UNIT 14 ADAPTIVE RADIATIONS

Structure

14.1 INTRODUCTION

You have read in our course on Taxonomy and Evolution (LSE-07) that living organisms are products of evolution. In simple words evolution may be defined as 'descent with change'. Here change is the basic factor. Evolution may be in the nature of the environment or in the form and function of the organism. The nature of the environment has a strong bearing on the form and function of the organism. You will see in Section 1.3 of this course (Unit 1, Block1) that the organisms always tend to establish harmony with their environment. This process, called adaptation, enables the organism to face the vagaries of the everchanging environment. Adaptation actually sums up the whole result of evolution.

You might have noticed that when organisms belonging to different groups come to occupy similar environment, they develop striking similarities in structure and behaviour, giving a false impression of closer relationship. For example, fishes and whales which belong actually to different classes (Pisces and Mammalia, respectively) are found in similar habitat i.e., they are both aquatic. They look so alike that for a layman both are 'fishes'. This condition where organisms belonging to different groups adapt themselves to the same environment and look and act alike, is called *adaptive convergence.*

On the other hand, there are situations where organisms belonging to the same or closely related groups may occupy different environments due to which they develop varied adaptations. It gives rise to diverse evolutionary lines. You know that house- lizard, snake, tortoise and crocodile belong to the same class, Reptilia. But they look so different from each other that one may be tempted to place them in separate classes. This situation in which animals belonging to same or closely related groups occupy different habitats and acquire different functional adaptations, is called *adaptive divergence* or *adaptive radiation.* In this unit you will study how adaptive radiations have evolved in different non-chordate groups.

Objectives

After studying this unit you should be able to:

- distinguish between solitary and colonial forms of animals and explain the needs for the evolution of true colonies in lower non-chordate groups,
- differentiate between adaptive convergence and adaptive divergence or adaptive radiation and identify the different ways in which adaptive radiations have occurred in Annelida, Arthropoda and Mollusca,
- describe the structure of insect wing and explain the mechanism of flight in insects,
- describe the meaning, process and significance of migration in insects.

14.2 SOLITARY AND COLONIAL FORMS

Animals may lead their lives either as individuals or in groups. When they exist as individuals, they are called solitary, but if they live in organised colonies, we name then colonial. Colonies are a form of intraspecific association in which the interests of an individual are subordinate to those of the whole group. In true colonies the individuals are organically connected together by living matter or through material secreted by them. The degree and extent of closeness among individuals in a colony may vary considerably. True colonies are found only in primitive groups with simple organisation, such as protozoans and coelenterates. In sponges it is difficult to ascertain whether the branched animal is an individual or a colony. Colonial forms mostly reproduce asexually. Actually the colony results due to the failure of the individuals to separate. Each individual in a colony is called a zooid.

14.2.1 Colonial Forms among Protozoans

Many well known colonial forms occur among protozoans. Simplest colony formation is seen in **Choanoflagellates**, which have a collar around the base of the flagellum (hence the name). There are a few zooids in a colony as for example, in *Codosiga* (Fig. 14.1 a). Each zooid leads an independent life though remaining attached to a common stalk. The volvocales form more complex colonies. For example, *Gonium* forms plate like colonies of 4-16 individuals; *Pandorina* forms spherical colony of 16 individuals; *Eudorina* is a spherical colony of 32 zooids arranged on the surface, *Pleodorina* has 128 zooids. An advanced form of colony is seen in *Volvox*, which is a plant-like mastigophore, or phytoflagellate. In this colony thousands of individuals remain embedded (Fig. 14.1 b) on the surface of a spherical jelly-like substance secreted by the zooids. Here also each zooid leads an independent existence except for a co-ordinated flagellar movement which helps in swimming. There is also connection among zooids by protoplasmic threads (Fig. 14.1). It is of interest to know that these colonies always swim with a particular side forward i.e., they possess polarity, an attribute of fundamental importance for colonial existence. In *Volvox* and *Pleodorina* some sort of division of labour is also noticed. The anterior zooids do not reproduce while those elsewhere are reproductive some of which become

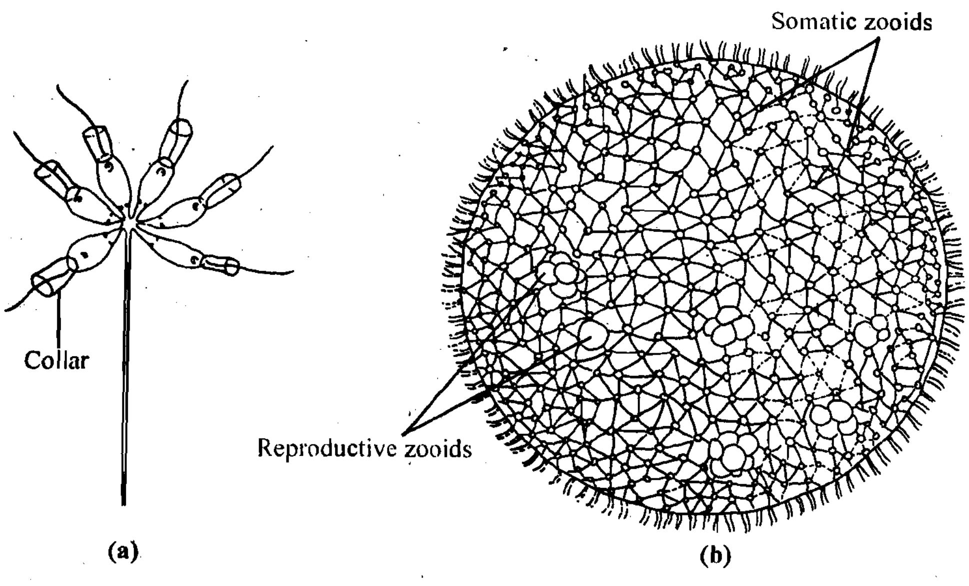


Fig. 14.1: a) Choanoflagellates : the simplest protozoan colony *codosiga* b) *Volvox*: an advanced colony.

Many ciliates like *Epistylis* and *Zoothamnium* also form colonies. Each of these colonies has bell-shaped zooids united by their stalks (Fig. 14.2 a and b) to a common stem. In *Epistylis* all zooids are alike while *Zoothamnium* shows polymorphism in zooid structure. There are four types of zooids in the colony (Fig. 14.2 b) a single terminal macrozooid which transforms into macro- conjugant; median axillary microzooids that can become migratory ciliospores; terminal branch microzooids which can form microconjugants and vegetative microzooids that can transform either into ciliospores or microconjugants.

Now let us examine the advantages of the colonial life in protozoans. Most of the protozoan colonies are **autotrophic** i.e. they obtain their food in a plant-like manner by photosynthesis. Therefore no apparent nutritive advantage is provided by the colonial way of existence. Then what are the benefits? We can observe following advantages:

1. Association of individuals in a jelly-like ground substance, especially when interconnected by protoplasmic strands, facilitates transmission of nutrients.
2. Combined flagellar activity of many zooids gives locomotory advantage.
3. Most of the colonies being spherical, minimum surface area for a given volume of sphere is exposed to the surrounding water, due to which the resistance offered by water is least.
4. In colonies of ciliates the group association provides protection and more efficient exploitation of food-supplies.

Before we pass on to colonial life in metazoans, let us see what you have learnt so far.

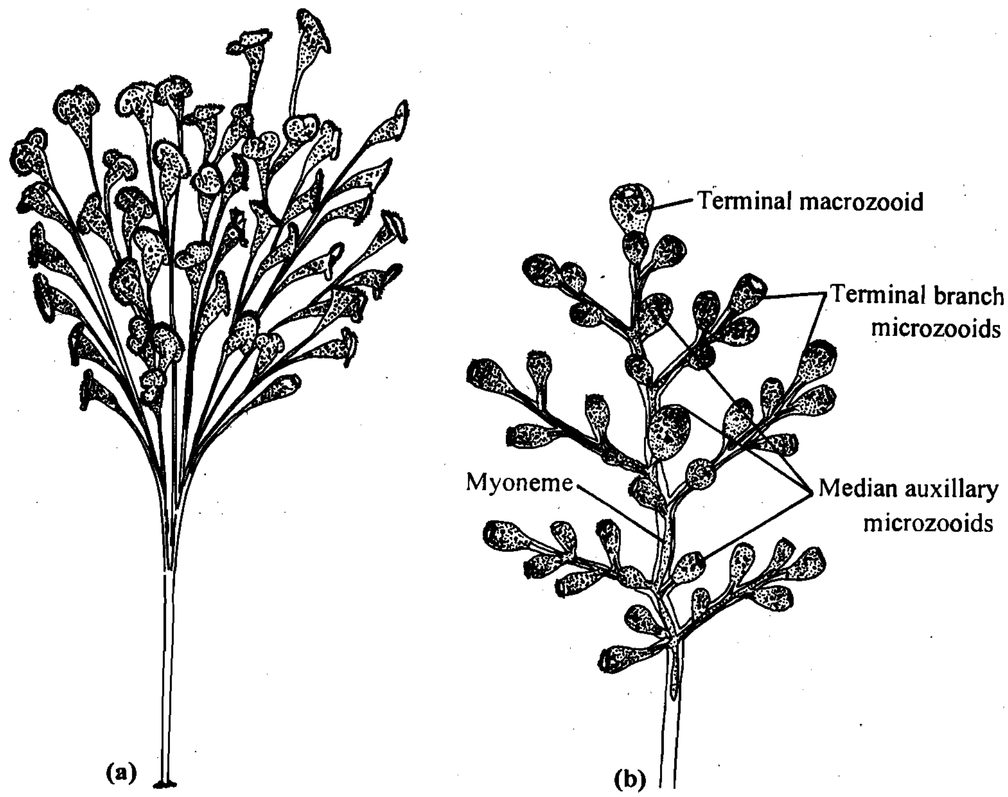


Fig. 14.2: a) *Epistylis* : Colony having similar zooids, b) *Zoothamnium* : a polymorphic protozoan colony.

SAQ 1

i) Fill in the blanks using the correct word given in parenthesis below: (environment, different, alike, adaptive convergence, adaptive divergence)

a) The condition where organisms belonging to widely different phylogenetic groups adapt themselves to the same .... and look and act alike is called ....

b) When animals belonging to phylogenetically closely related groups occupy different habitats and acquire different adaptive modification, it is called ....

ii) Indicate whether the following statements are true (T) or false (F):

a) In true colonies zooids are not organically connected with each other.
b) True colonies are found only in organisms with comparatively simple organisation.
c) Colonies in *Carchesium* show polymorphism.
d) Colonial life provides nutritive advantage in all colonial forms.

14.2.2 Colonial Forms in Metazoans

Among metazoans, true colonial forms are met with in coelenterates, though the term 'colony' is often used in relation to sponges and insects also. In sponges the 'colony' is arbitrarily defined on the basis of the number of oscula. One osculum-one-individual is the rule. However, this definition is more a matter of convenience. In insects the word 'colony' is employed to denote the complex societies that are formed by them, as in the case of honey bees, ants, termites etc. But these social groups do not strictly fall within the definition of the term colony.

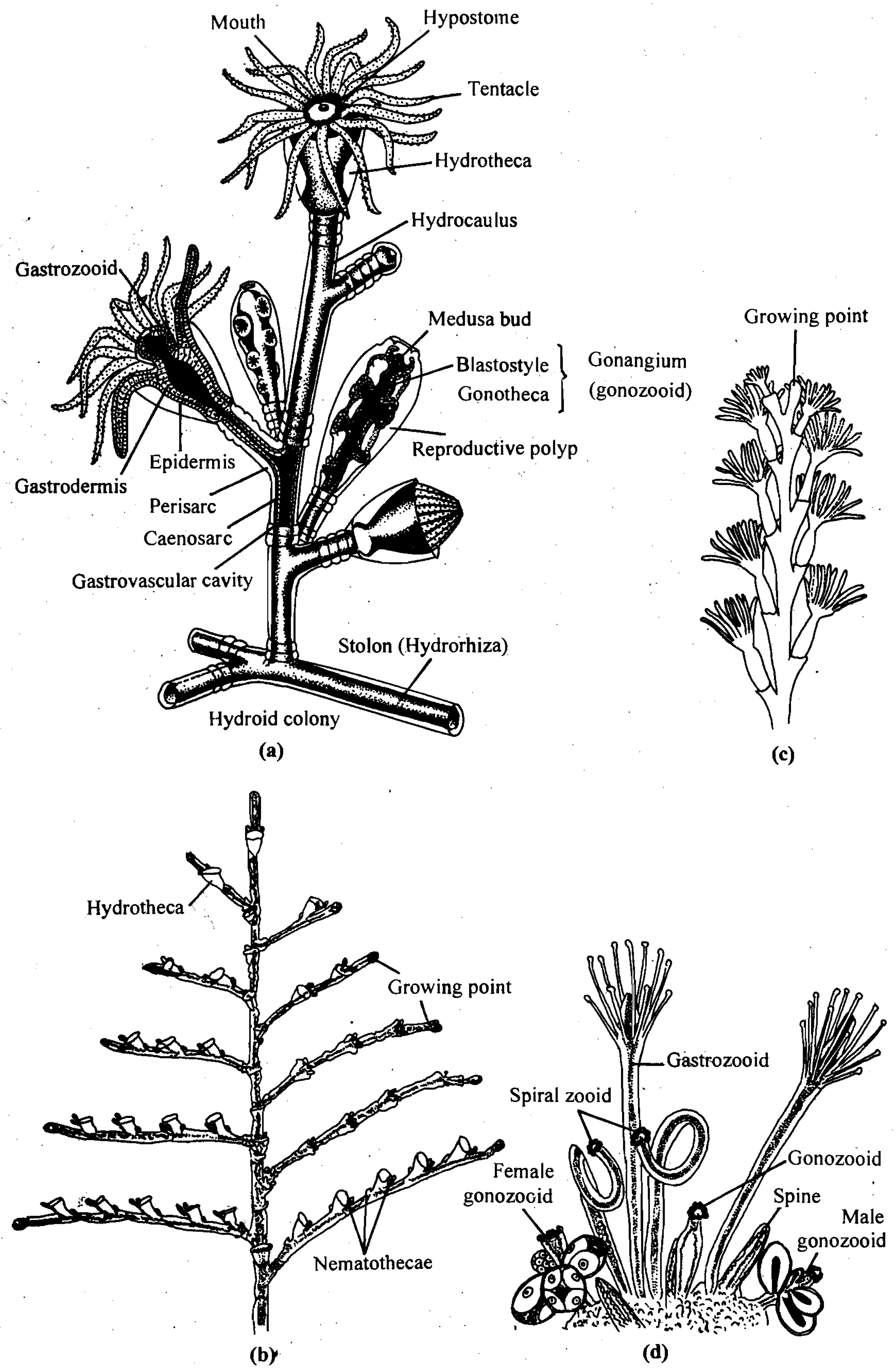


Fig. 14.3 ; a) *Obelia*, the hydroid colony (monopodial colony). (b) *Plumularia* colony showing monopodial growth. (c) Sympodial growth of *Halecium* colony. (d) *Hydractinia* colony where polyps grow directly from the mat of stolons.

Coelenterate Colonies

Members of the class Hydrozoa and Anthozoa form true colonies. Zooids with well-defined individuality are present in a colony, the shape and pattern of which varies from species to species. Floating colonies are formed by siphonophores. In the case of sedentary hydrozoan colonies, the colonies are attached to the substratum by living thread-like horizontal stolon or hydrorhiza (Fig. 14.3 a). From the stolon arise vertical branching stems called hydrocauli. Each hydrocaulus gives off lateral branches, which in their own turn bear branches of the third order. Zooids are borne on these branches (Fig. 14.3 a).

The branches and zooids in a colony are connected by a living coenosarc, over which a non-living horny perisarc is present. The coelenteron continues throughout. A zooid is cylindrical or umbrella-shaped, diploblastic structure with a body cavity or coelenteron opening to the exterior by a *mouth* situated on hypostome. A circlet of tentacles is usually present around the hypostome. In some cases the perisarc forms a cup like or capsule-like covering, variously named hydrotheca or gonotheca, around the zooids. The zooids covered with theca are called thecate; those without a thecal covering are naked ones or athecate.

The growth of the hydrocaulus is of two types viz. monopodial and sympodial (Fig. 14.3 b and 14.3 c). In the former the main axis maintains a single line of growth i.e., each branch ends in a permanent terminal zooid which is oldest of that branch. Below the base of this terminal zooid is the zone of growth. This zone lengthens the branch. The growth zone may also give rise to lateral buds, which may elongate in their turn. In the sympodial growth the primary polyp does not continue to elongate. But it produces lateral polyp. This also stops growth, but produces lateral buds again. Here the terminal polyp is the youngest. The main axis is formed by the combined hydrocauli of many polyps (eg. *Halecium*). In some forms like *Hydractinia* (Fig. 14.3 d) zooids arise directly from the stolon in an irregular fashion.

Polymorphism is another characteristic feature of coelenterate colony. The zooids exist in many forms and show division of labour. Usually some zooids are concerned with feeding; these are called **gastrozooids**. The **blastozooids** or gonozooids undertake reproduction, budding off medusae which are another type of zooids, while **dactylozooids** are meant for protection.

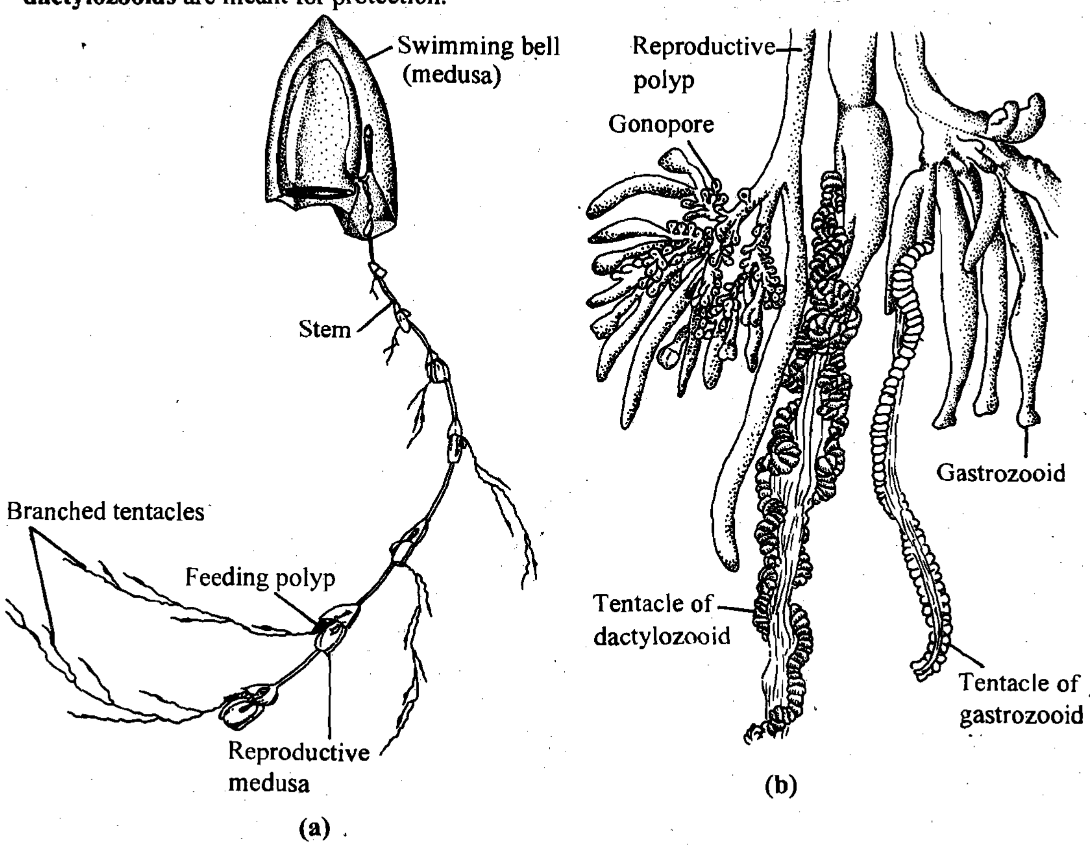


Fig. 14.4 : a) A typical submergent siphonophore *Muggiaea*; b) Part of another siphonophore *Physalia* colony showing the zooid polymorphism.

The saucer-shaped zooids called **medusae** produce gametes and reproduce sexually. You may recall here the siphonophores and other hydrozoan colonies which you have already studied in previous unit. Siphonophora shows extreme case of polymorphism, for example, *Muggiaea* and *Physalia* (Fig. 14.4). The group includes pelagic zooids. The colony comprises gastrozooids, dactylozooids and gonozooids. The medusae remain attached to the parents and modify to form **gonophores** (reproductive zooids), nectophores (locomotory zooids) and gas- filled pneumatophores (floating zooids).

In one of the previous units dealing with coelenterates you have studied in detail, corals and coral reefs. You may recall that section here. The Hydrocorallina (the hydrocorals; eg. *Stylaster*, *Millepora*) (Fig. 14.5) are colonial, polypoid, hydroid corals which may attain considerable size contributing to coral formation. Their skeleton is calcareous, internal and epidermal. Though not accompanied by polymorphism, many anthozoans are also Colonial, eg. *Palythoa.*

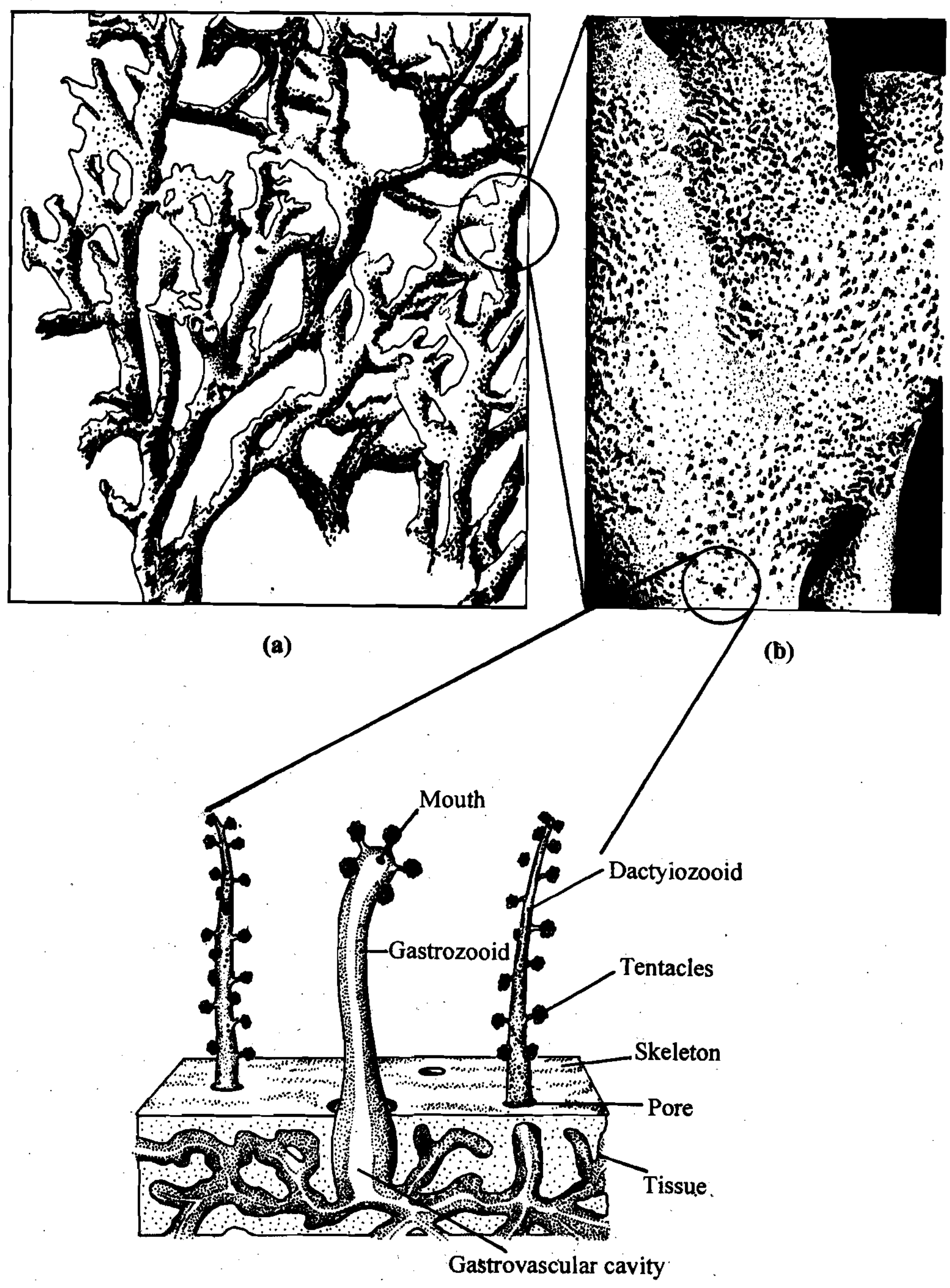


Fig. 14.5 : Hydrocoral *Millepora*; a) The colony, b) part of the colony magnified showing the pores, c) polyps of *Millepora* emerging from the pores in the skeleton.

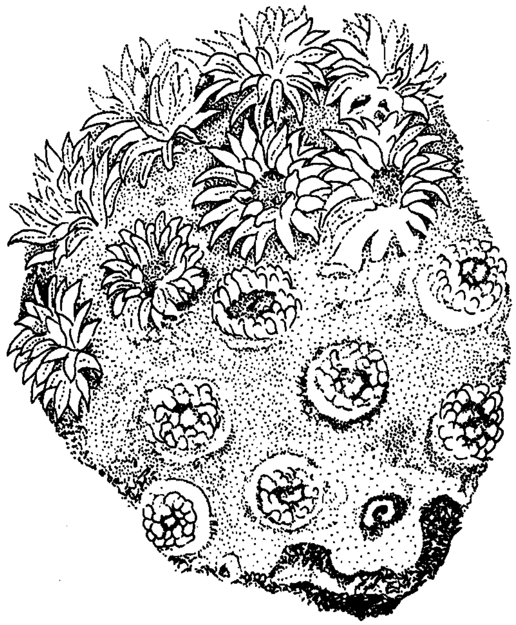


Fig. 14.6 : Part of the coral colony showing contracted and expanded polyps.

Many true corals, though not all, are also colonial. Conspicuous among the colonial anthozoans are in fact many coral formers. The colony-forming scleractinian corals or stony corals, also known as hexacorals and madreporerial corals (Fig. 14.6), include *Astrangia, Montastrea* and the brain coral. Here the polyps are interconnected by horizontal connections. The skeleton is epidermal and external (Fig. 14.7). There are solitary corals also among them, like *Fungia* (Fig. 14.8). The colony-forming octocorals (alcyonarians) among anthozoans include the common sea pens, sea rods, sea pansies, sea fans, whip coral, pipe corals etc. (Fig. 14.9). The ameobocytes secrete their skeleton which supports the colony. The skeleton of these octocorals is therefore internal and is part of the tissue.

From this account you will see that corals have developed from different groups of coelenterates. This is convergence in their adaptation.

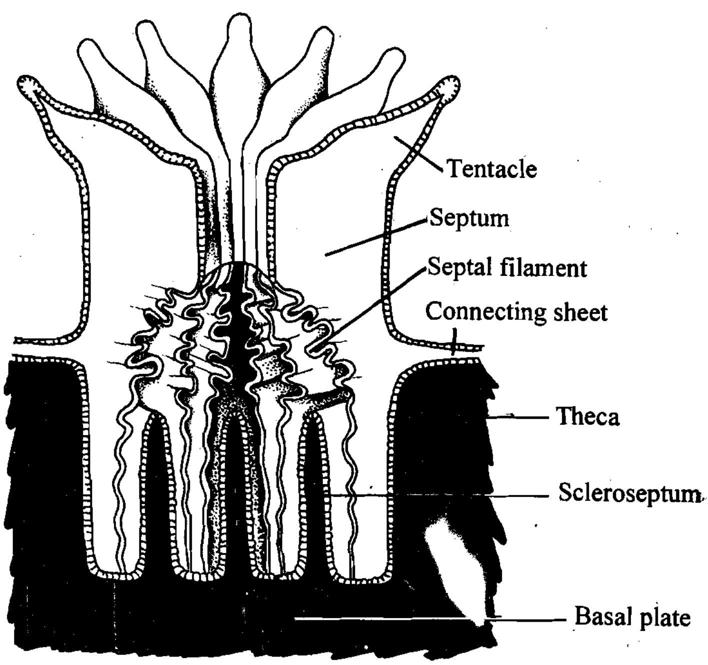


Fig. 14.7: Vertical section of the coral polyp in its theca.

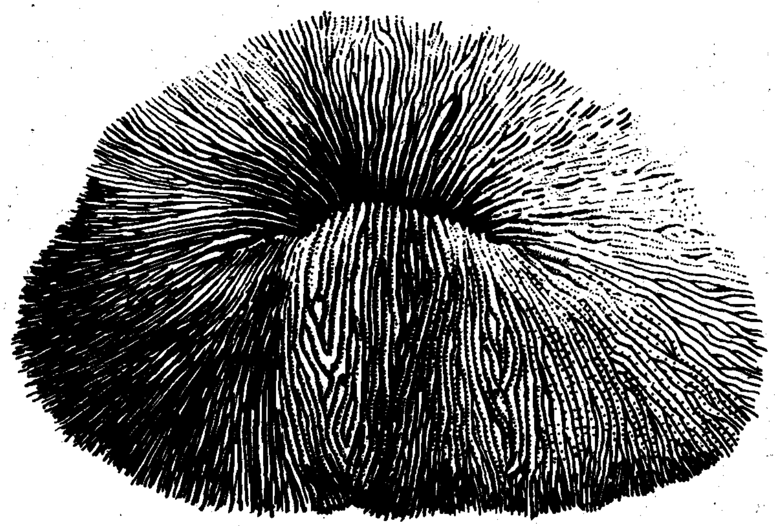


Fig. 14.8: *Fungia.*

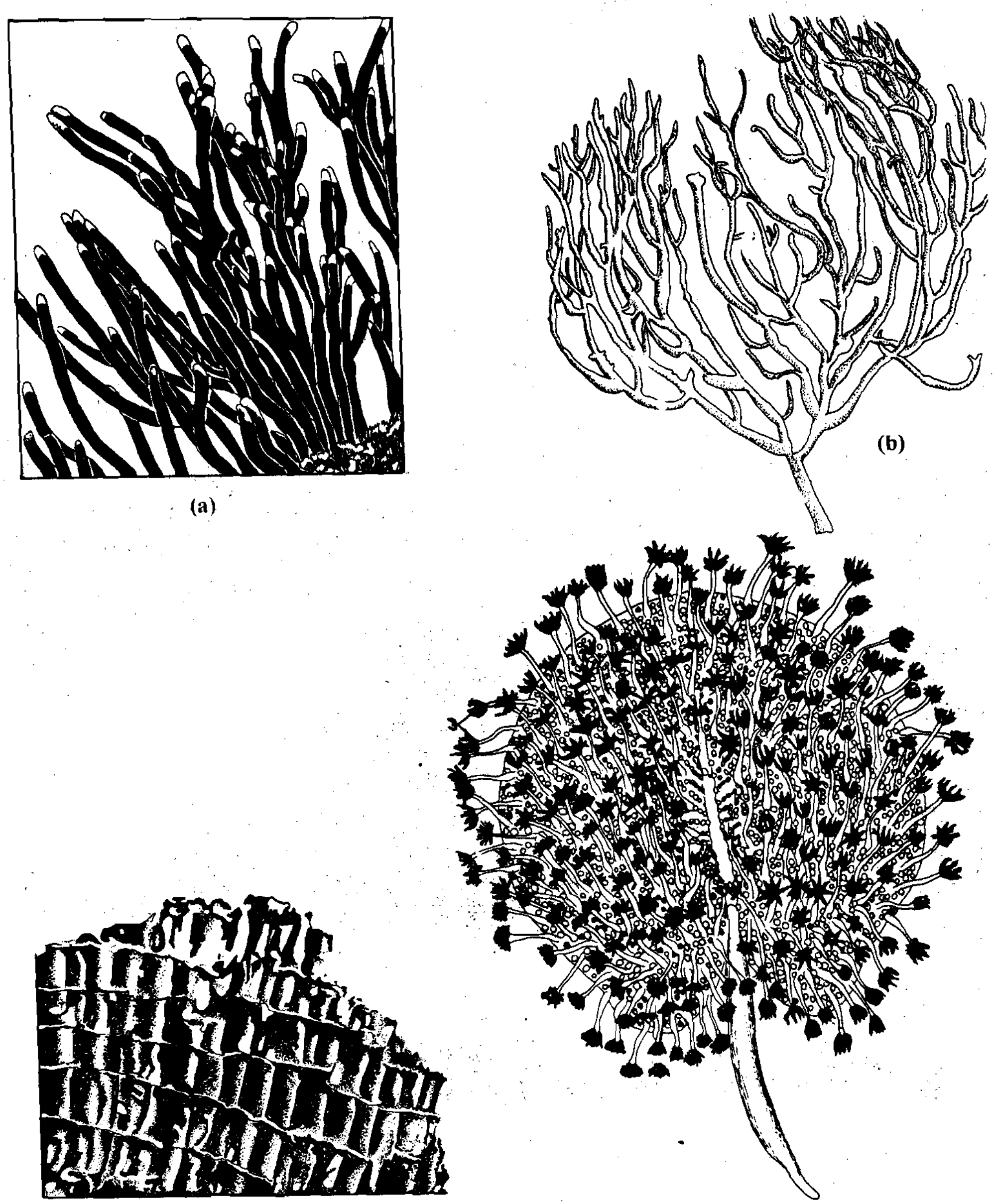


Fig. 14.9: a) Sea rods; b) Sea fan; c) Organ-pipe coral; d) Sea pansy.

Thus the benefit of colonial life is also clear: competition for survival among individuals is replaced by co-operation. This provides distinct nutritive, protective and reproductive advantages to them.

SAQ 2

i) Match the words in list A with those in list B.

	List A		List B
1)	Dactylozooid	a.	Feeding
2)	Gastrozooid	b.	Floating
3)	Pneumatophore	c.	Protection
4)	Medusa	d.	Sexual Reproduction

ii) Fill in the blanks in the following statements on the basis of what you have studied in subsection 14.2.2.

The growth of the hydrocaulus is of two types viz., ... or .... In the former each branch ends in an oldest terminal zooid, below the base of which is the zone of growth that lengthens the branch and gives rise to buds.

14.3 ADAPTIVE RADIATIONS

In the beginning of this unit, you have studied that when the animals belonging to the same or closely related groups adapt for different modes of life, they are said to show adaptive divergence or adaptive radiation. This concept was known to early zoologists like Lamarck and Darwin. Lamarck called it embranchment and Darwin called it divergence. The idea was, however, concretized in the form of a law by Osborn, the law of adaptive radiation. Though Osborn postulated the law of adaptive radiation on the basis of his studies on mammals, it applies equally well to other animal groups, whether non-chordates or chordates. There is always a brief period in the history of all animal groups when the rate of evolution is very rapid. It results in the emergence of many new major lines of evolution or adaptation. Further evolution of each of these lines is comparatively slow. This process of breaking up of the parent stock into diverse lines which continue their own evolution is adative radiation.

Two fundamental needs of the organisms are mainly responsible for adaptive radiation. These are need for food and need for safety. A major factor in the animal evolution has been their habit of food gathering. Two basic ways of this habit may be recognised. There were animals which would just wait for the food to come their way. Secondly, some animals would actively seek the food and go after it. The former acquired sedentary habits and radial symmetry. Radial symmetry would allow the fixed animals access to food in all directions. These animals evolved a special feeding device called filter-feeding. On the contrary, a typical food- seeker has to resort to movement for food gathering. They would go after the food. This gave rise to antero-posterior polarity, cephalisation, and bilateral symmetry. The anterior end may have developed into a distinct head, the seat of mouth-parts, sense organs and brain. (see earlier unit).

The second major factor in animal evolution has been the need for safety from the hostile abiotic and biotic components of the environment. All this has also led to exploitation of new habitats and acquisition of appropriate adaptations to suit the new surroundings. These modifications may have been in the habits, morphology and physiology of the animals. The evolutionary history of various lines or animal groups show that functional adaptations in different groups are different. Therefore you will find different lines of adaptive radiations in different groups of animals.

14.3.1 Adaptive Radiation in Annelida

Phylum Annelida includes three classes; **Polychaeta, Oligochaeta** and **Hirudinea**. Of these, the Polychaeta do not have clitellum; the Oligochaeta and Hirudinaria are **clitellate**. Now you should recollect the classification and characters of Annelida which you have studied in Unit 4, Block 1 of this course. The early annelids are supposed to have been marine worms burrowing in the bottom, in sand and mud on the shore.

Polychaetes comprise the marine species which continued their life in the sea diversifying into various niches there; Oligochaeta include the line which led to the fresh water forms and to the earth worms; Hirudinea includes the leeches which arose from some fresh water oligochaetes.

Adaptive Radiation in Polychaeta

Having evolved from some small, annelid worm-like creatures adapted for burrowing and crawling life in oceans, the group diverged into two main branches on the basis of their food habits; a group of active food seekers and another line of sedentary animals. The former actively sought after the food either scavenging or preying upon it whereas the latter gave rise mainly to burrowing or tubicolous forms. In this section we will discuss the polychaete groups adapted to various modes of locomotion, habitation and nutrition.

Errant Polychaetes: Worms such as nereids or hesionids are rapid crawling worms that crawl beneath stones and shells in rock and coral crevices and among algae and sessile animals. In these worms the head is well developed having one to four pairs of eyes, upto five antennae and a pair of palps (Fig. 14.10).

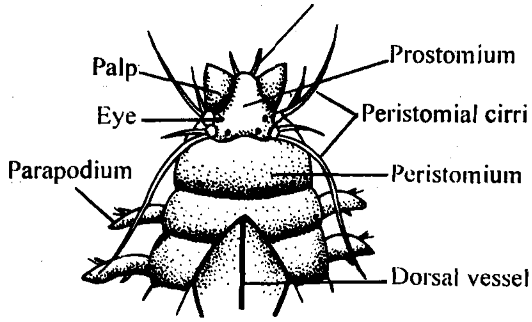


Fig. 14.10: The head region of the polychaete *Nereis*.

These worms have large parapodia that help in crawling. Many of these polychaetes are carnivores and feed on small vertebrates including other polychaetes. Food habits like scavenging, algae eating and detritus feeding have also evolved in some of these polychaetes. The pharynx of the errant polychaetes is muscular and eversible and possess teeth or jaws which vary in number in different families (Fig. 14.11).

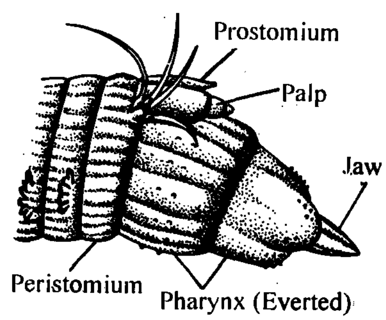


Fig. 14.11: The head of the polychaete *Nereis* with everted pharynx (lateral view) the jaw is open when pharynx is everted and closed when pharynx is retracted.

Pelagic Polychaetes: Certain families of polychaetes are adapted to life in oceans and thus are pelagic or planktonic. In these worms head is well developed and parapodia are large that are used as paddles to aid in swimming. Like other planktonic animals these polychaetes are pale or transparent. These worms are generally carnivores, e.g. *Rhynchonerella angelina* (Fig. 14.12), *Tomopteris renata*.

Gallery Dwellers: These polychaetes are adapted to live in burrows made of sand or mud. The gallery dwellers make extensive burrow system or galleries that open to the surface at many points (Fig. 14.13a). These burrows are lined by the mucus secreted by the worms that prevent the collapsing of burrows. The prostomium of these worms can be a simple lobe or of conical shape and lack the eyes and other sensory organs (Fig. 14.13 b).

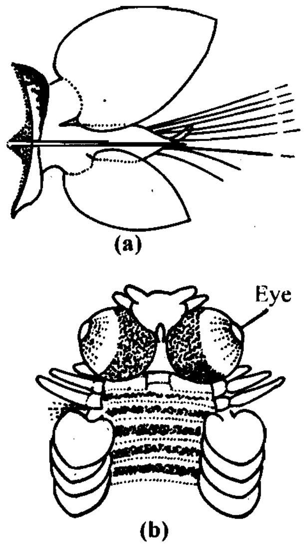


Fig. 14.12: Pelagic polychaete *Rhynchonerella angelina* (a) and its parapodium (b).

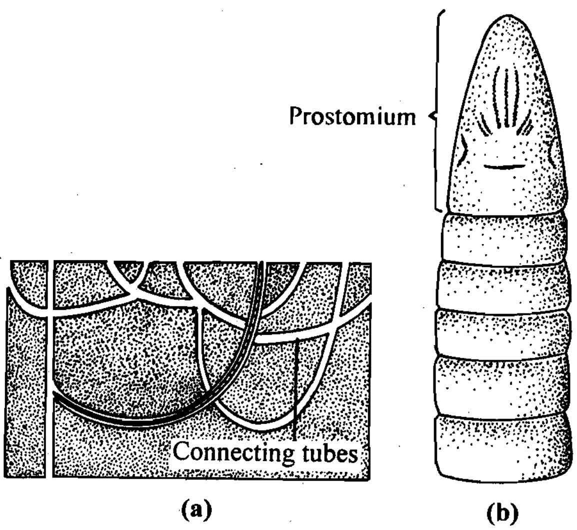


Fig. 14.13: a) Burrow system of a gallery dweller worm *Glycera alba* showing the worm lying in wait for the prey. b) Anterior end of the gallery dweller *Drilonereis* showing the conical prostomium that lacks eyes and sensory appendages.

The worms usually move in the burrows by peristaltic movements, and the parapodia are reduced and help to anchor the segments by gripping the walls of the burrow. The septa and circular muscles are well developed. However, some of the gallery dwellers may crawl with the help of parapodia. They may be carnivorous or non- selective deposit feeders and consume the substratum through which the burrows are made.

Glycera, is the best studied gallery dwelling polychaete and is also used as fishing bait. These worms lie in wait in the gallery system and when the prey moves across the surface creating pressure waves, the worm moves to a nearby opening. Blood worms have a long proboscis that is shot out with explosive force to seize the prey (Fig. 14.14).

Sedentary Burrowers: Certain polychaetes make simple burrows that have only one or two openings to the outside (Fig. 14.15 b). These worms move about very little when the move, they also go by peristaltic contractions only. Parapodium is reduced to hook like setae that help in gripping the burrow wall. The prostomium is devoid of most of the sensory structures. However, special feeding appendages may be present. Some of the sedentary burrowers are nonselective deposit feeders while others are selective deposit feeders. L-ug worms (*Arenicola*) (Fig. 14.15 a) nonselective deposit feeders, live in L-shaped burrows and ingest the sand at the bottom with an eversible pharynx. At fixed intervals the worm comes out of its burrow and defecates at the surface as a casting. After this the worm resumes feeding and ventilating. Ventilation occurs because peristaltic contractions bring in the water current.

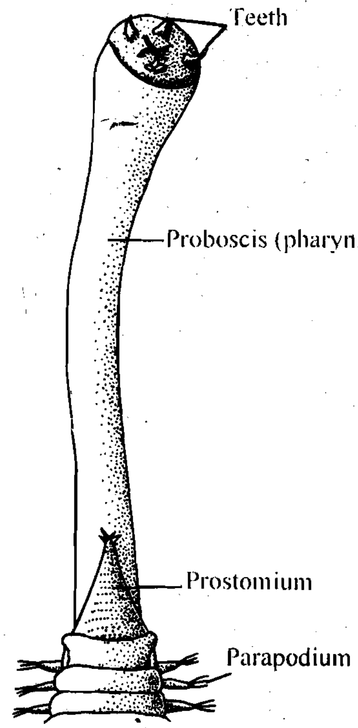


Fig. 14.14: Anterior end of *Glycera* showing the everted pharynx.

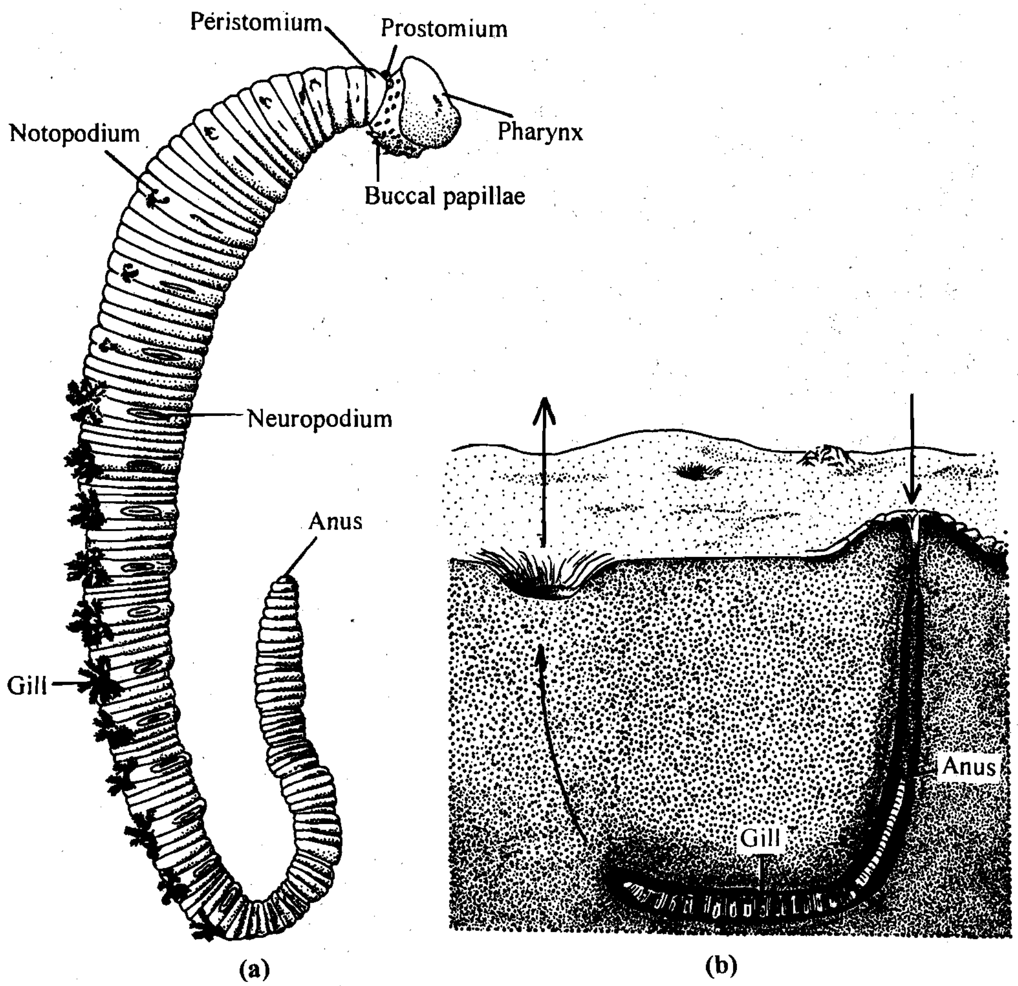


Fig. 14.15: The L ug worm (*Arenicola*) with its pharynx everted (a). Worm in the burrow (b)

In selective deposit feeders there is no eversible pharynx. Instead they have special head structures that pick up the organic matter from the surrounding sand grains. For example *Amphitrite* has a great mass of long tentacles that spread over the surface from the opening of the burrow (Fig. 14.16). The detritus material adheres to the mucus on the tentacles and is then passed on to the mouth in a ciliated tentacular gutter with the help of tentacular contraction.

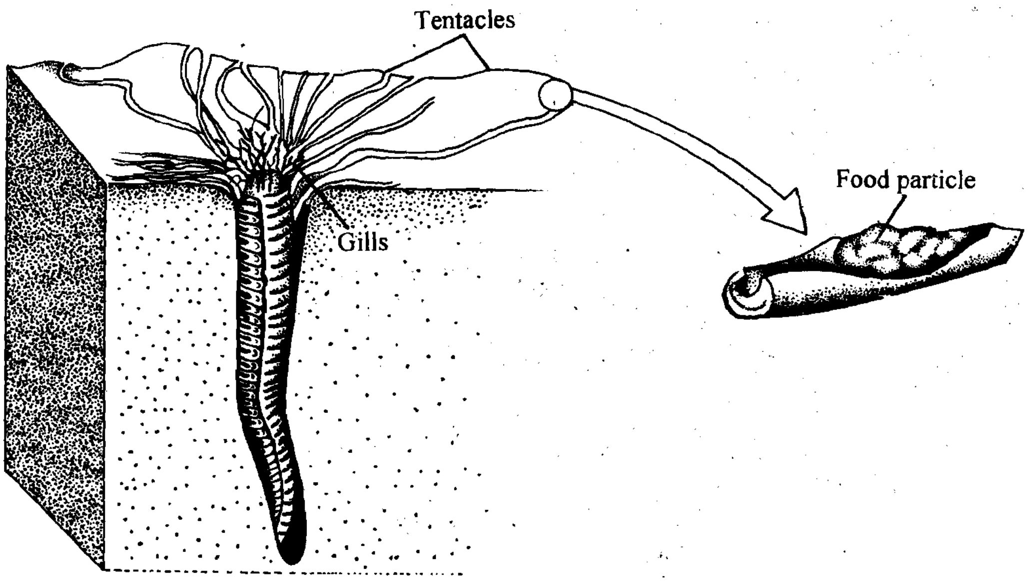


Fig. 14.16: ***Amphitrite*** **in its burrow with outstretched tentacles on the surface. Also shown is the food particles trapped in the tentacles that are rolled up to form a ciliary gutter.**

Tube-Dwelling Polychaetes: Tube dwelling is more widespread habit among the polychaetes as compared to other animal groups. The worms can make the tubes in the sand or in firm and exposed substrates such as algae, rock, coral or shell. The tube may be completely made up of hardened material secreted by the worm or composed of foreign material cemented together. Thus, a tube will remain intact when dug out of the sand.

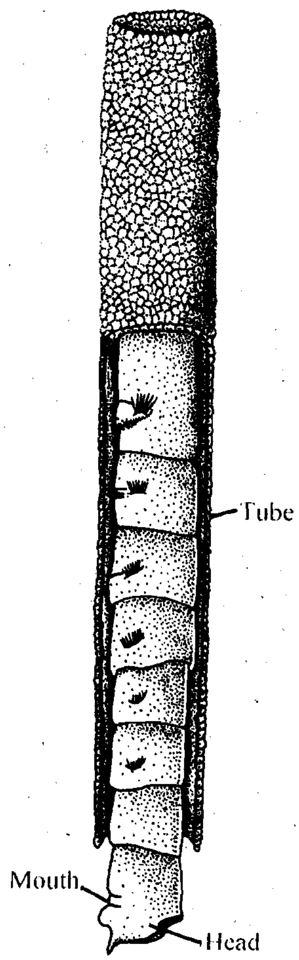


Fig. 14.17: Bamboo worm that lives upside down in the tube.

Tube dweller (tubicolous) polychaetes show structural diversity that is correlated with their different modes of feeding. Majority of the tube-dwellers are sedentary and move about within the tube lazily with the help of peristaltic contractions. They lack sensory structures, although feeding appendages may be present. Parapodia are reduced to ridges with hooked setae for gripping. Infact these adaptations are similar to those for sedentary burrowers as these two habitations are similar to some extent. Some families contain both burrow dwelling and tubicolous species.

The nonselective deposit feeders like bamboo worms (*Clymenella, Axiothella*) live in sand grain tube by keeping their head down and ingest the substratum at the bottom of the tube with the help of eversible pharynx (Fig. 14.17). Periodically the worm comes back to the surface and defecates.

Filter feeding is another mode of nutrition that has evolved in several families of sedentary and tube dwelling polychaetes. One kind of filter feeding is seen in fan worms or feather duster worms, where the prostomium palps have developed to form a funnel - shaped or spiral crown consisting of pinnate processes called radioles, for example in *Sabella* (Fig. 14.18). During feeding the particles are first trapped in the mucus of the radioles surface and then passed on to the mouth with the help of cilia. When the worm pulls back its anterior end into the free end of the tube, the radioles are rolled and closed up together.

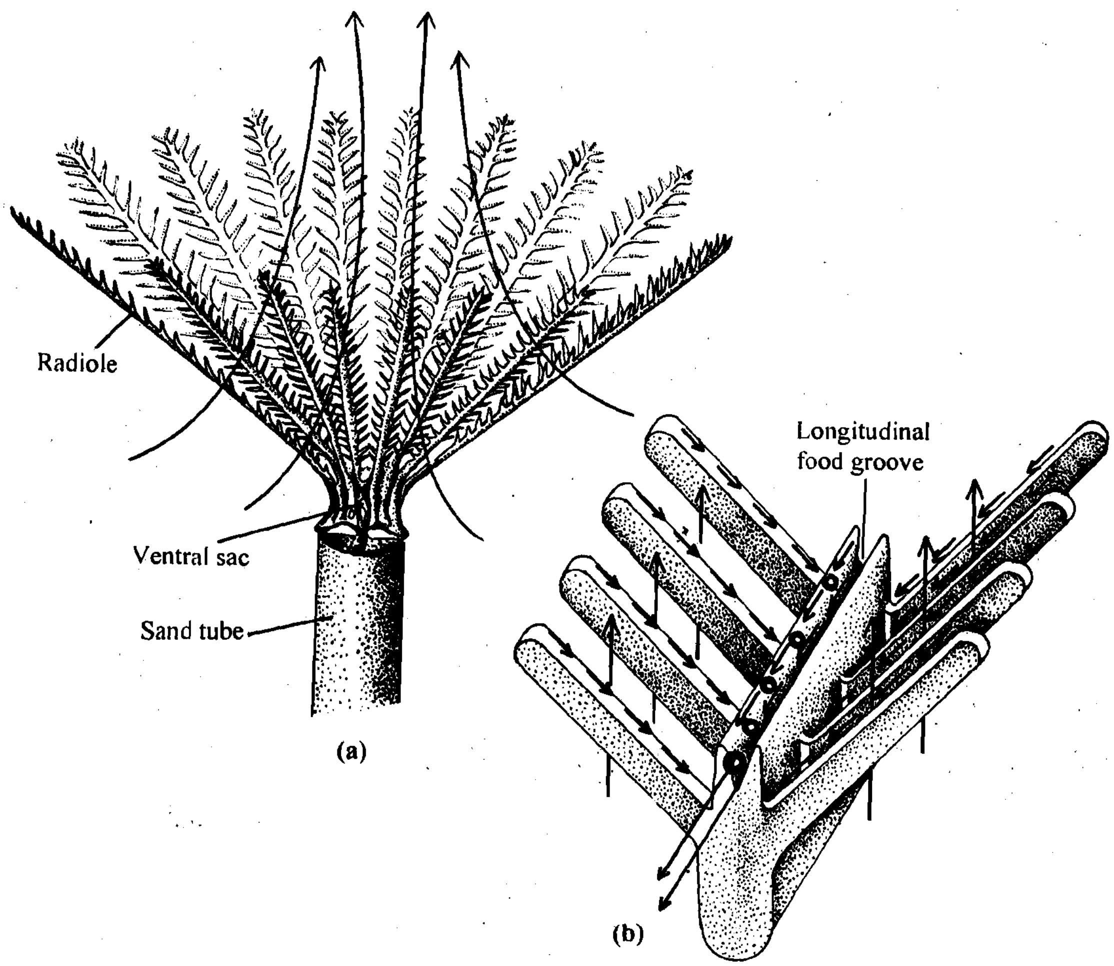


Fig. 14.18: Filter feeding in fanworm *Sabella* (a) Water current passing through radioles. (b) Water current and ciliary tract over a part of radiole.

Chaetopterus exhibits another mode of filter feeding. It feeds by filtering water through a mucus bag. These worms live in U- shaped tube made by secreted parchment like material (Fig. 14.19). In the middle of the body of the worm there are three piston like or 'fan' like parapodia that drive water through the tube. A pair of long winglike anterior notopodia secrete a film of mucus that is rolled up into bag like shape with the help of cilia. The water current driven in the tube passes through these mucus films. Periodically the mucus secretion is stopped and the mucus bag containing trapped food is rolled up into a ball which is passed along the ciliated groove to the mouth.

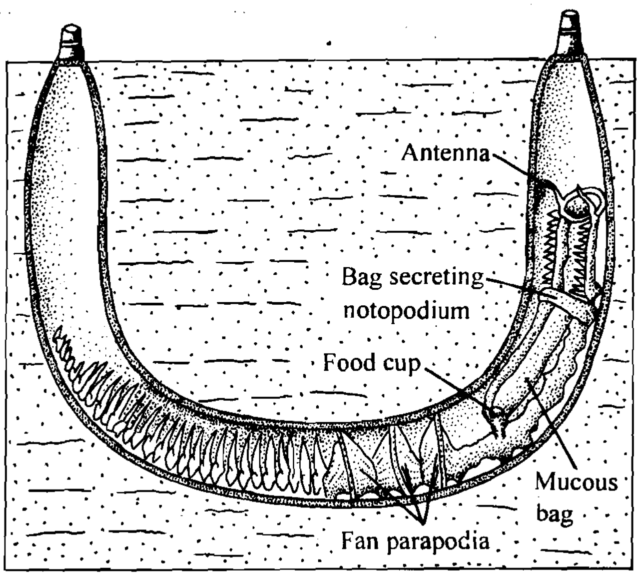


Fig. 14.19: ***Chaetopterus*** **in its tube (lateral view).**

Till now you have studied about the adaptations in annelida. Try the following SAQ before we proceed further.

SAQ 3

i) Mark (✓) the correct alternatives in the following statements :

a) Law of adaptive radiation was postulated by *Lamarck/Osborn.*
b) Adaptive divergence was called 'embranchment' by *Darwin/Lamarck.*
c) Worms with well developed head having eyes, antennae and a pair of palp are *gallery dweller polychaetes/errant polychaetes.*
d) Large parapodia in polychaetes that are used as paddles are adaptations to life in *oceans/sand and mud.*

SAQ 4

i) State whether the following statements are true (T) or false (F).

a) Sedentary burrower Polychactes are essentially carnivores.
b) Filter-feeding is mostly found in sedentary tube-dwelling polychaeta.
c) Polychaets are mainly fresh water animals.
d) Sedentary and tube-dwelling polychaetes mostly lack well-developed sensory organs.

ii) Name the two fundamental needs responsible for adaptive radiation.
a) ....,
b) ....

Adaptive Radiation in Clitellate Annelida

Polychaeta, being aquatic, lay their eggs in water and most of them develop through a *trochophore* larval stage. Aquatic environment offers many advantages: animals require less energy expenditure for supporting their body weight, water acts as a cushioned envelope providing protection from jerks and strains, temperature gradient in water is least and it provides an ideal medium for egg-laying and development. These advantages are available to marine as well as fresh-water forms. However, fresh water habitats have one big drawback. These are not permanent like marine habitats. They may dry up during some part of the year. Therefore the fresh water forms and terrestrial ones face a two fold problem to different extent. One, they are denied the benefits of permanent and continuous access to the aquatic medium and secondly, they are exposed to the risk of desiccation. This problem has been solved by clitellate annelids successfully. Let us examine how.

The clitellum-bearing Annelida, the Oligochaeta and Hirudinea, mostly inhabit fresh water and terrestrial habitats. They have no larval stage and the development is direct. Glandular cells of some of their body segments become active during breeding season and form a conspicuous belt-like **clitellum** (Fig. 14.20) which produces a cocoon. Eggs are laid and develop within these cocoons. The clitellum may be permanent (as in earthworms) or temporary (as in leeches). These annelids are hermaphrodites, though reciprocal copulation in earthworms is well known. The clitellates are devoid of antennae, palpi or parapodia.

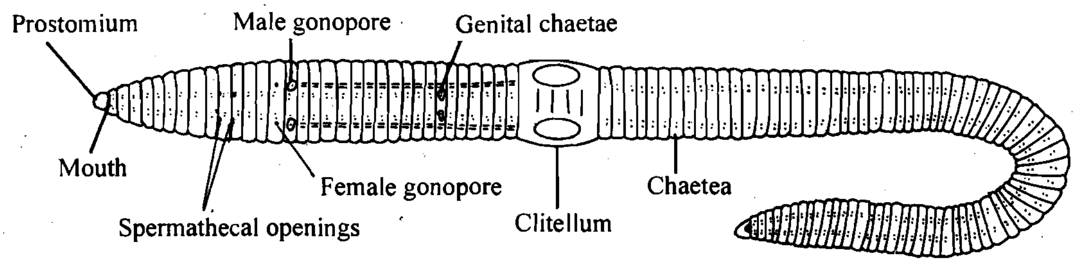
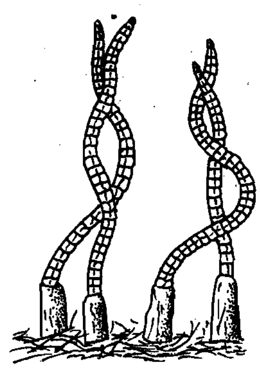


Fig. 14.20: Earthworm showing clitellum

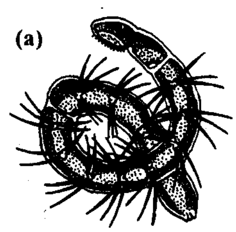
Oligochaeta appear to have evolved directly from the marine annelids, independently of polycheates. Some species of tubulificids and enchytraeids especially from littoral and intertidal zones and estuaries have been reported from marine waters.



Tubifex

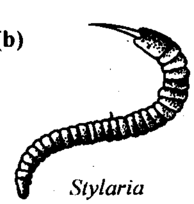
Fig. 14.21: *Tubifex* that lives head down in long tubes. The posterior end waves about in water to facilitate gas exchange.

(a)



Aeolosoma

(b)



Stylaria

Fig. 14.22: (a) *Aeolosoma* - the cilia around the mouth sweep in the food particles. (b) *Stylaria* - prostomium drawn out into long snout.

Tubifex (Fig. 14.21) and *Limnodrilus* are reported to thrive well in sewage-polluted waters. *Tubifex* which lives in stagnant water in mud, builds tubes. It projects posterior part of its body from the tube and waves it about in water facilitating gas exchange. Some like *Aeolosoma* and *Stylaria* (Fig. 14.22) are fresh water forms. Aulophorus constructs tubes in mud and debris. Aquatic forms like *Dero* (Fig. 14.23) and *Aulophorus* have finger like gills at the posterior end. *Branchiura* and *Branchiodrilus* have filamentous gills on the body. Aquatic forms are generally small; but they have longer setae. Some like enchytraeids are transitional between aquatic and terrestrial habitat, and live in marshes. These include lumbricids, megascolecids and moniligastrids. Earthworms are burrowing animals and are known to increase land fertility.

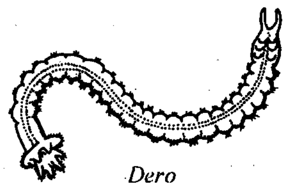


Fig. 14.23: *Dero* has ciliated anal gills.

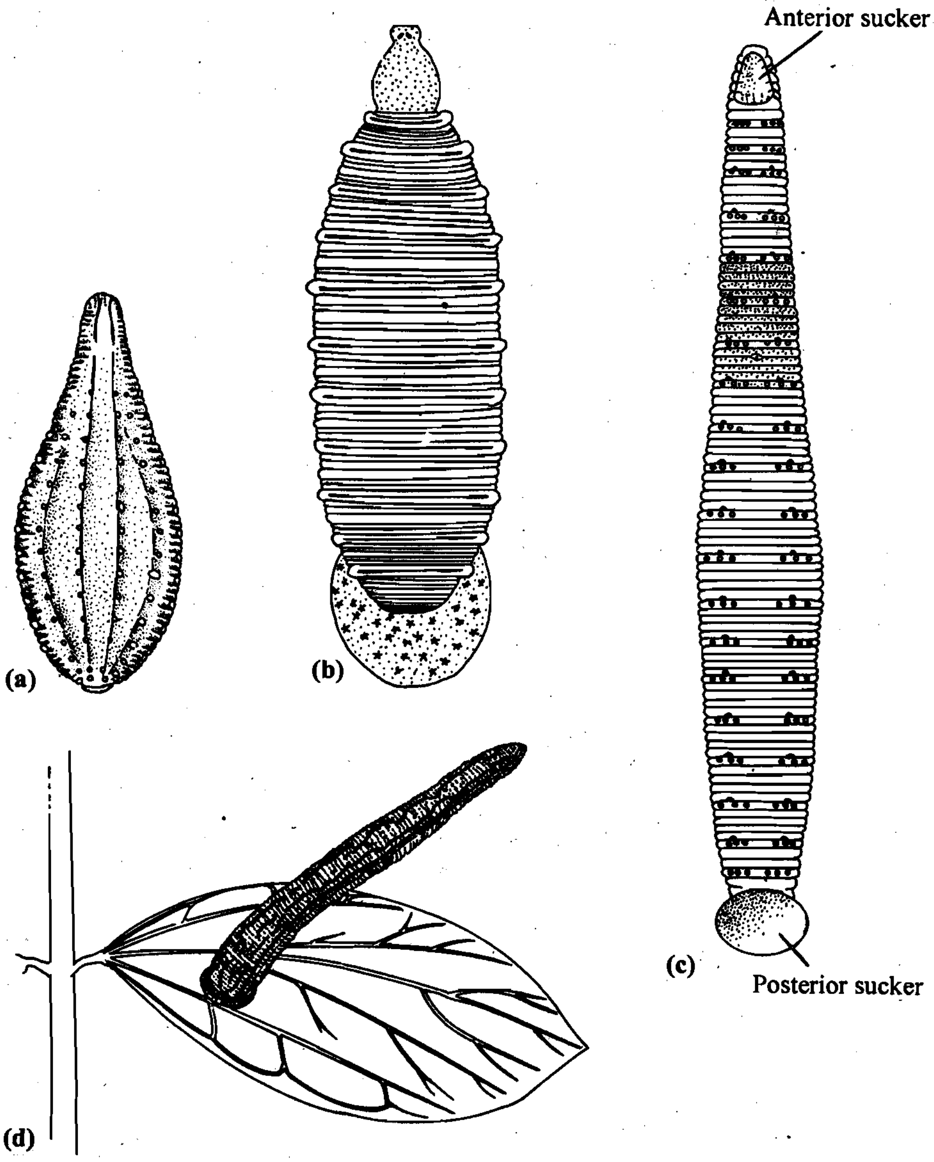


Fig. 14.24: a) Glossiphoniid leech *Glossiphonia complanata*; b) piscicolid leech *Cystobranchus*; c) hirudinid leech *Hirudo medicinalis*; d) haemadipsid leech *Haemadipsa*.

Hirudinea includes leeches. Many of the leeches are ectoparasites of vertebrates [glossiphoniids, piscicolids, hirudinids, haemadipsids (Fig. 14.24)]. The parasitic adaptations of the leeches are: presence of sucking pharynx and a post-anal sucker, provision for the secretion of mucus layer over the body by the skin glands to prevent dehydration, secretion of an anticoagulant **hirudin** to facilitate feeding on blood, and provision of food storage in the spacious crop. One full meal by a leech may last it for about four months. Leeches and oligochaetes have a common ancestry. Leeches are mostly fresh water animals. However, some have become adapted to terrestrial life (*Haemadipsa*). Some have also become secondarily adapted to marine habitat.

SAQ 5

i) Indicate whether the following statements are correct or not.

   a) All members of the phylum Annelida develop through a larval stage called trochophore.
   b) Clitellum is a well developed permanant structure in earthworms.
   c) The skin of leeches contains gland cells which secrete a mucus layer over the body which prevents desiccation.
   d) *Tubifex* is very comfortable in ponds polluted with sewage.

14.3.2 Adaptive Radiation in Arthropoda

Biologically Arthropoda is the most successful group in terms of numerical strength, adaptive diversity and extent of territorial distribution. They are supposed to be polyphyletic in origin, with a number of (three or four) independent lines of evolution. There is also a tendency among them for reduction of number of segments by fusion or loss. Arthropoda, literally meaning **joint- footed** (Gr. arthros = joint; podos = foot), is represented by horse-shoe crabs (Subclass Xiphosura), prawn, lobsters, crabs (Subphylum Crustacea), spiders and scorpions (class Arachnida), centipedes (class Chilopoda), millipedes (class Diplopoda) and insects (Class Insecta). Formerly *Peripatus* (Onychophora) also used to be included in this phylum. Arthropods have certainly evolved from marine Annelida by acquiring an armour of chitin over the body and paired appendages on almost all body segments. The armour not only provided support and protection to the animal but also prevented entry of excess water and salts in the body in aquatic forms and desiccation in terrestrial ones. But it interfered with smooth gas exchange through the body surface and hampered growth. The adaptive radiation in Arthropoda is mainly related to the evolution of suitable respiratory mechanism, appropriate limb modifications and flight.

Respiration

The annelids respire by the general body surface or by gills. In Arthropoda while gills are retained by aquatic forms, terrestrial members of the group have evolved **book-lungs** (scorpions) and **tracheae** (centipedes, milipedes and insects). Xiphosura and Crustacea are almost exclusively aquatic. They evolved in water and remained there. There are also some water-dwelling arthropods, which had actually invaded land and acquired terrestrial adaptations. They re-entered aquatic medium and made it a second home. This includes many adult insects (water-bugs, water-beetles, etc), which respire by tracheae while living in water. Thus, aquatic respiration in Arthropoda may be by gills (usually called branchial respiration) or by tracheae (tracheal respiration).

Aquatic Respiration by Gills

In Xiphosura, Crustacea and many larval insects respiration takes place by gills. A gill is a vascular outgrowth of the bodywall. It remains bathed in water and gaseous exchange occurs on its surface. In *Limulus* (Xiphosura) five pairs of **book-gills** are present on the ventral surface (Fig. 14.25). These are flat, lamellate abdominal appendages. Each gill supports about 150 gill lamellae arranged in a manner which gives it an appearance of the leaves of a book, hence the name.

In Crustacea the gills or branchiae are arranged as lateral extensions along the central axis. Gills may be of three types: **Phyllobranchs** are simple, leaf-like lobes set on either side of a main axis (Fig. 14.26 a), **Triochobranchs** have filaments arranged around a central axis (Fig. 14.26 b) and dendrobranchs are modified phyllobranchs with each lateral lobe being subdivided (Fig. 14.26 c). Gills have a supply of haemocoelomic channels. A continuous supply of water is maintained in the gill chamber. This ensures proper gas exchange.

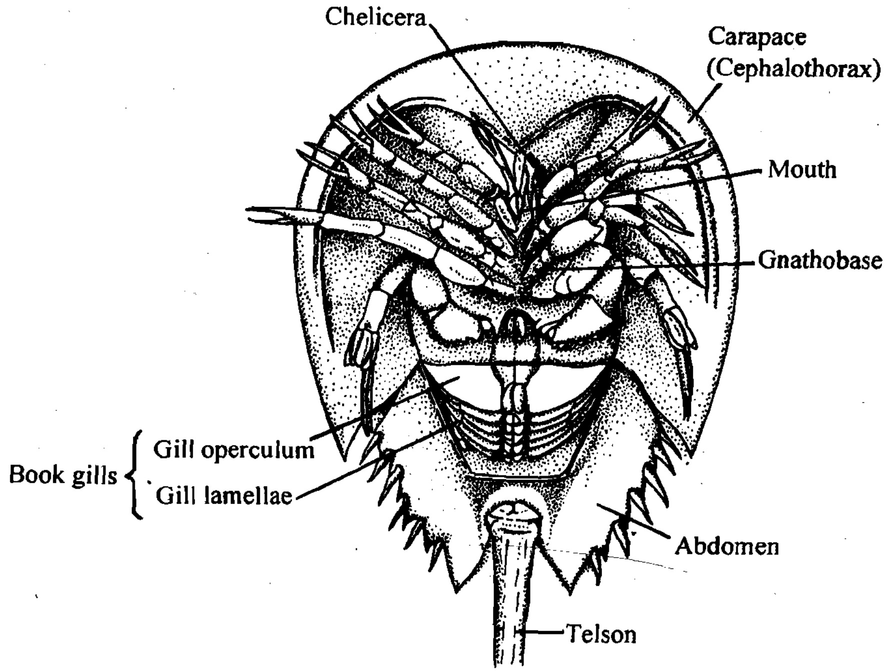


Fig. 14.25: Ventral view of horseshoe crab *Limulus polyphemus*.

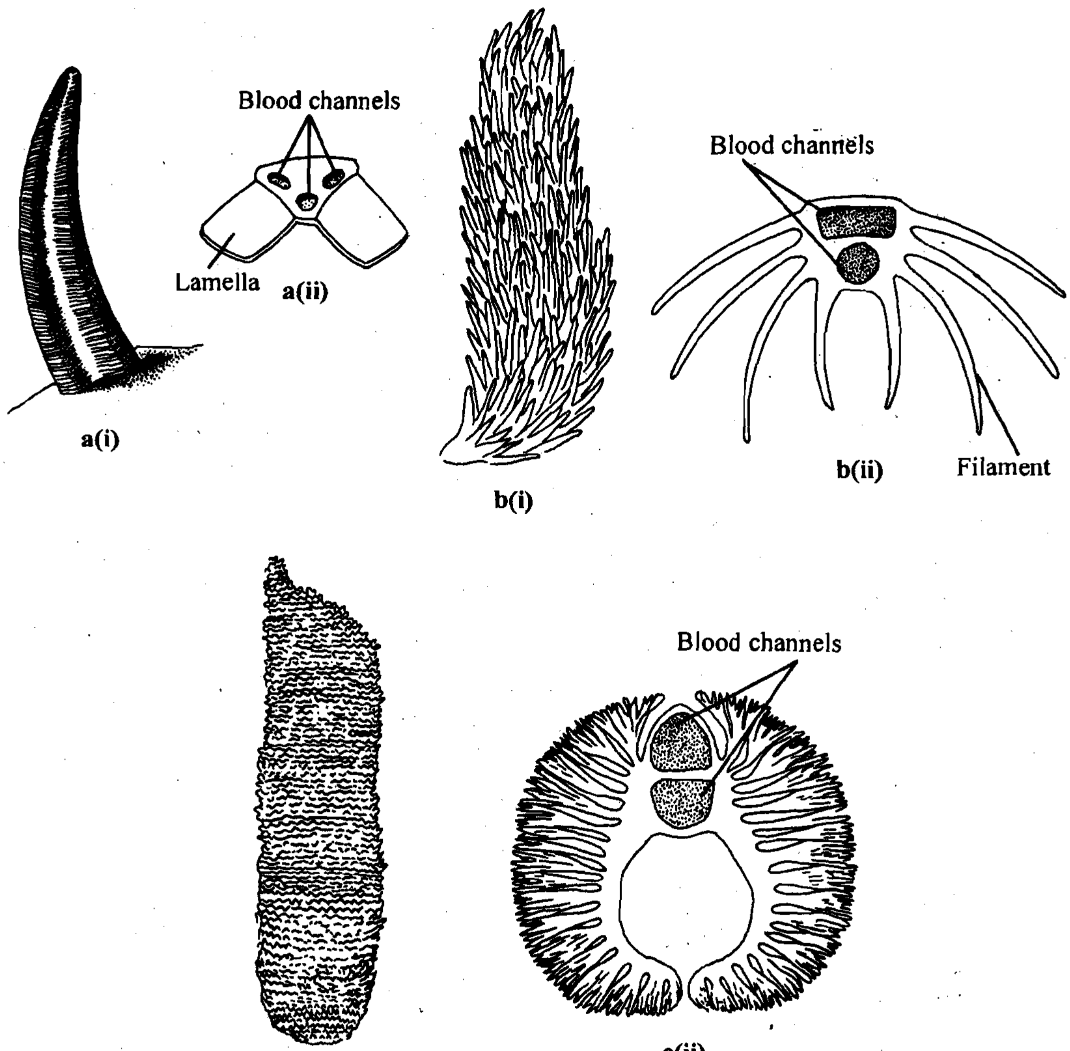


Fig. 14.26: Gill types in crustaceans, a) Phyllobranch, b) Triochobranch, c) Dendrobranch, (i) Lateral view (ii) Transverse view.

Aquatic Respiration in Insects

Two modes of aquatic respiration in insects are recognised. In one, the insects obtain oxygen dissolved in water. This may be affected either through the general body surface or by means of different types of gills. **Tracheal gills** of the aquatic larvae of mayfly, stonefly and caddisfly are the lateral outgrowths of the bodywall and contain tracheal branches. **Rectal gills** are present in the rectum of Odonata larvae. The stonefly larvae (Fig. 14.27) possess **tracheal gills** on various regions of the body and *anal gills* on each side of the anus. The **blood-gills** of some dipteran larvae are blood-filled out-growths of the bodywall. The blood of **Chironomus** larvae is red due to haemoglobin, giving the name blood-worm to the larvae.

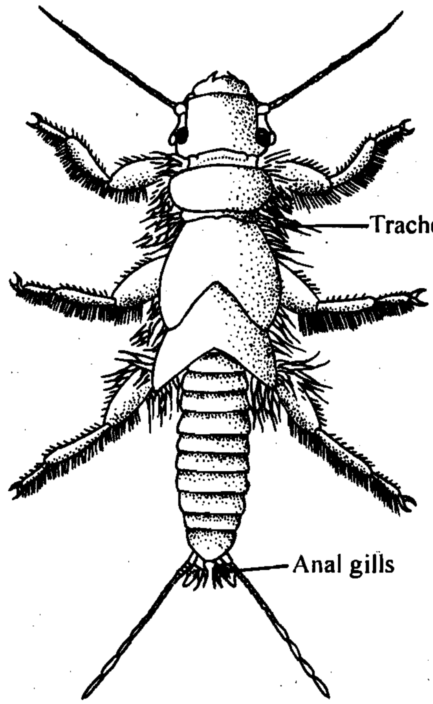


Fig. 14.27: Stonefly larva showing tracheal and anal gills.

There are some insects which live in water but still breathe air. They have devised modifications to obtain supply of fresh air at periodic intervals. We will discuss more about these forms when we deal with respiration in terrestrial insects.

Respiration in Terrestrial Arthropoda

In land-dwelling Arthropoda respiration is effected either by **book-lungs** (Arachnida) or by **tracheae** (Myriapoda and Insecta). The book-lungs seem to have been modified from the **book-gills** of the ancestral arachnids, the Merostomata. Scorpions possess four pairs of book-lungs, one inside each mesosomatic segments 3-6 (Fig. 14.28 a). A book-lung has a ventral atrial **chamber** and a dorsal **pulmonary chamber** (Fig. 14.28 b). The former opens to the exterior by **stigma** (plural-stigmata) and the latter contains about 150 vertically placed lamellae giving the whole structure an appearance of the leaves of a book that explains the nomenclature. In spiders the respiratory organs may be either primary book-lungs or some modified structures such as **tube- trachea** and **sieve-trachea**.

Respiration by Tracheae

In most animals, except small and simple integument-breathers, oxygen is supplied to the different body parts through blood stream. Blood and air come in contact either in the gills or in the lungs. However, the land arthropods like Myriapoda and Insecta evolved an entirely unique system for oxygen transport in the body. In their case a series of pores, called **spiracles** are present on either side of the thorax and abdomen. These pores lead into a network of branching tubules, the **tracheae** (Fig. 14.29), which ramify throughout the body. Finer branches of tracheae called **tracheoles** reach out almost every cell. Air enters the trachea via spiracles and directly reaches the tissues. Thus, blood does not carry respiratory gases in them.

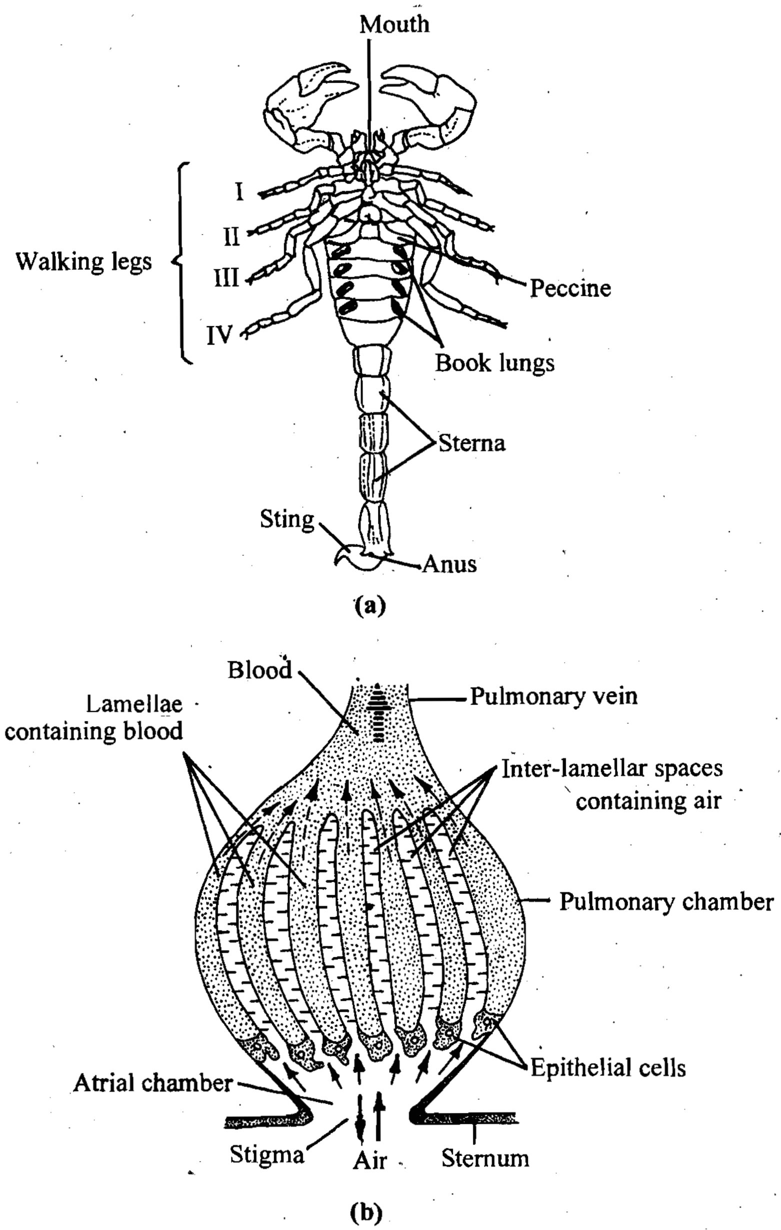


Fig. 14.28: Ventral surface of scorpion showing spiracle of book-lungs (a). Vertical section of a book lung (b).

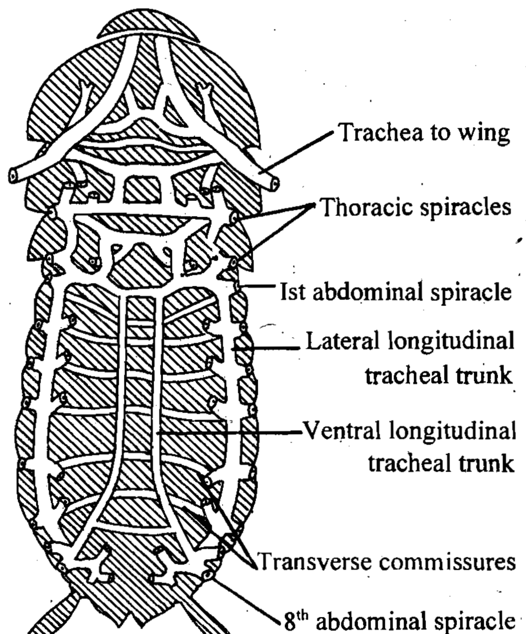


Fig. 14.29: Tracheal system in insects (Dorsal view)

While talking about respiration in aquatic insects it was mentioned that some insects live in water but breathe air. Let us now see how they do that. The tracheal system in such air-breathers is little altered and the spiracles are open. But these insects acquire various modifications to renew the supply of fresh air. The Odonata and mosquito larvae periodically come to the water surface to take in fresh one. In many water-bugs and water beetles there are tufts of water-proof (hydrofuge) hairs on different parts of the body. The air trapped among these hairs is used for breathing. In the water-beetle *Dytiscus* the air is enclosed between body and the forewings (elytra). The adults of water-bug Nepa or the larvae of *Eristalis* (Diptera) possess a long respiratory siphon (Fig. 14.30), which remains in contact with the air.

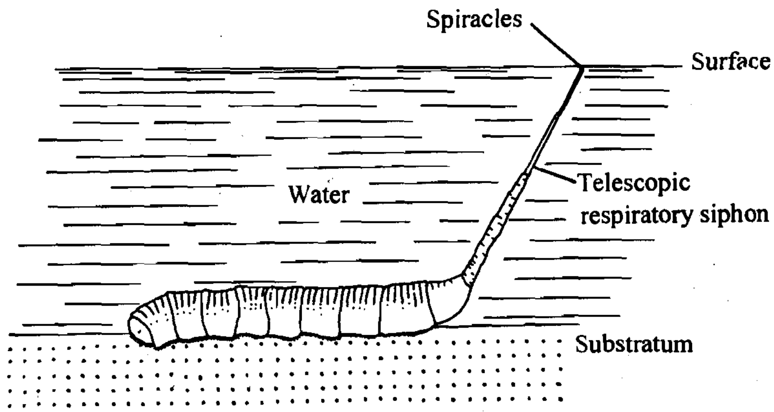


Fig. 14.30: Respiratory siphon in *Eristalis* larva.

SAQ 6

i) On the basis of what you have read in subsection 14.3.2 supply the missing words in the following sentences.

   a) In scorpions the respiratory organs are ...., of which there are .... pairs.
   b) Respiratory organs of *Limulus* are ....
   c) In Crustacea three types of gills are found. These are ...., ... and ....
   d) Rectal gills are present in the aquatic larvae of ....
   e) The adults of the water-bug, ... has a long respiratory siphon.

Modifications of Limbs

You may recall here what you have already studied under "Animal Diversity" on arthropod appendages. The appendages in Arthropoda have undergone three major functional modifications: (a) as sense organs, (b) as mouth parts, and (c) as locomotor organs. Out of these, maximum adaptive divergence is shown by the locomotor organs and mouth parts. Locomotor organs are modified in most of the arthropod groups. On the whole, primitive groups have more appendages. The locomotor appendages tend to become reduced in number as they become specialised and modified for various functions. This increases their maneuverability as well as speed. Two distinct lines of adaptations are recognised: aquatic and terrestrial. On the contrary, mouth parts show highest adaptive divergence only in insects, the details of which you have already studied in Unit 4, Block 1 of this course. Therefore, we will presently discuss the modifications of locomotor appendages only.

Locomotion in Aquatic Arthropoda

The aquatic arthropods are mostly adapted for crawling or walking on the substratum and for swimming. The horse-shoe crab *Limulus* is a coastal dweller. Its locomotion is effected by walking on sand or mud bottoms. For this it has five pairs of walking legs. The fifth pair of walking legs is specially modified for removing the mud while burrowing. The distal lamellae of this pair spread and can push against the floor to prevent sinking in the loose mud.

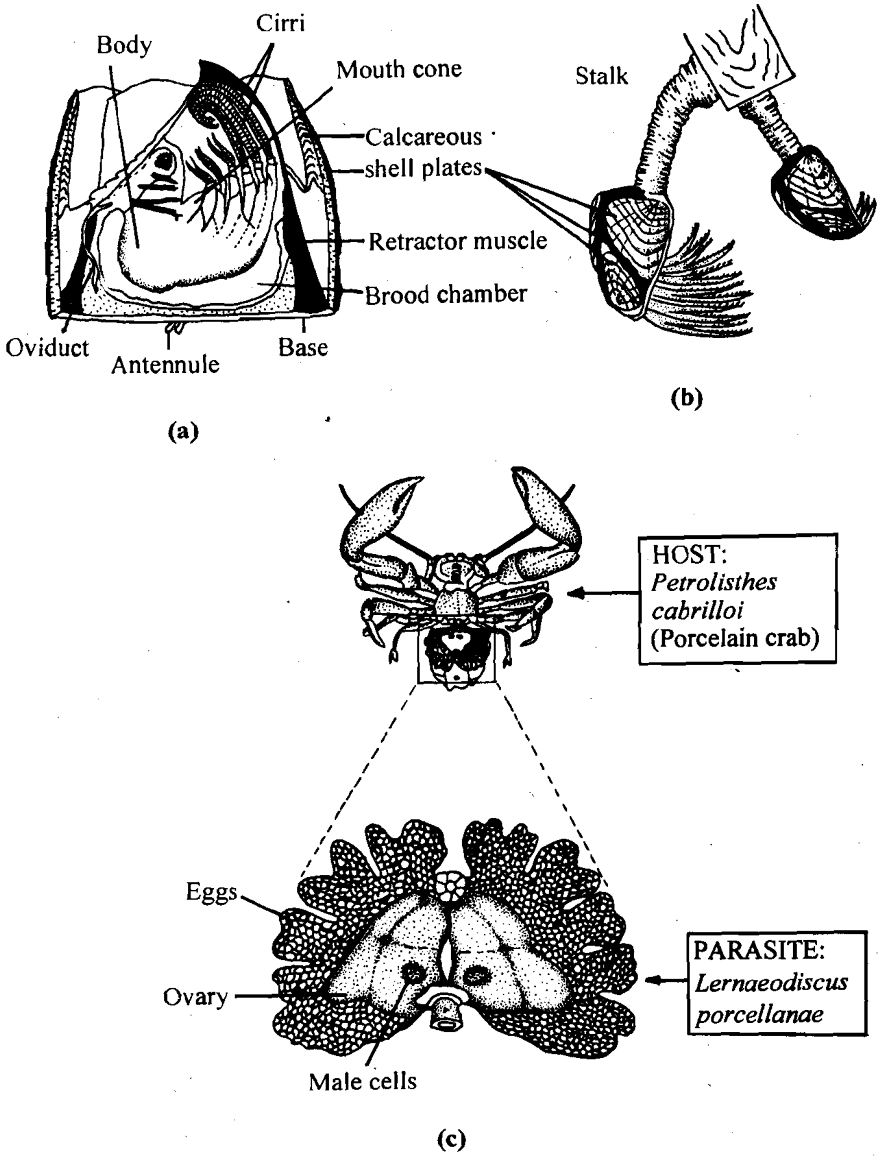


Fig. 14.31: a) Balanus a sessile barnacle; b) Lepas, a stalked barnacle. Barnacles, the marine animals belong to order Thoracica of subclass Cirripedia, that are usually enclosed in a shell of calcareous plates. In these arthropods head is reduced, abdomen is absent and the thoracic legs are long and many jointed cirri with hair like setae c) *Lernaeodiscus porcellanae*, the rhizocephalan barnacle, parasitic on the porcelein crab.

Most Crustacea, except the sessile and parasitic cirripedes (Fig. 14.31), are active swimmers. Their thoracic and abdominal appendages are adapted for swimming. These are oar-like and are usually provided with fringed setae which increase surface area of the swimming organs. In Branchiopoda (small fresh-water crustaceans) all appendages are adapted for swimming and respiration (Fig. 14.32).

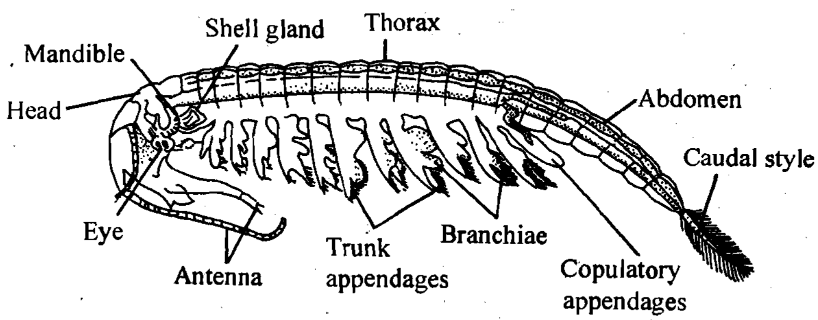


Fig. 14.32: Branchiopoda: appendages used for swimming and respiration

The water fleas swim by strong second antennae. The free living tiny copepods also use mainly their second antennae for swimming (Fig. 14.33 a). Most crustaceans have become crawlers, though they can also swim and burrow. Whereas many parasitic copepods (Fig. 14.33 b) have become highly modified for parasitic mode of life, the prawns, lobsters, crabs and many others possess well-formed swimming and walking appendages. The walking in prawns and lobsters is effected by five pairs of walking legs, which are the posterior thoracic appendages (Fig. 14.34 a). For swimming, these animals have six pairs of abdominal appendages, named **pleopods** and **uropod** (Fig. 14.34 b). The crabs have abandoned swimming and are adapted for walking. Consequently they have their abdomen shortended, abdominal appendages absent and five pairs of thoracic legs developed for walking.

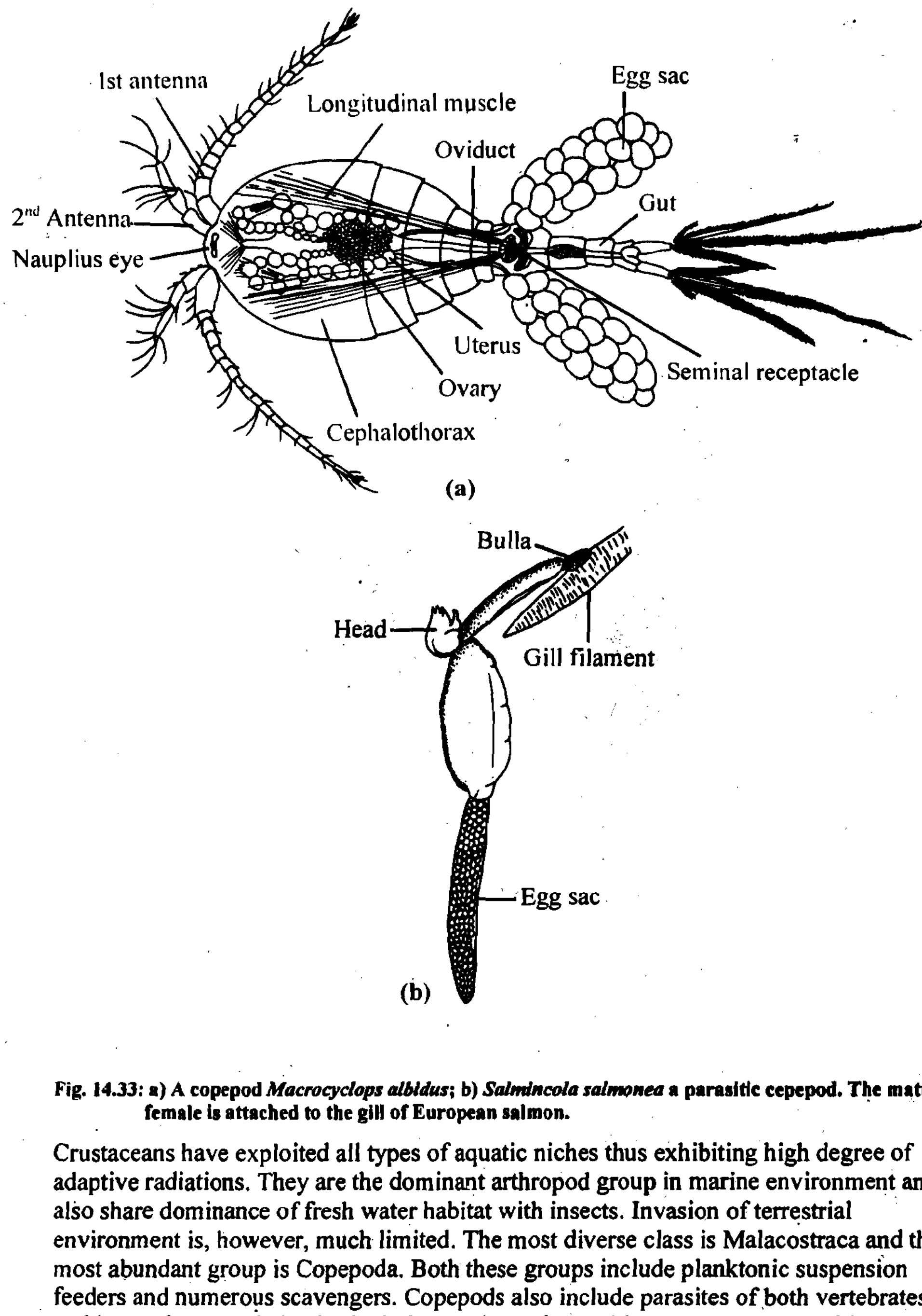


Fig. 14.33: a) A copepod *Macrocyclops albidus*; b) *Salmincola salmonea* a parasitic cepepod. The mature female is attached to the gill of European salmon.

Crustaceans have exploited all types of aquatic niches thus exhibiting high degree of adaptive radiations. They are the dominant arthropod group in marine environment and also share dominance of fresh water habitat with insects. Invasion of terrestrial environment is, however, much limited. The most diverse class is Malacostraca and the most abundant group is Copepoda. Both these groups include planktonic suspension feeders and numerous scavengers. Copepods also include parasites of both vertebrates and invertebrates. Cirripedes includes sessile and parasitic crustaceans. Parasitic copepods exhibit varying degree of modifications as compared to the free living ones. In most parasitic copepods the adults are parasitic exhibiting free swimming larval stages. Parasitic cirripedes also show modifications as compared to free living ones. Their body is saccular and the mantle is devoid of calcareous plates. There is also the absence of appendages and segmentation.

In aquatic insects swimming is effected by variously modified legs (Fig. 14.35 a). In many larval forms hairy bristles help in swimming e.g. rudder-bristles on the ninth abdominal segment of mosquito larvae (Fig. 14.35 b).

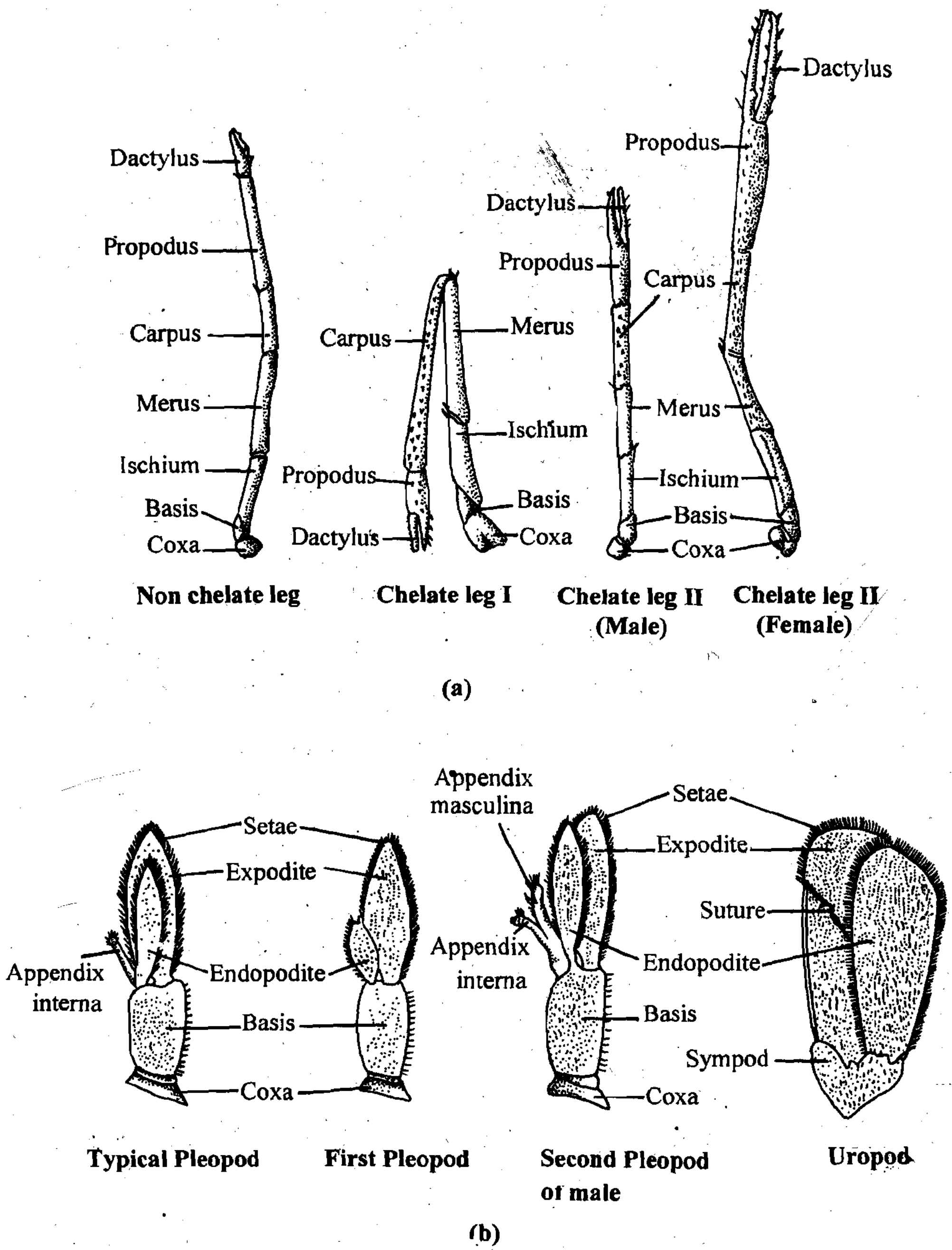


Fig. 14.34: Walking legs of prawn (a) Swimming appendages of prawn (b).

Locomotion in Terrestrial Arthropoda

In most adult terrestrial arthropods well developed walking legs are present, which are adapted to the needs of their habitats. Their number and structure are variable. Scorpions possess four pairs of walking legs (Fig. 14.28 a) meant for running fast. In spiders also four pairs of walking legs are present and all of them are used in walking. These arthropods can move very rapidly for short periods.

Centipedes and millipedes are adapted for living in soil and among litter and in crevices among stones, logs and bark. Centipedes have one pair of legs per segment while in millipedes there are two pairs per diplosegment. Unlike other arthropods these legs are short and stumpy. They are adapted for crawling, swift walking and running. Millipedes can also effectively push into soil.

Adult insects, as a rule, possess three pairs of legs and are appropriately called **hexapoda,** i e, *six-footed.* An insect leg is attached to the thoracic wall by means of a ring-shaped coxa. Besides coxa it has five more segments viz. **trochanter, femur, tibia, tarsus** and **pretarsus,** (Fig. 14.36). The tarsus may have three to five sub segments called **tarsomeres.** The insect legs not only serve the function of locomotion but also undertake other roles like jumping (hind-legs in grasshopper, Fig. 14.37 a), **swimming** (hind-legs in *Gyrinus*, Fig. 14.35 a), **digging** (fore-legs in mole-cricket, Fig. 14.37 b), **grasping** (fore-legs in praying- mantis, Fig. 14.37 c) and **grooming** (toilet-organ in the hind- legs of honey-bees, Fig. 14.37 d).

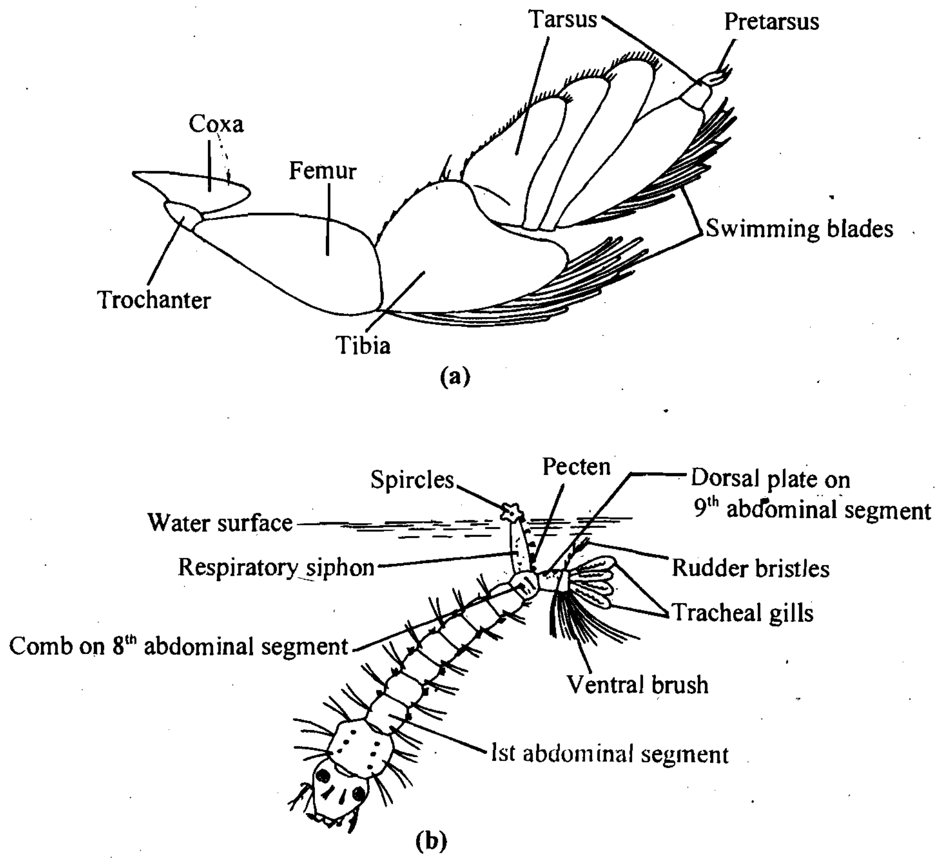


Fig. 14.35: An insect leg adapted for swimming (a); Rudder- bristles of mosquito larva (b).

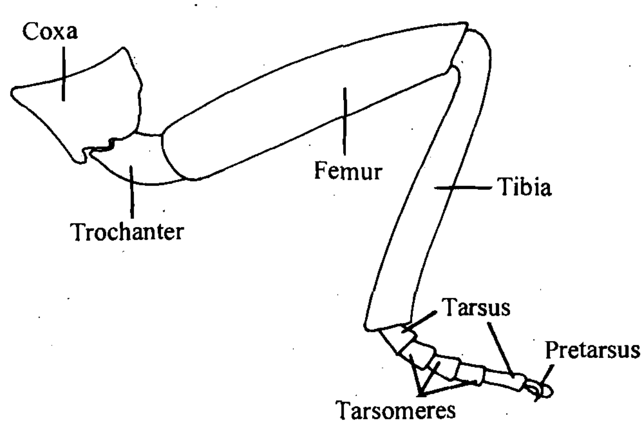


Fig. 14.36: Insect leg adapted to different functions.

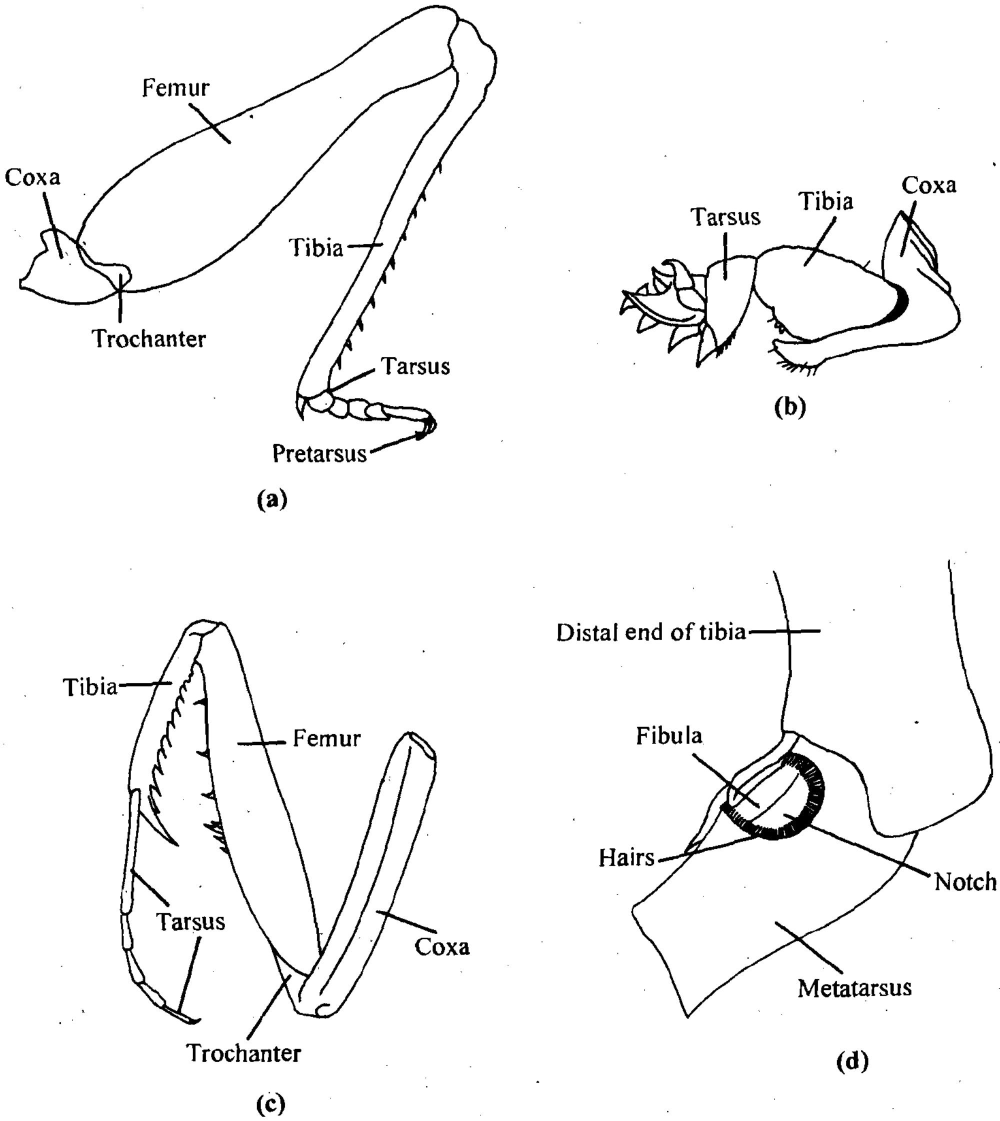


Fig. 14.37: Insect legs adapted for a) jumping; b) digging; c) grasping; d) toilet organ of honey bee for grooming.

Insect Wings: The outstanding success of insects as terrestrial animal is, to a great extent, on account of their ability to fly. For this purpose most of them usually bear two pairs of wings on their thoracic segments. We will discuss the wing structure and the mechanism of flight, in insects in section 14.4.

SAQ 7

i) Indicate whether the following statements are correct or incorrect.

a) Mouth parts in Arthropoda are modified segmental appendages.
b) In prawns and lobsters walking is effected by abdominal appendages.
c) In aquatic insects swimming is brought about by six pairs of abdominal appendages.
d) The hind-legs in grasshoppers are adapted for jumping.
e) In centipedes two pairs of legs are present in each segment.
f) Rudder-bristles in mosquito larvae are used for respiration.

14.3.3 Adaptive Radiation in Mollusca

Presence of shell, mantle, radula and foot distinguishes mollusca from the other animal phyla. Present-day molluscans are represented by forms like *Neopilina* (Monoplacophora), chitons (Polyplacophora), *Dentalium* (Scaphopoda), snails and slugs (Gastropoda), mussels and oysters (Pelecypoda), and squids and octopuses (Cephalopoda). Respiration in aquatic forms takes place by means of gills and in terrestrial molluscs by lung. The adaptive modifications in Mollusca are chiefly reflected in the shell, foot and respiratory apparatus. You have already studied extensively the structure and types of molluscan shell in Unit 4 Block 1 and the various modifications of the foot in Unit 7, Block 11 of this course. You may recall those portions here. We will now discuss the structural modifications of respiratory mechanism in Mollusca in the following paragraphs.

Respiration in Mollusca

Molluscs are mostly marine. Some gastropods and pelecypods are found in fresh-water while the pulmonate gastropods occur on land. Aquatic molluscs employ gills or **ctenidia** (singular- ctenidium) for respiration. The terrestrial forms, on the other hand, breathe by means of the **pulmonary chamber**, usually referred to as the 'lung'. In some molluscs exchange of respiratory gases takes place through the general body surface. Thus we have branchial, pulmonary and cutaneous respiration in Mollusca.

Branchial or ctenidial respiration occurs in aquatic molluscs. Formed as an outgrowth of the bodywall the ctenidia are present in the **mantle cavity**. In all molluscan groups the basic structural plan of the ctenidium is the same. A gill has a horizontal main axis, which remains attached to the body. The axis possesses on one or both sides a row of delicate, flexible **respiratory lamellae** (singular-lamella) with their surface covered with ciliated epithelium (Fig. 14.38). When the lamellae are present on one side only, the gill is called **monopectinate** and if the lamellae are present on both sides, **bipectinate**. The ciliary movement drives a continous flow of water over the richly vascular gills, which receive deoxygenated blood through inlet veins or **afferent branchial** veins. The gills return oxygenated blood through outlet or **efferent branchial** veins. The direction of flow of water current over the gills is always opposite to the direction of blood-flow within the gills (Fig. 14.38 c). This countercurrent flow ensures maximum and efficient gas exchange.

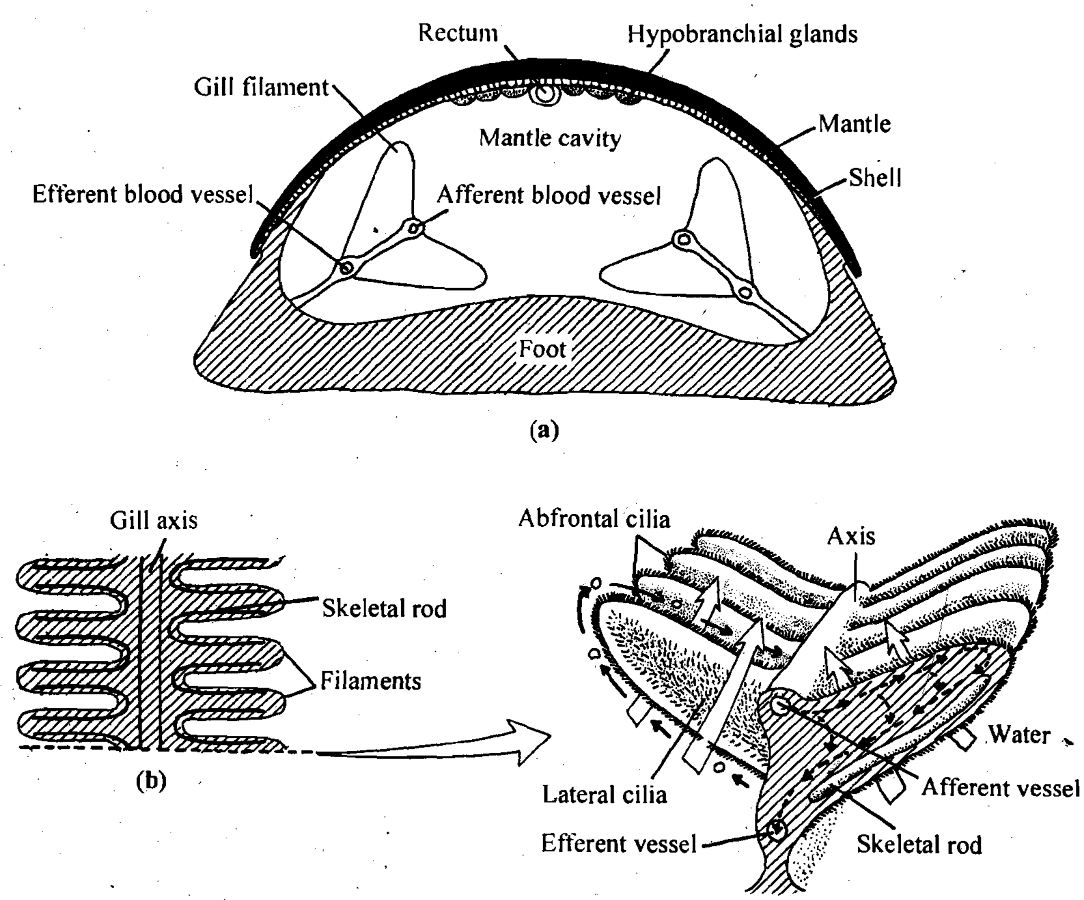


Fig. 14.38: Transverse sections through the body of a mollusc at the level of mantle cavity a). Frontal section through the gill showing gill lamellae b). Transverse section through current and blood flow c). the gill lamellae showing directions of water current.

The **ctenidial arrangment** differs in different classes of Mollusca. In Pelecypoda the gills subserve not only respiration but help in feeding also. In Monoplacophora there are five pairs of monopectinate gills with finger-like lamellae (Fig. 14.39 a). The position of the gills in this class shows segmental nature of the Mollusca, which otherwise is not apparent in other classes. In Polyplacophora the chitons have six to eighty bipectinate gills arranged in a row within the two mantle cavities (Fig. 14.39 b). While in the Aplacophora (Solenogastres) the gills are reduced or absent.

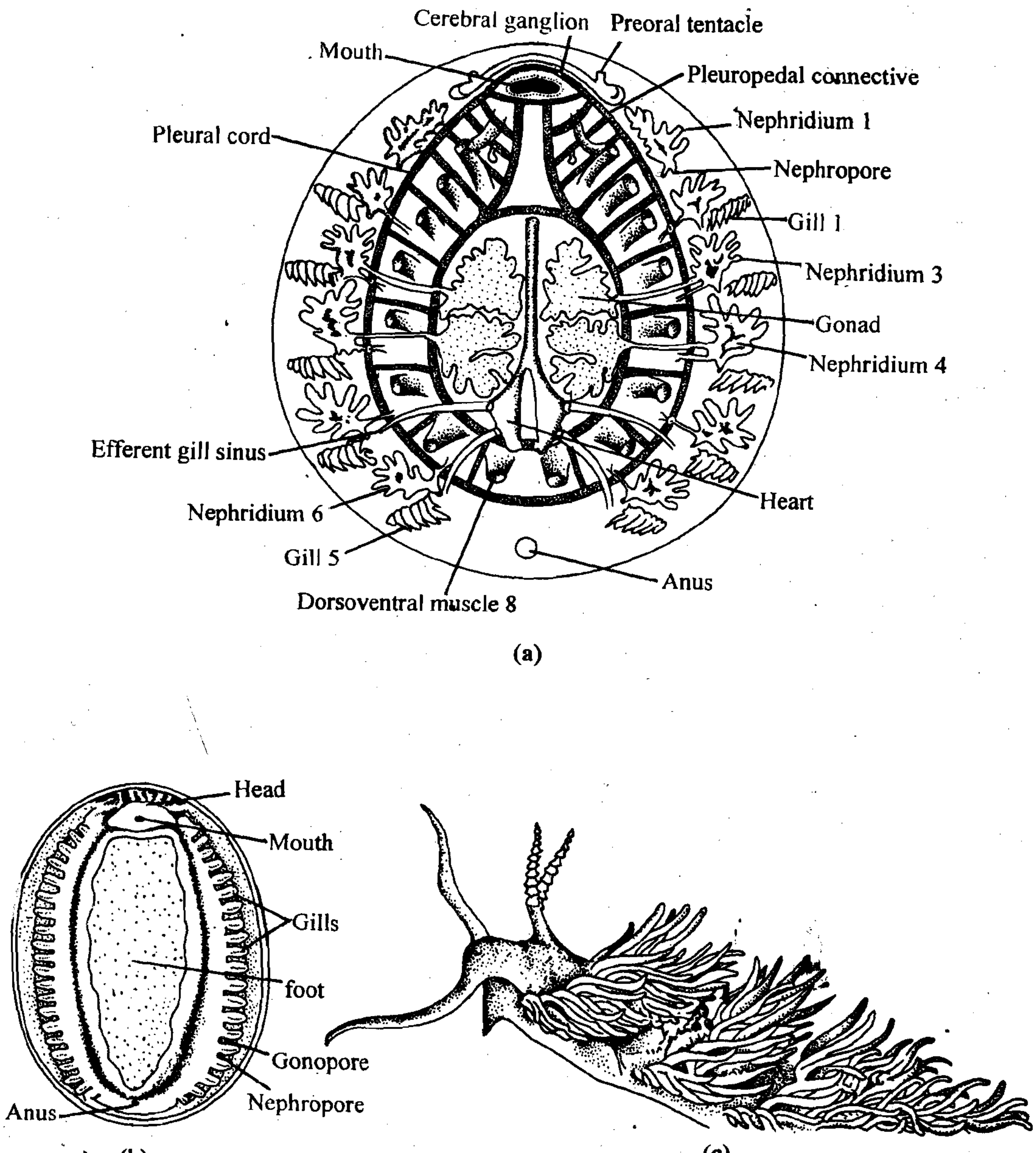


Fig. 14.39: Molluscan gill - a) Monoplacophora (*Neopilina*); b) *Chiton*; c) Sea slug (*Aeolis*).

Gastropoda has three subclasses : Prosobranchia, Opisthobranchia and Pulmonata. In Prosobranchia the gills are shifted in front along with the mantle cavity due to torsion and there may be one monopectinate gill (as in *Pila*) or two bipectinate gills (as in *Haliotis*). In **Opisthobranchia** the mantle cavity and the organs it contains shift to the right side due to detorsion (see earlier unit for torsion). Forms like **Aplysia** (sea-hare) possess one ctenidium on the right side while **Doris** and **Aeolis** (Nudibranchia) have altogether lost true gills. Instead, they have acquired secondary gills which are present either around the anus or on the lateral edge of the mantle or in rows on dorsal body surface (Fig. 14.39 c). In pulmonates, gills are absent. Mantle cavity is on the right side. This becomes a vascularised "lung" for air breathing.

Pulmonary Respiration: In terrestrial gastropods the mantle cavity is transformed into a **pulmonary chamber** or **lung**, the roof of which is richly supplied with blood vessels. The evolution of the pulmonary sac is a land adaptation. Alternate muscular contraction and relaxation of the mantle floor causes the air to enter in and pass out of the pulmonary sac through a small aperture guarded by a valve. The exchange of gases occurs through the mantle wall. In some forms the pulmonary sac may also help in aquatic respiration.

The gills in Pelecypoda have a complex structure. Besides breathing, they also help in collecting food and serve as a brood-pouch. There is one pair of bipectinate gills in the mantle cavity, one on either side of the body. These extend from the anterior to the postrior end of the animal. On either side of the axis in each gill, long filaments extend ventrally and then bend upward like a hairpin (there being two "hair pins" on each side) (Fig. 14.40). There is an ascending and a descending limb in each "hairpin". These filaments may hang freely or the adjacent ones may be joined by inter filamentar junctions forming a gill-plate or demibranch. There are two gill plates on each side, an outer and an inner one. Each gill-plate has two lamellae each made of an ascending and a descending limb. The outer and the inner lamellae are joined together by interlamellar junctions (Fig. 14.40). The gill-plates divide the mantle cavity into an upper **suprabranchial** and a lower **infrabranchial chamber**. The former opens to the exterior by excurrent (exhalant) or dorsal siphon which drains the water out. The infrabranchial chamber has an incurrent (inhalant) or ventral siphon through which the water enters the mantle cavity. The action of the cilia present on the gills maintains a continuous water current over their surface in the mantle cavity, where exchange of gases take place.

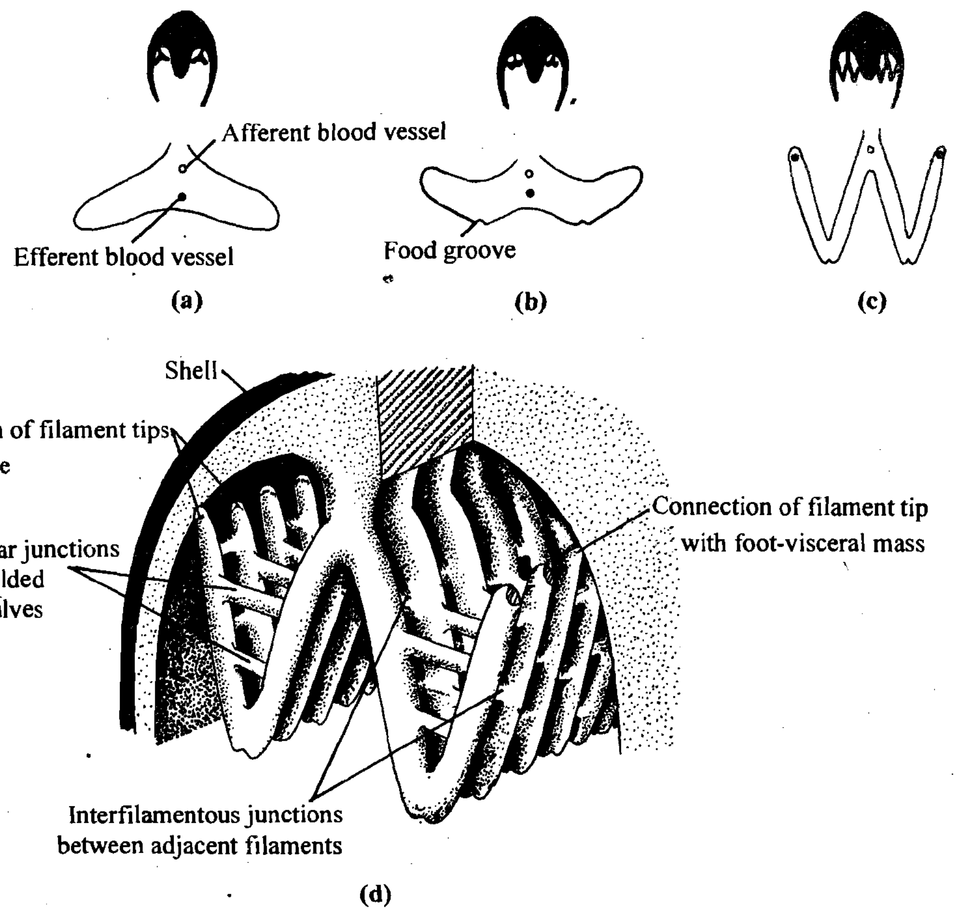


Fig. 14.40: Evolution of Lamellibranch gills in Pelecypoda. a) Primitive protobranch gill b) Food groove development to create lamellibranch condition. c) At food groove the filaments fold to form lamellibranchs conditions. d) Lamellibranch gills with tissue junctions providing support to the folded filaments.

Filter Feeding

Pelecypods are sedentary feeders and wait for the food to come their way. The constant inflow of water through the incurrent siphon into the mantle cavity brings in food particles which include micro-organisms and organic debris. When water enters the mantle cavity the heavier particles sink down and are expelled. The lighter food particles pass over the outer surface of the gill lamellae where they get entangled in mucus secreted by the gills. The mucus-mixed food particles pass into food grooves on the ventral edges of the gills, which take these towards the mouth. Near the mouth the labial palps further sort out the particles according to their nature. Smaller digestible particles are taken to the mouth while larger indigestible ones are thrown out of the mantle cavity.

Cephalopods have simple bipectinate gills situated on either side of the anus. The leaf-like lamellae are arranged in a linear row on the axis. There are no cilia on the gill surface and the flow of water is regulated by the muscular mantle, funnel and the inlet-valves. There are two gills in the cuttlefish, squids and octopuses and four in nautiloids.

Cutaneous Respiration

In Scaphopoda, Aplacophora and parasitic or terrestrial Opisthobranchia respiration occurs through the moist integument of the mantle cavity or through the general body surface. It is called cutaneous respiration.

SAQ 8

i) Fill in the blanks in the following sentences using words given in the parenthesis below:

(deoxygenated, efferent branchial, ctenidia, afferent branchial, oxygenated, flow, drives, vascularised)

a) Formed as an outgrowth of the bodywall, the .... are present in the mantle cavity.

b) The ciliary movement drives a continuous flow of water over the richly .... gills, which receive .... blood through inlet veins or .... veins and return .... blood through outlet veins or .... veins.

ii) Indicate whether the following statements are true (T) or false (F).

a) In Pelecypoda gills also serve food capture.

b) There is one monopectinate gill in *Pila*.

c) *Aeolis* and *Doris* do not possess true gills.

d) The gill surface in Cephalopoda is ciliated.

e) Pulmonary chamber is found only in aquatic Mollusca.

f) In Opisthobranchia the gills are anteriorly placed.

14.4 FLIGHT IN INSECTS

Insects are unique among non-chordates to have evolved the ability to fly. For this purpose most adult insects possess one or two pairs of wings on their thoracic segments. The wings form an important basis of insect classification. There are chiefly two types of insects : winged and wingless. Wingless insects may be primarily wingless or secondarily wingless. In the former (primarily wingless insects) the wings have not evolved. The primarily wingless insects include silverfish and springtails. Secondarily wingless insects lost the wings during their evolution from winged insects. The ants, lice and fleas fall in the category which has secondarily lost wings. The dragonflies, butterflies, houseflies, mosquitoes, bugs, beetles etc. are winged insects. The wings of insects evolved as lateral outgrowths of the body.

Structure of Wings

The wing (Fig. 14.41) arises as dorso-lateral outgrowths of the bodywall on mesothorax and metathorax. It is a thin membrane and is supported by a system of tubular veins. The membrane actually consists of two layers of closely apposed integument. The veins are the heavily sclerotised regions where the two layers remain separate. The veins have branches of nerves and tracheae. Blood circulates through the veins in the wing.

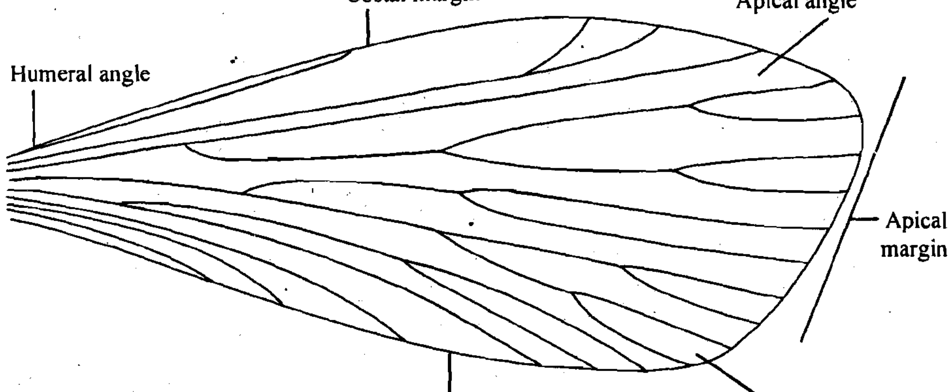


Fig. 14.41: Wing of an insect.

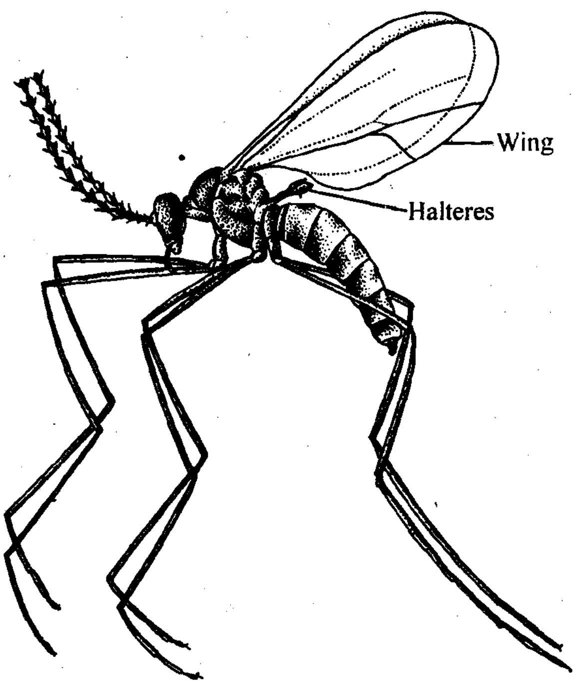


Fig. 14.42: A gall gnat showing wings and halteres. Halteres are responsible for equilibrium during the flight.

The forewings sometimes become hardened serving to protect the hindwings, as in the beetles. In the dipterans (eg. housefly and gnat) the hind wings have become modified into a sense organ called haltere (Fig. 14.42).

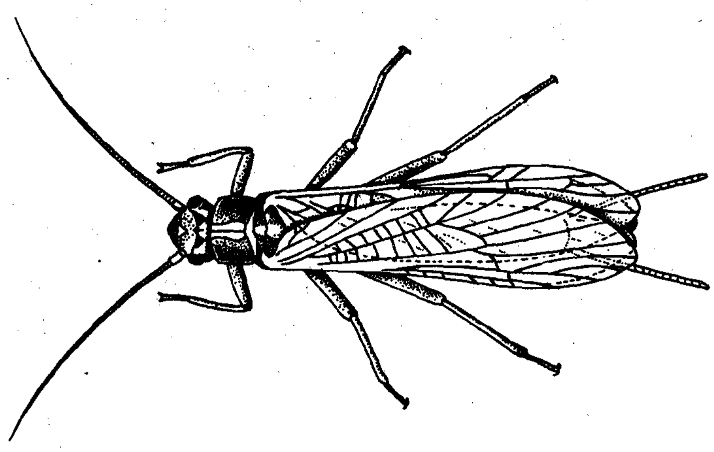


Fig. 14.43: Stonefly showing the wings folded at rest.

In most insects however the two wings on each side are membranous and can be folded at rest (Fig. 14.43). They are coupled to function as a single wing functionally. This increases their efficiency during flight.

Wing movement

Flight in insects is the result of co-ordinated wing beats. These movements are highly complex, involving various components like elevation (upward movement), depression (downward movement), and forward as well as backward movements. These wing movements are produced mainly by (1) muscles directly inserted into the wing base (direct flight muscles); (2) distortions of thorax brought about by muscles which are not directly associated with wings (indirect flight muscles) (Fig. 14.44 a-d); (3) elasticity of wing hinge. Once the muscles have moved the wings in a particular unstable position, the elasticity movements result in bringing the wings automatically into the stable position, with great force. This is known as "click" mechanism. Presence of a protein called "resilin" with considerable elastic property, in the hinge joints of insects, enables insects to bring about this "click" movement.

Insects thus fly with a wing beat frequency of 4-20/second as in butterflies or 190/second in honeybees and house flies. Some small dipterans may show a wing beat frequency of 1000/second.

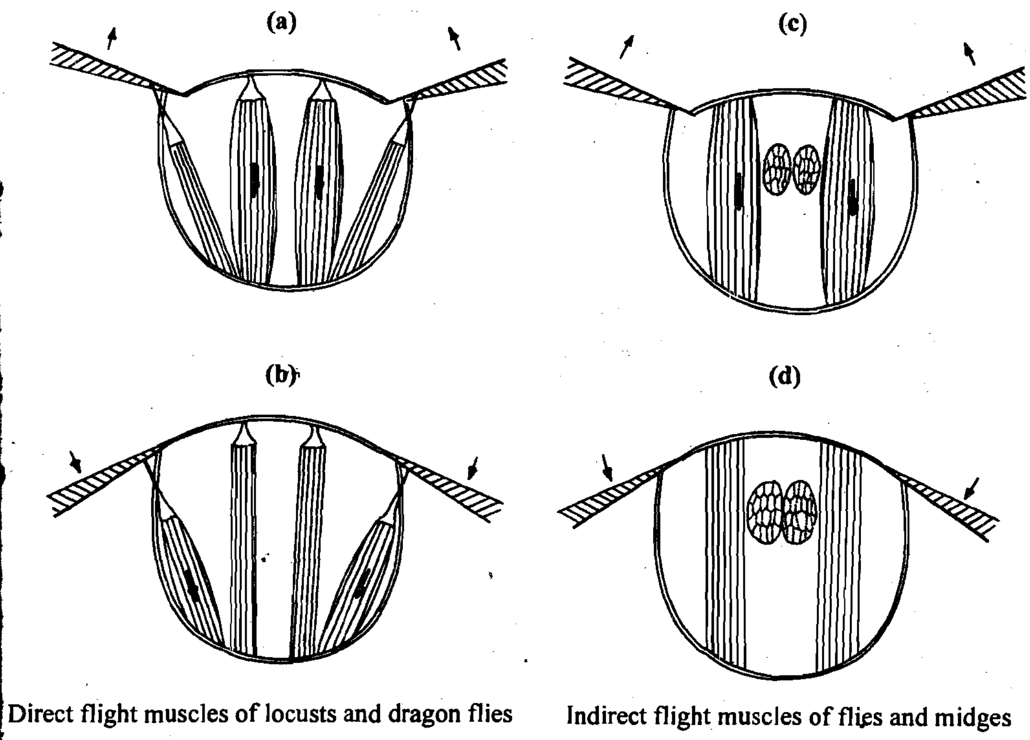


Fig. 14.44: (a) and (b) Flight muscles of insects such as dragonflies and locust where upward stroke is by indirect muscles and downward stroke is by direct muscles. (c) and (d) Flight muscles of insects like bees where both upstroke and downstroke are by indirect muscles.

Flight

The wing movements are very complicated. The whole mechanism of flight may be described in simple words as follows : The various wing movements create a low air pressure zone above and a high pressure zone below the wings due to which the body of the insect lifts above in the air. Similarly the wing twisting creates an area of low air pressure ahead and high air pressure behind the insect. This provides a forward thrust to the body. Many insects can remain stationary during flight. In their case wing movements create only lift and no thrust. Steering during flight is effected by shifting the centre of gravity or by altered wing- beats.

SAQ 9

i) Mark the correct alternative in the following statements.

a) The insects in which wings have not evolved at all, are called primarily/ secondarily wingless insects.
b) Dragonflies are winged/wingless insects.

ii) Match the words in list I with those in list II.

	List I		List II
1.	Silverfish	a.	Secondarily wingless
2.	Ants	b.	Primarily wingless
3.	Haltere	c.	Modified hind wings
4.	Resilin	d.	Help the click movement

14.5 MIGRATION IN INSECTS

In insects mainly two types of flight activity occurs. Trivial flight serves routine activities such as feeding and mating while during migration flight activity dominates. Migration is essentially dispersal. Whenever in a partciular habitat any environmental factor hinders feeding or breeding activity, the insects fly out to explore new pastures for food and reproduction. This is what we call migration. In the adult life of many insects there is a particular phase when this activity predominates. It is called the **migratory phase** and varies from a few hours as in many insects, to many days (as in some Coleoptera and Lepidoptera). In migration usually the animals move out from the feeding ground at the end of that activity in search of breeding ground and after breeding, they come back to the old habitat.

Since the main aim of migration is dispersal, females invariably participate in it, while males may or may not do so. In the locust, *Schistocerca* both sexes are included in migratory flights, but in the bug, *Eurygaster* males as well as females migrate from breeding to feeding grounds but only the females return to the breeding ground. In *Rhyacionia*, a lepidopteran, females are fertilized before they start migration to the breeding ground. The males do not migrate.

Direction of Migration

Direction of migration is mainly influenced by the wind-speed and direction of the wind. Wind speed increases as one moves higher in the air. The speed of insects in flight in relation to air is called air-speed. Wind-speed is comparatively lower closer to the ground. This forms what is called **boundary layer**. Air speed is greater than the wind speed at the boundary layer. However at higher levels, wind speed exceeds air speed. The insect can determine the direction and course of migration on its own in the boundary layer. For example, the moth *Ascia monuste* in Florida (US) flies 1 to 4 m above ground level. It can easily proceed against a wind current of 10 km/hour velocity. The direction of migration in this moth is determined by availability of flowers in the area. In other insects, factors responsible for determining the direction of migration may include position of the sun, landmarks such as roads, coastline etc. In the boundary layer the migration may be initiated by a number of factors but ultimately the position of the sun, pattern of the polarized light in the sky and the visual landmarks decide the migratory path.

Migration outside the boundary layer is seen in many insects. Sometimes those insects which usually migrate in the boundary layer, are seen flying above the boundry layer.

Ascia monuste has been reported flying at a height of 1500 m and above in Argentina. At higher altitude the insects fly in the direction of the wind current. Denser swarms of locusts at higher levels, in higher wind-speeds, fly in the direction of the wind. Aphids with a low air speed (0.6 m/second) find it difficult to fly against wind currents or to migrate within the boundary layer. They ascend up in the air due to positive phototactic reaction to ultra violet rays, and are then carried to long distances by wind currents. Many other insects such as dragonflies, beetles, butterflies and moths also move down-wind (in the direction of wind) at higher levels. Once the insects are carried to higher altitudes by higher wind currents (convection current) these carry the insects over long distance in a shorter duration. It is observed that swarms of locust *Schistocerca* cover a distance of 1200 km within 24 hours at 700 m above ground at a wind-speed of 45 km/hour.

Return Migration

Some insects show to and fro migratory movements. The monarch butterfly, *Danaus plexippus* in the United State migrates in autumn from the north where winter temperature becomes too low and food scarce, to the south where temperature is moderate and food supply plenty. In February these insects start return migration northward. This sentence is not fitting properly. Such two way migration by the same individuals is exhibited by *Agrotis infusa* (Lepidoptera) in Australia and *Hippodamia convergens* (Coleoptera) as well as a number of other insects.

Locust Migration

Locusts exhibit mass migration or swarms. The swarms of the desert locust, *Schistocerca gregaria* may cover an area of 10 to 250 square km. You may be surprised to know that a swarm spread over about 20 square km may contain about 100 crore individuals. The swarms may cover a distance of up to 100 km a day.

Locusts form two types of swarms viz. **stratiform** and **cumuliform.** In the former the locusts fly flat in the form of the thin layer within few meters above the ground and there may be 1 to 10 individuals per cubic meter. In cumuliform swarms locusts fly in a tower-like column extending up to 1000 m above the ground, with a low density of only 0.001 to 0.1 individual per cubic metre. The stratiform swarms are formed in the absence of convective currents to take them up while the cumuliform ones occur when there is convection current.

An interesting aspect of locust swarms is that all individuals in a swarm do not face forward. Their heads face in different directions. This is called **random orientation.** However, the locusts at the edge of the swarm face towards the body of other locusts. This helps to maintain the integrity of the swarm.

Beginning and End of Migration

Let us now examine the cause of migration. Migration is often initiated not by the actual onset of adverse environmental conditions. For example, in the monarch butterfly, the southward migration begins before the onset of cold conditions in the north, and locust swarms leave their habitats while plenty of food is still available. This shows that migration is an evolved adaptation in these cases and does not result from adverse environmental stimuli as such. Migration begins even before the onset of adverse conditions. This may be called **spontaneous migration.** On the contrary, in some cases migration may be stimulated by some physiological or behavioural phenomena which put the insect into a state of readiness to migrate. This type may be called **facultative migration.** Photoperiod, temperature and food supply are some such factors. Once the insects are kept in a state of readiness to migrate, the actual take off may be stimulated by another set of factors, like light of a particular intensity, wind speed, temperature etc. Similarly, it is not the physical exhaustion which brings migration to an end, but different wave-lengths of light being reflected by leaves (as in aphids), smell of salt-marshes (as in *Ascia*) and odour from host trees (as in beetle Melolontha) etc. may be responsible for the termination of migration.

Significance of Migration

Migration enables the species to cope with the changes in the location of its habitats. It is more common in those insects which occupy temporary habitats. For example, many species of Odonata, which live in permanent streams do not migrate whereas more than half of those living in temporary pools do so. The temporary nature of habitats may be due to changes in temperature, humidity, rainfall, etc. Migration is a way of over coming the adverse environmental conditions.

SAQ 10

i) Indicate whether the following statements are true (T) or false (F).

a) Trivial flight serves feeding and mating.
b) In the locust *Schistocerca*, only males are included in migratory flights.
c) Boundary layer of the air is near the ground and within this layer the air-speed is greater than the wind-speed.
d) Monarch butterfly, *Danais plexippus* in the US migrates in winter from south to north.
e) At higher altitudes in the air the insects fly downwind i.e. in the direction of the wind.
f) Spontaneous migration is initiated by one or the other environmental factor.
g) Physical exhaustion of the insect brings migration to an end.
h) Migration is common in those insects which live in temporary habitats.

14.6 SUMMARY

In this unit you have learnt that:

- Animals which lead their lives as individuals are called solitary and those living in organised groups are known as colonial. True colonies in which individuals or zooids are organically connected by living matter, are present in protozoans and coelenterates. Polymorphism and division of labour are some of the important features of colonial life.
- If the animals of the same or closely related groups adapt for different modes of life, they are said to show adaptive radiation or adaptive divergence.
- The basic needs of animals viz. food and safety, lead to adaptive radiation. Among non-chordates Annelida, Arthropoda and Mollusca exhibit clear adaptive radiation.
- Adaptive radiation is chiefly reflected in method of feeding and exploitation of different habitats in Annelida, respiratory modifications and limb modifications in Arthropoda as well as modifications of shell, foot and respiratory apparatus in Mollusca.
- Wings are unique acquisitions of insects. Formed as dorso- lateral outgrowths of the body wall, these are moved by direct and indirect flight muscles as well as by elasticity of the thorax, of flight muslces and of wing hinge. They impart capability of flight to the insects.
- Two types of flight activity are shown by the insects. Trivial flight for routine activities like feeding mating etc., and migration for dispersal. Migration is common in many species of insects and may be either spontaneous or facultative.

14.7 TERMINAL QUESTIONS

1. Differentiate between adaptive convergence and adaptive divergence. Write the answer in two or three lines in your own words.

....

....

....

....

2. Name three flagella-bearing Protozoa which form advanced colonies. Does any of these show polarity and if yes, explain why you think so.

....

....

....

....

3. Define polymorphism. Why do you say that Siphonophora colony is polymorphic?

....

....

....

....

4. Mark the correct alternative in the following statements:

   a) The animals which would wait for the food to come their way, acquired radial/bilateral symmetry.
   b) Filter-feeding has evolved in sedentary/active food- seekers.
   c) Eversion of proboscis affects feeding in predatory/parasitic Polychaeta.
   d) Earthworms lack/possess antennae and palpi.
   e) One full meal by a leech may last for four hours/months.

5. Give two advantages and two disadvantages of the hard and tough body cover in Arthropoda.

....

....

....

....

6. Match the words in the List A with the most appropriate ones in the List B.

	List A		**List B**
1.	Branchiae	a.	Dipteran larvae
2.	Tracheae	b.	Stonefly larvae
3.	Anal (tracheal) gills	c.	Insects
4.	Blood-gills	d.	Crustacea

7. Molluscans are believed to have evolved from annelidan ancestors, though they show no trace of segmentation. Give two grounds on the basis of which their ancestry may be linked with Annelida.

....

....

....

....

8. Indicate whether the following statements are correct or incorrect.

   a) Migration in insects is meant for feeding only.
   b) In a stratiform swarm locusts fly in a column at about 1000 m above ground.
   c) In random orientation all individuals in a locust swarm face forward.
   d) The course and direction of the insect migration is determined by the position of the sun alone.

14.8 ANSWERS

Self Assessment Questions

1. i) (a) environment, adaptive convergence.
   (b) adaptive divergence.

   ii) (a) F, (b) T, (c) F, (d) F

2. i) (1) c, (2) a, (3) b, (4) d.
   ii) monopodial, sympodial, permanent.

3. i) Osborn, ii) Lamarck, iii) errant polychaetes, (iv) oceans

4. i) (a) F, (b) T, (c) F, (d) T.

ii) (a) food, (b) safety.

5. i) and ii) incorrect, iii) and iv) correct.

6. i) booklungs, four, ii) book-gills, iii) Phyllo-branch, trichobranch and dendrobranch, iv) Odonata, v) *Nepa*.

7. i) Correct, ii) and iii) incorrect, iv) Correct, v) and vi) incorrect.

8. i) (a) ctenidia, (c) vascularised, deoxygenated, afferent branchial, Oxygenated, efferent branchial.
   ii) (a) T, (b) T, (c) T, (d) F, (e) F, (f) F.

9. i) (a) primarily, (b) winged,
   ii) 1 - b; 2 - a; 3 - c; 4 - d

10. i) a) T, b) F, c) T, d) F, e) T, f) F, g) F, h) T.

Terminal Questions

1. In adaptive convergence animals of unrelated groups adapt for the same habitat while in adaptive divergence those belonging to same or closely related groups adapt for different habitats.
2. *Volvox*, *Pleodorina* and *Pandorina* form advanced colonies among flagella-bearing protozoans. All of them show polarity because they swim always with a particular side facing forward.
3. Polymorphism is the occurrence of zooids or individuals in a colony in many forms, which exhibit division of labour. Siphonophora colony consists of gastrozooids for feeding, dactylozooids for protection, and three types of other zooids - gonozooids concerned with reproduction, nectophores for locomotion and gas-filled pneumatophores for floating.
4. Correct alternatives are : (a) radial, (b) sedentary, (c) predatory, (d) lack, (e) months.
5. **Advantages:**
   1) Provides support and protection,
   2) Prevents desiccation,

   Disadvantages:
   1) Hampers growth
   2) Hinders smooth gaseous exchange through general body surface.
6. (1) e, (2) d, (3) b, (4) a.
7. The two grounds are :
   1) A trochophore larval stage occurs in Polychaeta among Annelida as well as in Mollusca.
   2) The arrangement of paired gills in *Neopilina* (Monoplacophora) points to the segmental nature of Mollusca.
8. All statements are incorrect.