

“शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।”

— इन्दिरा गांधी



“Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.”

— Indira Gandhi

Block

2

COELOMATES

UNIT 7**Phylum Annelida****7**

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UNIT 10**Echinodermata and Hemichordata****107**

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BLOCK 2 COELOMATES

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, Pseudocoelomata and Coelomata. In Block 1 you studied about acoelomates and pseudocoelomates. This block deals with coelomates. In this block you will learn about the classification, characteristic features of the various phyla of coelomic invertebrates. The block comprises four units.

The study of Coelomate group of animals begins with Unit 7. Annelids are discussed in the unit. Segmentation of the body is characteristic of this phylum. 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. They 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 study about arthropods in Unit 8. They are the most successful group of animals among invertebrates and constitute nearly 75% of all the living species found on the earth. Arthropods having inhabited all types of aquatic habitats are 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. Thick chitinous cuticle and varied mouth parts are their important features.

Unit 9 relates to the study of soft bodied animals, the molluscs. Molluscs which include snails, clams, oysters, squids and octopus 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. Unit 10 discusses the structure, organisation and classification of echinoderms which are exclusively marine in their habit. They are spiny skinned animals. The most striking features of echinoderms are water vascular system, haemal system and metamorphosis from bilateral larva to radial adult. Hemichordates are also dealt with echinoderms. They are soft bodied, worm like animals and show burrowing habits. They show some of both echinoderms and chordate characteristics.

Objectives

After studying this block you, should be able to:

- enumerate the characters of phyla Annelida and Arthropoda, name the classes under each phylum and relate their salient characters;
- discuss the reasons for the success of arthropods;
- describe how the mouth parts of insects are adapted for their various feeding habits with the help of diagrams;
- 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;
- describe the natural history and basic adaptive features of hemichordates; and
- outline the affinities, ancestry and evolution of hemichordates.

UNIT 7

PHYLUM ANNELIDA

Structure

7.1	Introduction Objectives	7.4	Classification of Phylum Annelida
7.2	Coelomata – Eucoelomata – Phylum Annelida The Coelom Metamerism (Segmentation)	7.5	Summary
7.3	Characteristic Features of Phylum Annelida	7.6	Terminal Questions
		7.7	Answers

7.1 INTRODUCTION

In this unit you will learn about coelomate animals. 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 (Fig. 7.1). This will be followed by the study of phylum Arthropoda – a successful group of invertebrates with jointed legs. You will study about Arthropoda in Unit 8.

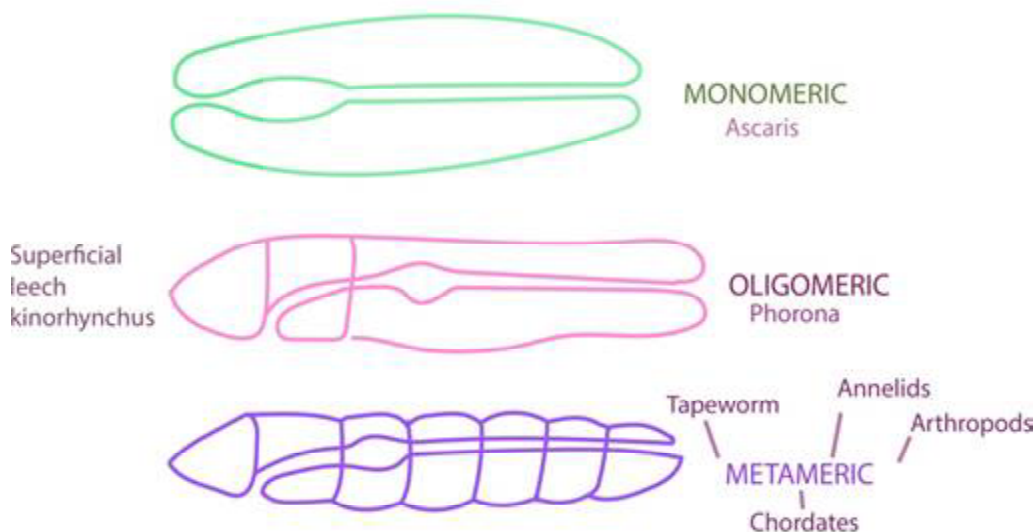


Fig. 7.1: Fundamentally different vermiform body plans in diagrammatic longitudinal section.

Objectives

After studying this unit you should be able to:

- ❖ discuss true coelomates and their advantages,
- ❖ enumerate the characters of phylum Annelida,
- ❖ name the classes under the phylum Annelida and relate their salient characters, and
- ❖ explain the phenomenon of metamerism.

7.2 COELOMATA – EUCOELOMATA – PHYLUM ANNELIDA

The animals belonging to phylum Annelida are true coelomates and they are also called eucoelomates. 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 sub-sections.

7.2.1 The Coelom

You have already learnt in the previous units 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. 7.2). 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 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.

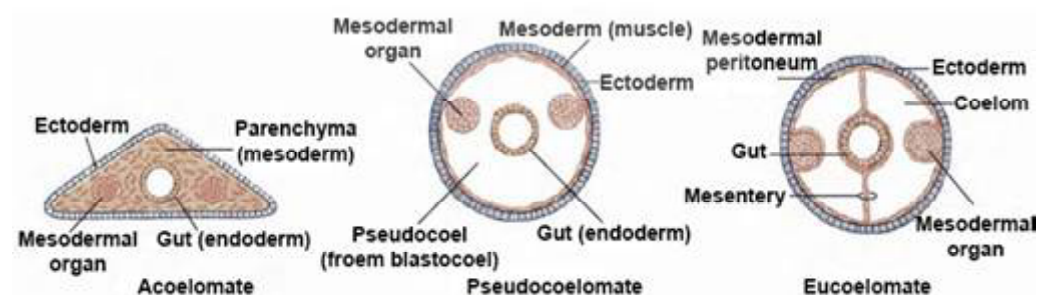


Fig. 7.2: Acoelomate, pseudocoelomate, and eucoelomate body plans.

7.2.2 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) (Fig. 7.3).

SEGMENTATION:

When body is marked by transverse constrictions on A/P axis it is called segmentation.

A) SUPERFICIAL: A series of ring like creases develop in the cuticle and the body wall which facilitate the bending and telescoping of body. It is strictly ectodermal.

B) METAMERIC: When the body is divided into smaller compartments on its A/P axis. Each compartment is separated by septum; when most of the mesodermal derivatives are also segmentally arranged.

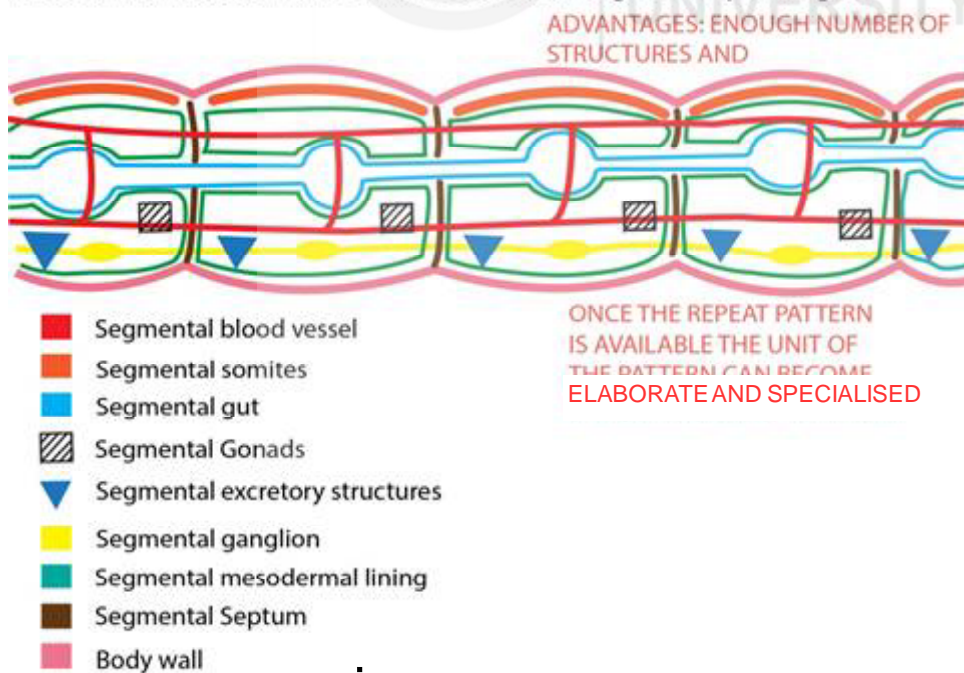


Fig. 7.3: Body Segmentation in Annelid

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

7.3 CHARACTERISTIC FEATURES OF PHYLUM ANNELIDA

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 respiratory pigments; plasma contains amoebocytes.
6. Gut muscular, with mouth and anus.
7. A pre segmental prostomium and a post segmental pygidium.
8. Nervous system consists of supraoesophageal ganglion (cerebral ganglion). Circumoesophageal ring and ventral nerve cord with segmental ganglia.
9. Different degrees of cephalisation are 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. 7.4). 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 in front backwards. Prostomium and pygidium are not considered segments. Mouth opens on the first segment, and anus opens on the pygidium. Anterior few segments fuse with the prostomium to form head. New segments are added on in front of the pygidium. So the youngest segments are situated posteriorly, first in front of the pygidium, and the oldest segments are situated anteriorly.

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

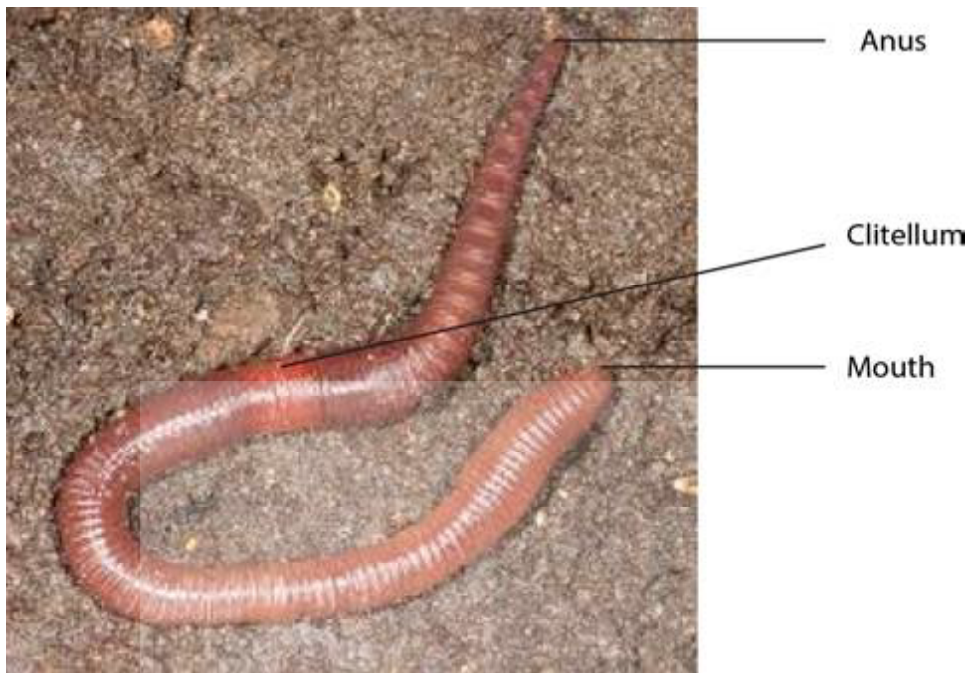


Fig. 7.4: *Lumbricus*.

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 i.e., 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 in front 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.

7.4 CLASSIFICATION OF PHYLUM ANNELIDA

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. Others 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 or 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 pre-oral 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. 7.5). These segments also usually carry sensory structures, but their parapodium also bears bundles of chitinous setae in the setal sacs. *Nereis* (Fig. 7.5) is a typical example. A cross section of its body through one of its middle segments (Fig. 7.6) shows well its internal organisation.

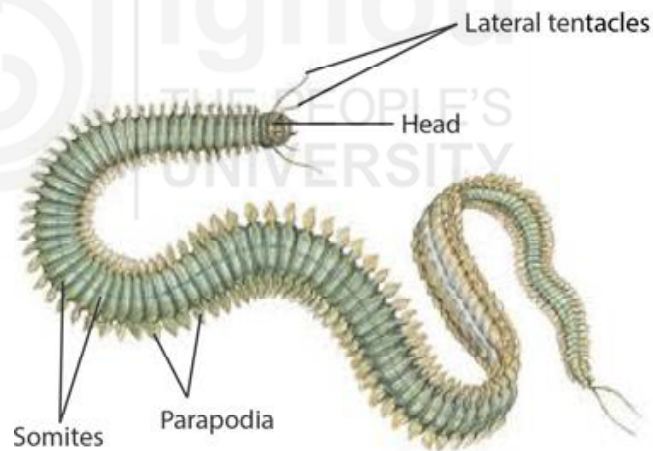


Fig. 7.5: *Nereis*.

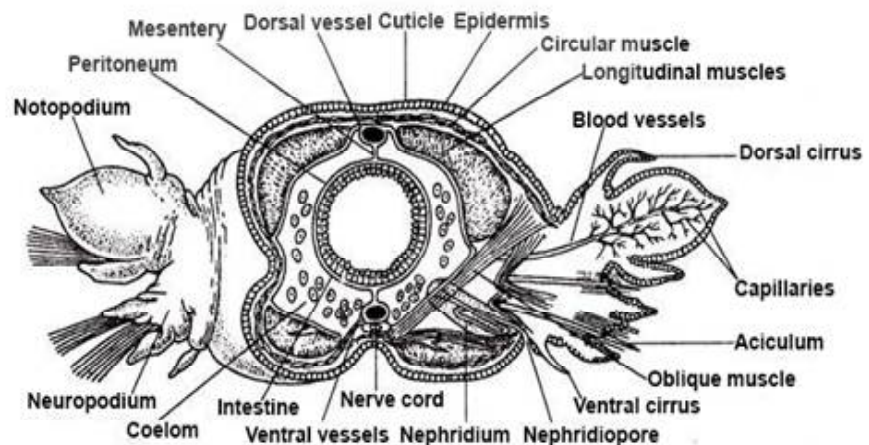


Fig. 7.6: Organisation of cross section of trunk *Nereis*.

Amphitrite is an example of a sedentary polychaete found in tubes built in mud or sand (Fig. 7.7). 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. 7.8) 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. 7.9) 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 with mucous secreted by wing like notopodia of the 12th segment. *Arenicola*, the lug worm (Fig. 7.10A) lives in a burrow which is 'L' shaped (Fig. 7.10 B). 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.

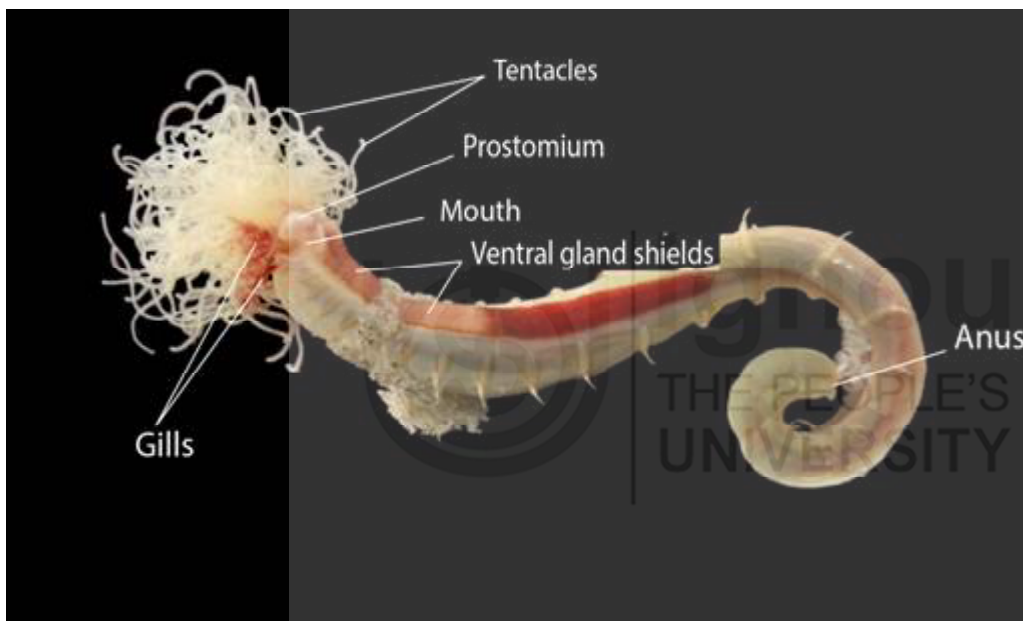


Fig. 7.7: *Amphitrite*.



Fig. 7.8: *Sabella*.

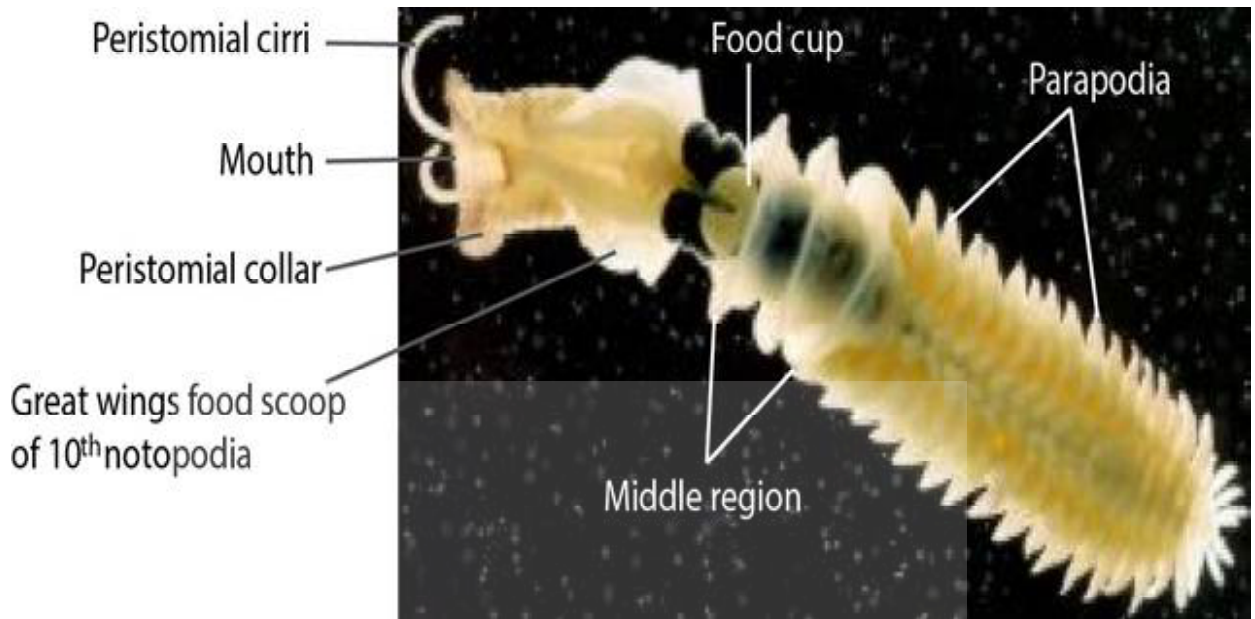


Fig. 7.9: *Chaetopterus*.



Fig. 7.10: A) *Arenicola*.

Eunice viridis (Fig 7.11) 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 there by 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.

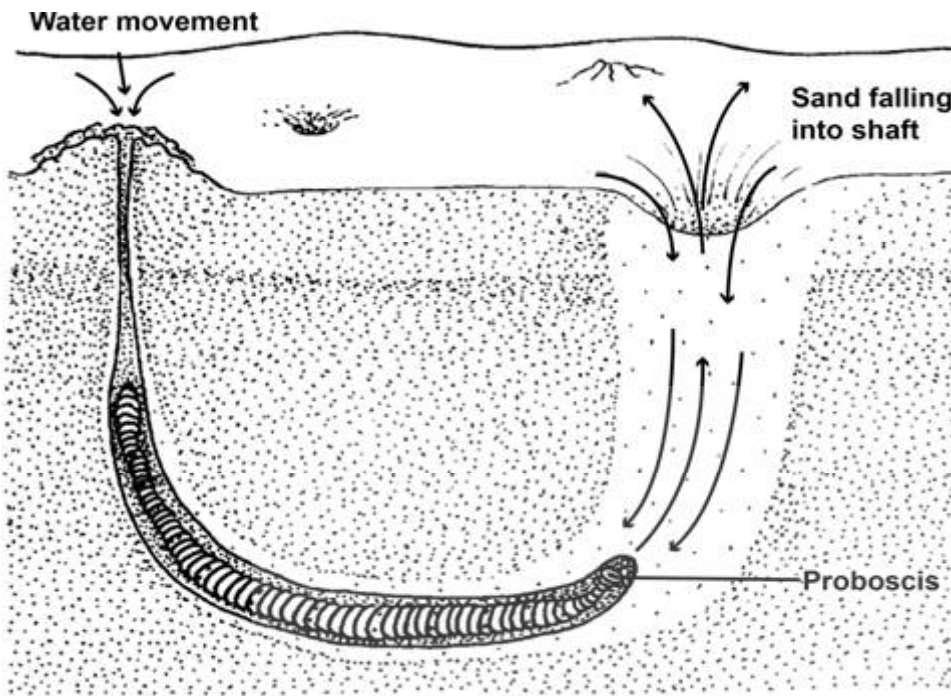


Fig. 7.10 : B) *Arenicola*, the lugworm, lives in an L-shaped burrow in intertidal mud flats. It burrows by successive eversions and retractions of its proboscis. By peristaltic movements it keeps water filtering through the sand. The worm then ingests the food-laden sand.

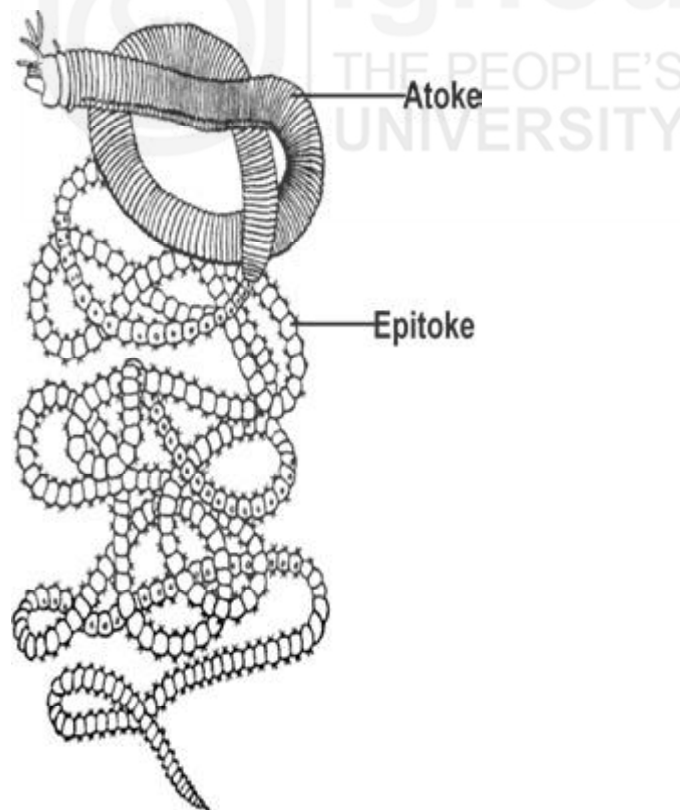


Fig. 7.11: *Eunice viridis*, The Samoan palolo worm. The posterior segments make up the epitokal region, consisting of segments packed with gametes. Each segment has an eyespot on the ventral side. Once a year the worms swarm, and the epitokes detach, rise to the surface, and discharge their ripe gametes, 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. Clitellum present. 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. 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. 7.12) 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.

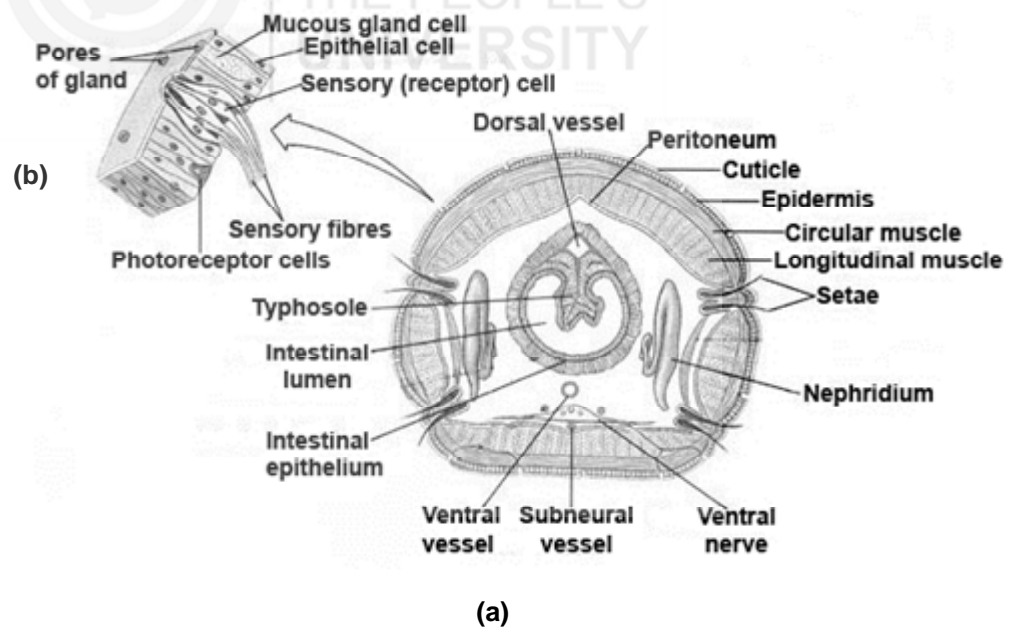


Fig. 7.12: Earthworm anatomy: a) Generalised transverse section through region posterior to clitellum; b) Portion of epidermis showing sensory, glandular, and epithelial cells.

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 and infolding of its wall, the typhlosole increases the surface 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 consists of the brain situated above the pharynx and made up of a pair of cerebral ganglia. A pair of circum-pharyngeal connectives connect the brain with the 1st ganglion of the double ventral nerve cord (sub-pharyngeal ganglion). The cord runs throughout the length of the animal, with a ganglion in each segment.

Earthworms are hermaphrodites. However, copulation between two worms takes place (Fig. 7.13 b), 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 mucous 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 end closes. Young earthworms hatch out from the eggs. *Lumbricus*, *Pheretima* (Fig. 7.13 a) and *Megascolex* are typical examples of earthworms.



(a)

(b)

Fig. 7.13: a) *Pheretima*; b) Mating and reproduction in earthworms.

Aelosoma (Fig. 7.14) is an example of fresh water oligochaete. It is about 1 mm long. *Stylaria* (Fig. 7.15) has a prostomium extended into a long process, *Dero* (Fig. 7.16) lives in tubes and has 3-4 pairs of gills, *Tubifex* (Fig. 7.17) usually has its head buried in mud in ponds and body showing a waving movement. It is reddish in colour. All these are aquatic oligochaetes.



Fig. 7.14: *Aelosoma*.

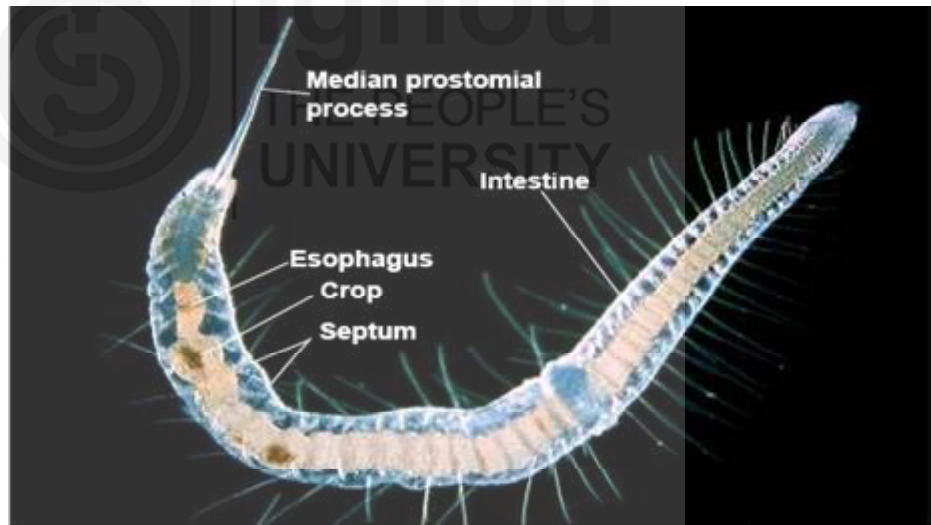


Fig. 7.15: *Stylaria*.



Fig. 7.16: *Dero*.



Fig. 7.17: *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 suckers 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. 7.18), and are flattened dorsoventrally. The **clitellum**, though present, appears only during breeding season. Their gut is highly specialised 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. 7.19).

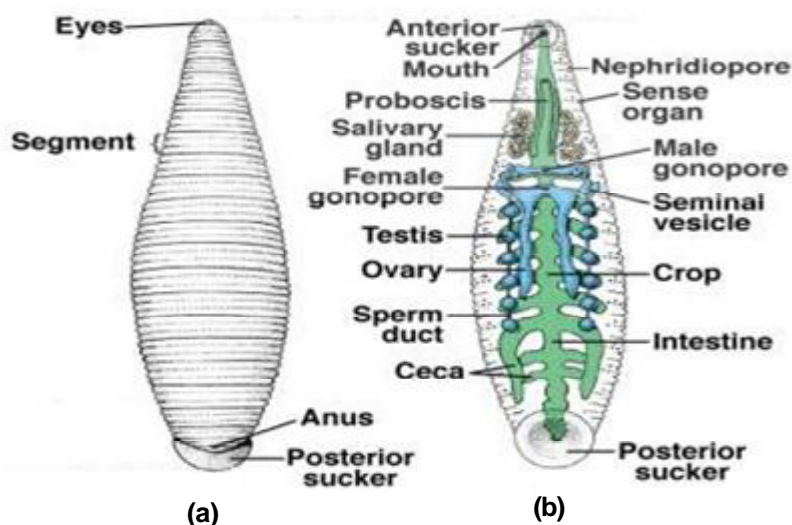


Fig. 7.18: Structure of a leech, *Placobdella*, a) External appearance, dorsal view; b) Internal structure, ventral view.

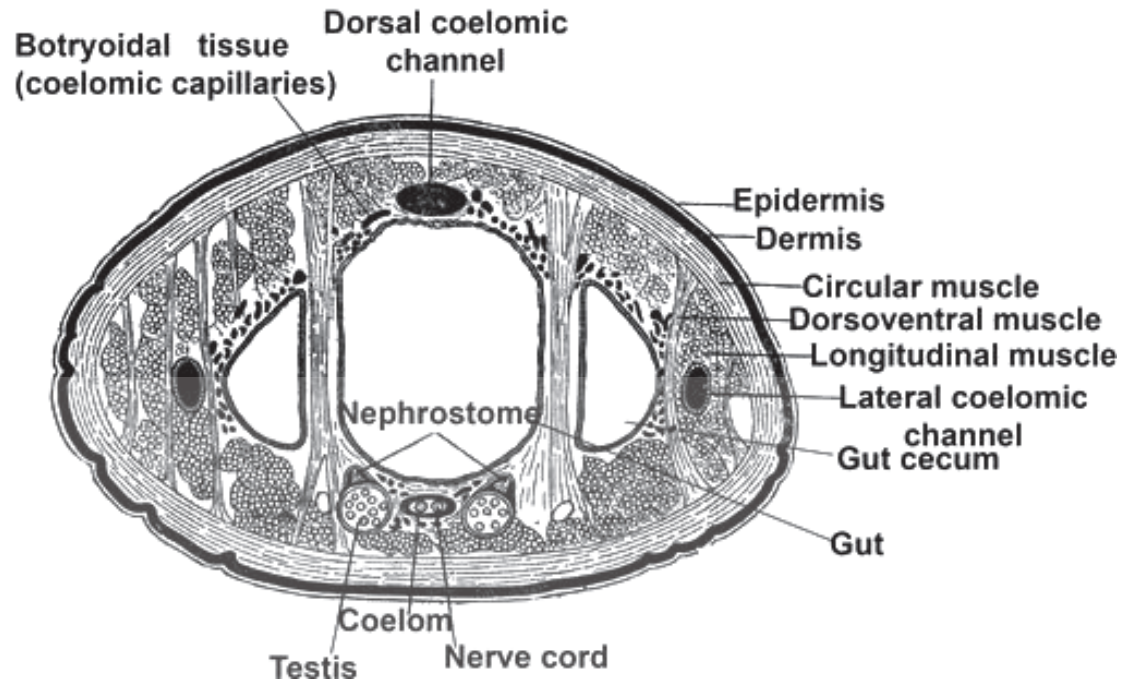


Fig. 7.19: Transverse section through the arhynchobdellid leech, *Hirudo*. In archynchobdellid leeches, the blood-vascular system has been completely replaced by the modified coelomic circulatory system.

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. 7.20), the medicinal leech; *Glossiphonia* (Fig.7.21), *Haemadipsa* (Fig. 7.22), a blood sucking terrestrial leech; *Piscicola* (Fig. 7.23), a fish parasite.



Fig. 7.20: External and ventral surface of the medicinal leech, *Hirudo medicinalis*.



Fig. 7.21: *Glossiphonia*.



Fig. 7.22: *Haemadipsa*.



Fig. 7.23: *Piscicola*.

SAQ 1

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

Absent	Parapodia	Citellum	Suckers	Setae	class
i)	absent	present only during breeding	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	?

7.5 SUMMARY

Let us summarise what we have learnt so far:

- Phylum Annelida which includes segmented worms is the first coelomate you have studied.
- Animals belonging to phylum Annelida are true coelomates and they are called eucoelomates.
- Annelids have elongated body divided externally into a number of rings representing a division of the internal parts into a series of segments or metameres.
- The fluid-filled space (coelom) serves as a hydroskeleton increasing the efficiency of burrowing.
- Body of annelids are vermiform, bilaterally symmetrical with metamerism.
- Triploblastic with tissues, organs and organ systems; body wall with outer circular and inner longitudinal layers: epithelium secretes an outer transparent, moist cuticle.
- Closed blood vascular system, respiration through skin, gills or parapodia.
A pair of nephridia in each segment to serve as excretory system.
- Sexes may be separate or animals may be hermaphrodite, some animals show a sexual reproduction by budding.

7.6 TERMINAL QUESTIONS

1. What do you mean by true coelomates? Discuss their advantages.
2. Explain the phenomenon of metamerism.
3. Discuss the characters of phylum Annelida.

7.7 ANSWERS

Self-Assessment Question

- 1)
 - i. Hirudinea
 - ii. Polychaeta
 - iii. Oligochaeta

Terminal Questions

1. Refer to Subsection 7.2.1.
2. Refer to Subsection 7.2.2.
3. Refer to Section 7.3.



PHYLUM ARTHROPODA

Structure

8.1	Introduction Objectives	8.5	Vision in Arthropods
8.2	General Characters of Arthropoda	8.6	Metamorphosis in Insects
8.3	Characteristic Features of Arthropoda	8.7	Summary
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8.1 INTRODUCTION

In the previous unit you have 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 with 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 that occupies every possible niche there. Like annelids, arthropods are coelomates and segmented, and probably both the phyla arose from a common ancestor.

Objectives

After studying this unit, you should be able to:

- ❖ enumerate the characters of phylum arthropoda;
- ❖ name the classes under the phylum arthropoda and relate their characters;
- ❖ discuss the reasons for the success of arthropods;
- ❖ describe how the insectan mouth parts are adopted for their various feeding habits;
- ❖ discuss the vision in arthropods; and
- ❖ describe the phenomenon of metamorphosis in insects.

8.2 GENERAL CHARACTERS OF ARTHROPODA

One of the distinguishing features of arthropoda 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. 8.1). The cuticle in each segment forms a dorsal plate the **tergum**, a ventral plate **sternum** and the lateral structures the **pleura** (sl. Pleuron) (Fig. 8.2). 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. 8.3). Muscles are attached to these apodemes.

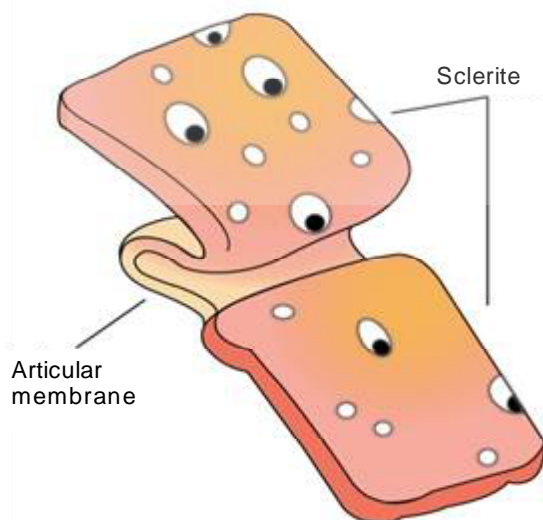


Fig. 8.1: Articular membrane between segments.

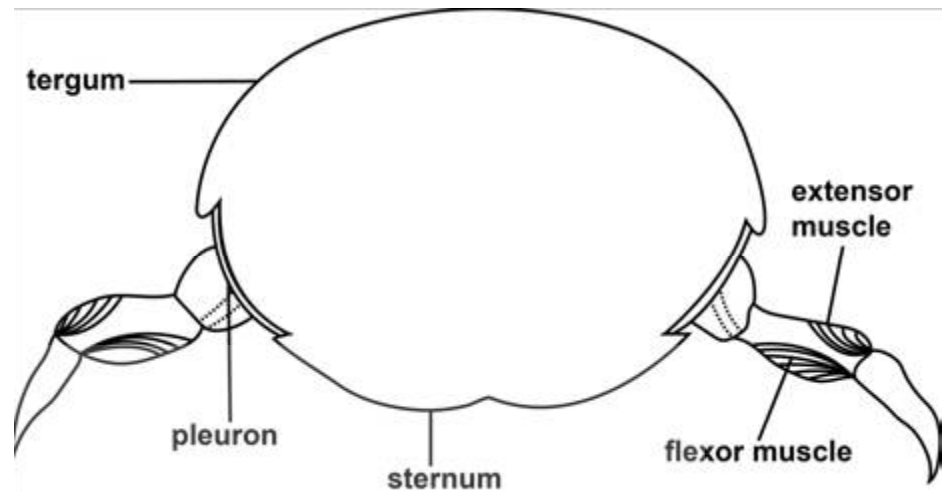


Fig. 8.2: Structure of a generalised segment.

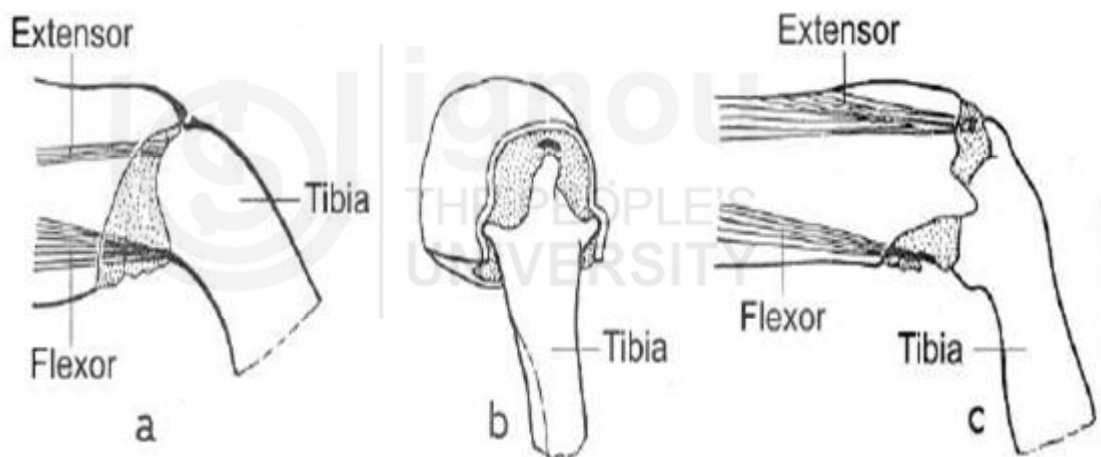


Fig. 8.3: Figure (a, b, c) showing apodeme, the site of muscle attachment.

The integument in arthropods has an epidermal layer that rests on a basement membrane. The epidermis secretes the cuticle as we have 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 animals. 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. 8.4).

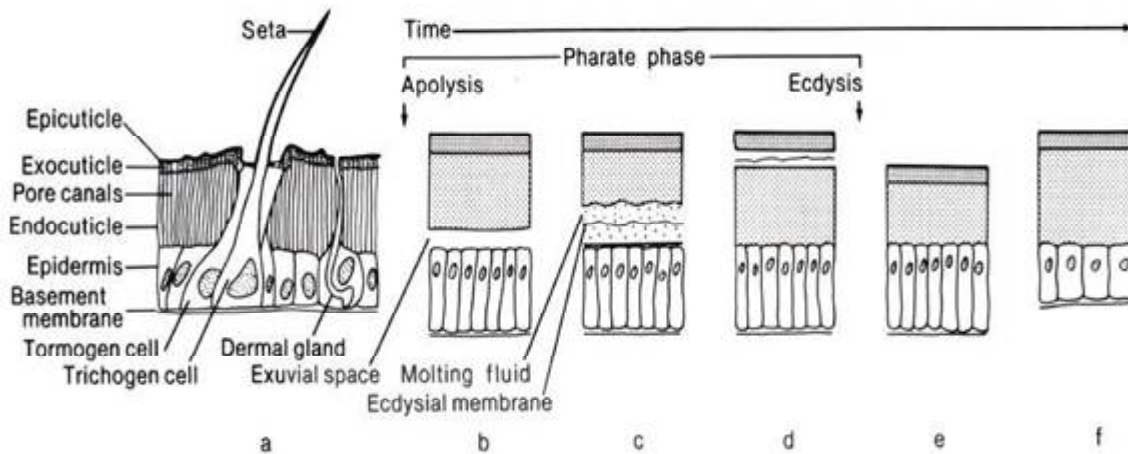


Fig. 8.4: Moulting in an arthropod: a) Fully formed cuticle; b) Separation of epidermis and secretion of molting fluid and new cuticle; c) Digestion of old endocuticle and secretion of new pro-cuticle; d-f) Newly formed cuticle and the old cuticle before it is shed.

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. 8.5). 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 haemocyanin as the respiratory pigment, and in a few species the pigment is haemoglobin.

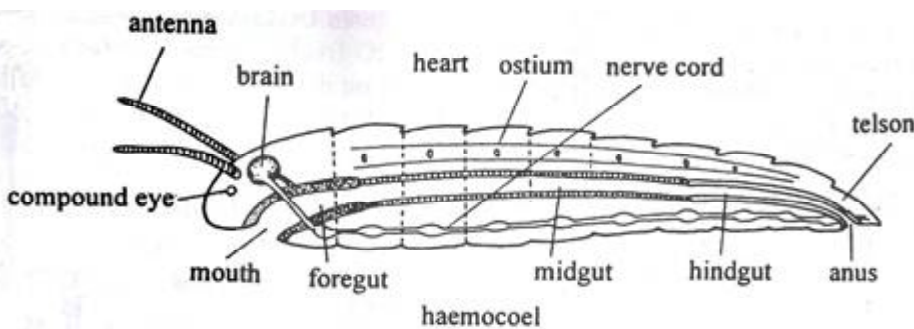


Fig. 8.5: Structure of a generalised arthropod.

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. 8.6).

Arthropod digestive tract is generally divided into three parts the foregut or stomadaeum, the midgut or mesenteron and the hindgut or proctodaeum (Fig. 8.7). 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.

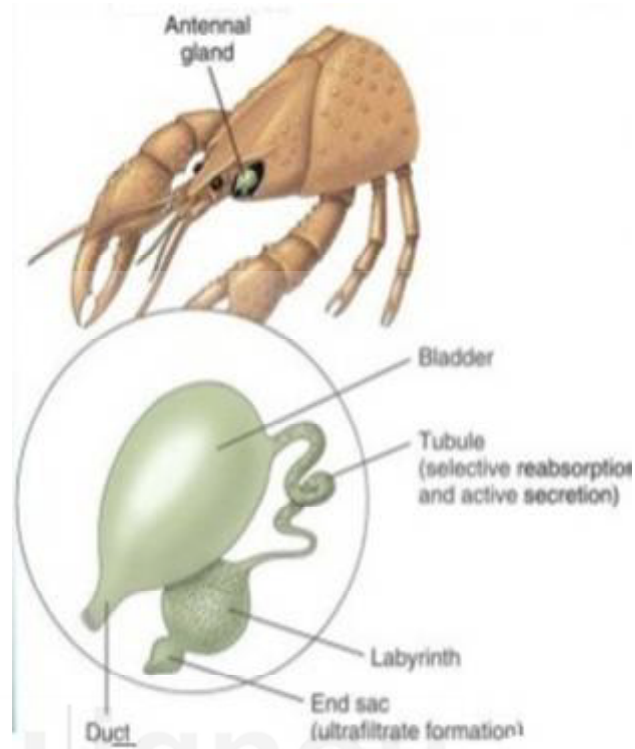


Fig. 8.6: Excretory organs of aquatic arthropods.

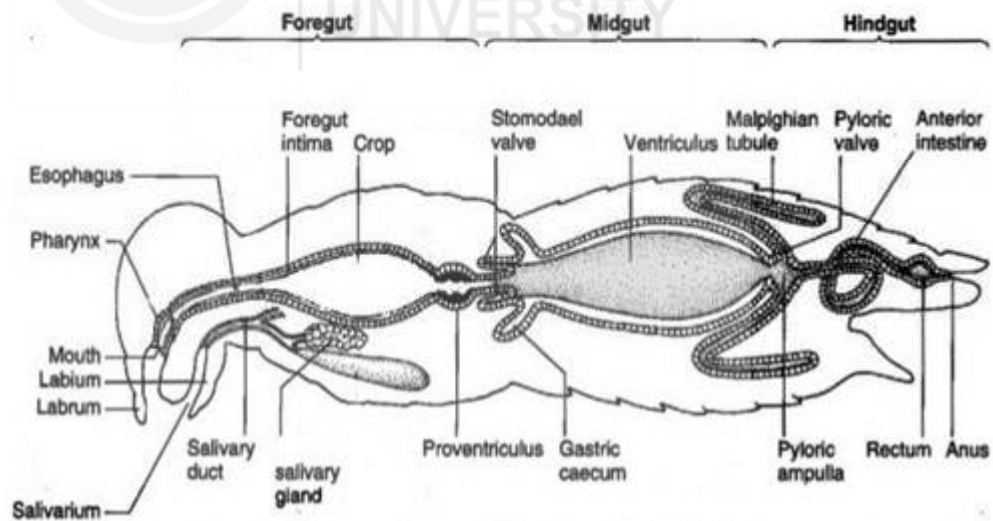


Fig. 8.7: Generalised digestive tract of an arthropod.

The nervous system of arthropods is built on the annelidan plan (Fig. 8.8). There is a brain dorsally connected to suboesophageal 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 sensillae vary from hairs, bristles, setae etc. (Fig. 8.9) with sensory neurons plus a number

of cells that produce the cuticular housing apparatus. Insects and crustaceans have compound eyes formed of a number of long, cylindrical units called **ommatidia** (sl. ommatidium) possessing all the elements for light refraction and reception (Fig. 8.10).

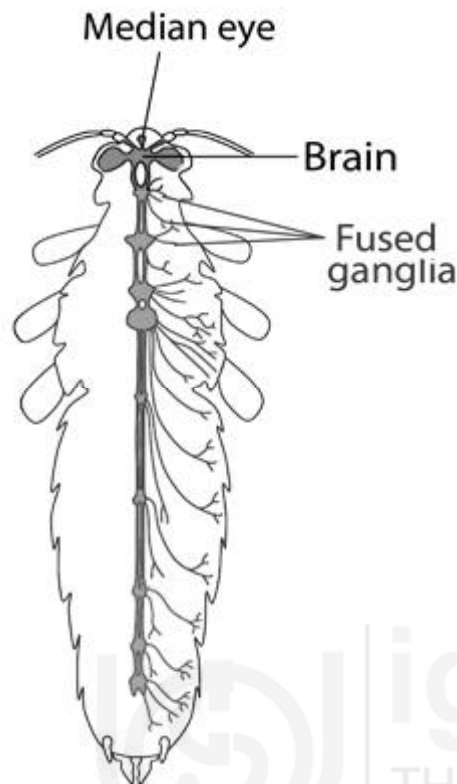


Fig. 8.8: Generalised structure of nervous system of an arthropod.

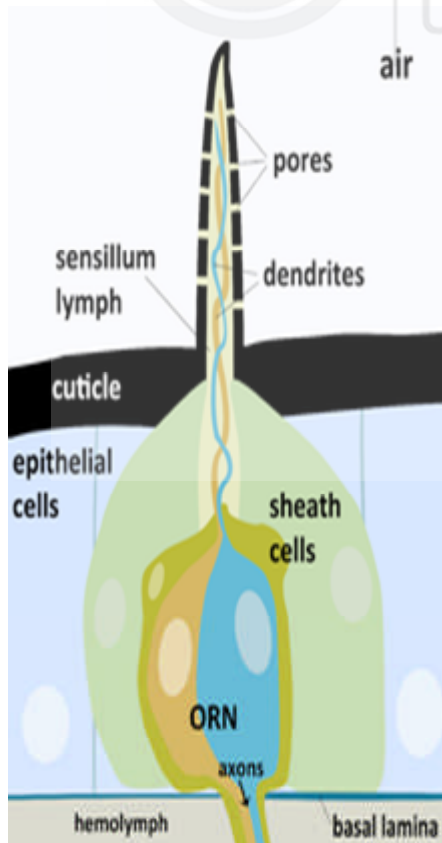


Fig. 8.9: A chemo-sensory hair of an arthropod.

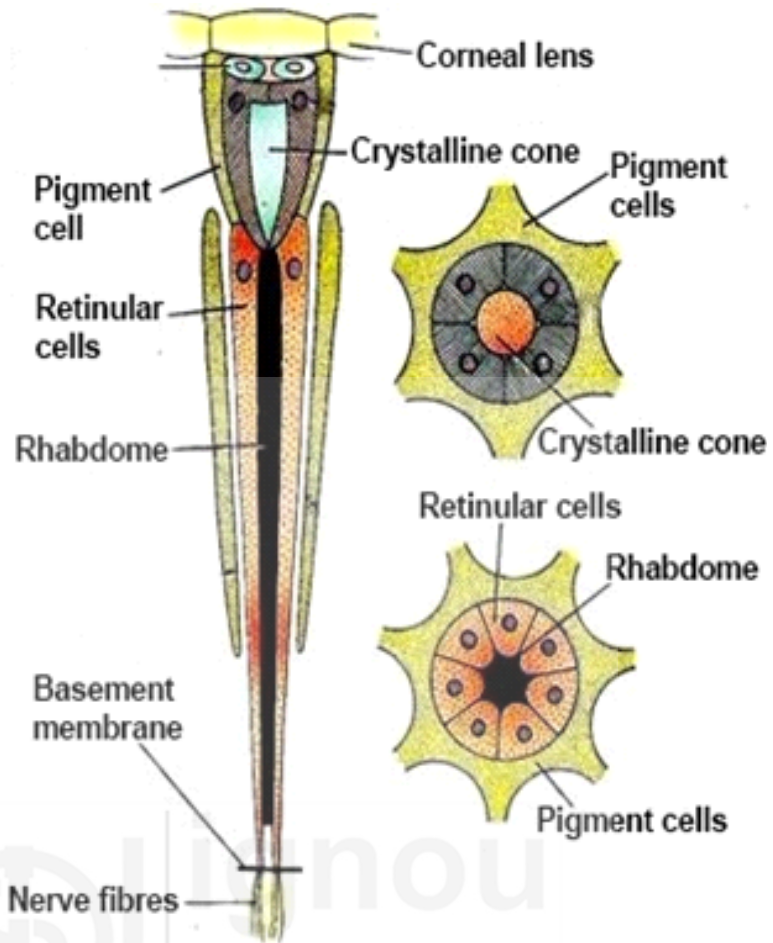


Fig. 8.10: Insect ommatidium.

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. 8.11).

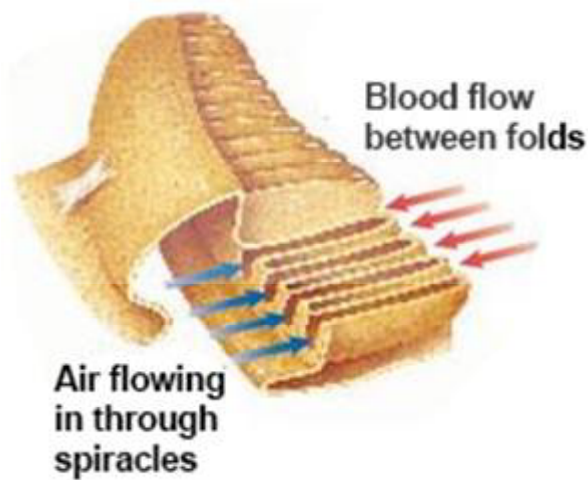


Fig. 8.11: Book lung of an arachnid (Diagrammatic).

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 general characters of the phylum Arthropoda. Arthropods have evolved along four main lines. Each of these lines is treated as a subphylum. 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** comprises 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 1

- I) Fill in the blanks with appropriate words.
 - i) Phylum Arthropoda includes nearly _____ species of animals.
 - ii) The term "Arthropoda" means _____.
 - iii) The different segmental appendages of various arthropods are said to be _____ organs.
 - iv) The branched appendages of crustaceans are known as _____ organs whereas the unbranched ones of centipedes, millipedes and insects are _____.
 - v) The dorsal chitinous plate of each segment in arthropods is _____, the ventral plate is _____ the lateral structures are _____.
 - vi) The cavity enclosing the gonads and the end sacs of the excretory organs in crustaceans is the _____.
 - vii) _____ and _____ are the excretory organs of arthropods.
 - viii) The component unit of a compound eye is called _____
 - ix) The four subphyla of phylum Arthropoda are 1) _____
2) _____ 3) _____ & 4) _____.
- II) List any five distinctive characters of phylum Arthropoda.

8.3 CHARACTERISTIC FEATURES OF ARTHROPODA

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 are either **Malpighian tubules**, **coxal glands**, **antennary glands** or **maxillary glands**.
11. Nervous system is of the annelidian plan.
12. Sexes are separate; fertilization internal; development often involves metamorphosis.

8.4 CLASSIFICATION OF PHYLUM ARTHROPODA

The phylum Arthropoda has been divided into four sub-phyla as under:

Subphylum-Trilobitomorpha

Subphylum-Chelicerata

Subphylum-Crustacea

Subphylum-Uniramia

You will study the characteristic features of each sub-phylum with its example in detail in the following sub-sections.

8.4.1 Subphylum Trilobitomorpha

Subphylum Trilobitomorpha includes the trilobites (Fig. 8.12). 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.

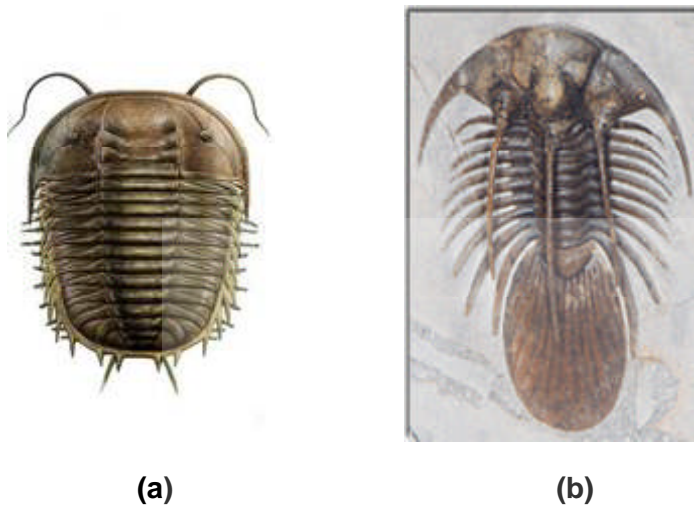


Fig. 8.12: Extinct trilobites: a) *Megalaspis* sp.-burrowing form, b) *Radiaspis* sp.-planktonic form.

8.4.2 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 three classes: Merostomata, Arachnida and Pycnogonida.

Class 1 Merostomata: Aquatic chelicerates 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 1 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. 8.13). 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 opisthosoma 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 leaf like 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. 8.14). 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**.

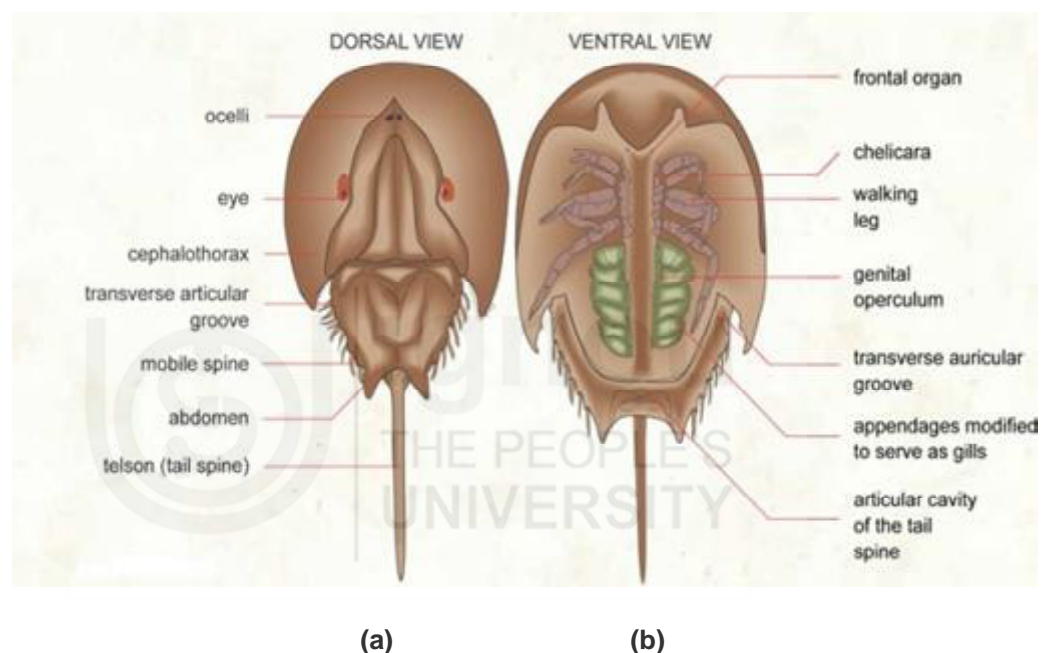


Fig 8.13: *Limulus*: a) dorsal view; b) ventral view.

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 pre-abdomen (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; e.g. *Eurypterus* (Fig. 8.15).

Class 2: 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 metamorphosis.

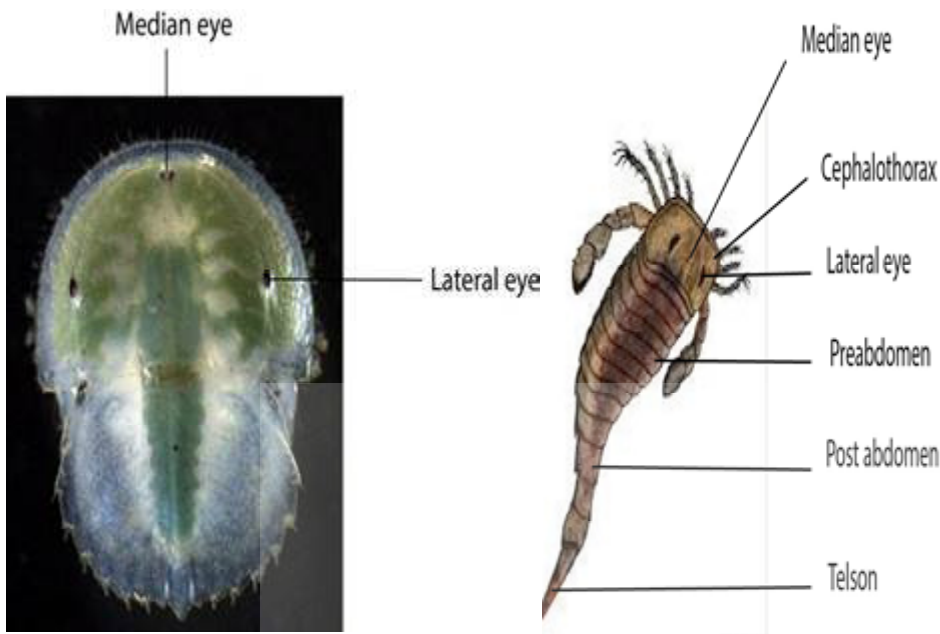


Fig. 8.14: Trilobite larva.

Fig. 8.15: *Eurypterus*.

Arachnids, the largest of all the chelicerate classes, include some of the common and familiar but diverse forms, like spiders, ticks, mites, scorpions, pseudoscorpions, whip-scorpions, harvestmen (daddy longlegs) etc. Arachnids are one of the oldest classes of arthropods, the fossil forms dating back to the Silurian period. Most living arachnids are terrestrial. As a result, the epicuticle has become 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. 8.16) shows three distinct regions: the **prosoma** which is unsegmented and covered by a carapace; the **mesosoma** or preabdomen and the **metasoma** or post-abdomen. 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.

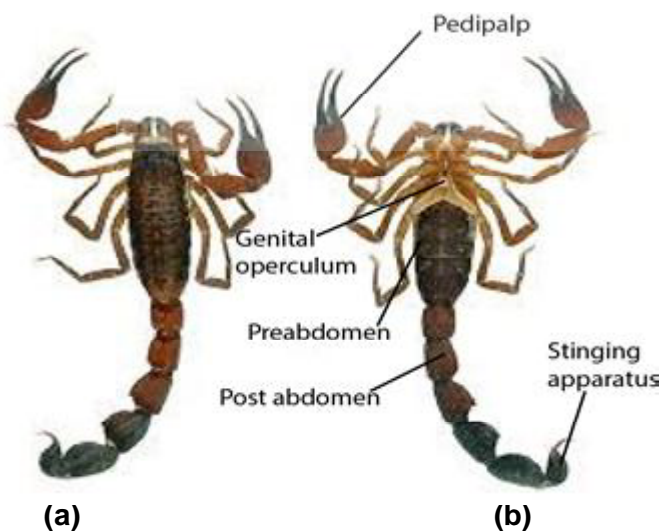


Fig. 8.16: Scorpion: a) dorsal view; b) ventral view.

Arachnids are generally carnivorous and partial digestion of food takes place outside the body of 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. 8.17). 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.

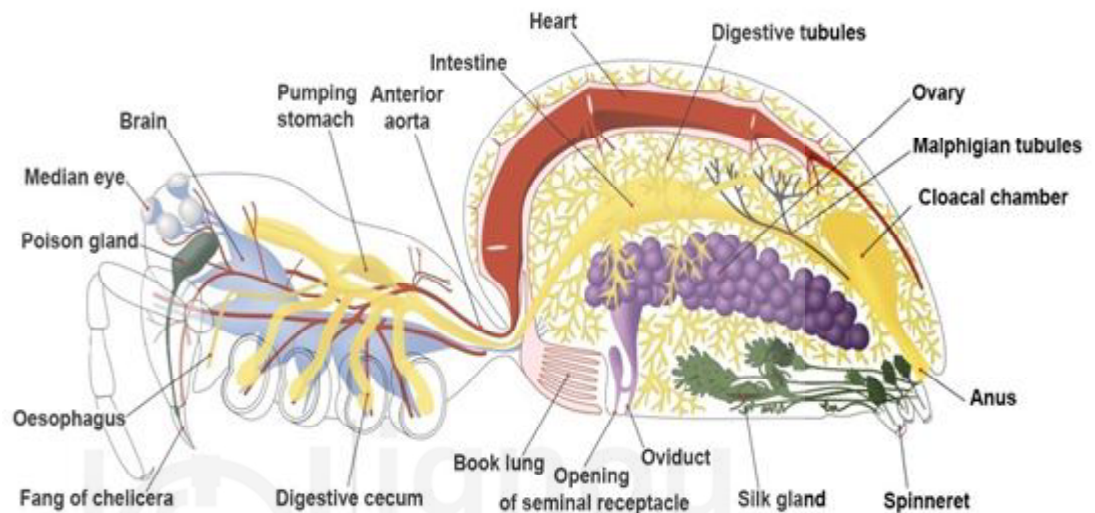


Fig. 8.17: Internal organisation of a spider.

The nervous system (Fig. 8.18) 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 sub-oesophageal ganglion. Thus often the nervous system 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. 8.16). 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.

Arachnids possess booklungs (Fig. 8.11) or trachea or 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 interior 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. 8.6) and **malpighian tubules**. Coxal glands are derived from coelomic sacs. Their ducts open on the coxae of the leg. Malpighian tubules are slender tubes arising from the midgut and opening into it.

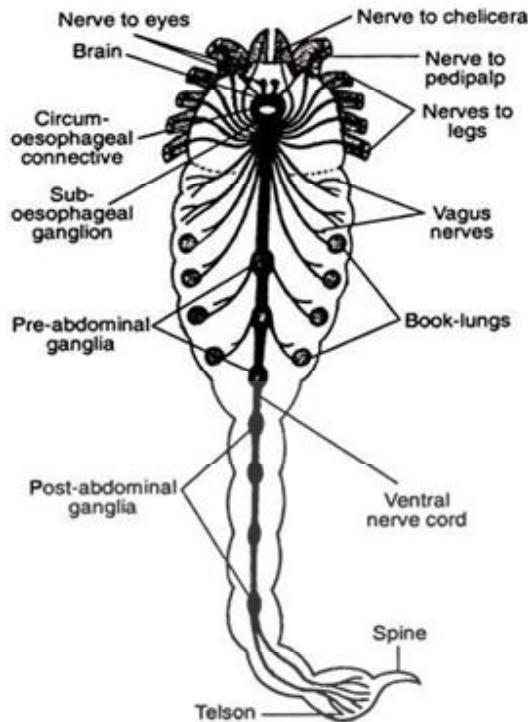


Fig. 8.18: Nervous system of Scorpion.

Gonad (Fig. 8.19) is either single or paired, genital opening 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.

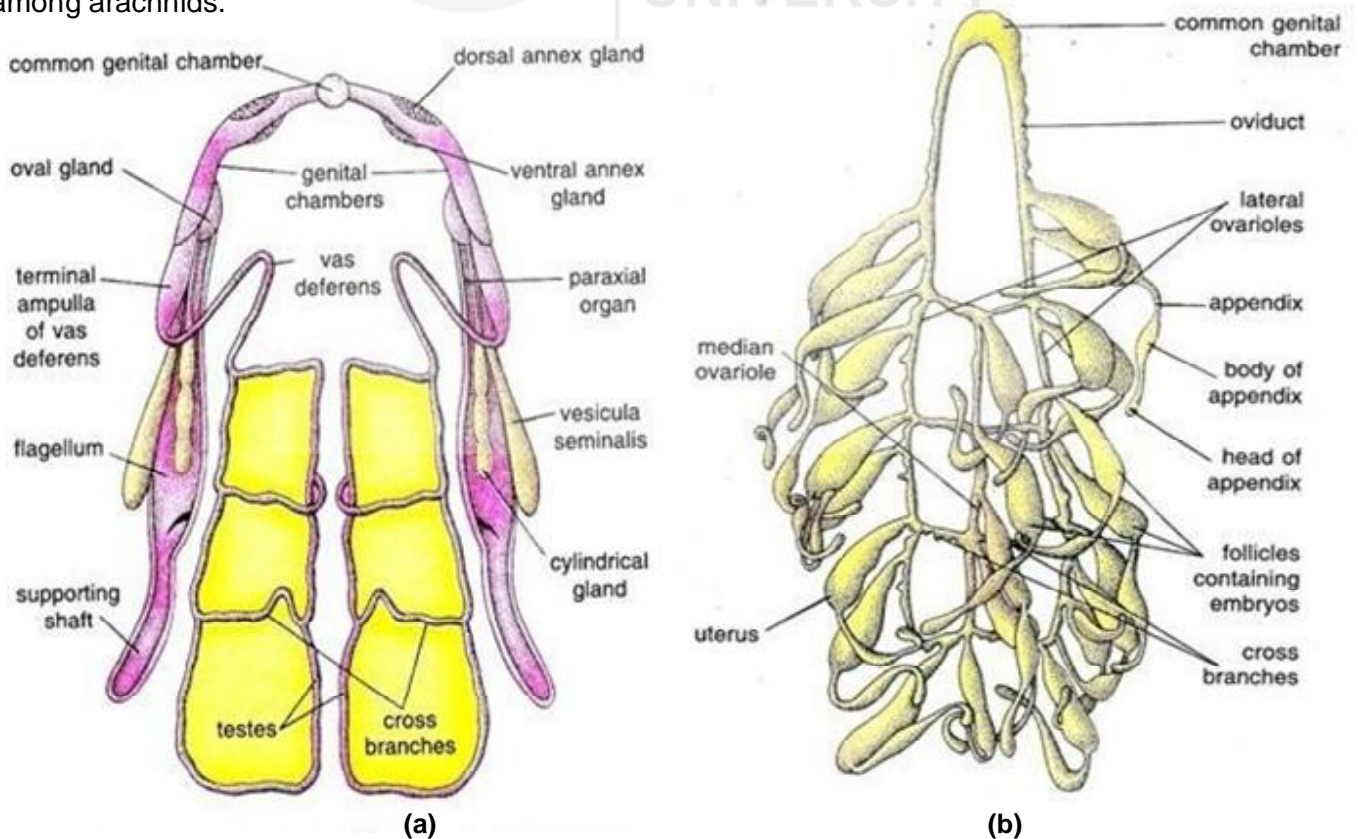


Fig. 8.19: Reproductive system of Scorpion: a) male; b) female.

Of particular interest, are the **silk glands** and the associated **spinnerets** of many spiders. The spinnerets or the spinning organs (Fig.8.20) are modified appendages and are located on the abdomen ventrally, in front of the anus. They bear a number of Spigots, reservoir and 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. 8.20 : Spinnerets of a spider

Examples

Order 1 Scorpiones: Includes scorpions: e.g. *Buthus*, *Palamnaeus* (Fig. 8.21). *Androctonus*, *Centruroides*. *Heterometrus*. Their abdomen ends in a stinging apparatus.



Fig. 8.21: *Palamnaeus*.

Order 2 Palpigradi: These are the palpigrades; e.g. *Eukoenenia* (Fig. 8.22).

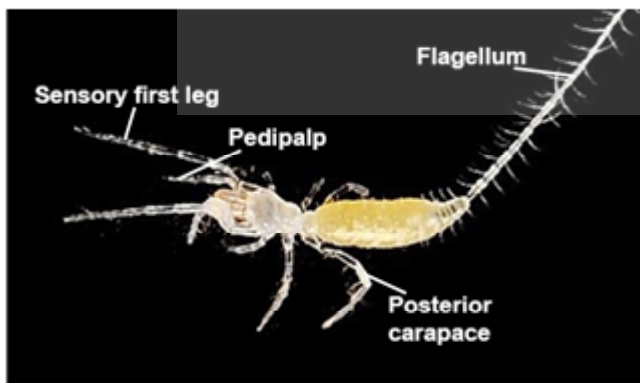


Fig. 8.22: *Eukoenenia*.



Fig. 8.23: *Schizomus*.

Order 3 Schizomida: These tailless whip scorpions; e.g. *Schizomus* (Fig. 8.23).

Order 4 Uropygi: These are the whip-scorpions; e.g. *Thelyphonus* (Fig. 8.24).

Order 5 Araneae: These comprise spiders; e.g. *Latrodectus*, black widow spider (Fig. 8.25); *Synema*, a crab spider.

Order 6 Amblypygi: These are found beneath logs, barks, stones, leaves etc; e.g. *Tarantula*, *Charinus* (Fig. 8.26).



Fig. 8.26: *Charinus*.

Order 7 Ricinulei: These are known as tick spiders mostly confined to Africa and America; e.g. *Cryptocellus*, *Ricinoides* (Fig. 8.27).

Order 8 Pseudoscorpiones: Includes pseudoscorpions found beneath barks, stones, etc; e.g. *Chelifer* (Fig. 8.28).



Fig. 8.24: Whip scorpion.



Fig. 8.25: Black widow spider.



Fig. 8.27: *Ricinoides*.

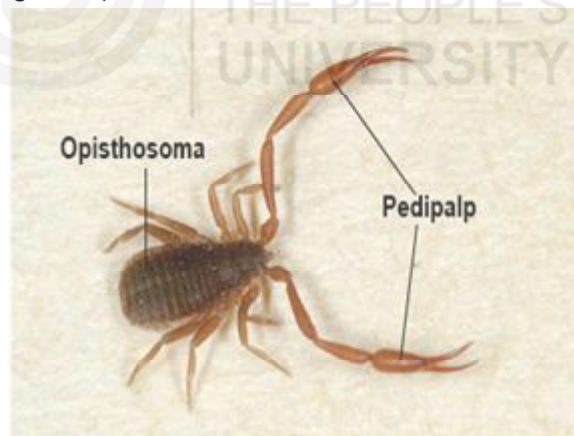


Fig. 8.28: *Chelifer*.

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; e.g., *Galeodes* (Fig. 8.29).

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. Phalangids 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 opilliones are long and slender and exceed body length several times. e.g. *Leiobunum* (Fig. 8.30).



Fig. 8.29: *Galeodes*.



Fig. 8.31: A tick.

Fig. 8.30: *Leiobunum*.

Fig. 8.32: A mite.

Order 11 The Acarina: The Acarina are a group of very diverse assemblage of arachnids known as ticks and mites (Figs. 8.31 and 8.32). 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, humans, 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. 8.33). 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 tunnelling into epidermis.

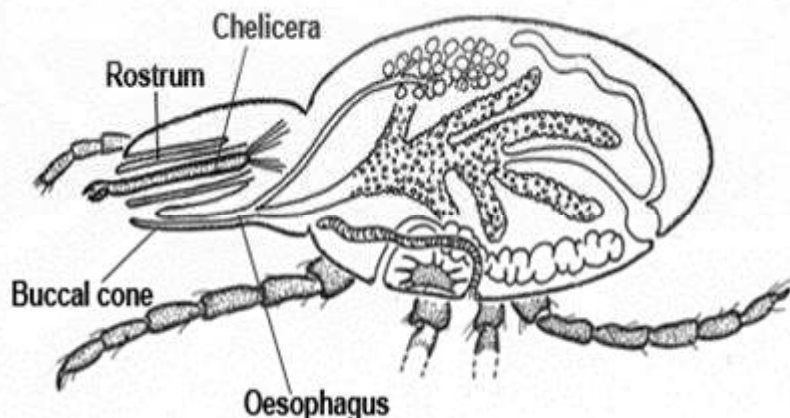


Fig. 8.33: Capitulum of a mite.

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. 8.34) 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.

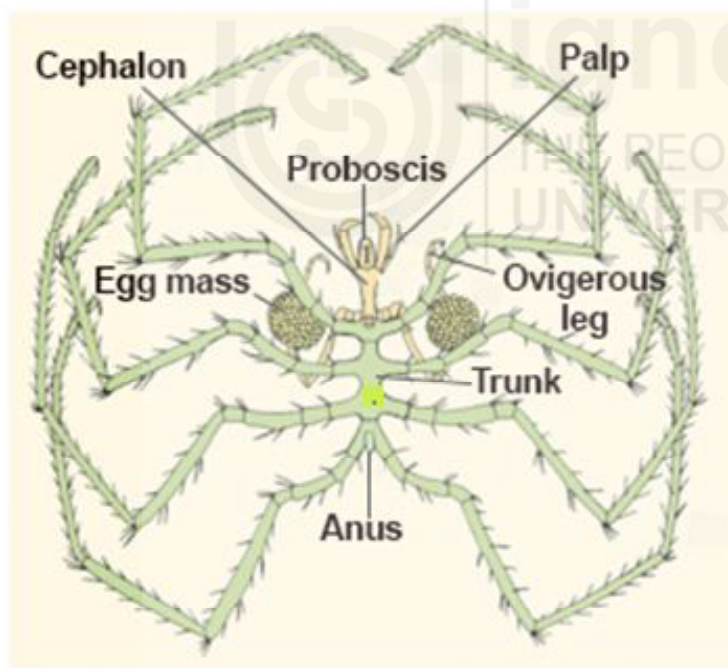


Fig. 8.34: A sea spider.

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. 8.35). From the extensive intestine (midgut) caecae 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.

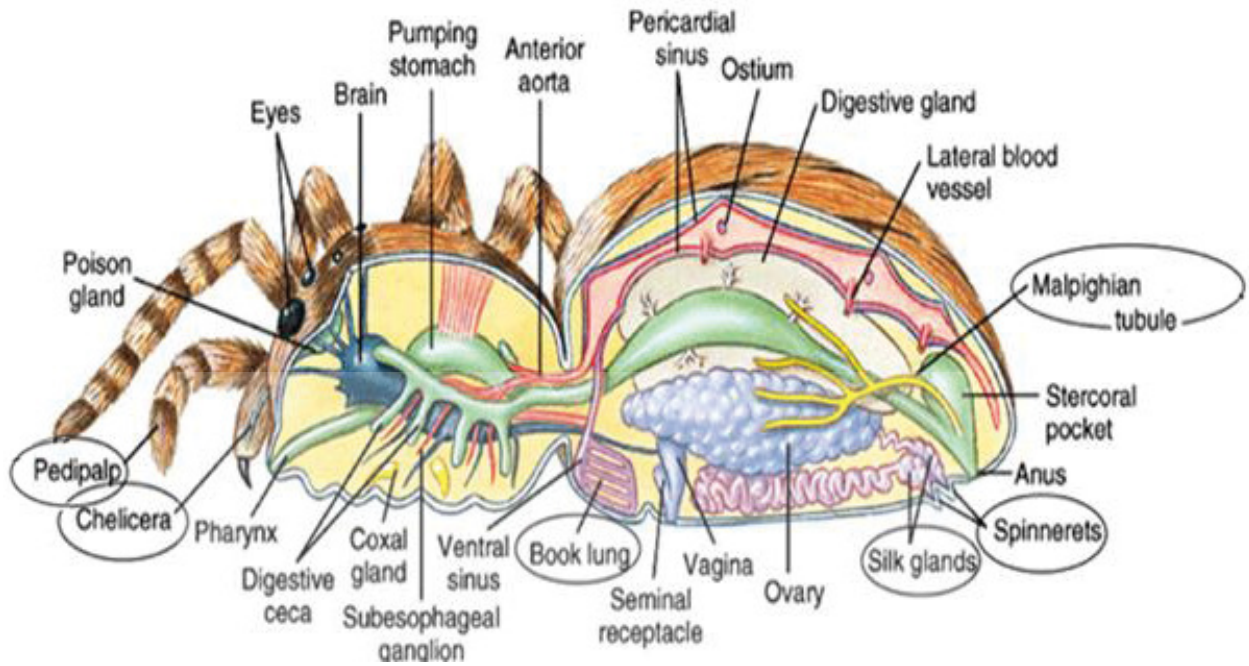


Fig. 8.35: Sagittal section of a sea spider showing internal organisation.

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. 8.36) which may remain in the ovigerous legs of the male or may develop among the hydras and corals. A sequence of moults and development lead to the transformation of larvae into adult.

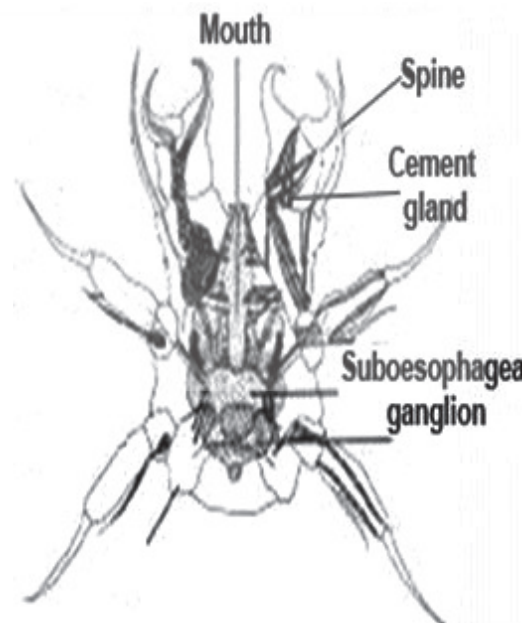


Fig. 8.36: Protonymphon larva of a sea spider.

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 2

- I) Choose the correct word from the alternative given:
- Trilobites are an extinct group of **primitive/advanced** arthropods.
 - One of the characteristic features of chelicerates is **presence/absence** of antennae.
 - The second pair of appendages of chelicerates is known as **chelicerae/pedipalpi**.
 - Class Merostoma consists of **terrestrial/aquatic** chelicerates.
 - Class **Xiphosura/Arachnida** are regarded as living fossils.
 - Spiders, ticks, mites and scorpions are included under the class **Eurypterida/Arachnida**.
 - In scorpions the post-abdominal region is known as **mesosoma/metasoma**.
 - Spinning organs or spinnerets are characteristic of **Araneae/Acarina**.
 - Order **Solifugae/Acarina** includes mites.
- II) Fill in the blanks with suitable words:
- The three classes of the subphylum Chelicerata are _____ and _____.
 - Horse-shoe crabs are included under the subclass _____.
 - Xiphosurans are called _____ because they have continued to live on the earth for over 100 million years without having undergone much change and have remained an evolutionary relic.
 - The slit organs of arachnids that occur in groups are called _____.
 - The special comb-like sense organs of scorpions are _____.
 - _____ are the arachnids that are popularly known as daddy long legs or harvestman.
 - Many members of Acarina are _____ on humans, domestic animals and crops.
 - Some of the diseases caused to humans by ticks are _____, _____ and _____.
 - _____ organ is the sense organ in mites that is useful in detecting air currents.
 - Sea spiders belong to the class _____.
-

8.4.3 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 viz, head, thorax and abdomen (Fig. 8.37). 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.

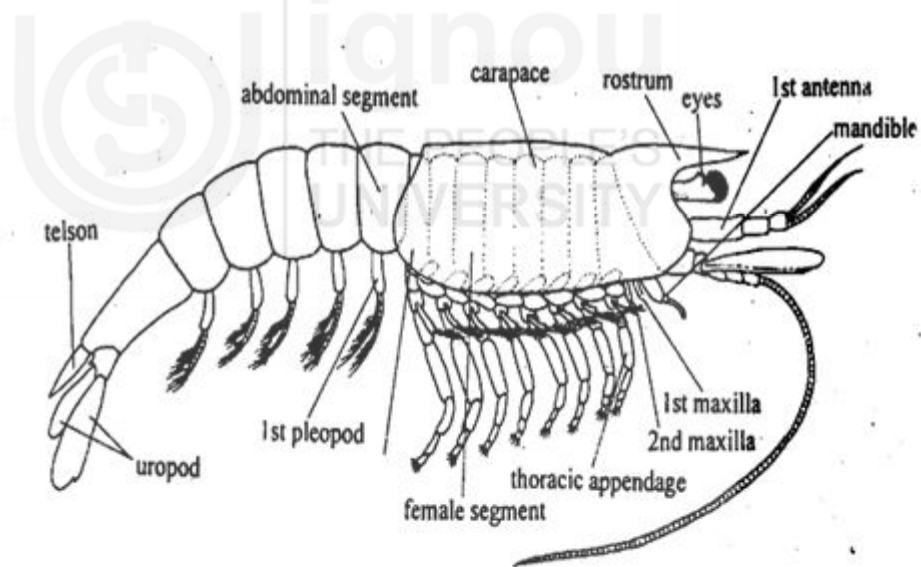


Fig. 8.37: A generalised crustacean.

The head has five pairs of appendages, corresponding to its five segments. The first two appendages (Fig. 8.38) are **antennules (first pair of antennae)** and **antennae (second pair of antennae)**. Thus crustaceans are the only arthropods with two pairs of antennae. These are followed by a pair of **mandibles** - short and heavy structures with opposing 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**, 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. The number of segments in crustaceans vary: 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.

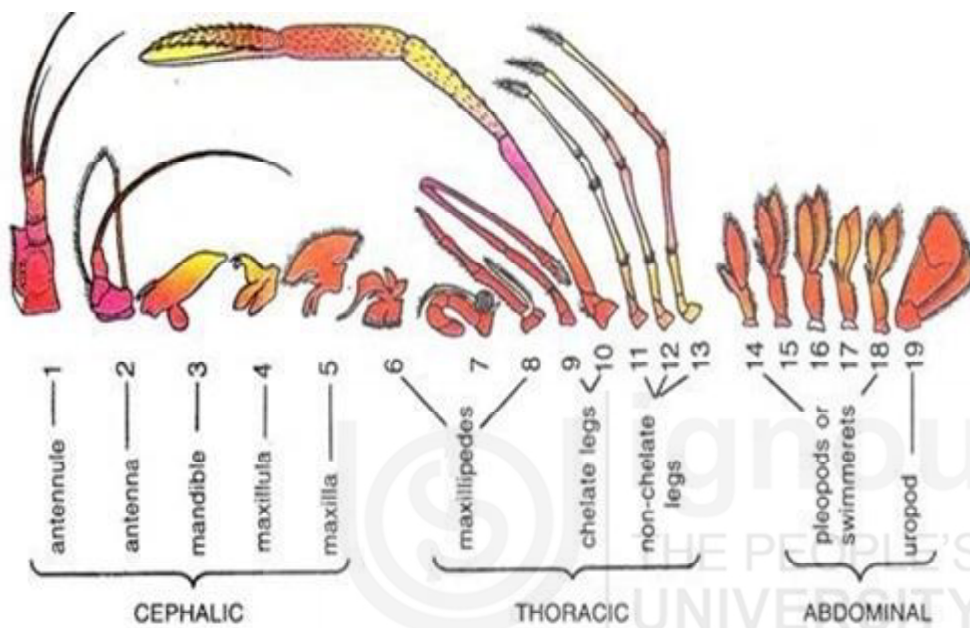


Fig. 8.38: Appendages of prawn.

The cuticle of crustaceans 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 sub-epidermal. 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 **maxillipedes**. 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. 8.6). 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**, **protozoaea**, **zoea**, **mysis** and **megalopa** are some of them (Fig. 8.39). Primitive crustaceans have fewer larval stages; more advanced forms have several larval stages.

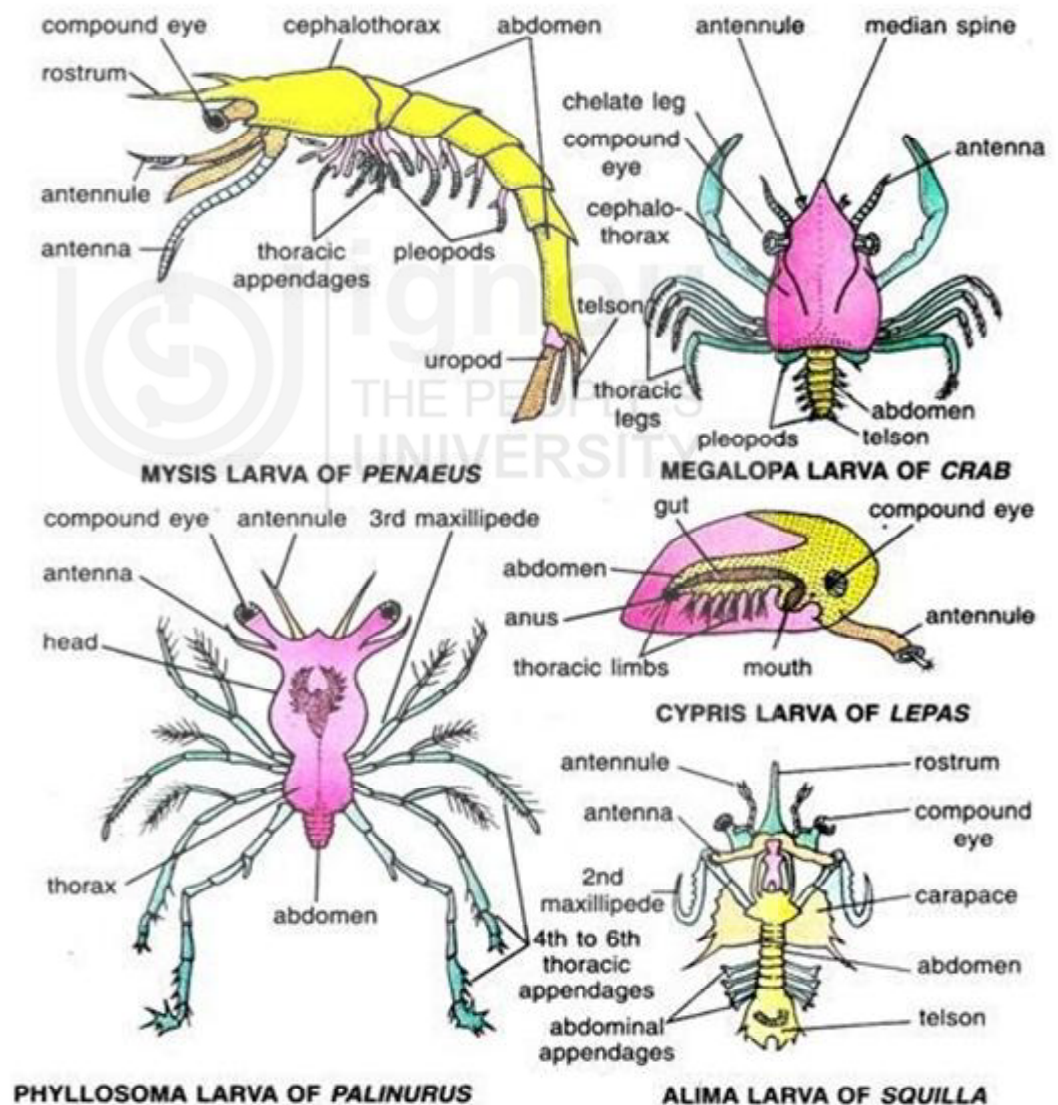


Fig. 8.39: Some larval stages of crustaceans.

Crustaceans 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 up to 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. e.g. *Triops*, the tadpole shrimp (Fig. 8.40) *Branchinecta*, the fairy shrimp (Fig. 8.41), *Daphnia*, waterfleas (Fig. 8.42), *Artemia* the brine shrimp (Fig. 8.43) that lives in salt lakes and ponds.



Fig. 8.40: *Triops*.



Fig. 8.41: *Branchinecta*.

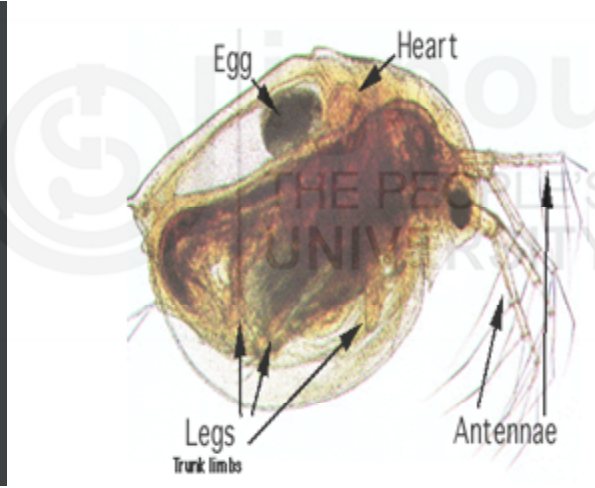


Fig. 8.42: *Daphnia*.



Fig. 8.43: *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. e.g. *Cypricerus*, (Fig. 8.44) *Gigantocypris*, *Cypris*, *Pontocypris*, *Candona* (Fig. 8.45).

Class 3 Copepoda: Copepoda is a large class of small (1–5 mm) 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 of thoracic appendages are maxillipedes used for feeding. Abdomen has five segments and lacks appendages. Last abdominal segment has pair of caudal rami. Planktonic copepods are either saprophytic feeders, or they may feed on phytoplankton or detritus. Some are carnivores. Nauplius larval stage is seen, e.g. *Calanus*, (Fig. 8.46), *Diaptomus*, *Monstrilla*, *Haemocera* – both parasitic on polychaetes; *Salmincola* and *Penella* (Fig. 8.47) – adults parasitic on freshwater and marine fish invertebrates. *Cyclops* (Fig. 8.48), *Doropygus*, *Ergasilus* (Fig. 8.49) and *Chondracanthus* are parasitic copepods living in marine fish and invertebrates.



Fig. 8.44: *Cypricercus*.



Fig. 8.45: *Candona*.



Fig. 8.46: *Calanus*.



Fig. 8.47: *Penella* attached to flying fish.

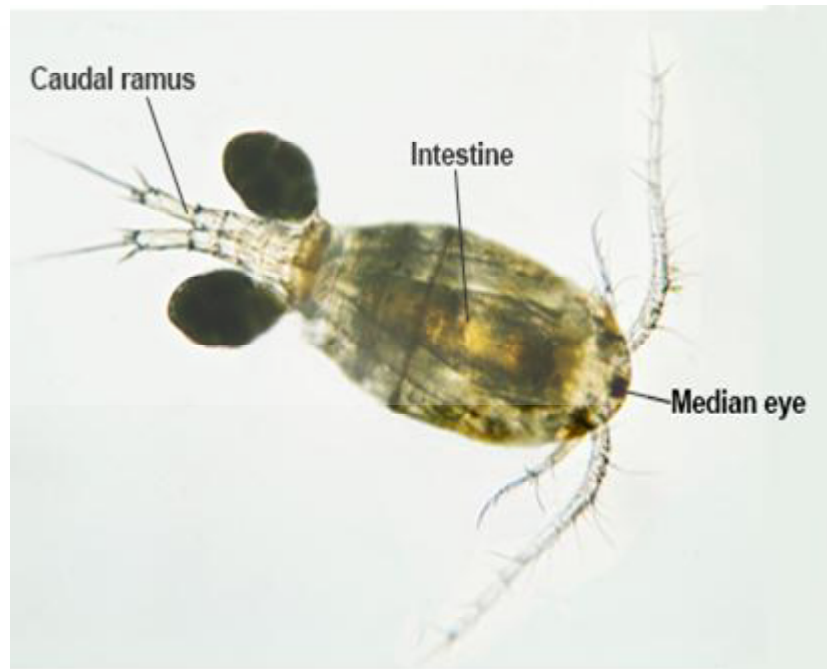


Fig. 8.48: *Cyclops*.

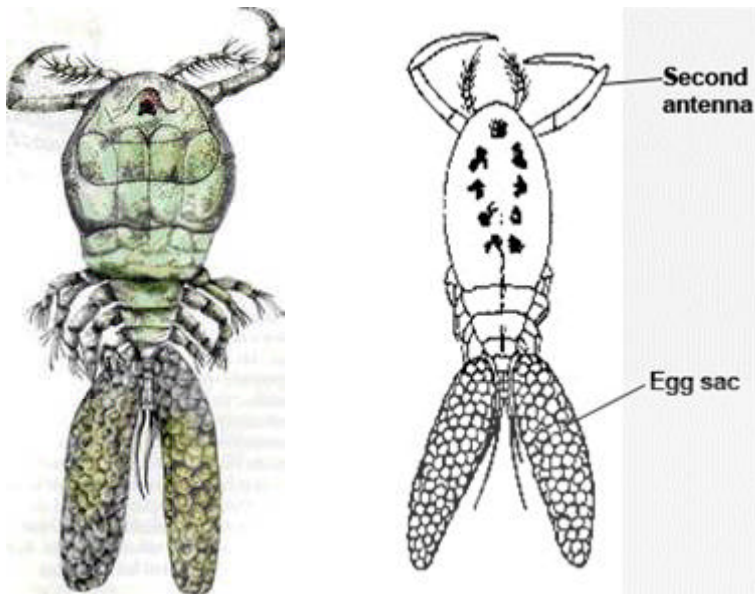


Fig. 8.49: *Ergasilus*.

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 mucous 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 maxillae or they are vestigial. Mouth parts are adapted for feeding on mucous 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. e.g. *Argulus* (Fig. 8.50), *Porocephalus*.

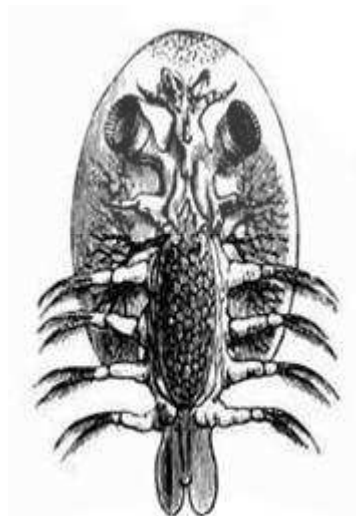


Fig. 8.50: *Argulus*.

Class 5 Cirripedia: The 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 forms (goose barnacles) measure a few mm to 75 cm in length. Sessile forms are a few centimeters 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 (Fig. 8.51): 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**, is surrounded by a wall of plates and within this wall the animal is covered by an operculum formed by movable terga and scuta.

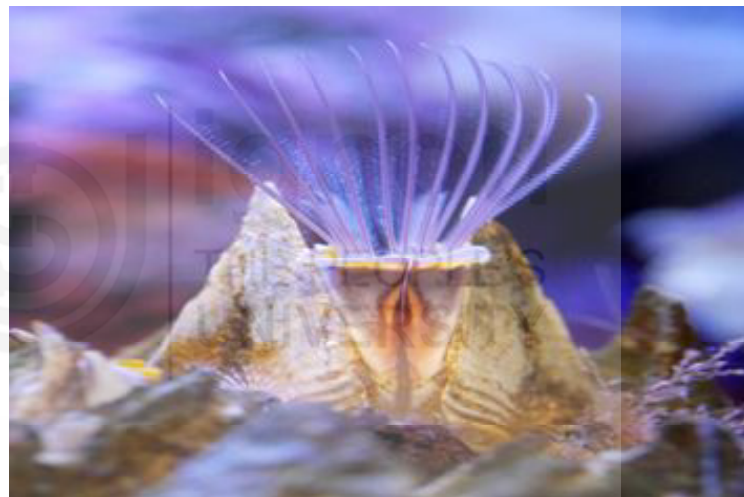


Fig. 8.51: *Balanus*—a sessile barnacle.

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. 8.52). The cirri may be long setae on them and are useful in suspension feeding.

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. 8.53). The cypris larva settles onto a substratum and metamorphoses into an adult. e.g. *Ascothorax*, *Dendrogaster* – parasitic on invertebrates, *Trypetesa*, *Berndtia* – bore into calcareous substratum such as shells or corals, *Lepas* (Fig. 8.54) *Scalpellum*, *Verruca* are all freeliving barnacles or commensals. *Sacculina* (Fig. 8.55) and *Peltogasterella* belong to the order Rhizocephala; they are parasitic barnacles living mostly in decapod crustaceans, the crabs. A few

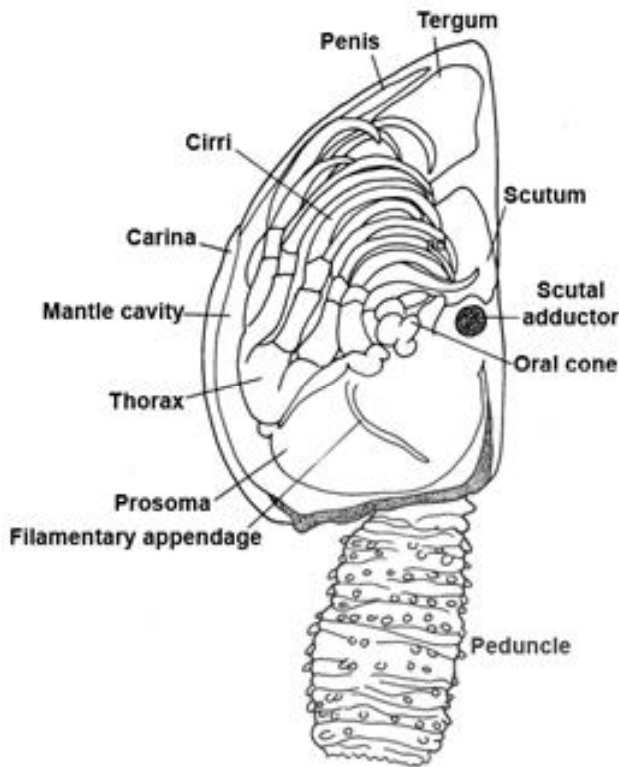


Fig. 8.52 : *Lepas* – stalked barnacle- showing internal organisation

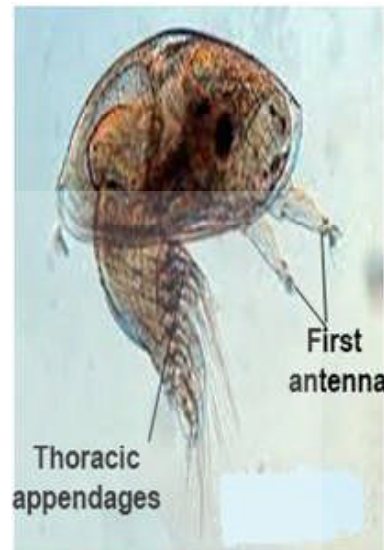


Fig. 8.53: *Cypris* larva.

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. 8.54: *Lepas*.

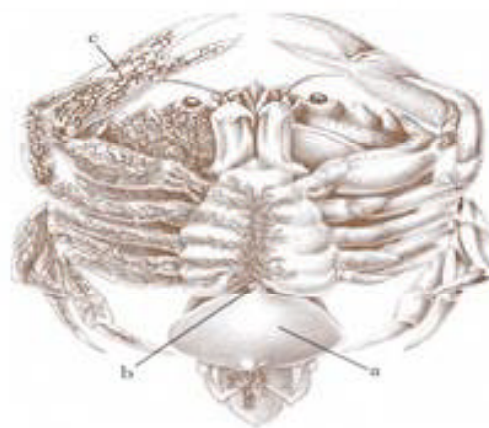


Fig. 8.55: *Sacculina*.

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 post-abdominal 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 **maxillipedes** 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.

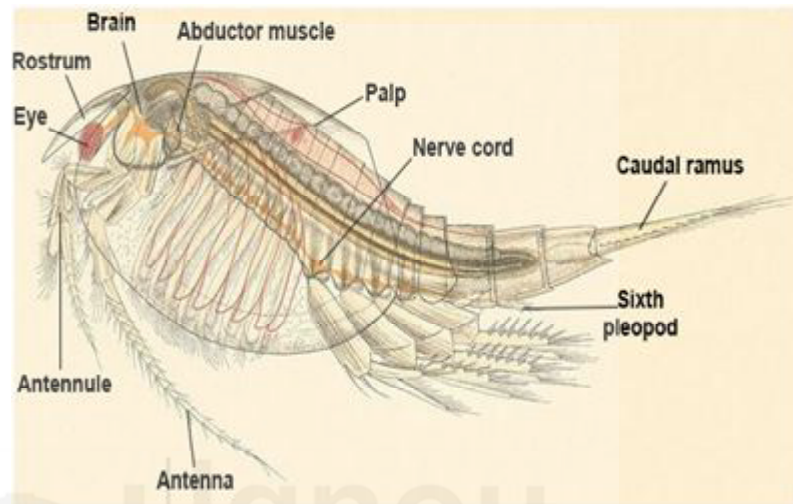


Fig. 8.56: *Nebalia*.

Malacostracans generally have a foregut 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. 8.56) in many respects differs from most other malacostracans, and is included with a few other similar species under subclass Phylocarida (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. 8.57). Freshwater forms; *Euphausia* (Fig.8.58) one of the krills that is pelagic in marine waters. Biramous thoracic appendages; the anterior ones are not modified into maxillipeds. Gills are not tightly enclosed in a carapace.



Fig. 8.57: *Anaspides*.

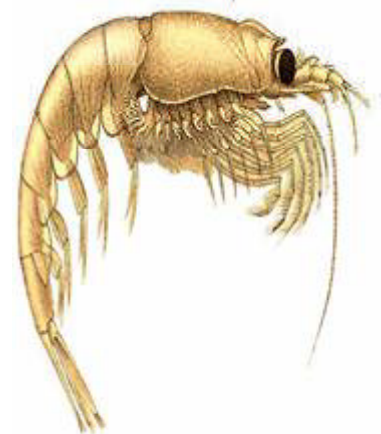


Fig. 8.58: *Euphausia*.

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: e.g. *Penaeus* (Fig. 8.59), *Palaemonetes* (Fig. 8.60) and *Macrobrachium* (Fig. 8.61).

Crayfish: e.g. *Astacus*:

Lobsters: e.g. *Homarus*, *Palimnurus*:

Hermit crabs: e.g. *Clibanarius*:

Mole crabs: e.g. *Hippa*, (Fig. 8.62) *Albunea*; and

Crabs: e.g. *Portunus*, *Potamon*, *Uca*, *Ocyrode*.



Fig. 8.59 : *Penaeus*

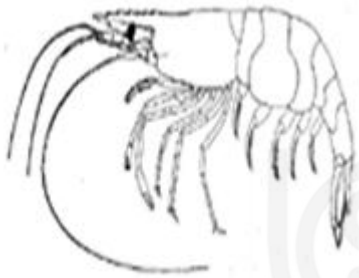


Fig. 8.60: *Palaemonetes*.

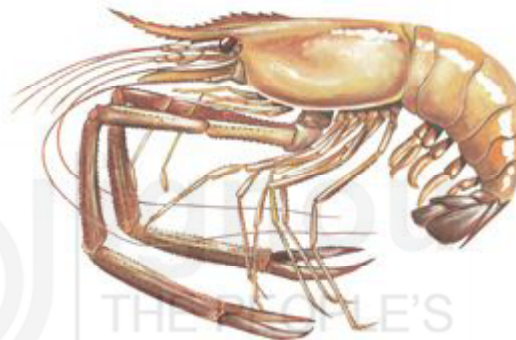


Fig. 8.61 : *Macrobrachium*.

Mysis; *Diastylis*, (Fig. 8.63); *Armadillidium* and *Ligia* (Fig. 8.64) are dorsoventrally flattened and *terrestrial*, known as wood lice, belonging to order Isopoda.

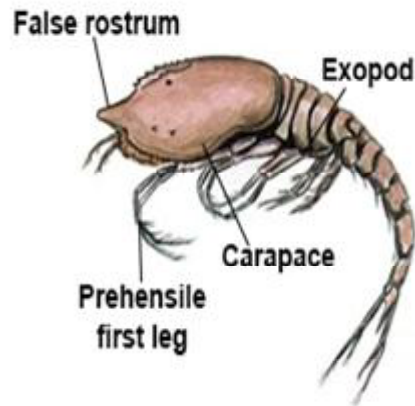


Ventral side



Dorsal side

Fig. 8.62: *Hippa*

Fig. 8.63: *Diastylis*.Fig. 8.64: *Ligia*.

SAQ 3

- I) Indicate whether the following statements are true or false.
- In most crustaceans there is fusion of head and thorax to form cephalothorax.
 - There are six pairs of appendages in the head of crustaceans corresponding to six segments.
 - Protopodite, exopodite and endopodite are three divisions of the appendages of crustaceans.
 - In crustaceans maxillipeds are the trunk appendages modified for filter feeding.
 - Tracheae are the respiratory structures of crustaceans.
 - The excretory organs of crustaceans are called antennary or maxillary glands depending on their position.
 - Most crustaceans are hermaphrodites.
 - Crustaceans mostly undergo direct development into adults, without passing through larval stages.
 - Malacostracans account for over 60% of all the crustaceans.
 - Crabs, molecrabs and horseshoe crabs are all the members of the subphylum Crustacea.
- II) Match the items in Column A with those in Column B.

Column 'A'	Column 'B'
a) Branchiopoda	i) Mussel Shrimps
b) Ostracoda	ii) Barnacles
c) Copepoda	iii) <i>Argulus</i>
d) Branchiura	iv) Lobsters
e) Cirripedia	v) Water fleas
f) Malacostraca	vi) <i>Cyclops</i>

8.4.4 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; they 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 tracheae 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 **Symphyla**. These latter four groups are collectively known as myriapodous arthropods. Let us now study briefly the characters of each class of subphylum Uniramia.

Class 1 Chilopoda: Chilopoda comprises the centipedes (Fig. 8.65). 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. 8.65: A centipede (Scolopendra).

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 poison 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 poison gland opens. Following the first trunk segment there may be 15 or more trunk segments each having a pair of legs with sensory or defensive function. Appendages are usually absent in the last

two trunk segments. The 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. In some forms, partial digestion of the food may occur before ingestion. The digestive system (Fig. 8.66) 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**.

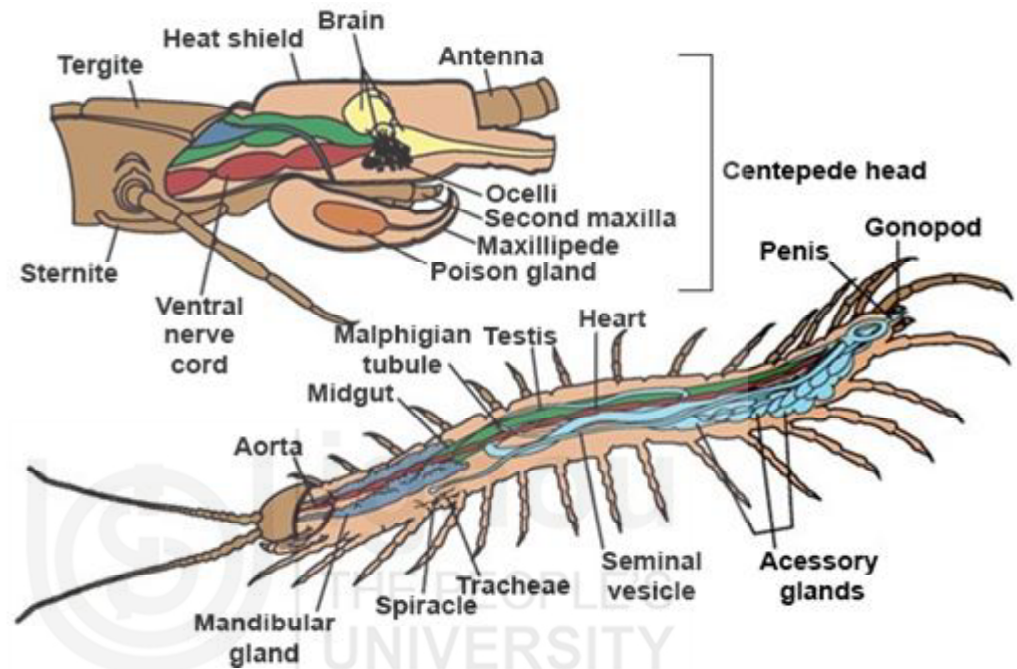


Fig. 8.66: Internal structure of a centipede.

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**. Centipedes 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*, *Strigamia*; *Scolopendra, (Fig. 8.65) ***Theatops*; *Lithobius*** (Fig. 8.67); ***Scutigera*** (Fig. 8.68), young ones do not possess the full complement of segments on hatching. Adults have 15 pairs of legs.



Fig. 8.67: *Lithobius*.



Fig. 8.68: *Scutigera*.

Class 2 Diplopoda: Diplopoda comprises the millipedes which are nocturnal and live beneath leaves, stones, bark and logs as well as in soil and 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. 8.69), 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 chitinous mandibles and a fused pair of maxillae called **gnathochilarium** (Fig. 8.70). 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.

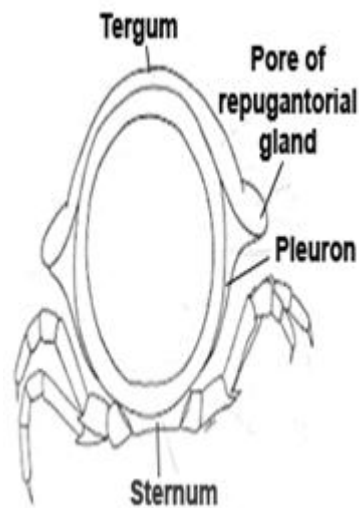


Fig. 8.69: A diplosegment.

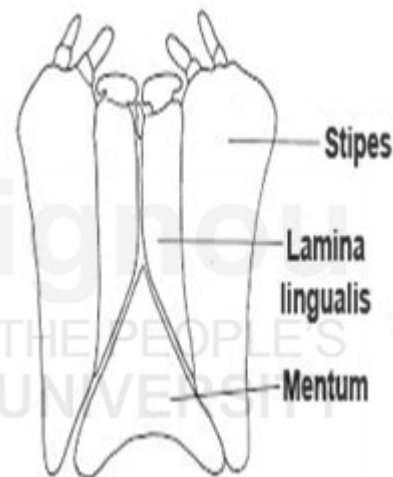


Fig. 8.70: Gnathochilarium.

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 preying 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 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 millipedes 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. Millipedes also fabricate **sprematophores** for sperm transfer. As in centipedes there is courtship behaviour 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:

Polyxeunus (Fig. 8.71) and *Lophoproctus* are : 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. 8.72), and the pill millipede: *Glomeris* (Fig. 8.73) are the forms with arched tergal plates; last two pairs of legs are modified for clasping; *Polyzonium*, (Fig. 8.74); *Narceus*, *Rhinocricus*, *Spirostreptus*, (Fig. 8.75) *Orthoporus*, *Julus*, *Blaniulus*, *Chordeuma* (Fig. 8.76) have one or two pairs of legs located on the seventh segment modified as gonopods for sperm transfer; *Polydesmus*, *Oxidus*, flat back, with lateral tergal keels; gonopods present; other examples are *Cleidogono*, and *Chordeuma*.



Fig. 8.71: *Polyxeunus*



Fig. 8.72: *Sphaerotherium*.



Fig. 8.73: *Glomeris*.



Fig. 8.76 : *Chordeuma*



Fig. 8.74: *Polyzonium*.



Fig. 8.75: *Spirostreptus*.

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: *Paupopus*, (Fig. 8.77) *Allopaupopus*.

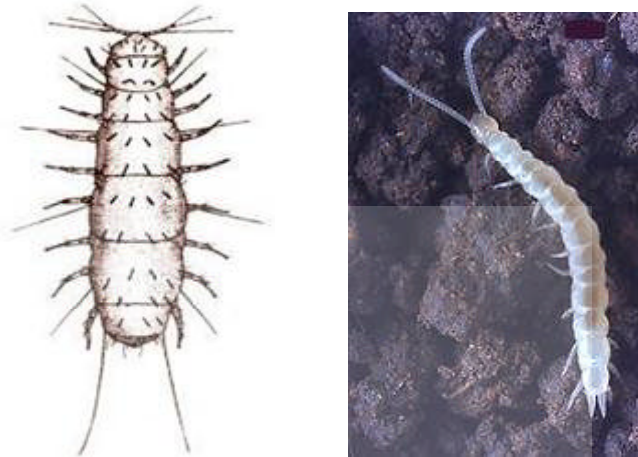


Fig. 8.77: *Paupopus*.

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 114 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. They 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 fertilize them. Development is anamorphic. Parthenogenesis is also common in symphylans e.g. *Scutigera* (Fig. 8.78).

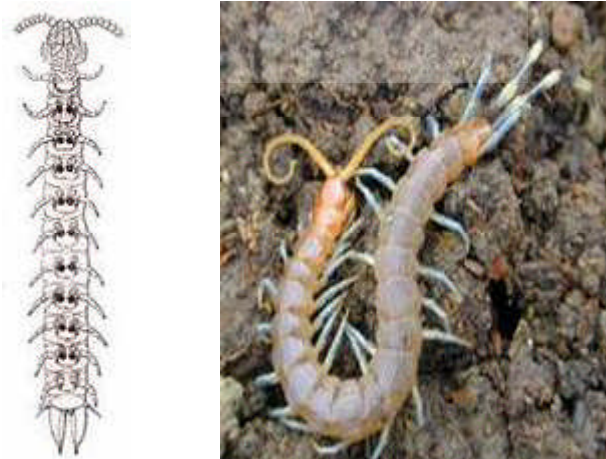


Fig. 8.78: *Scutigera*.

SAQ 4

Write brief answers to the following questions:

- i) Why is the name Uniramia given to centipedes, millipedes and insects?
 - ii) Name the five classes included under the subphylum Uniramia?
 - iii) Name the cephalic appendages of chilopods.
 - iv) What is a diplosegment?
 - v) a. The fused pair of maxillae of millipedes is called
 - b. The legless first trunk segment of millipedes is
 - vi) What is the peculiarity of the antennae of pauropods?
 - vii) 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. 8.79). 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.

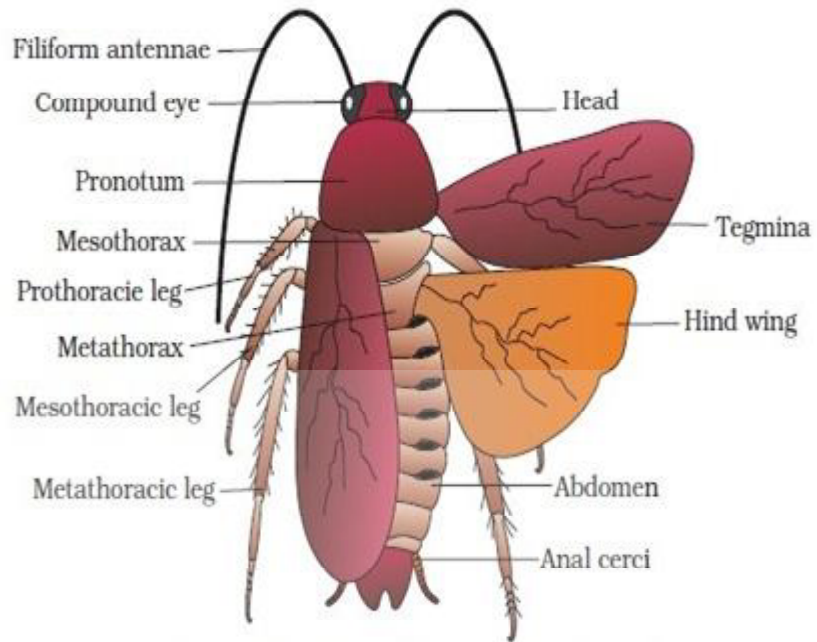


Fig. 8.79: Cockroach (*Periplaneta*): External organisation.

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. 8.80). There is also a median hypopharynx behind the mouth.

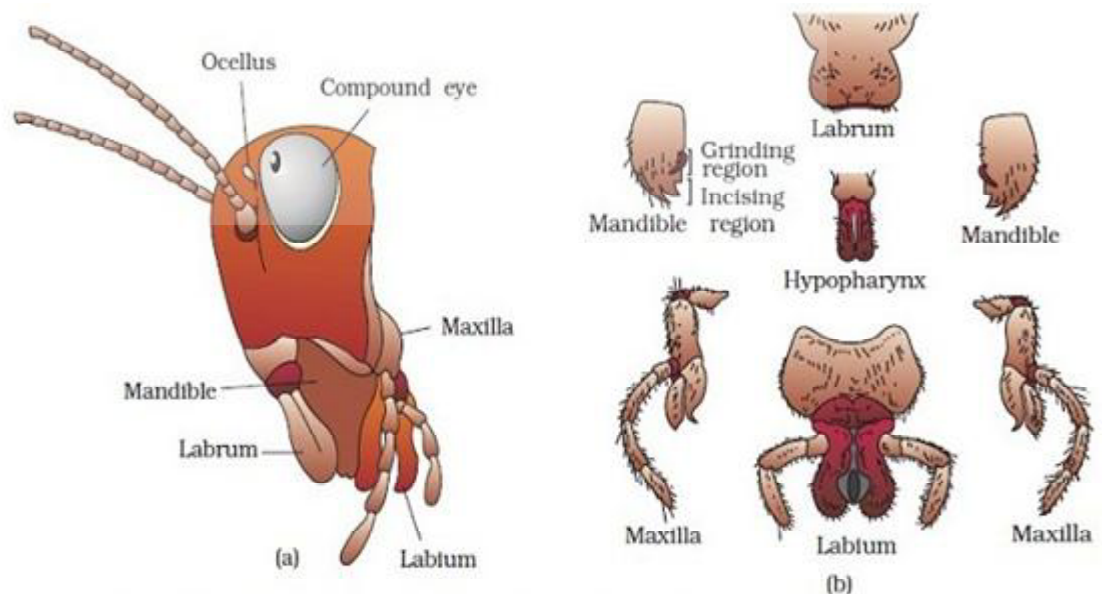


Fig. 8.80: Mouth parts of cockroach.

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.

- Sucking type:** In moths and butterflies, the mouth parts are adapted for sucking nectar from flowers (Fig. 8.81). Here, the two galea from a long tube (proboscis) for sucking food. The proboscis is kept coiled when the insect is not feeding.

In bees (Fig. 8.82) 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 wax.

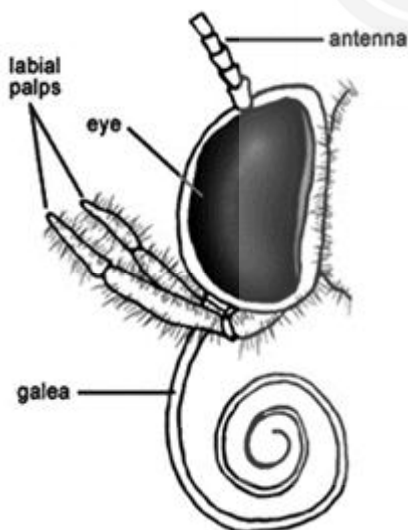


Fig. 8.81: Mouth parts of a butterfly.

Fig. 8.82: Mouth parts of a honeybee.

Piercing mouth parts are found in insects such as plant bugs and aphids which suck plants 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 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. 8.83), however, labrum and the labium together form the food canal, whereas the salivary canal runs through the hypopharynx.

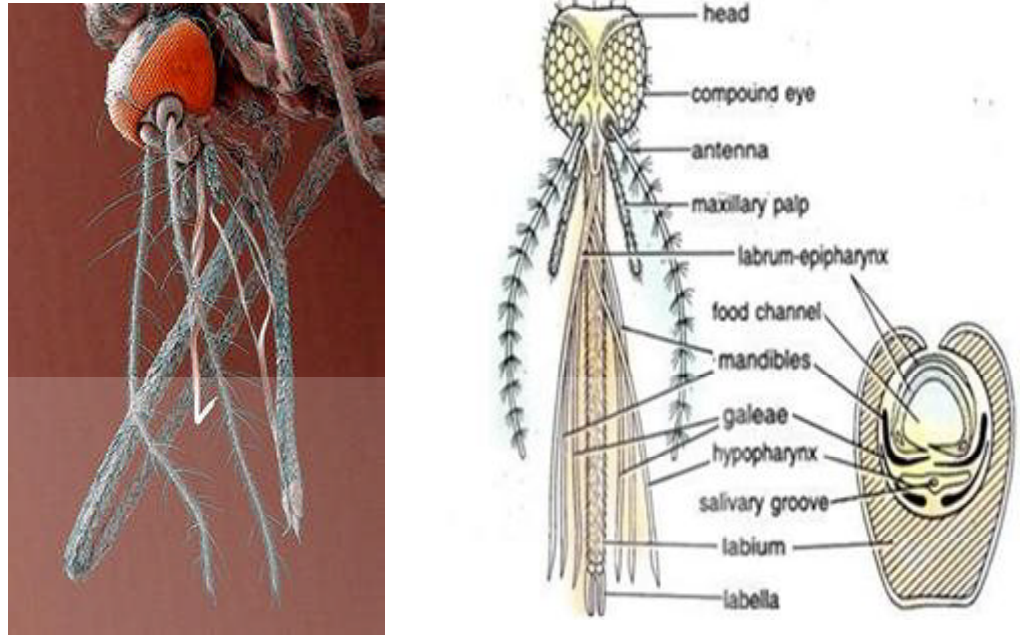


Fig. 8.83: Mouth Parts of mosquito.

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. 8.84) sponge-like labium serves the purposes, 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.

The alimentary canal (Fig. 8.85) 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 gastric caeca or hepatic caeca are present. The hindgut shows three divisions, **ileum**, **colon** and **rectum**.

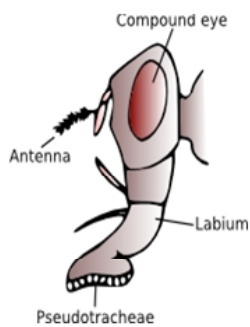


Fig. 8.84 : Mouth parts of a house fly.

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 vertebrates in its functioning.

The circulatory system consists of a tubular heart that is enclosed in a pericardium (Fig. 8.86). 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. 8.87). Eight to ten pairs of spiracles are generally located on the lateral surface in the pleural membrane. The spiracles lead into a trachea which branches and finally end in minute tubules the **tracheoles** (Fig. 8.88). Exchange of gases occurs by diffusion. Aquatic insects which utilize dissolved oxygen in water have structures called **gills** (e.g. 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.

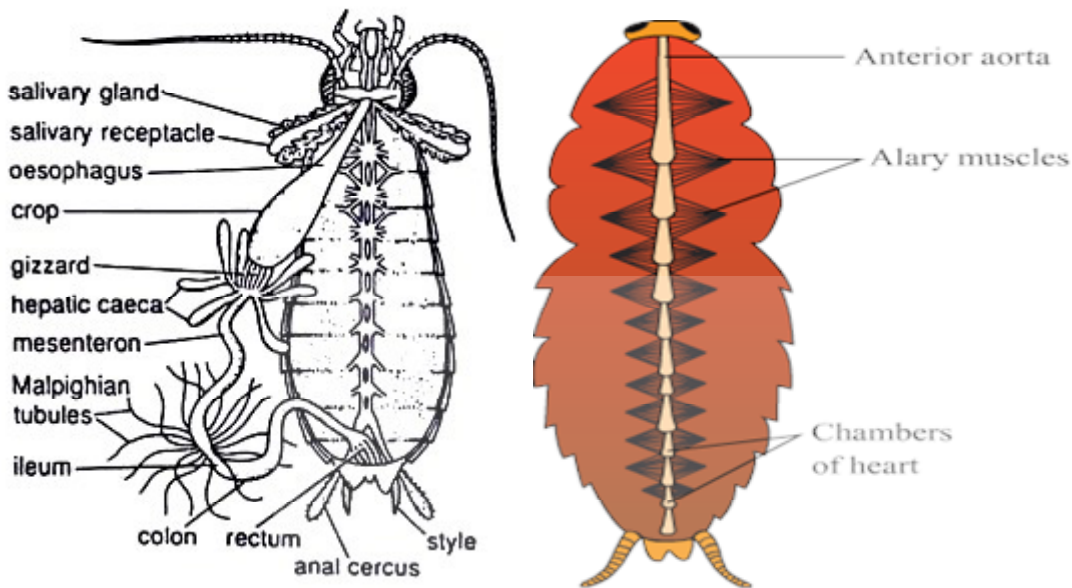


Fig. 8.85: Viscera of a cockroach.

Fig. 8.86: Circulatory system of cockroach.

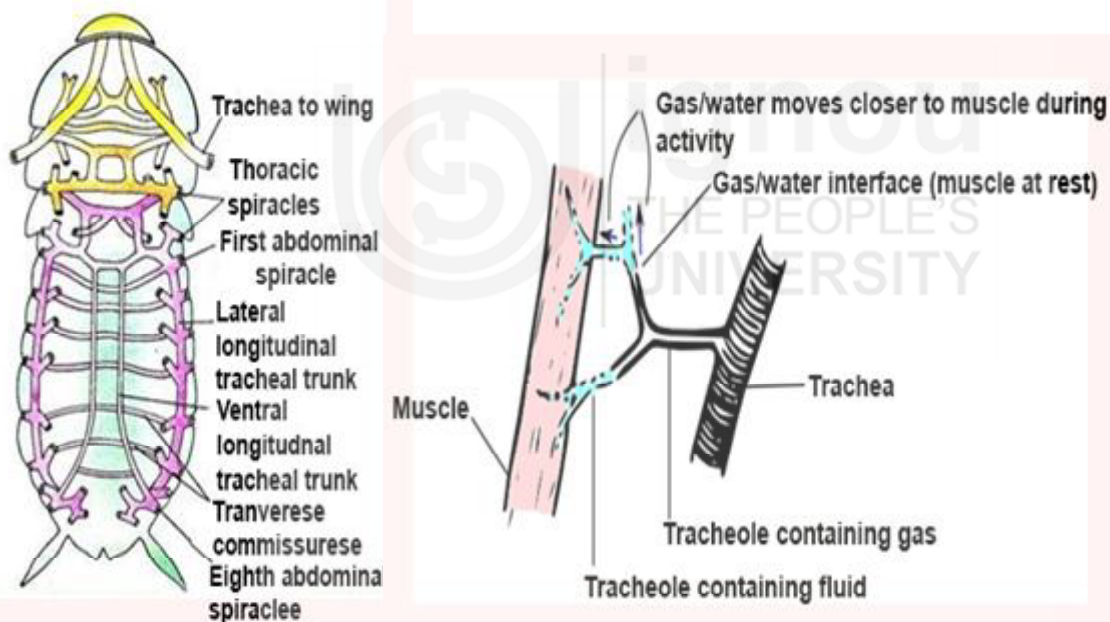


Fig. 8.87: Tracheal system of cockroach.

Fig. 8.88: 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 2 to 250.

Insects possess typically arthropodan nervous system. Brain, sub-oesophageal 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** are 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. 8.89 a). 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 gland 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. 8.89 b). Sperm transfer may be direct as **spermatophores**. Development may occur without metamorphosis as in silver fish, or incomplete metamorphosis as in bugs where the young one resembles the adults except for the development of wings and reproductive organs. Complete metamorphosis (Fig. 8.90) occurs in many as in butterflies, beetles and houseflies. In these insects the larva does not resemble the adult and develops into a non-feeding quiescent **pupa** before becoming as adult. Different examples of inserts are depicted in Figs. 8.91 and 8.92.

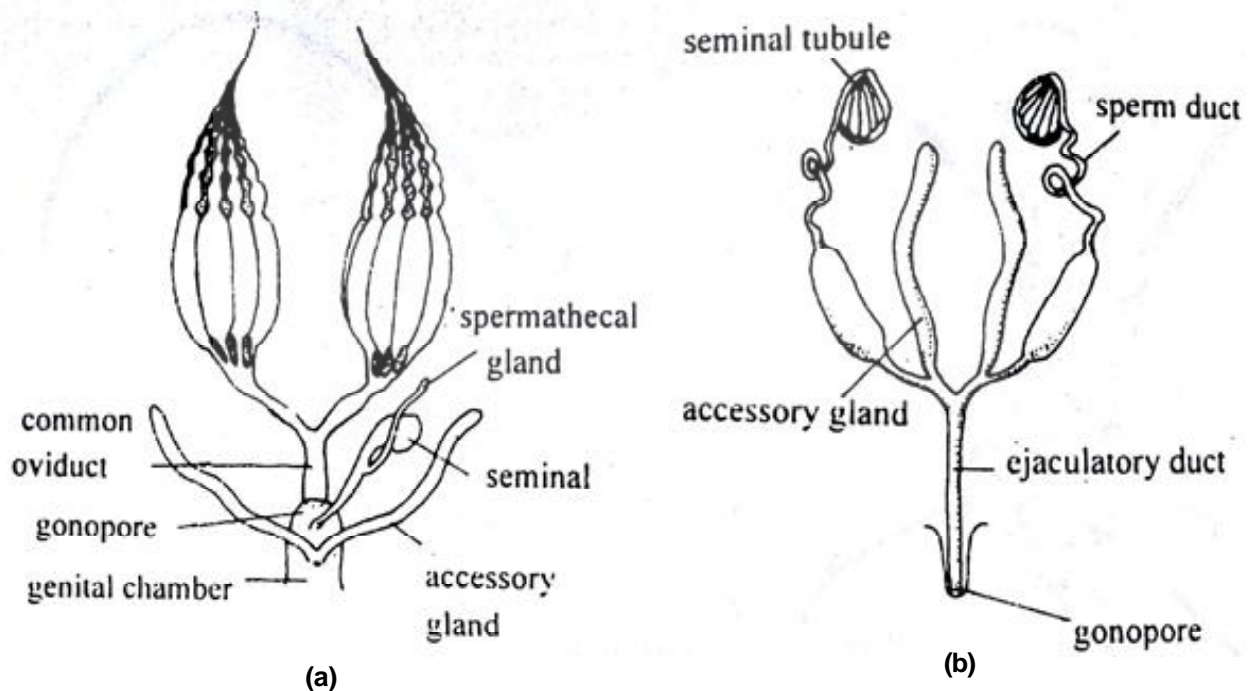


Fig. 8.89: Reproductive system of an insect: a) female; b) male.

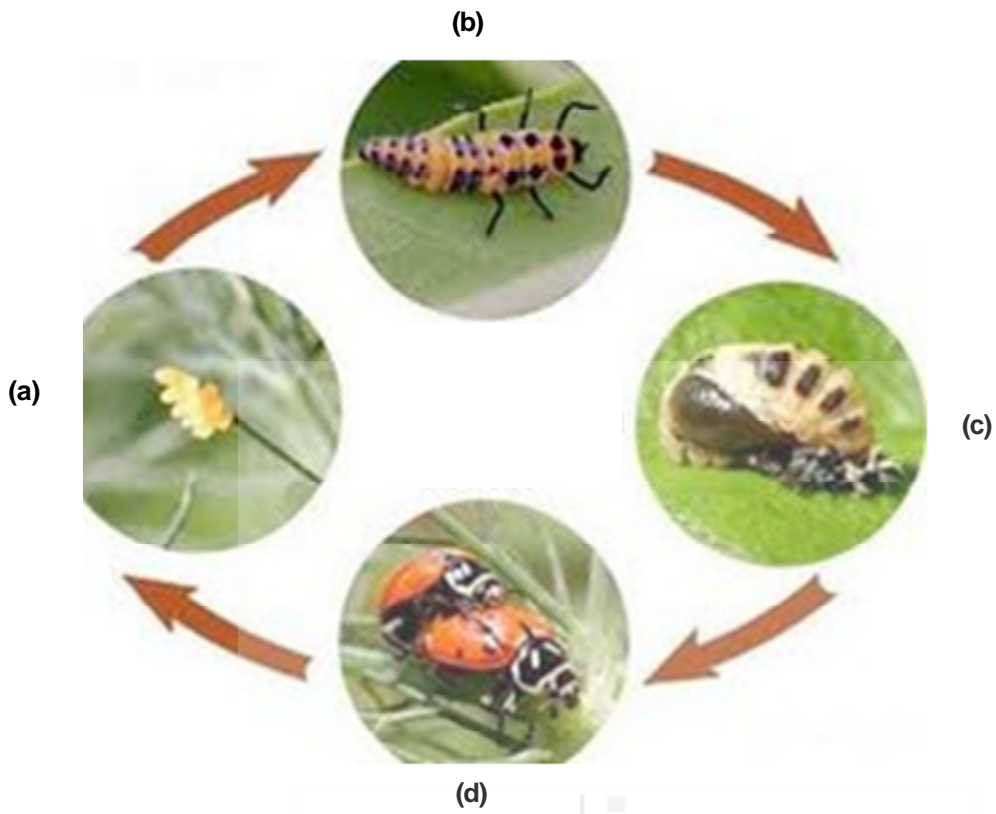
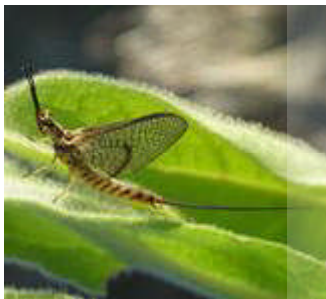


Fig. 8.90 : Complete metamorphosis in a beetle: a) egg; b) grub; c) pupa; d) adult



Ephemeroptera – Mayfly



Odonata – Dragonfly



Orthoptera – Cricket



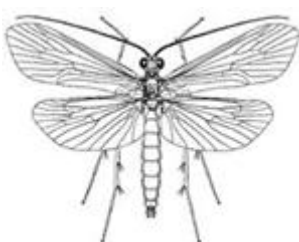
Strepsiptera – Twisted wing Parasite



Dermaptera – Earwing



Protura – A proturan



Isoptera – Termite



Trichoptera – Caddis fly



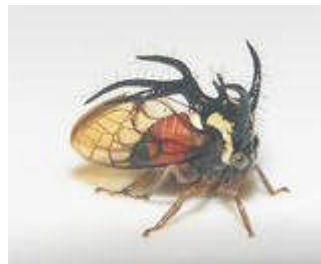


Mallophaga – Head louse



Anoplura – Bird louse

Fig. 8.91: Examples of insects of different orders (to be continued).



Homoptera – Tree hopper



Mecoptera – Scorpion fly



Lepidoptera – Butterfly



Diptera – House fly



Coleoptera – Beetle



Siphonoptera – Flea

Fig. 8.92: Examples of insects of different orders.

SAQ 5

- l) State whether the following are True or False:
- i) Class insecta is the largest class in the animal kingdom.
 - ii) 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.
 - iii) The body of insects is made up of three tagmata.
 - iv) The two pairs of insect wings are articulated with pro and mesothorax.
 - v) The mouth parts of all adult insects are identical in structure despite the differences in their food habits.
 - vi) Haemocoel is the site of intermediary metabolism in insects.
 - vii) The exchange of gases in the tracheal system of insects occurs by diffusion.

- viii) All aquatic insects depend on dissolved oxygen in water for their respiratory needs.
- ix) The secretion of prothoracic glands regulates metamorphosis in insects.
- II) Match the insects listed in Column 'A' to their respective orders listed in Column 'B'.

Column 'A'	Column 'B'
i) Silver fish	a) Lepidoptera
ii) Grasshopper	b) Coleoptera
iii) Plant bug	c) Hymenoptera
iv) Dragonfly	d) Ephemeroptera
v) Mayfly	e) Thysanura
vi) Housefly	f) Hemiptera
vii) Beetle	g) Odonata
viii) Moth	h) Orthoptera
ix) Wasp	i) Isoptera
x) Termites	j) Diptera

8.5 VISION IN ARTHROPODS

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. 8.92) is made up of large number of units called ommatidia. Often you may be able to recognise 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 biconcave, 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.

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 rhabdomeres, the pigment granules in the primary and secondary pigment cells are not photopigments but serve to cut off light entering one ommatidium into the adjacent ommatidium. The nerve

fibres of the retinula cells enter the optic lobe. The electrical recordings of the response of the eye is called electroretinogram.

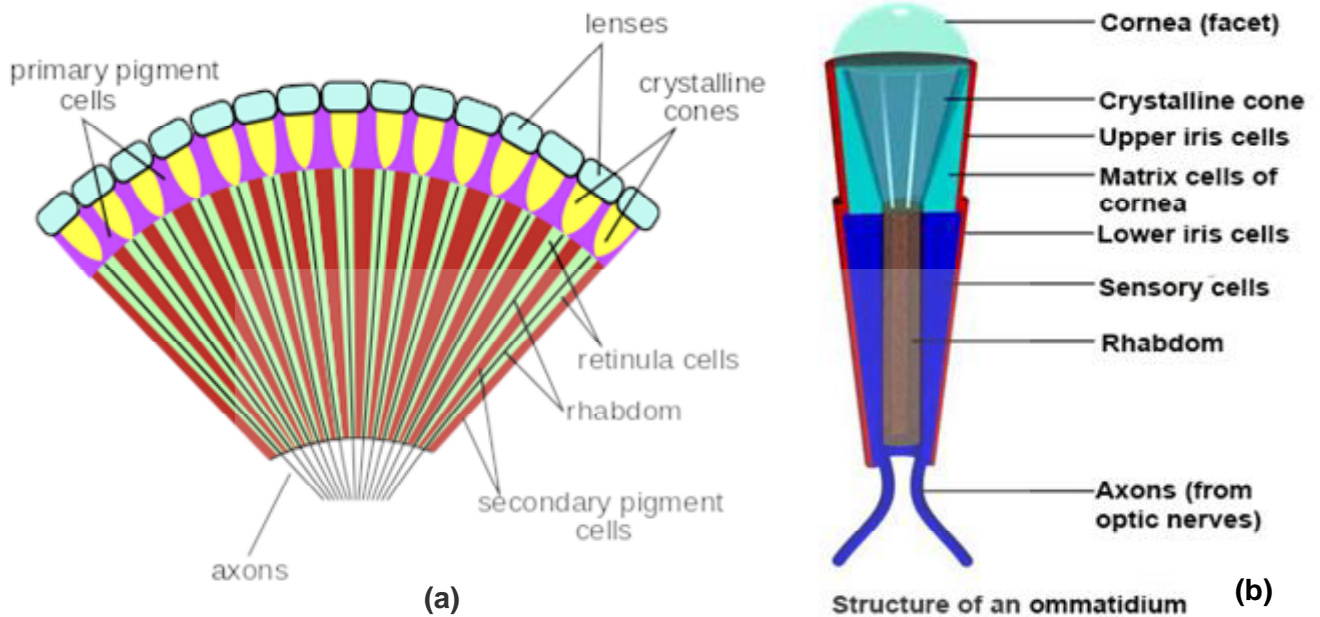
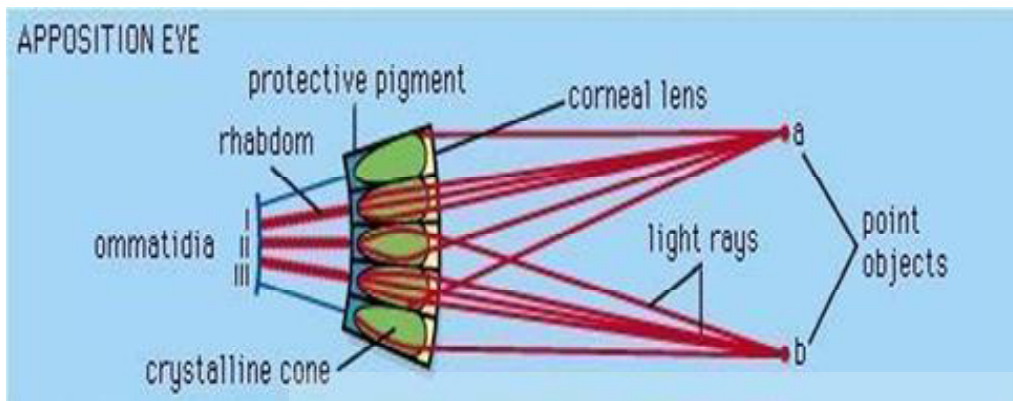


Fig. 8.93: Diagrams illustrating the structure of the compound eye. a) Section through part of an eye showing the arrangement of ommatidia. b) Detail of a single ommatidium.

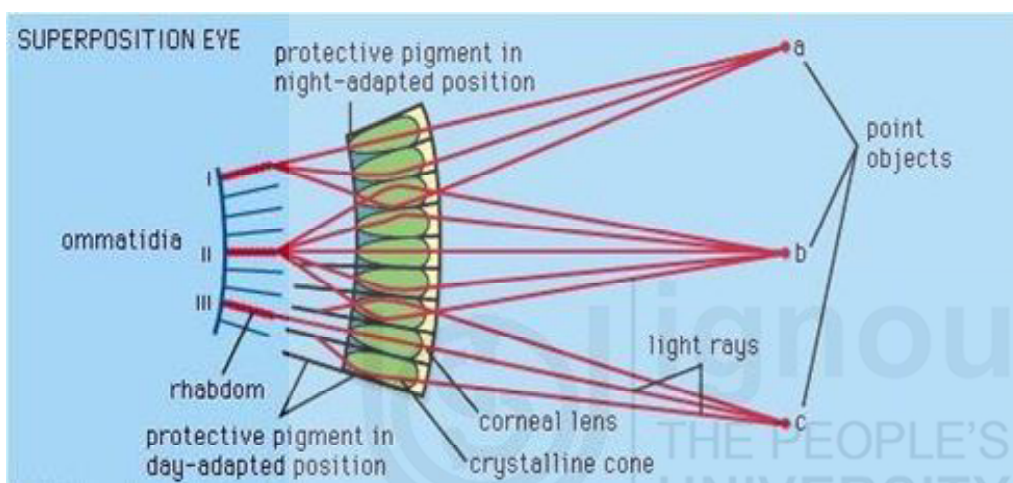
There are two types of compound eyes: (i) the **apposition eyes** and (ii) **superposition eyes**. The apposition eye is characteristic of diurnal species. The receptor cells are highly elongated, extending distally as far as the crystalline cone. The image formed by the eye as a whole is a mosaic of area (Fig. 8.94). Nocturnal insects have superposition eyes (Fig. 8.94). 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.

8.6 METAMORPHOSIS IN 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.



(A)



(B)

Fig. 8.94: A) Insect ommatidia, showing a diurnal type and a nocturnal type, B) 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.

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. 8.95). 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 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.

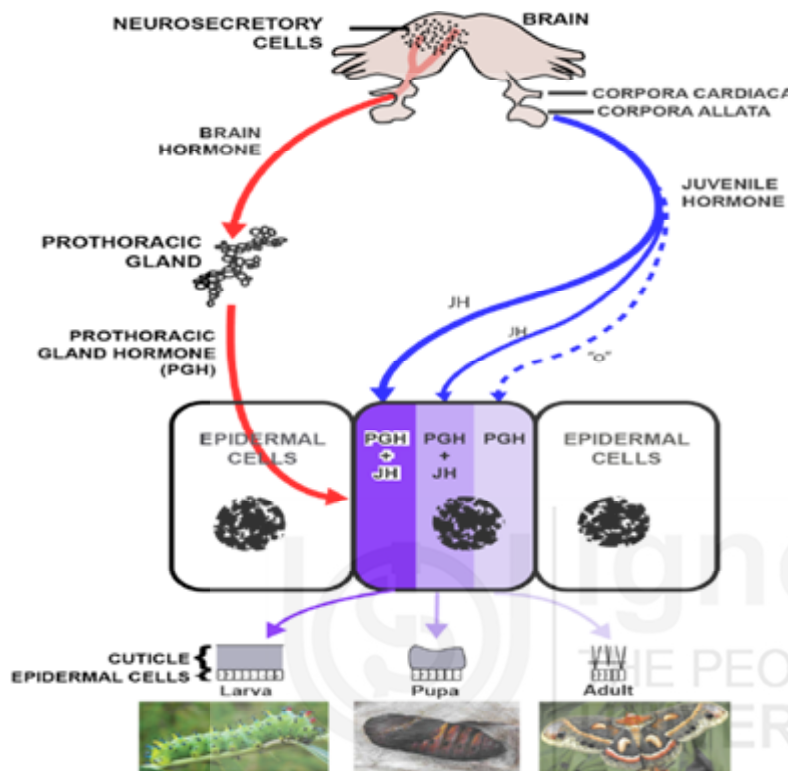


Fig. 8.95: Hormonal mechanism of moulting and metamorphosis in insects.

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 vitellogenin 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, i.e. 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.

SAQ 6

Correlate the following organs given under Column 'A' with their direct positive functions given under Column 'B'.

Column 'A'		Column 'B'	
i)	Prothoracic gland	a)	Secretion of JH
ii)	Rhabdomere	b)	Oocyte development and oviposition
iii)	Corpus allatum	c)	Images formed by the eye during the day
iv)	Apposition eyes	d)	Moulting
v)	Pars intercerebralis	e)	Nerve impulse.

8.7 SUMMARY

Let us summarise what we have learnt so far:

- Phylum Arthropoda 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 (*Scutigera*) and the largest class of Animalia – Insecta which comprises nearly a million species (cockroaches, grasshoppers, bugs, ant-lions, moths, butterflies, housefly, ants, bees, wasps, beetles etc.).
- The appendages of head of arthropods are the food capturing devices and the postcephalic appendages are locomotory in function. The digestive system shows regional specialisation with foregut generally serving as a storage and masticatory 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. Fertilization is internal. Development is through metamorphosis and includes more than one larval stage.

- In arthropods there are simple eyes like 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 is made up of large numbers of units called ommatidia.
- Insect hormones regulate moulting and metamorphosis. The larvae or nymphs which hatch out of the eggs undergo regular moulting that is followed by growth and ultimately they become adult. The change in form from larva to adult is known as metamorphosis.

8.8 TERMINAL QUESTIONS

1. List the characters of phylum Arthropoda.
2. a) Briefly describe the characters of subclass Xiphosura.
b) Why is Xiphosura considered an evolutionary relic?
3. Write short notes on the following with suitable diagrams.
a) Book lungs of Arachnida
b) Pectines of scorpions
4. Write descriptive notes on:
a) Class Copepoda b) Barnacles
5. Briefly describe the organisation of Malacostraca. Give a few examples of decapod malacostracans.
6. What are the classes included under Uniramia? Give examples of a few genera under each class.
7. What is a diplosegment? List the characters of class Diplopoda.
8. "Insects have dominated the terrestrial environment". What are the reasons for the success of the insects in the terrestrial environment?
9. Name the orders to which the following insects belong:
a) silverfish, b) grasshopper, c) plant bug, d) dragon fly,
e) ant-lion, f) head louse, g) moth, i) housefly, j) wasp, k) beetle.
10. Write short notes on:
a) Compound eye
b) Moulting

8.9 ANSWERS

Self-Assessment Questions

- 1) I) i) a million, ii) jointed legs, iii) homologous, iv) biramous, uniramous, v) tergum, sternum, pleuron, vi) coelom, vii) coxal glands and malpighian tubules, viii) ommatidium, ix) trilobitomorpha, crustacea, chelicerata, uniramia.
 - II) i) Segments fuse to form functional units called tagmata.
 - ii) Segments carry jointed appendages
 - iii) Cilia are absent
 - iv) Coelom is reduced and confined to the cavity enclosed by excretory organs and gonads.
 - v) Development often involves metamorphosis.
- 2) I) i) primitive ii) absence iii) pediapalpi iv) aquatic v) xiphosuran vi) arachnida vii) metasoma viii) Araneae ix) Acarina
 - II) i) Merostomata, Arachnida, Pycnogonida ii) Xiphosura iii) living fossils iv) lyriform organs v) pectines vi) phalangids vii) ectoparasitic viii) tularemia, relapsing fever and lyme disease ix) pseudostigmatic x) pycnogonida.
3. I. i) T ii) F iii) T iv) F F v) F F vi) F T vii) F viii) F ix) T x) F
 - II) a-v; b-i; c-vi; d-iii; e-ii; f-iv
4. i) The appendages of millepedes. Centipedes and insects are all unbranched, hence the name Uniramia.
 - ii) Chilopoda, Diplopoda, Pauropoda, Symphyla and Insecta
 - iii) A pair of antennae, a pair of mandibles and two pairs of maxillae
 - iv) A diplosegment is the segment of diplopods formed by the fusion of two originally separate segments.
 - v) a) gnathochilarium b) collum
 - vi) The antennae of pauropods are biramous.
 - vii) The males of Symphyla deposit 150–450 spermatophores which are swallowed by the female. They are stored in buccal pouches. The sperms are subsequently smeared over the eggs once they are deposited.
5. I) i) T ii) F iii) T iv) F v) F vi).T vii) T viii) F ix) T
 - II) i) e ii) h iii) f iv) g v) d vi) j vii) b viii) a ix) c x) I
6. i) d, ii) e, iii) a, iv) c, v) b

Terminal Questions

1. Refer to Section 8.3.
2. Refer to subphylum Chelicerata under Subsection 8.4.2.
3. a) and b) Refer to subclass Xiphosura under Subsection 8.4.2.
4. Refer to class 3: Copepoda and class 5: Cirripedia under subsection 8.4.3.
5. Refer to class 6: Malacostraca under subphylum Crustacea under Subsection 8.4.3.
6. Class Chilopoda, class Diplopoda, class Pauropoda, class Symphyla and class Insecta under Subsection 8.4.4.
Chilopoda: Scolopendra, Lithobius and Scutigera.
Diplopoda: Spirostreptus, Sphaerotherium, Glomeris
Pauropoda: Pauropus, Allopauropus
Symphyla: Scutigera
Insecta: Periplanata, Musca, Apis
7. 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 8.4.4
8. Refer under class Insecta of Subsection 8.4.4
9. a) Thysanura b) Orthoptera c) Hemiptera d) Odonata
e) Neuroptera f) Anopleura g) Lepidoptera h) Diptera
i) Hymenoptera j) Coleoptera
10. a) Refer to Section 8.5.
b) Refer to Section 8.6.

PHYLUM MOLLUSCA

Structure

9.1	Introduction		Class Gastropoda
	Objectives		Class Bivalvia
9.2	Characteristics of Mollusca		Class Scaphopoda
9.3	A Generalised Mollusc		Class Cephalopoda
9.4	Classification of Phylum Mollusca	9.5	Summary
	Class Monoplacophora	9.6	Terminal Questions
	Class Polyplacophora	9.7	Answers
	Class Aplacophora		

9.1 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 is second only to Arthropoda in number of living species. It includes many familiar animals, such as clams, oysters, mussels, snails, slugs, and squids in seven classes. As was done in the previous units, in this unit also we shall describe the characters of the 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:

- ❖ describe the general characters of phylum Mollusca and have a clear understanding of the major classes it comprises; and
- ❖ explain torsion in gastropods.

9.2 CHARACTERISTICS OF MOLLUSCA

Phylum Mollusca is one of the largest phyla among the invertebrates and includes over 100,000 living species and about 35,000 extinct. 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.**

9.3 A GENERALISED MOLLUSC

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. 9.1). 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.

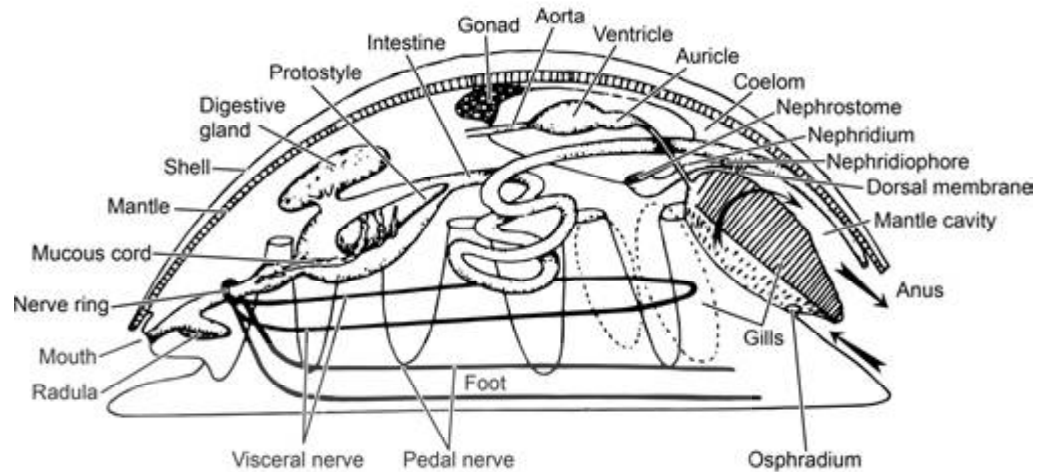


Fig. 9.1: Organisation of a generalised mollusc.

The shell has three layers (Fig. 9.2):

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.

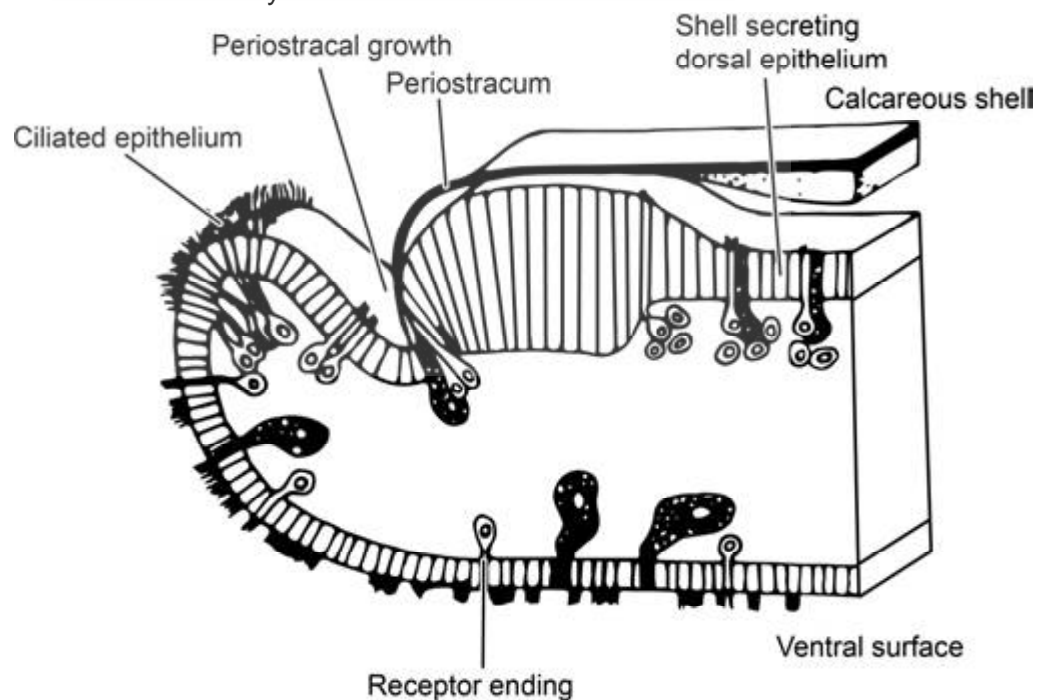


Fig. 9.2: A section through the mantle edge of a gastropod snail.

i) Respiration

In molluscs, the respiratory structures are usually **gills** or **ctenidia** (Sing. Ctenidium) (Fig. 9.1). 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. 9.3). 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 is 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. 9.4).

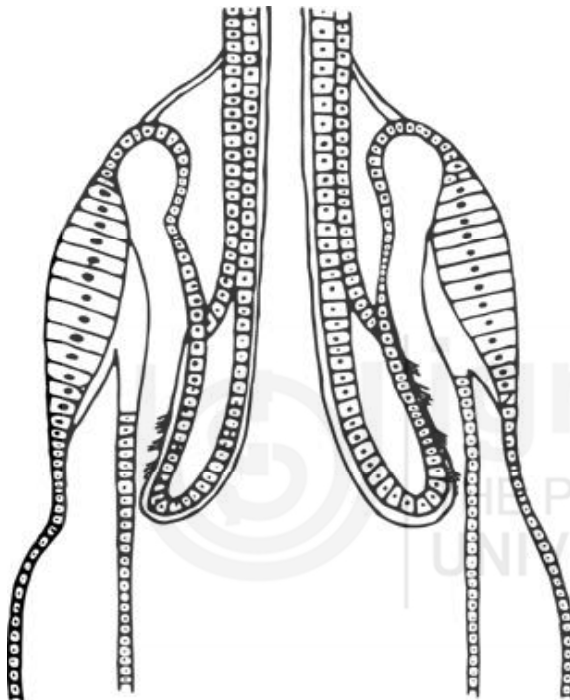


Fig. 9.3: Frontal section through a gill.

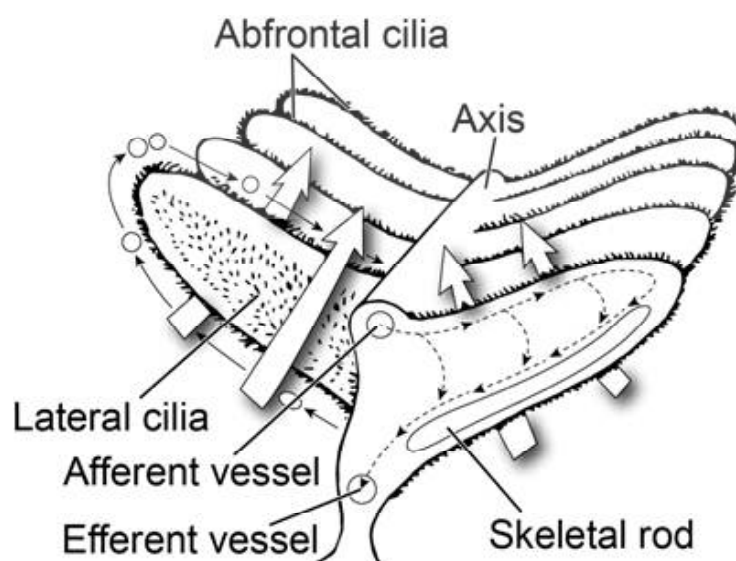


Fig. 9.4: Transverse section through a gill.

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.

ii) Digestion

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. 9.5). 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. 9.1). The anterior region of the stomach is lined with chitin except for a short, ciliated and ridged region called the sorting region. The **hepatopancreas** constitutes 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. 9.1).

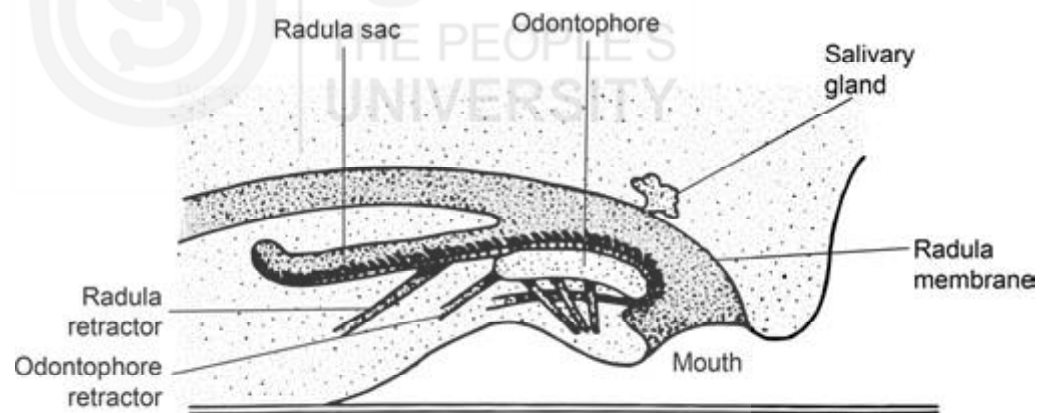


Fig. 9.5: The inner view of molluscan radular apparatus.

iii) Circulation

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. 9.1). 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.

iv) Excretion

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 (Fig. 9.1).

v) Nervous System

The nervous system of molluscs consists of a nerve ring around the oesophagus from which two pairs of nerve cords extend posteriorly (Fig. 9.1). 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. 9.1).

vi) Reproductive System

Molluscs may be hermaphrodites or the sexes may be separate. The mature gametes may be released into water in which case fertilization will be external. In forms where fertilization is internal, sperm transfer may occur directly or the sperms will be packaged into structures called spermatophores and transferred. Cleavage is spiral and a free swimming **trochophore** larva (Fig. 9.6) develops from the gastrula. The trochophore in many molluscs transforms into another larval stage, the **veliger** larva (Fig. 9.7) in which the foot, shell and other structures begin to appear. Veliger larva metamorphoses into an adult.

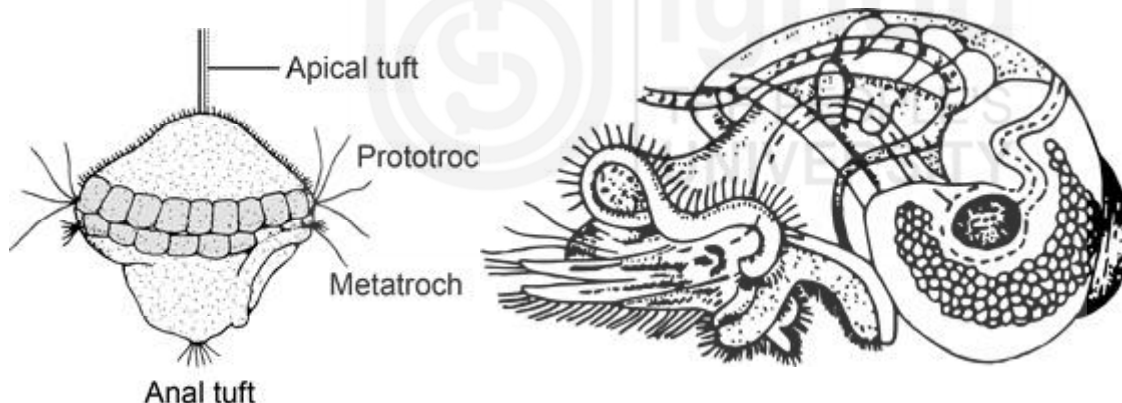


Fig. 9.6: Trochophore larva of gastropod.

Fig. 9.7: Veliger larva.

SAQ 1

Fill in the blanks with suitable words.

- The molluscs comprise the following major groups, commonly known as _____, _____, and _____.
- The rich fossil record of molluscs is due to the presence of _____ in many organisms.
- The ovoid dorsal side of the body of molluscs that contains the internal organs is called _____.
- _____ is an epidermal covering over the visceral mass.
- The gills of molluscs are known as _____.

9.4 CLASSIFICATION OF PHYLUM 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.

9.4.1 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.

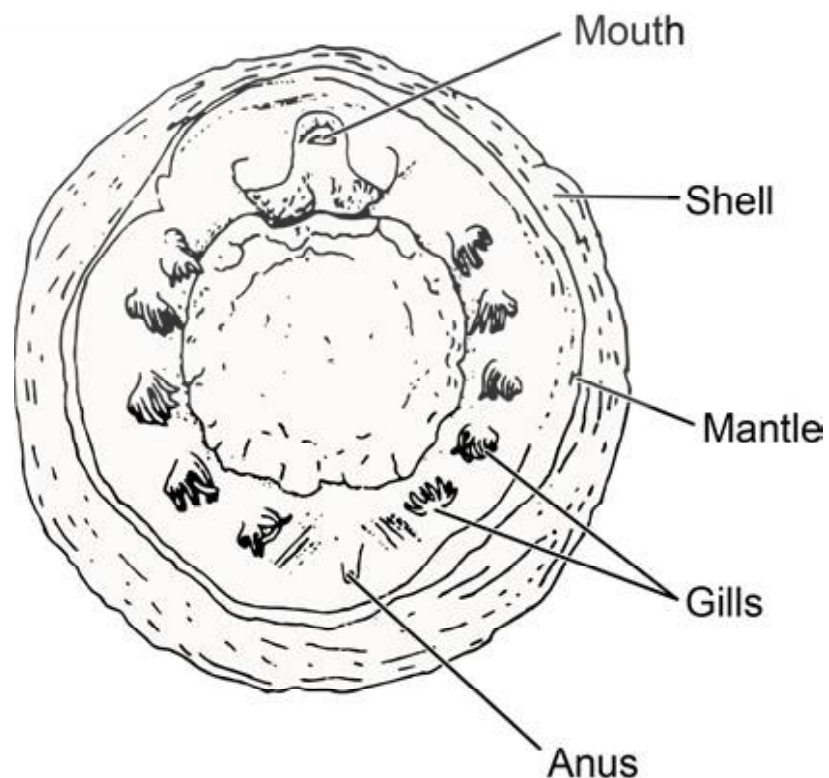


Fig. 9.8: Monoplacophoran *Neopilina* (ventral view).

Monoplacophorans have following salient features:

- The shell varies in shape from a flat shield to short cone: length of the animals ranges from 3 mm to 3 cm (Fig. 9.8).
- 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. 9.9) 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. Fertilization is external. Example : *Neopilina*.

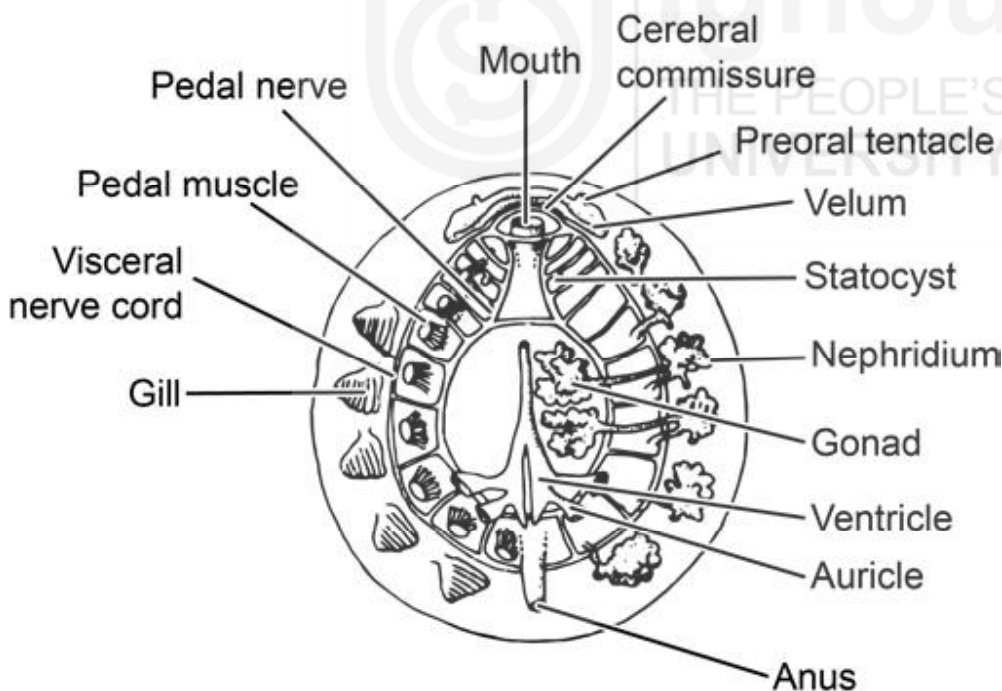


Fig. 9.9: Internal anatomy of *Neopilina*.

9.4.2 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.

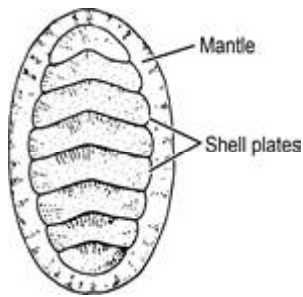


Fig. 9.10: *Chiton*.

Class Polyplacophora include chitons (Fig. 9.10). 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:

- 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. 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. 9.11). 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.

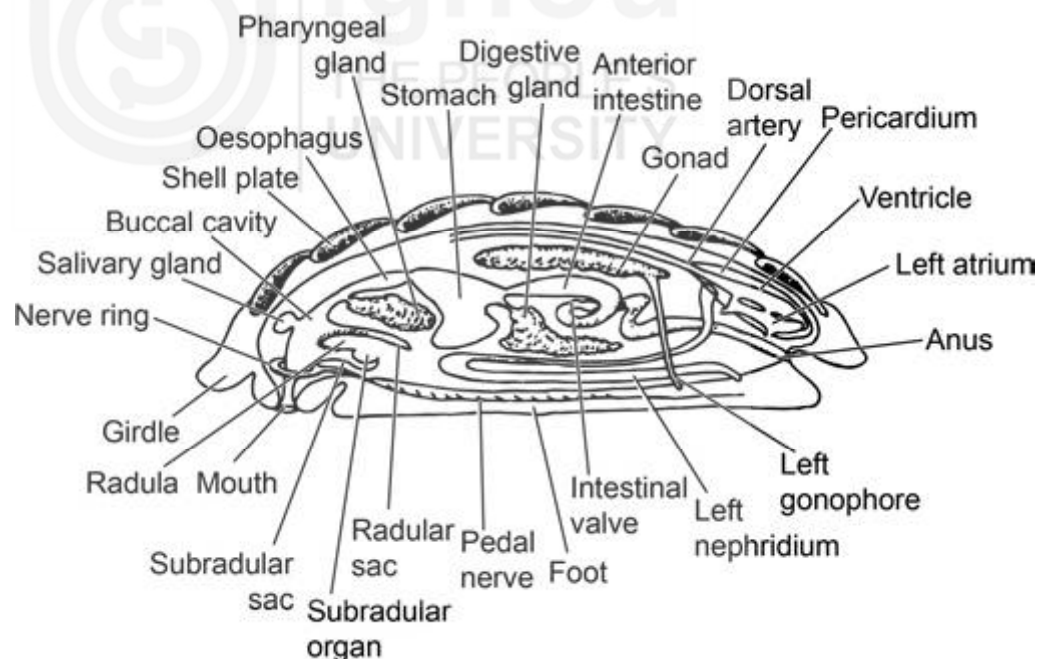


Fig. 9.11: Internal anatomy of *Chiton*.

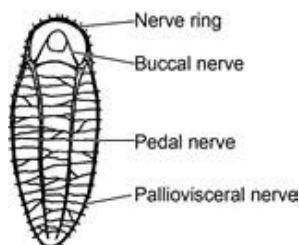


Fig. 9.12: Nervous system of *Chiton*.

- 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. 9.12). However, ganglia are lacking or poorly developed. From the circumoesophageal nerve ring, the pedal nerves and palliovisceral nerve arise. The sense organs include subradular organs, girdle hairs and mantle structures known as **esthetes** of unknown sensory function.
- 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 fertilization is external in water or in the mantle cavity of females.
- Development includes a free swimming larval stage.

9.4.3 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. 9.13) 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. 9.13: 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 Column 'A' with their characters in Column 'B'.

Column 'A'	Column 'B'
i) Aplacophora	a) Presence of esthetes.
	b) Heart with 2 pairs of auricles and a pair of ventricles.
ii) Monoplacophora	c) Body covered by a cuticle lined integument embedded with calcareous scales or spicules.
iii) Polyplacophora	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.

9.4.4 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**.

Torsion in Gastropoda

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. 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 of 9. Only the head and foot remain untorted. The shell is usually a conspiral.

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 visceral 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. 9.14).

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. 9.15). 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.

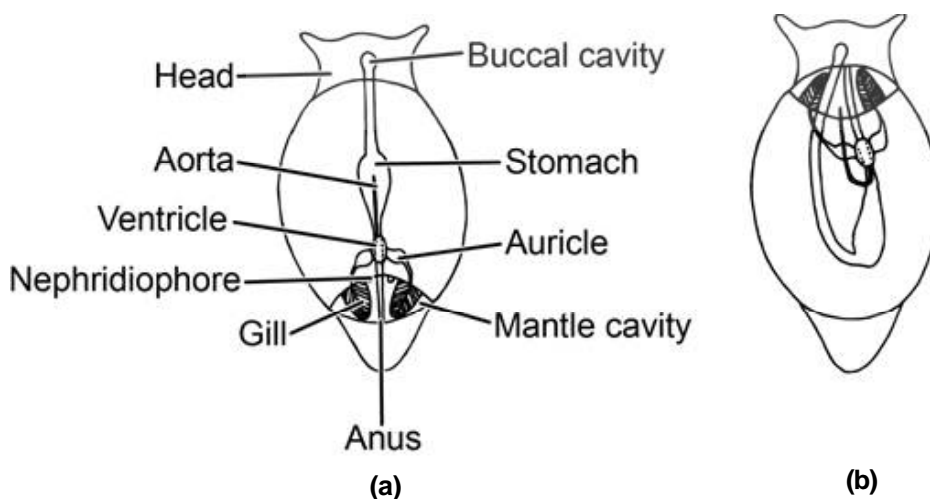


Fig. 9.14: Torsion in a gastropod: a) before torsion; b) after torsion.

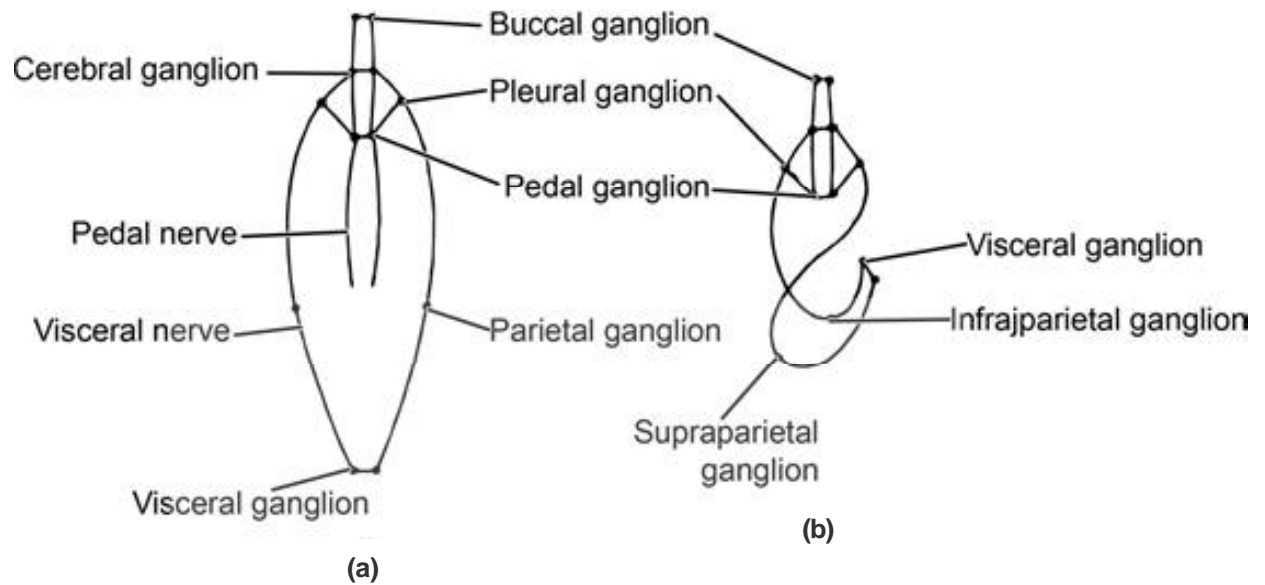


Fig. 9.15: a) pre torsion nervous system; b) post torsion nervous system.

The condition described above is seen in the primitive gastropods (such as 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 nudibranchs.

Coiling of the shell

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. 9.16). 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 atrophy 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.

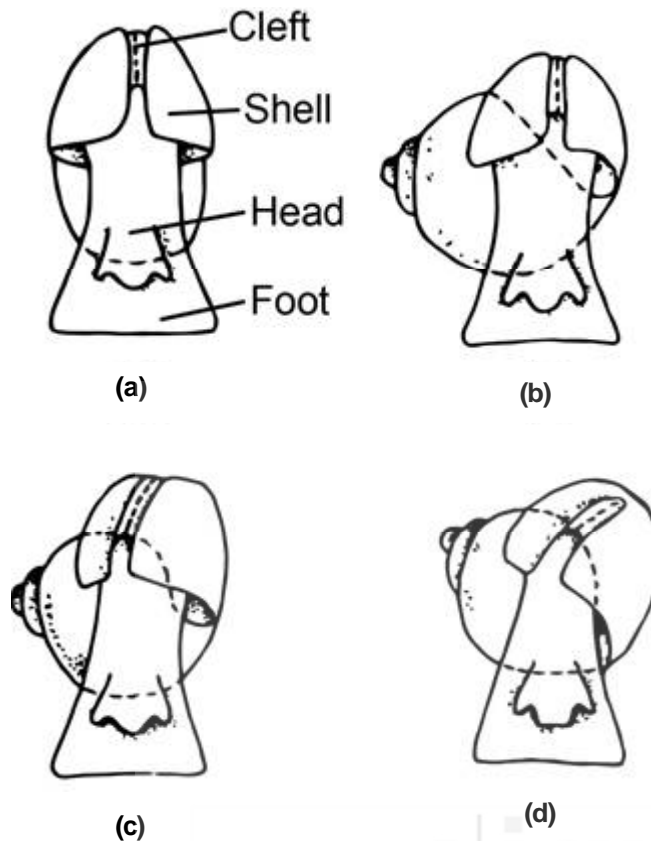


Fig. 9.16: Evolution of the asymmetrical gastropod shell: a) Ancestral planospiral shell; b) Apex of the shell is drawn out producing a more compact shell; c) Position of the shell over the body is shifted producing a more equal distribution of weight; d) Final position of the shell over the body as seen in most living gastropods.

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 gigantean*. Many of them are of exquisite beauty. They present varying hues, shapes and surface sculptures of ridges, grooves, ribs, tubercles, and spines.

The typical gastropod shell is asymmetrical, conical spiral (Fig. 9.17) around an axis called columella (Fig. 9.18). It has evolved from the primitive planospiral shell as a result of torsion (Fig. 9.19). 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 preceding 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. 9.20). 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. 9.21). 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 sinistral, has genetic basis.

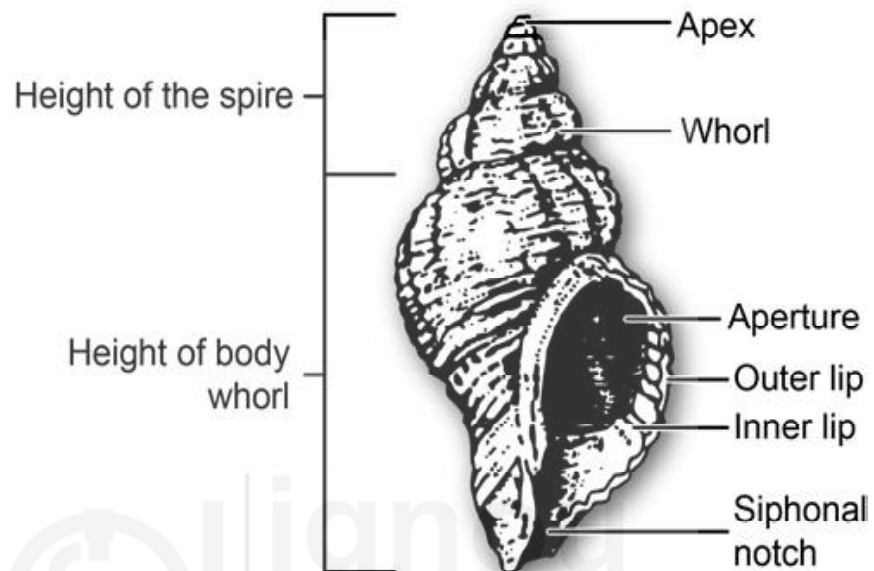


Fig. 9.17: A typical conospiral shell of a gastropod.



Fig. 9.18: A longitudinal section through shell.

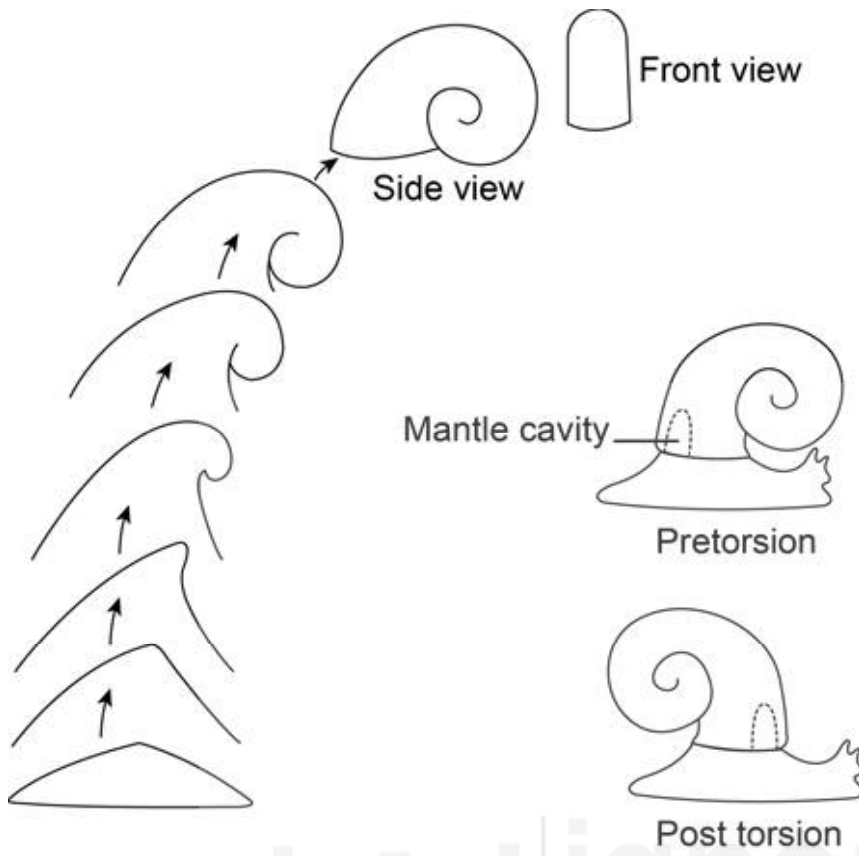


Fig. 9.19: Planospiral shell: a) before torsion; b) after torsion.



Fig. 9.20: Shell with operculum.

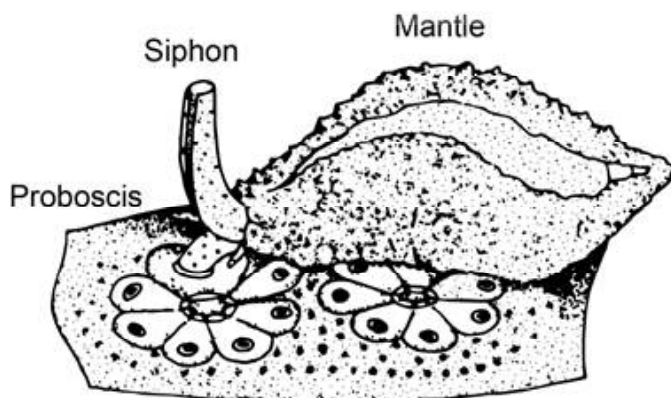


Fig. 9.21: The Cowrie.

(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. 9.22) with large number of whorls on the one hand, and the short broad smooth shell of *Laoina* (Fig. 9.23) with the large body whorl and the tiny spire, on the other. The spire is not even visible in the shell of *Cylindrella* (Fig. 9.24). The limpets (Fig. 9.25) 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 nudibranchs.



Fig. 9.22: *Turitella*

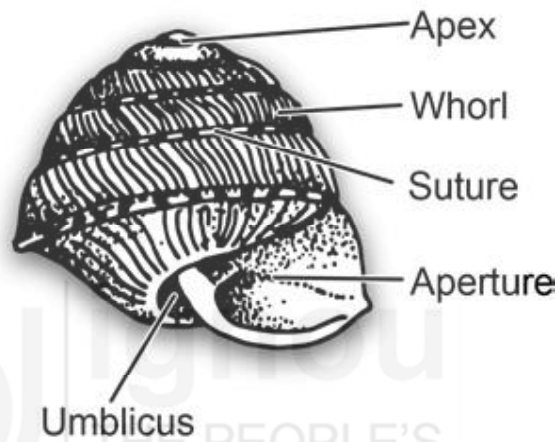


Fig. 9.23: *Lahaina*.



Fig. 9.24 : *Cylindrella*



Fig. 9.25: *Fissurella*

The shell basically consists of an outer periostracum and a varying number of inner calcareous layers. But there are 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 animal 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. 9.26).

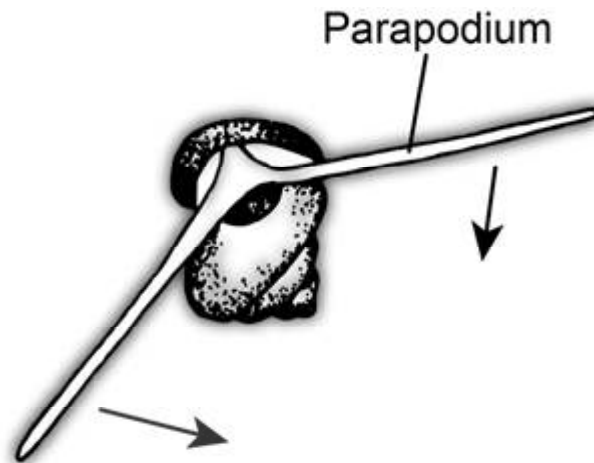


Fig. 9.26: Sea-butterfly.

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. 9.27). 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.

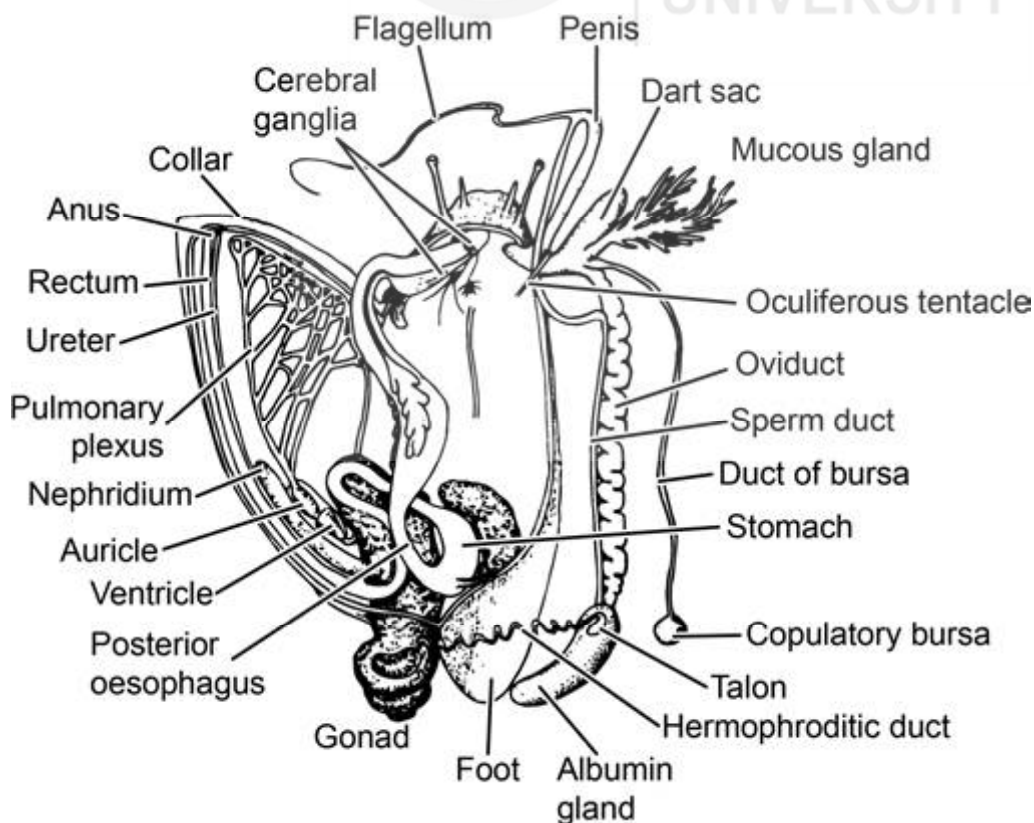


Fig. 9.27: Viscera of a land snail.

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. 9.28).

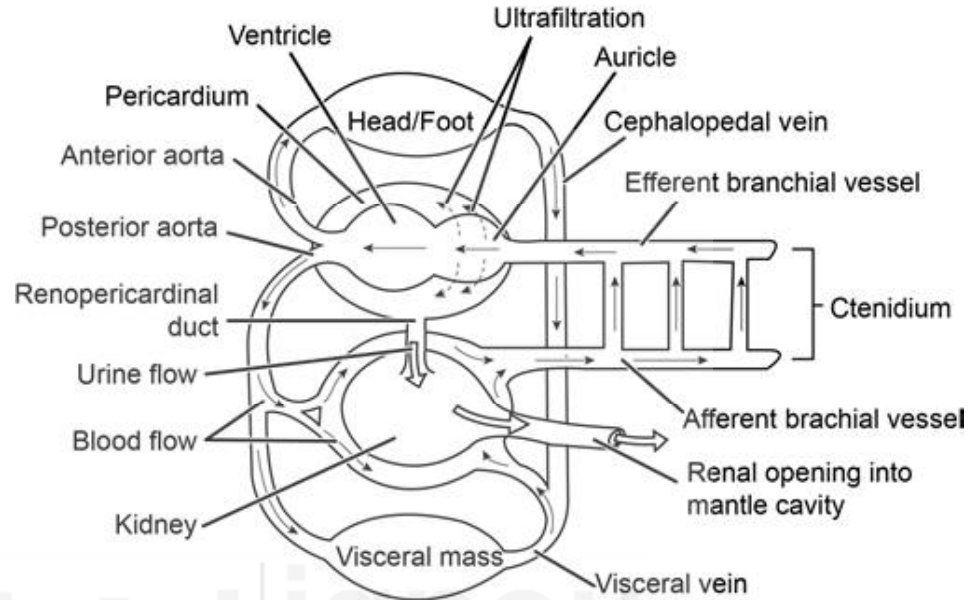


Fig. 9.28: Blood circulation in a gastropod.

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 Fig. 9.15.

Gastropods may be hermaphrodites or dioecious and possess unpaired gonad. Fertilization is mostly internal. Fertilized 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. 9.29), *Fissurella*, *Patella*, *Trochus*, *Nerita*: all are primitive forms: *Pila*, *Crepidula*, *Strombus*: (Fig. 9.30); *Murex* (Fig. 9.31). *Nucella*: These are all examples of subclass **Prosobranchia**. They show torsion, and have gills.



Fig. 9.31: *Murex*

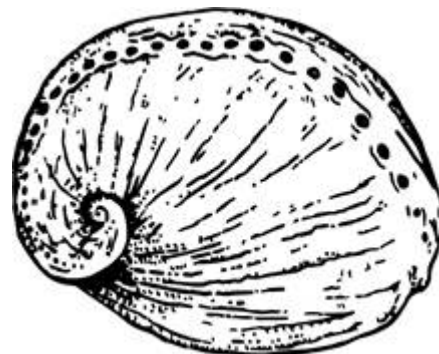


Fig. 9.29: *Haliotis*.

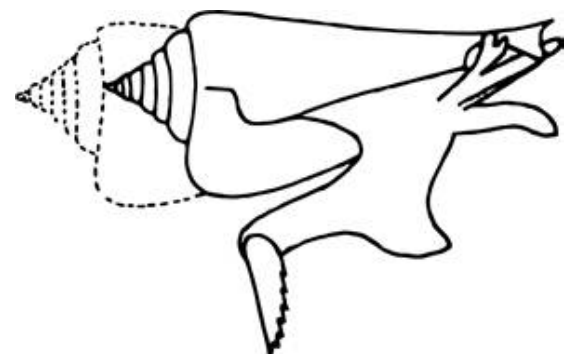


Fig. 9.30: *Strombus*.

9.4.5 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 mussels. The body of 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 9.1

The shell of bivalves consists of two more or less similar oval valves (Fig. 9.32). 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.

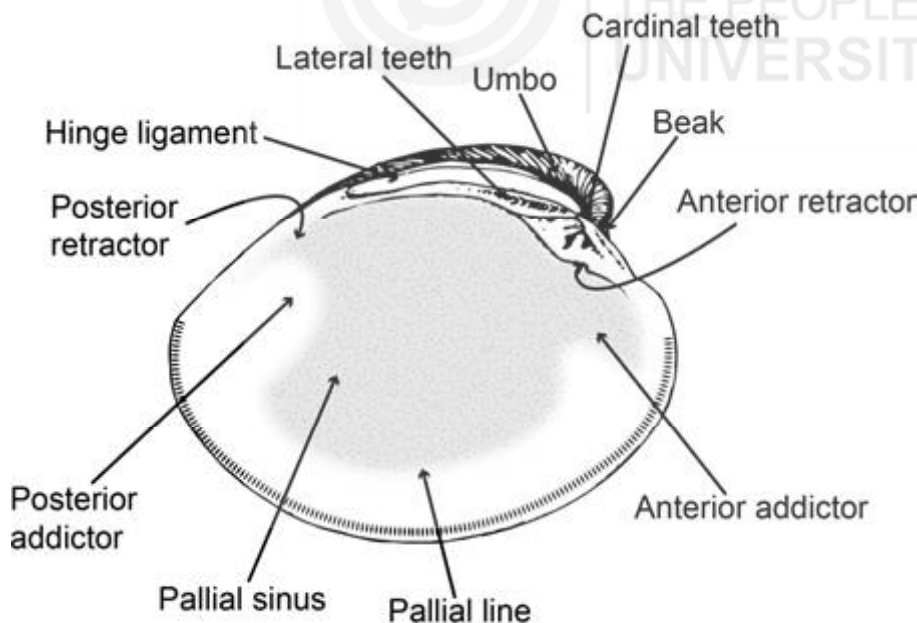


Fig. 9.32: Inner surface of the left valve of a bivalve.

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

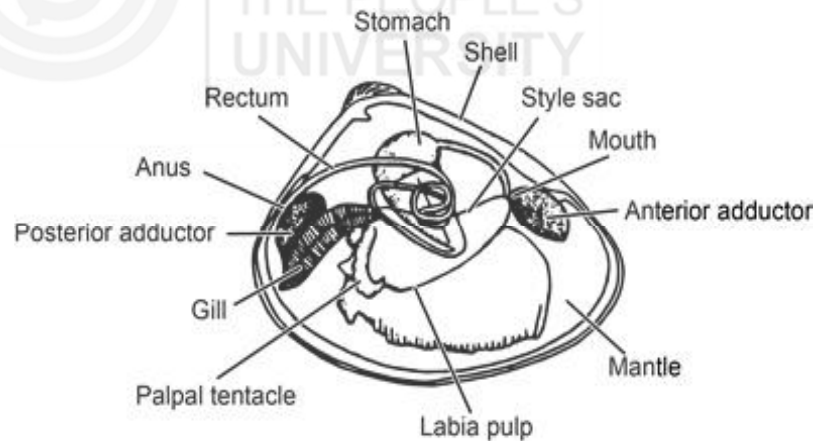
deposits of concentric layers of nacre around foreign objects such as sand grains or parasites.

The pearl oysters *Pinctada margaritifera* and *Pinctada wertsorsii* produce best quality natural pearls. Oysters can be artificially induced to produce pearls.

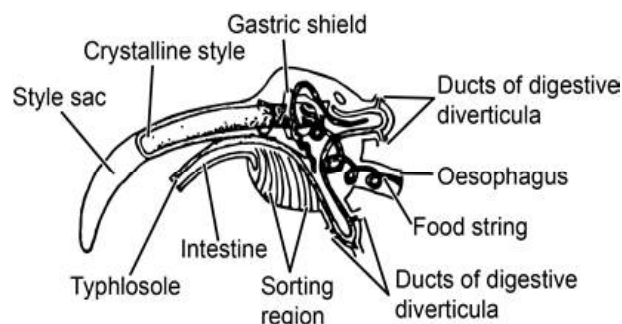
Bivalves range in size from 2 mm in length to giant forms such as *Tridacna* which measures over a meter in length. The line of the mantle attachment to the inner surface of the shell is called pallial line.

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. 9.33 a). 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. 9.33 b) 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 digestive tract.



(a)



(b)

Fig. 9.33: a) Internal organisation of a bivalve; b) Crystalline style.

Gills also function as organs of gas exchange (Fig. 9.34). 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 connectives (Fig. 9.35). 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. 9.36). Some clams have **glochidium** as the larval stage (Fig. 9.37).

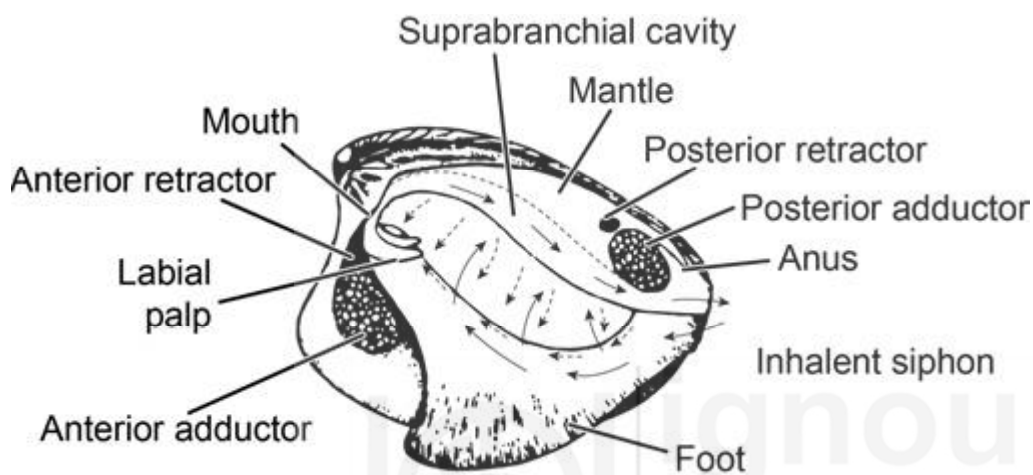


Fig. 9.34: Route of entry and exit of water for gas exchange.

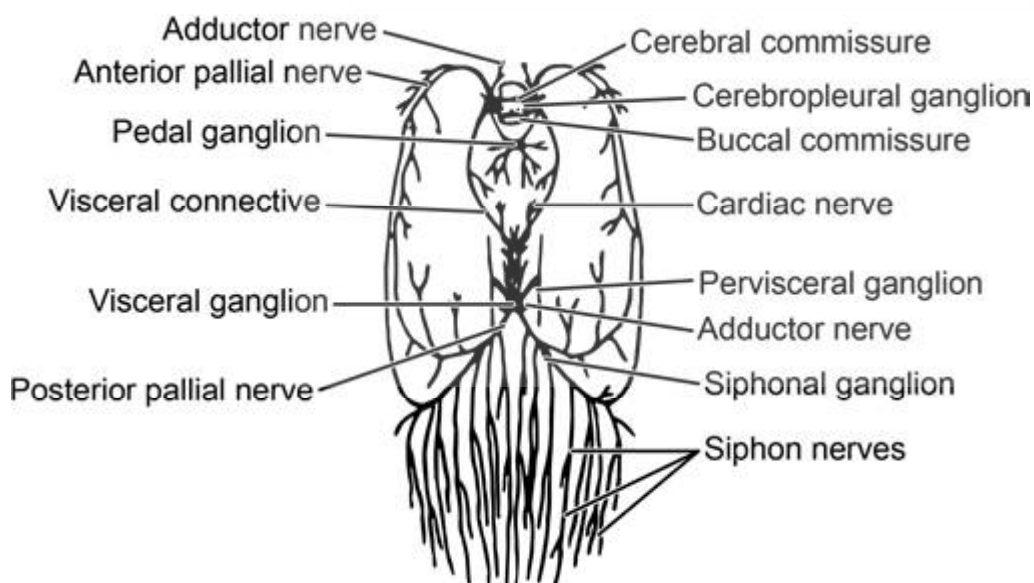


Fig. 9.35: Nervous system of a bivalve.

Examples: *Nucula*: The shell valves are equal and carry a row of teeth along the hinge. *Area*, the arks (Fig. 9.38), *Mytilus* (Fig. 9.39), pen shells and winged oysters. *Pecten* (Fig. 9.40) (scallop) *Solen* (Fig. 9.41).

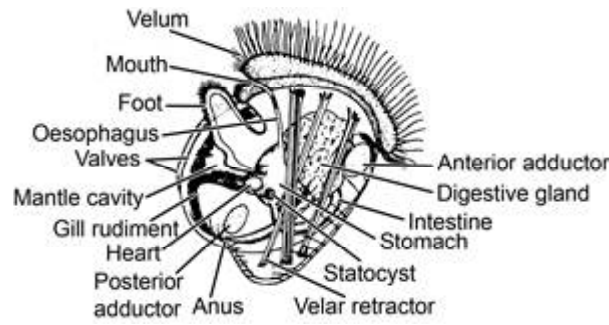


Fig. 9.36: Veliger Larva.



Fig. 9.37: *Glochidium*.



Fig. 9.38 : *Arca*.



Fig. 9.39: *Mytilus*.

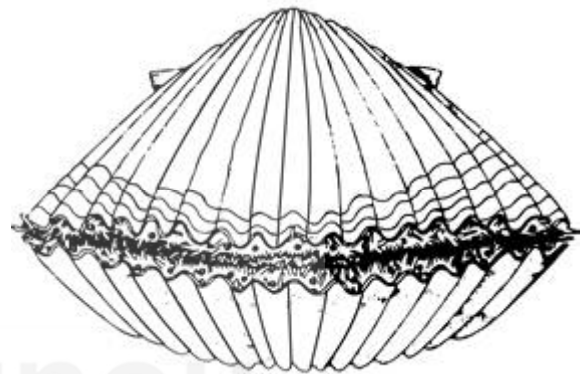


Fig. 9.40: *Pecten*.



Fig. 9.41: *Solen*.

9.4.6 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. 9.42 a). 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.

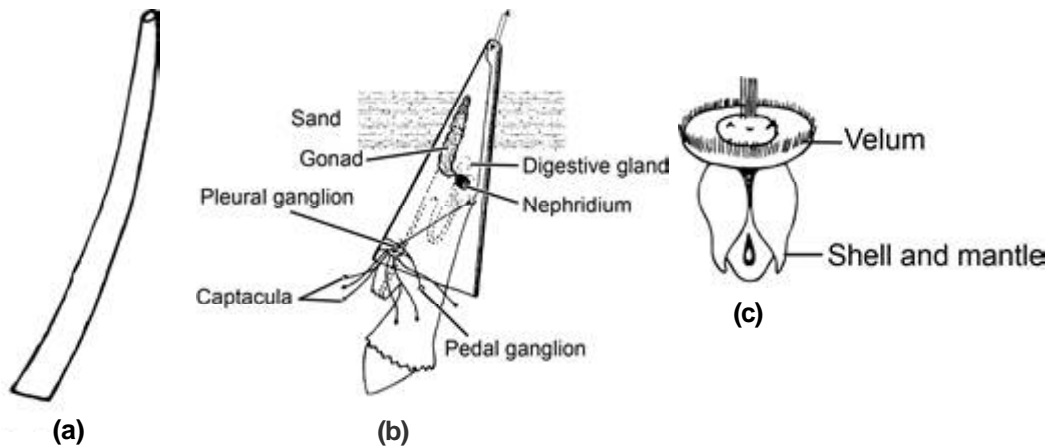


Fig. 9.42: a) Shell of *Dentalium*; b) Organisation of *Dentalium*; c) Veliger larva.

The body of scaphopods is elongated and the head and foot project from anterior larger aperture of the shell (Fig. 9.42 b). 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 consists of cerebral, pedal, pleural and visceral ganglia. 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. 9.42 c) e.g. *Dentalium*, *Cadiilus*.

9.4.7 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. 9.43 a), squids, octopus (Fig. 9.43 b) and *Nautilus* (Fig. 9.43 c). The body is lengthened in the dorsoventral axis and this has in effect become 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.

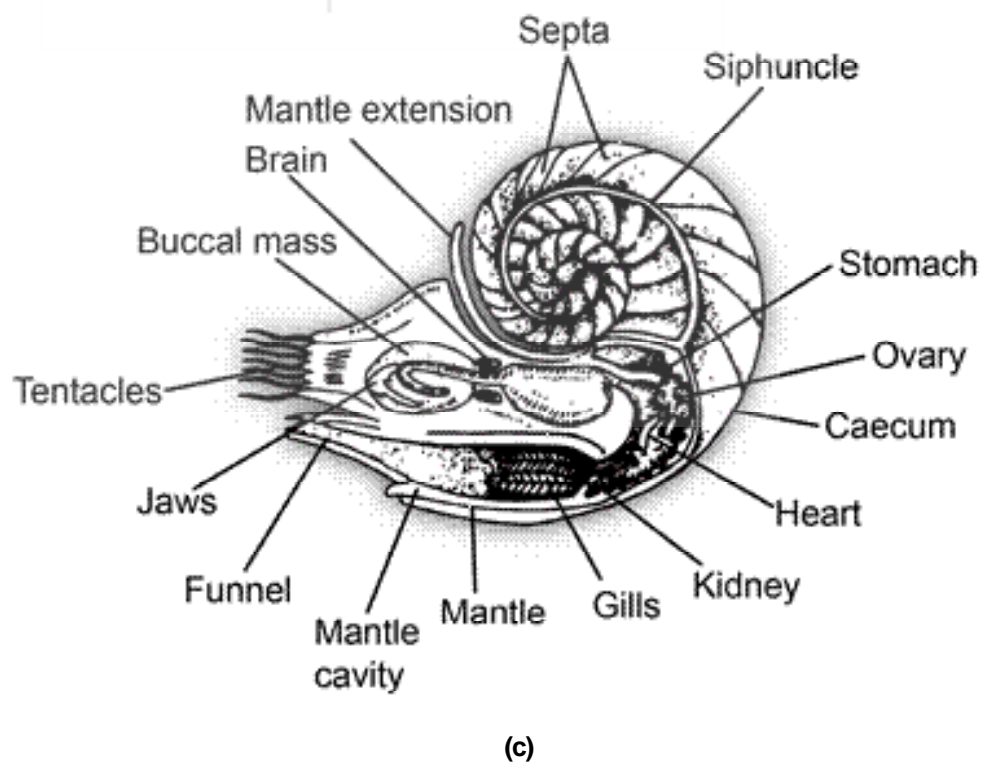
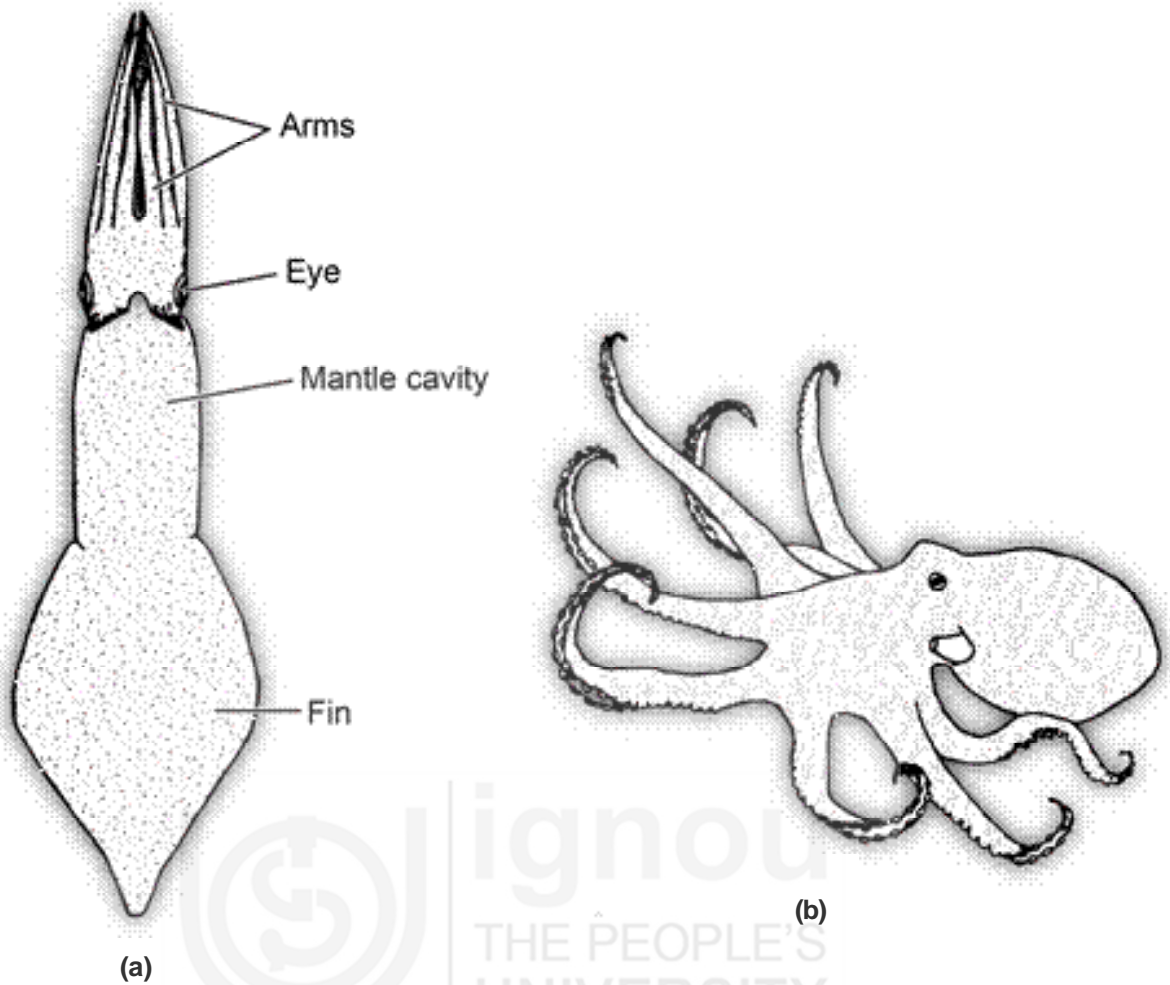


Fig. 9.43: Some Cephalopods: a) Cuttlefish *Sepia*; b) *Octopus*; c) *Nautilus*.

Box 9.2

The shell of *Nautilus* is a planospiral (Fig. 9.43c). 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 are 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 cattle fish *Spirula* (Fig. 9.44) the internal shell is coiled. In the *Sepia* and *Loligo*, the shell is reduced to a “pen” (Fig. 9.45).

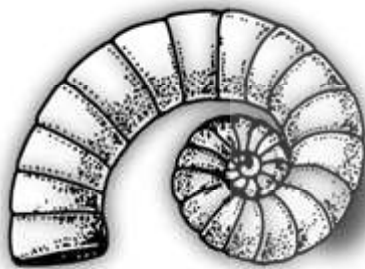


Fig. 9.44: Shell of *Spirula*.



Fig. 9.45: Shell of *Sepia*.

Cephalopods are carnivorous and capture their prey by tentacles or anus. 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. 9.46). 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 exhalant water jet. Respiration is by gills. The circulating water in the mantle cavity is the source of oxygen for the gills.

Nephridia are the excretory organs (Fig. 9.47). 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. 9.48). 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 ganglia** 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. 9.48) that secretes brown or black fluid or ink made of melanin pigments. The ink sac opens into the rectum. When the organism is disturbed 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.

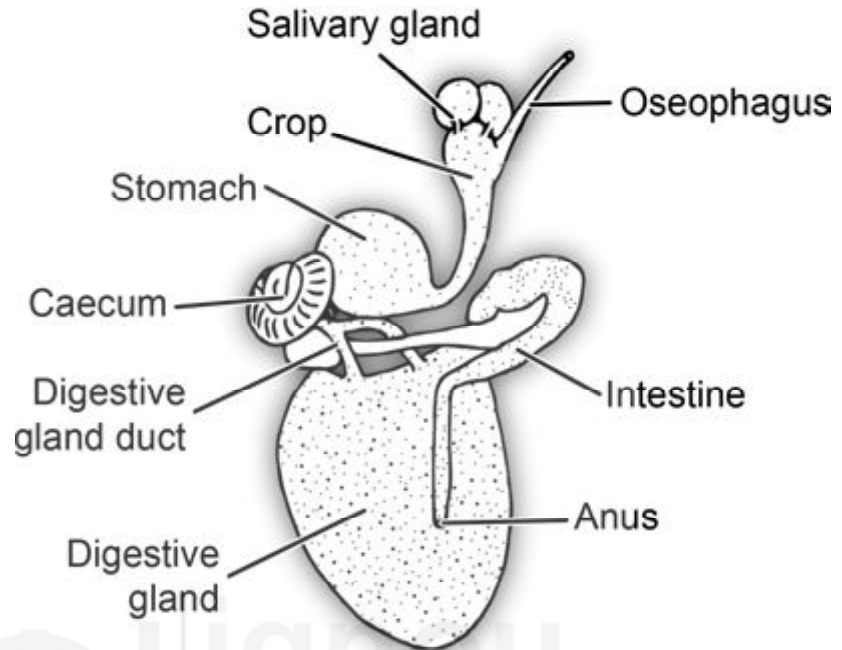


Fig. 9.46: Digestive System of *Octopus*.

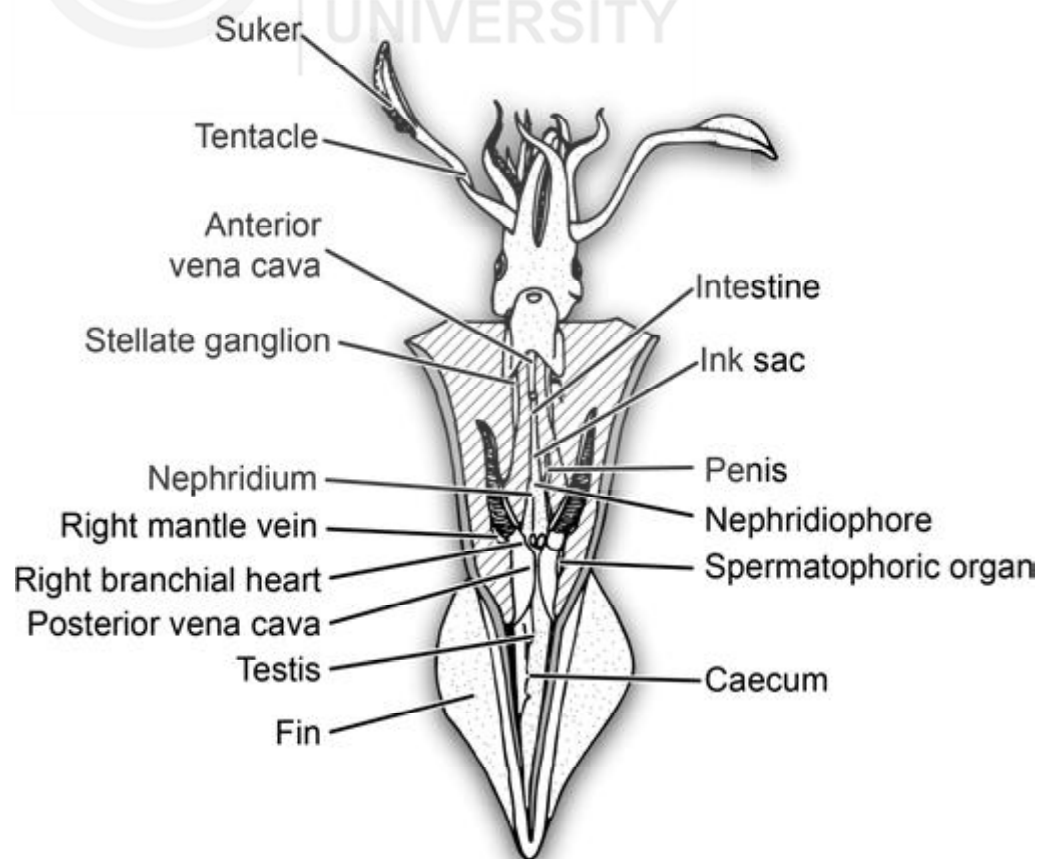


Fig. 9.47: Internal anatomy of squid.

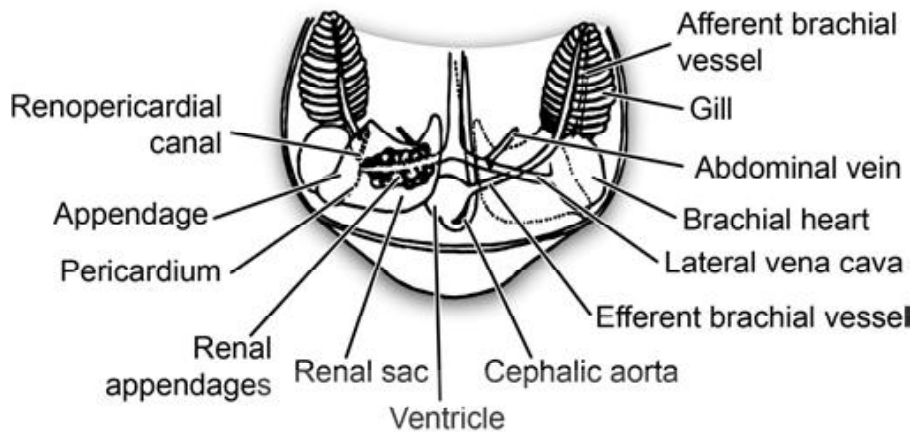


Fig. 9.48: Excretory and Circulatory systems of Octopus.

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**.

SAQ 3

Answer the following questions briefly.

- i) Name four major characteristics of the Gastropoda.
- ii) What is meant by torsion?
- iii) What is the composition of molluscan shell?
- iv) Name the respiratory organ of pulmonates.

SAQ 4

State whether the following statements are true or false:

- A) Class Bivalvia includes snails, slugs, limpets and abalones.
- B) Bivalves have the smallest mantle cavity among molluscs.
- C) The inner surface of shells of bivalves have a lustrous appearance.
- D) Bivalves have adapted for filter feeding methods.
- E) The crystalline style of bivalves produces digestive enzymes.
- F) The crystalline style is a long gelatinous rod.
- G) The gills of bivalves play a key role in filter feeding mechanism.
- H) The blood of cephalopods contains haemocyanin.
- I) Cephalopods have one of the best developed nervous systems among invertebrates.
- J) Development in bivalves includes trochophore and veliger larvae.

SAQ 5

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.

9.5 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.
- Fertilization 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° 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 cephelopods, 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.

9.6 TERMINAL QUESTIONS

1. List the diagnostic characters of phylum Mollusca.
2. Briefly write about the organisation of chitons.
3. What is torsion? Briefly discuss the process of torsion in gastropods.
4. Write brief notes on:
 - a) Shell in Bivalvia
 - b) Crystalline style

9.7 ANSWERS

Self-Assessment Questions

1.
 - a) snails, clams and squids
 - b) mineralised shell
 - c) visceral mass
 - d) mantle
 - e) ctenidia
2. i) c, e, i; ii) a, b, f, h; iii) d, g.
3. i)
 - a) Development of distinct head
 - b) Dorsoventrnl elongation of the body
 - c) Gastropods exhibit torsion
 - d) Conversion of plate like shell into a spiral asymmetrical shell.
 ii) Torsion is the twisting of the visceral mass 180° 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.

- iii) 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.
- iv) The large gills that are located in the spacious mantle cavity are the respiratory organs in bivalves.
4. A) F; B) T; C) T; D) T; E) T; F) T; G) T; H) T; I) T; J) T.
5. A) scaphopoda
B) captacula
C) *Nautilus*
D) gas, buoyancy
E) branchial
F) endothelium
G) stellate
H) spermatophores

Terminal Questions

1. Refer to Section 9.2.
2. Refer to Sub-section 9.4.2.
3. Refer to Sub-section 9.4.4.
4. a) Refer to Sub-section 9.4.5.
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.

UNIT 10

ECHINODERMATA AND HEMICHORDATA

Structure

10.1	Introduction Objectives	10.4	Phylum Hemichordata Class Enteropneusta Class Pterobranchia Basic Adaptive Features Affinities
10.2	Characteristic Features of Phylum Echinodermata	10.5	Summary
10.3	Classification of Phylum Echinodermata Class Asterozoa Class Ophiurozoa Class Echinozoa Class Holothurozoa Class Crinozoa	10.6	Terminal Questions
		10.7	Answers

10.1 INTRODUCTION

Phylum Echinodermata belongs to the Deuterostomia branch of the animal kingdom, the members of which are enterocoelous coelomates. Hemichordata and Chordata are also assigned to this group. Echinoderms have a unique blend of characteristics found in no other phylum. The most striking features are system of coelomic channels composing the water vascular system, calcareous endoskeleton, the haemal system and the metamorphosis from bilateral larva to radial adult. The echinoderms are marine forms and include the sea stars (starfish), brittle stars, sea urchins, sea cucumbers and sealilies.

The Hemichordata are marine animals that were formerly considered a subphylum of the chordates, based on their possession of gill slits and rudimentary notochord. However the so-called hemichordata notochord is really a buccal diverticulum and not homologous with the chordate notochord so the hemichordates are given the rank of a separate phylum. Hemichordates show some of both echinoderm and chordate characteristics. They are soft bodied, worm like animals and show burrowing habits. Most are sedentary or sessile.

Objectives

After studying this unit, you should be able to:

- ❖ explain the characteristic features of Phylum Echinodermata;
- ❖ mention the important characters of various classes included under the Phylum Echinodermata;
- ❖ discuss their structural organisation with special reference to water vascular system in class Asterozoa;
- ❖ explain the characteristics and basic adaptive features of hemichordates; and
- ❖ outline the affinities, ancestry and evolution of hemichordates in relation to other groups in the animal kingdom.

10.2 CHARACTERISTIC FEATURES OF PHYLUM ECHINODERMATA

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.

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, cylindrical 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 perihemal 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. Pedicellariae 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.

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.

10.3 CLASSIFICATION OF PHYLUM ECHINODERMATA

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 the characters of other classes briefly.

10.3.1 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; pedicellariae are present.

The class includes sea stars or starfishes (Fig. 10.1). The seastars 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. 10.1: 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. 10.2). 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 tentacle like sensory tube feet and a red pigment spot. The upper surface of the animal is called **aboral surface** (Fig. 10.3) and it bears arms 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.

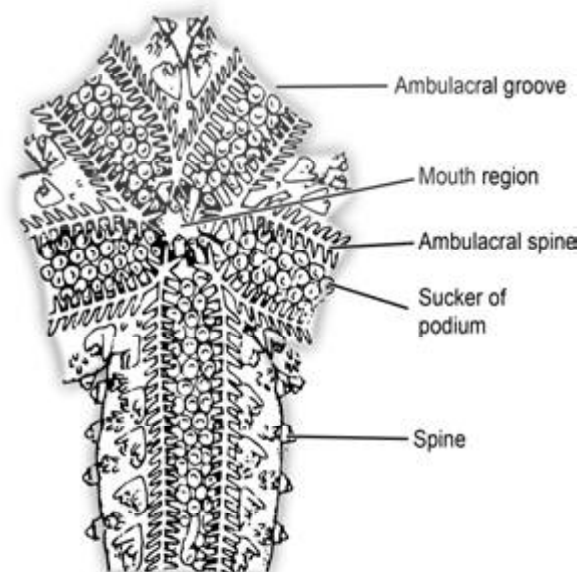


Fig. 10.2: Cental disc and part of one arm of oral surface of starfish *Asterias*.

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 **pedicellariae** (Fig. 10.4) meant for the protection of the animal from small animals and larvae that try to settle on the seastars. The pedicellariae may be stalked or sessile.

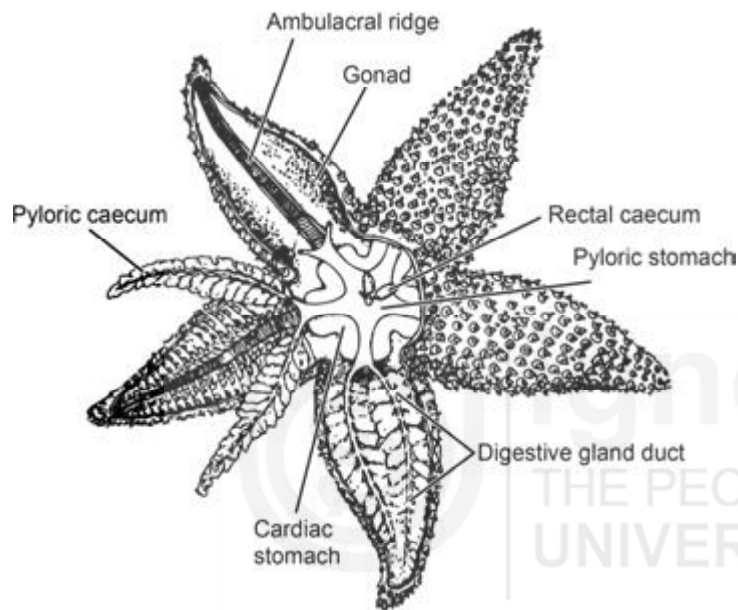


Fig. 10.3: Aboral surface of starfish showing the internal anatomy.

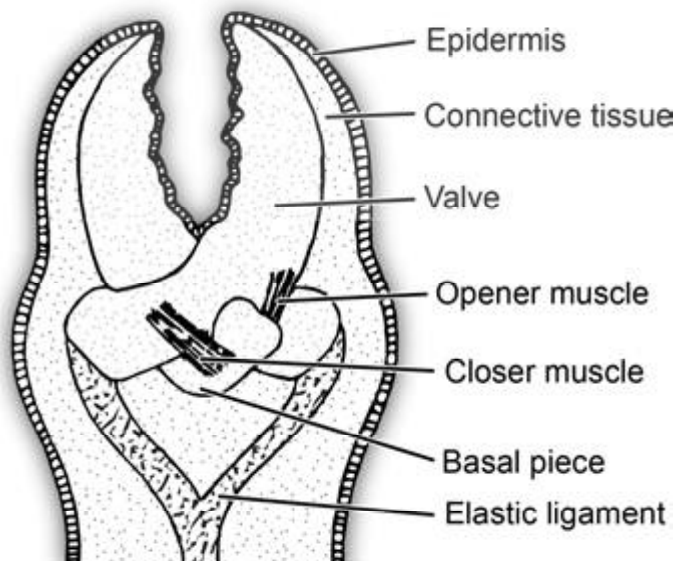


Fig. 10.4: A pincer like pedicellaria of starfish.

Water Vascular System

Echinoderms have a unique system that consists of canals and appendages of body wall called water vascular system (Fig. 10.5). 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 tube foot 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**.

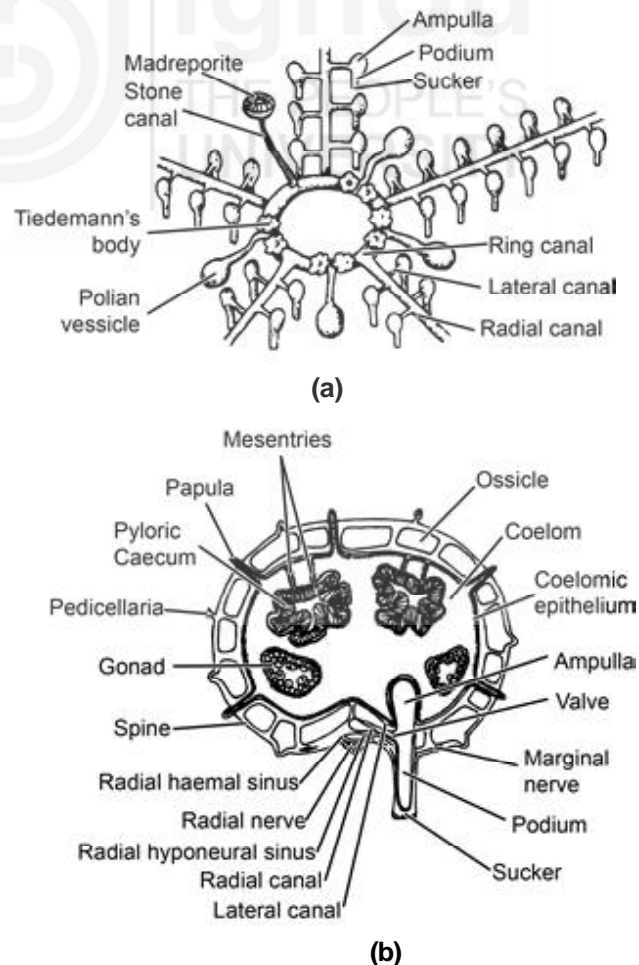


Fig. 10.5: a) Water vascular system of starfish; b) Cross section through an arm of starfish.

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. 10.6). 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 caecae 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 perihemal sinuses. There are four coelomic circulatory systems in asteroids (Fig. 10.6)

1. 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.

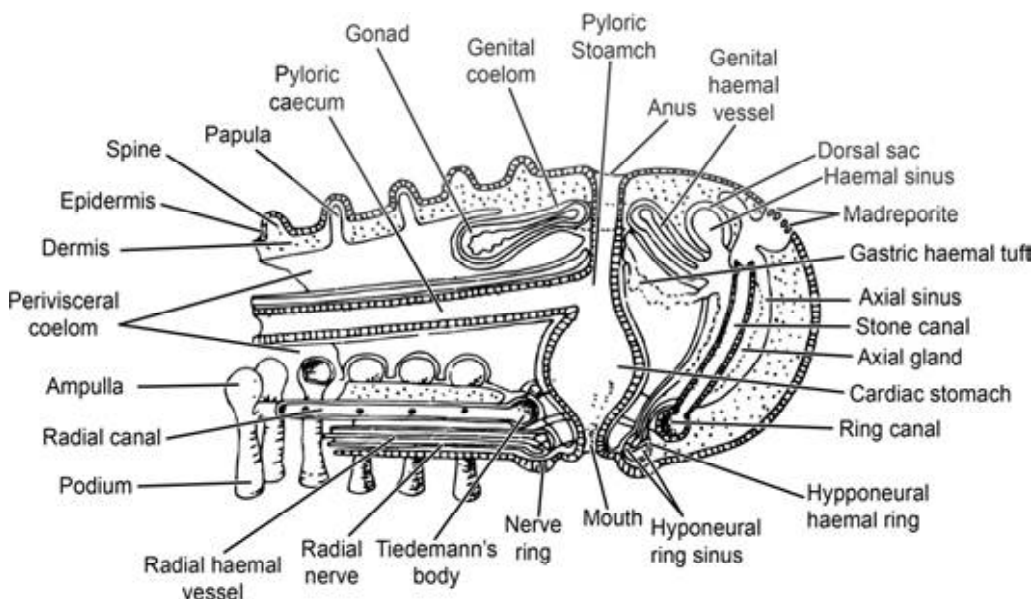


Fig. 10.6: Diagram showing blood vascular and coelomic system in a starfish.

Nervous System

The nervous system of asteroids 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 fertilization is external. A single female may shed as many as 2.5 million eggs. Development includes a larval stage—the **bipinnaria** larva (Fig. 10.7). 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. 10.8) with the appearance of additional arms at the anterior end. The brachiolaria then metamorphoses into an adult.

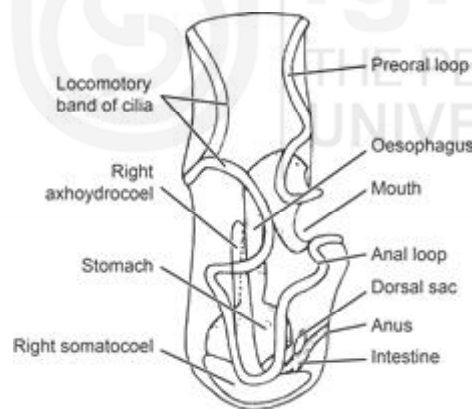


Fig. 10.7: Bipinnaria larva.

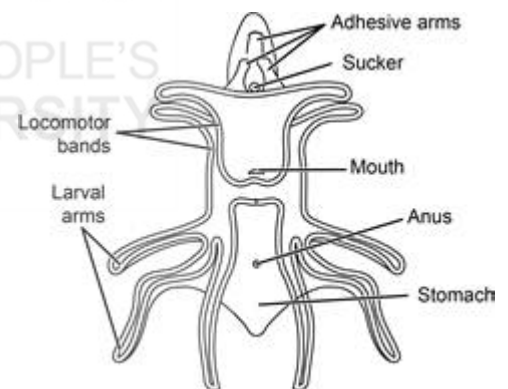


Fig. 10.8: Brachiolaria larva.

Now you have studied in detail the organisation of asteroids. Since the members of the other classes of the Phylum Echinodermata are exhibit 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 SAQ.

SAQ 1

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 cannals 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 larval stages of asteroids are _____ and _____.
-

10.3.2 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. 10.9), 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. 10.9: 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 locomotion. 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** (si. 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. Fertilization is external. Development includes a larval stage **ophiopluteus** (Fig. 10.10). Asexual reproduction is observed in the form of regeneration eg. *Ophiura*, *Ophioderma*.

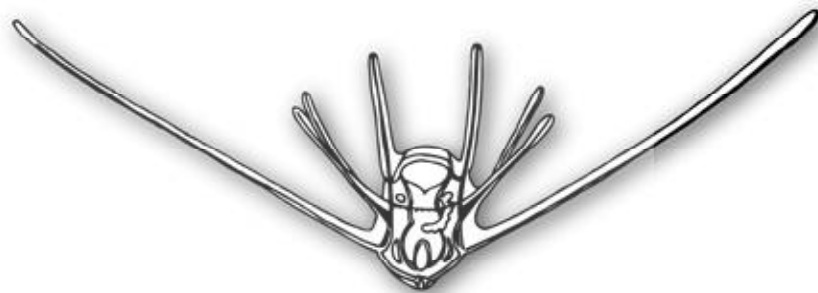


Fig. 10.10: Ophiopluteus larva.

10.3.3 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.

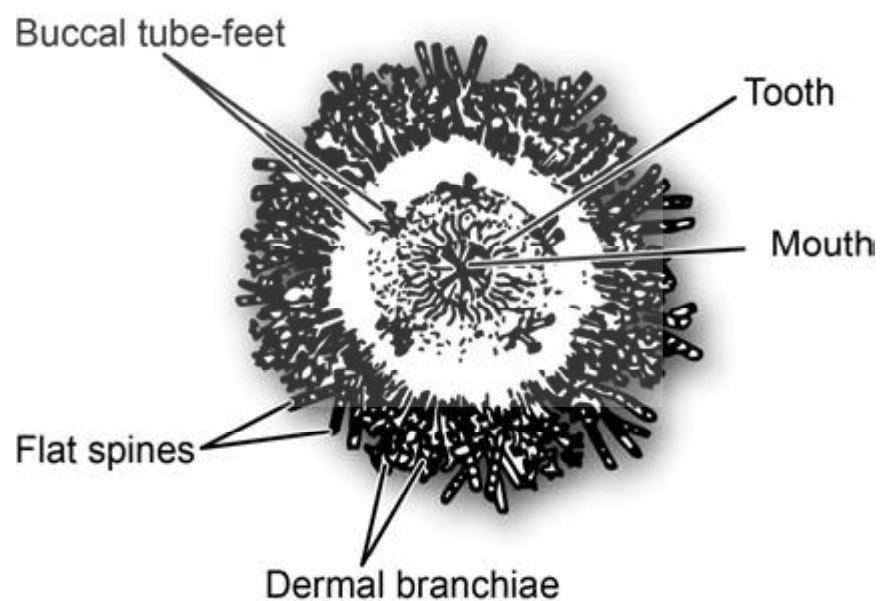


Fig. 10.11: Sea urchin.

Class Echinoidea includes sea urchins (Fig.10.11), sand dollars (Fig.10.12) 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.

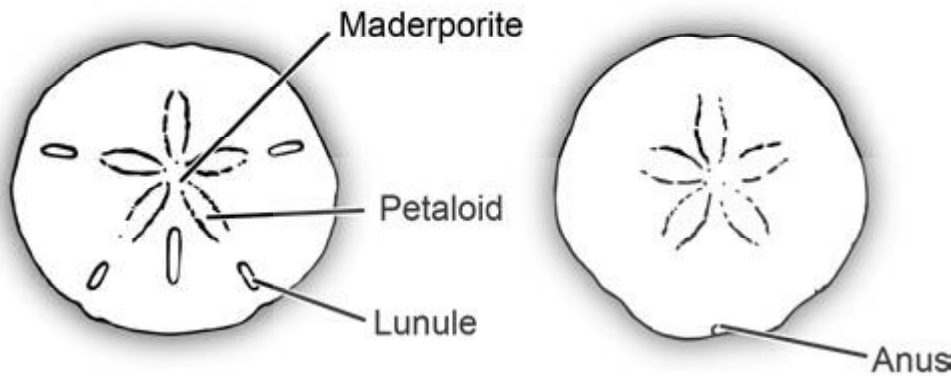


Fig. 10.12: Sand dollar.

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. 10.13 b). 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. 10.13 a). Thus the animal can concentrate the food for digestion in the intestine. The anus is located at the aboral surface.

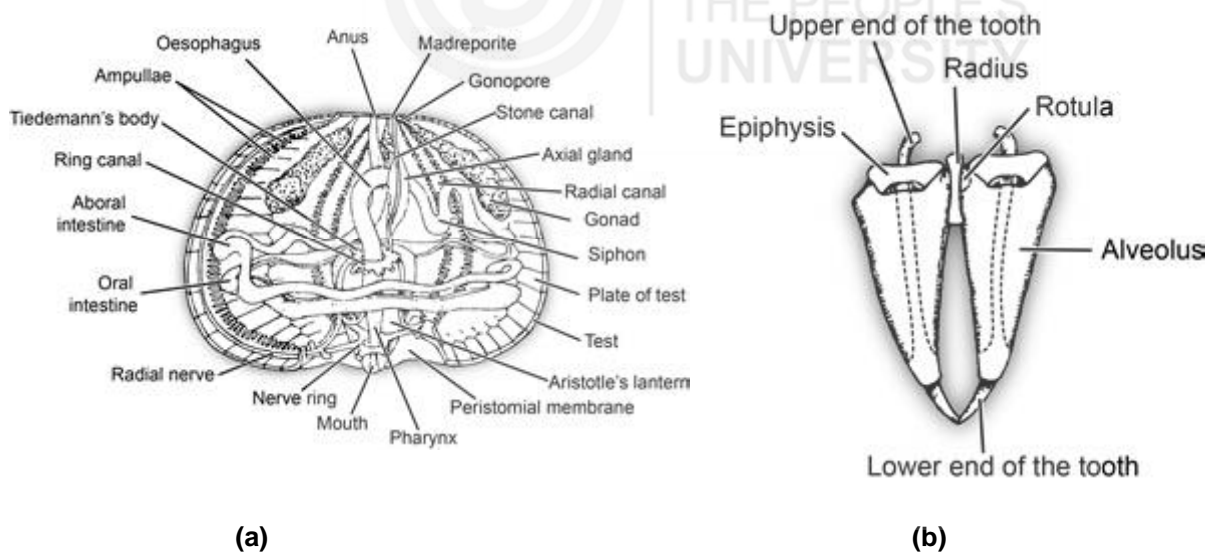


Fig. 10.13: a) Internal anatomy of a sea urchin; b) Aristotle's lantern.

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 fertilization is external. Some individuals may brood the young ones in the depression between the spines. Development includes- a larval stage, the **echinopluteus** larva (Fig. 10.14). The larva leads a planktonic life for several

months before metamorphosing into an adult. Common genera are *Arbacia*, *Strongylocentrous* (sea urchins) ; *Dendraster* (sand dollar).

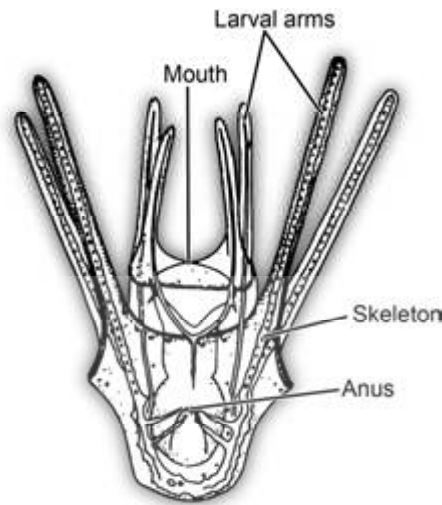


Fig. 10.14: Echinopluteus larva.

10.3.4 Class Holothuroidea

Body cucumber-like; no arms; no spines; no pedicellariae; oscicles 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.

Holothuroidea are commonly known as sea cucumbers because of their resemblance to cucumber (Fig. 10.15). They differ from the rest of the echinoderms in many respects. Holothurians have greatly elongated oral-aboral axis. The ossicles (Fig. 10.16) 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 mucous secreted by the oral tentacles. The tentacles are then stuffed on through the mouth into the pharynx and the food particles are sucked off.

A spacious, fluid filled coelomic cavity is present in holothurians. The digestive system consists of oesophagus, stomach and intestine. The intestine opens to the exterior by a cloaca (Fig. 10.15). There is a unique respiratory tree (Fig. 10.16) 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.

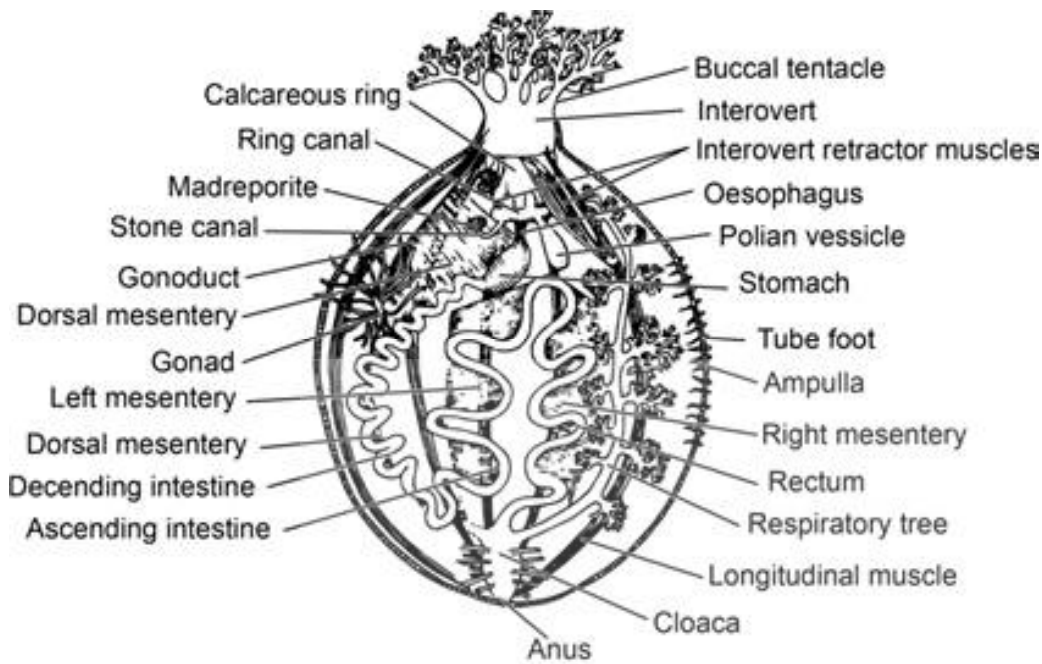


Fig. 10.15: Internal organisation of a sea cucumber.

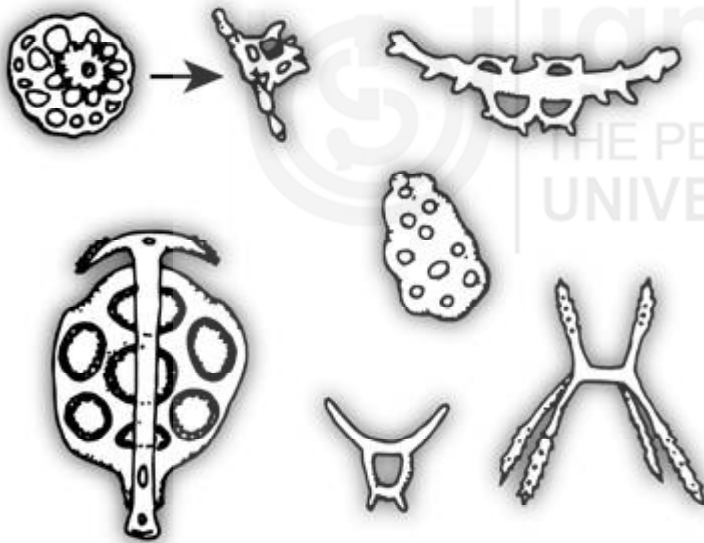


Fig. 10.16: Ossicles of sea cucumber.

Sexes are generally separate. Holothurians have an unpaired gonad that appears as one or two clusters of tubules.

Gametes are shed into water and fertilization is external. A free swimming larva called auricularia (Fig. 10.17) emerges from the fertilized 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, e.g. *Cucuinana*, *Leptosynapta*, *Synapta*.

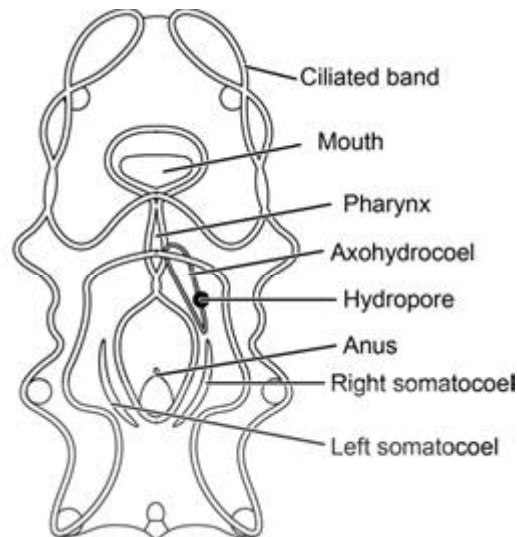


Fig. 10.17: Auricularia larva.

10.3.5 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. 10.18) 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 sessile 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.

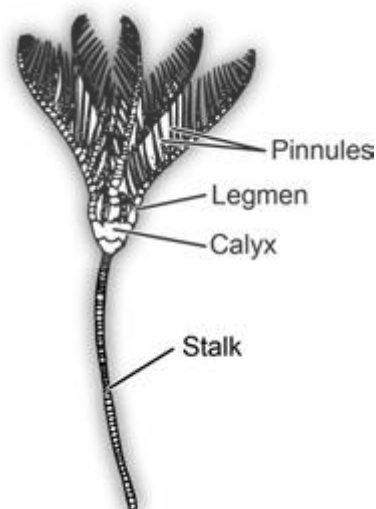


Fig. 10.18: A sea lily.

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 feather. The calyx and arms together are called the **crow**. 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 madreporite, spines and pedicellariae are absent.

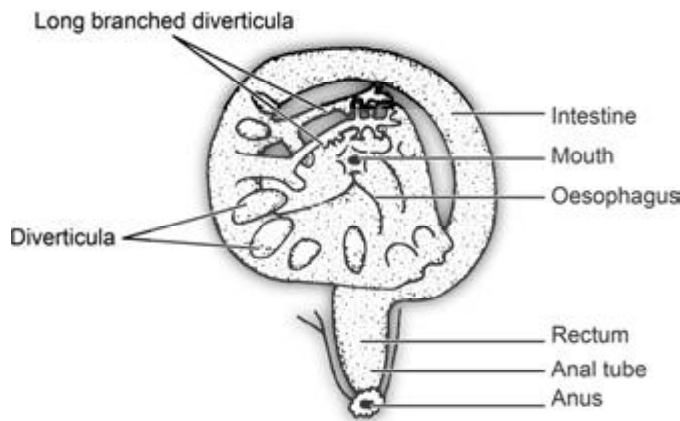


Fig. 10.19: Digestive system of a sea lily.

The mouth leads into a short oesophagus followed by the long intestine (Fig. 10.19). The intestine bears diverticula 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. Fertilization is external. Development includes a free swimming larval stage *Doliolaria* that later on attaches itself to a substratum before metamorphosis into adult, e.g. *Antedon*, *Heterometra*.

SAQ 2

State whether the following statements are true/or false:

- i) Brittle stars are pelagic.
- ii) Bursae in ophiuroids are respiratory in function.
- iii) In brittle stars tube feet aid in locomotion.
- iv) Echinoid shell is compact formed by close suturing of dermal plates.
- v) Aristotle's lantern is a complex chewing organ of sea urchin.
- vi) Holothurians closely resemble other echinoderms both morphologically and physiologically.
- vii) The respiratory tree of holothurians is respiratory and excretory in function.

- viii) Sea lilies and feather stars are most advanced echinoderms.
 ix) Crinoids do not have madreporite.

SAQ 3

Match the items given in Column A with those given in Column B.

Column A	Column B
I) Holothuroidea	a) Doliolaria
II) Crinoidea	b) Bipinnaria
III) Asteroidea	c) Echinopluteus
IV) Echinoidea	d) Ophiopluteus
V) Ophiuroidea	e) Auricularia

10.4 PHYLUM HEMICHORDATA

Initially hemichordates were considered a subphylum of the chordates. The basis for this was the presence of rudimentary notochord and gill slits. But the hemichordate notochord is in reality a buccal diverticulum and not homologous with chordate notochord. Therefore, the hemichordates are now put as a separate phylum.

Characteristics of Hemichordata

Hemichordates (Hemi – half + Chorda - chord) are soft bodied, marine animals; bottom dwellers, found usually living in U-shaped burrows in sand or mud in shallow waters; worm like or short and compact with stalk. The body has three parts - proboscis, collar and trunk (protosome, mesosome and metasome). Coleomic pouch is single in proboscis but paired in collar and trunk with buccal diverticulum in posterior part of proboscis. Circulation through dorsal and ventral vessels and dorsal heart; respiration through gill slits; excretion, by a single glomerulus connected to blood vessels. Nervous system consists of subepidermal nerve plexus thickened to form dorsal and ventral nerve cord, with connective ring in the collar and the dorsal nerve cord of collar is hollow in some. The phylum Hemichordata consists of two classes: class Enteropneusta and class Pterobranchia.

10.4.1 Class Enteropneusta

Commonly known as acorn worms, these are worm like, sluggish animals that live in burrows or under stones, e.g. *Balanoglossus*, *Saccoglossus* (Fig. 10.20) and *Ptychodera*.

Body is mucous-covered and divided into a preoral proboscis, a round collar behind the mouth and a long trunk. The proboscis probes its surroundings and collects food in mucous strands on its surface. The food particles are then carried by cilia to the groove at the edge of the collar, directed underside to the mouth and swallowed (Fig. 10.21 a). Large particles can be avoided by closing the mouth with the edge of the collar (Fig. 10.22 b). Bottom dwellers use proboscis and collar for building U-shaped mucous-lined burrows.

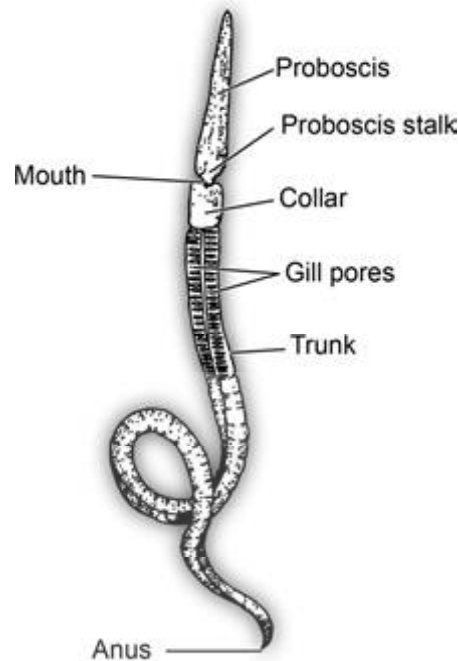


Fig. 10.20: External characters of acorn worm *Saccoglossus*.

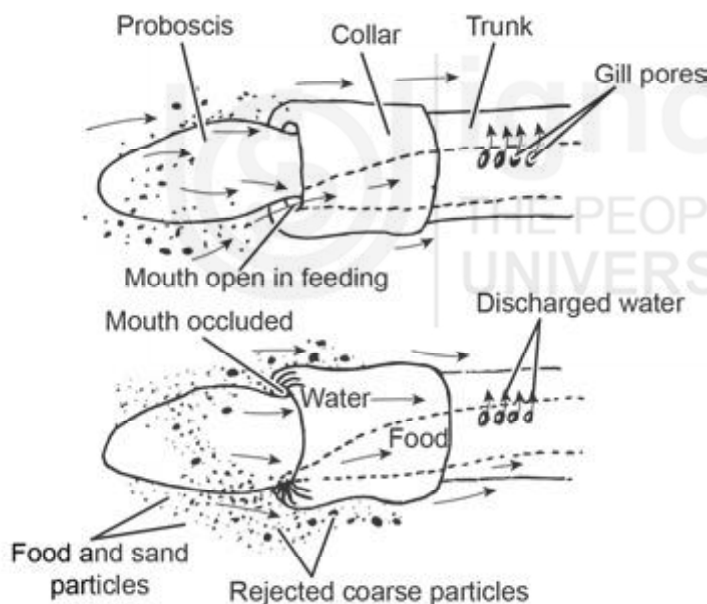


Fig. 10.21: Water currents carrying food particles in enteropneust hemichordate: a) Side view showing the open mouth and direction of currents indicating that food particles are directed towards the mouth and digestive tract. Particles not taken in, move outside the collar and water leave through the gill pores; b) Mouth is closed and in this state all particles are kept out which pass over the collar.

A small coelomic sac (protocoel) exists at the posterior end of the proboscis into which buccal diverticulum extends. A thin canal connects the protocoel with the proboscis pore and then to the outside. The paired coelomic cavities of the collar also open through pores (Fig. 10.22). Water is taken through the pores into the coelomic sacs and the proboscis stiffened in this way is used for burrowing. By contractions of body wall musculature excess water is driven out through the gill slits allowing the animal to move forward, and the food passes into the alimentary canal for digestion.

Buccal diverticulum is a slender blindly ending pouch of gut that reaches into the buccal region. It is this gut part that was formerly considered to be nerve cord.

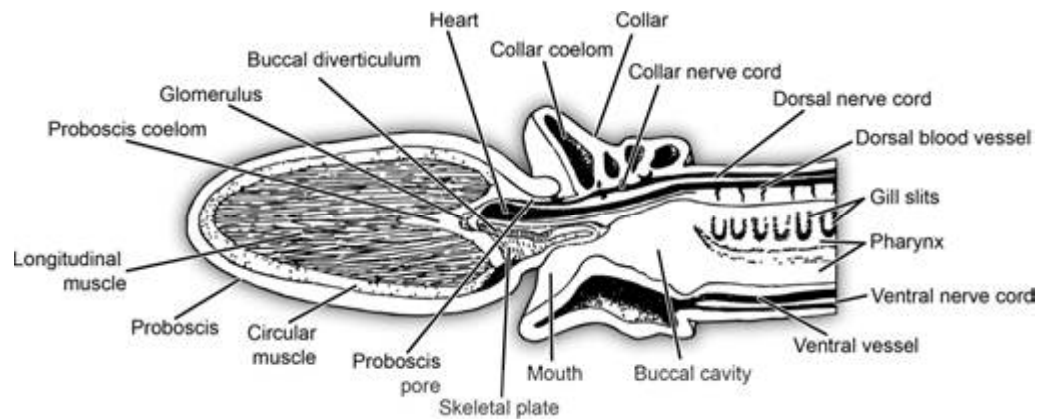


Fig.10.22: Longitudinal section through anterior end of a hemichordate (showing internal structures).

A row of gillpores located dorsotaterally on each side of the trunk open into series of gill chambers that in-turn are connected to a series of gill slits. Gills are absent. Water moves from mouth through the pharynx to the gill slits and branchial chambers and then to out side (Fig.10.21 a). Oxygen is removed from the indrawn water and carbon dioxide is released into it. The gaseous exchange occurs in the vascular branchial epithelium and at body surface.

Hemichordates are mainly ciliary-mucous feeders. Pharynx that lies behind the buccal cavity acts as a strainer or filter separating food particles from the water. Food particles, trapped in the mucous are brought to the mouth by the ciliary action on the proboscis and collar. The food particles, then strained out of the water that leaves through the gill slits, pass through the ventral part of the pharynx and oesophagus to intestine where digestion and absorption occur.

Circulatory system is open and consists of a median dorsal vessel above the gut and a median ventral vessel below the gut, both connected by open spaces. The dorsal vessel expands into heart and a group of sinuses above the buccal diverticulum (Fig. 10.22). This group of sinuses is called as glomerulus as it is assumed to have an excretory function. The colourless blood flows anteriorly above the gut in the dorsal vessel, and then posteriorly through the ventral vessel, passing through the extensive open spaces to the gut and body wall.

Nervous system is subepidermal (intraepidermal) consisting of plexus of nerve cells and fibres that are thickened to form dorsal and ventral nerve cords. Both the cords are connected with a ring posteriorly to the collar. The dorsal cord in some species contains one or two cavities and continues in the collar region giving out many fibres in the proboscis. This feature is suggestive of the dorsal hollow nerve cord of chordates, however the nervous system as a whole is simpler than in most of the chordates. Neurosensory cells that are present throughout the epidermis and photoreceptor cells are the sensory receptors.

Sexes are separate. Gonads are arranged in rows, dorsolaterally on each side of anterior part of the trunk. Fertilization is external in sea-water. In some species there is a free swimming, pelagic and ciliated larva called tornaria (Fig. 10.23).

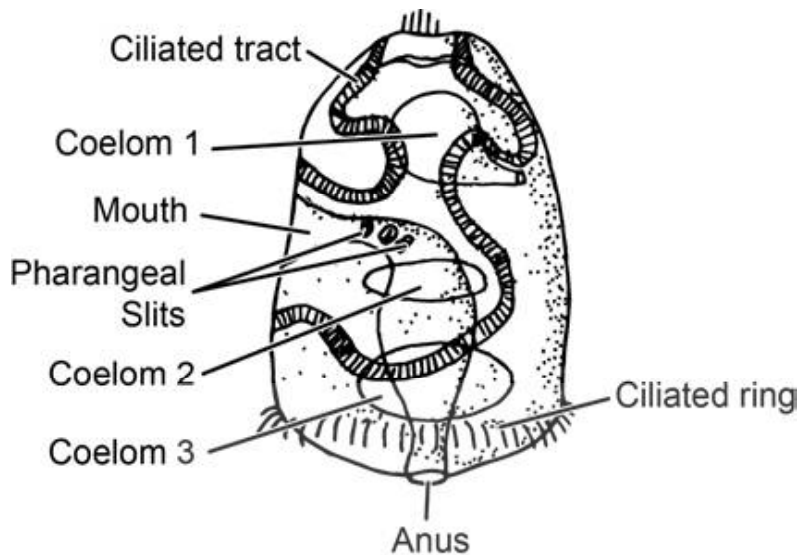


Fig. 10.23: Tornaria larva: larval stage of a hemichordate.

10.4.2 Class Pterobranchia

Pterobranchs are sessile, sluggish hemichordates and live in the tube made up of their own secretions. Their size varies from 1 to 7 mm. in length, although the stalk may be longer. The basic plan of class Pterobranchia is similar to that of the Enteropneusta. However, certain structural differences are correlated with the sedentary life style of pterobranchs. Several genera are recognised but details of only two genera *Cephalodiscus* and *Rhabdopleura* are known.

Many individuals of *Cephalodiscus* (Fig. 10.24) live together in anastomosing gelatinous tubes, attaching themselves to the walls of the tubes by extensible stalk. The zooids however live independently and can move about their trunk in and out of the tubes. Typical of hemichordates, the body of *Cephalodiscus* consists of three parts-proboscis, collar and trunk. There is only one pair of gill slits. The alimentary canal is U-shaped and the anus is placed near the mouth.

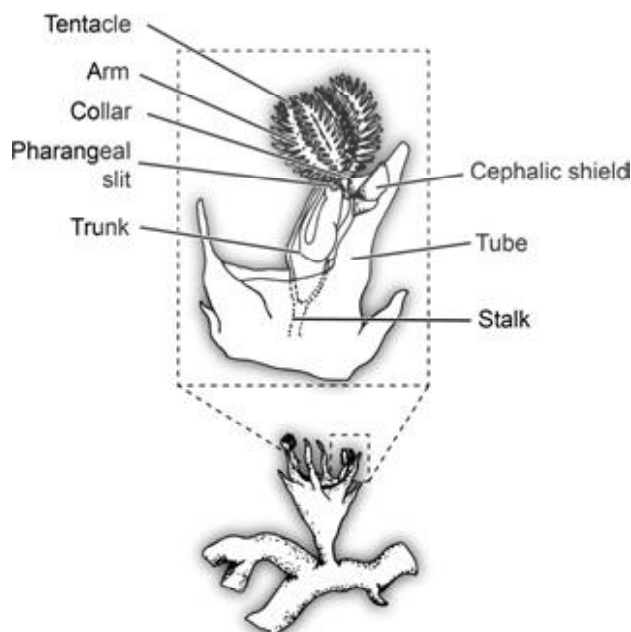


Fig. 10.24: Structure of pterobranch hemichordate *Cephalodiscus*, that lives in tubes in which they can move about.

The proboscis is shield shaped. Beneath the proboscis there are five to nine pairs of branched arms with tentacles, containing the coelomic extensions. The animal collects the food with the help of the ciliated grooves present on the arms and tentacles. This whole structure is called lophophore. Sexes are separate in some species, while some are monoecious. Asexual reproduction, wherever occurs is by budding.

The members of *Rhabdopleura* form a colony of zooids that are connected by a basal stolon and enclosed in the tubes (Fig. 10.25 a). Collar contains two branching arms (Fig. 10.25 b). Glomeruli and gill clefts are absent. Nervous system is similar to that in Enteropneusta except for the absence of tubular nerve cord in the collar. Asexual reproduction occurs by budding from the creeping stolon.

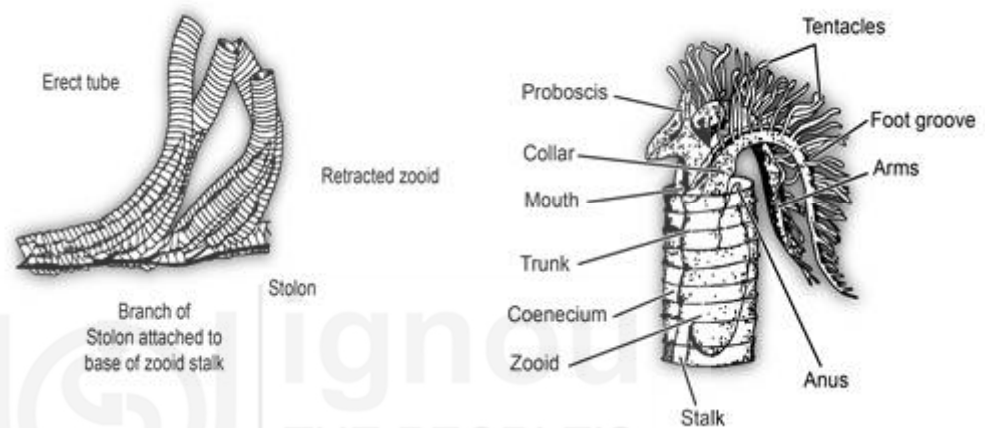


Fig. 10.25: a) Portion of a colony where individuals of pterobranch hemichordate *Rhabdopleura* live in branching tubes connected by stolon; b) structure of *Rhabdopleura*.

SAQ 4

- i) List out any three characteristics of Hemichordata.
- ii) Write one major difference between Enteropneusta and Pterobranchia.

10.4.3 Basic Adaptive Features

The two major groups of Hemichordata are diverse in their habit. The main adaptive feature in the free swimming form is found in the efficiency of proboscis which also aids in burrowing. In a way, life in burrows offers safety from predators. The gill slits are primarily used for filter feeding and secondarily for breathing. The colonies of the sessile forms are well protected by chitinous material. The presence of large, branched lophophore bearing ciliated bands in *Cephalodiscus* and *Rhabdopleura* is very well adapted to feeding and thus contributes to the success of the species. The multiple gonads provide reproductive efficiency. In addition,, the capacity to regenerate the lost parts contributes to the survival of the race. The free swimming larva during the development enables wider distribution and thus contributes further to the success of the species.

10.4.4 Affinities

Let us now consider the inter-relationships of the hemichordates with other members of the animal kingdom. The systematic position and phylogenetic relationship of hemichordates has been a puzzle among zoologists over decades. Hemichordates show following affinities with different phyla.

Affinities with annelids:

1. Bilateral symmetry.
2. Adults with similar morphology, burrowing and feeding habits.
3. In both digestive tract is straight and tubular.
4. Similar mode of blood circulation.
5. Similarities between the tornaria larva of enteropneusts and the trochophore larva of polychaetes including the apical tuft of cilia, apical sense organs and larval gut.

There are, however, serious objections to relate the hemichordates with annelids such as :

1. Annelids do not possess gill slits.
2. Excretion in annelids is carried out by means of nephridia. On the other hand, glomeruli take up the role of excretion in enteropneusts.
3. The coelom is schizocoelous type in annelids while in hemichordates it is enterocoelous type.
4. In hemichordates the cleavage is holoblastic whereas in annelids it is spiral.
5. Nephridia are present only in the trochophore.

In addition complete absence of branchial respiration and notochord argues against any phylogenetic relationship between hemichordates and annelids.

Relationship with Pogonophora:

Hemichordates and pogonophores (beard worms) have many similar structures - such as:

1. Tentacular apparatus;
2. Septum, separating the mesosome and metasome;
3. Intraepidermal nervous system;
4. Pericardial sac;
5. Gonads in the trunk.

In spite of the above similarities there are many structural differences.

Pogonophora differ in the following characters:

1. Tentacles originate from the protosome and protocoel extends in all tentacles.
2. The main component of the nervous system is located in the protosome.

3. Absence of gill slits and digestive tracts.
4. The gonopores are ventral in position.

Because of these differences the two groups are treated as separate and their similarities are due to remote connection with the ancestral stalk.

Relationship with Echinoderms:

Among the invertebrates echinoderms seem to be close to hemichordates. Their affinities are:

1. Similar feeding habits;
2. The general plan of sub-epidermal nervous system;
3. Enterocoelous origin of coelom i.e., the coelom arises as outpocketings of archenteron of the embryo and formation of the anus from the embryonic blastopore. Thus, there is a marked functional similarity between hydraulically operated water vascular system and proboscis-collar coelom;
4. Both the groups show relationship in indeterminate cleavage with equipotential blastomeres;
5. Marked similarities between tornaria larva and bipinnaria larva. These include presence of similar ciliary bands, sensory cilia at the apical regions, curved gut with ventral mouth and posterior anus. There are also similarities between the auricularia larva of echinoderms and the tornaria larva of hemichordates (see discussion under ancestry);
6. Recent studies on the fossil echinoderms *Stylophora* furnished evidence linking echinoderms with chordates. These small nonsymmetrical forms like *Coturnocystis* have a head resembling a long toed medieval time boot, a series of branchial slits like the gill openings of shark and a post anal tail resembling a notochord, a dorsal nerve cord and muscle blocks. Whether this evidence would sufficiently justify the concept that the echinoderms are the true ancestors to chordates needs to be further examined.

Apart from the above considerations, it is interesting to note that the energy rich compounds phosphocreatine and phosphoarginine which generally characterise vertebrates and invertebrates respectively, are present in *Balanoglossus*. This is the basis for some authors to postulate that the hemichordates form a connecting link between invertebrates like echinoderms and vertebrates. Subsequently this view lost its credential when both phosphocreatine and phosphoarginine were found in the muscles of many invertebrate phyla.

SAQ 5

Fill in the blanks with appropriate words.

- i) Annelids and hemichordates have _____ of circulation.

- ii) _____ in hemichordates provide reproductive efficiency.
- iii) Nephridia are _____ in hemichordates.
- iv) Both hemichordates and pogonophora have intraepidermal _____.
- v) The bipinnaria larva of _____ is similar to tornaria larva.

10.5 SUMMARY

In this unit you have learnt;

- 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 pedicellariae may be present as organs of protection.
- The water vascular system, unique to echinoderms derived from some of the coelomic cavities performs varied functions such as food gathering, locomotion respiration and circulation.
- Haemal or circulatory system of undefined function is seen in echinoderms.
- Sexes are separate and reproductive systems are simple. Development invariably includes a larval stage.
- Echinodermata includes five classes: Asterozoa, Ophiurozoa, Echinozoa, Holothurozoa and Crinozoa which are represented by starfish, brittle star, sea urchin, sea cucumber and sea lilies respectively.
- Water vascular system in asteroids is highly significant. Class Ophiurozoa represents the largest class in terms of number of species.
- Aristotle's lantern, a special chewing organ is present in class Echinozoa.
- Each class has a characteristic larval stage.
- Hemichordates are the group of animals that are characterised by the presence of chordate features i.e. gill slits and rudimentary notochord. However, the hemichordate notochord is in reality the buccal diverticulum and not the true notochord. It is for this reason hemichordates are now considered as a separate phylum.
- Hemichordates show affinities with two groups of invertebrates viz. annelids and echinoderms. Echinoderms are closer to hemichordates. However, both phyla have their own specialisations.

10.6 TERMINAL QUESTIONS

1. What are the characteristics of echinoderms that are unique to them and not found in other phyla?
2. Describe the water vascular system of a seastar.
3. List the various classes of phylum Echinodermata giving one example for each class.

10.7 ANSWERS

Self-Assessment Questions

1. a) radial, bilateral
b) dermal ossicles
c) water vascular
d) tube feet, dermal branchiae
e) pedicellariae
f) bipinnaria, brachiolaria
2. i)-F; ii)-F; iii)-T; iv)-T; v)-T; vi)-F; vii)-T; viii)-F; ix)-T
3. I)-e; II)-a; III)-b; IV)-c; V)-d.
4. i) a) Body divided into three parts Proboscis, Collar and Truck.
b) Gill slits present.
c) Dorsal nerve cord present. You can write about other characteristics of hemichordates from Section 10.3.
ii) Pterobranchs live in the gelatinous tube secreted by them whereas enteropneusts live in burrows. You can read about the other differences from Subsections 10.3.1 and 10.3.2.
5. i) similar mode
ii) multiple gonads
iii) absent
iv) nervous system
v) echinoderms.

Terminal Questions

1. 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 (Ophiuroidea).
 - vi) Absence of excretory organs.
 - vii) Occurrence of bilateral symmetry during the larval stages.
2. Refer to Sub-section 10.3.1
- 3.
- i) Asteroidea Seastar
 - ii) Ophiuroidea Brittle star
 - iii) Echinoidea Sea urchins
 - iv) Holothuroidea Sea cucumber
 - v) Crinoidea sea lily



GLOSSARY

- Aboral** : a region opposite the mouth.
- Caste** : one of the polymorphic forms within an insect society. Each caste has its specific duties as queen, worker, soldier so on.
- Chitin** : a horny substance that forms part of the cuticle of the exoskeleton of arthropods and is rarely found in other invertebrates. It is a nitrogenous polysaccharide, insoluble in water, alcohol, dilute acids and digestive juices of most animals.
- Coelom** : body cavity in triploblastic animals lined by a mesodermally derived epithelium (peritoneum).
- 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.
- 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.
- Hermaphroditic** : having both male and female reproductive systems in the same individual.
- Madreporite** : sieve like structure that is for the intake for water-vascular system of echinoderms.
- 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.
- 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.
- Tergum** : primary dorsal exoskeletal plate of each arthropod segment.
- Test** : a shell or hardened outer covering.

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Thank you,

Yours sincerely

Course Coordinator

Animal Diversity (Acoelomates, Coelomates, Anaminotes, Aminota)

Course Code: BZYCT-131

Please write your feedback here.



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To,

The Course Coordinator
Animal Diversity (Acoelomates, Coelomates, Anaminotes, Aminota)
Course Code: BZYCT-131
School of Sciences
Indira Gandhi National Open University
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