrobrachium scabriculum* : seen in fresh water only; and *Macrobrachium rosenbergii*: The giant fresh water prawn.

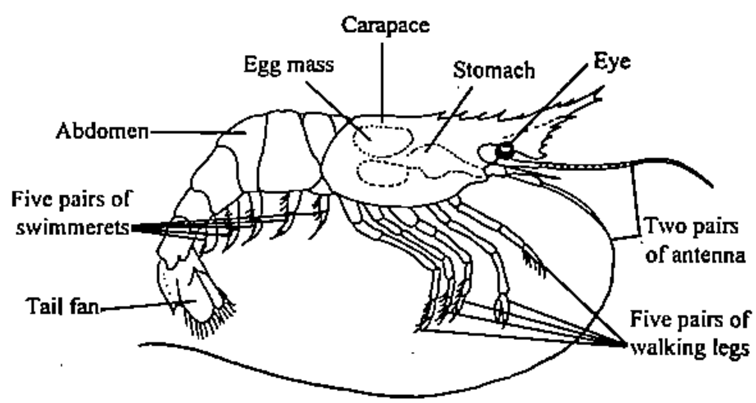


**Fig. 17.1: A Shrimp Crangon, side view**

*Penaeus indicus* is the commonest Indian prawn which constitutes the bulk of the catch. It grows upto 20 cm in length. *P. monodon* grows even longer upto 30 cm. *Metapenaeus* *nonoceros* is one of the most suitable species to be cultured in India and other tropical countries. For fresh water culture the giant prawn *Macrobrachium rosenbergii* is the most suitable.

Prawn culture or farming is rapidly growing in various countries like Philippines, Japan, U.S.A., Taiwan, as well as India where ponds, tanks, paddy fields, estuaries and coastal sea waters are being converted into prawn raising areas.

**2. Lobsters**

Lobsters are large heavy bodied marine crustaceans. They have straight dorsoventrally flattened body, with heavier legs. Their first pair of walking legs are strongly chelate (chelipeds) for capturing prey. They are adapted for creeping or crawling. *Homarus americanus* (Fig. 17.2) the American lobster, may grow to a length of 60 cm and weigh over 20 kg. The European lobster *Homarus gammarus* is smaller. *Scyllarus* is the spanish lobster. *Panulirus* is the Indian lobster.

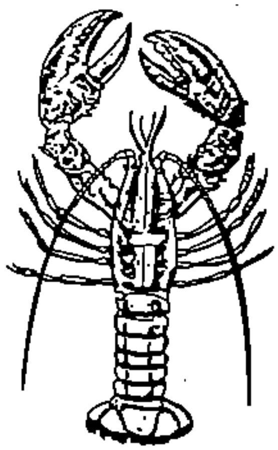

Fig. 17.2: A lobster-*Homarus americanus*.

**. Crabs**

Crabs are chiefly marine crustaceans with short body and flattened broad carapace (cephalothorax) usually as wide as it is long. They have a small abdomen that curls forward and is held tightly beneath the cephalothorax. The chelipeds are modified as grasping pincers (Fig.17.3). Crabs crawl on the surface when crawling rapidly they move sideways. Many crabs are treated as delicacy in many parts of the world. *Portunus sanguinolentus, P. pelagicus* and *Charybdis cruciata* are some edible Indian crabs.

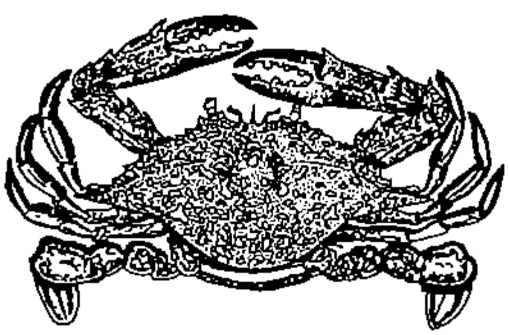

Fig. 17.3: A crab

## 7.3.2 Phylum Mollusca as Source of Food

Many molluscs are edible, Scallops, mussels, clams, oysters, snails, squids and octopuses are examples. *Ostrea* is perhaps the best known edible oyster *Crassostrea madrasensis* (the Indian backwater oyster), *Crassostrea cucullata* (the rock oyster) and *C. discoidea* (disc oyster) are Indian edible oysters. They are marine bivalves. Several fresh water mussels such as *Unio* and *Anodonta* are also eaten. The common edible European mussel are *Mytilus edulis* and the closely related *M. galloprovincialis*. They are also cultivated in the sea either on poles, or on the seabed or from fixed frames or from freely floating structures in the sea. *Mytilus viridis* and *M. edulis* are the Indian species. The important molluscan beds in India are along the west coast and the Palk strait and the Gulf of

Mannar. The gastropods are not of much significance as a source of food, though some species are eaten by poor people. So are cephalopods also in India, though they are caught from the east coast for export. *Sepioteuthis arctipinnis* is such an Indian species.

## SAQ 1

i. Which two non-chordate phyla provide the largest variety of edible forms ?

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ii. List any four crustaceans that are commonly eaten.

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iii. Mention if the following statements are true (T) or false (F).

(a) Prawn culture is a growing industry.
(b) Shrimps are chiefly marine forms.
(c) No insects are eaten in any part of the world.
(d) All fresh water mussels are avoided as food.
(e) Primitive human races often include insects like beetles, grubs and caterpillars in their food.
(f) Shrimps can grow to a size of 30 cm in length.

# 17.4 NON-CHORDATES YIELDING FOOD - HONEY

We have all tasted honey at some time or the other in our lives and are familiar with the honey bees. The honey bees are insects (order Hymenoptera). Social life has attained a high degree of perfection in these insects and their social organisation and behaviour will be dealt with separately under the unit Behavioural Patterns. These honey bees produce honey and store it in their hive and use it for themselves and for their young ones. Man discovered it and started gathering honey long back. In the early days they squeezed out the honey from the hives of the bees that lived in wild state. Even today many tribal people collect honey like this from forests. Later, they devised various types of apiaries and domesticated the honey bees. The practice of bee keeping is now very common almost throughout the world and is designated as apiculture. In India, the Khadi and Village Industries Commission is encouraging bee keeping on a large scale. Tamil Nadu, Kerala, Karanataka, Jammu and Kashmir and Himachal Pradesh are major honey producing states in India.

## 17.4.1 Composition of Honey

Honey is an aromatic viscid product. It is sweet and a highly nutritious food. It is a product modified by the honey bees from plant nectar, and is consumed in many ways, as a spread, and is used in making drinks, candies, cakes, and is also used as a medicine.

Honey is an instant source of energy. Its solid constituents are mostly monosaccharides which are readily absorbed into the blood. The rich vitamin and mineral contents further enhance the nutritive value of honey.

**Chemical composition of honey:** The composition of honey varies and the composition of an average sample of honey shows the following table:

**Sugars**

Fructose - 40-50%
Glucose - 32-37%
Sucrose - 2%
Maltose - traces

**Polysaccharides**

Dextrins - 1-12%

**Vitamins** – Abundant A,B and C vitamins

**Minerals** - Traces of iron, copper, manganese, magnesium, sodium, potassium, calcium, silica and phosphates. Acids like acetic, butyric, citric, formic, lactic, malic and succinic are also present as also amino acids. Enzymes like invertase, diastase and phosphatase also occur.

**Water** - 13-20%

The colour and odour of honey usually depend on the flowers from which the nectar has been collected.

## 17.4.2 Kinds of Honey Bees

The honeybees are insects that belong to the order Hymenoptera. There are four species of honey bees.

1. *Apis dorsata* (The rock-bee): This is the largest honey bee. It constructs its huge, single open comb or hive on high branches of trees, on tall deserted buildings or on rocks. This species cannot be domesticated, it is ferocious and has a poisonous sting that can cause fever.
2. *Apis indica* (The Indian bee): This is a medium-sized bee. It builds hives consisting of several parallel combs side by side in dark places like the cavities of tree trunks, mud walls, earthen pots, etc. This is not so ferocious and can be easily domesticated. This is the species used in apiculture (Fig. 17.4).
3. *Apis florea* (The little bee): This bee is even smaller. It builds single small combs in bushes, hedges, etc. Its honey yield is poor and therefore not economical.
4. *Apis mellifera* (The European bee): It is primarily found in Europe but it has also been introduced in many parts of the world including India, because of the greater quantity of honey that can be gathered from its hive.

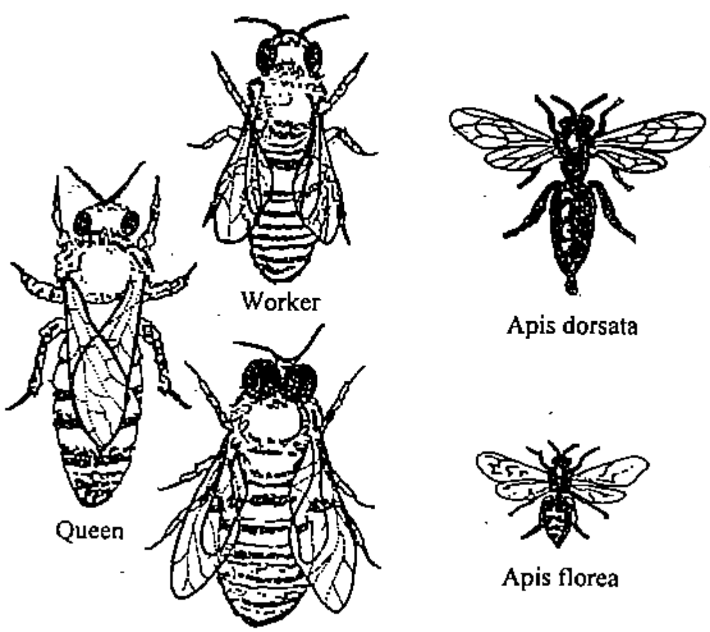


Fig. 17.4: Three Indian bees: *Apis indica* 1. Worker, 2. Queen, 3. Drone, and other two common Indian bees *A. dorsata* and *A. florea*.

## 17.4.3 How is Honey Produced

The worker bees visit flowers and obtain nectar from them.

**Mouth parts of honey-bee:** Adult honey bees have mouth parts that are modified in order to utilize liquid food i.e. nectar and honey. Mouth parts are chewing - lapping type. The major feeding apparatus consists of a maxillo - labial complex. Surrounding the central 'tongue' the glossae of the labium, is a tube formed from the galeal part of the maxillae. With the combined action of both the sucking pump and 'tongue' moving up and down, nectar is drawn up into the body. The mandibles usually do not function directly in feeding but may be used not only for cutting flowers that have long corolla t gain access to the nectar but also for defense and for molding into combs for storing honey in the hive.

Nectar contains disaccharides (mainly sucrose). While sucking nectar the bees mix thei own saliva with it and swallow it into a honey stomach (crop). After flying back to the hive the workers regurgitate the mixture into their mouth where they again masticate thoroughly with saliva. The saliva is rich in the enzyme invertase which hydrolyses sucrose into glucose and fructose. This processed nectar (honey) is deposited in the storage cells of the hive. This rather watery honey is then thickened by evaporating a large portion of water content by rapid beating of the wings of the worker bees. When a cell is filled with "ripened" honey it is capped over with wax.

**SAQ 2**

1) List any two uses of honey.
   i) ..........................................................................................
   ii) ..........................................................................................

2) Column I below lists some of the constituents of honey. Rearrange these in colum II according to their approximate percentage given alongside.

| Column I | Column II | Percentage (Aprox.) |
|---|---|---|
| Water | i. ...................... | 45% |
| Fructose | ii. ...................... | 15% |
| Sucrose | iii. ...................... | 2% |

3) Give the scientific names of the following bees :
   i) The domesticated Indian bee – ..................................
   ii) The rock bees – ..................................

4) How does saliva of bees contribute in changing nectar into honey?
   ..........................................................................................
   ..........................................................................................

5) Name any three principal Indian states which produce large quantities of honey.
   i) ..................................
   ii) ..................................
   iii) ..................................

## 17.5 NON-CHORDATES YIELDING INDUSTRIAL PRODUCTS

We have seen that many non-chordates, serve as human food or indirectly their product like honey serve as food. We shall describe here some other uses of non-chordates.

The following industrial products are obtained from some non-chordates:

1. Silk
2. Shellac
3. Beeswax
4. Shells
5. Pearls
6. Corals
7. Sponges
8. Dyes and pigments

### 17.5.1 Silk

Though various species of insects produce silk, which is a secretion of their salivary glands, silk of commercial quality is produced only by a very limited number of specie: The silk produced by the mulberry silk worm of the species *Bombyx mori* is the most valued of these. This species belongs to the family Bombycidae. This silk is one of the most valuable and widely used products. It is the secretion of the paired salivary glands of the full grown last larval stage of the silk moth *Bombyx mori* (Fig. 17.5). The worm feeds on mulberry leaves (*Morus alba*).

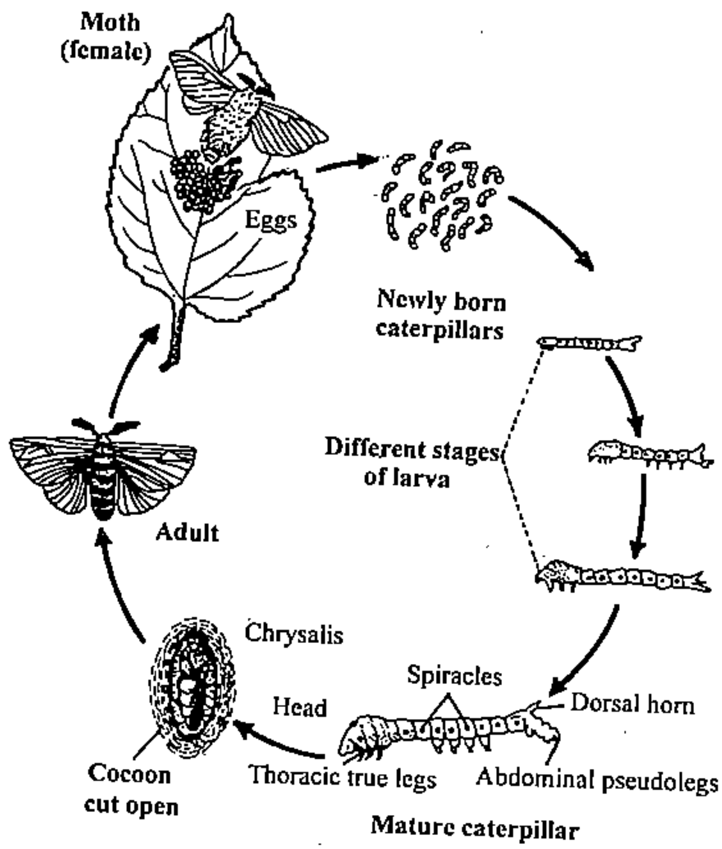


**Fig. 17.5:** Life-cycle of *Bombyx mori.*

The adult moth is creamy white about 5 cm across with fully spread wings. From head to the tip of the abdomen, it measures about 3 cm. The wings are however feeble and the insect scarcely flies. As adult it takes no food and lives for only 2-3 days during which the female lays 300-500 eggs. The eggs hatch into tiny larvae by 8-12 days. These feed on mulberry leaves and grow in size. These moult four times to reach full grown size of about 8 cm in length. It is grayish and has a hump behind the head and a spine-like horn at the hind end dorsally. Full growth is reached by 28-30 days. When full grown it becomes restless and spins a cocoon.

**Spinning of cocoon** takes about 3 days. During this operation the head is constantly moved from side to side swiftly at the rate of about 65 times per minute. As this larva does so, the secretion of the salivary gland is continuously poured out through the common opening at the tip of a median cylindrical spinneret on the lower lip or labium. This is a clear viscous fluid, but as it is exposed to the air it hardens into the fine silk fibre. This fibre forming the cocoon is continuous and ranges in length from 700 to 1100 metres. Silk consists of two proteins: fibroin and sericin. The silk thread is elastic, resistant and non-conductor of heat and electricity. It has also good tensile strength, comparable to steel. The cocoons are oval. The colour of the silk varies from white to a beautiful golden yellow.

**Pupation:** The larva pupates within the cocoon. The cocoon is made up of a single reelable thread. The pupa is the inactive stage undergoing metamorphosis to become adult moth. The **adult moth** emerges from the cocoon after 10-12 days. While coming out it softens one end of the cocoon by an alkaline secretion which enables it to break through the strands of silk. Such cocoons through which the moths emerge are called pierced cocoons. These are of low value because they cannot be reeled.

**Reeling:** For reeling (winding the thread on a wheel), the cocoons are gathered about 8 days after spinning begins, and the pupae are killed usually by heat from steam or hot air or even by fumigation and then thoroughly dried. Next, the cocoons are immersed in warm water. This loosens the fibre. The fibres from four or five cocoons are caught up together and twisted into a thread that is wound on the reel.

**History of Silk:** Usefulness of silk was first discovered by Empress Lotzu in China about 2700 B.C. Since then silkworms were reared and silk was produced in that country as a monoply for about next 2000 years. In the year 550 A.D. two European monks smuggled out eggs of silk moth and thus introduced silk culture in Europe.

Today, sericulture, or the commercial production of silk, is an important industry in several countries including China, Japan, India, France, Spain and Italy. In India the mulberry silk is produced extensively in Karnataka, Tamil Nadu, Assam, West-Bengal, Jammu-Kashmir and Punjab.

**Non-mulberry silk industry.**

You have studied above how mulberry silk is produced by the silkworm *Bombyx mori*. This moth no more exists in wild state and is completely domesticated. However, other moths still exist in the wild condition. They and their products are described below.

1. **Tasar Silk**

   Tasar silk is produced by three species of *Antheraea*, a moth belonging to the family Saturnidae. The commonest of this genus is *A. paphia* (Fig. 17.6). Its larvae feed on some trees like *Terminalia, Dalbergia, Shorea, Zizyphus, Ficus* etc. in the thick jungles of Bihar, Madhya Pradesh and Orissa. The silk of its cocoons is also reelable and is brown or coppery in colour.

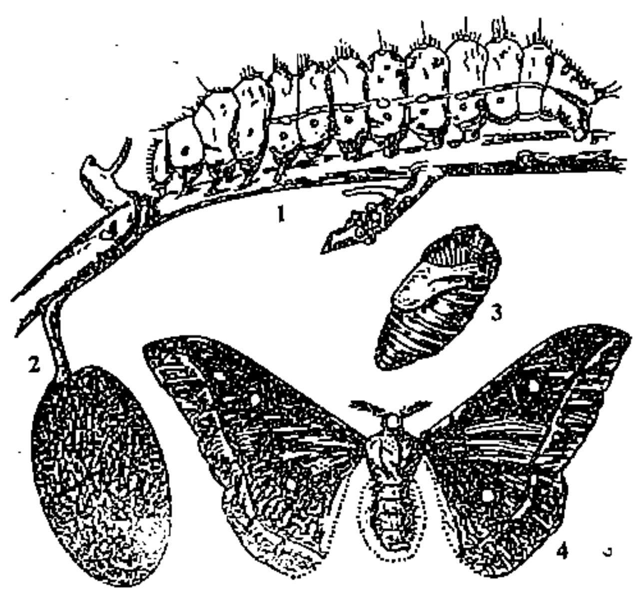


**Fig. 17.6: Tasar silk moth *Antheraea paphia*: Adult, egg, larva, pupa and cocoon.**

2. **Muga Silk**

   This is produced by *Antheraea assamia* (Fig. 17.7) confined to Assam along Brahmaputra Valley of India.

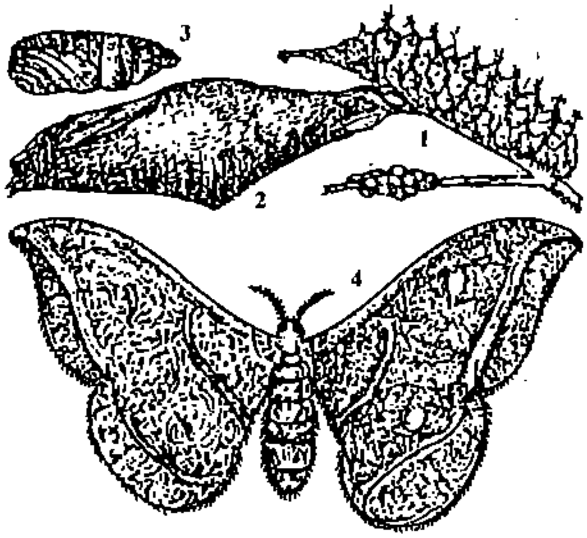


Fig. 17.7: Muga silk moth *Antheraea assamia*. Adult, eggs, cocoon (enclosed inside leaf) and pupa.

3. **Eri Silk**

Eri silk is the product of the eri silkworm *Phylosamia ricini* (Fig. 17.8) that feeds on *Ricinus communis* (Castor plants). This species also is a moth belonging to the family Saturnidae. It is raised in Orissa and Assam commercially, and can be reared on castor leaves. Its silk is white or brick red in colour, though not as glossy as mulberry silk. It is not in one single strand. So it is not reelable, but has to be spun like cotton. So the moths can be allowed to emerge from the cocoon.

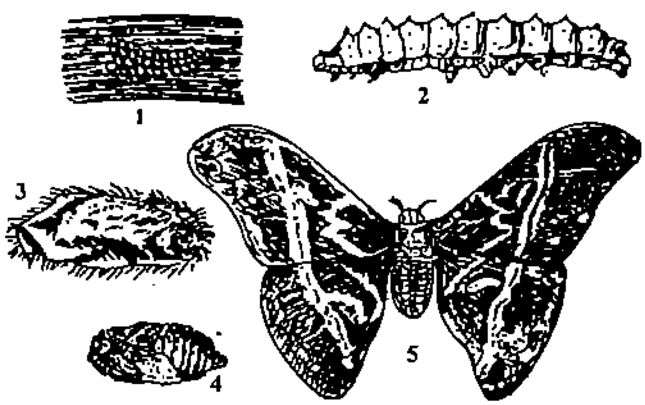


Fig. 17.8: Eri silk moth *Phylosamia ricini*, Adult, eggs, larva, cocoon and pupa.

## 17.5.2 Lac

Lac and the related shellac are familiar substances used for making french polish and floor polish, gramophone records, bangles, printing ink, electrical insulators and sealing wax. It is also employed for a host of other purposes. However, now-a-days substitute synthetic substances are being used for some of the above items.

Lac is the product of a tiny insect *Laccifer lacca*, popularly called the lac insect. The insect lives on a number of forest trees, especially *Butea frondosa*, (Palas), *Zizyphus jujuba* (Ber) and *Schleichera trijuga* (Kusum) . Besides India, lac insect also grows on certain forest trees in Pakistan, Myanmar (formerly Burma), Malaysia, Sri Lanka, China, Thailand and Indo-China.

**Life History:** Minute young lac insects called crawlers (larvae) hatching out of the eggs find a suitable place or a twig. Then they insert their proboscis or beak into the succulent plant tissues, and start sucking the plant sap. Thus they grow and secrete a resinous material that ultimately covers it. The resinous encrustation increases in size with growth of the insect. As thousands of crawlers settle side by side and the resinous encrustation builds up around them, it ultimately completely encloses the twig. After three months, most crawlers develop into females which cannot escape from the resinous mass. The males, which may be winged or wingless forms, emerge and fertilise the females through minute openings, that extend to the surface of encrustation, thereafter the males die. As the eggs develop inside the body of the female, she grows fast and assumes a sac-like bright red appearance. This red pigment is a source of lac dye. The female dies inside its little chamber, the eggs hatch into crawlers which escape through the narrow opening, move to a nearby uninfested part of the twig and the process is repeated (Fig. 17.9).

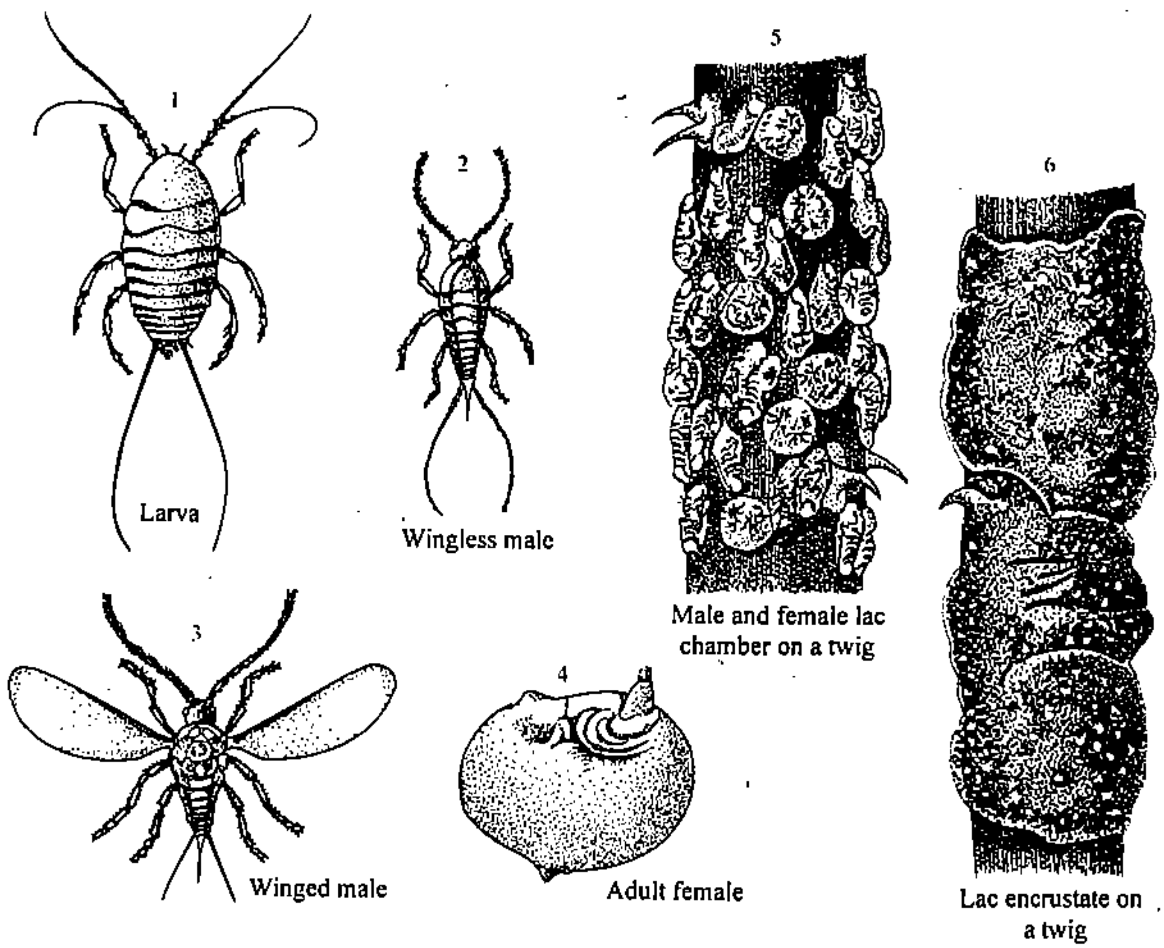


Fig. 17.9: Lac insect. 1. Larva, 2. Wingless male, 3. Winged male, 4. Adult female, 5. males and females on a twig. 6. Resinous encrustation encloses twig.

**Stick lac and Seed lac** - The encrusted twigs are called the stick lac. Such twigs are removed and the encrustation is then scraped, ground, soaked and washed, now it is called seed lac. It is then processed with certain other materials to make shellac in the form of thin orange or yellow flakes.

### 17.5.3 Beeswax

Beeswax is the material that makes the beehive. This material is a secretion of the *worker bees* that is poured out from the wax glands that open on the underside of the abdomen forming thin delicate scales. The worker bee removes these wax flakes with its legs, picks them up into mouth, manipulates by the mandibles and builds the combs of the hive. Wild bees especially *Apis dorsata* is the main source of beeswax in India. Beeswax is used in manufacturing candles, shaving creams, cosmetics (various creams, lotions, lipsticks, eyebrow pencils, rouges, pomades etc.), polishes, floor waxes, models, crayons, etc. However, now-a-days, in many cases the use of beeswax has been replaced by paraffin wax and other products.

### 17.5.4 Shells

"Shell" is applicable to the hard skeletal structures, chiefly of the two phyla Protozoa and Mollusca. In Protozoa the foraminiferans possess a hard calcareous shell and in Mollusca most have either a single valved shell (gastropods and cephalopods) or a double valved shell (bivalves). The protozoan shells have mainly contributed to the formation of chalk as you have already learnt in Unit-2 of this course.

**Chalk** - Chalk is a soft white, gray or buff limestone chiefly composed of the shells of foraminiferans such as *Elphidium* (*Polystomella*), and *Globigerina*. Shells of these dead organisms cover 30 to 40 per cent of the ocean floor as "foraminiferan ooze". In course of time the products of these bottom deposits have become rocky limestone and chalk. When uplifted geologically these form the limestone mountains and the chalk cliffs. Chalk finds use in several ways.

**Molluscan shells**

Some of the well known commercial or industrial uses of molluscan shells are the following: Shells of a variety of molluscs have been used for making quick lime used for construction work. Shells of fresh water mussels in particular have been used for making buttons almost throughout the world. These are lustrous and shiny and are not affected by washing. However, these days buttons are mostly made from synthetic material.

**Cowries** - Cowries are exquisite shells of *Cypraea* and related species (Cypraeacea). Their shells have been used in making ornaments and other decorative items. Cowries are also used in certain indoor games.

**Conches** - These are the shells of certain large spiral shelled marine gastropods (such as the genera *Strombus* and *Cassis*). These shells have been used for making sculptures or carving on them. The sacred shankh, *Xancus pyrum* is a conch. This is used in temples, for blowing. A number of other shells are beautiful items for collectors. Several gastropods like *Triton* and *Terebra* and a cephalopod *Nautilus* are specially very attractive. The sectional view of *Nautilus* reveals the lovely internal design. The inner surface of the shell is very smooth with pearl-like shine and hence this mollusc is also called pearly *Nautilus*.

**Cuttle bone** - It is the calcareous internal shell of cuttle fish Sepia. Sometimes it reaches a fairly large size of about 20 cm length.

Cuttle bones are light due to minute air spaces inside. As the animal dies and finally decomposes, the clean cuttle bones float on the surface of the sea and are often thrown on the sea shore. The cuttle bone has been widely used for polishing and as a food supplement for pet birds including poultry.

### 17.5.5 Pearls

Pearls have been highly valued by man since ancient times. These beautiful and costly objects, have been used in making jewellery. Pearls are produced by two kinds of molluscs:

i. Pearl oyster: Several species of *Pinctada*, with common species *P. vulgaris* and *P. margaritifera*. Pearl oysters (Fig. 17.10 A) are all marine and these produce oriental pearls of good quality.

ii. Freshwater mussels (*Unio* and *Anodonta*): Pearls produced by mussels are of inferior quality.

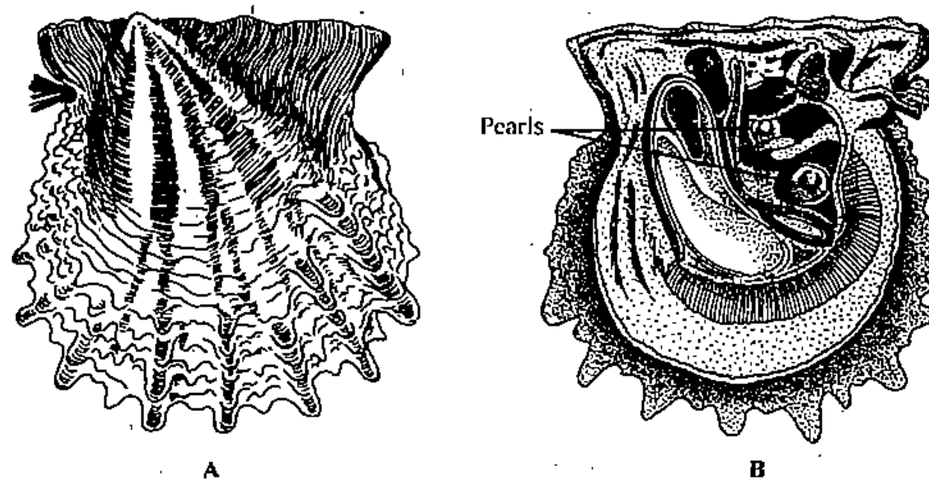


Fig. 17.10: A. Pearl oyster, complete. B. Pearl oyster opened to show pearls in it.

**Sites of pearl production:** Main sites of pearl production are Persian Gulf, Gulf of Mannar, Palk Bay, Gulf of Kutch, Panama Bay, and Gulf of California. But now Japan is the largest pearl producer through their pearl culture technique.

**Formation of Pearl**

Before we study formation of pearl, let us see the structure of the shell of the mollusc. The shell is secreted by the underlying mantle. Cross section through a shell valve of the mussel or oyster shows three distinct layers that constitute the shell (Fig. 17.11).

i. **Periostracum:** Outermost horny layer. This protects the shell from dissolution.

ii. **Prismatic layer:** It is calcareous and is made up of minute crystals of calcium carbonate, separated by thin layers of conchiolin.

iii. **Nacreous layer:** Innermost smooth layer of the shell. This is also called the "mother of pearl". It is composed of calcium carbonate crystals aligned parallel to the mantle surface. This is the lovely shining and smooth inner surface of the shell valves.

The mantle has also three layers.

i. **Columnar epithelium:** This is immediately next to the nacreous layer of the shell. It consists of cells that secrete the "Mother of Pearl".

ii. **Connective tissue layer:** This is the middle layer.

iii. **Ciliated epithelium:** This is the layer farthest from the nacreous layer (Mother of pearl) of the shell and it secretes mucus.

Pearl is produced when a minute foreign object like a sand grain or a parasite larva lodges itself between the mantle and the shell valve. As a protective measure against the irritating foreign object, the epithelium of the mantle slowly encloses the object forming an epithelial sac. The epithelium secretes concentric layers of nacreous substance. In about 3-4 years, the pearl is completed (Fig. 17.11).

Fishing of pearl oysters is carried out by divers. These are left exposed to air for a few days for the organic matter to decompose. Finally they are washed and the pearls are picked up by hand.

Pearl culture is a new technique chiefly developed and practised in Japan. Small artificial objects are introduced between mantle and the shell of the pearl oyster. This "impregnated" oyster is allowed to live in its normal habitat and in course of time it produces pearl.

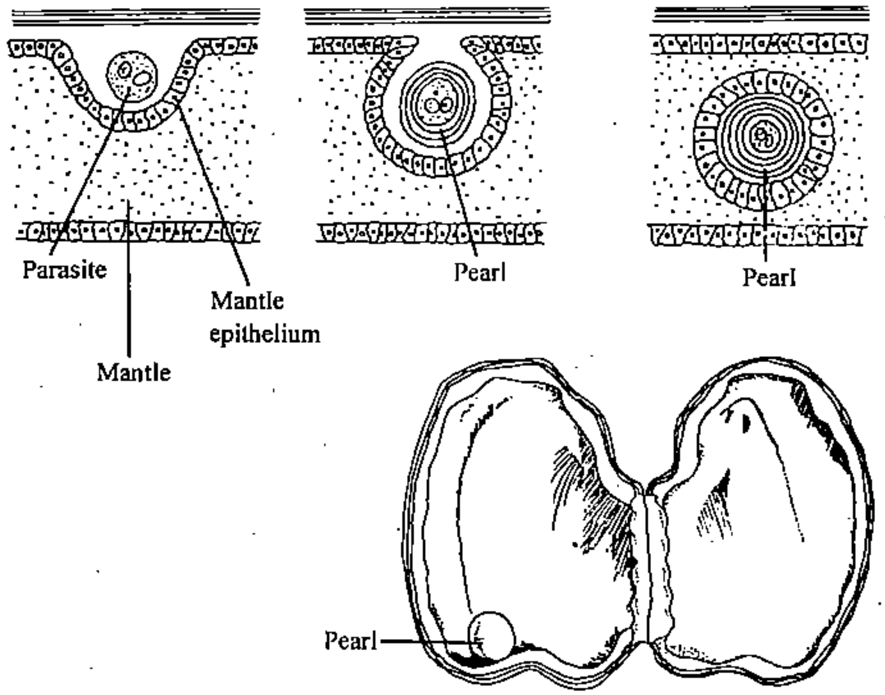


**Fig. 17.11: Pearl formation. A. A foreign object caught between mantle and shell. B. the mantle epithelium encloses the object and starts secreting nacre in concentric layers around it. C. Completely enclosed sac showing a pearl inside it. D. A pearl attached to the shell valve.**

## 17.5.6 Precious Corals

Coral is a general term employed to denote the calcareous or the horny skeletal deposits produced by certain cnidarians (anthozoans and rarely hydrozoans). One of these, the red

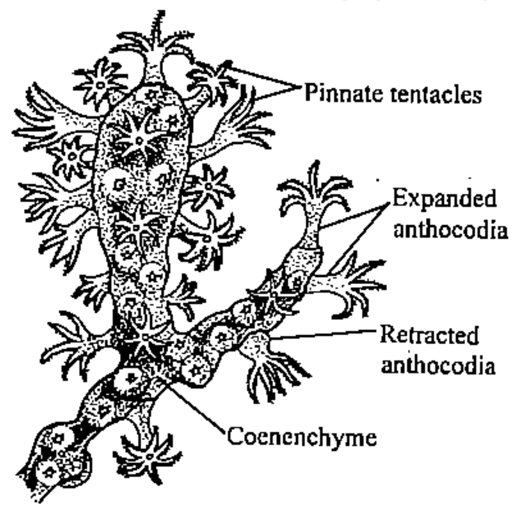


**Fig. 17.12: The red coral of commerce *Corallium rubrum*.**

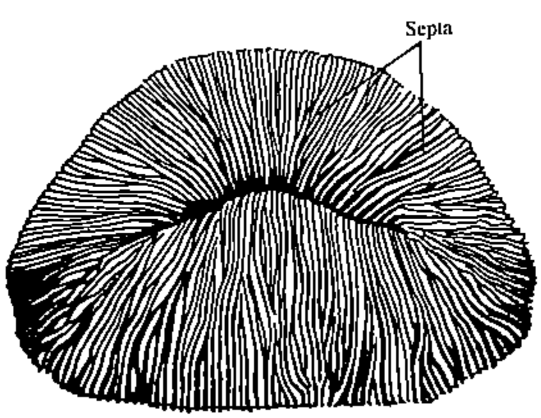


**Fig. 17.13: Fungus coral, *Fungia*.**

coral of commerce is highly valued and is precious. It is used in making jewellery. This coral is the skeleton produced by *Corallium rubrum* which grows as a branched colony (Fig. 17.12). The red coral of commerce naturally occurs in the sea around Japan and in the Mediterranean sea.

Several corals (Cnidaria) are appreciated for their beauty. The fungus coral (*Fungia*), (Fig. 17.13) rose coral are some such examples that lend beauty to any collection of natural objects.

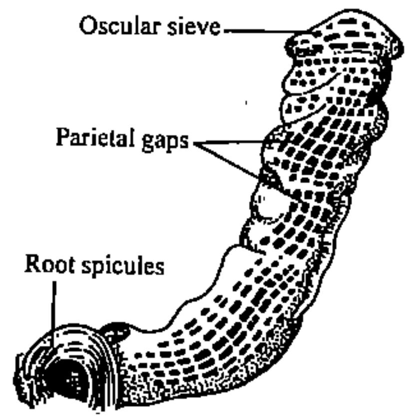


**Fig. 17.14: Venus's flower basket, *Euplectella aspergillum.***

### 17.5.7 Sponges

Sponges have been in use since ancient times. The Greeks, and later the Moghuls in particular, used the dried fibrous skeletons of the sponges for various purposes - bathing, washing, scrubbing floors and padding shields and armour. The Romans used them for painting. These were also being used in hospitals, infant nurseries, etc. All these are actually the skeleton of the sponges. However, the synthetic "sponges" have virtually replaced the natural ones.

The water-holding capacity of sponges, is on account of the minute capillary spaces enclosed by the spongin fibres.

Commercial sponges are obtained exclusively from the sea. The common bath sponges are *Spongia* and *Hippospongia*. They come under family Spongiidae. They are gathered from the Gulf of Mexico, the Caribbean and the Mediterranean. Some of these are as follows:

| **Source animal** | **Place of occurrence** |
|---|---|
| *Euspongia officinalis* | Mediterranean and Adriatic Sea |
| *Spongia dura* | Bahamas |
| *Hippospongia lachne* | Bahamas |

After collection their living tissues are allowed to decay. These are then thoroughly washed, cleansed, cut, trimmed, bleached and graded.

Venus flower basket *Euplectella* is a glassy sponge, its skeleton (Fig. 17.1) is an object of beauty often used as a gift.

### 17.5.8 Dyes and Pigments

Best known examples under this category are certain pigments obtained from insects. A very common pigment widely used since olden times is that of **cochineal dye.** It is a beautiful red dye that has been much used in textiles and is highly preferred as it imparts permanent colour. It has also been used in cosmetics, as a colouring for beverages and in decorating cakes and pastries. Its source is'a tiny insect *Dactylopius coccus* that lives on the prickly pear *Opuntia coccinellifera* in Mexico. The related *Dactylopius tomentosus* occurs in India, on *Opuntia dillenii*. These insects are close relative of lac insects. The dye is obtained by grinding the dried body of these insects.

**Dyes from insects galls:** Galls are peculiar growths in plants caused by a number of insects. These insects insert their eggs in plant tissues which produce the gall containing the developing larval stages. Some galls yield dyes used for dyeing hair, wool, leather and for preparing permanent inks. Some galls contain high percentage of *tannic acid.*

## 17.6 MEDICINAL USES OF NON-CHORDATES

Some non-chordates are of use in medicine especially in traditional, ancient medicine. **Leeches** are still widely used in blood letting. People believe that the leeches suck the "bad blood".

**Honey bees** have been used to extract a medicine from the excited worker bees used to cure diphtheria. Bee venom is used for curing rheumatism and arthritis.

**"Allantoin"** is obtained from the maggot larvae. It is said to be effective in treating deep wounds.

**The Spanish fly** *Lytta* (*Cantharis*) *visicatoria* and *Mylabris* species are an excellent source of **cantharidin**, a pharmaceutical product.

## SAQ 3

1) Match the commercial products given in column I with the source animals in column II.

| | Column I (Commercial Product) | | Column II (Source animal) |
|---|---|---|---|
| a) | Mulberry silk | i. | *Laccifer lacca* |
| b) | Pearl | ii. | *Antheraea paphia* |
| c) | Lac | iii. | *Bombyx mori* |
| d) | Tasar silk | iv. | *Corallium rubrum* |
| e) | Honey | v. | *Pinctada margaritifera* |
| f) | Red coral of commerce | vi. | *Euspongia* |
| g) | Bath sponge | vii. | *Apis indica* |

2) Why is it necessary to kill the pupa in silk cocoons to obtain silk fibre for realing?

..........................................................................................................

..........................................................................................................

3) Fill in the blanks:

i) The eri silkworm mainly feeds on the leaves of ................................. tree.
ii) The adult ............................ of the lac insect cannot come out of its resinous chamber, and finally dies in it.
iii) Chalk is a substance produced by certain members of the phylum ..............................
iv) The cochineal insect lives on .................................. .

4) Name any four kinds of molluscan shells and their main commercial or industrial use.

..........................................................................................................

..........................................................................................................

5) What induces the pearl oyster to produce a pearl?

..........................................................................................................

..........................................................................................................

6) Given below is a list of certain non-chordates:

Maggot **larvae**, **honeybee**, leech, Spanish fly

Fill in the blanks by choosing appropriate non-chordate

i) Allantoin for treating deep wounds is obtained from ............................

ii) Cantharidin is obtained from ....................................

iii) The bee venom used to treat rheumatism and arthritis is obtained from ........................................

iv) ........................................ is sometimes used for blood letting.

7. Give one example each from the following phyla, which is used as decoration object.

i) Mollusca ......................................

ii) Cnidaria ..................................

## 17.7 NON-CHORDATES - USEFUL IN AGRICULTURE

Though many non-chordates are harmful to the crops as you have already seen in Unit 1( there are several of this group that are remarkably useful. Three major areas of their usefulness are:

1. In improving fertility of the soil
2. In bringing about pollination
3. In destroying harmful pests

### 17.7.1 Non-Chordates Improve Fertility of Soil

There are two major contributors which improve the physical condition and the fertility of soil. These are:

i. Earthworms ( Phylum Annelida)

ii. A variety of insects ( Phylum Arthropoda)

**Earthworms:** Earthworms have been regarded as excellent friends of farmers. They improve the soil in many ways:

i. As they burrow through the soil they build channels and furrows which assist in aeration and irrigation and improve drainage. It helps in mixing and churning of the soil. This is perhaps the biggest use of earthworms.

ii. During feeding, earthworms take decomposing matter from surface leaves and coarse soil particles into their digestive tracts, grind them up and after absorbing organic matter from them, pass out the fine pulverised soil constituents as castings. This is an excellent organic manure. Thus the soil is pulverised and turned over from lower levels to upper surface.

iii. Nephridial excretions add to the nitrogenous content of the soil.

iv. At death the earthworms enrich the soil with the organic remains of their decomposed body.

**Insects:** Many insects and their larval stages habitually live in soil. They make burrows and make the soil porous thus contributing to what the earthworms also do. Some common examples of such insects are ants, beetles and grubs (beetle larvae), and certain species of wild bees. Many insects like beetles, ants, termites and spring tails (collembolans) break down the fallen leaves, twigs, etc. into minute pieces, eating them up and return the nutrients back to the soil.

### 17.7.2 Non-Chordates as Pollinators

Fruits rarely develop and seeds seldom set in without pollination. Moreover, cross pollination between two plants of the same kind has definite advantages. Animal visitors which go round from flower to flower in pursuit of nectar and pollen play an important role in cross pollination. Insects are intimately associated with this activity, and there are thousands of species of insects playing this role as pollinators.

**Plants pollinated by insects**

Some major crops that largely benefit from insect pollination leading to higher agricultural and horticultural yield are given below.

| | | |
|---|---|---|
| Apples | Oranges | Brinjals |
| Pears | Lemons | Tomatoes |
| Peaches | Melons | Soybeans |
| Plums | Cucumbers | Sunflower |
| Cherries | Beans | Cotton |
| Strawberries | Peas | Tobacco |
| Figs | | Many ornamental flowers |

A large number of forest trees and other wild plants owe their continuance of species olely to insects.

**Common insect Pollinators**

Among the thousands of insect pollinators some are mentioned below.

Honey bees, wild bees, bumble bees, wasps, a variety of flies, butterflies, moths, some eetles and ants. In fact, orcharders, especially in many western countries practise bee eeping to enhance productivity in orchards.

**ome adaptations of insect - pollinators and the flowers pollinated by them.**

he insect pollinated flowers in general, are large, usually brightly coloured, scented, and ossess nectaries. Their pollen grains are relatively large and sticky.

Most insect pollinators have a long probing type of tongue (**proboscis**) which they thrust nto the deep nectaries of flowers. While they do so their bodies are rubbed against the nthers to get a powdery smear of the pollen. As the insect visits another flower of the ame kind, this pollen gets brushed against its stigma to accomplish pollination. The oney bees are one of the most frequent visitors of flowers for nectar but they also collect rge quantities of pollen which they use as "bee-bread" for their developing larvae. For ollecting pollen the bees have a special "pollen basket" on the tibia of their hind legs Fig. 17.15). This pollen gathering habit of honey bees make them potent pollinators.

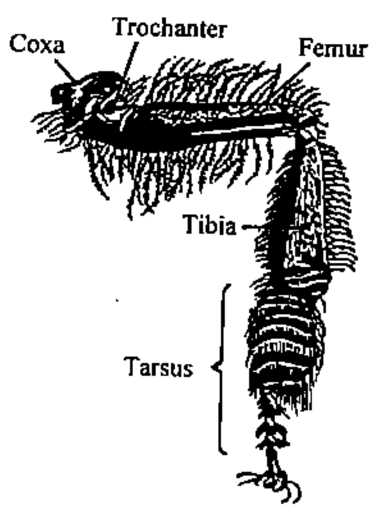


**Fig. 17.15: Hind leg of honey bee, showing pollen basket on tibia and wax sheers on tarsus.**

n the so-called hawk-moth orchids, the nectar in their flowers lies at the bottom of a long arrow tube and is accessible only to the "long-tongued" hawk moths. While probing for ectar the moth brings each eye against a sticky disc to which a mass of pollen is tached. Then the moth flies away carrying the mass (pollinia) on its eyes. When the oth inserts its proboscis into another flower the pollinia fit perfectly against the stigma nd adhere to it.

## 7.7.3 Non-Chordates as Destroyers of the Pest (Biological Control)

he three non-chordate groups which play important role in destroying various pests ome under Protozoa, Nematoda and Arthropoda respectively.

### Protozoa

Several Protozoan species are parasites of certain nematodes and insects that attack the agricultural crops. This is happening in a natural way, and offers the possibility of a wider application for achieving biological control of harmful nematodes. The protozoan *Malpighamoeba locustae* is known to be pathogenic to grasshoppers. *Farinocystis tribolii* infects the grain beetle *Tribolium castaneum* in India. Many protozoans such as *Nosema bombycis* and *Nosema lymantriae* are used against the insect pest European corn borer (*Ostrinia nubilalis*).

### Nematoda

Many nematodes, especially the rhabditids, in conjunction with bacteria, form disease complex affecting many insect pests. The nematode *Neoaplectana carpocapsae* forming a complex called DD-136 along with the bacterium *Achromobacter nematophilus* is an example. It affects caterpillars of the codling moth *Cydia pomonella.*

### Arthropoda

Arthropoda includes both predators and parasites that destroy harmful pests. Predators capture and devour their prey. Scorpions, spiders, centipedes and a very large number of insects are useful predators. A few examples of **insect predators** are given below:

| | |
|---|---|
| Dragonflies (odonates) | - Adults feed on some pests |
| Aphid-lions | - These are larvae of caddisflies that eat aphids (plant lice) |
| Ladybird beetles (Coleopterans) and their larvae | - Feed on aphids |
| Ground beetles (Coleopterans) | - Adults feed on various pests |
| Syrphid fly larvae (dipterans) | - Feed chiefly on aphids |

There are several **parasitic insects** which lay their eggs in or on the body of certain insect pests (Fig. 17.16). These parasitic insects belong mainly to the order Hymenoptera (Families: Ichneumonidae, Braconidae, Encyrtidae, Eulophidae, Aphelinidae, Pteromalidae and Trichogrammatidae) and Diptera (Family: Tachinidae). The eggs hatch and the larvae feed on the tissues of the host, ultimately destroying it. The adult parasite emerges out before the host insect dies continues egg laying, seeking out other host insects. Certain parasites lay their eggs inside the eggs of other insects. *Trichogramma minutum* is an example of such an egg parasite (Fig. 17.27).

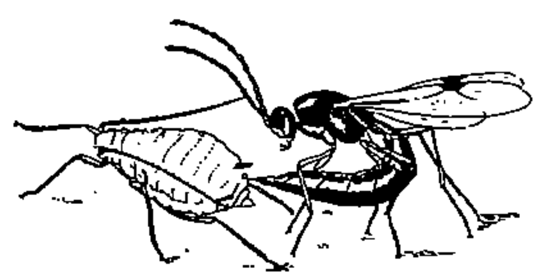

**Fig. 17.16: A parasitic chalcid wasp introducing an egg inside an aphid.**

**Fig. 17.17: *Trichogramma minutum* injecting its egg into the egg of a moth.**

Many of the predators and parasites are being employed in a scientific way to control pests. This method of controlling pests is known as biological control. Thus the pest cottony cushion scale, *Icerya purchasi* (coccid) was controlled in California (USA) by the predatory beetle *Rodolia cardinalis* (a lady bird beetle of the family Coccinellidae). Attempts are being made to control the coconut blackheaded caterpillar *Opisina arenosella* (*Nephantis serinopa*) by parasites *Peresierola nephantidis, Trichospilus pupivora* and *Bracon brevicornis*. These are only some examples of organisms employed in biological control. It may also be mentioned here that some insects keep weeds under check and have been used as biological control agents. Thus, the prickly pear, *Opuntia inermis* infesting extensive land mass in Australia was eradicated by introduction of an insect *Cactoblastis cactorum.*

## SAQ 4

1. List any three ways in which non-chordates are useful to agriculture.
   i. ____________________
   ii. ____________________
   iii. ____________________

2. Name any four non-chordates that substantially increase the porosity of the soil.
   i. ____________________
   ii. ____________________
   iii. ____________________
   iv. ____________________

3. How do earthworms improve the fertility of soil?
   ..........................................................................................................

4. Match the items in column I with the animals in column II.

| Column I | Column II |
|---|---|
| a) Pollen basket | i. Larvae of ladybird beetles |
| b) Predator of aphid | ii. *Trichogramma minutum* |
| c) Parasitic insect | iii. Honey bee |

## 17.8 NON-CHORDATES AS COMPONENTS IN FOOD CHAINS AND AS SCAVANGERS

The great majority of non-chordates form integral parts of food chains. Many such food chains ultimately produce organisms that may either be used as human food or in some other way useful to human beings. Small fish feed on minute aquatic organisms collectively called the plankton (a collective term for the passively floating or weakly swimming very small organisms). The larger fish which devour the smaller ones ultimately depend on this planktonic life since the small fish eat plankton. In this way, most planktonic organisms in the ocean constitute important useful components in the food chain, ultimately increasing the fish population in the ocean and inland reservoirs.

**Scavengers** : Any organism that feeds on dead material belongs to this category. Practically all phyla have some examples of scavengers. Arthropoda in particular have numerous such examples centipedes, millipedes, many crustaceans, common flies and a number of insects are scavengers. Ants, dung beetles, flesh flies etc. are examples.

## SAQ 5

1. Mention if the following statements are true (T) or false (F).

   i) All food chains are beneficial to humans.. ☐

   ii) Marine zooplankton largely consists of some ciliates and flagellates and a lot of small crustaceans. ☐

   iii) Non-chordates are constituents of food chains leading ultimately only to fishes. ☐

2. "Centipedes and ants can be regarded as scavengers". How do you justify this statement?

..........................................................................................

..........................................................................................

## 17.9 SUMMARY

- Many non-chordates are beneficial to man in a number of ways. Some are used as food, some collect food that can be used by man, some yield industrial products, and some have an important role in food chains.
- The commonest edible non-chordates are prawns, shrimps, lobsters, crabs, etc. and a few molluscs like the oysters and freshwater mussels. Honey is a main food item collected by a non-chordate that is widely used by man. Honey is mainly composed of predigested monosaccharides with rich vitamin content. In India apiculture employs mainly the Indian honey bee *Apis indica* for obtaining honey. *Apis mellifera* is the European species, gaining popularity in India also, due to greater quantity of honey it produces. Silk is the salivary secretion of silkworms, with which they spin cocoons. There are four common silk moths in India *Bombyx mori*, the mulberry silk moth, *Antheraea assamia* which gives muga silk; *Antheraea paphia*, the source of tasar silk and *Phylosamia ricini* which produces eri silk.
- India is the largest lac producing country. The tiny insect *Laccifer lacca* thrives on several forest trees. The minute male and female lac insects crowd on the twigs and secrete resinous protective chambers which form encrustations, which is lac. Lac is used extensively in several industries. Useful body secretions of non-chordates also include beeswax and a variety of protective mollusc shells. Chalk is the shell material of foraminiferan protozoans. Molluscan shells find several uses such as in making of buttons, and object of beauty and decoration. Pearls are objects of beauty and are used in making jewellery. These are produced by pearl oysters and clams as a protective measure by secreting pearly layers around some foreign object like a parasite larva lodged between mantle and shell. Pearl culture and pearl fishing are now well established industries.
- Certain corals like the red coral of commerce have ornamental value. Some other corals may be used as decoration objects. Several species of sponges are used for bathing, washing or padding purposes.
- A crimson red cochineal dye is obtained by grinding the dead bodies of the cochineal insect *Dactylopius cactus* that lives on a prickly pear.
- Medicinal uses of non-chordates are largely traditional. Leeches, honey bees, and "spanish flies" have been used for treating certain ailments. Many non-chordates lend beauty to the environment and serve as articles of decoration.
- Earthworms and several insects improve the soil through their burrowing and other activities. Pollination of crop plants by the bees and other insects results in fruit setting and thus contributes towards human welfare. Similarly, many arthropods kill agricultural pests either as predators or as parasites, and keep them under check. Some insects feed on weeds and keep them under check. A great many non-chordates are intermediate links in food chains that are ultimately beneficial to man. Quite a few non-chordates are valuable scavengers keeping the environment clean.

## 17.10 TERMINAL QUESTIONS

1. Categorise the different ways in which non-chordates are beneficial to man giving one example of each.

..........................................................................................

..........................................................................................

..........................................................................................

..........................................................................................

..........................................................................................

2. Describe how the non-chordates serve as food.

3. How are honey bees useful to man?

4. Describe the varieties of silk and how it is obtained.

5. What is lac? List any three trees on which lac is commonly produced.

6. How are pearls produced?

## 17.11 ANSWERS

### Self Assessment Questions

1. i. Arthropoda, Mollusca
   ii. Prawns (eg. *Penaeus*), shrimps (eg. *Crangon*), lobsters(eg. *Homarus*) crabs (eg. *Portunus*).
   iii. (a) T, (b) T, (c) F, (d) F, (e) T, (f) F

2. i. (a) used as a food/nutrient
      (b) used in medicines
   ii. (a) Fructose
      (b) Water
      (c) Sucrose

iii. (a) *Apis indica*
(b) *Apis dorsata*
iv. Saliva contains invertase which converts sucrose of nectar into glucose and fructose.
v. Tamil Nadu, Karnataka, Jammu and Kashmir.

3. i. (a) iii, (b) v, (c) ii, (d) vii, (e) iv, (f) vi
ii. If the pupa is allowed to grow into adult, it will break through the cocoon and will not yield a continuous silk fibre.
iii. (a) Castor, (b) female, (c) Protozoa, (d) Prickly pear/Opuntia coccinellifera.
iv. Freshwater mussel - button; cuttlefish - cuttle bone; Marine gastropods/ Strombus - conch, Cyprea - cowries, Oyster - quick lime a building material
v. Any foreign object such as tiny parasite which gets lodged between shell and mantle.
vi. (a) Maggot larvae, (b) Spanish fly, (c) Honeybee, (d) Leech
vii. (a) *Nautilus*, (b) Fungus coral (*Fungia*)

4. i. (a) Improve fertility of soil/make soil porous
(b) Bring about pollination
(c) Destroy harmful pests
ii. (a) Earthworms, (b) ants, (c) grubs, (d) termites
iii. (a) Burrow through soil making it porous
(b) Excrete out nitrogenous wastes which are thrown out mixed with soil as castings
(c) Soil turned over from deeper layers to upper surface
(d) At death their organic remains decompose
iv. (a) iii, (b) i, (c) ii

5. i. (i) F, (ii) T, (iii) F
ii. Both can eat dead organisms, and thus clean the environment.

## Terminal Questions

1.

| | | | |
|---|---|---|---|
| i) | used as food | - | prawns |
| ii) | Food gatherer | - | honey bee |
| iii) | Secrete industrial products | - | silk worm |
| vi) | Yield medicine | - | allantoin |
| v) | Decoration | - | corals |
| vi) | Support agriculture | - | honeybee |
| vii) | Parts of food chains | - | crustacean larvae |
| viii) | Clean environment | - | dung beetles |

2. Primarily two non-chordates phyla are providing food to humans, these are Arthropoda and Mollusca. Among arthropods the prawns (several species of the genera *Penaeus*, *Metapenaeus*, *Macrobrachium*). shrimps such as *Crangon*, lobsters like *Homarus* and several crabs are delicacy. Among molluscs the edible oysters and mussels are a precious food item.
3. Honey bees pollinate flowers, contributing to higher yield from agricultural and horticultural crops. Honey bees produce honey which is a rich source of energy and nutrients. Honey is used in medicines. Honey bees secrete wax as the nest-building material. Bees wax has numerous industrial uses.
4. There are four principal kinds of silk - mulberry silk obtained from *Bombyx mori*, tasar silk from *Antheraea paphia*, Muga silk from *Antheraea assamia* and Eri silk from *Phylosamia ricini*. Silk is the secretion of the last larval stage, and it comes from the salivary glands. It is a continuous fibre that is used by the larva to spin the cocoon. Normally adult moth emerges from the cocoon through a hole produced cocoon. But for industrial purpose the cocoons are heated to kill the moth inside and a continuous silk fibre is obtained for reeling.
5. Lac is a resinous secretion of the insect *Laccifer lacca*. Lac commonly grows on "Palas", "Ber" and "Kusum" trees.
6. Pearls are produced by the pearl oyster and by some freshwater mussels, when any foreign object like parasites or tiny inert materials lodge themselves between shell valve and the mantle. The mantle epithelium encloses the object and starts secreting pearly material around it in concentric layers to produce the spherical pearl.

## GLOSSARY

**Host**: Animal or plant which sustain a parasite.

**Intermediate host**: ordinarily the host in which live the larval or immature or asexual stages of a parasite.

**Parasite**: an organism that depends on its host for some essential metabolite, i.e., for its survival.

**Periodicity**: recurrence of a parastie at regular time intervals.

**Vector**: an essential intermediate host in which the parasite undergoes some development and which transmits the parasite further to a newer host.

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