UNIT 1: INTRODUCTION TO INVERTEBRATES

CONTENTS

1.1. OBJECTIVES

After reading this unit the readers will be able to:

- Explain the types of coeloms,
- Explain enterocoelomate and schizocoelomate animals,
- Discuss about significance of coelom,
- Differentiate between protostomia and deuterostomia, and
- Discuss about diploblastic and triploblastic animals

1.2. INTRODUCTION

Among living organisms,the estimated number of animal species on our planet falls somewhere in the vast range of 7.77 million (Chapman's 2009).Of this number about 3 percent have a backbone and are known as **vertebrates**. All other, thatcomprise about 97% of the animal kingdom, are **invertebrates**. The invertebrates include vast and heterogeneous groups. The range in their size, in structural diversity and in adaptation to different modes of existence, is enormous. Some invertebrates have common phylogenetic origins, others are only remotely related. However, the life of invertebrates is fascinating and without a thorough study of invertebrates, it is hardly possible to know the secrets of life of animals on the whole.

Presently, there are 30 invertebrate phyla and these are characterized by a unity ofbasic structural patterns. However, the members of each phylum may differ in external features, but the anatomical features are constructed on the same ground plan in many respects. Customarily, the invertebrate phyla have been divided into **major** and **minor phyla**. This concept is based on two factors.

(i) The number of species and individuals

(ii) Their participation in ecological communities

On the basis of first factor, phylum Protozoa (50,000 *sp.*), Porifera (10,000 *sp.*), Coelentrata(11,000 *sp.*), Mollusca (112,000 *sp.*), Annelida (17000 *sp.*), Arthropoda (9.00,000*sp.*) Ectoprocta (4000 *sp.*), Rotifera (1500 *sp.*) and Echinodermata (7,000 *sp.*) are major phyla.

On the basis of second factor, if the phyla are represented in great majority of ecological communities, they would be regarded as major phyla. On this basis, in spite of greater in number Rotifera and Ectoprocta cannot be considered as major phyla. These are included in minor phyla due to their limited participation in animal communities and they form only a fraction of animal communities.

The invertebrate phyla are termed as **higher** and **lowerinvertebrates**. It usually refers to the levels at which species or groups have stemmed from certain main lines of evolution. Various phyla like Porifera, Coelenterata, Platyhelminthes and Nematoda occupy lower position in phylogenetic tree, so are included in **lower invertebrates**. The lower invertebrates also have simple body organization. On the other hand, various phyla like Annelida, Mollusca, Arthropoda and Echinodermata occupy higher position in phylogenetic tree, so are included in **higher invertebrates**. They also have complex body organization. More rationally the animal kingdom is divided into two sub kingdoms called **Protozoa**and **Metazoa.** The protozoans are noncellular organisms *i*.e. the body of the individual is not divided into cells as in case of metazoans. Very frequently, the protozoans are described as unicellular eukaryotic protist animals.

The **metazoans** are multicellular and eukaryotic animals. The metazoans have certain qualities that must be considered in concert with the basic idea of multicellularity. Inspite of difference in structure and form of different animals, there are fundamental characteristics common to various individuals. These features are used as the basis of animal classification. Some characteristic features of metazoans are as follows.

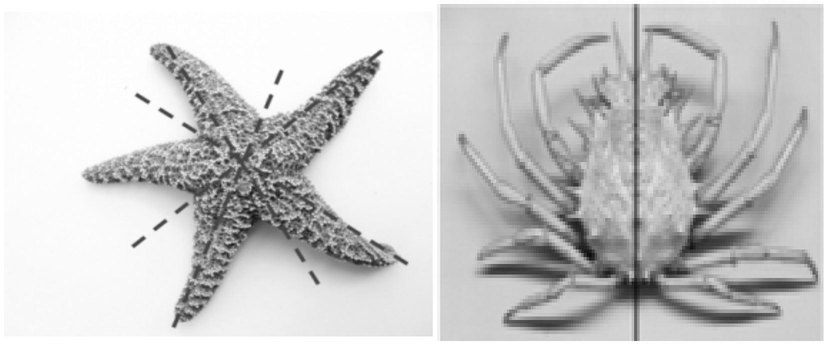
a. Levels of Organisations: Though animals are multicellular, the level of organization of cells varies from one animal to another. Certain animals have a loose mass of cells which may be similar or show minor division of labour. These animals exhibit cellular **level of organization.** e.g., **sponges**.As we move on, the complexity of body design amplifies and thecells of metazoans are organized into function units, generally as tissues and organ with specific roles which support the life of whole animal. The cells form poorly defined tissues, and exhibit **tissue level of organization**e.g. **Cnidarians** (=coelenterates), **ctenophores**.Phylum Platyhelminthes and Aschelminthes have **organ level of organization**. Nor-chordates such as Annelids, Arthropods, Molluscs, Echinoderms, and Chordates have specialised organ- systemfor theirphysiological activities. They have the **organ-system level of organisation**. Although these animals have organ-system levels of the organisation, the complexities of organ systems vary in different phyla.

b. Symmetry: Generally, metazoan animals show following types of symmetry -

Radial symmetry: A symmetry where any plane passing through the central axis divides the body into two equal halves is called the radial symmetry. Coelenterates, ctenophores and adult echinoderms show radial symmetry (Fig 1.1 A).

Bilateral symmetry: In bilateral symmetry, only a single plane divides the body into two equal halves. Annelids, Arthropods and Molluscs etc. show bilateral symmetry (Fig 1.1 B).

However, some animals do not show any symmetry i.e. their body can't be divided into two halves in any plane passing through the centre. Such animals are said to be **asymmetrical**, e.g. Poriferan.



AB

Fig 1.1 A. Starfish showing radial symmetry; B. Crab showing bilateral symmetry

Diploblastic and Triploblastic Organisation: Structurally the cells of metazoans are organized as embryonic or germ layers, which develop through a series of events early in an organism's embryogeny (Fig 1.2) **All** animals develop their tissues, organs and organ system from the cells that form the embryonic layers. These germ layers are the framework upon which the metazoan body is constructed. Based on the number of embryonic layers, animals are classified into two- diploblastic and triploblastic animals.

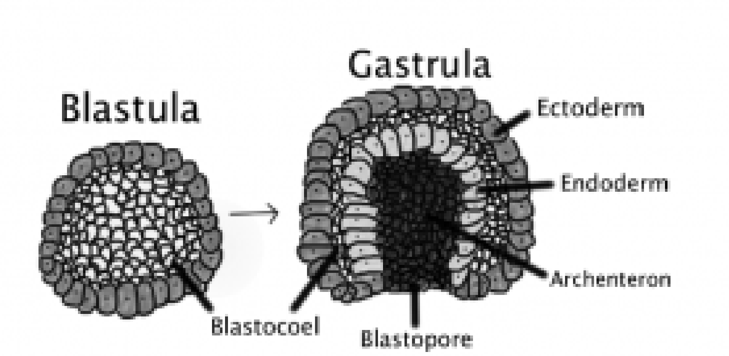


Fig 1.2 Formation of germ layers during embryogeny of an organism

Diploblastic animals: In diploblastic animals, the cells are arranged into two embryonic layers, i.e., an outer layer- ectoderm and an inner layer – endoderm. The layer present in between the ectoderm and endoderm is called mesoglea.Animals belong to Phylum Coelenterata exhibit diploblastic organisation.

Triploblastic animals: In triploblastic animals, the cells are arranged in three embryonic layers- ectoderm, endoderm and a middle layer – mesoderm. Animals belong to Phyla Platyhelminthes to Chordata have a triploblastic organisation.

Coelom: Coelom is a key feature for classification in metazoans. Coelom is a cavity between the body wall and gut wall, lined by mesoderm. Depending on presence/absence of coelom, animals have been classified into coelomates, pseudocoelomates and acoelomates.

Segmentation: The body of some animals is externally and internally divided into segments with serial repetition of at least some organs. For example; the body of the earthworm shows metameric segmentation. This phenomenon is called metamerism.

Body Plans of Animals: Animals have three types of body plans:

Cell Aggregate Plan: The body consists of a cluster or aggregation of cells. It is found in sponges.

Blind Sac Plan: The body has a single cavity with one opening to the outside. The single opening functions as both mouth for ingestion and anus for egestion. It is found in Cnidarians (=coelenterates) and flatworms.

Tube-within-a-Tube Plan: The body has two tubes i.e., body cavity and gut cavity.Gut cavity is a continuous tube-like structure within body cavity and has two openings, a mouth for ingestion and anus for egestion.Tube-within-a tube plan is of two types:**Protostomic plan** in which the mouth of the digestive tract develops first in the embryo and anus is formed later and **Deuterostomic Plan** in which the anus of the digestive tract develops first in the embryo and the mouth is formed later.

The metazoansare subdivided into three branches -**Mesozoa,Parazoa** and **Eumetazoa**. The mesozoa includes about 50 species of cellular animals, consisting of surface layer of somatic cells and inner reproductive cells. The **parazoa** or **porifera** include the sponges which are diploblastic and multicellular but have loose aggregations of cells which do not form tissues. There is no mouth or digestive tract. The body is porous with one or more internal cavities lined by choanocytes. The **eumetazoa** includes the animals of tissue or organ-system grade of organization with mouth and digestive tract. The eumetazoans include diploblastic animals with radial symmetry (Radiata) and triploblastic animals with bilateral symmetry (Bilateria). Bilateria is divided into two divisions - **Protostomia** and **Deuterostomia**.A broad outline of the subdivisions and main phyla of protostomia and of deuterostomia is given inTable 1.1.You will study about Protostomia and Deuterstomia in the Unit in detail.

Table 1.1: Outline Classification of Animal Kingdom (Meglitsch, P.A. 1972)

Kingdom Animalia

Protozoa
Unicellular(acellular)

Phylum Protozoa

Metazoa
Multicellular

Mesozoa

Phylum Mesozoa
Middle animals

Parazoa

Phylum Porifera
Pore bearing animals
Cellular grade of organization
No mouth and digestive cavity

Eumetazoa

Radiata
(Diploblastic)

Animals having two germ layers are diploblastic
Animals with radial symmetry
Tissue grade of organization
Body cavity and digestive cavity is common

Phylum Cnidaria
Radial Symmetry

Phylum Ctenophora
Biradial Symmetry

Bilateria
(Triploblastic)

Animals having three germ layers are triploblastic
Animals with bilateral symmetry
Organ/ organ system grade organization
Body cavity and digestive cavity areseparate

Protostomia
Blastoporegive rise to mouth

Acoelomata
Phylum Platyhelminthes
Phylum Nemertinea

Pseudocoelomata
Phylum Nematihelminthes
Phylum Entoprocta
Phylum Rotifera

Coelomata
Phylum Sipunculida **Phylum Phoronida**
Phylum Mollusca **Phylum Ectoprocta**
Phylum Echiurida **Phylum Brachiopoda**
Phylum Annelida
Phylum Onychophora
Phylum Arthropoda

Deuterostsmia
Blastopore give rise to anus

Phylum Echinodermata
Phylum Hemichordata
Phylum Chordata

TABLE 1.2Summary of important features of animal groups.

Animal Phyla	***Symme try***	***Grade of Organisa-tion***	***Coelom/ Germ layers***	***Respiratory Surface***	***Excretory structures***	***Modes of Reproduc-tion***
Protozoa	—	Protoplasmic level	-	Plasma-Lemma	Plasma-lemma	Asexual/ Sexual
Porifera	—	Cellular Grade	Diploblastic	Body wall	Body wall	Asexual/ Sexual
Cnidaria	Radial/ Biradial	Cell Tissue grade	Diploblastic	Body wall	Body wall	Asexual/ Sexual
Ctenophora	Biradial	Cell Tissue grade	Diploblastic	Body wall	Body wall	Only sexual
Platyhelminthes	Bilateral	Organ grade	Acoelomate /Triploblastic	Mostly anaerobes	Flame cells	Asexual/ Sexual
Aschelmin thes	Bilateral	Organ system grade	Pseudocoelo-mate/ Triploblastic	Mostly anaerobes	Glandular-organs & Canals	Sexual
Annelida	Bilateral	Organ-system grade	Eucoelomate (Schizocoelic)/ Triploblastic	Gills and Skin	Nephridia	Asexual/ Sexual
Arthropoda	Bilateral	Organ-system grade	Eucoelomate (Schizocoelic)/ Triploblastic	Gills, Tracheal tubes, Book Lung	Malpighian tubules, Green Gland	Asexual/ Sexual
Mollusca	Bilateral	Organ system grade	Eucoelomate (Schizocoelic) / Triploblastic	Gills/Ctenidia Pulmonary Sac	Keber's organ, Organ of Bojanus	Asexual/ Sexual
Echinodermata	Bilateral	Organ-system grade	Eucoelomate (Enterocoelic) /Triplobastic	Dermal bran-chiae, Gills	Amoebocytes	Sexual
Hemichor data	Bilateral	Organ-system grade	Eucoelomate (Enterocoelic)/ Triplobastic	Gills	Proboscis gland	Sexual
Chordata	Bilateral	Organ-system grade	Eucoelomate (Enterocoelic)/ Triploblastic	Gills, Lungs, Skin, bucco-pharyngeal cavity,	Neural glands, Paired kidneys	Sexual

1.3. DEVELOPMENTAL PATTERNS OF INVERTEBRATES

The bilateralmetazoans can be differentiated into two main assemblages based on either the formation of mouth first or the anus. Metazoans in which blastopore forms the mouth of the animal and anus is formed secondarily are called 'Protostomes' and in which blastopore forms the anus of the animal and mouth is formed primarily are called “Deutrostomes”.You will study about these two groups in the following subsections.

1.3.1 PROTOSTOMIA

The metazoans in which mouth is derived from blastopore on the anterior end and anus appears later to complete the alimentary canal are included in Protostomia (Fig. 1.3). As the mouth forms first, there animals are included in ‘Protostomia” (Mouth first) division of animal kingdom. Nerve cord is ventral in protostomes.

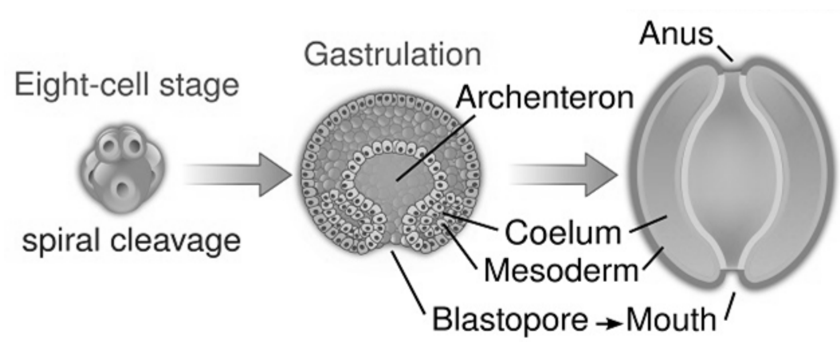


Fig. 1.3 Diagram showing development of mouth from blastopore

The developmental characteristics of protostomes are as follows.

1. **Pattern of embryonic cleavage:** Cleavage is spiral in protostomes, i.e., axis of cleavage plane is oblique, and so that blastomeres have a spiral arrangement in which one tier of cells alternates with the next tier of cells. The spiral cleavage is masked at the 6th cleavages 64-cell stage.

2. Fate of embryonic blastomeres: Fate of blastomeres is determined very early during holoblastic cleavage. This is called determinate or mosaic cleavage, which means blastomeres are destined to form a particular organ in very early stage of cleavage. In Figure 1.4 just after first cleavage ablation of one of the cells takes place which leads to the loss of head structure in embryo that drive from it. Such type of development is said to be mosaic.

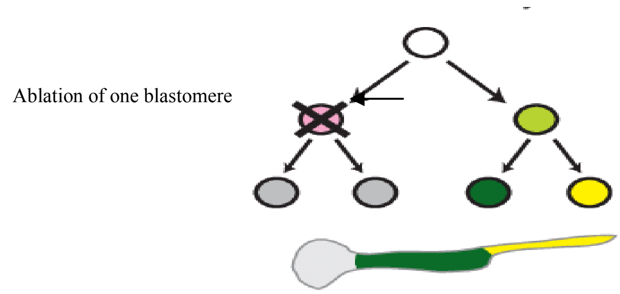


Fig 1.4 Development of mosaic embryo

3. Fate of blastopore:

The blastopore either becomes mouth (e.g., Mollusca) or gives rise to both mouth and anus (e.g., some molluscs, polychaetes and onychophorans) in adult.

4. Formation of mesoderm:

Mesoderm originates from the fourth cell, named as mesentoblast (also called as '4d' cell) which increases in number by proliferation.

5. Formation of coelom:

Coelom originates by the splitting of the mesodermal cell mass. This proess of coelom formation is known as**schizocoely**and coelom is called schizocoelom ('schizo' means'split').

Examples:

Coelomate protostomes include Sipuncula, Echiura, Annelida, Pogonophora, Mollusca, Onychophora, Tardigrada, Pentastomida and some groups of arthropods.

1.3.2.DEUTEROSTOMIA

The metazoans in which anal opening are derived from blastopore during embryonic development and represents the posterior end of body and mouth is formed later are included in deuterostomia (Fig. 1.5). As the anus forms first and mouth is formed secondarily, these animals are grouped in deuterostomia (Mouth second). Nerve cord is dorsal in deuterostomes.

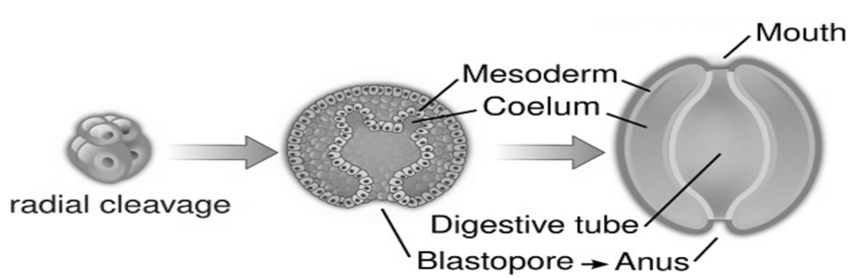


Fig. 1.5 Diagram showing development of anus from blastopore

The developmental characteristics of deuterostomes are as follows.

1. Pattern of embryonic cleavage: Radial pattern of embryonic cleavage occurs in which the cleavage plane is either parallel or at right angle to the polar axis. Blastomeres are arranged directly above or below one another.

2. Fate of embryonic blastomeres:

Cleavage is indeterminate and if blastomeres are separated at 4 cell stages, each one will develop into a complete individual.Cleavage is regulative because each of the blastomeres, if separated can regulate its development (Fig 1.6). In figure 1.6, if ablation of one cell takes place, then the descendants of the remaining cell can give rise to the structure in embryo that would have developed from the lost cell. In this case green cell is able to regenerate head structure as well as trunk region. Such development is said to be regulative.

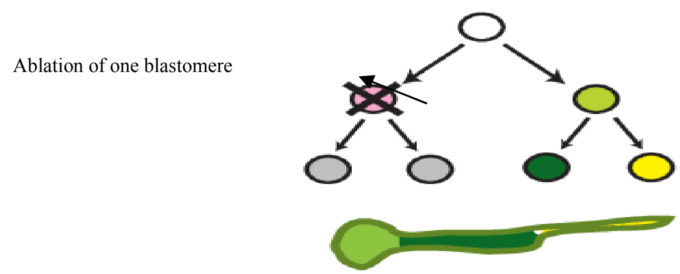


Fig 1.6Development of regulative embryo

3. Fate of blastopore:

Blastopore becomes the adult anus and then the formation of mouth takes place from a second opening on the dorsal surface of the embryo.

4. Formation of mesoderm: Mesodermal tissue is formed by the outgrowth of endodermal wall of the archenteron.

5. Formation of coelom: Coelom is formed by evagination of pouches from the wall of archenteron and each diverticulum becomes separated from the archenteron and develops independent coelomic pouch. This process of formation of coelom is called as **enterocoely**and coelom is calledasenterocoelom.

Examples: Deuterostomes include echinoderms, chordates, pogonophores, hemichordates and some minor phyla.

Major differences between Protosomia and Deutrostomia are listed in Table 1.2.

Table 1.2: Differences between Protostomia and Deuterostomia

S. No.	Protostomia	Deuterostomia
1.	Mouth originates from blastopore	Anal opening originates from blastopore
2.	Coelom is formed from schizocoely	Coelom is formed from enterocoely
3.	Cleavage is spiral and determinate	Cleavage is radial and indeterminate
4.	Composed of a solid ventral nerve cord	Composed of hollow dorsal nerve cord

1.4 BODY CAVITY AND COELOM

All animals have cavities. These cavities perform different functions in different animals.Generally, body cavity means a large fluid filled space lying between the body wall and the internal organs. The coelom is a perivisceral cavity between the body wall and alimentary canal. During embryonic development, coelom arises as a split in the mesoderm which becomes bifurcated into two layers, a **somatic layer** lying next to the epidermis and a **splanchnic layer** around the endoderm. Coelom becomes bounded on all sides by coelomic epithelium which secretes coelomic fluid. The excretory organs open into coelom at one end and to exterior at the other end. The wall of coelom gives rise to reproductive cells and to coelomoducts which carry sperms or eggs from the coelom to the exterior. The greater part of the coelom forms the perivisceral cavity or splanchnocoel, which is a fluid- filled space inside which visceral organs are lodged. Certain portions of the perivisceral cavity are cut off from it to form restricted cavities; such as gonocoel and nephrocoel, whose coelomic nature can only be realized, if their developmental history is followed. The annelids are the first animals to have a **true coelom**.

1.4.1 TYPES OF COELOMS

The evolutionary sequence of coelom is from acoelomate to pseudocoelomate and then to coelomate. The difference between a pseudocoelomate and a coelomate animal is the absence or presence of epithelial lining or peritoneum. It is present in a coelomate animal and absent in a pseudocoelomate animal. The embryological origin of a true coelom varies. If it develops from a split in cells of the mesoderm, it is said to be **schizocoelous**. If it develops from outpocketing from the embryonic gut, it is said to be **enterocoelous**. Thus, on the basis of presence or lack of coelom and its nature, when present the metazoans are often divided into three large groups.

I. ACOELOMATA

When coelom or fluid-filled cavity is absent, the animals are said to be acoelomates and the group is referred to as acoelomata. The Platyhelminthes having no coelom, are termed acoelomates. The space between the gut and body wall is filled by a kind of densely packed connective tissue derived from both ectoderm and endomesoderm (entomesoderm), called parenchyma (Fig.1.7A).

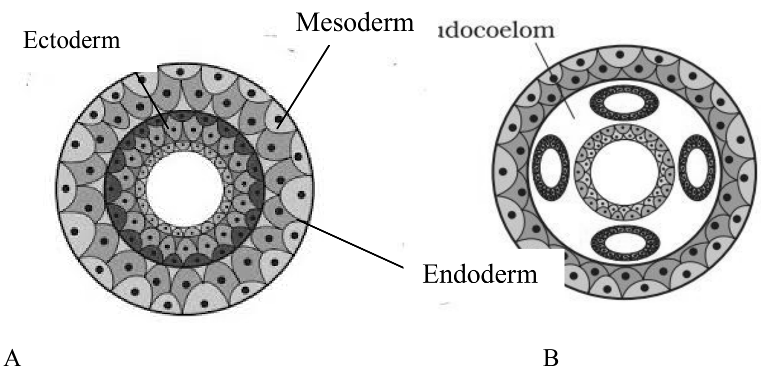


Fig. 1.7: Diagrammatic representation of A. Acoelomates B. Pseudocoelomates

II. PSEUDOCOELOMATA

The body cavity which is lying between the gut and outer body wall musculature andisgenerally formed by persistence of **embryonic blastocoel**, called as pseudocoelom. The term 'pseudocoelom' usually refers to the space which does not develop from embryonic mesoderm and it is lined by mesoderm only on the outer body wall side and not around the gut. Externally the pseudocoelom is bounded by the fibrous processes of the longitudinal muscle cells (mesoderm) and internally by the intestine (endoderm) (Fig.1.5B). The pseudocoelomic fluid acts as a hydrostatic skeleton to maintain body shape and circulate nutrients. In **nematyhelminthes**, pseudocoel is found so they aretermed as **pseudocoelomates**.

III. COELOMATA OR EUCOELOMATA

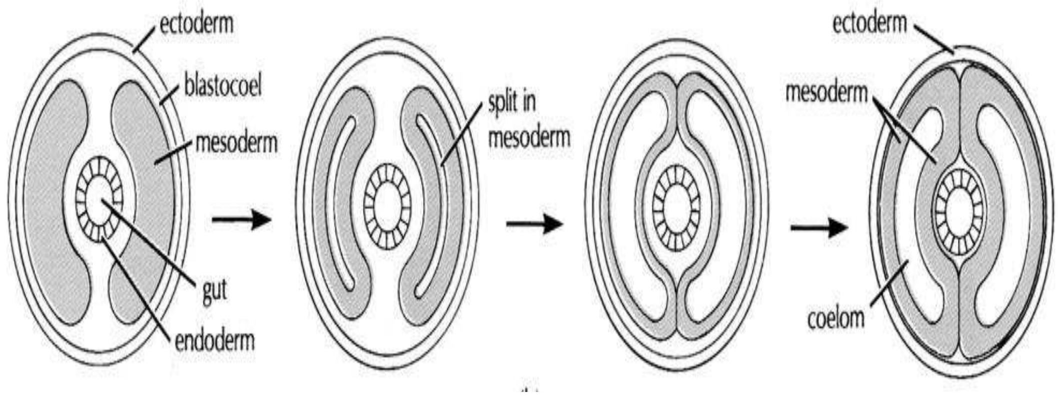
The coelom lying between the gut and outer body wall musculature and lined both on the inside of the body wall as well as around the gut by mesoderm, is referred to as **true coelom**. The true coelom is mesodermal in origin and opens to the exterior through the coelomoducts like the oviducts and the excretory ducts. The coelomic fluid contains amoeboid cells or amoebocytes. The animals containing such a body cavity or coelom, are termed as **eucoelomates**.

1.4.2 MODE OF COELOM FORMATION

According to the mode of coelom formation, there are generally two types of animals.

I. SCHIZOCOELOMATE

When coelom arises by the splitting of



mesodermal bands or masses during embryonic development, it is called as schizocoel and animals are called as schizocoelomates (Fig. 1.8). The animals belonging to phylum Mollusca, Annelida, Arthropoda, and Onychophora are schizocoelomates.

Fig.1.8Coelomformation by splitting of mesoderm

II. ENTEROCOELOMATE

When coelom is formed by the evagination from the embryonic archenteron and the pouch-like structures are detached from the archenteron and gradually occupy the whole body by enlargement, called as enterocoel (Fig. 1.9). The animals having enterocoel are called enterocoelomate. The animals belonging to phylum Echinochordata, Hemichordata and Chordata are enterocoelomates.

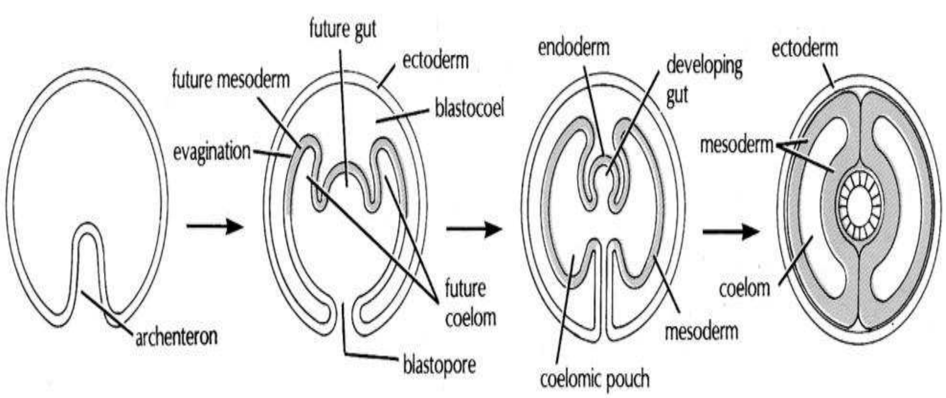


Fig 1.9Coelom formation by outpocketing of primitive gut

1.4.3 SIGNIFICANCE OF COELOM

The coelom has several advantages in the triploblastic animals.

i) It surrounds and protects the internal organs from external shocks.

ii) The coelomic fluid facilitates smooth transportation of nutritive substances within the body.

iii) Coelom provides flexibility to the body and permits free movement of the gut and its associated organs which remains suspended in it.

iv) Gonads which develop from coelomic epithelium are housed in the cavity of the coelom. The gonoducts allow the eggs and sperms to pass out of body. The excretory substances are collected from coelomic fluid andarepassed out of the body through the nephridia.

v) The coelom filled with incompressible coelomic fluid acts as a hydrostatic skeleton and helps in locomotion.

1.5. SUMMARY

Let us summarise whatever you have learnt so far:

- The invertebrates include vast and heterogeneous groups. The invertebrate phyla are termed as **higher** and **lowerinvertebrates**. The lower invertebrates have simple body organization while higher invertebrates have complex body organization. The animal kingdom is divided into unicellular protozoa and multicellular metazoan. The cells of metazoansare specialized and interdependent and their activities are coordinated into predictable patterns and relationships. The cells develop through layering during embryogeny. The animals with two germ layers i.e. ectoderm and endoderm, are called **diploblastic animals (**Radiata**)**. The animals with three germ layers i.e. ectoderm, mesoderm and endoderm are called **triploblastic animals (**Bilateria**)**. The diploblastic and triploblastic animals are included in branch eumetazoa.
- Protostomes and Deuterostomes are two clades of animals that make up the Bilateria, a *grade* of branch: Eumetazoa, which consists of animals, composed of bilateral symmetry and three germ layers.

- The main difference between protostomes and deuterostomes originates from the development of their blastopore, a transient opening of the archenteron to the exterior of the embryo at the gastrula stage, which is related to the later development of mouth or anal openings. In Protostomes mouth is developed from the blastopore during the embryonic development of embryo. On the other hand, in deuterostomes anus is developed from the blastopore. Deuterostomes have a higher modified nervous and muscular system. The key difference between protostomes and deuterostomes is thus the fate of blastopore in their embryonic development.
- A **coelom** is a fluid-filled body cavity that is completely lined by tissue created from the mesoderm, the middle layer of the primary cells found in an embryo. The coelom is a body cavity found in those metazoans animals that develop from an embryo with three tissue layers: ectoderm, mesoderm, and endoderm. The cells in each tissue layer become differentiated during development, becoming different tissues, organs, and a digestive tract. The coelom is found between the intestinal canal and the body wall, lined with mesodermal epithelium.
- Organisms that possess a true coelom are called coelomates. The coelomates are categorized into **shizocoelomates** and **enterocoelomates**. The organisms in which coelom is absent, are called as **acoelomate.** The body cavity which is lying between the gut and outer body wall musculature and generally formed by persistence of embryonic blastocoel, called as pseudocoelom.
- The coelom is advantageous to the triploblastic animals. It surrounds and protects the internal organs from external shocks.

1.6.SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

1.6.1.MULTIPLE CHOICE QUESTIONS

1. Echinoderms and chordates are

(a) Deuterostomes (b) Protostomes

(c) Animal in which blastopore becomes mouth (d) Both b and c

2. Radial symmetry is characteristics of

(a) Echinodermata only (b) Coelenterata and Porifera

(c) Echinodermata and Porifera (d) Echinodermata and Coelenterata

3. The group of animals in which the mouth arises away from the blastopore belongs to

(a) Protostomia (b) Protozoa

(c) Deuterostomia (d) Parazoa

4. In nematodes coelom is

(a) True coelom (b) Schizocoel

(c) Pseudocoel (d) Haemocoel

5. A coelom derived from blastocoel is known as

(a) Haemocoel (b) Schizocoel

(c) Enterocoel (d) Pseudocoel

6. Which phylum is characterized by the absence of the true coelom?

(a) Mollusca (b) Nematoda

(c) Echinodermata (d) Annelida

7. In animal kingdom, true coelom appeared for the first time in

(a) Annelida (b) Chordata

(c) Coelenterata (d) Arthropoda

8. In animal kingdom, triploblastic animals are for the first time seen in

(a) Annelida (b) Platyhelminthes

(c) Nematihelminthes (d) Mollusca

9. Radial symmetry is best seen in

(a) Star fish (b) Sponges

(c) Fishes (d) None

10. In which phylum adults have radial symmetry and the larvae have bilateral symmetry?

(a) Echinodermata (b) Porifera

(c) Coelenterata (d) Annelida

11. The animal with bilateral symmetry and absence of coelom

(a) *Fasciola* (b) *Ascaris*

(c) *Nereis* (d) None

12. Echinoderms are

(a) Enterocoelomate (b) Schizocoelomate

(c) Pseudocoelomate (d) Acoelomate

13. Phylum Porifera is included in

(a) Mesozoa (b) Eumetazoa

(c) Parazoa (d) None

14. When coelom is formed by the evagination from the embryonic archenteron, it is called as

(a) Haemocoel (b) Schizocoel

(c) Enterocoel (d) Pseudocoel

15. Which is the characteristic of Echinodermata?

(a) Spiny skin and radial symmetry

(b) Smooth skin and radial symmetry

(c) Smooth skin and bilateral symmetry

(d) Spiny skin and bilateral symmetry

16. Which of the following metazoan phyla are grouped under radiata.

(a) Arthropoda and Porifera (b) Coelenterata and Ctenophora

(c) Echinodermata and Mollusca (d) Mollusca and Coelenterata

17. Coelom is a space between

(a) Mesoderm and ectoderm (b) Mesoderm and body wall

(c) Ectoderm and endoderm (d) Splitted mesoderm

18. Which of the followingis characteristic of deuterostomes

(a) Spiral cleavage, Blastopore becoming mouth

(b) Radial cleavage, Blastopore becoming anus

(c) Spiral cleavage, Blastopore becoming anus

(d) Radial cleavage, Blastopore becoming mouth

19. Embryologically coelom arises from a split in the mesodermal bands, plates or masses in

(a) Nematoda (b) Some Chordata

(c) Platyhelminthes (d) Most protostmia

20. Schizocoelomates and enterocoelomates are

(a) Acoelomates (b) Invertebrates

(c) True coelomates (d) Echinoderms only

21. In which triploblastic animal, coelom is absent

(a) Annelida (b) Arthropoda

(c) Aschelminthes (d) Platyhelminthes

22. Triploblastic, unsegmented, acoelomate exhibiting bilateral symmetry and reproducing both asexually and sexually, with some parasitic forms. The above description is characteristic of the phylum

(a) Cnidaria (b) Arthropoda

(c) Platyhelminthes (d) Aschelminthes

23. Which is not correctly matched?

(a) Annelida - Enterocoelomate (b) Platyhelminthes - Acoelomate

(c) Arthropoda-Schizocoelomate (d) Aschelminthes - Pseudocoelomate

24. Deuterostome condition and indeterminate radial cleavage are characteristics of

(a) Chordata and Arthropoda

(b) Chordata and Echinodermata

(c) Arthropoda and Echinodermata

(d) Chordata, arthropoda and Annelida

1.6.2. VERY SHORT QUESTIONS

1. What is grade of organization in Phylum Cnidaria?
2. Categorize the eucoelomates on the basis of mode of coelom formation.
3. Define enterocoelomates.
4. Name any two phyla which are schizocoelomates.
5. Give pattern of cleavage in protostomes.
6. Define diploblastic animals.
7. Explain the term deuterostomia.
8. Write down key difference between protostomes and deuterostomes.

ANSWERS

1.6.1. 1.(a); 2.(d); 3.(c); 4.(c); 5.(d); 6.(b); 7.(a); 8.(b); 9.(a); 10.(a); 11.(a); 12.(a); 13.(c); 14.(c); 15.(a); 16. (b); 17. (d); 18. (b); 20. (d); 21. (c); 22. (d); 23. (c); 24. (a); 25. (b)

1.6.2.
1. Cell-tissue Grade;
2. Schizocoelomate and enterocoelomate;
3. The animals having enterocoel are called enterocoelomate;
4. Annelida and Mollusca;
5. Spiral and determinate;
6. The animals with two germ layers i.e. ectoderm and endoderm, are called as diploblastic animal;

7. The animals in which blastopore give rise to anal opening are called deuterostomia;

8. The key difference between protostomes and deuterostomes is thus the fate of blastopore in their embryonic development.

1.7. TERMINAL AND MODEL QUESTIONS

1. Differentiate between protostomes and deuterostomes.
2. Describe significance of coelom.
3. Describe about the coelom in annelids.
4. Differentiate between shizocoelomate and enterocoelomate.
5. Give answersof the following.

   (i) Acoelomata and pseudocoelomata

   (ii) Developmental characteristics of Protostomia

   (iii) Classification of Animal Kingdom

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UNIT 2: LOCOMOTION

CONTENTS

2.1. OBJECTIVES

After reading this unit the readers will be able to:

- Define locomotion
- Discuss the pattern of flagellar and ciliary movement in protozoa
- Discuss the pattern of movement in coelenterate
- Discuss the pattern of movement in annelida
- Discuss the pattern of movement in echinodermata

2.2. INTRODUCTION

Locomotion is the movement in which animal changes its place and position in search of food, partners, protection and suitable environment in response to stimulus.Locomotion is a characteristic and fundamental attribute of all forms of animals. Unicellular animals swim by cilia or flagella and crawl about with pseudopodia. Multicellular animals are characterized by the muscles—the specialized contractile tissues unique to the animal world. All these diverse modes of movement depend on very similar biochemical mechanisms. At the molecular level, a relatively small group of protein molecules, actin and myosin, polymerize to form elongated microtubules or delicate microfilaments. These cell organelle helps in animal movement at all levels in phylogeny. The survival and success of multicellular organisms depend on the versatility of the muscular system. However, in most metazoan animals the muscular tissue alone is not sufficient to bring about effective movement of the body because the contraction of muscle fibre is an active process whereas their relaxation is not. So, if the form of the body is to be maintained, the contracted fibres must be restored to their original length by some force. In vertebrates, the force is external and applied through the jointed skeleton and attached muscles. But in soft-bodied animals, this force is achieved by a special type of skeletal system known as **hydrostatic skeleton**. Its function depends upon the musculature which surrounds an enclosed volume of fluid. The contraction of the musculature system sets up a pressure in the fluid. This pressure is then transmitted in all directions to the rest of the body and thus making its movement possible. In coelomates, the coelom with its contained fluid provides more highly organized structural basis for the hydrostatic skeleton than that of the acoelomate animals like coelenterates and platyhelminthes. Coelomates like annelids, echinoderms and many other small groups move upon hydrostatic principles. Along with the coelom, the development of metamerism is another innovation in structural organisation during course of evolution. In metamerism, the body is differentiated along long axis into a series of units, each of which contains elements of some chief organ systems like appendages, nerve ganglia, excretory organs etc. In some metameric annelids, the locomotion depends upon the segmental partitioning of coelomic fluid as well as the refinement of integration exerted by the metamerically segmented nervous system

2.3. FLAGELLA AND CILIARY MOVEMENT IN PROTOZOA

In protozoans, different modes of locomotion are reported due to presence of different types of locomotory organelles. It includes pseudopodia, cilia, flagella and pellicular contractile structure.

2.3.1. LOCOMOTORY ORGANELLES IN PROTOZOA

2.3.1.1PSEUDOPODIA

Pseudopodia are extruded from body protoplasm of naked protozoa. These protozoans do not possess a definite pellicle. Pseudopodia are mainly formed from the ectoplasm although the endoplasm may flow later on. According to shape, size, structure and activity, pseudopodia are of following types.

i. Lobopodia: These are broad, lobe like and sometimes branched pseudopodia with rounded tips. These pseudopodia consist of both the ectoplasm and the endoplasm. Several lobopodia may be given out from the body surface in different directions or single lobopodium may also be given out from body surface. Lobopodia is characteristics of *Amoeba* (Fig. 2. 1A).

ii. Filopodia: These are thread like hyaline projections with pointed tips and radiate from body in all directions. These pseudopodia consist of only ectoplasm. Filopodia is characteristic of ***Euglypha***. (Fig. 2.1B)

iii. Reticulopodia: These are branched pseudopodia and branches anastomose, often produces large, complex networks which mainly help in food capturing. It is characteristic of foraminiferans like *Elphiduim*, *Globigerina* and *Chlamydophyrsetc*. (Fig. 2.1C)

iv. Axopodia: These are spine like pseudopodia which radiate from the surface of rounded body. It is composed of an outer cytoplasmic sheath covering an axial rod. It is characteristic of heliozoans and radiolarians, *eg*.,*Actinophrys*. (Fig. 2. 1D)

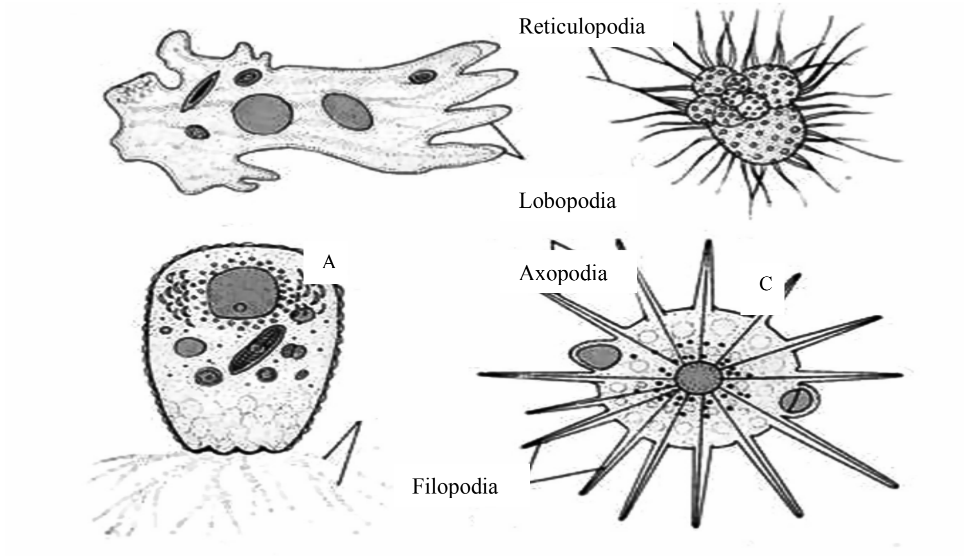


Fig.2.1. Different types of pseudopodia. A- [illegible]f Amoeba; B- Filopodia of Euglypha; C- Reticulopodia of Globigerina; D- Axopodia of Actinophrys

2.3.1.2 FLAGELLA

These are fine, delicate and thread like extensions of the protoplasm. It consists of axial filament or axoneme surrounded by a protoplasmic sheath. The axoneme consists of two longitudinal fibrils and protoplasmic sheath consists of nine doublets of longitudinal fibrils. These fibrils lie in a matrix of dense cytoplasm. The outer sheath may have laterally frayed out fibrils. These fibrils are known as mastigonemes. On the basis of the arrangement of mastigonemes, flagella are of following types.

(i). Stichonematic flagella bear only single row of lateral mastigonemes.eg. Flagellum of *Euglena, Astacea. (*Fig. 2.2 A)

(ii). Panotonematic flagella bear two or more rows of lateral mastigonemes. eg. Flagellum of *Perenema*. (Fig. 2.2 B)

(iii). Acronematic flagella bear a single terminal filament at distal end of the flagellum.eg. Flagellum of *Chlamydomonas*. (Fig. 2.2 C)

(iv). Pentachronematic flagella bear a single terminal filament at distal end of the flagellum and two rows of mastigonemes on the lateral side.eg. Flagellum of *Urcoelus, Monas* and *Polytoma*. (Fig. 2.2 D)

(v). Simple flagella bear neither terminal filament nor mastigonemes. eg. Flagellum of *Trypanosoma*. (Fig. 2.2 E)

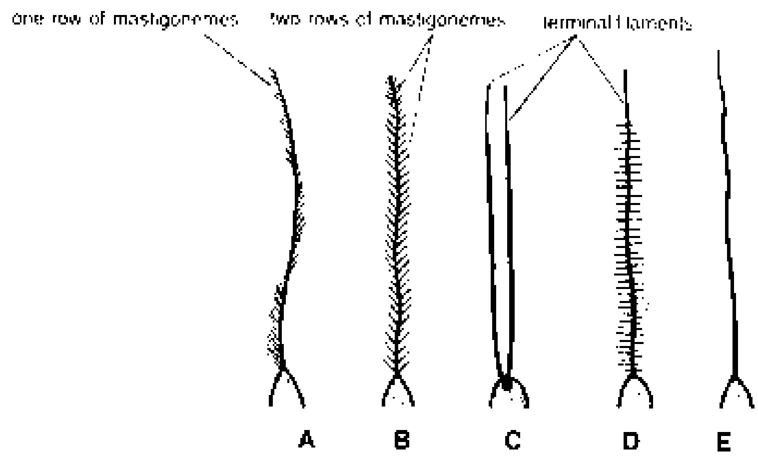


Fig.2.2. Types of flagella. A- Stichonematic flagella; B- Panotonematic flagella; C- Acronematic flagella; D- Pentachronematic flagella; E- Simple flagella

a. Number and arrangement of Flagella

The number of flagella varies from species to species. Mostly one or two flagella are present but parasitic forms may have a greater number of flagella. Often one of them is the main flagellum and rests are accessory flagella. Mostly flagella originate from anterior end of body but in some cases, it originates from posterior end of body (*Trypanosoma*).

2.3.1.3 CILIA

Cilia are slender, fine and more or less short hair like processes of the ectoplasm. Cilia resemble in structure with flagella but also differ from flagella in the following respects.

1. They are relatively much shorter when compared to the size of the body.
2. They are more in number and cover the entire body.
3. The cilia move in different way from those of the flagella.

Cilia consist of an axial filament or axoneme surrounded by an elastic sheath continuous with the plasma membrane of the cell surface. The axoneme consists of nine doublets of peripheral microfibres and two central fibres. The central fibres are enclosed within a delicate inner sheath. All fibres are present in a fluid matrix.

The cilium arises from a basal granule or blepharoplast. It is made up of nine triplets of peripheral microfibers arranged in a twisted fashion. Basal granule is situated deep in the ectoplasm. (Fig. 2.3)

a. Ciliary arrangment

The manner of arrangement of cilia is rather constant within a species. The cilia may be uniformely distributed all over the body as in *Opalina* and *Paramecium* or may be restricted to certain parts of the body as in *Vorticella*. The cilia may be of uniform length as in *Opalina* or may be longer on the extremities of the body as in *Paramecium*.

In many species, the cilia become fused variously to form composite motile organelle. These composite motile organelles are as follows.

(i) **Undulating membranes:** These are thin, transparent sheet like flaps and made up of one to several longitudinal rows of cilia fused together sidewise. These are found in the buccal cavity and are used for food collection. In *Pleuronema,* the undulating membrane can be protruded to serve as scoop for food capture. These are found in *Holotrichan* and *Heterotrichan*.

(ii) **Membranelles:** The membranelles are paddle like structure and arranged in spiral rows in the peristomial area. These are formed by the fusion of two or more transverse rows of cilia which remains free at their edges and make powerful sweeps. They help to bring the food particles to the cytostome. These are found in *Spirotrichans* and *Peritrichans*.

(iii) **Cirri:** Cirri are found on ventral surface of the body of some ciliates. These are formed by fusion of two or three rows of cilia. They can move in all the directions and helps in crawling. They may also serve as tactile organs. They are found in *Hypotrichans*.

2.3.1.2 MYONEMES

These are contractile fibrils and found in ectoplasm or pellicle of various protozoans like flagellates, ciliates and sporozoans. In *Monocystis andPlasmodium* they serve for locomotion. In *Paramecium,* metaboly is performed by myoneme fibrils.

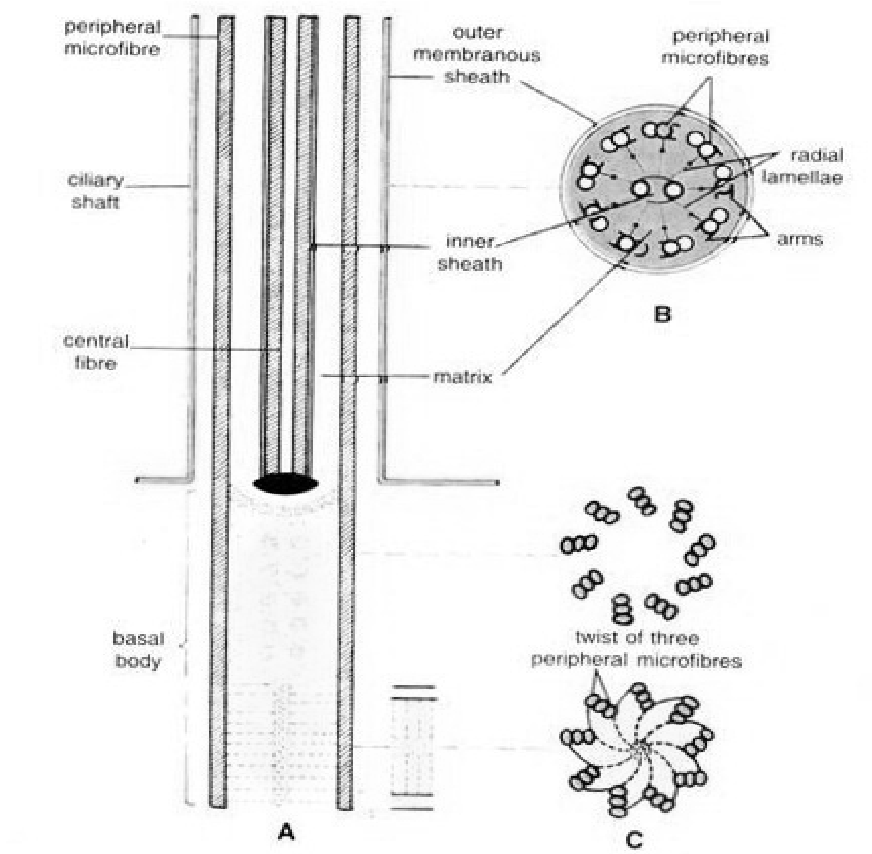


Fig.2.3 Structure of cilium.A-L.S of cilium; B-T.S. of cilium; C-Basal Body in T.S.

2.3.1. MODES OF LOCOMOTION

In protozoans, different modes of locomotion are reported due to presence of different type of locomotory organelles in them.

2.3.2.1 AMOEBOID MOVEMENT

Amoeboid movement is found in all Sarcodina, certain mastigophora and sporozoa. Sarcodines move from one place to other by pseudopodia. It is well illustrated by *Amoeba*.According to more recent change of viscosity theory or Sol-gel theory, amoeboid movement is effected by changes of colloidal protoplasm form (sol) to a solid state (gel) and vice-versa. It was proposed by **Hyman** in 1917 and later supported by **Pantin** and **Mast**. Amoeboid movement is brought about by the formation of pseudopodia in the direction of movement. Pseudopodia formation depends upon active contraction of plamagel at anterior end so, plasmasol flows forward to form pseudopodia. This process involves **gelation** of plasmasol at the anterior advancing pseudopodia and **solation** of plasmagel at posterior end. During locomotion of

*Amoeba,*the elastic strength of plasmagel is highest at the sides, intermediate at the posterior end and lowest at the anterior end. This results in an elongated shape of animal and a forward extension of the anterior end to bring about locomotion.

2.3.2.2 FLAGELLAR MOVEMENT

The flagella are highly vibratile structures and perform lashing movements with a rowing action or undulating motion. Flagellar movement can be explained by following theories-

(i) Paddle Stroke

According to this explanation, a flagellum ordinarily moves in a sidewise lash during rapid locomotion. When flagellum is held out rigidly with a slight concavity in the direction of stroke, it is called **effective stroke**. When flagellum is relaxed and brought forward again, it is called **recovery stroke**.

(ii) Simple Conical Gyration

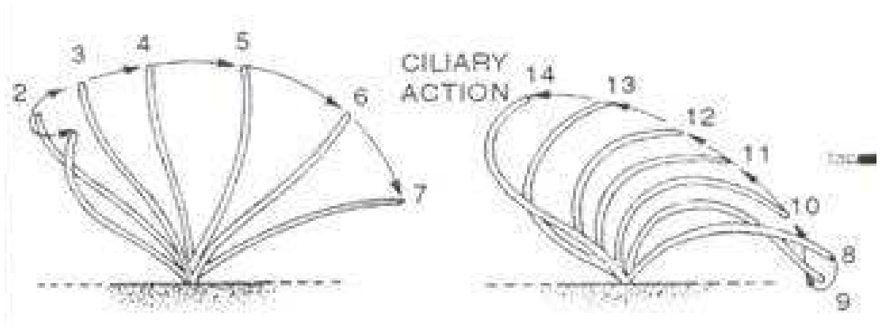
According to **Butschli's screw theory**, the flagellum undergoes a series of lateral movements so, a pressure is exerted on the water at right angle to its surface. Two forces are created now. One force is parallel to the main axis of the body which drives the animal forward. The other force is at right angle to the main axis of the body which rotates the animal on its own axis.

(iii) Undulating Motion

When a series of wave pass from one end of flagellum to the other, it creates two types of forces. One force is in direction of movement and it drives the animal forward. The other force is in the circular direction with the main axis of the body and it rotates the animal.

2.3.2.3 CILIARY MOVEMENT

The constant backward beating of cilia pulls the animal forward and the constant forward beating of cilia pulls the animal backward. The cilia bend backwards which is called **effective stroke** and straighten slowly to return to the original vertical position, which is called **recovery stroke** (Fig. 2.4). The water moves in the direction of beat and ciliate move in opposite direction. When, a wave of pulsation passes from one end of the body to the other, the cilia of longitudinal row beat one after the other. This coordinated movement of cilia is called **metachronously movement**. This causes the movement of animal in forward direction. When body cilia beats obliquely and at same time longer cilia of oral groove beat more vigorously, it causes the anterior end to move to the left. The action of cilia of body and oral groove makes the animal to rotate on its long axis.



A **B**

Fig.2.4. Diagram showing flagellar and ciliary movement. A- Effective stroke; B- Recovery stroke

2.3.2.4 METABOLIC MOVEMENT

The sporozoans show contractile movement due to the presence of myonemes fibrils. They contract and expand bringing about a change in the shape of the body. Thus, animal moves from its original place. This type of movement is exhibited by *Monocystis*.

Euglena sometimes shows wriggling movements. These are brought about by contraction of myonemes present in the cytoplasm below the pellicle. A peristaltic wave of contraction and expansion passes over entire body from anterior to posterior end and animal moves forward. The body becomes shorter and wider first at anterior end, then in middle and later at the posterior end.

2.4. HYDROSTATIC MOVEMENT

A hydrostatic skeleton consists of a fluid-filled cavity called *coelom* and the muscles that surround it. This fluid in the coelom (haemocoel) is called haemolymph. The haemolymph is present in open circulatory systems and is equivalent to a combination of blood and interstitial fluid. It is incompressible, and hence, maintains a constant volume against any pressure exerted on it. The contraction and relaxation of the muscles against the wall of the haemocoel bring about localization of the fluid pressure in few body segments and causes movements in the animal body. It is known as **hydrostatic movement**. In addition to this function, a hydrostatic skeleton is also supportive structure for the body and can be used by the organism to modify its own shape.

Hydrostatic movement can be observed in the case of the animals belonging to phyla cnidaria (sea anemone, jellyfish and *Hydra*), platyhelminthes (tapeworm, liver fluke), nematoda (*Ascaris* and *Ancylostoma*), mollusca (snails, clams and *Octopus)*, annelida (earthworm and leech) and echinodermata (starfish, sea urchin, brittle stars and sea cucumbers).

2.4.1. COELENTERATA

Cnidarians are very simple, diploblastic animal in which polymorphism is found. These animals exhibit a cylindrical body structure at the polyp stage and an umbrella-like structure in the medusa stage. These animals have ciliated grooves called **siphonoglyphs** along one or both ends of the mouth. The **siphonoglyphs** extendsinto the pharynx. It is used to create currents of water into the pharynx. Once the cavity is filled, the organism closes its mouth, while the cilia keep moving in order to create and maintain a positive pressure. The trapped sea water in body cavity is utilized as the fluid required for the hydrostatic skeleton to function. The muscles are arranged in a circular manner along the wall of the body cavity. When these muscles are contracted, the cylindrical cavity is compressed and its diameter decreases. This change in dimensions exerts pressure on the fluid which then causes the cavity to elongate. This elongation along the column affects the mesentery tissues that are situated longitudinally along the body wall, and cause them to stretch out. Once fully stretched, these muscles contract to return to their original position, which in turn causes the cavity column to shorten. Thus, the diameter of the cavity increases causing the mouth to open. The water is released from the mouth which flattens the animal. This process is carried out repeatedly to allow it to move and feed at the same time (filter feeders). This action on the water is carried out by two opposing sets of muscles working against each other called antagonistic muscles. They are called so because the contraction of one set causes the relaxation of the other and vice versa.

2.4.2. ANNELIDA

Annelids exhibit a well-developed body and musculature along with a true coelom. They have a segmented body pattern with sets of setae projecting out from the body wall. Each segment has a segmental sphincter at its end which closes during the movement of the animal. This causes the quantity of fluid contained within a segment to remain constant. Each segment also shows presence of longitudinal and circular muscles. These are antagonistic muscles. During movement, contraction and relaxation in each segment of the body takes place in sequential manner. As a result of the incompressible nature of the fluid, the contraction of the longitudinal muscles causes the circular muscles to stretch. This causes the segment to become short and wide, and the pressure causes projection of the setae (fig 2.5). These setae allow the worm to get a foothold on the substratum where it is moving on. The sequential relaxation of the longitudinal muscles, coupled with the contraction of the circular muscles, allows the segments to become long and thin. The animal, then, utilizes its anchored position to withdraw the setae and move forward.

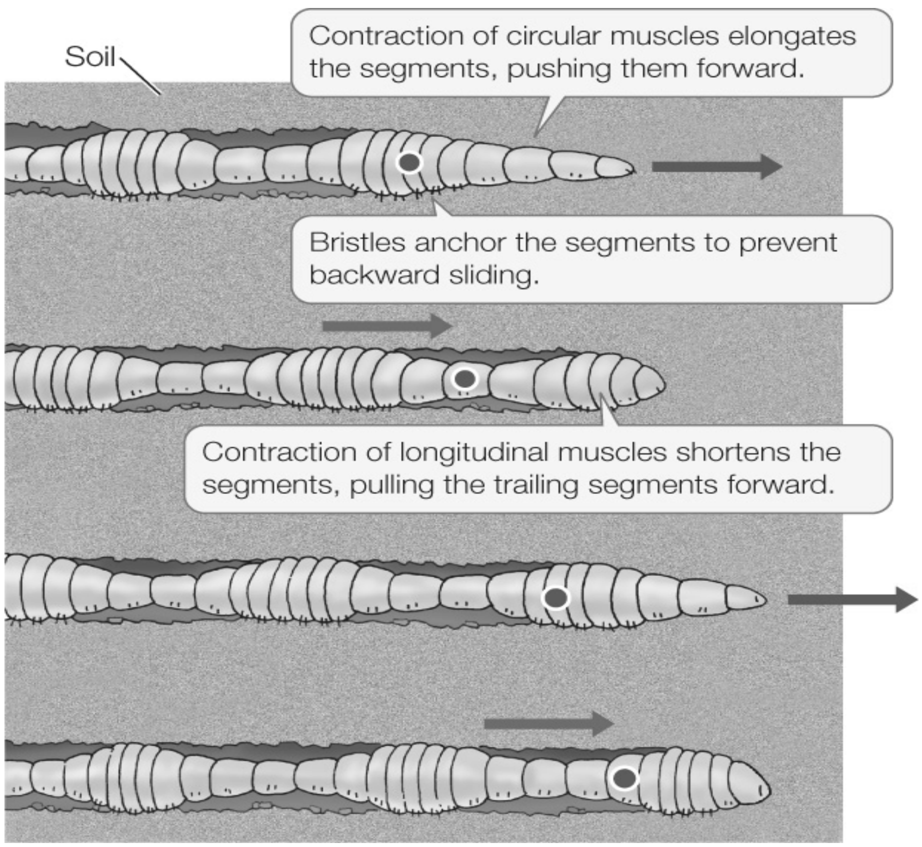


Fig 2.5 Diagram showing movement in Earthworm

2.4.3 ECHINODERMATA

In echinoderms an internal system of coelomic canals and surface appendages is found. This entire system is derived from the coelom and the canals are lined with a ciliated epithelium and filled with sea water. This peculiar system of echinoderms is called as **water vascular system**. The water vascular system provides a **hydraulic pressure mechanism** for movement and locomotion. The water vascular system runs internally along the body wall, from the madreporite to the tip of tube feet. The tube feet are present all over their body. The water vascular system is a series of specialized hydrostatic structures that transport sea water through ciliary action. The tube feet are a hollow, elastic and thin-walled muscular structure. Its outer end is flattened, forming a **sucker** for attachment. The inner end of each tube foot pierces the ambulacral ossicle and then expands to form a little rounded bulb, called **ampulla.** Changing the local pressure within the tube feet allows it to extend and contract. Uni-directional flow of water is ensured by the presence of one-way valves. The ampulla contains smooth circular muscle fibre, called ampullary muscle that expands when water is pumped into it. When these fibers contract, the water is forced out into the tube foot, and the ampulla is deflated. This causes the tube feet to project out of their grooves and attaches to the substratum with the help of suckers. Successive rings of connective tissue strands prevent lateral expansion of the tube foot. If the feet are pressed against a rigid substratum, the centre of the sucker is withdrawn. It causes the creation of a vacuum in that space allowing the animal to hold on due to the resultant suction. The tip of the tube foot also secretes a sticky secretion for adherence. The action of certain muscles in the foot provides a forward thrust of the animal's body. Contraction of the longitudinal muscles of tube foot forces water back into the ampulla and stretches the ampullary muscles. It causes the retraction of the tube feet and the animal is drawn forward. Thus, the animal is moved by just the length of its contracting tube feet. These tube feet are also under the control of the nervous system of the animal and can be used to move the feet in any direction.

2.5. SUMMARY

All living organisms show a characteristic phenomenon of either **locomotory movement** i.e. moving their whole body from one place to another place or **non-locomotory movement** i.e. only a part of the body while the whole body remains fixed to a place. Various acts of the body like walking, running, crawling, jumping, flying, swimming etc. are locomotory movements which helps the organism to shift its entire body from one place to another. Generally, the animals show locomotory movements in search of food, mate and shelter. It also helps the animals to run from the adverse environmental conditions, and to move away from the predators.

Locomotion in protozoa is characterized by **pseudopodial movement, flagellar movement ciliary movement and peristaltic movement.** Some protozoans move with the help of pseudopodia which are blunt, finger like temporary protrusions of the cytoplasm. These may be variously shaped. Large numbers of pseudopodia are present on the body surface of some individuals. Certain protozoans move with the help of flagella. Flagella are whip-like structures and usually 2-4 in number. A flagellum has an inner stiff structure, known as axoneme, which is surrounded by a protoplasmic sheath. Some protozoans move with the help of cilia. Cilia are small hair-like structures, present usually in large numbers on the body surface. Cilia are usually arranged in definite rows. Some protozoans move with the help of myonemes. Myonemes are small thread-like contractile fibrils usually located in the inner layer of ectoplasm.

A remarkably diverse group of organisms rely on a hydrostatic skeleton for movement. A hydrostatic skeleton consists of fluid-filled cavity surrounded by circular and longitudinal muscles. Because of the lack of permanently rigid structures, creatures with hydrostatic skeletons have a relatively flexible shape. In hydrostatic skeletons, force is transmitted by internal pressure. Functioning of these systems depends on the fact that they are essentially constant in volume as they consist of relatively incompressible fluids and tissue. Hydrostatic skeletons allow movement through peristaltic motion. In peristaltic motion, as one portion expands, another contracts, slowly pulling along the creature. The peristaltic movement generally is disadvantageous if speed is needed.

The **siphonoglyph** is a ciliated groove at one or both ends of the mouth of sea anemones and some corals. The siphonoglyph extends into a pharynx and is used to create currents of water into the pharynx. These water currents are important for maintenance of internal pressure. The trapped sea water in body cavity is utilized as the fluid required for the hydrostatic skeleton to function. The decrease and increase in the diameter of the fluid filled cavity allow the animals to move. This action on the water is carried out by two opposing sets of muscles working in antagonistic manner.

Earthworms have a sleek, streamlined body and a hydrostatic skeleton that allows them to change their shape and squeeze themselves into very tight crevices. In earthworms, the skeleton consists of pressurized fluid within a cavity in the body known as the coelom. The coelom extends throughout the body and is separated into many segments. Although the segments are interconnected, the worm is able to move them independently. Surrounding the fluid-filled coelom, earthworms have muscle fibres of the body wall that help these animals to crawl on land. These muscle fibres are of two types – longitudinal muscle fibres and circular muscle fibres. Circular muscles wrap around each segment, and longitudinal muscles extend across the length of the body. These muscles are powerful and well-developed. The locomotion of the body is brought about by alternate contraction of circular and longitudinal muscles, causing waves of thinning and thickening to pass backwards. It involves partly a pushing of the anterior end and partly of the posterior end and help the earthworm writhe, wiggle and push its way through the substratum of soil. The coelomic fluid gives turgidity as it acts as a hydraulic skeleton making the body wall tough.

The echinoderms have got a water vascular system that helps them in their locomotion. In echinoderms, the water vascular system bears tube feet and has a central coelomic cavity that transports sea water within the animal. A podium or tube foot is a short, hollow, elastic, thin walled, tubular external projection of the body wall present in the ambulacral groove of arms in echinoderms. Each tube foot extends through a gap, called ambulacral pore, which lies between two ambulacral ossicles. Each tube foot consists of three distinct regions: (i) A rounded sac like structure, **ampulla** which is situated above the ambulacral ossicles and projects into the coelom. In the ampulla the muscles consist mainly of rings of smooth muscles which are set vertically. (ii) The middle tubular portion, podium which is extending through the ambulacral groove. The wall of each podium is covered on the outside by a ciliated epithelium and internally with peritoneum. The musculature of the tube foot, in contrast to that of the ampulla, consists of longitudinal muscles. (iii) The lower end of the podium is flattened forming a cup like structure called **sucker**. The entire water vascular system provides hydraulic pressure mechanism for locomotion. Body is moved by the stepping action of tube feet which are alternately adhered and raised from the substratum. One or two arms, in the desired direction of movement, are raised from the substratum. The hydraulic pressure mechanism for locomotion is as follows.

- Water enters through the madreporite and moves along different canals such as, stone canal, ring canal, radial canals and lateral canals.
- From lateral canals water enters into the ampulla of the tube feet.
- Simultaneously the vertical circular muscles of the ampulla contracts and the valves of the lateral canals are closed. Contraction of these muscles brings about protraction of the tube foot and drives the fluid out of the ampulla into the foot.
- This increases hydrostatic pressure within the tube feet.

- The tube feet consequently elongate, extend forward.
- The suckers adhere to the substratum by suction force as well as the adhesive secretory products of the tips of tube feet.
- Then by muscular activity, tube feet assume a vertical posture, dragging the body forward.
- Contraction of longitudinal muscles is followed by withdrawal of foot from the substratum. Tube feet then shorten by contracting their longitudinal muscles, forcing the water back in to the ampulla.
- Consequently, the suckers release their hold on the substratum.

During movement one or two arms act as leading arms and all the tube feet extend in the same direction in a coordinated manner. All these make possible the highly organised stepping movement by which the star fishes pull themselves in direction of movement.

2.6. SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

2.6.1. Multiple Choice Questions:

1. Cilia in *Paramecium* arise from
   (a). Basal granules (b) Pellicle
   (b). Cytopharynx (d) Trichocyst

2. Down stroke and recovery stroke are the two phases of
   (a) Movement of contractile vacuole (b) Flagellar movement
   (c) Movement of food vacuole (d) Amoeboid movement

3.Type of pseudopodia present in *Actinophrys* is
   (a) Axopodia (b) Reticulopodia
   (c) Lobopodia (d) Filopodia

4. Organs of locomotion in Echinodermata are
   (a) Pseudopodia (b) Parapodia
   (c) Foot (d) Tube feet

5. Type of pseudopodia present in *Amoeba* is
   (a) Axopodia (b) Reticulopodia
   (c) Lobopodia (d) Filopodia

6. Which of the following animals utilizes a flow of water for crawling over a surface
   (a) Starfish (b) Leech
   (c) Snake (d) Fish

7. Skeletal system is not involved in locomotion

(a) Frog (b) Man

(c) Rabbit (d) *Hydra*

8. Major constituent of muscle is

(a) Protein (b) Carbohydrate

(c) Fat (d) Mineral

9. What type of skeleton would you find in earthworm and sea anemone

(a) Fluid hydrostatic (b) Rigid exoskeleton

(c) Rigid endoskeleton (d) All of the above

10. Which of the following is contractile protein of a muscle?

(a) Myosin (b) Actin

(c) Tropomyosin (d) a and b both

11. In annelid due to contraction of which muscles the segment becomes short and wide

(a) Longitudinal muscle (b) Circular muscle

(c) Oblique muscle (d) a and b both

12. Pseudopodium of *Amoeba*is composed of

(a) Ectoplasm only (b) Endoplasm only

(c) Both Ecto and Endoplasm (d) None

13. The skeleton supported by fluid pressure, and common among simple invertebrate organisms, is called as

(a) Hydrostatic skeleton (b) Exoskeleton

(c) Endoskeleton (d) None

14. Identify the type of flagellum in *Monas, Urceolus* and *Polytoma* in their sequential order from the following:

(1) The flagellum is stichonematic.

(2) Two or more rows of lateral appendages on the axonemes.

(3) The flagellum is pantacronematic

(4) Lateral appendages are absent at distal end and axoneme ends as terminal filament

(a) 1,2,4 (b) 1,3,4

(c) 2,1,3 (d) 2,3,4

15. The flagellum in *Astasia* is

(a) Pantonematic (b) Acronematic

(c) Stichonematic (d) Pentachronematic

2.6.2. Very short questions:

1. Define locomotion.
2. Name the locomotory organelle found in unicellular organisms.
3. Define hydrostatic movement.
4. What is the use of siphonoglyph?
5. Name different types of pseudopodia on the basis of shape, size, structure and activity.6. How cilia differ from flagella?

ANSWERS

2.6.1. 1.(a); 2.(b); 3.(a); 4.(d); 5.(c); 6.(a); 7.(d); 8.(a); 9.(a); 10.(d); 11.(a); 12.(c); 13.(a); 14.(d); 15.(c)

2.6.2. 1. Locomotion is the movement in which animal changes its place and position in search of food, partners, protection and suitable environment in response to stimulus; 2.Unicellular organisms swim by cilia or flagella and crawl about with pseudopodia; 3. The contraction and relaxation of the muscles against the wall of the haemocoel bring about localization of the fluid pressure in few body segments and causes movements in the animal body. It is known as **hydrostatic movement**; 4. The siphonoglyph extends into a pharynx and is used to create currents of water into the pharynx. These water currents are important for maintenance of internal pressure; 5. Pseudopodia assumes four shapes-Axopodia, Lobopodia, Reticulopodia and Filopodia; 6. Cilia resemble in structure with flagella but also differ from flagella in the following respects (i). They are relatively much shorter when compared to the size of the body. (ii). These are more in number and cover the entire body.

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2.8. TERMINAL AND MODEL QUESTIONS

1. Describe mode of locomotion in protozoans.
2. Describe hydrostatic movement in annelids.
3. Describe function of tube feet in hydrostatic movement of echinoderms.
4. Write a note on locomotory organelles in protozoans.
5. Give answer of the following.

    (i) Classify flagella on the basis of arrangement of mastigoneme.

    (ii) Write a note on different types of pseudopodia.

    (iii) Write a note on structure of cilia.

UNIT 3: NUTRITION AND DIGESTION

CONTENTS

3.1. OBJECTIVES

After studying this unit,you should be able to:

- Define nutrition,
- Discuss the pattern of feeding in lower metazoans,
- Explain digestion of food in lower metazoans
- Describe filter feeding in invertebrates, and
- Discuss feeding mechanisms and digestion in higher metazoans

3.2. INTRODUCTION

The multicellular non-chordate animals exhibit a variety of feeding habits. The success with which animals exploit the food resourcescould be compared only with their complexity and functional adaptations. The nutrientsare required by animals to provide fuel in terms of energy so as to keep alive and maintain body processes, as well as raw materials for building and maintaining cellular and metabolic machinery, and also for growth and reproduction.

Generally, plants use the solar energy and carbon-di-oxide to synthesize all the components that constitutes it. All animals derive chemical compoundsfrom plants and therefore, indirectly from sunlight to get energy as well as for their building materials. The acquisition and ingestion of food by the animals are referred to as **feeding**. The food taken by animals, whether of plant or animal origin, is composed of highly complex compounds which cannot be incorporated by the animals or used as fuels without being broken down into simpler units.The process of breakdown of complex food compounds into simpler one is known as **digestion**. A variety of chemical compounds can be utilized by the animals for energy. But for maintaining proper body function, animals require some compounds which they cannot synthesize-like vitamins, certain salts, some amino acids etc. The interaction of nutrients and other substances in food in relation to maintenance, growth, reproduction, health is called **nutrition**.

3.2.1 FEEDING IN INVERTEBRATES

The invertebrates capture food by various mechanical processes. The processes are developed in accordance to their different feeding habits.

According to **Yonge (1928)**, feeding mechanisms in invertebrates can be grouped into three major categories on the basis of size and type of food utilized.

a. **Microphagy:** The vast majority of invertebrates feed on particulate food material of very small size which is called **microphagy**. Microphagous animals make effective use of their cilia or setae for obtaining food. They are therefore commonly known as **ciliary feeders**. Ciliary feeders fall into two categories. One type known as **suspension feeders** which feed on minute organisms and other feed on particulate matter suspended in water. In this type of feeding food particles are extracted by filtering water, hence the organisms are known as **filter feeders**.

b. **Macrophagy:** When invertebrates feed on large masses of food, it is called **macrophagy**.Generally large invertebrates are macrophagous organisms. Macrophagous feeders could be active predators and may feed on live material. Cephalopod molluscs, for example, are completely predaceous. Large crustaceans and in general all the living arthropods are macrophagous.

c. **Fluid or Soft Tissue Feeding:** These types of feeders generally suck fluid food. Some pierce and then suck the body fluid of the prey and some simply absorb the liquid food from the substrate through body surface.

According to **Morton (1967),** on the basis of nature of the food, the animals are categorized as follows.

a. **Herbivores:** A herbivore is an animal that gets its energy from eating plants. These animals have special digestive system that let them digest all kinds of plants.

b. **Carnivores:** A carnivore is an animal that gets food from killing and eating other animals. They generally eat herbivores.

c. **Omnivores:** The animals that eat both plants and animals are called omnivores.

d. **Deposit Feeders:** These animals pass large amount of substratum through their gut.

e. **Filter Feeders:** They continuously filter small particles from large volumes of water and trap these particles in mucus films or screens of setae and have elaborate devices for sorting and transporting them.

f. **Fluid Feeders:** They pierce and suck juices from animals and plants.

3.2.2 DIGESTION IN INVERTEBRATES

In all the members of the animal kingdom, the food is made up of organic materials, e.g., carbohydrate, protein, fats, etc. having a very large molecular configuration. These large molecules of food are first broken down into simpler units, like monosaccharides, amino acids, fatty acids and glycerol respectively and then absorbed and either incorporated into the body or metabolized to provide energy.

The breaking of large and complex molecules of the food, after which, they become absorbable and available for use in the body, is called **digestion**. It is an essential physiological activity in animals, whether they feed on minute food particles or on large plants and animals.

In macrophagous animals, digestion takes place by both mechanical and chemical means. When large plant or animals are taken as food then firstly mechanical digestion takes place which is followed by chemical digestion. According to the site of enzymatic action, chemical digestion is of two types.

(a) Intracellular Digestion: When digestion takes place within the cell, it is called as intracellular digestion. The protoplasm of the unicellular animal captures the food in a food vacuole, digests it, discharges the wastes and incorporates the digested simple organic components into the protoplasm.

(b) Extracellular Digestion: When digestion takes place outside the cell and generally within the digestive tract of the higher animals, it is called extracellular digestion. Digestion is wholly intracellular in Protozoa and Porifera. In other phyla, extracellular digestion either supplements the intracellular mechanisms or completely replaces it. In the following discussion we shall describe the process of feeding and digestion in some invertebrates.

3.3. PATTERN OF FEEDING AND DIGESTION IN LOWER METAZOA

After getting acquainted general feeding mechanism and digestion in invertebrates in previous section, let us now discuss about feeding and digestion patterns in lower metazoan in this section. In the first subsection you will study about feeding and digestion in sponges followed by those coelenterates and flatworms.

3.3.1. FEEDING AND DIGESTION IN SPONGES

Sponges are filter feeder and make use of their canal system for feeding, respiration and excretion. The body surface of sponges presents innumerable elevations of polygonal shape separated from one another by furrows. These furrows are pierced by dermal ostia. These pores act as simple but effective sorting device that permit the entry of only the smallest particles. Sponges feed by filtering particulate matter from nutritive water that enters through ostia. In syconid and leuconid sponges, choanocytes line small flagellated chambers, thereby increasing the area of ingestive epithelium. As the water current passes through the flagellated chambers, the food particles adhere to the outer sticky surface of the collars of thechoanocyte. Each of the choanocytes or collar cells possesses a single flagellum surrounded at its base by a protoplasmic collar. The flagella beat outwards from their base, drawing food particles towards the collar and move water forward. The microvilli of the collar act as a filter for trapping smaller food particles which move towards base of choanocytes by protoplasmic streaming. They are engulfed by the cell body. Food may also ingest by wandering amoebocytes and even by dermis cells. The digestion is intracellular, within the food vacuoles (Fig.3.1). The partly digested food vacuoles from choanocytes may also be passed on neighboring amoebocytes. The digestion of food is completed within these amoebocytes which distribute the digested food from cell to cell by diffusion. **Amoebocytes**also serve to store digested food materials in the form of glycogen, protein and fats. These are now called as **thesocyte**. Undigested food is egested into the spongocoel. Water is expelled from the spongocoel through osculum and thus the entry of new nutrient rich water is facilitated.

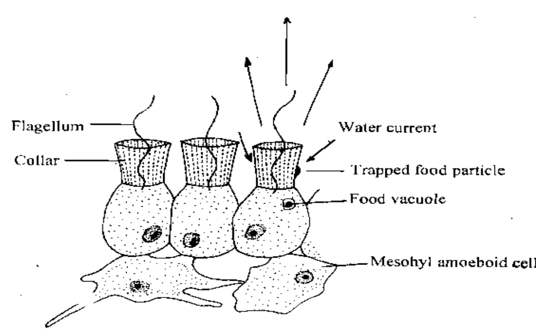

Fig. 3.1 Diagram showing intracellular digestion in sponges

3.3.2 FEEDING AND DIGESTION IN COELENTERATES

Coelenterates have tissue grade of organization and therefore their feeding and digestive mechanisms are also more complex. Coelenterates, in general, are macrophagous carnivores and they use their tentacles to capture the prey. Their food consists of worms, eggs, larvae and small animals especially crustaceans. Some scyphozoans and anthozoans may even feed on fish. However, certain anthozoans and scyphozoans are **microphagous suspension feeders**. They either trap the prey in mucus secreted by the tentacles or filter plankton from water passing through tentacular fringe. In the sea anemone,*Metridium* and jelly fish,*Aurelia* mucus and nematocyst play an important role in capture of planktonic organisms. In *Aurelia*, the mucus may entangle small planktonic organisms. The food laden mucus is moved by flagella towards the bell margin, from where it is collected by the oral arms and moved to the mouth by ciliary action.

Macrophagous carnivorous coelenterates use **cnidoblasts** (Fig.3.2) for trapping the food by tentacles. Cnidocil projecting from cnidoblast, as is found in *Hydra,* is believed to be the sensory element. Each cnidoblast has an oval sac filled with **hypnotoxin** (mixture of protein and phenol). The sac is known as **nematocyst**. The outer end of nematocyst is invaginated into long thread, coiled inside the sac itself. When discharged the nematocyst pierces into the prey and injects poison into it.

Digestion in coelenterates is firstly extracellular and then intracellular. During extracellular digestion, the large prey is broken into smaller particles in the Gastro vascular cavity (GVC). Some of the endoderm cells are secretory in nature and they release the enzymes into GVC for extracellular digestion of proteins, fats, carbohydrates and even chitin. Intracellular digestion occurs in food vacuoles by the gastrodermal cells. The digested food is collected and distributed by the wandering amoebocytes of the mesogloea. Reserve food is stored in the form of glycogen by the gastrodermal cells.

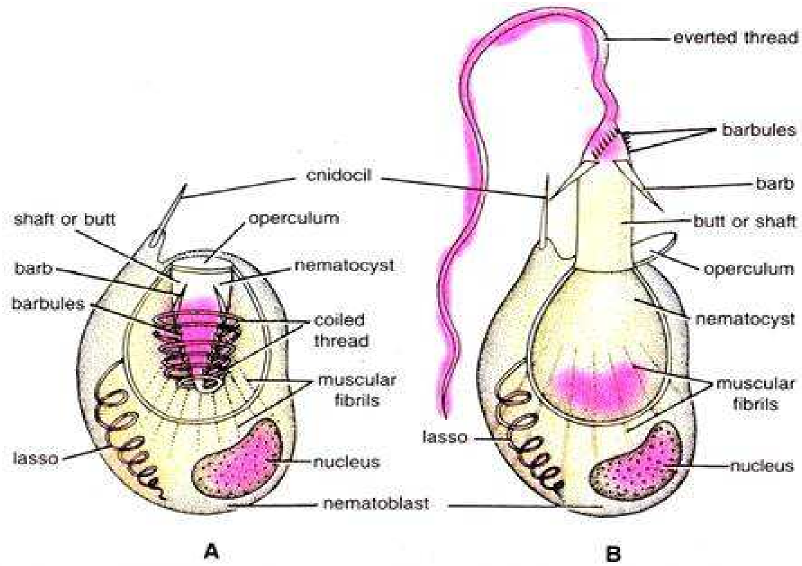

Fig 3.2 Structure of Cnidoblast A. Undischarged cnidoblast; B. Discharged cnidoblast

3.3.3 FEEDING AND DIGESTION IN FLATWORMS

Flatworm are both free as well as parasitic mechanism of feeding and digestion are different in living forms and in parasitic forms. Free living flatworms have distinct and incomplete alimentary canal as anus is absent. The alimentary canal includes mouth, pharynx, and intestine. The intestine is branched and each branch gives out numerous lateral branches or diverticula which end blindly (Fig. 3.3). Free living flat worms' preys upon crustaceans, worms, nematodes, insects etc and also feed on fragmentations of plant and animals. Free living flat worms are known to digest the food intracellularly or both intracellularly as well as extracellularly and or exclusively extracellularly. Exclusive intracellular digestion is seen in acoelan *Convoluta.* They feed upon microscopic organisms by protruding the pharynx like pseudopodium through mouth. The ingested food is taken into the mesenchyme. Digestion occurs intracellularly. In the triclad worm, *Polycelis* the food such as crustaceans is trapped in the mucous secretion. The long protrusible pharynx is inserted into the prey and the soft contents are withdrawn. The food is broken down to small particles extracellularly while passing to the alimentary canal. On reaching the gut, the particulate food is engulfed by digestive cells and intracellular digestion takes place. The polyclad worm, *Cycloporus* feeds exclusively on ascidian colonies *Botryllus* and *Bottylloides,* sucking the individual zooids with the help of protrusible pharynx. The food reaches intact in the gut and digestion is extracellular. The food is homogenised and digested within the alimentary tract and there is no intracellular digestion.

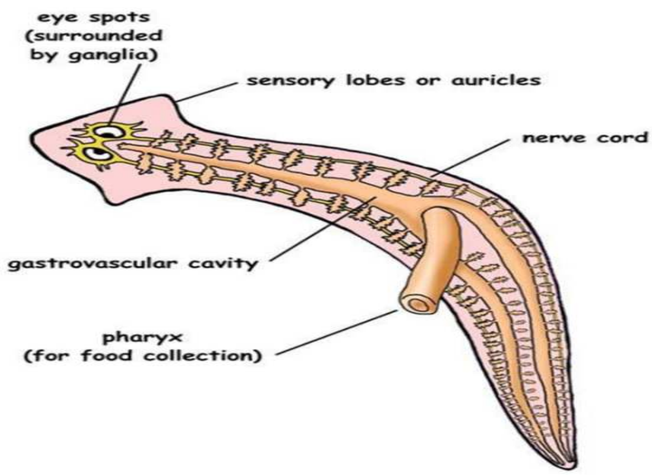

Fig 3.3 Digestive system of Planaria showing protruded pharynx

In trematodes, which are parasitic, the digestive system is incomplete i.e., lack anus and highly branched. The mouth is surrounded by oral sucker and leads into muscular pharynx which is followed by a short oesophagus and a branched intestine bearing a number of diverticula (Fig. 3.4). The highly ramified diverticula fill the most of the interior of the body. A trematode such as liver fluke feeds on the biliary matter as well as the blood of the host. The muscular pharynx aids in sucking of the food. Digestive glands have lost their utility in these animals and therefore they are absent. The food is already in a state ready for absorption. The branched alimentary canal helps in the reaching of the food to all part of the body.

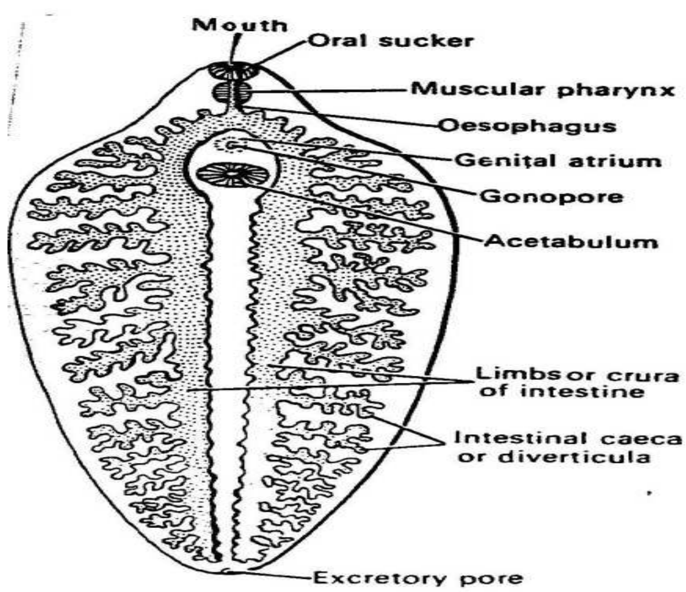

Fig 3.4 Digestive system of liver fluke

3.4. FILTER FEEDING

An aquatic animal, which feeds on minute planktonic organisms or suspended particles and filters it from the water, is called **filter feeder**. Filter feeders are animals that get their food by moving water through a structure that acts as a sieve. **Active filter feeders** like many annelids and crustaceans draw water actively by moving their cilia or extremities or contracting their muscles while **passive filter feeders** make use of water currents. Filter feeders set up a current in surrounding water with their cilia or setae. The food is collected by filtration as well as by trapping food in mucous. The chosen food particles are then directed towards the mouth whileinedible materials are usually discarded by a well-developed**sorting cum rejecting mechanism**. Both sessile and free-swimming organisms have evolved filter feeding mechanisms. Some filter feeders are free-swimming organisms that filter the water while swimming, or even actively pursue their prey. Free swimming animals move in water containing food particles. Sessile animals depend on natural currents in water as well as those created by cilia and other appendages. The sessile organisms are also deposit feeder as they feed on deposits of organic material that accumulate on substratum as well as in the sand or mud. The deposit feeders, like suspension feeders, depend on cilia for feeding. In fact some organisms may feed on both suspended and deposited food materials. Some filter feeders depend on encrusted organisms like algae as food organisms. The mouth parts of such feeders are modified for rasping and browsing food. Sedentary polychaetes and molluscs, sponges, small crustaceans as well as a number of other groups of small animals are microphagous filter feeding organisms. Filter feeders like mussels and oysters filter small particles and even toxins out of the water and improve water clarity and, play important role to keep a water body healthy

3.4.1 FEEDING MECHANISM IN ANNELIDS

These are variety of feeding mechanism in annelids. In polychaetes specially there is diversity buccal organs. Five types of buccal organ can be distinguished in polychaetes.

a) Muscular axial pharynx b) Simple axial probosis c) Ventral buccal organ d) dorsal buccal organ e) buccal organ absent

In oligocheta and Hirudinea the feeding mechanism is comparatively simple.

3.4.1.1 OLIGOCHAETA

The oligochaetes comprise mostly earthworms which ingest the soil for decaying of animaland plants contained in it.Aquatic forms also feed on algae, grasses, seeds and microorganisms. Freshwater forms like *Aeolosoma* collect detritus with its prostomium for which its ciliated ventral surface is placed against the substratum and the center is elevated by muscular contraction. The partial vacuum thus created releases the food particles which are swept into mouth by cilia. Some oligochaetes like *Chaetogaster* catch amoebae, ciliates, rotifers and trematode larvae by the sucking action of pharynx.

In oligochaetes, the alimentary tract is simple and straight tube of varying diameter. The mouth situated at the base of prostomium leads into a buccal cavity which opens into a spacious and muscular pharynx. In earthworms, the contraction of radial dilator muscle dilates the pharyngeal cavity so; pharynx functions as a suction pump. Pharyngeal glands secrete mucus as well as digestive enzymes. Pharynx is followed by a narrow tubular oesophagus. The oesophagus terminates into an oval shaped and thick-walled gizzard. The muscular and cuticle- lined gizzard functions as triturating organ and grinds the food particles. If crop is present, it functions as a storage organ. Rest of the digestive system, starting anywhere from 15^{th} and 24^{nd} segment is intestine (Fig.3.5). Anterior half of the intestine is secretory in function and the posterior half is absorptive. The absorptive area of the intestine is increased by a median dorsal and longitudinal internal fold of tissue, called **typhlosole**. A layer of yellowish peritoneal cells called **chloragogen cells**around the intestine are said to serve for storage of reserve food, deamination of proteins, and formation of urea from ammonia etc. These cells have the same function as the liver in vertebrates and fatbody in insects.

When food is ingested by sucking action of pharynx, the mucins lubricate it to facilitate its smooth passage down the gut. In stomach and intestine food is acted upon by digestive enzymes. Besides amylases, proteases and lipases, earthworms also secrete cellulase and chitinase. The digested food is absorbed by epithelial lining of the intestine and passed into blood stream for circulation to various parts of the body. Undigested food is egested through anus in the form of worm castings.

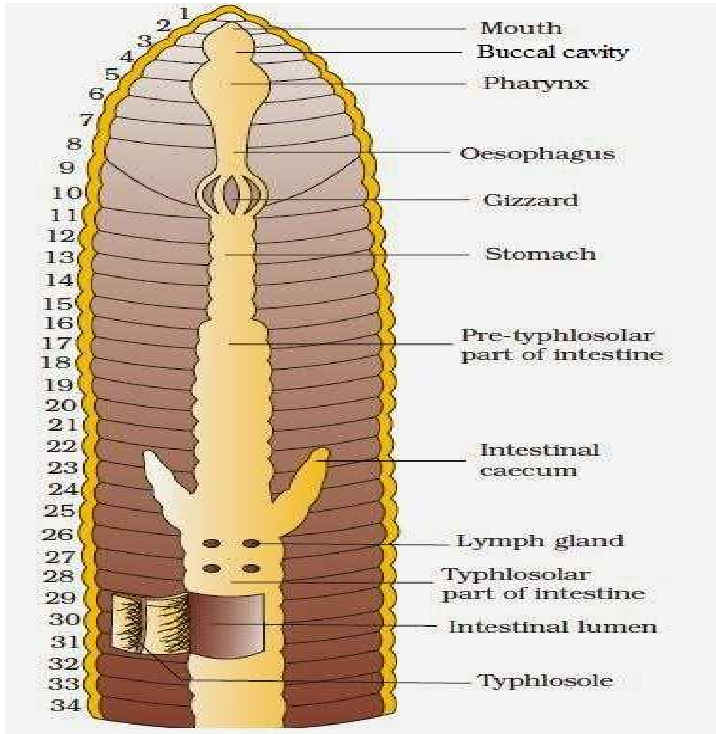

Fig 3.5 Digestive system of Earthworm

3.4.1.2POLYCHAETA

Polychaetes include both free moving and sedentary species. The free moving species are generally macrophagous and the sedentary forms are microphagous. The digestive system in polychaetes is differentiated into foregut, midgut and hind gut. The foregut comprises of buccal cavity and pharynx. The midgut comprises of oesophagus and stomach-intestine while hindgut comprises of rectum (Fig 3.6). *Nereis* is an example of a free moving macrophagous polychaete. But *Nereis* spends most of its time concealed safely in the burrow and makes use of its proboscis (buccal cavity and pharynx) for burrowing. Its head and anterior part of the body protrude out of burrow slightly. The eversible proboscis is a feeding organ. The buccal cavity and the pharynx protrude out through the mouth in the form of introvert or proboscis. The pharynx is lined with hooked jaws and is everted for seizing the prey(Fig.3.7). The genus *Nereis* includes species which are carnivorous. Some species of *Nereis* are omnivorous, feeding on diverse material such as algae, invertebrates or detritus on the substratum. Some are scavengers. The tentacles and palps present around the mouth assist in the manipulation of food, besides serving sensory function. Digestion is extracellular occurring mainly in the stomach-intestine. Digested food is absorbed by diffusion through enteric epithelium into the blood of the gut capillaries. The undigested food passes on to the rectum and egested through the terminal anus.

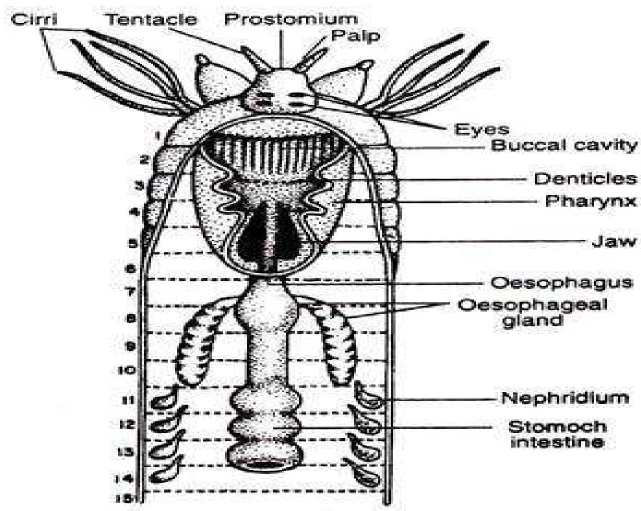

Fig 3.6 Anterior part of Nereis showing digestive system

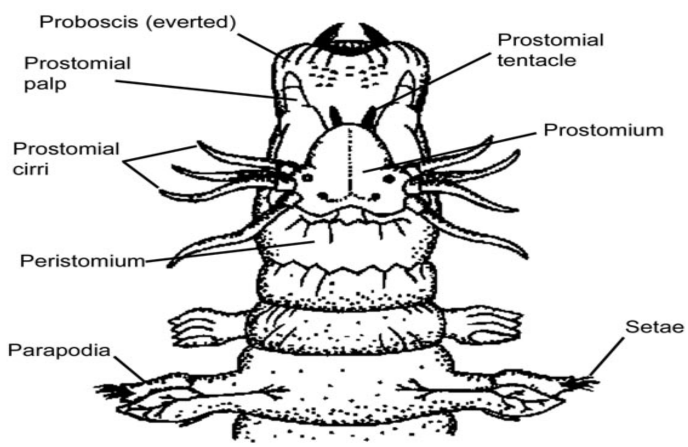

Fig 3.7 Anterior end of Nereis showing everted pharynx

The detritus feeding lugworms *(e.g Arenicola*) swallow the food contaiing mud or sand. The swallowing is done by the sucking action of the proboscis. Other sedentary polychaetes have evolved very fine mechanisms of ciliary- mucous feeding. *Amphitrite*and *Terebella* live in permanent mud tubes and are detritus feeders. From the tubes they extend their long ciliated prostomial tentacle clusters over the surface of the substratum to catch the food particles. The food particle gradually accumulates at the base of the tentacle. The cilia are actively involved in driving the food particles. The mucus-trapped food particles pass through the ciliated grooves of the tentacles and enter into the mouth.

Sabella is a large tube dwelling polychaete and builds tubes in sand among the rocks. The small head along with feather like appendages protrudes from the end of tube. The feathery appendages are the palp modified to form gill filaments or radioles. The coordinated action of cilia, present on the radioles, (Fig.3.8) creates water currents and the food is extracted from the currents. The radioles forms a wide funnel at the base of which the mouth of the animal is present. The filaments of the radioles bear rows of outgrowths called pinnules. Toward the lower part of branchial funnel, the pinnules interlock to form a filtering system. They are covered by mucus, in which the food particles are trapped. Food particles that enter the funnel along with the stream of water are directed into a groove that runs along the inner edge of each pinnule. The cilia located at the base of the pinnule drive the food particles to the base of pinnules from where they enter into a ciliated longitudinal groove that runs the entire length of filament and then into the mouth.

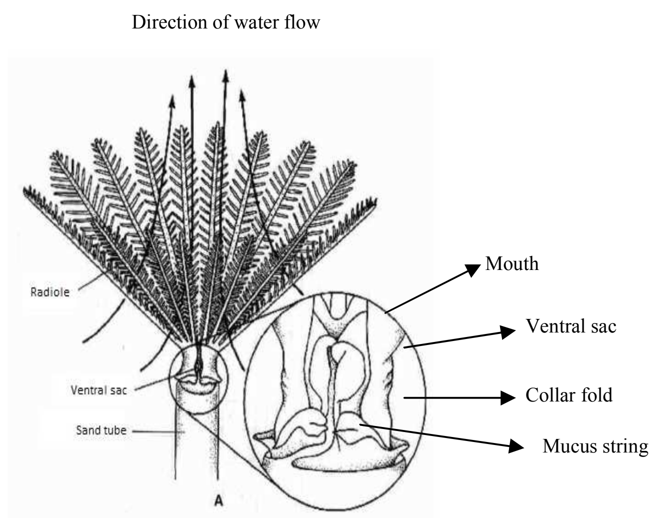

Fig 3.8 Sabella with extended radioles from its sand tube

In *Chaetopterus,* which lives in U shaped tubes made of sand or mud (Fig.3.9), a branchial crown is absent. It is **true filter feeder**. The water current is maintained by the rhythmical flapping of the muscular fans. Water is drawn by the beating of three pairs of fan shaped parapodia as well as by another pair of wing like outgrowths located anteriorly. The water is pumped through tube from anterior to posterior. Mucus traps the food particles and is drawn into a ventral groove, where it is shaped into a conical mucus bag. The conical bag, held between the parapodia and connected to food cup, filters the water passing through tube. The food particles are filtered through the bag andare rolled into a ball by a secretion of the wing like structures. The cilia in the ventral groove transport the ball of food to the mouth.

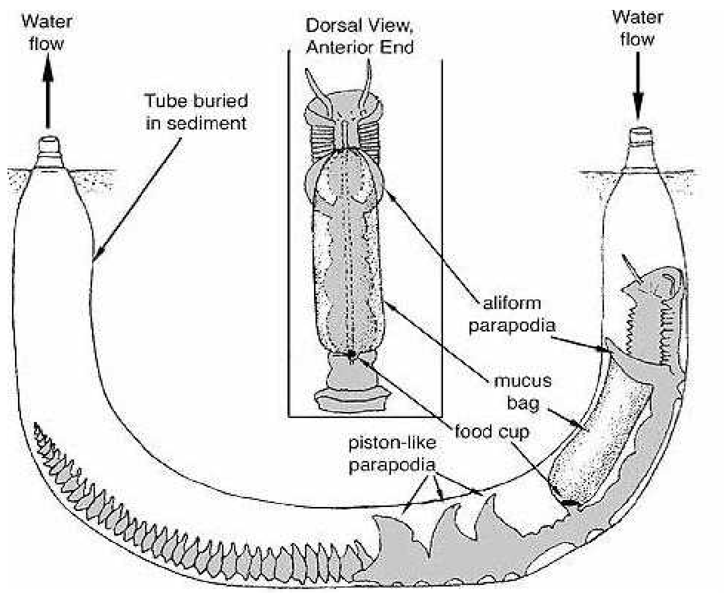

Fig 3.9 Feeding process in Chaetopterus

3.4.1.3 HIRUDINEA

Hirudinea includes free living and ectoparasitic leeches. Leeches are **sanguivorous**(blood suckers) in habit. The digestive system of leech is a straight tube of varying diameterrunning from mouth to anus. At the base of preoral chamber the triradiate mouth opening is present. The mouth leads into buccal cavity. In the mucous lining of the buccal cavity three jaws are embedded, of which one is mid-dorsal and the other two ventro-laterals. Each jaw bears a row of minute teeth. The buccal cavity leads into a thick muscular pharynx followed by a short oesophagus. Unicellular salivary glands are found on either side of the pharynx. The oesophagus is followed by a crop, an extensive sac consisting of 10 to 11 chambers, the chambers communicate with each other by openings surrounded by sphincters (Fig. 3.10). Each chamber is provided with a pair of backwardly directed lateral caeca. There is a progressive increase in the size of caeca, the anterior pairs being smaller in size, and the caeca of last chamber being the largest.

Following the crop, there is a small round stomach with a much-folded inner wall, and the stomach in turn leads into a narrow intestine. The inner wall of intestine is provided with numerous villi like processes to increase the absorptive surface. The intestine is followed by rectum that opens outside by anus.

Leeches feed on blood of man and cattle. A feeding leech adheres to the victim by its posterior sucker and then applies its anterior suckers and makes an incision in the skin with their jaws. The muscular pharynx sucks the blood. The salivary secretions contain an anti-coagulant, the hirudin, which prevents the clotting of blood and ensures a free flow of blood into the crop. The crop is thus, a reservoir for the storage of blood. Once a leech takes single meal, it may not again feed for several months. The food from the crop passes into stomach from time to time and the digestion takes place in the stomach. The digested food is absorbed in the intestine. The undigested blood remains are eliminated through anus.

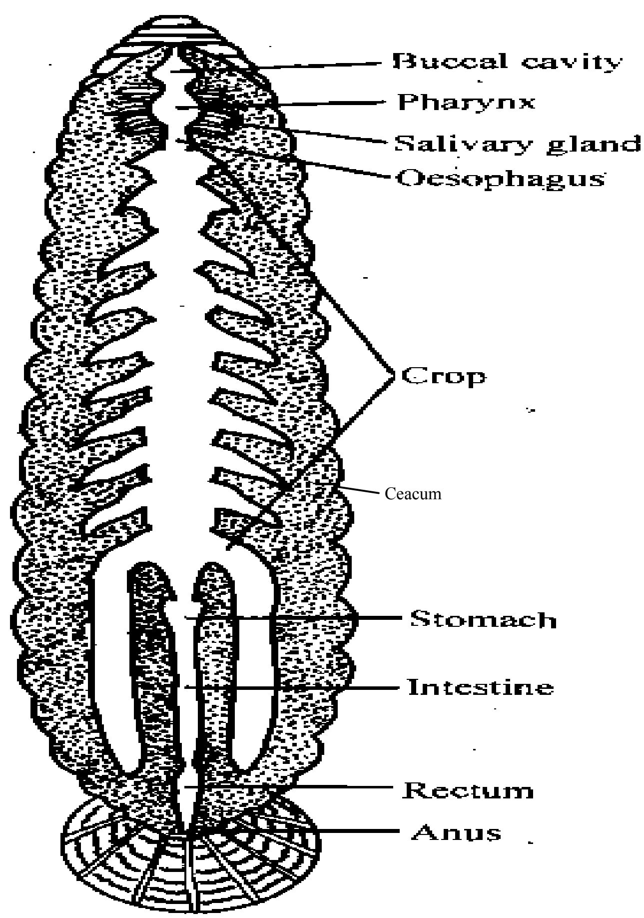

Fig3.10. Digestive system of leech

3.4.2 FEEDING MECHANISM IN MOLLUSCA

Molluscs have a variety of different feeding mechanisms. The bivalve molluscs do filter-feeding. Some of the single-shelled molluscs (e.g.limpets) possess a ribbon-shaped tongue or radula, covered with rasping teeth, which enables the animal to scrape algae from the rock. Whelks have a radula on a stalk that can extend beyond the shell and is used to drill holes into the shells of other molluscs. Through these holes they enter the tip of the radula and suck out the flesh of the victim. The cone-shells also have a stalked radula with which they secure their prey before injecting it with poison.

3.4.2.1 IN LAMELLIBRANCHS

Lamellibranchs are semi-sessile animals confined to their protective shells and inhabit muddy or sandy substrata. These are **microphagous filter feeders** and make use of their ciliated gills or lamellae as food-gathering devices. The lamellae are structured to filter suspended and deposited material from water current that enters through inhalant siphon and exits through exhalant siphon of the animal. During this process, water current is maintained through cilia present on the gills.

The ctenidia of the mussel are of eulamellibranch type. Each gill or ctenidium is formed of two demibranchs attached to a central axis and each demibranch has a parallel row of filaments. The structure of the filament varies in different groups of bivalves. In *Mytilus,* ctenidium is made up of two gill plates or laminae. Each lamina consists of two lamellae,having V-shaped gill filaments. Inter-lamellar junctions are present but inter-filamentar junctions are absent. In *Anodonta,* the filaments are joined to each other by vacuolar inter-filamentar junctions. In lamellibranchs, the gill filaments are strengthened by chitinous rod and covered by three types of cilia. Those arranged on its outer ridge are called frontal cilia, on lateral part are lateral cilia and those lying in between are the latero-frontal cilia. Water is drawn into the mantle cavity by beating of the lateral cilia. As water passes through the filaments, the food is gathered by **latero-frontal cilia** and is thrown towards frontal cilia. The food particles now entangled in mucus and food-laden mucous masses from both the side of gill lamina are swept over the surface of gill lamellae and find their way to food groove. This may be ventral marginal groove or dorsal groove along the axis of the gill, depending on the species. Food material is then carried to the two pairs of labial palps lying on each side of the mouth and then forwarded towards the mouth. The ciliary tracts on gills as well as labial palps do the sorting of food which depends on the weight of particles. Fine cilia on certain gill tracts convey the fine particulate food to the mouth and the heavier particles that settle down on palps are swept away by powerful ciliary currents. Lighter ones avoid this current, sink to the bottom and are swept towards the mouth. The rejected particles get entangled in mucus and are ejected out through exhalant siphon. The mouth leads into oesophagus and oesophagus opens dorsally into a wide, thick-walled stomach. From posterior end of stomach, a tubular diverticulum emerges ventrally, known as style sac. Lamellibranchs are characterised by a very compact and long rod formed by the consolidation of **mucoprotein**, called as **crystalline style**. It is secreted by the **style sac**. The style sac is lined with cilia which rotate the crystalline style and drive it forward into the stomach so that its free end projects into stomach. It is constantly rubbed against the **gastric shield**, which is a thickening of the cuticular lining of the stomach (Fig 3.11). Stomach is surrounded by digestive gland. In front of style sac, intestine arises from the stomach floor and runs ventrally in foot region and coiled upon itself. Now it runs dorsally and continued into rectum. Rectum opens to outside by the anus.

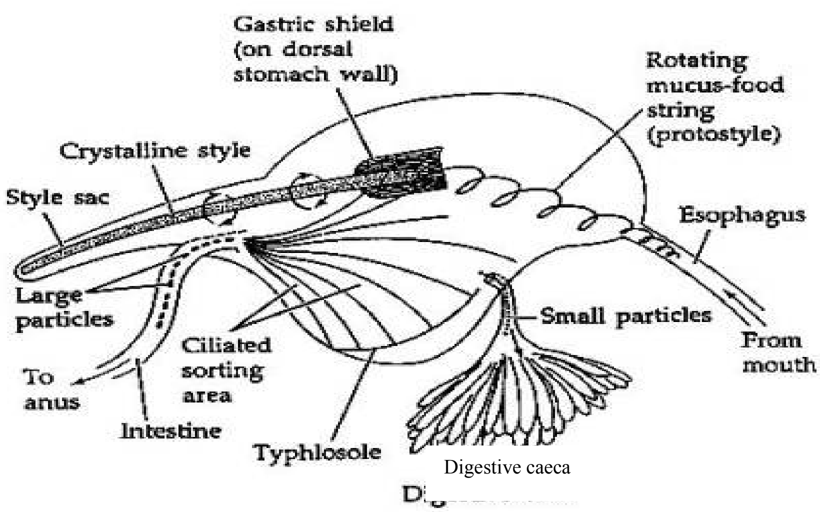

Fig.3.11Feeding mechanism in a lamellibranch

Digestion is mostly intracellular and occurs in digestive gland. From stomach, only the fine food particles enter the digestive gland. Extracellular digestion also takes place for which digestive enzymes are secreted by the digestive gland and released in to stomach by ducts. During this process, the crystalline style also helps in extracellular digestion. Mechanically it churns the food and chemically it releases **amylase** enzyme, to digest **carbohydrate**. In some species **cellulase** is also released. The rotation of the mucus-cum-food strand by the crystalline style as well as the pH of the stomach contents (pH5-6) result in the continuous separation of the food and-mucus into fine particles. The detached particles are sorted out by the stomach wall and the larger and heavier particles are transported by cilia into the intestine where they are converted into faecal pellets and removed. The finer particles are carried towards the digestive gland where intracellular digestion takes place. The digestive gland is made up of highly branched system of blind tubules. The tubules are lined by ciliated epithelium, having vacuolated cells of phagocytic nature. The cells ingest the fine particles into food vacuoles and digest them. Thus digestion in lamellibranchs is largely intracellular, although secretions from style sac initiate carbohydrate digestion extracellularly.

3.4.2.2 GASTROPODA

In most gastropods, the digestion is extracellular. The herbivore gastropods like *Crepidula* are ciliary feeders and have a digestive system similar to that of lamellibranchs. Here, amylase is the only extracellular enzyme; the digestive gland does not secrete any enzyme but is only absorptive in function. *Crepidula* also has a crystalline style similar to those of lamellibranchs. The herbivorous gastropods belonging to Taenioglossa, Rhapidoglossa and Pteropoda also possess crystalline style. The crystalline style is confined in only those herbivorous gastropods that are microphagous feeders.*Patella, Haliotis, Aplysia and Helix* some of the herbivorous gastropods that do not possess a crystalline style.Essentially in those forms where extracellular digestion has replaced intracellular digestion, a crystalline style is absent.

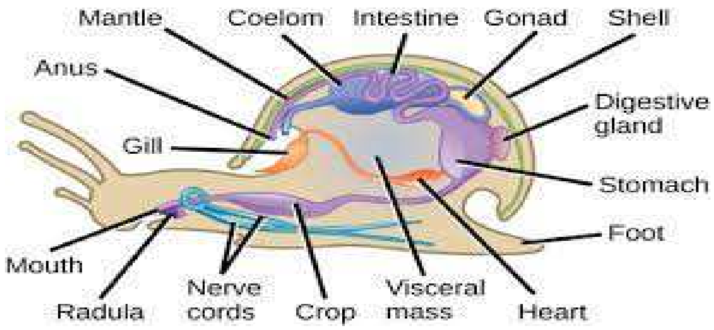

Fig.3.12 Digestive system in gastropods

3.4.2.3 CEPHALOPODA

Cephalopods are carnivorous. Tentacles or arms are food capturing organs and aid in holding the prey tightly after it is captured. The number of tentacles varies in different cephalopods like ten in *Sepia*, eight in *Octopus* and around 90 tentacles in *Nautilus*. In squids and cuttlefishes, four pairs of short and heavy tentacles are called arms and a pair of long structures is called tentacles. The inner surface of the arms is provided with stalked and cup-shaped suckers which are adhesive in nature. The suckers are provided with horny rings and hooks. In the mobile tentacles, the suckers are present only at the flattened ends. However, in *Octopus* suckers are stalkless and devoid of horny rings and hooks. In cephalopods, the mouth is present in mid of oral arms and surrounded by lips. The lips are embedded by a powerful pair of beak shaped jaws. The jaws are used for tearing and biting the prey before the tongue like action of radula pulls the food down and aids in swallowing. The mouth leads into a large thick-walled buccal cavity, containing tongue and radula. The oesophagus is a narrow tube-like structure, which opens into stomach. The stomach of cephalopods is highly muscular and contains a caecum attached to its anterior end. The stomach opens into intestine, which runs parallel to oesophagus and merges into rectum. The rectum opens into mantle cavity by the anus.

The digestive glands of cephalopods include salivary glands -two pairs of them located on either side of buccal cavity. The posterior pair of salivary glands secretes poison which is glycoproteins. In *Octopus* they also secrete proteolytic enzymes. Cephalopods also possess pancreas and liver. In squid the two structures are separated from each other and the pancreas empties their secretions into the duct of the liver.

Octopods feed on crabs, bivalves, snail and fish, which are seized by movement of arms and broken into pieces by radula and horny jaws. While feeding on shelled gastropods, octopods drill a hole in the prey with radula and then inject poison into the animal through the hole. The cuttlefish feeds on surface inhabiting organisms such as shrimps and crabs and *Nautilus* is a scavenger-predator feeding specially on decapod crustaceans, particularly hermit crabs. The buccal cavity conducts the food into stomach by peristaltic-action. Inside the stomach, the food mixes with the digestive secretions. The semi digested food passes to the caecum, where digestion is completed. The walls of the caecum absorb the digested food and the absorptive function is carried out to a certain extent by the intestine as well. The undigested food is expelled out of the anus.

3.4.3 FEEDING AND DIGESTION IN ECHINODERMS

Echinoderms exhibit a variety of feeding habits. Most of them are carnivorous but some of them are suspension feeders, some are deposit feeders, others could be scavengers and still others are grazers. Digestion in echinoderm is largely extracellular and occur in the gut lumen. The living cells of the digestive tract secrete digestive enzymes and mucus which lubricates the food. Most of the cells living the gut have an extensive brush border of microvilli which increase the surface area for absorption. Laemal sinus in the gut wall appears to store the products of digestion. Now we will study absent digestion system of different groups of echinoderms.

3.4.3.1 ASTEROIDEA

In asteroids (starfish), digestive system is compressed onoral-aboral axis (Fig 3.13). The mouth lies on oral surface in the centre of a muscular peristomial membrane and leads into a short esophagus, followed by the stomach. The stomach is differentiated into two parts, a large oral chamber - cardiac stomach and a small aboral chamber - the pyloric stomach. Each angle of pyloric stomach is drawn out radially into a duct which enters the corresponding arm and branched to form a pair of suspended inthe coelom of the arm by a mesentery. The caeca and pouches together constitute digestive gland. The pyloric stomach leads in to a short intestine which gives off two or three hollow diverticula,called as rectal cancan. The part of intestine distal to the caeca is called rectum. It opens to outside by rudimentary anus, situated on aboral suface.

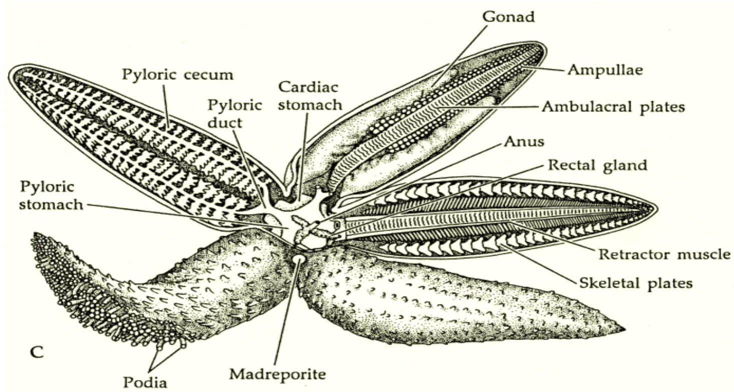

Fig. 3.13 Digestive system of starfish

Asteroids are scavengers and carnivores and feed on invertebrates such as snails, bivalves, crustaceans, polychaetes and other echinoderms. When a starfish comes across a prey *such as* a mussel, it bends its flexible arms over it in an umbrella fashion and attaches the tube-feet to the valves of mussel. The two valves are pulled apart and the soft body of the mussel is exposed. Then the cardiac stomach is everted through the mouth, inserted into the mantle cavity and wrapped over the soft body of the mussel. The stomach engulfs the prey and the digestive juices are poured on it from the pyloric caeca. After the completion of the partial digestion, the stomach is withdrawn into the body, leaving the shell outside. The digestion is thus extracellular and the products of digestion are stored in the cells of pyloric caeca or passed through the caeca into the coelom for distribution. The undigested waste is ejected through the anus by pumping action of rectal caeca.

3.4.3.2 OPHIUROIDEA

In ophiuroids (brittle star), the alimentary canal consists of mouth, a short oesophagus, and a saccular stomach that ends blindly and its wall is closely attached to the aboral body wall of the disc. The stomach is eversible. The digestive system does not extend into arms and there is no intestine and no anus. The undigested food is eliminated through the mouth.

Ophiuroids are also carnivorous and they could be scavengers, deposit feeders or filter feeders. The food consists of minute organisms and decaying matter. During filter feeding, the arms are waved in water, and the plankton and detritus adhere to mucous cord strung between the spines of adjacent arms. The trapped food particles may be swept downward by a reduced spine, called tentacular scale due to ciliary action. In some ophiuroids, the food particles may be collected by the two pairs of tube feet located close to the mouth of each arm. The tube feet are then scraped across the tentacular scales and the collected particles are deposited in front of the scale, and passed along the mid-dorsal line of the arm towards the mouth by the ciliary action.Extracellular and intracellular digestion as well asabsorption occurs mostly within the stomach.

3.4.3.3 ECHINOIDEA

In echinoidea (sea urchin), the mouth lies in the centre of the peristome on the oral pole and leads into a buccal cavity. From buccal cavity a slender pharynx runs vertically which is surrounded by a masticatory apparatus, the **Aristotle's lantern**. Oesophagus follows the pharynx and runs vertically upwards close to the aboral end continue into stomach. The saccular stomach at first has a downward course, reaches almost the oral end and then curves to makes a loop, runs anti-clockwise closely opposed to the inner side of the test. The stomach then continues into intestine which runs parallel to stomach in clockwise direction (Fig.3.14). The intestine is followed by rectum which ascends vertically to open by the anus, situated on aboral side. The oesophagus, stomach and intestine are all suspended by mesenteries. A small, narrow, cylindrical tube is connected at both ends of stomach, called as intestinal siphon. One end of the siphon opens into stomach at its junction with the oesophagus and the other end passes into the intestine. Aristotle's lantern, the masticatory apparatus, is formed of five plates or jaws fitted together as an inverted pyramid (Fig. 3.15). Each plate is a triangular framework, within which a long-pointed tooth is present. The tooth is long, narrow, curved and pointed. It can slide up and down in the frame by muscular action. In addition to the jaws and teeth, Aristotle's lantern also consists of a number of smaller, rods like pieces at the aboral end. The lantern can be protruded from the mouth by the action of the muscles. In addition to scraping, the lantern is also useful in pulling and tearing of food. Echinoids are grazers and use their teeth for scraping the substratum on which they live. They feed on a wide variety of plant and animal material and the algae are most important food. The function of the siphon is to remove excess water from the food before the digestion starts in the intestine.

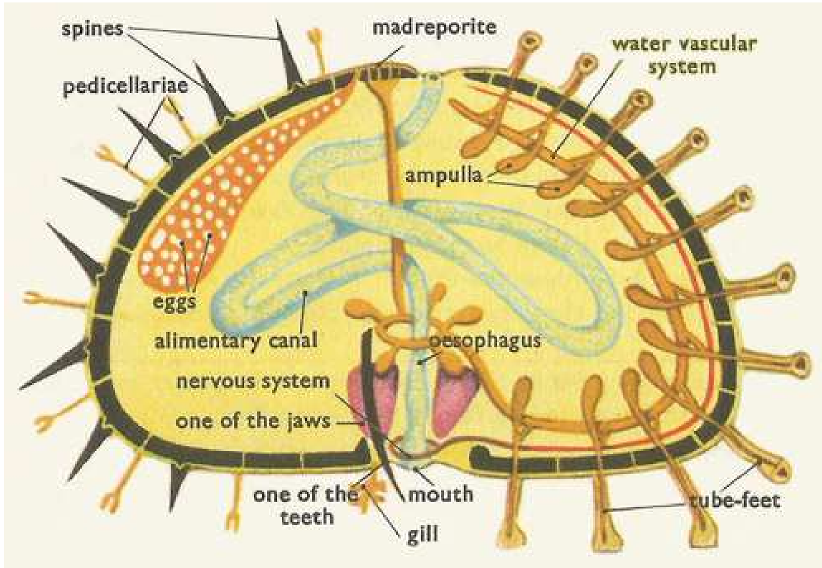

Fig 3.14 Digestive system of sea urchin

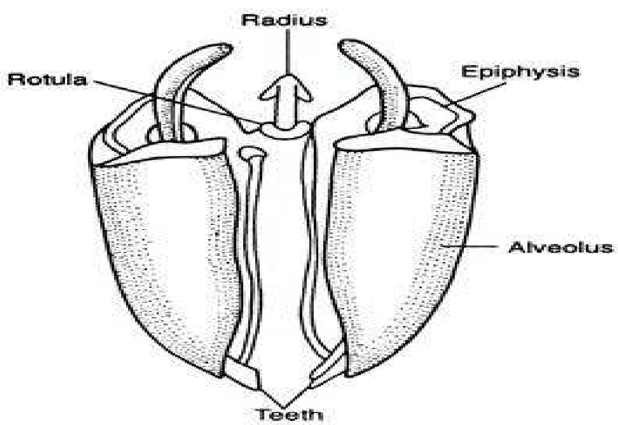

Fig 3.15 Structure of Aristotle's lantern

3.4.3.4 HOLOTHUROIDEA

The alimentary canal of sea cucumber consists of mouth, pharynx, an indistinguishable stomach, a long, narrow and thin-walled intestine which ends into short and wide cloaca terminating at the anus. The mouth is located in the middle of a buccal membrane at the base of the tentacular crown. The branched tentacles are the food capturing organs. Sea cucumbers feed on minute planktonic organisms and detritus. The food particles are trapped on to the adhesive papillae located on the tentacular surfaces. One by one the tentacles are stuffed into the pharynx and the food particles are wiped off the adhesive papillae even as the tentacles are pulled out of the mouth. Digestion is extracellular, begins in the stomach and is completed in the intestine.

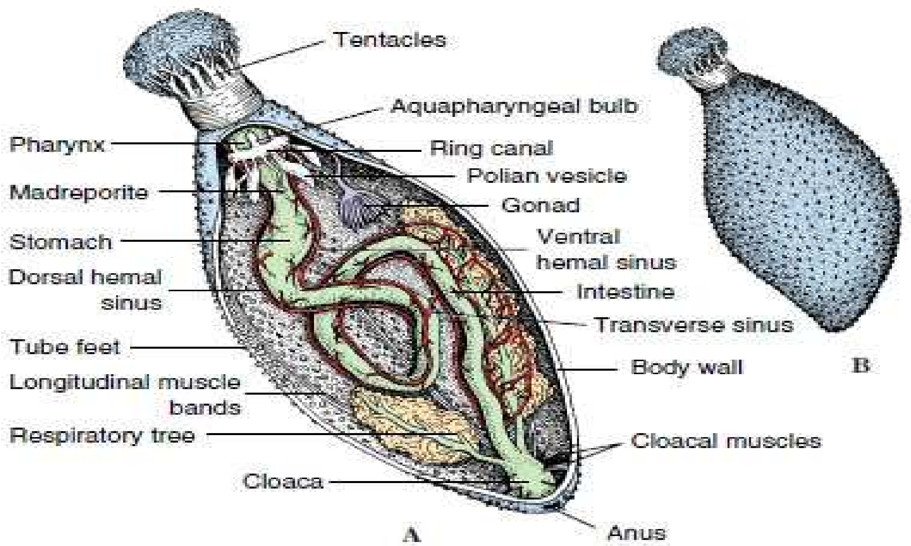

Fig. 3.16 Digestive system of holothurians (sea cucumber)

3.4.3.5 CRINOIDEA

The alimentary canal of crinoides (feather star) is tubular and consists of the mouth, a wide funnel shaped oesophagus, a spacious stomach and a coiled ascending intestine opening outside by anus. The stomach gives off many diverticula and a pair of hepatic caeca(Fig 3.17). The crinoids are suspension feeders. During feeding, the arms and pinnules are outstretched and the tube feet are erect. The tube feet appear as small tentacles and bear mucus secreting papillae along their length. The food particles trapped in the podia are passed into the mouth by the ciliary currents.

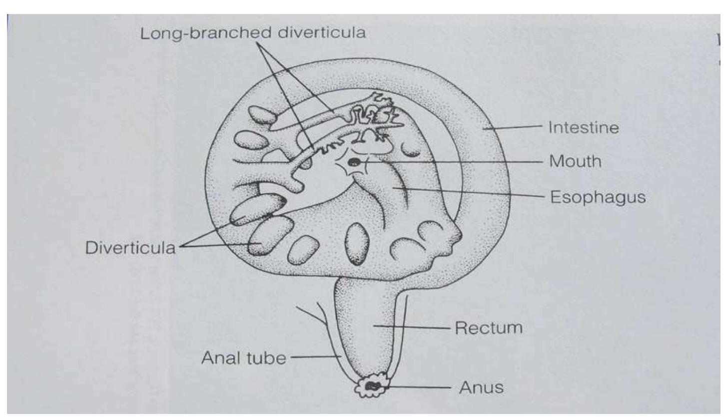

Fig 3.17 Digestive system of Antedon

3.5. SUMMARY

- Depending on the environment,the metazoans have evolved a variety of feeding habits in which they live and availability of the type of food. They may be microphagous or macrophagous feeders. The microphagous feeders may be filter feeders or feed on deposited food materials. Filter feeders may use ciliary-mucus feeding mechanism or make use of setae for gathering food.
- Sponges make use of the canal system for filter feeding of particulate food materials. Digestion is intracellular.
- Among coelenterates, the macrophagous and carnivorous feeders use the tentacles and the cnidoblasts for capturing prey. Digestion is firstlyextracellular then intracellular.
- Flatworms may digest food exclusively intracellularly as in *Polycelis* or exclusively extracellulary as in *Cycloporus.*
- Annelids generally exhibit extracellular digestion. Among annelids, oligochaetes feed on dead organic matter. In these organisms' food is acted upon by digestive enzymes. Besides amylase, protease and lipase, the oligochaetes also secrete enzymes such as cellulase and chitinase. The polychaetes include both, free living macrophagous forms and the sedentary microphagous forms. Macrophagous feeders have eversible proboscis as feeding organ. Sedentary polychaetes resort to ciliary mucus -feeding. Sedentary forms have a branchial crown of tentacles; protrude from the end of tube. The tentacles are lined with pinnules which interlock and form a filtering device. Cilia are borne on the pinnules and direct the food into mouth. Tube dwelling polychaetes are efficient ciliary-mucous feeders.
- Among molluscs, lamellibranchs are ciliary-mucus feeders. The gills plates along with labial palps are food gathering devices. V- Shaped gill filaments of lamella are covered by cilia. Water is drawn into the mantle cavity by beating of the lateral cilia of gill filament. Coarse cilia reject the large food particles and fine cilia direct the movement of food towards the mouth. Digestion is mostly intracellular in lamellibranchs. A unique structure called crystalline style releases carbohydrate digesting enzymes. In gastropods the digestive system is similar to those of lamellibranch. Some herbivorous microphagous gastropods also possess

crystalline style. Both in gastropods and cephalopods digestion is extracellular.

- Among echinoderms, the digestive system is compressed on oral-aboral axis. Their digestive system extends into arm. These are carnivores and digestion is extracellular. The digested food is stored in cells of pyloric caeca. In ophiuroides, the entire alimentary canal is restricted within the disc and it is not extended into arms. There are no caeca, no intestine and no anus. The undigested food is eliminated through the mouth. Extracellular and intracellular digestion as well as absorption occurs mostly within the stomach. In echinoides, oral surface bears the mouth surrounded by a membranous peristome and aboral end bears anus. A unique and complicated masticatory apparatus is connected with digestive system. It is known as Aristotle's lantern. The cylindrical siphon connects the two ends of stomach. It removes excess water from the food, accomplishing digestion in intestine. Sea cucumber feeds on minute planktonic organisms and crinoides are suspension feeders.

3.6. SELF ASSESSMENT QUESTIONS AND ANSWERS

3.6.1. MULTIPLE CHOICE QUESTIONS

1. The Aristotle's lantern is useful in

(a) Photoreception (b) Chewing

(c) Excretion (d) Respiration

2. Which of the following cell stores digested food in sponges?

(a) Thesocyte (b) Choanocyte

(c) Porocyte (d) Pinacocyte

3. Aristotle's lantern is present in

(a) Sea lillies (b) Sea cucumber

(c) Sea urchins (d) Sea pen

4. Anus is absent in the digestive system of

(a) Flat worms (b) Polychaetes

(c) Lamellibranchs (d) Cephalopods

5. In lamellibranchs, the crystalline style secretes

(a) Carbohydrate digesting enzymes (b) Protein digesting enzymes

(c) Fat digesting enzymes (d) none of the above

6. The digestion in sponges is

(a) Intercellular (b) Extracellular

(c) Intracellular (d) Holozoic

7. The pointed part of the nematocyst projecting out of the body of *Hydra*is

(a) Barbs (b) Style

(c) Capsule (d) Cnidocil

8. Typhlosole serves for

(a) Absorption (b) Excretion

(c) Nutrition (d) Egestion

9. Chlorogogen cells of earthworm are analogous to vertebrates

(a) Liver (b) Kidney

(c) Gut (d) Lung

10. In which of the animal, the cardiac stomach comes out of the body, feeds and digests food outside the body

(a) Starfish (b) Fresh water mussel

(c) *Pila* (d)*Neries*

11. Digestion in coelenterates is

(a) Intracellular (b) Extracellular

(c) First extracellular then intracellular (d)First intracellular then extracellular

12. Role of typhlosole in the intestine of earthworm is

(a) To control flow of blood (b) To produce digestive enzymes

(c) To increase absorptive surface (d) To kill bacteria

13. The chief function of nematocyst is

(a) To paralyse its prey (b) To test the quality of water

(c) To capture its prey (d) To test the quality of food

14. The poisonous fluid present in the nematocyst of *Hydra* is

(a) Toxin (b) Venom

(c) Hypnotoxin (d) Haematin

15. Starfishes are

(a) Herbivores (b) Omnivores

(c) Carnivores (d) none of the above

3.6.2. VERY SHORT QUESTIONS

1. Define microphagy.
2. Define nutrition.
3. Define macrophagy.
4. Define filter feeders.
5. Answer the following.
   a. Lamellibranchs are ciliary- mucus/rasping feeders.
   b. As the water passes through the gill filaments food is gathered by latero-frontal/frontal cilia.
   c. The crystalline style is formed of mucoprotein/glycoprotein.
   d. Crystalline style releases carbohydrate/protein digesting enzymes.
   e. In most gastropods, digestion is extra/intra cellular.
   f. Herbivorous microphagous gastropods do have/do not have a crystalline style.

.

ANSWERS

3.6.1. 1.(b); 2.(a); 3.(c); 4.(a); 5.(a); 6.(c); 7.(d); 8.(a); 9.(a); 10.(a); 11.(c); 12.(c); 13.(a); 14.(c); 15.(c)

3.6.2. 1. The vast majority of invertebrates feed on particulate food material of very small sizethis process is called **microphagy**.

2. The interaction of nutrients and other substances of in food in relation to maintenance, growth, reproduction and health is called **nutrition**.

3. When invertebrates feed on large masses of food, it is called **macrophagy.**

4.

An aquatic animal, which feeds on minute planktonic organisms or suspended particles and filters it from the water, is called **filter feeder**.

5. a) ciliary-mucus; b) Latero-frontal; c) mucoprotein; d) carbohydrate; e) extracellular; f) do have

3.7 TERMINAL AND MODEL QUESTIONS

1. Describe feeding pattern in lower metazoans.
2. Describe feeding mechanism and digestion in different classes of molluscs.
3. Describe feeding mechanism and digestion in different classes of annelids.
4. Write a note on filter feeders.
5. Give answer of the following.

    (i) Structure of Aristotle’s lantern with suitable diagram.

    (ii) Write a note on feeding mechanism and digestion in starfish.

    (iii) Write a note on feeding mechanism and digestion in polychaetes.

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UNIT 4- RESPIRATION

CONTENTS

4.1 OBJECTIVES

After reading this unit, you should be able to –

- Enumerate the different respiratory organs found in animals.
- Describe various types of gills found in invertebrate phyla and their structures.
- Describe ctenidial respiration in molluscs.
- Describe pulmonary respiration (respiration through lungs) in invertebrates.
- Describe the tracheal system of insects.
- Give an account of the respiratory pigments found among invertebrates and their characteristics.
- Describe briefly the mechanisms of respiration through main respiratory organs of invertebrates.

4.2 INTRODUCTION

- **Respiration** is an essential physiological process of living organisms. It is the process in which oxygen is transported from outside environment to the cells/tissues of the organism with simultaneous transport of carbon dioxide in the opposite direction i.e., from tissues to the environment. The primary function of the respiratory system is to deliver oxygen to the cells/tissues of the organism and remove carbon dioxide from the tissues. The oxygen supplied to the tissues is used up by the cells in the breakdown of food stuff into carbon dioxide and water with the release of energy. Thus, respiration is the biochemical oxidation of food stuff into carbon dioxide and water to release energy.

- In higher animals, respiration occurs in two stages- **external respiration, internal respiration**and **cellular respiration.** External respiration refers to the exchange of oxygen and carbon dioxide across the respiratory surfaces such as skin, gills, lungs etcand involves two phases-
    - **Inspiration-** It is the process of taking in air to the respiratory organs or lungs.
    - **Expiration-** During expiration, the air is expelled out from the respiratory organs to the exterior.

External respiration is referred to as breathing or pulmonary ventilation in higher organisms.

Internal respiration refers to the transport of gases to and from the tissues by blood. In tissues, the exchange of gases is made between blood and interstitial fluid.

Cellular respiration refers to the biochemical pathway by which food molecules (glucose) are oxidized to carbon dioxide and waterin presence of oxygen with the release of energy in the form of ATP.

It is represented by the following equation-

$$C_6H_6O_6 + O_2 \longrightarrow CO_2 + H_2O + \text{energy}$$

Aerobic respiration refers to the respiration occurring in the presence of air (oxygen) but it can occur in the absence of oxygen called **anaerobic respiration.**

- Diffusion is the basic physical process underlying the exchange of gases that occurs during respiration. You know that gases move from the area where its partial pressure is greater to the area where its partial pressure is lower.
- Different organisms have different modes of respiration. In simplest form, the respiration is direct e.g., in Protozoa while others have special respiratory organs to carry out the process of respiration- integument or skin, gills, tracheae, lungs and other accessory structures. The structure and complexity vary from species to species. The complexity of the respiratory system correlates with the size of the organism. Aquatic animals having respiratory organs like gills depend on water for the oxygen and require more energy is to ventilate their organ by water. You know that tracheae and lungsare air breathing respiratory organs. Gills are found in both some invertebrates and aquatic vertebrates such as fishes. Invertebrate have simple respiratory organs than those of vertebrates.
- Some invertebrates and all vertebrates except Antarctic fish have certain coloured substances in their blood that increase the oxygen carrying capacity and have the property of combining with oxygen reversibly. They are referred to as respiratory pigments. The most widely distributed pigment is haemoglobin. The respiratory pigment may be corpuscular i.e., present inside the cells or extra-corpuscular i.e. present in the plasma.
- Animals employ different mechanistic strategies to carry out respiratory function depending on their habitat and complexity of respiratory organs.

4.3 ORGANS OF RESPIRATION

You know that in simplest forms of life, the respiratory gases diffuse in and out through the general body surface. In absence of respiratory organ, oxygen enters the cells and carbon dioxide is removed from the cells by the process of **simple diffusion** as they are in direct contact with the environment. Similarly, poriferans possess no respiratory organs but depend on the water that enters their body through ostia for the exchange of gases. Respiratory system is wanting in Coelenterates, Platyhelminthes and Aschelminthes.Annelids, arthropods, molluscs and vertebrates have special structures that carry out the function of respiration for the animal. The respiratory organs in vertebrates are more developed compared to those in invertebrates. Thus, the respiratory organs range from general body surface to highly specialized lungs in human. However, the respiratory organs must have certain characteristics to work as respiratory organ for the animal.

- The respiratory surface should be thin to allow diffusion of gases. Diffusion is indirectly proportional to thickness of the respiratory membrane.
- It should be highly vascularised i.e., should have extensive network of blood vessels
- Respiratory membrane should be moist to better facilitate diffusion.
- There must be a mechanism for driving in and out air or water for diffusion and ventilation to occur.

Different **modes of respiration/respiratory organs** are encountered among invertebrates and vertebrates. They are-

General body surface- Respiration through general body surface occurs in protozoa, porifera, coelenterate, some annelids**.** It is referred to as **direct diffusion**e.g. Protozoa**.**

Skin/integument- The respiration through skin or integument is referred to as **cutaneousrespiration**. It occurs in many annelids such as oligochaetes, hirudinarians, and some polychaetes, some sipunculid worms, frogs, eels etc.

Gills- Gills are highly vascularized respiratory organs adapted to carry out exchange of gases in the water medium. These are present in aquatic animals. Some poylcheate worms,aquatic insects, crustaceans, molluscs etc.They have large surface area. Different types of gills are found among animals. In mollusks, respiration through gills or ctenidia is called **ctenidial respiration**.

Lungs- Lungs include a variety of sac like structures that are richly supplied with blood vessels. Invertebrate lungs are diffusion lungs while vertebrate lung are ventilation lungs with good mechanism for ventilation. Respiration through lungs is referred to as **pulmonary respiration.**

Tracheae- are extensive network of air tubes found in insects. Tracheae carry air directly to the cells without blood (**trachealrespiration**).

Let us learn about main respiratory organs of invertebrates- gills, lungs and tracheae in detail.

4.3.1 GILLS

You know that gills are the respiratory organs of the aquatic animals. They are well adapted to extract oxygen from the aquatic medium through its epithelium but require a regular and continuous supply of water. Gills are highly vascularized structures with large surface area. Anatomically, they are the evaginations of the body wall. The exchange of gases in the gills is referred to as **branchial respiration**.

Gills of invertebrates are simpler than that of the vertebrates and are not associated with thepharyngeal gill slits. In some invertebrate's gill structure is modified to serve as feeding organ in addition to the respiratory organ for the animal.

Types of gills-

a) External and internal gills

External gills

- are not enclosed within the body structures.
- They are normally branched but may be filamentous and have large surface area.
- External gills are present in some annelids e.g. *Arenicola*, *Amphritie*, young ones of certain insects e.g. dragon flies, fish and amphibian larvae, echinoderms.

Internal gills-

- They are enclosed by or present within specialized branchial chambers or structures.
- Internal gills are found in prawn among invertebrates, among vertebrates in some fishes where the gills are covered by operculum.

b) True gills and epipodites

- True gills are laminated structures where gill laminae are arranged like the pages of the book.
- Epipodite are the false gills and are sac like structures located at the base of the maxillipedes of crustaceans.

Let us study the gills in invertebrate phyla- annelid, arthropoda and mollusca**.**

Gills in Annelida

Most annelids have no special organs for gaseous exchange and respiration occurs through the body wall. However, some aquatic annelids have gills or gill like structures through which gaseous exchange takes place between blood and the environment.

Gills are common among the polychaetes but vary greatly in both structure and location. They are never enclosed within the protective chambers since most species possessing gills live in tubes and burrows. Thus, **the polychaete gills are external gills and bear cilia**. You have studied that polychaetes possess lateral extensions of the body, called parapodia. The main function of these parapodia is locomotion but they also serve as respiratory function. In some annelids the modified parts of parapodia act as gills. You may remember the structure of parapodia which are made up of two lobes namely notopodium (upper lobe) and neuropodium (lower lobe). It is the upper lobe that carries out the function of respiration.

The gills in polychaetes may be or may not be associated with the parapodia.

Gills those are associated with parapodia

- The notopodium may possess a flattened branchial lobe which acts as a gill e.g., in *Nereis*.
- Dorsal cirrus of the parapodium is modified to serve as a gill. Cirrus may be formed like a long-inverted cone as in *Sabellaria*, a large flattened lobe as in *Phyllodoce* or irregularly branched filaments as in *Arenicola*.

In *Nereis*, the respiration is carried out not only by the body surface but also by the thin flattened lobes of parapodia which possess extensive capillary networks lying close to the surface. You know that*Arenicola*(Fig. 4.1 A), commonly called as Lug worm lives in J-shaped burrows in sea or estuaries having less salinity. Its body is elongated and is divisible into three regions namely anterior, middle and posterior region. Out of these regions the middle region is made up of thirteen segments, each bearing parapodia and irregularly branched gills. These gills are in fact the modified part of dorsal (notopodial) cirri.They are hollow branched outgrowths enclosing a central coelomic cavity and afferent and efferent vessels.

Gills those are not associated with the parapodia(refer to Invertebrate Zoology by R.D. Barnes)

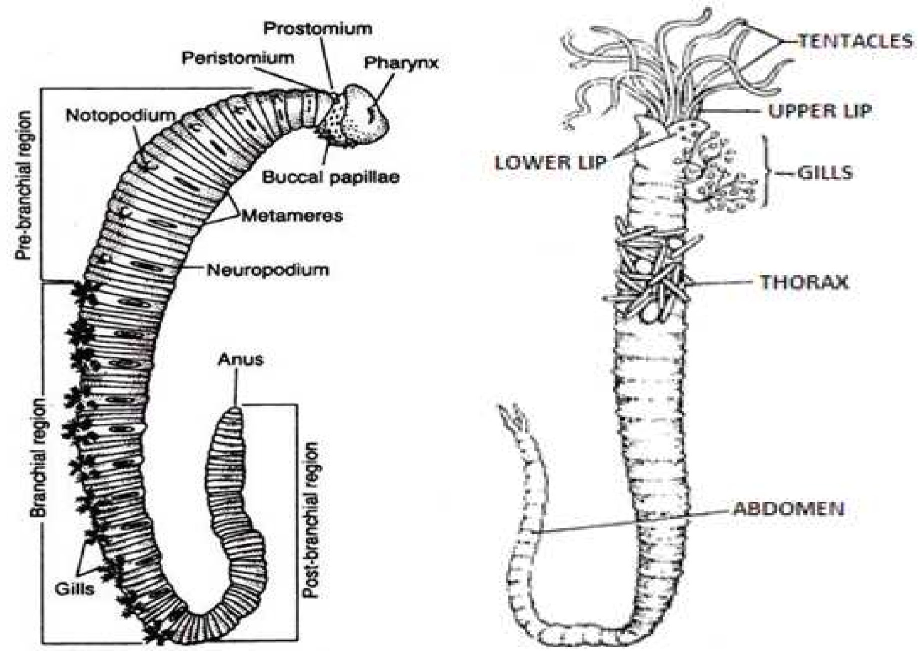
- Gills of annelids like *Amphitrite*
- Thread like gills of cirratulids
- Bipinnate radioles composing the fans
- Tentacles as gill in sedentary polychaetes.

*Amphitrie*is a marine tubicolous polychaete which lives permanently in tube of mud or sand between tide marks. Like *Arenicola*, its body is also divided into three regions-anterior, middle and posterior regions. The first three segments of the anterior region bear three pairs of gills. These gills are dorso-lateral branched tree like (arborescent) which act as respiratory surfaces. These gills can be projected from the opening of the burrow or the tube and have great surface area that may account to 25 to 30 percent of the total body surface of the worm.

The cirratulids like*Cirratulus cirratus* have long thread like gills arising from the many segments of the body.

Some sedentary polychaetes like *Serpula* and *Sabella* possess a crown of tentacles arranged in two bundles one on the either side giving a fan like appearance, hence commonly called fan worms. These tentacles are referred to as branchiae or radioles. Though the primary role of these radioles is to function as an organ for filter feeding, they also serve as respiratory organs. Because of their role in gas exchange, they are often referred as gills.

You know that *Terebella*(Fig. 4.1B*),* possessthree pairs of gills just below the head region.*Terebella*closely resembles *Amphitrite* but can be distinguished from the latter in having its third pair of gills smaller than the first two. Apart from this, the anterior region of *Terebella*bears long tentacles that also contribute to respiration function.



A **B**

Fig. 4.1 A. Arenicola B. Terebella
(Note the presence of external gills)

Oligochaeteslike earthworms do not have any respiratory organs and respiration occurs through body surface only.

Among **Hirudinea**, gills are found only in the **family Piscicolidae**.Most marine leeches belong to this family. These leeches are the macro-parasites of fishes and hence the name of the family. Piscicolid gills are lateral leaf like or branching outgrowths of the body wall. These lateral gills are vesicular and are filled with coelomic fluid.

Gills in Mollusca

You very well know that one of the distinguishing features of molluscs is the presence of a mantle that encloses a cavity called mantle cavity with some organs enclosed herewith. Most of the molluscs are aquatic and respire through gills which are the most important of all the organs in mantle cavity.

Gills of molluscs are-

- Highly specialized derivatives of the mantle.
- Suspended in the mantle cavity from the visceral mass.

- also referred to as ‘ctenidia’
- Composed of flattened filaments bearing lateral of frontal cilia

Let us study the structural details of a typical ctenidium.

Ctenidium

A ctenidium consists of a horizontal main axis attached to the body and bearing delicate, flexible lamellae or filaments. Surface epithelium of gills is usually covered by cilia, the movements of which cause continuous renewal of water over the gills. Most mollusks possess one pair of lamellar ctenidia while Cephalopods possess more than one pair of ctenidia. Near the ctenidia are found the osphradia which test the nature of the incoming water current.

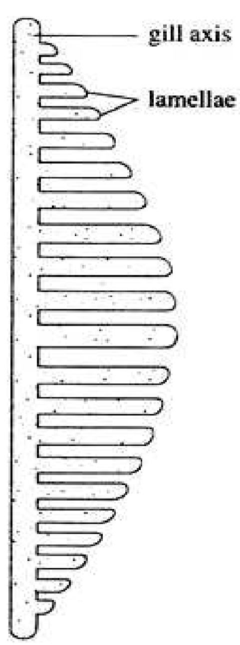
Based on the topography, the mollusc gills are grouped as

- **Holobranchiate**- ctenidia extend all over the body
- **Merobranchiate**- when ctenidia remain restricted to particular area of the body.

Based on the arrangement of leaflets, the gills are grouped into-

- **Monopectinate or unipectinate gills**
- **Bipectinate gills**

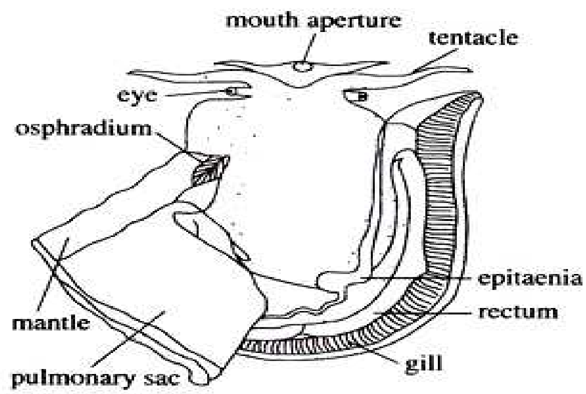
Monopectinategills (Fig. 4.1A) are comb like and are present in mollusks like *Neopilina, Pila* etc. The monopectinate gill of *Pila*is situated on the right side of the branchial chamber hanging from its dorsolateral wall (Fig. 4.1B) Itconsists of a long axis, ctenidial axis and a long series of flat and triangular leaflets (lamella) on one side only, hence the namemonopectinate (Fig. 4.2 A). Each lamella is attached to the ctenidial axis. Moreover, all the lamellae are not of the same size. In the middle the lamellae are larger and decrease in size towards the two ends. Each lamella is attached by the broad base to the ctenidial axis from which hangs down into the mantle cavity.



Ctenidial axis is traversed by an afferent and an efferent blood vessel. Afferent blood vessel carries deoxygenated blood to the gill while the efferent blood vessel delivers oxygenated blood from the gills to the heart.

Transverse ridges or pleats are present on the anterior and posterior faces of each lamella. These ridges contain branches of blood vessels through which the blood flows from the afferent blood vessel to the efferent blood vessel.

Ctenidium is innervated by nerves from the left pleural and supra intestinal ganglion. Histologically, each lamella is made of double layer of epithelium which encloses a narrow cavity. The epithelial layer consists of ciliated and non ciliated columnar cells and glandular cells.



A B

Fig.4.2A. Monopectinate gill B. Pila Mnatle cavity showing the gill

Bipectinate gills- Such type of gills is believed to be present in the ancestors of molluscs. The bipectinate gill or ctenidium consists of a long hollow axis, thesuprabranchial chamber. From this axis arise two filaments or laminae at right angles to each other. These filaments bear lateral cilia. Each gill lamina is made up of two gill lamellae

-outer lamella

-inner lamella

The outer and inner laminae are united at the ventral tip. The cavity within outer and inner lamellae is dividedby a series of vertical partitions; inter lamellar junctions that form a number of vertical compartments called water tubes. All the water tubes of a lamina open dorsally into the common supra branchial chamber.

In Unio, there are two such gills hanging in the mantle cavity, one on each side between the mantle and the visceral mass.

Bipectinate gills are of two types-

- **Equal-** when both are of equal size, e.g., bivalves
- **Unequal-** when right gill is smaller, e.g., Haliotis

Ctendia in different classes of molluscs

You know that phylum Mollusca is divided into many classes namely Aplacophora, monoplacophora, Polyplacophora, Gastropoda, Pelecypoda, Scaphopoda and Cephalopoda.

In class **Monoplacophora** e.g. *Neopilina* five pairs of monopectinate gills bearing finger like lamellae are present in the pallial groove. They are probably not considered true gills.

In **polyplacophorans** like *Chiton* ctenidia are arranged in two rows, one in each pallial groove. The number of ctenidia may vary from 6 to 80 among species. They are bipectinate and bear structure similar to that of the ancestral mollusks. The mantle in polyplacophorans is primarily posterior bearing true gills.

In class **Gastropoda**, ctenidia are found anteriorly as the mantle cavity is shifted to the front of the body as the result of torsion. Class Gastropoda is divided into three subclasses- prosobranchia, opisthobranchia and pulmonata.

- **Prosobranchia** – Most Prosobranchia retain a single pair of gills of the right side which have primitive bipectinate structure of the gill.
- **Opisthobranchia** – The mantle cavity tends to become shorter and moves back along the right side to its posterior position as a result of shell reduction and detorsion. In opisthobranchs, there has been a tendency towards the loss of true ctenidium and a greater demand on the mantle for respiratory needs, resulting in the development of secondary gills.
- In subclass **Pulmonilibranchiata** of terrestrial snails' gills disappear and the mantle is modified to form a sac like lung for aerial respiration.

Class **Bivalvia** (**Pelecypoda**) -The most complex molluscangills are found among pelecypods

A single pair of gills is present which has ancestral characteristics. Bipectinate gills which are equalon both sides. The function of these gills is bifold serving both as respiratory and feeding organs. Members of this class are referred to as lamellibranchs since they possess plate like gills.

Four types of gills are found in the members of this class-

- **Protobranch**- They are primitive type of gills in which gill filaments are not folded (Fig. 4.3 A).

- **Filibranch-** In filibranch, thegill filaments are elongated and thread like. Each gill filament is bent upon itself to form an elongated 'V forming ascending and descending limbs (Fig.4.3 B). Each gill is made up of two such V, called demibranchs (half gill), each demibranch being two lamellae thick. Thus, each gill forms a 'W' shaped structurein section (Fig. 4.3B). Demibranchs bear groups of large, stiff and interlocking cila. Non vascular inter-lamellar junctions may be present the ascending and descending limb of and hold together the two lamellae of each demibranch. Filibranch gills are modified as food collecting structures besides being respiratory organs.
- **Eulamellibranch-** These are the most developed gills in mollusks. Theyalso form W shaped gills in which inter filamentary connections and inter- lamellar connections are present (Fig. 4.3 C).
- **Septibranch-**The gills degenerate and are replaced by a horizontal, perforated, muscular septum, extending from the base of foot to the mantle.Based on the presence of type of gills, class pelycepoda is further divided into sub classes-Protobranchia, Flibranchia, Eulamellibranchia and Septibranchia,

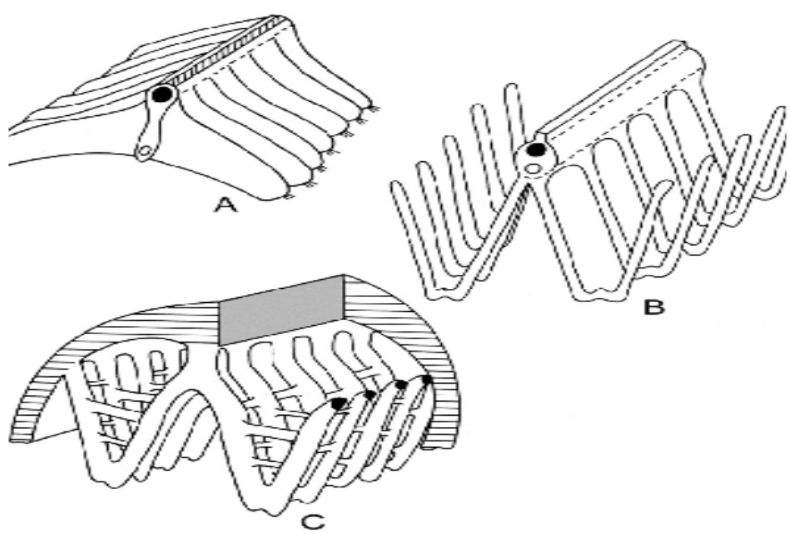


Fig.4.3 Different types of gills of Bivalves A. Protobranch B. Filibranch C. Eulamellibranch

Out of these eulamellibranchtype of gillneed special reference. Unio, a fresh water mussel possesses eulamellibranch gills.

Let us learn the structure of eulamellibranch in afreshwater mussel, *Unio.*

In *Unio*, there are two gills hanging in the posterior part of the mantle cavity. Each ctenidium is bipectinate and of eulamellibranch type. It consists of a hollow axis lying along the antero- posterior axis of the body from which two gill lamina arises. Each lamina is made up of twolamellae, an outer lamella and inner lamina both united at their tips. The cavity within these is divided vertically by a series of partition, the interlamellar junctions. These junctions thus divide cavity of lamella into many vertical cavities called water tubes. The entire outer surface of the laminae is covered by close sets of gill filaments imparting striated appearance to them. At their bases, the adjacent filaments are connected by horizontal inter filamentary junctions. The gills have a sieve-like appearance as they possess minute pores called ostia between the filaments. These ostia connect the mantle cavity with the water. Gill filaments are covered with cilia.

In class **cephalopoda,** gills are simple and bipectinate suspended on eitherside of the anus. Cilia are absent so that the water is pumped in and out by the coordinated activities of the mscular mantle and inlet valves. There are two in Dibranchia (e.g. *Loligo, Sepia, Octopus* etc.) and four in tetrabranchia (e.g. *Nautilus*).

In some molluscs, true ctenidia are absent; instead, different structures develop that act as accessory respiratory organs or adaptive gills. They are-

- **Anal gills**- a rosette of delicate, feathered and retractile gills surrounding the anus at the posterior end of the body. e.g. *Doris*
- **Cerata-**is comprised of numerous branched secondary gills on the dorsal surface of the body. They are richly vascular and have high power of regeneration. e.g. *Aeolis*
- **Pallial gills**-are present in a row on the lateral side in the pallial groove, hence the name pallial gills. e.g. *Patella*

Gills in arthropoda

Among arthropods, gills/gill structures are found mainly in crustaceans, aquatic insects and in some chelicerates.

Following types of gills are known to occur in arthropods:

A) Gills or branchiae
B) Branchiostegiteor gill cover
C) Epipodites
D) Book gills
E) Tracheal gills

F) Blood gills

G) Rectal gills

A. Gills or branchiae- Most well developed in crustaceans, especially in decapoda. Based on the shape, gills of decapods are divided into following three types-

a) **Phyllobranchiate gill** -In this type, the central axis of gills bear flattened branches, which are usually arranged in two rows along the axis (Fig.4.4 A and B). The gills of *Palaemon* are of this type.

b) **Trichobranchiate gill -** the branches of tricobranchiate gills are filamentous and sub branched and there are several series along the axis. Tricobranchiate gills are found in crayfish and rock lobsters (Fig.4.4 C and D).

c) **Dendrobranchiate** gill– In *Penaeus*, the gill is composed of central axis which bears on either side main branches that are in turn sub branched (Fig. 4.4 E and F).

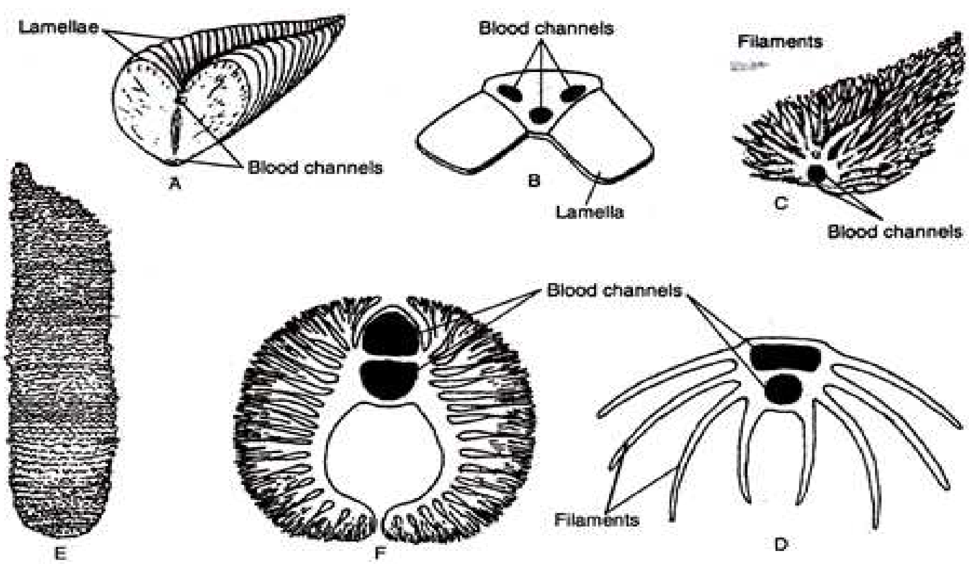


Fig. 4.4 Types of gills in decapods crustacean- A. lateral view of a phyllobranchiate gill. B. Transverse section of a phyllobranchiate gill, C. Entire trichobranchiate gill. D. Transverse section of a tricobranchiate. E. Entire dendrobranchiate gill. F. Transverse section of dendrobranchiate gill

Let us study the gills of *Palaemon* that are present in the chamber covered by gill cover called branchistergites. The respiratory system of Palaemon consists of a) the inner lining of the branchostegite, b) epipodites and c) gills or branchiae (gill chambers).

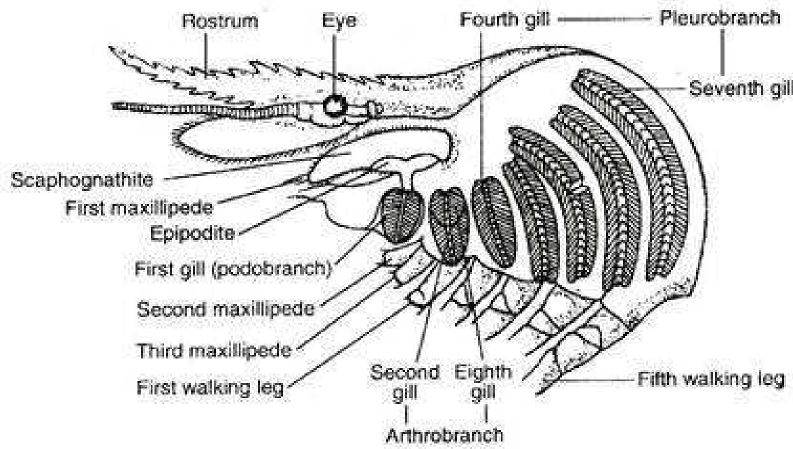


Fig. 4.5 Gill chamber of Palaemon

The **gill chamber**or the main respiratory organ of Palaemon is present on both sides of Palaemon houses eight gills or branchiae in each chamber. Only seven of them are exposed as the eighth gill lies beneath the dorsal part of the second gill. Gills are more or less crescentricin shape (Fig. 4.5). They gradually increase in size backwards so that each gill is larger than the one in front of it. Each gill is attached in its middle to the wall of thorax by gill root. The gills of Palaemon are of phyllobranch type.

According to the attachment, gills are divided into three groups-

a) Podobranch or foot gill is attachedto the coxa of appendages**.**

b) **Arthrobranch or joint gill** is attached to the arthrodial membrane joining a limb with the body.

c) **Pleurobranch or side gill** isattached to the lateral wall of segment bearing the limb

B. Branchistegite or gill cover- The thin, membranous and highly vascularised inner lining of gill cover form large surfaces that help in respiration e.g. in*Palaemon***.**

C. Epipodites are highly vascularized leaf like membranous outgrowth s of integument on the outer side of the coxa of the maxillipedes in first three segments. They carry out the respiratory functions e.g. *Palaemon*.

D. Book gillsare a kind of gills that consists of membranous folds arranged like the leaves of a book similar to book lungs found in some arachnids. However, book gills are extremely present while book lungs are found internally. Inxiphosuran, *Limulus*, which lives in shallow water, the abdomen bears six pairs of appendages, the first pair forming the genital aperture. The nextfive appendages are modified as flap likeand membranous, each pair being fused along the midline. The under surface of each flap is formed into many leaf like folds called lamellae. Each gill contains approximately 150 lamellae.

E. **Tracheal gills**are leaf like or filiform outgrowths covered by very thin cuticle with a network of tracheoles. They are known to occur in water nymphs and larvae of many aquaticinsects e.g. nymphs and larvae of many aquatic insects**.**

F. **Blood gills**Some aquatic insects possess gills that are devoid of tracheae but containing blood. These are termed as blood gills. They are present in aquatic insects such as trichopterus and tipulid larvae.

G. **Rectal gills-**In larvae/nymphs of some insects, tracheal gills in the form of an elaborate system of folds in the wall of the rectum, used in respiration. Thus, rectal gills are internal gills associated with the rectum e.g. larval Anisoptera/dragon flies.

4.3.2 LUNGS

You know that lungs are internal vascularized air sacs where air and blood are brought together in close proximity for the exchange of gases between air and blood. Among invertebrates, the lungs are found in several of the terrestrial species viz. pulmonate snails, scorpions, some spiders and several crustaceans.

Lungs are classified as

- **Water lungs**
- **Diffusion lungs**
- **Pulmonate sac/lung**
- **Book lungs**
- **Ventilation lungs**
- **Alveolar lungs** includelungs of terrestrial vertebrates

Invertebrate lungs lack good ventilating system as compared to the ventilating lungs/alveolar and hence are referred to as **diffusion lungs.** Lungs of vertebrates have good ventilating mechanisms and are not related to the invertebrate lungs Moreover; invertebrate lungs are leaf like whereas they are alveolar in case of vertebrates.

Let us study about the lungs of invertebrates in detail.

Water lungs are filled with water that are alternatively filled and emptied of water e.g. water lungs of sea cucumber also reffered to as **respiratory trees**. A respiratory tree consists of a series of narrow tubules branching from a common duct and lie on either side of the digestive tract. Sea cucumbers extract oxygen from water in respiratory trees that branch in the cloaca just inside the anus, so they breathe by drawing water in through the anus and then expelling it. Gaseous exchange occurs through the thin walls of tubules of respiratory trees.

Diffusion lungs include pulmonary chambers of snails and book lungs of scorpions and spiders.

a) **Pulmonate sac/lung**

In terrestrial pulmonates like Limax, a true ctenidium disappears and the mantle cavity is transformed into a vascularized pulmonary sac or lung for aerial respiration. Pulmonary sac/lung of molluscs does not correspond morphologically with the spongy, cellular lungs of vertebrates. It simply performs the same function. In certain forms like *Pila*(prosobranchiate), both ctenidia and pulmonary sac are present and the mantle cavity is divided into right pulmonary chamber and left branchial chamber by an incomplete septum. Animal can breathe in water by its gills and by its lung in air. Pulmonary sac is a bag like structure that hangs into the pulmonary chamber of the mantle cavity and communicates with the pulmonary chamber through a large, oblique pulmonary aperture, pnematostome. Alternate muscular contraction and relaxation of mantle floor result in the movement of air in and out of the pulmonary chamber respectively.

b) **Book lungs :** In some air breathing arthropods like scorpions and some spiders, the respiratory structures are made up of several thin membranes that are layered like the pages of the book, hence the name book lungs (Fig. 4.6). Book lungs are more primitive and probably are a modification of book gills. The two are similar but in contrast to book gills, book lungs are internal.

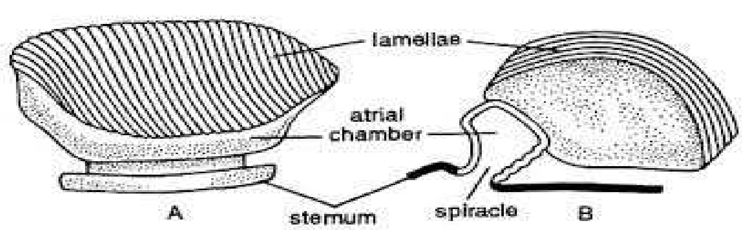


Fig. 4.6 Scorpion book lung A. Entire view B Lateral view

They are surrounded by the haemolymph. There are four pairs in scorpions and two pairs in spiders. In simple words, book lungs are paired invaginations of the ventral wall.

They are actually formed by invaginations of cuticle and hence are also referred to as cuticular air sacs.

Let us talk about the book lungs of a common scorpion in order to understand the basic structure of book lungs.

Palamnaeus, a common scorpion possesses four pairs of book lungs. The four pairs of book lungs are located in the third, fourth, fifth and sixthmesosomal segments ventrally, one pair in each segment.

Each book lung consists of two parts (Fig. 4.6 B)

- **Proximal or ventral part**which has following structures
  - **Atrium**- an air cavity
  - **Spiracle or stigma**- slit like opening in the atrial chamber present in the ventrolateral side of the sternum
- **Dorsal part-** is made of about 150 vertical folds or lamellae, stacked together like the leaves of book and is richly supplied with blood. Each lamella is hollow structure made up of two thin layers of cuticle which are united at the edges (Fig.4.6 A). The interlamellar space is filled with air. Air chamber, atrium is continuous with the interlamellar space.

Venous blood from ventral sinus enters each book lung through a diverticulum which opens at the base of the lamellae. Aerated blood is collected by a pulmonary vein which runs dorsally to open into the pericardium. Air enters the book lungs through a spiracle and circulates between the lamellae. Respiratory gases diffuse between the haemolymph moving along the lamellae and the air in the air chamber

4.3.3 Trachea

In insects, the respiration occurs mainly through an elaborate system of branching and anatomizing tubes which opens to the exterior through pairs of pores, **spiracles** (usually one pair in each segment) on the lateral sides of the body.These tubes are referred to as **tracheae** (singular- **trachea**) and together constitute the tracheal system that delivers oxygen to and remove carbon dioxide from the tissues.The general plan of tracheal system of insects is similar to the circulatory system of vertebrates. Tracheal tubes are distributed throughout the body of the insect so that air is brought in direct contact with the tissues and cells of the body.

You know that mammals possess ‘trachea’ which is a single tube-like structure that helps in transport of gases to and from the lungs. Though the basic physiological function of the trachea of both insects and mammals is to help in breathing their mode of action, anatomy and specific function differs.

Tracheal system of insects is classified into following types based on the number and distribution of function spiracles-

- **Holopneustic**- when all the spiracles remain open e.g. most adults and many larval insects
- **Apneustic**- when the spiracles are altogether lacking e.g. endoparasitic and aquatic larval insects
- **Hemipneustic-** when one or pair of spiracles remains closed e.g. some flies, beetles, butterflies etc.

Anatomical structures of the tracheal system

The tracheal system of insects is composed of the following structures (Fig. 4.12 A)-

- Spiracles
- Atrial chamber
- Tracheae
- Tracheoles
- Air sacs in few insects

Spiracles are the series of external openings present laterally in the thoracic and abdominal segments of the insect body. Each spiracle is supported by a small annular sclerite and is provided with a closing mechanism. They are closed by the action of sphincter muscle and their opening results from the elasticity of the surrounding cuticle when sphincter muscles relax.

Atrial chamber or atrium- In most insect's **s**piracles open internally into a space or pit called atrium or atrial chamber. It possesses a **filtering apparatus** and a **valve** that functions as closing apparatus so as to regulate the movement and direction of the air flow and prevent undue loss of water. Filtering apparatus is composed of fine hair or bristles that do not allow dust particles to enter the tracheal system.

Tracheae-Atrial chamber opens into an extensive network of branching and anatomizing tubes. Such tubes are called tracheae and are the main components of tracheal system along with its finer branches, tracheoles. The wall of trachea in insects is made up of three layers, innermost layer composed of epicuticle, middle cellular layer of epithelium and outer most basement membrane. The pattern of the internal tracheal system is quite variable, but a pair of longitudinal trunks with cross connections forms the ground plan of most species. The tracheae are supported by thickened spiral rings of cuticle, the taenidia. These taenidina prevent the tracheae from collapsing.

Tracheolesare the smallest subdivisions of the tracheae and are often given as clusters from the tracheae. They in turn further branch into a fine network over tissue cells (Fig.4.12). A number of tracheoles may be formed from a single tracheole cell. Tracheoles differ from tracheae in many respects. They have lesser diameter than that of tracheae. Tracheoles are not uniform in diameter being broader proximally and tapering down distally to end blindly in the individual cells. They lack taenidia and are lined by a protein called trachein. They are permeable to liquids. Their tips are filled with a fluid called tracheole fluid at their distal end. They enter individually into cells, tissues, muscle fibers without disturbing the cell membrane. The tracheole cuticle is not shed during molting as occurs in tracheae. After molting, new tracheae are formed and joined to old tracheoles.

Air sacs-In some insects, tracheae form internal air sacs which do not have taenidia and are responsive to the ventilation pressures. These may be found in places where the muscle movements may fill and empty them and offer a greater breathing capacity to the insect.

The **tracheal system** is also known to be present in **arachnids** similar to that of insects but has evolved independently. In fact, the tracheal system appears to be derived from the book lungs in some cases.

4.4 RESPIRATORY PIGMENTS

Respiratory pigments are coloured proteins that combine with oxygen and help in its transport in animals. They are of great physiological importance especially in large sized animals. Oxygen diffuses across the respiratory epithelium into the blood and combines with the respiratory pigment. The combination of oxygen with respiratory pigment is reversible and forms a loose combination. The presence of these pigments in blood increasesits oxygen content thereby increasing the oxygen carrying capacity of blood and thus theefficiency of the respiratory system. In the absence of a respiratory pigment, the oxygen content of blood would be low. In other words, the presence of a respiratory pigment in blood enables it to carry more oxygen than the same blood could carry without it. The capacity of respiratory pigments to become saturated with oxygen is affected by a number of factors such as temperature, pH, partial pressure of oxygen and the presence of CO_2 in the medium etc. These respiratory pigments may be present in blood plasma or corpuscles (cells) or in both.

Structurally, respiratory pigments are conjugated proteins containing two parts, protein part and a non protein part. The non protein part is tightly attached to the protein part and is referred as prosthetic group. Every respiratory pigment contains one or the other metallic ionswithin their prosthetic group which imparts the pigment their characteristic colour.

Four distinct respiratory pigments are found in animals

- **Haemoglobin**
- **Haemocyanin**
- **Chlorocruorin**
- **Haemoerythrin**

Out of all these pigments, the first two**, Haemoglobin** and **Haemocyanin** are widely distributedOther respiratory pigments include **Pinnaglobin** (in lamellibranchs), **Vanadium** (in ascidians),

Echinochrome, chlorocruorin etc.

Haemoglobin- It is the most widely distributed and studied respiratory pigment in the animal kingdom. All vertebrates possess intracellular haemoglobin in their blood while in invertebrates, if present remains dissolved in the plasma. You know that haemoglobin is made up of two parts- a non protein part called **haem** and a protein part **globin**. Haem in turn is made up of porphyrin containing iron atom in the center. Each haemoglobin molecule contains four haem groups and four proteins chains. In polychaetes such as Glycera and Notomastus, the haemoglobin contains two monomers having molecular weight of 34,000. The haemoglobin varies in oxygen carrying capacities depending upon the number of monomers present in it though other factors also affect oxygen carrying capacity of blood.

Haemocyanin-Thenext most widely distributed pigment is haemocyanin which is a copper containing respiratory pigment. It is less efficient oxygen carrier than haemoglobin. Unlike haemoglobin, it is a non haem protein and isextra-corpuscular pigment i.e. present only in blood plasma and not in corpuscles. It is light blue in colour in its oxidized form and colourless in its reduced form. Haemocyanin is known to occur in Cephalopods, such as *Sepia, Octopus, Loligo*, gastropods, many crustaceans and few arachinids such as scorpion and king crab.

Haemerythrin –It is an exclusively corpuscular pigment and is found to be present in some spinunculids and brachiopods. Like haemoglobin, it is also iron bearing protein and is red in colour. It is less efficient oxygen carrier as compared to haemoglobin and chlorocruorin.

Chlorocruorin –It is a green-coloured pigment known to be present in some polychaetes, particularly in the families, Sabellidae and Serpulidae. It also exists in oxidized and reducd form.

The oxygen carrying capacity of chlorocruorin is comparatively low and is estimated to be about 2.0 ml of oxygen per 100 ml of blood.

Respiratory pigments of Annelids

The blood of many polychaetes contains respiratory pigments in the plasma. Three out of four above mentioned pigments are found in polychaetes namely, **haemoglobin, chlorocruorin and haemerythrin**. Chlorocruorin is the characteristic of the blood of the serpulid and sabellid fan worms. Interestingly, the blood of *Serpula* contains both haemoglobin and chlorocruorin. *Amphitrite ornata*possesses haemoglobin in coelomic corpuscles as well as in blood vascular system. The two haemoglobins are not alike, coelomic haemoglobin possessing greater affinity for oxygen at low tensions. *Magelona*, a polychaete uses haemerythrin to transport oxygen and the molecule of oxygen is carried between two iron atoms. Polychaetes such as *Glycera, Capitella* and some terebellids contain haemoglobin located in coelomic corpuscles. Plasma or extra cellular haemoglobin and chlorocruorin are always large than that present in corpuscles.

Among oligochaetes, respiratory pigments are lacking in the blood of Aeolosomatidae and in many Naidae and Enchytraeidae. Other oligochaetes usually have haemoglobin dissolved in plasma. Among leeches, extracellular haemoglobin is found only in gnathobdellid and pharyngobdellid leeches and is responsible for about half of the oxygen transport.

Respiratory pigments of Molluscs

Haemocyanin is the main respiratory pigment of molluscs that gives faintly blue colour to the blood. The blood of cephalopods contains a haemocyanin that loads at the gills and unloads at the tissues at relatively high oxygen pressures. The blood of most gastropods, bivalves etc. contains haemocyanin dissolved in the plasma. Few gastropods such as *Planorbis*are known to contain **haemoglobin**in place of haemocyanin. The blood of most bivalves lacks any respiratory pigment, except in some species. Some bivalves such as *Solen* possess haemoglobin as respiratory pigment.The blood of Pinna (lamellibranch) has manganese containing brown pigment, **pinnaglobin**.

Respiratory pigments of arthropoda

Among arthropods, some arachnids such scorpions and many spiders with book lungs and xiphosuran, *Limulus* contains **haemocyanin**. Crustaceans contain either **haemoglobin** or haemocyanin. Malacostracans such as crabs, lobsters and shrimpscontain haemocyanin dissolved in the plasma.Refer to table 1 for comparison of respiratory pigments of animals**.**

Table1. Some important respiratory pigments of animals

Pigments	**Site**	**Metallic group**	**Colour**	**Distribution in animals**
Haemoglobin	Corpuscles Plasma	Iron	Red	All vertebrates Annelids and Molluscs
Haemocyanin	Plasma	Copper	Blue	Cephalopods and crustaceans
Chlorocrurin	Plasma	Copper	Green	Annelids
Haemoerythrin	Corpuscles	Iron	Red	Spinunculids and Brachiopods
Pinnaglobin	Plasma	Manganese	Brown	Lamillibranch

4.5 MECHANISM OF RESPIRATION

You studied the structure of specialized respiratory organs found among invertebrates. The main respiratory organs are gills, lungs and tracheae (in insects). These organs are adequately modified to perform respiratory function.

You know that respiration involves **inspiration** and **expiration**. Inspiration refers to the inflow of air into the respiratory organ while expiration refers to the expulsion of the inspired air to the exterior in terrestrial respiration. During inspiration oxygen is taken in and carbon dioxide is removed from the blood during expiration. In aquatic animals, water flows over the respiratory structures for respiration to occur. The water enters through particular pathway and moves out of the body of animals through the same pathway or in different direction.

A) Mechanism of respiration in gills/gill like structures of invertebrates

You know that gills are found in some annelids, mollusca and arthropoda. Let us learn about the mechanism of respiration in these organisms.

Annelids

In annelids some polychaetes such as *Nereis*, respiration occurs through thewhole-body wall and also through flattened lobes of parapodia which possess extensive capillary network lying very close to the surface. Blood running through them gives up oxygen collected from tissues and receives oxygen dissolved in surrounding water. Water is constantly renewed by gentle undulations of body.

Tubicolous annelids like *Amphtrite*, *Arenicola* and *Terebella* have gills that are uncovered. They drive water in their tube by the peristaltic movements of the body that flows over the gills and gaseous exchange takes place.

In **fan worms**, *Sabella* and *Serpula*that permanently remain in their tubes, radioles serve as the site for respirations (Fig. 4.7). The pinnules of each radioles are covered by tracts of cilia. Fan worms pump water through the tube by means of peristaltic contractions of the body. The cilia of radioles generate water currents flowing over the radioles where gaseous exchange takes place. There is a single branchial sinus in a radiole through which blood flows in both directions in a tidal fashion. When the crown is retracted inside the tubesensing some danger, the radioles cease to function as respiratory organ.

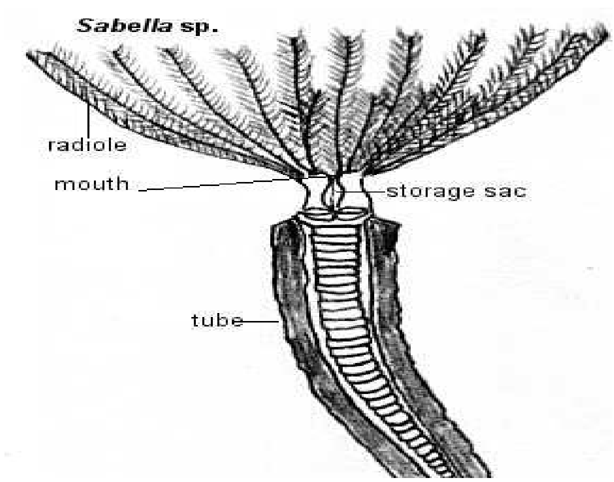
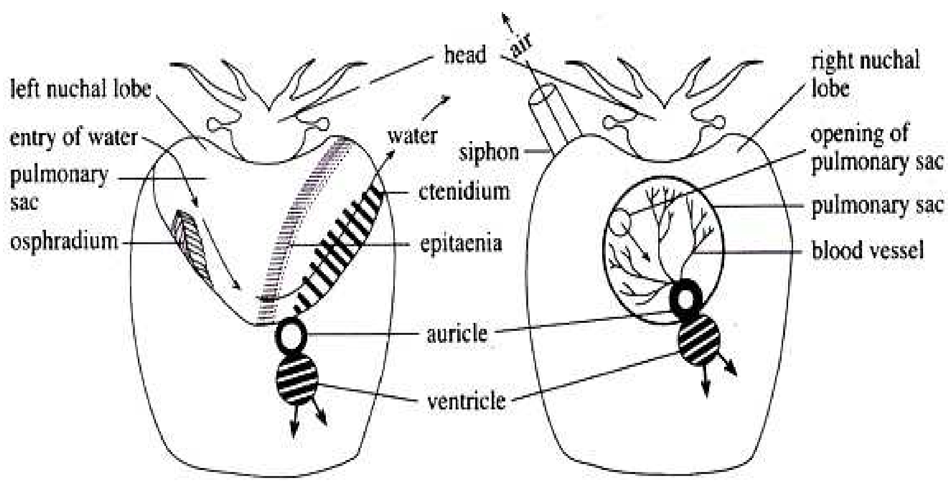


Fig.4.7 Sabella with extended radioles

Mechanism of respiration in Mollusc's gill or ctenidia

You know that aquaticrespiration takes place by ctenidium in molluscs which is an important organ of the mantle cavity. In molluscs, water is drawn into the mantle cavity by the beating of the cilia of gill epithelium or muscular pumping. Let us study the mechanism of ctenidial respiration in apple snail, *Pila* to understand the basic principle of respiration through ctenidia.*Pila* possesses monopectinate type of gill. It respires through ctenidia when it is at the bottom or is floating or lying suspended in mid waters or attached to water plants (Fig. 4.8 A). During aquatic respiration, *Pila* keeps its head and foot fully extended. Two nuchal lobes form channel like structures facilitates the entry and exit of water current. The water enters the mantle cavity through left nuchal lobe. This flow of water is maintained by the alternate protrusion and retraction of the head and by the beating of cilia on the lamellae of ctenidium. While water flows over the gill the exchange of gases takes place between the water and the blood vessels of gills.The water current first flows beneath the ospharadium that test the nature of incoming waterand then crossing over the epitaenia reaches the branchial chamber. After washing the entire length of the ctenidium, it flows through the right nuchal lobe. The oxygenated blood in the gill filaments is sent back to the heart through the efferent blood vessel.



A B
Fig. 4.8Pila A. Aquatic respiration B. Aerial respiration

The **bipectinate ctenidium of Unio is eulamellibranch** type. In *Unio,* thelateral cilia of the gill filaments and cilia lining the mantle generate current of water under the influence which the water enters the body of *Unio* through inhalant siphon. Thereafter the water enters the water tubes of the gill lamina through ostia. In the water tubes, the water flows upwards to enter the suprabranchial chambers. During the movement of water, exchange of gases takes place. The water flows backwards and reaches the cloacal chambers and moves out of the body through exhalent siphon (Fig. 4.9 and Fig.4.10).

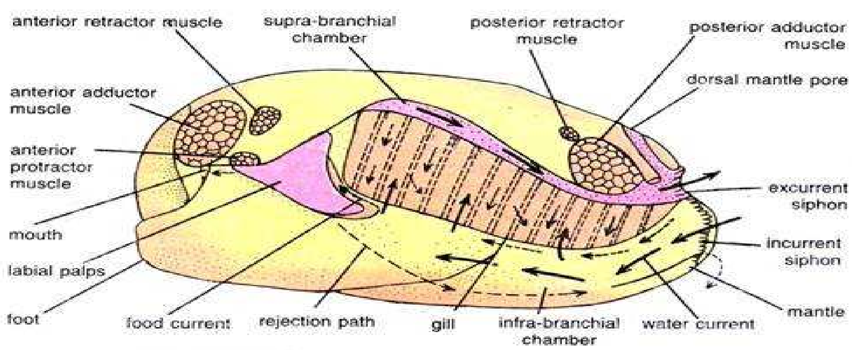


Fig. 4.9 Course of water in Unio

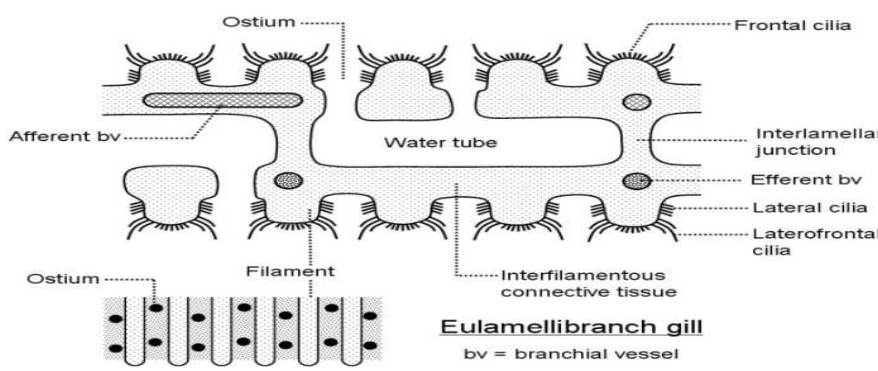


Fig. 4.10 Cross section of gill filament of Unio (schematic)

Mechanism of respiration in book lungs of arthropods

The movement of air in and out of the book lungs is controlled by the contraction and relaxation of dorso-ventral and atrial muscles. When these muscles contract, book lungs are compressed and air in interlamellar spaces is forced out into atrial chamber. From atrial chamber air is expelled to the exterior through stigmata (Fig. 4.11). When these muscles relax, the book lungs resume their normal shape so that fresh air enters first into the atrial chamber and then into interlamellar spaces. Thus, interlamellar spaces are filled with fresh air and exchange of gases takes place between air of interlamellar spaces and venous blood through the membranous walls of lamellae. Blood gets oxygenated and the carbon dioxide is passed out along the expelled air.

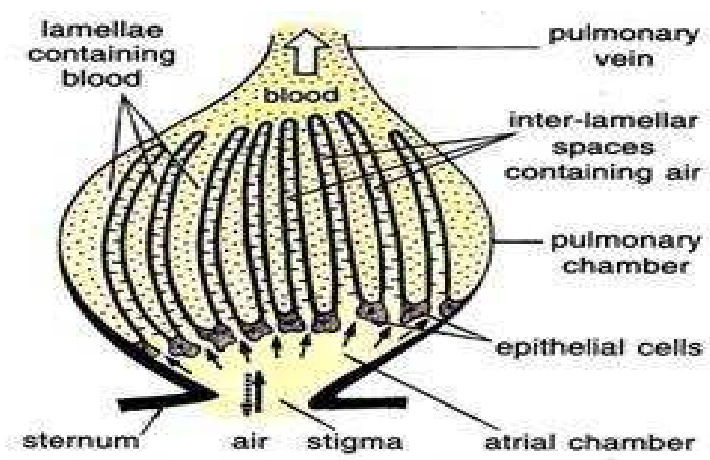


Fig. 4.11 Course of air through book lung

Mechanism of gaseous exchange in the tracheal system of insects

Respiratory exchange in the tracheal system occurs partly by diffusion and partly by ventilation as found in a vertebrate lung. However, air breathing tracheal system in insects is fundamentally different from that found in air breathing vertebrates.

You studied the structure of the tracheal system in the earlier part of this unit. Let us learn how respiration takes place in tracheal system of insects. You are aware that tracheae open to exterior through spiracles. It is through these **spiracles** air enters the trachea when they are open. The opening and closing of spiracles is controlled by neurosecretion and direct innervations from central nervous system. After reaching **tracheae**, the air passively moves into the **tracheoles** as the partial pressure within the tracheoles is lower than that of the trachea. From tracheoles, air enters the **tips of fine branches of tracheoles**which are filled with fluids. This fluid takes up the oxygen and diffuses inwards to the tissues or active cells through the tracheolar walls. Greater the need for oxygen more is the withdrawal of the tracheole fluid into tissue and vice versa. The tracheolar walls are very thin with an approximate thickness of only 40-70 nm. Thus, the gases those diffuse from tracheoles to the tissues move through **the fluid in the tracheoles, the tracheolar wall and the cell membrane ultimately toreach cells/tissues** where oxygen is utilized and carbon dioxide is produced. When the air is expelled outside (during expiration), the tracheolar fluid again fills into the tracheole tips. CO2 produced mostly diffuses out through the tracheae (Fig. 4.12 A and B).

Small insects such as *Drosophila* may get sufficient oxygenby diffusion alone but forms that weigh more than 1g or that are highly active require some degree of **ventilation** to fulfill their high demands for oxygen. Ventilation in large and active insects is brought about by the changes in tracheal volume, which in turn are caused by the movements of abdominal muscles. In some insects, tracheal system contains air sacs within the tracheal system which alternately collapse and expandcausing much larger changes in tracheal volume.

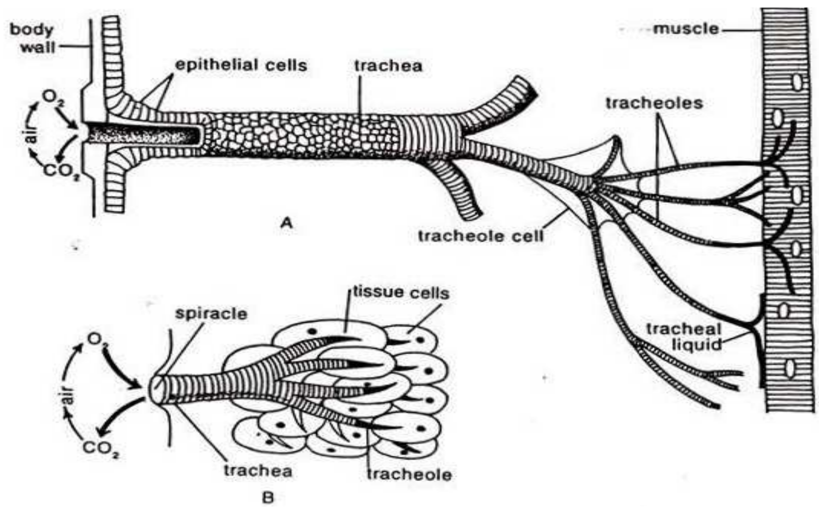


Fig. 4.12 Diffusion of gases in insects: A. Tracheal System B. Trachea and Tracheoles

Mechanism of respiration in invertebrates having lung or lung like structures

Pulmonary sac

Aerial respiration in *Pila* is observed when the animal is in water or out on land. When it is in water, it comes near to the water surface and then extends its left nuchal lobe to form a tube-like structure, called **siphon** (Fig. 4.8 B). The opening of the siphon projects above the water surface through which air enters the pulmonary sac through pulmonary aperture. Air always backs through this path. To maintain the inflow and outflow, the alternate expansion and contraction of the pulmonary sac takes place. Epitaenia is raised to push the mantle wall and hence the air is not allowed to enter the branchial chamber. The wall of the pulmonary sac contains blood vessels and sinuses whose blood takes up oxygen of the air and gives out carbon dioxide.

You know that *Pila* comes on land for two purposes, first when it travels from one source of water to the other and secondly for the purpose of laying eggs. When on land, it respires through its pulmonary sac but without forming a siphon. The left nuchal lobe simply expands and air enters the pulmonary sac through the expanded nuchal lobe. Exchange of gases takes place in the pulmonary sac.

Mechanism of respiration in Pulmonate lung

In terrestrial pulmonates such as Limax, mantle cavity is transformed into a pulmonary sac or lung for aerial respiration. Roof of the pulmonary lung is richly supplied with blood vessels. Alternate muscular contraction and relaxation of mantle floor, lower or raise it, causing the air to rush in and out of the mantle cavity through pulmonary aperture. Compression of mantle cavity increases the partial pressure of oxygen and facilitates its absorption.

4.6 SUMMARY

- Respiration is the process of exchange of gases through which oxygen is taken in and carbon dioxide is removed from the tissues to the environment. It provides energy which is used by the cells for various activities. External respiration refers to the exchange of gases between the environment and the blood while internal respiration is the exchange of gases between blood and tissues. The basic physical phenomenon involved in the exchange of gases is diffusion. Respiration can be aerobic occurring in presence of oxygen or anaerobic when oxygen is not involved and involves bio-oxidation of food stuff.
- External respiration may occur through general body surface/ skin/integument or through some specialized respiratory structures called respiratory organs. Many respiratory organs are found among animals though of varied structures such as gills, lungs, tracheae etc. Few other minor structures are also capable of performing respiratory function for the animals which are referred to as accessory respiratory structures.
- Gills are the respiratory structures found in aquatic animals. They can be external (uncovered) or internalif present inside the body or are covered. They are found in aquatic species of annelids, insects, molluscs and arthropods. The various gills found among animals are true gills, book gills, epipodites, rectal gills, tracheal gills, blood gills etc. In some species such as *Sabella*, *Serpula* etc gills are greatly modified as feeding organs and they serve both as respiratory and feeding organs. In such animals' gills are referred to as radioles.
- Lungs are vascularized sac like structures which may or may not have good ventilation mechanism. They are well suited for terrestrial respiration and occur in air breathing animals. Lungs found in invertebrates are called diffusion lungs

as they do not have good ventilation mechanism as compared to the ventilation lungs of vertebrates. Among invertebrates' pulmonary sac/lungs are found in prosobranchiates like *Pila* and pulmonates, as book lungs in some arachnids etc.

- Air breathing insects possess a peculiar system of numerous tubules (trachea, tracheoles etc) called as tracheal system. The pattern of trachea and tracheoles may differ from species to species.
- Respiratory pigments are coloured substances that are present in blood and increase the oxygen carrying capacity of blood and makes respiratory system more efficient in comparison to the blood without any pigment. They are conjugated proteins that impart colour to the blood depending upon the metallic ion present in their prosthetic group. Four distinct respiratory pigments are found in animals are haemoglobin, haemocyanin, chlorocruorin and haemoerythrin.Most of the annelids, arthropods and mollusks have respiratory pigments in their blood.
- The process of respiration requires inflow of air/water into the respiratory structures/organs from the environment and outflow of air/water from the body of the animal back to the environment. It occurs differently in different animals and depends on the type of the respiratory organs and the body organization. In some animal's respiration may involve only diffusion while in others it involves both diffusion and ventilation.

4.7 TERMINAL QUESTIONS AND ANSWERS

(1) Define the following- Tracheae, gills, ctenidia, Lung

(2) Describe the tracheal system of insects and explain the mechanism of respiration in insects.

(3) Write short notes on

Respiratory pigments found in invertebrates

Book lungs

Gill chamber of Prawn

(4) Describe the dual mode of respiration in*Pila.*

(5) Describe the structure of monopectinate ctenidia.

(6) Give a brief account of the different respiratory organs found in invertebrates.

(7) Describe the mechanism of respiration through eulamellibranch gills of *Unio*.

Multiple choice questions:

1. Book lungs are respiratory structures of ………..

a) Earthworm
b) Coelenterates
c) Molluscs
d) Arachnids

2. Which of the following pigment imparts green colour to the blood?

a) Haemoglobin
b) Haemocyanin
c) Chlorocruorin
d) None of these

3. Iron containing pigment is……………

a) Haemocyanin
b) Haemoglobin
c) Haemoerythrin
d) Both b and c

4. Which of the following molluscs have monopectinate ctenidium?

a) *Chiton*
b) *Nautilus*
c) *Pila*
d) None of these

5. The subclass of Bivalvia in which gills degenerate and respiratory function is entirelytaken up by the mantle.

a) Protobranchia
b) Filibranchia
c) Septibranchia
d) Eulamellibranchia

6. The respiratory organs of which animal serves both as respiratory and feeding organ.

a) Serpula
b) *Sabella*
c) *Sabellaria*
d) All of these

7. Tracheal system is present in……………

a) Insects only
b) Arachnids
c) Both a and b
d) None of these

8. Respiration in Palaemon occurs by……………

a) Gill cover
b) Epipodites
c) Branchiae or gills
d) All of these

9. Which of the following nuchal lobes extend to come to the surface during aerial respiration in*Pila*?

a) Right nuchal lobe
b) Left nuchal lobe
c) Both of these
d) None of the lobe extend

10. Respiratory organs for terrestrial mode of living is/are………….

a) Tracheae
b) Pulmonary sac
c) Lungs
d) All of these

Answers: 1. d, 2. c, 3. d, 4. c, 5. C, 6. d, 7. c, 8. d, 9. b, 10.d.

UNIT 5: EXCRETORY SYSTEM AND OSMOREGULATION IN INVERTEBRTAES

CONTENTS

5.1 OBJECTIVES

After studying this unit, you should be able to:

- list the excretory organs found among the various groups of non-chordate metazoan invertebrates and describe their functioning,
- outline the mechanisms of water and ion regulation in organisms occupying different habitats, and
- outline excretion of different modes of nitrogen based excretory products

5.2 INTRODUCTION

Excretion is concerned with the removal of metabolic wastes that arise as a result of oxidation of energy rich compounds and metabolism of proteins and nucleic acids. No special organs of excretion are present in many marine protozoans and sponges. Similarly, the coelenterates, which are mostly marine and the echinoderms, which are restricted to the sea, are devoid of excretory organs. These marine invertebrates, being is osmotic to their habitat, do not need organs of water and ionic balance. Discharge of nitrogenous wastes and ionic regulation are carried out through the general body surface.

In all the other animal groups, there are discrete organs which function in osmotic regulation, ionic regulation and nitrogen excretion. These are the contractile vacuoles of protozoans and poriferans, the nephridia of flatworms, roundworms and annelids, the green glands of crustaceans, the coxal glands of arachnids, the Malpighian tubules of insects and the metanephric kidney of vertebrates. Depending on whether the nephridial tubule is closed at the inner end or opens into the coelom by funnel shaped structure called nephrostome, nephridia are respectively termed as protonephrldia. or metanephridia. The excretory organs of molluscs, crustaceans and arachnids are actually modified coelomoducts and hence are not true nephridia. With the exception of the contractile vacuoles of protozoans and sponges, the excretory organs are either tubules or aggregates of numerous tubules.

In this unit you will study in detail these organs and how they carry out excretion. Excretory organs serve not only to eliminate the nitrogenous waste products, but also to remove accurately regulated amounts of all substances present in excess in the body.

Thus, they contribute to maintain a steady state or homeostasis in animals to over-ride the influence of all those factors in the environment that tend to impose a change. A third aspect of study covered in this unit relates to the regulation of water and ionic content of the body of non-chordate metazoans. These may be osmoconformers or osmoregulators. Osmoconformers maintain their internal body fluid in osmotic equilibrium with the aqueous environment in which they live. In other words, the salt concentration of the internal and external media is more or less same. Other organisms are osmoregulators and they maintain the concentration of their internal body fluids relatively constant. This may be often at a different osmotic and ionic level from that of the environment. In this unit, you will also study the mechanisms of regulation of water and ionic content of body fluids in these animals. The processes of excretion and osmoregulation are performed by the same set of organs and maintain homeostasis.

You already know that excretion refers to removal of the waste products of metabolism - carbon dioxide and water released by the oxidation of energy rich compounds and the nitrogenous wastes released by the metabolism of proteins and nucleic acids. However, we will here limit ourselves to elimination of nitrogenous waste in this unit. The nitrogen -containing excretory end-products are ammonia, urea and uric acid. Animals are often grouped according to their main excretory products as ammonotelic, ureotelic, uricotelic and guanotelic. You will also study details of this aspect later in the chapter.

5.3OSMOREGULATION AND EXCRETION IN PROTOZOA

Osmoregulation or water balance in protozoa is accomplished by contractile vacuoles. One to several contractile vacuoles may be present within the animal which may or may not have fixed sites in the cytoplasm and may have contributory canals or other vesicles opening into it. These are water and ion regulating structures, acting as pumps to remove excess water from the cytoplasm. All freshwater protozoans have functioning systems of contractile vacuoles whereas; marine and parasitic forms have these less frequently. Excretion of metabolic wastes is dope almost exclusively by diffusion. All protozoans are ammonotelic i.e., the end product of their nitrogen metabolism is ammonia, which is readily diffused in the surrounding medium. The contractile vacuoles may differ in complexity in various groups of protozoans. In amoebae the vacuoles are carried around in the cytoplasm. Small vesicles join them emptying their contents into the vacuoles till the vacuole joins the membrane emptying its content to the outside (Fig(a)). In ciliates (e.g., Paramecium) the contractile vacuoles have a more complex structure. The contractile vacuole is located in a fixed position with an excretory pore leading to the outside surrounded by ampullae of feeder canals (Fig. b & c). The feeder canals are surrounded by a network of fine canals (20nm) in diameter, which are also connected to the tubular system of endoplasmic reticulum. The ampullae are surrounded by a bundle of fibrils that may have a role in contraction of the ampullae. The ampullae contract thereby, filling the vacuole and when the contents of the vacuole are discharged to the exterior the ampullae get disconnected so that back flow is prevented.

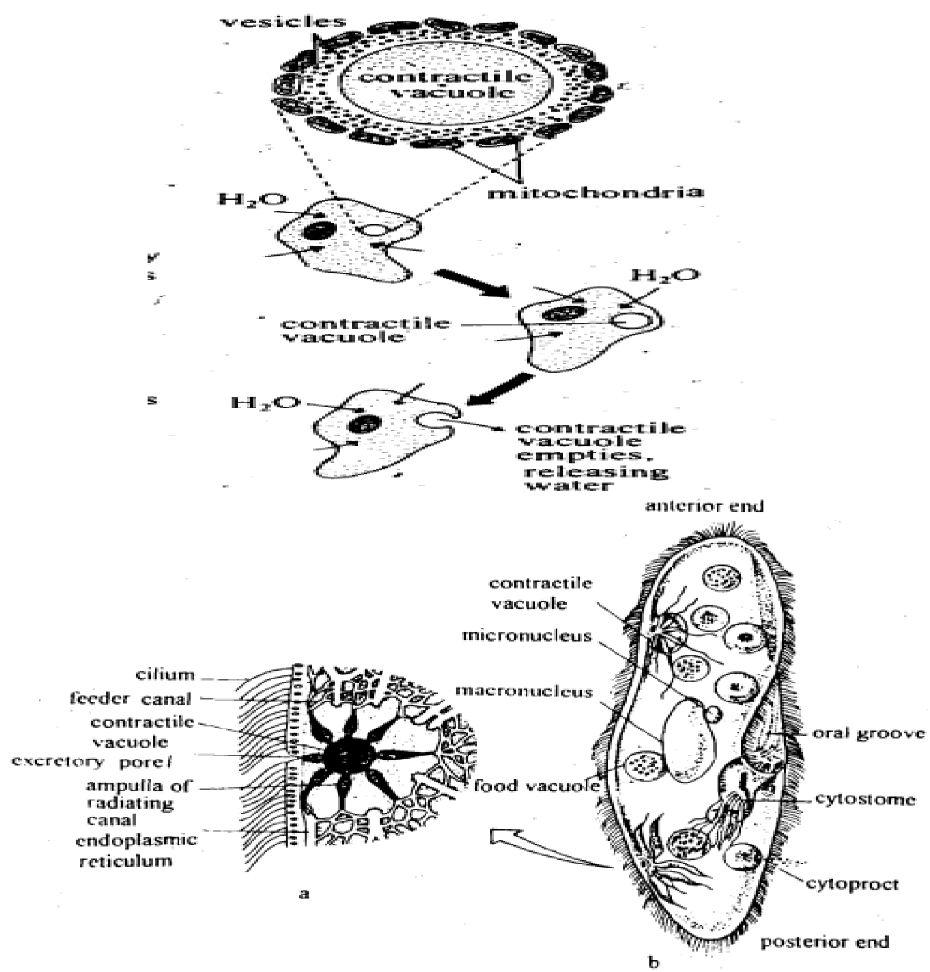


Fig. 5.1 a.The contractile vacuole of Amoeba proteus is surrounded by tiny vesicles that fill with fluid, which is then, emptied into the vacuole. Note the numerous mitochondria that are believed to provide energy needed to adjust' the salt - content of the tiny vesicles.

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

5.4 EXCRETORY ORGANS OF METAZOANS

In lower invertebrates (Porifera and Cnidaria), especially aquatic ones, simple diffusion from body surface plays an important role in elimination of nitrogen of wastes. Even in larger aquatic animals – simple diffusion takes place from body surface, but they have evolved specialised organs for excretion, which play the major role in elimination of nitrogenous waste material. However, it has to be remembered, that many of these organs serve primarily osmoregulatory function rather than excretory. Well defined excretory organs are seen from the pseudocoelomate animals onwards. Many groups of metazoans have nephridia as excretory organs. A nephridium develops from the ectoderm centripetally. The lumen of the nephridium is formed by the hollowing out of nephridial cells. Thus nephridia are intracellular. In primitive animals this lumen is closed internally but subsequently acquires an opening into the coelom. The opening is called nephridial funnel or nephrostome. Its opening to the outside is by nephridiopore.

Most main bilaterian lineages possess nephridia. Based on morphological correspondences they can be grouped in two major architectural units: the protonephridia, only found in Protostomia, and the metanephridia, present in both Deuterostomia and Protostomia. You will study it in detail in following section. Besides nephridia many other excretory structures are seen in higher invertebrates like coxal glands, coelomoducts, Malpighian tubules which you will study in the coming sections of this unit.

5.4.1 PROTONEPHRIDIA IN FLATWORMS

Nephridia occur in two major forms - the protonephridium and metanephridium. Protonephridia are found in flat worms. The protonephridia canals end bIindly in structures called flame cells or solenocytes internally. Flame cells have central cavities that are continuous with the cavities of tubules and contain a bunch of cilia - the flame. Actually, the flame cell interdigitates with the first cell of the tubule, by means of finger shaped processes. In solenocytes, the cell lumen is prolonged into a delicate tube and the flame is reduced to a single flagellum. Flat worms generally have a pair of protonephridia. The protonephridial canals are much branched bearing flame ceIls at the end of branches. The flame cells are found scattered throughout the parenchyma. The flame cells do the filtration, the filtered fluid is propelled by flagella. The nephridial epithelium carries out the functions of reabsorption and secretion. These physiological mechanisms are comparable with those carried out by a vertebrate kidney.

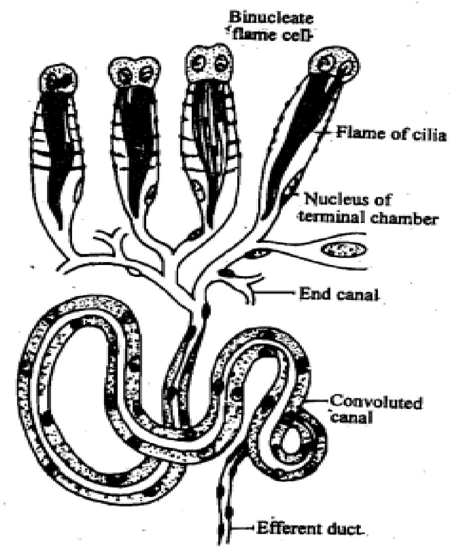


Fig.5.2 A single nephridium of a flatworm

5.4.2 EXCRETORY SYSTEM IN ANNELIDA

In annelids, nephridia frequently bear ciliated funnels at the inner end and are then termed as metanephridia. Metanephridia are open at both ends. The nephrostome located in the coelom waft the waste materials by their cilia and passes them intonephridial tubes where they find their way to outside through the nephridiopores. However, in trochophore larva of certain polyachetes possess a pair of simple typical protonephridia each with a flame cell bearing a single flagellum. But adults possess segmental metanephridia with open ciliated channels. In certain adult polychaetes such as *Nephtys* and *Phyllodoce* there are only protonephridia with solenocytes. Except in the polychaete family Capitellidae where there are separate nephridia and coelomoducts, in other families they become associated and form a compound organ called the nephromixium. The nephridium in a nephromixium may be a protonephridium or a metanephridium. In protonephromyxium (Fig.5.3 A) the developing coelomoducts grows backwards alongside the protonephridial canal and an open communication arises between the two at sexual maturity. In metanephromixium (Fig.5.3 B), the nephridial component is a metanephridium. In *Arenicola* the recombined structure forms a mixonephridium serving both excretory function as well as transportation of germ cells.

In oligochaetes the nephridia are all metanephridial type. The coelomoducts are also present, but are restricted to genital segments, one duct being associated with each gonad. A similar arrangement is seen in leeches as well.

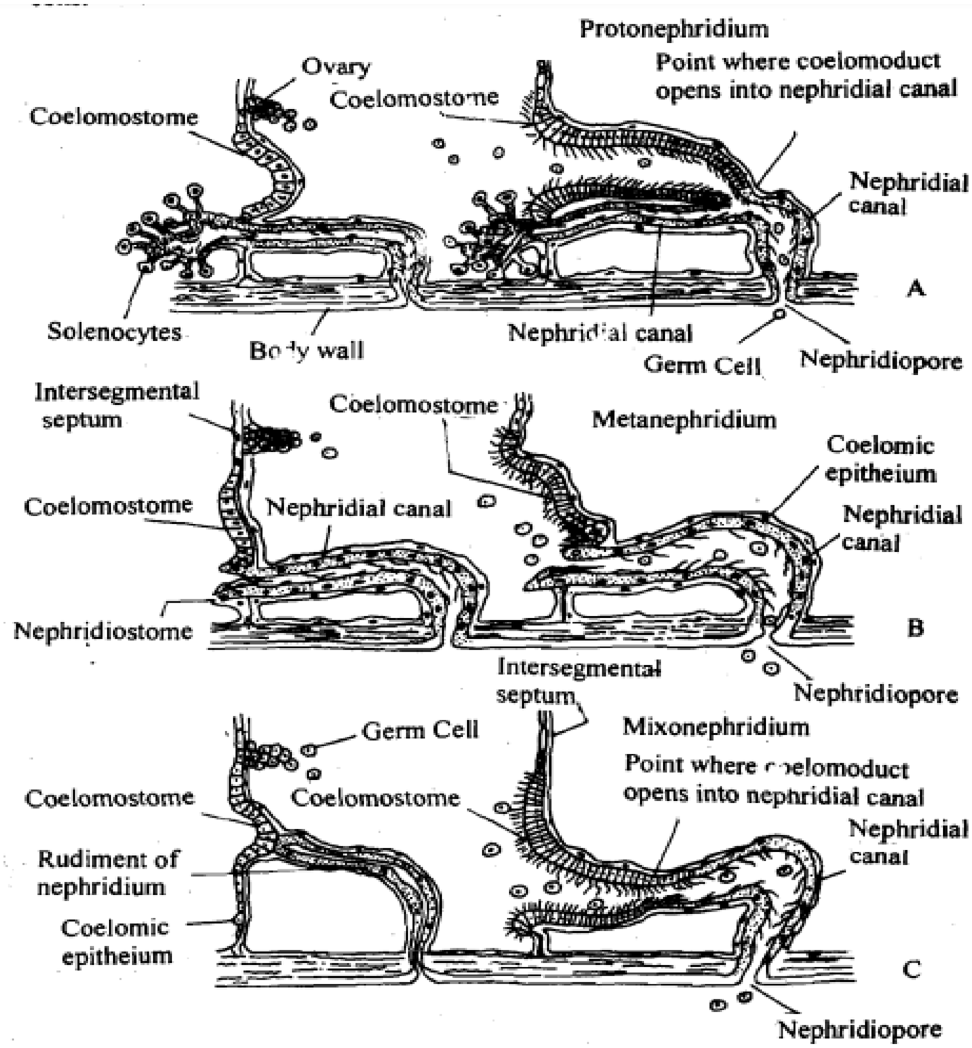


Fig.5.3 Nephridia in Polychaeta, Annelida A) Protonephromyxium B) Metanephromixium and C) Mixonephridium

5.4.3 EXCRETORY SYSTEM IN ARTHROPODS

As arthropods inhabit a variety of habitats, they exhibit different types of excretory structures like coxal glands and Malpighian tubules which are described below:

5.4.3.1 COXAL GLANDS: In crustaceans coxal glands are found in third and sixth segments and they are appropriately named depending on the site of their opening to outside. The one located at the base of the third segment opens at the base of the antenna, hence called **antennal gland** (Fig). The one located in the sixth segment opens at the base of the second maxilla, and is called **maxillary gland**. Antennal gland is present in the larval forms of Branchiopoda, Ostracoda, Copepoda, Branchiura, Cirripedia and lower Malacostraca but the adults of these groups have maxillary glands. The adult amphipod and decapod crustaceans have antennal glands. Mysidaceae, a primitive group of crustaceans have both antennal and maxillary glands functional. Most arachnids have a pair of coxal glands opening in the sixth segment, opening at the base of third pair of walking legs. In Limulus, there are four pairs of coxal glands.

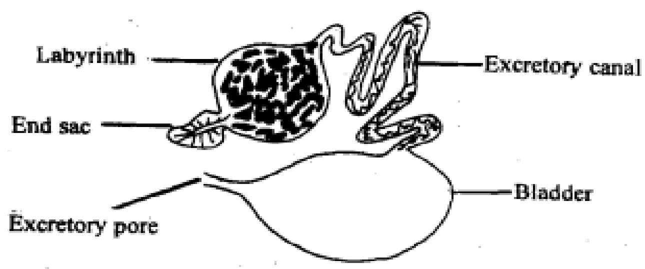


Fig.5.4 Antennal gland of crustacea.

5.4.3.2 MALPIGHIAN TUBULES

Other arthropods such as insects and myriapods and arachnids have Malpighian tubules, the outgrowths of alimentary canal as excretory organs. Malpighian tubules are totally new structures, having no resemblance either to nephridia or coelomoducts. Generally, the Malpighian tubules are composed of single layered epithelium and are bathed in the blood of haemocoel. By the process of active secretion water passes into the lumen of Malpighian tubule together with nitrogenous wastes and dissolved salts. The secretion essentially occurs in the distal parts of the tubules. The proximal parts of the tubule as well as the rectum are the sites of absorption. Most of the terrestrial arthropods excrete uric acid (Fig. 5.5)

Fig. 5.5 Malpighian tubules

5.4.4 EXCRETORY SYSTEM OF MOLLUSCS

In Molluscs, as in crustaceanephridia are absent. But certain of the larval pulmonates do possess protonephridia suggesting that they have been secondarily lost in molluscs. The excretory system is more or less similar in all the groups of molluscs. In molluscs it is assumed that the two coelomic cavities meet dorsally to enclose the heart and their walls proliferate into germ cells. Their cavities by further differentiation give rise to gonad anteriorly, pericardial canal centrally and gonoduct posteriorly. The last segment, in addition had an excretory function (Fig.).

i. In Aplacophora the coelomoducts of adults consist of a pair of tubular structures, leading from the coelomic cavity to the outside and primitively constitute the genital ducts (Fig.5.6a). But in other mollusc's modifications have arisen in the following lines:
    i) There is the development of certain degree of asymmetry.
    ii) There is a separation of genital and excretory organs.
ii. In Polyplacophora the coelomoducts split in the region of coelomostome and the gonadal cavities become closed off from pericardial coelom. The excretory coelom remains connected with pericardial coelom (Fig.5.6 b).
iii. In gastropods there is a marked asymmetry in the coelomic complex. The left gonad disappears and the right gonad opens into coelomoduct that has lost its renal function and its connection with the pericardial coelom. The excretory organ is present only on one side (left kidney) and that is large and thick walled.
iv. In prosobranchs, the excretory opening is in the posterior part of mantle cavity and in pulmonates it opens outside the mantle cavity.
v. In lamellibranchs, though the complications of asymmetry in gastropods do not exist, the genital and renal ducts get separated. In the primitive group protobranchs, the entire coelomoduct has an excretory function. The gametes are discharged into renal organs(Fig.5.6 d).
vi. In filibranchs the coelomoduct is bent into a "U" shaped structure, the lower limb being glandular and the more distal upper limb forms a bladder (Fig.5.6 e). The connection has shifted to the posterior end of the kidney.
vii. In eulamellibranchs, the two organs have developed separate openings (Fig.5.6 f).

viii. In cephalopods also the separation of genital and excretory components of the coelomic complex has been achieved. The genital duct comes to run separately from the renopericardial canal and kidney (Fig.5.6 g).

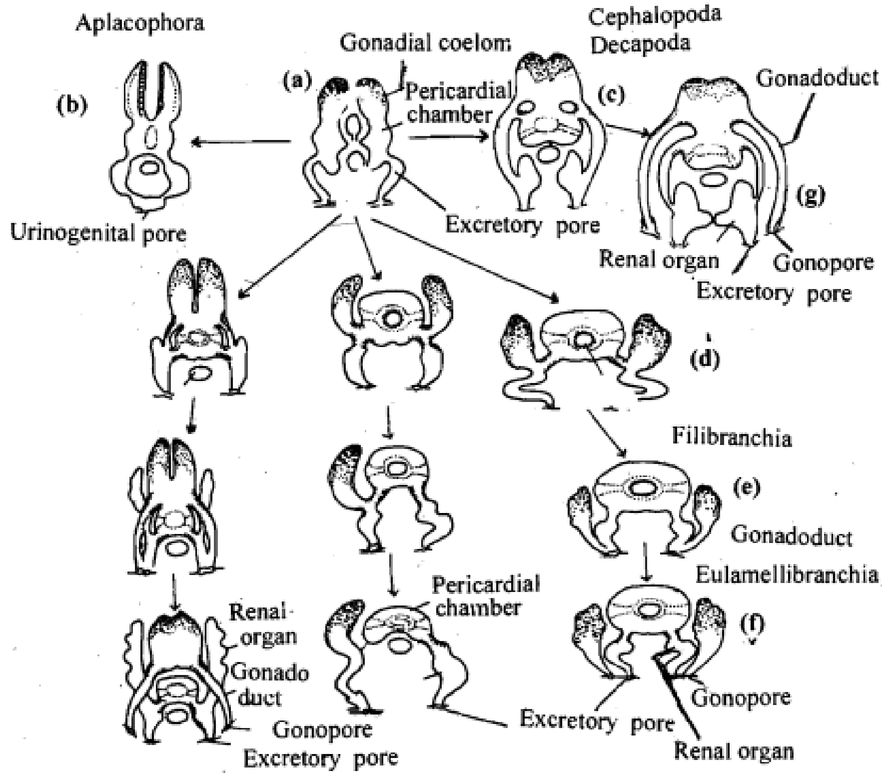


Fig.5.6 Coelom and coelomoducts in molluscs a) Primitive mollusc b) Aplacophora c) Polyplacophora d) Protobranch e) Filibranch f) Eulamellibranch g) Cephalopod

5.5 OSMOREGULATION

Earlier in this unit you have studied that in protozoans, particularly fresh water protozoans, contractile vacuoles play a significant role in the regulation of water content of the body. Fresh water organisms often face the problem of their body being flooded with water and have to constantly regulate the water content of their body. Marine animals, although, isotonic with the medium in which they live have to maintain an ionic composition of their body fluids that may be unique to them. Terrestrial organisms - confront the problem of water conservation and have developed adaptations that prevent the water loss from the body. Essentially osmotic relationships-of the organism have to be considered in relation to the ion composition of body fluids. Ionic regulation could be defined as' maintenance in body fluid, concentrations of ions differing from those that would result from a passive equilibrium from the medium. In this section we shall briefly discuss the mechanisms of osmotic and ionic regulation of metazoan organisms adapted to living in different habitats.

5.5.1 OSMOREGULATION IN FRESHWATER METAZOANS

Freshwater and brackish water animals live in hypoosmotic (of lower osmotic pressure) environment and maintain a hyperosmotic (of higher osmotic pressure) condition in their body fluids. They may be able to tolerate only a narrow range of salinity of the medium in which they live. These are called stenohaline animals. If they tolerate a wide range of salinity they are known as euryhaline animals. Essentially their living environments are osmotically less concentrated than their body fluids. They face the problem of the water continuously entering into the body and leaching of salts from the body. You have already studied the role of contractile vacuole as water pumps in osmoregulation of freshwater protozoans. Such vacuoles are present in fresh water sponges as well. Protonephridia of freshwater flatworms, metanephridia of annelids and coxal glands of crustaceans are other such water pumps that are capable of removing large amounts of fluids from the body. In fact such organs have the primary function of water balance rather than excretion of nitrogenous wastes. In some animals there are no special organs for the removal of water. Hydra is one such example. The regulation of both water and salt in Hydra is carried out by active transport of sodium. In the absence of calcium or sodium in the environment the osmoregulatory process breaks down in Hydra. The pumping in of sodium into the gut is followed by the passive flow of water along the osmotic gradient. The mesoglea functions like an extracellular fluid space. It is believed that two pumps may be operational in Hydra, one transporting Na into mesoglea and the second that transports it into gut. Water taken osmotically is expelled through the mouth. Active transport of sodium takes care of both osmotic and volume regulation. Thus, there is an influx of water into the body through the external surface, and the excess water is removed through the gastrovascular cavity, through the mouth. Fluid in the gastrovascular cavity is hypo-osmotic to tissue fluid. The gastrovascular cavity is thus supposed to act likebig contractile vacuole.

Ability to produce dilute urine has been demonstrated in animals belonging to more advanced phyla (arthropods, earthworms and fresh water molluscs). Using the techniques of micropuncture and clearance of tubular fluid in the metanephric tubules, both filtration and active transport have been demonstrated. For instance, in the antennal gland of fresh water crayfish, the end sac functions as the site of filtration. Chloride is reabsorbed as the filtered urine passes through the long tubule resulting in conservation of salts and reabsorption of water.

Filtration in arthropods and molluscs is essentially carried out by the hydrostatic pressure of the blood. In arthropods, the wall of the coelomic sac is highly vascularised. In molluscs the heart passes through the filtration cavity or pericardial sac. There is filtration through the wall of the heart, into the pericardial cavity. From the pericardial cavity, filtrate passes through the nephrostome into the kidney. Generally, the coelomic sac is located near the heart or near the region of high blood pressure. The observed dilution of urine in the distal tubule and ureter could be due to the addition of water or to the reabsorption of salts. But the use of metabolic poisons that arrests the active uptake has clearly demonstrated that absorption of solutes is responsible for the excretion of hypo osmotic urine. It could be said that the capacity of excretory organs to form hypo osmotic urine and to trap ions from ambient fluid played a significant role in the colonisation of the fresh water environment.

5.5.2 OSMOREGULATION IN MARINE NON-CHORDATE METAZOANS

Studies on the osmotic pressure of body fluids of marine organisms have shown that their internal osmotic pressure is more or less similar to the sea water in which they live. Marine invertebrates are isotonic with the seawater in which they live, but the ionic composition of their body fluids may be markedly different from that of the normal sea water. For instance, the mesogloea of the coelentrates has a high potassium and a low sulphate concentration as compared to the seawater in which they live. This is true of polychaets and echinoderms as well. Marine and brackish water animals have isoosmotic or slightly hyperosmotic body fluid. Production of an isoosmotic or a slightly hyperosmotic urine may cause the loss of valuable electrolytes. Therefore, there is a continuous regulation of electrolytes of body fluids. Such regulation is achieved by several ways. Surface areas permeable to water and ions are generally reduced to a minimum. Water pumps in the form of contractile vacuoles and nephridial tubules are present. But the most important machinery that remains a part of every cell is the active transport. In certain organs such as gills of crustaceans, highly specialised tissues exploit the capacity of active transport of large amounts of salts. In decapod crustaceans and cephalopods, ionic regulation may extend to every ion. For instance, in these organisms'calcium and potassium are more concentrated in body fluids than in the external medium, whereas magnesium, sulphate and chloride are less concentrated. Reduction in anion concentration such as sulphate is compensated by an increase in sodium concentration. Thus, in marine invertebrates including coelenterates, the internal medium has a specialised ionic composition quite distinct from that of external medium. Excretory organs play a role in ionic regulation.

5.5.3 WATER RELATIONS IN TERRESTRIAL ENVIRONMENT

Insects are the largest group of metazoans that have most successfully invaded the terrestrial environment. Besides, most arachnids, myriapods and isopod crustaceans do not depend on the aquatic environment for their survival. Terrestrial arthropods owe their success to life on land to the presence of an impermeable cuticle that prevents evaporation of water from the body. Their cuticle, a chitin-protein complex with a hydrophobic wax layer on the surface is the water-proofing structure. The cuticle is an important structure that had made possible to a large extent the successful colonisation of land. Water loss through the spiracular openings is minimised by keeping the spiracles closed whenever the inspiration does not take place. The proximal region of Malpighian tubules and more importantly, the rectum play a significant role in water resorption expelling only dry faecal pellets with insoluble uric acid as nitrogenous waste. Pulmonate molluscs which have taken to terrestrial habitat have a calcareous shell that prevents desiccation of the soft inner parts of the body. Physiological adaptations such as aestivation help them to overcome adverse climatic conditions.

5.6 MODES OF EXCRETORY PRODUCTS

You must have understood by now that excretion is the removal of toxic waste products of metabolism from the body. The end-products of metabolism are either eliminated or conserved by an animal depending on its physiology. The carbon, hydrogen, oxygen and nitrogen are the end-products of catabolism. Carbon atoms are eliminated in carbon dioxide, hydrogen in water, and oxygen in carbon dioxide and water. Nitrogen which is the end-product of protein catabolism is found in large quantities. It is highly toxic and needs to be excreted as soon as it is formed, or converted into less toxic form before being eventually excreted. Here you will learn how animals get rid of the toxic nitrogen.

The nitrogen-containing excretory end-products are ammonia, urea and uric acid. Animals are often grouped according to their main excretory products.

a. Those that excrete mainly ammonia (NH_3) as the end-product of protein metabolism are called ammonotelic.
b. Those that excrete mostly urea are ureotelic.
c. Those that form mainly uric acid are uricotelic.
d. Those that secrete guanine are guanotelic

Excretion of nitrogen as ammonia, urea or uric acid is closely related to the normal habitat of the animal and to the availability of water. In no animal nitrogen excretion is restricted to a single product. Animals are designated as ammonotelic, ureotelic, uricotelic or guanotelic only to indicate the predominant form in which nitrogen is excreted. The term uricotelism, for example, does not preclude the excretion of ammonia and urea in minor quantities.

5.6.1 AMMONOTELIC

Ammonia diffuses through cell membranes extremely fast because of its high-water solubility and small molecular size. Hence, it can be excreted as such only when there is ample water for its rapid removal from the body in the form of a dilute solution. Prompt excretion of ammonia therefore, occurs in aquatic animals, both freshwater and marine, in which there are constant water fluxes occurring between the environment and the body. Freshwater and marine invertebrates excrete a major portion of their waste nitrogen as ammonia and thus called ammonotelic or ammoniotelic. Ammonia is the first metabolic waste product of protein metabolism and no energy is required to produce ammonia. Most of the aquatic invertebrates including protozoans, poriferans, crustaceans, platyhelminthes, cnidarians and echinoderms and aquatic vertebrates like bony fishes and aquatic amphibians are ammonotelic organisms.

5.6.2 UREOTELIC

Terrestrial animals with restricted water availability in the environment are faced with the formidable task of water conservation. Since they cannot afford to use liberal quantities of water for excretion, ammonia is converted into a less toxic product. In mammals and semi-terrestrial adult amphibians, the major nitrogenous excretory product is urea, which is less toxic and easily soluble. These animals are therefore called ureotelic. The synthesis of urea (H2N.C0.NH2) from one molecule of C02 and two of NH, occurs in the liver of ureotelic vertebrates by a metabolic pathway known as the ornithine-urea cycle, discovered by Kreb and Hensleit in 1932.Ureotelism is exhibited by semi-terrestrial animals, e.g. adult amphibians and mammals. In earthworm chloragogen cells are said to be concerned with deamination of proteins, formation of ammonia and synthesis of urea. So, these cells are analogous to liver of vertebrates

5.6.3 URICOTELIC

In animals which inhabit extremely arid environments, ammonia is converted into uric acid. Uric acid is least toxic, relatively insoluble and is easily precipitated. Hence, it can be excreted in solid form without loss of substantial amount of water. Pulmonate snails, terrestrial insects, squamate reptiles (lizards and snakes) and birds excrete a major portion of their waste nitrogen in the form of semi-solid or solid uric acid and hence are referred to as uricotelic animals.Many insects exhibit a phenomenon known as storage excretion. If excretory products are stored in the body instead of being eliminated, no water is expended for their excretion. Since uric acid is non-toxic and highly insoluble, it can be retained in the body for an indefinite period, without any ill-effect. This alternative strategy to the problem of excretion is quite common in cockroaches which store uric acid in fat body and cuticle. The stored uric acid, which may account for as much as 10°/o of the dry body weight, also provide a-nitrogen depot for mobilisation at times of nitrogen deprivation.

5.6.4 GUANOTELIC: Arachnids (spiders and scorpions) excrete mostly guanine and hence are said to be guanotelic. Guanine, like uric acid, is relatively non-toxic and insoluble and is excreted in solid form. It is an adaptation to life in arid habitats. Itis also a purine and has the same atoms in its ring structure as in uric acid. In fact, guanine is formed as an intermediate during uric acid synthesis in uricotelic animals.

5.7 SUMMARY

In this unit you have learned:

- Metazoans have evolved a variety of 'excretory' structures. Many of these are however primarily osmoregulatory.
- Nephridia which are ectodermal derivatives are intracellular, formed by the hollowing out of the nephridial cells.

- Protonephridial canals that end blindly, carry solenocytes or flame cells secrete fluid into lumen and waft the materials towards nephridjopore.
- Metanephridia which are characteristic of annelids are closely associated with coelomoducts.
- Coelomoducts known as coxal glands are the excretory structures in many arthropods. In primitive arthropods, the coxal glands are present segmentally, but in higher arthropods they are present in one or two segments. Depending on their position they are variously named as antennary glands or maxillary glands.
- Insects have Malpighian tubules as excretory structures. The epithelial cell lined tubules secrete fluid into their lumen in the distal region and in the proximal segment there is reabsorption. Much of water from the excretory material is resorbed both by the Malpighian tubule and rectum and dry insoluble uric acid is excreted.
- Molluscs have coelomoducts as kidneys and they are closely associated with genital ducts. Marked asymmetry in the coelomic complex and gradual separation of excretory and genital structures are important features of molluscan coelomoducts.
- Regulation of water and ionic components of the body is the adaptation required for survival in aquatic environment. Fresh water organisms live in a hypo-osmotic environment and have to maintain hypertonic fluid in their body. They excrete a hypo-osmotic urine and their excretory system resorbs the vital ions required by the body.
- Marine organisms are more or less iso-osmotic with the medium in which they live; nevertheless, the ionic composition of their body fluids is at variance with that of the medium. They resort to active uptake of ions to maintain the ionic composition of the body fluid.
- Terrestrial metazoans face the problem of water loss from their body and the problem has been solved by evolving a number of water conserving measures such as an impermeable integument, excretion of dry nitrogenous waste materials and keeping the respiratory apertures closed to minimise water loss through them.
- Catabolism of proteins gives rise to nitrogen which is highly toxic to the animal. Therefore, animals get rid of the toxic nitrogen in the form of ammonia or

convert it into less toxic forms such as urea and uric acid before it is being excreted.

- Animals which predominantly excrete ammonia are called ammonotelic, those that excrete urea are known as urotelic and uric acid excreting animals are known as uricotelic.
- The mode of nitrogen excretion in animals is an adaptive character related to the availability of water in the environment.

5.8 SELF ASSESSMENT QUESTIONS

Q1. Match the following.

a) Flatworms	1) Malpighian tubules
b) Annelids	2) Metanephridia
c) Crustaceans	3) coelomoducts (kidneys)
d) Insects	4) coxal glands
e) Molluscs	5) protonephridia

Q2 State whether the following statements are true or false.

1) Osmoconformers can have an ionic composition of their body fluids very different from that of the medium in which they live.

2) Euryhaline animals can tolerate only narrow ranges of salinities.

3) Marine animals excrete a hypo-osmotic urine.

4) Water resorption is more pronounced in fresh water metazoans than in marine forms.

5) Insects excrete dry pellets as urine.

Q3 Fill in the blank spaces and compare your answers with those given in section

i. Depending on whether the nephridial tubule is closed at the inner end .or opens into the coelom by a funnel-shaped structure called nephrostome, nephridia are respectively termed .... or ....

ii. If two solutions have the same osmotic concentration, they are said to be ....

TERMINAL QUESTIONS

Q1. Differentiate between protonephridia and metanephridia.

Q2. Describe the different types of excretory organs found in Arthropods?

Q3 Describe the coelomoducts of different groups of molluscs.

Q4. With suitable examples, describe how the fresh water organisms maintain the water and ionic content of the body.

Q5. How the physiology of an animal does related to the type of its excretory product? Explain with examples.

5.10 ANSWERS SELF ASSESSMENT QUESTIONS

Q1. a) 5, b) 2, c) 4, d) 1, e) 3

Q2. 1- F, 2- F, 3- F, 4- T, 5- T

Q3. Protonephridia, Metanephridia

ANSWERS OF TERMINAL QUESTIONS

Q1. Please refer to section 5.4.1 and 5.4.2

Q2. Please refer to section 5.4.3

Q3. Please refer to section 5.4.4

Q4. Please refer to section 5.5

Q5. Please refer to section 5.6

UNIT 6 - NERVOUS SYSTEM AND SENSE ORGANS

CONTENTS

6.1 OBJECTIVES

- Describe organization of nervous system in invertebrates
- Explain characteristics of primitive nervous system
- Describe organization and functions of primitive nervous system in coelenterata and echinoderma
- Explain feature advanced nervous system
- Describe organization and functions of advanced nervous system in different phyla of invertebrate (other than coelenterates and echinoderms)
- Discus trends in neural evolution

6.2 INTRODUCTION

Invertebrates are a heterogenous assemblage of organisms which do not possess a backbone or vertebral column. They are much simpler organisms compared to the vertebrates that possess vertebral column and so are the various systems operating in their body. Of all systems, nervous system is the most fascinating to study. It allows the animal to respond to the environment- a step necessary for its survival.

Organization of Nervous System-

Before talking about the nervous system in higher vertebrates, let us get familiar with the terms which will be used to describe the nervous system in higher invertebrates. In the nerve nets, you learnt that neurons are far apart from each other. In contrast to this, a ganglionis a dense group of interconnected neurons. Brain is actually a large structure formed by the fusion of several ganglions.Nerve cord is composed of nerve cells and longitudinal fibers. The nerve cells are preferably confined to the ganglia. Connectives include nerve fibers that join dissimilar ganglions while commissures are stout, short, thick nerve fibers that join similar ganglia. Nerves are the nerve fibers (bundles of axons) arising from brain or ventral nerve cord reaching the target organ.

Fundamentally, nervous system of all animals is derived predominantly from its ectoderm. You know that the functional unit is the nerve cell or neuron; a cell specialized to transmit/receive a stimulus and that it appeared in the biological system in primitive aquatic life.

Besides neurons, there are another type of cells present in nervous tissue called glial cells which are important for the proper functioning of neurons.

The nervous system has two divisions- one sensory to receive stimulus and the other motor to respond.

Interneuron present between sensory and motor neurons is required for integration and determines the complexity of the nervous system.

Invertebrate nervous system is less complex and has lesser number of neurons than that of the vertebrates. Regardless of their number all neurons (with minor variations) work on the same basic principle (electrochemical).

6.3 PRIMITIVE NERVOUS SYSTEM

A well equipped absent nervous system is in invertebrate phyla, protozoa and porifera though they have some ability to respond to some stimulus to some extent. Primitively, the nervous system is composed of neurons that are far apart from each other but connected to form a loose network.

It is a simplest nervous system characterized by few neurons interconnected to form a network. This loose network of neurons is called **nerve net** and such a system is referred to as primitive nervous system.

It is a decentralized system with no cluster of neurons forming either a ganglion or brain. It is even difficult to delineate the sensory and motor divisions.

It does not contains or very few interneurons that determine the complexity of the nervous system.

Each nerve cell in a nerve net consists of a cell body containing nucleus with two to four processes. These processes are called neurites as they are not differentiated into dendrites or axon.

Nerve nets provide animals with the ability to sense object as they contain sensory cells within them.

Nerve nets are of two types- diffuse and complex nerve nets. In diffuse nerve nets neurons are far apart and not as organized as in case of complex nerve nets.

Nerve nets conduct impulses bidirectionally i.e. in both the directions or in multiple directions due to restriction and no polarization. The impulses are in the form of action potentials that are driven primarily by sodium and potassium currents as in case of more complex nervous system.

Transmission in the nerve nets is relatively slow compared with that in the other organisms.

The predominant signaling molecules in the primitive nervous system are believed to be chemical peptides, which perform both excitatory and inhibitory functions. However, the primitive nervous systems do not preclude prolonged and coordinated responses.

The anatomy and positioning of nerve nets can vary from organism to organism.

Primitive nervous system is the characteristic feature of coelenterates and echinoderms, both exhibiting the radial symmetry. Let us study the organization and function of primitive nervous system in these organisms.

6.3.1 COELENTERATA

Coelenterates are radially symmetrical, diploblastic animals with tissue grade of organization which includes the hydras, jelly fish, sea anemones etc. and is divided into three classes- hydrozoa, schyphozoa and anthozoa. Generally, two forms occur in a coelenterate species- polyp and medusa. Nervous system in coelenterates is of primitive type comprising of nerve nets. It consists of one or more nerve nets and neurites (processes) located beneath the epidermis. The neurites of adjacent cells form synaptic contacts i.e. they lie very close together with the microscopic gaps between them.

Nerve cells of coelenterates- True nerve cells occur for the first time in coelenterates. They are derived from the interstitial cells of ectoderm and occur at the base of epithelio-muscle cells just above their muscle processes. Nerve cells, linked up with the synaptic contacts, thus form an epidermal nerve net in the ectoderm. The nerve cells within the nerve nets show mixed characteristic of motor as well as sensory neurons.

It has been reported that at some places neurons may cluster to form plexus. Thus, the basic plan of coelenterate nervous system is that of a diffuse nerve net which at some regions of the body wall has condensed to form plexus.

Nerve nets in Hydra (polyp form) - You all are familiar with the fresh water coelenterate, ***Hydra*** which belongs to the class hydrozoa. *Hydra* has a diffuse network of neurons that present throughout their body (Fig.6.1). The nerve cells in *Hydra* contain 2 to 3or more processes may terminate in muscle fibers, in sensory cells or in the other ganglionic cells. There are two nerve nets in *Hydra,* one in connection with the ectoderm which is more developed and the other near the endoderm. These two nerve nets lie on the either side of the mesoglea. The ectodermal nerve net is concentrated around the mouth and basal disc regions of *Hydra*. The two nerve nets are joined to each other and to the sensory cells of both ectoderm and endoderm. It has been reported that In general, *Hydra* does not have any grouping of nerve cell bodies into either nerve ring or brain. Also, there are no sense organs instead, sensory cells serve as undifferentiated receptors for sensitivty to touch, light and chemicals and external stimuli pass from them through the nerve nets to muscle processes which act as effectors (sensory cells – nerve cells-effector system).

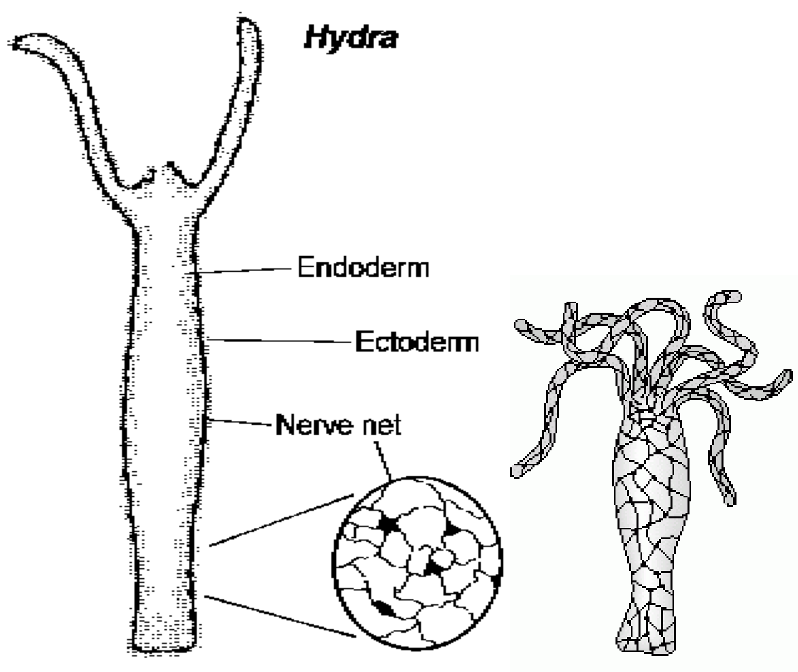


Fig.6.1 a) Nerve nets in Hydra b) Body wall of Hydra showing nerve nets in epidermis and gastro dermis.

Nerve nets in Medusoid forms – Medusa forms are mobile; bell shaped with the mouth and tentacles hanging down from an umbrella and occurs in other hydrozoans like *Obelia* etc and schyphozoans (jelly fishes). The nervous system of the medusa is highly specialized than that of the polyp because of its swimming capacity.In *Obelia* medusa (Fig.6.2), the epidermal nerve cells (nerve nets) are concentrated into two nerve rings, one just above and the other just below the attachment of the velum (bell perimeter). Formation of nerve rings along the bell margin is correlated with the concentration of muscle ring and presence of sense organs (statocysts) in this region. The nerve rings connect with fibers innervating the tentacles, the musculature and the sense organ. The lower ring is the centre of the rhythmic pulsations. It is with the lower ring that the statocysts (sense organs for the equilibrium) are connected. Statocysts are located between the tentacles or associated with the tentacular bulb (swollen bases of tentacles).

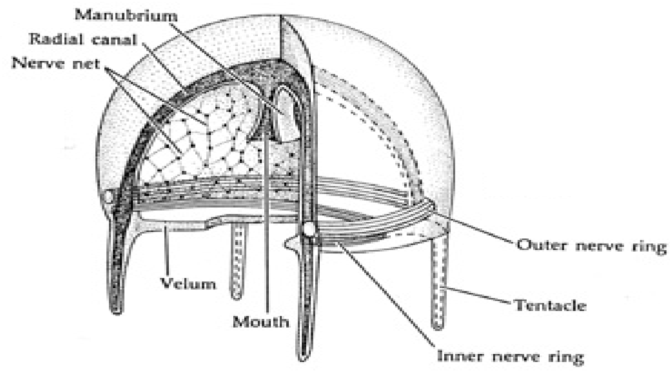


Fig. 6.2 Nervous system of Obelia medusa

In case of jelly fishes (class scyphozoa), the nervous system is like that of hydromedusa, only marginal nerve ring is absent. It has a main nerve net located in the subumbrellar ectoderm which causes pulsations of the bell by controlling the ectodermal muscles. The second nerve net is more diffuse with smaller nerve cells in the endoderm of both subumbrellar and exumbrellar surface. It controls local reactions such as feeding but it can also inhibit bell pulsations because the two nerve nets are joined through the tentaculocysts. Sense organs in jelly fishes are represented by rhopalia. Each rhopalium is located in a sensory pit roofed by a hood like extension of the exumbrella.

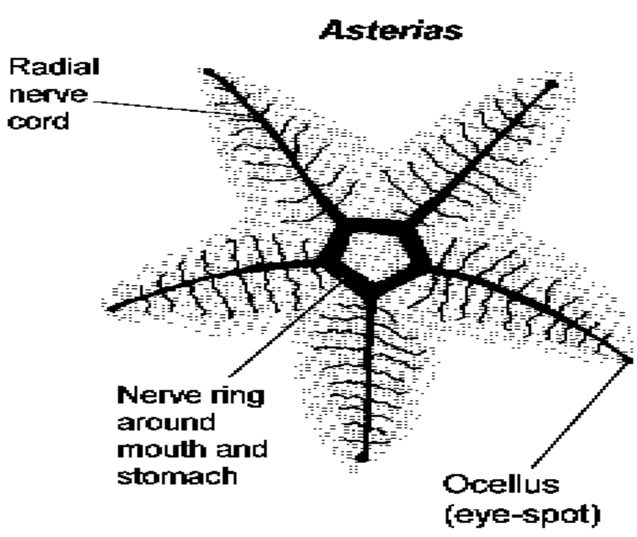


Fig.6.3 Nervous system of star fish

6.3.2 ECHINODERMATA

Echinoderms are distinct in their morphology and have a characteristic pentamerous radial symmetry. They have simple and primitive nervous system composed of nerve nets, similar to that of coelentrates. In echinoderms, the nerve nets are concentrated into rings (around mouth) and radial nerves (Fig. 6.3).They display some degree of organization in their nervous system owing to which they can organize and control complex behavior and movements. Though decentralized, this modification in nervous system reflects the change in the structural complexity in echinoderms. Interestingly, the nervous tissue in the echinoderms lies at different levels relative to oral- aboral axis. These components are distinct and are separated by thin layer of connective tissue. It consists of three main components –

- Ectoneural system
- Hyponeural system and
- Aboral nervous system

The **ectoneural system** is composed of a circum-oral ring or nerve pentagon running around the mouth. From this central nerve pentagon arise, five radial nerves each running into one arm between the rows of the tubefeet. This system is both sensory and motor in nature.

The second component of the nervous system is situated in the deeper portion beneath the epidermis of the oral surface and is thus referred to as **hyponeural system**. It has its own nerve pentagon and the radial nerves in this system are paired cords lying internal to the radial branches of the epidermal system. This system is exclusively motor and is associated with the skeletal muscle system.

The third component, the **aboral nervous system** occurs in asteroids and crinoids and is absent from the other groups. As the name indicates, it is situated aborally. It is composed of anal nerve ring that lies surrounding the anus. From this anal nerve ring arise radial nerve cords that are located in the peritoneum in each arm.

It has been reported that a fourth component also exists in echinoderms within the digestive system termed enteric nervous system. The association between the enteric nervous system and epineural and hyponeural components of the nervous system is not well established.

6.4 ADVANCED NERVOUS SYSTEM

You are aware that the invertebrate phyla are usually referred to as lower and higher invertebrates. Higher invertebrates include the phyla annelida, mollusca, arthropoda and echinodermata which are generally larger in size and bear complex body organization. Coelentrates and echinoderms, both radially symmetrical animals have simple and primitive nervous system represented by nerve nets. In primitive nervous system, there is no clear distinction between central and peripheral components. Higher invertebrates except echinoderms are bilateral animals. The development of complex body organization and behaviour, active predaceous life and complex body organization runs parallel with the complexity in the nervous system. Thus, the nervous system of higher invertebrates except echinoderms possesses advanced features and is referred to as advanced nervous system.

6.4.1 ANNELIDA

Annelids are triploblastic, true coelomate, bilaterally and metamerically segmented animals. Thenervous system of a typical annelidan (Fig.6.4) is composed of

- A nerve ring around the pharynx
- Ventral nerve cord arising from the subpharyngeal ganglion
- Ventral segmental ganglia in the ventral nerve cord
- Transverse connectives in case of double nerve cord
- Nerves- transverse, lateral and nerves arising from cerebral ganglia
- Platyhelminth nervoua system (ladder like) to be discussed in subsection 6.4.1. Annelida should be 6.4.2.

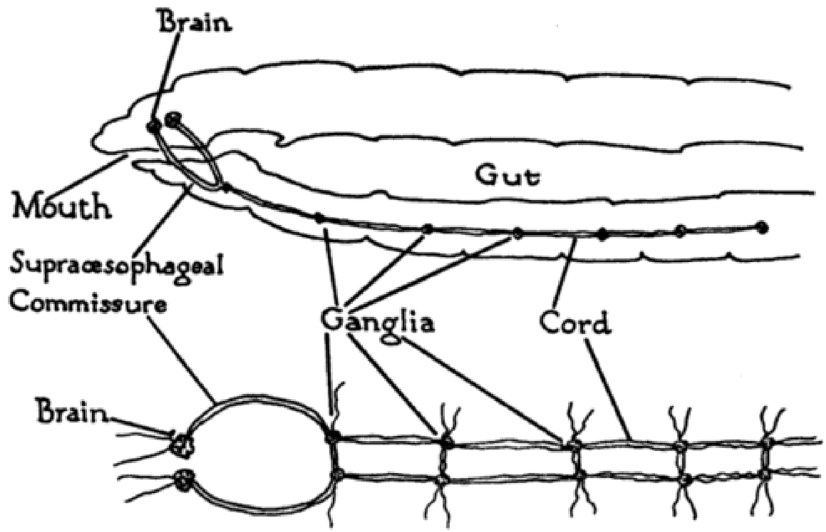


Fig.6. 4 Diagrammatic representations of basic plan of nervous system in annelids

Nerve ring in annelids is composed of paired cerebral ganglia, circumpharyngeal connectives and a subpharyngeal ganglion. Cerebral ganglion or brain is large, bilobed and situated dorsally. The subpharyngeal ganglion, as the name indicates is situated below the pharynx. A pair of circumpharyngeal connectives arises laterally from the cerebral ganglion and joins the subpharyngeal ganglion on the underside of the pharynx, forming a complete ring around the pharynx, hence the name nerve ring.

Ventral nerve cord arises from the subpharyngeal ganglionand runs backwards in the mid ventral line to the posterior end of the body. It bears a slight enlargement or ganglia/ ganglion in each segment. The ventral nerve cord in some annelids is double but mostly it is fused to form a single nerve cord and so are the ganglia.

The nerve ring and the ventral nerve cord along with its segmental ganglia form the central nervous system.

Peripheral nervous system is represented by the nerves coming out from the brain or cerebral ganglia and the lateral nerves arising from the ventral nerve cord.

Class Polychaeta

You have studied in earlier units that the phylum Annelida is divided into three main classes namely Polychaeta, Oligochaeta and Hirudinea. Class Polychaeta is the largest class of phylum annelida and includes marine worms though some are fresh water worms. *Nereis* is the typical polychate genus living in burrows, in sand or mud. It possesses a well-developed nervous system because of its active predaceous life. In *Nereis,* the tendency towards centralization of the nervous system is higher than that found in flatworms (Platyhelminthes). The nervous system of *Nereis* is based on and similar to the ground plan of annelidan nervous system described above. It is comprised of central nervous system, peripheral nervous system and visceral nervous system.

Central nervous system is composed of the brain and ventral nerve cord.

Brain- It consists of a pair of cerebral ganglia located dorsally in the prostomium which forms a 'simple brain'. In active annelids like *Nereis* the brain is large and is divided into three sections- anterior, middle and posterior centres. Middle centre bears a pair of small lobes called corpora pedunculata which coordinates all impulses entering the brain. The brain is connected by circumpharyngeal connectives, running one on the either side to a subpharyngeal ganglion, which is formed by the fusion of two ganglia of ventral nerve cord and lies below the pharynx in the first trunk segment. Connectives bear small ganglia near their attachment to the brain. **Ventral nerve cord**- It arises from the subpharyngeal ganglion and runs backward along mid ventral midline throughout the body, immediately below the ventral blood vessel. In *Nereis*, the ventral nerve cord is actually formed by the fusion of two nerve cords enclosed in the commonsheath of connective tissue. The nerve cord is dilated into a segmental ganglion in each segment which represents a pair of ganglions fused together. Cell bodies of nerve cord are confined to the ganglia. Nerve cord also has longitudinal fibers running along the cord. Few of these fibers are very long and thick through which the impulses travel very fast. Such fibers are called giant axons and are present in most annelids. In *Nereis*, there are 5 giant fibres or axons, three central and 2 in lateral position. These giant axons allow the animal to respond to an alarm by sudden contraction of the entire body.

Peripheral nervous system – It includes all the nerves arising from the components of central nervous system i.e., brain, circum-pharyngeal connectives, sub-pharyngeal ganglion and segmental ganglion of the ventral nerve cord.

In the brain

- a pair of short nerves to prostomial palpsarise from anterior centre
- two pairs of stout nerves to the eyes and a pair of nerves to prostomial tentacles arise from middle centre and

- a pair of nuchal organs arise from posterior centre

The ganglia of the circum-pharyngeal connectives supply nerves to the ventral pair of peristomial cirri.

The anterior part of sub-pharyngeal ganglion gives out a pair of long nerves which run almost parallel to the circum-pharyngeal ganglion to supply the dorsal pair of peristomial cirri. Posteriorly, the sub-pharyngeal ganglion gives out a pair of nerves to the body wall and the parapodia of the first trunk segment.

The segmental ganglia of the ventral nerve cord give out the lateral nerves supplying the muscles, appendages and body wall. Each segmental ganglion gives out four pairs of peripheral nerves, containing both afferent and efferent fibres. I and IV pairs supply the longitudinal muscles and body wall. The second pair supplies the parapodia while the third pair is composed of fibres from proprioreceptors in muscles.

Visceral nervous system- Many polychaetes, having eversible proboscis, possess a system of stomatogastric nerves arising from the posterior part of the brain. The stomatogastric nerves are composed of a network of fine nerves that supply the dorsal and ventral walls of the pharynx. These nerves are responsible for the motor control of the proboscis

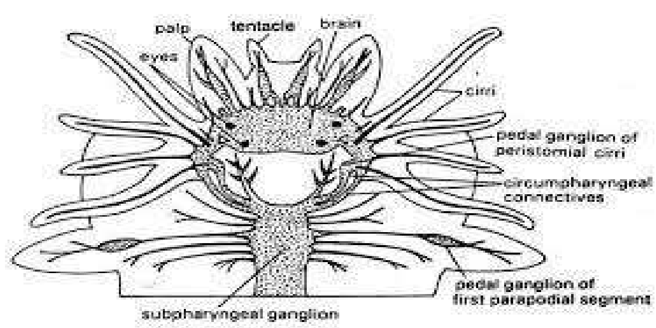


Fig. 6.5 Neries nervous system

Class Oligochaeta

You know that class oligochaeta includes the familiar earthworms and have both terrestrial and aquatic forms. The nervous system of oligochaetes is similar to that of polychaetes comprising of the anterior nerve ring and a posterior ventral nerve cord with segmental ganglions. Unlike polychaetes the brain in oligochaetes has shifted posteriorly and lies in the third segment. Like polychaetes the brain is made up of two large cerebral ganglia.

In earthworm the brain is located dorsally in depression between the buccal cavity and pharynx. It is composed of a pair of closely united, white pear-shaped cerebral ganglia. A pair of thick, stout circum-pharyngeal connectives arises laterally from the brain. These connectives encircle the pharynx and join the sub-pharyngeal ganglion present beneath the pharynx in the fourth segment, thus forming a ring like structure known as **nerve ring**(Fig.6.6).

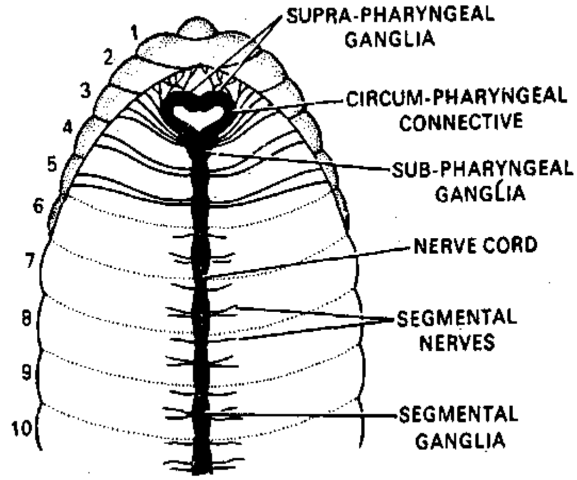


Fig.6.6 Nerve ring of earthworm

Ventral nerve cord

It appears to be single but it is actually made up of two longitudinal cords fused together. It consists of segmental ganglia where the two cords are fused to greater degree with the nerve cells present on the sides and below the cords. Two types of nerve cells are present in the segmental ganglia – motor and association nerve cells. The ventral nerve cord is covered by a mass of glial tissue.

Each segmental ganglion of the ventral nerve cord supplies 3 pairs of lateral nerves which innervates the gut wall, body wall and other internal organs of the segments. As in polychaetes, giant axons are also present in earthworm. The earthworm possesses four such giant nerve fibres that run dorsally along the length of entire nerve cord. They are responsible for very fast conduction.

Peripheral nervous system

In earthworm peripheral nervous system comprises of

- 8-10 lateral nerves arising from the cerebral ganglion which innervate the prostomium and buccal chamber.
- Nerves arising from the connectives of the nerve ring that supply to peristomium and ducal chamber.
- Nerves arising from the sub-pharyngeal ganglia that supply the structures in 2 nd, 3 rd and 4 th segment.
- Lateral nerves arising from the segmental ganglia. The nerves are of mixed type consisting of both sensory and motor fibers.

Class Hirudinea

You know that Class Hirudinea includes leeches. The body of leeches is dorsoventrally flattened and tapered at the anterior end. The segments of both the end are modified to form suckers- anterior and posterior sucker.Unlike other annelids, leeches have fixed number of segments i.c. 34. Nervous system of leeches is specialized (Fig.6.7) though the basic planis similar to that of the polychaetes and oligochaetes. There is a fusion of ganglia at the anterior and posterior position. The nervous system of a leech is divided into

I- Central nervous system
II-Peripheral nervous system and
III-Sympathetic nervous system

I Central nervous system- The entire central nervous system lies within the haemocoelomic channel and is composed of Anterior Nerve ring, Ventral nerve cord and Terminal ganglionic mass

a) **Nerve ring** is comprised of a dorsal brain formed of a pair of fused cerebral ganglia, a pair of short and stout peri-pharyngeal connectives on either side of the pharynx with a ventral sub-pharyngeal ganglionic mass situated beneath pharynx in the fifth segment. The sub-pharyngeal ganglionic mass is a composite structure formed by the fusion of four pairs of embryonic ganglia. Thus, the cerebral ganglia and sub-pharyngeal ganglia represent the ganglia of first five segments.

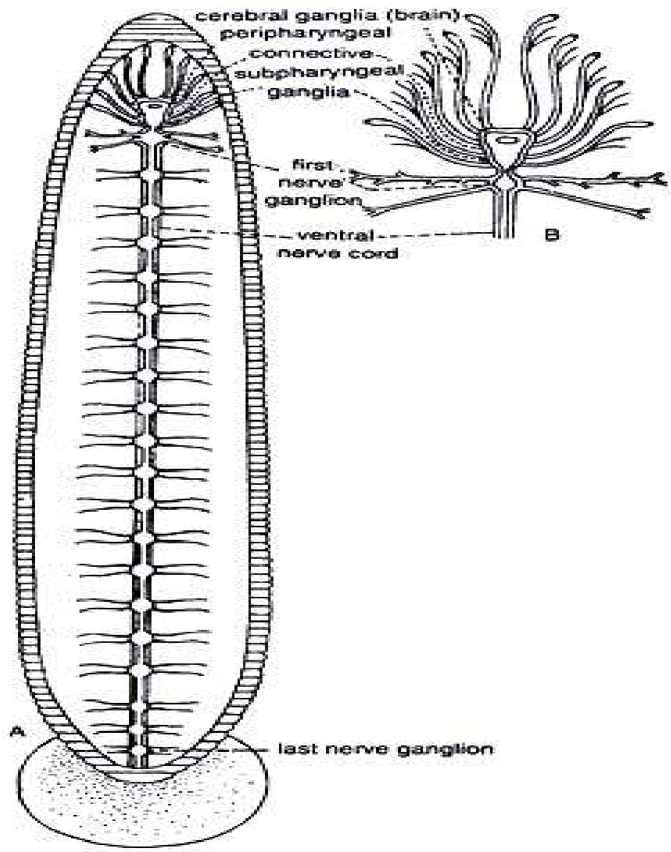


Fig. 6.7 Nervous system of leech A. entire B. anterior end

b) Ventral nerve cord arising from the sub-pharyngeal ganglia runs backward along the midventral line from 6th to 26th segment. The nerve cord is made up of nerve cells and nerve fibres. Like earthworm, the ventral nerve cord appears to be single but actually it is covered with double protective sheath, the neurilemma. It bears 21 well formed segmental ganglia at wide intervals, each located in the first annulus of its own segment. Each of the segmental ganglia in *Hirudo* contains 175 pairs of neuron cell bodies of unipolar motor neurons or interneurons arranged bilaterally around a central neuropil (The term neuropil is used for the interior of the ganglion which is filled with neuronal processes) where synaptic junctions are made. Interneurons are important part in the nervous system of leeches.

c) Terminal ganglionic mass- The end part of the ventral nerve cord bears a large, ovoid terminal ganglionic mass situated within the posterior sucker. It is formed by the fusion of 7 pairs of embryonic ganglia of the last 7 segments that constitute the posterior sucker.

II Peripheral nervous system

It consists of paired nerves arising from the components of central nervous system which includes

- A pair of stout optic nerves arising anteriorly from the brain that runs forward to supply the first pair of eyes, prostomium and the roof of buccal chamber.
- Four pairs of optic nerves arising laterally from the sub-pharyngeal ganglionic mass to supply the 2^{nd}, 3^{rd},4^{th} and 5^{th} pairs of eyes.
- Two pairs of lateral nerves arising from each of the segmental ganglion- anterior laterals and posterior laterals. Anterior laterals and posterior laterals are stout nerves and branch to supply the structures of their own sides.
- Terminal ganglionic mass gives out several nerves supplying the receptor organs and other structures found in the posterior sucker.

III Sympathetic nervous system

It is represented by an extensive nerve plexus present beneath epidermis, within muscles and on the gut wall.

6.4.2 ARTHOPODA

The phylum Arthropoda is the largest and the most successful group of animals on the earth. Like annelids, arthropods are also bilaterally symmetrical and metamerically segmented organisms with jointed appendages. Some anterior segments have undergone cephalization to form a distinct head. The degree of cephalization is very high in arthropods. Due to these structural modifications nervous system has been modified accordingly. Basically, the ground plan of arthropod's nervous system is similar to that of annelids. The nervous system of arthropods is distinguished into central nervous system, peripheral nervous system and sympathetic nervous system.

Central nervous system is represented by a comparatively large brain and a longitudinally running mid ventral nerve cord. We will study about the nervous system of two important classes here i.c. Crustacea and Inseta. Let us begin with class Inseta.

Class Crustacea includes some of the most familiar arthropods such as crabs, prawns, lobster, shrimps, crayfish etc. In crustaceans, head is often joined with thorax to form cephalothorax. Thus, body is divided into cephalothorax and abdomen. The most distinguishing feature of crustaceans is the presence of two pairs of antennae. The abdomen is composed of series of many distinct and similar segments and a terminal telson bearing the anus at its base.

The nervous system of crustacean is comparatively larger than that of annelids and has more fusion of ganglia. It is composed of the central nervous system, peripheral nervous system and sympathetic nervous system (Fig.6.8).

I Central nervous system consist of following components-

- Brain or supra-oesophageal ganglion
- Circum-oesophageal commissures
- Ventral thoracic ganglionic mass
- Ventral nerve cord

Brain or supra-oesophageal ganglion lies at the base of rostrum, anterior to oesophagus and is surrounded by a thick mass of fat. It forms a bilobed structure derived from the fusion of three ganglia indicated only by the three pairs of nerves arising from the brain.

A pair of circum-oesophageal commissures arising from the posterior part of brain runs either side of the oesophagus to join the brain with sub-oesophageal ganglion. Each commissure bears a small ganglion near its anterior end. Sub- oesophageal ganglion is indistinguishable anterior part of ventral thoracic mass. Both oesophageal commissures are connected together by a slender transverse commissure near their posterior ends.

Like segments, the segmental nerve ganglia of cephalothorax are also fused to form an elongated ventral thoracic ganglionic mass, lying midventrally on the floor of the cephalothorax.

Ventral nerve cord bears many segmental ganglia, usually one per segment in the abdomen. The number of segments varies from species to species depending upon the reduction in the number of segments due to fusion or structural modifications. The last abdominal ganglion is composed of several fused ganglia and is the largest of all abdominal ganglia.

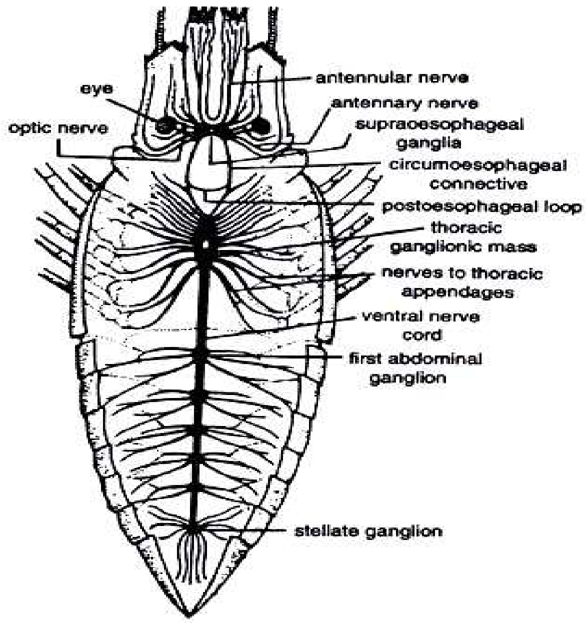


Fig.6. 8 Basic pattern of crustacean nervous system

II Peripheral Nervous system

It is comprised of the paired nerves.

Nerve arising from the brain- antennulary nerve, stout optic nerve, ophthalmic nerve, antennary nerve, a slender nerve to the labrum and a pair of circumoesophageal commissures arising from the posterior part of the brain

- Nerves arising from the ventral ganglionic mass
    - Cephalic nerves that supply cephalic appendages, mandibles, maxillullae and maxilles
    - Thoracic nerves supplying maxillipedes and walking legs, each nerve to a leg bifurcates before entering the legs.
- Nerves arising from abdominal ganglion
    - Pedal nerves
    - Nerves to both extensor and flexor muscles
- Nerves arising from the last stellate abdominal ganglion
    - Two pairs of nerves to flexor muscle
    - Two pairs of nerves to uropods

- Two pairs to telson
- A single median nerve to hind gut

III Sympathetic nervous system

It is represented by a few ganglia and nerves supplying the walls of oesophagus and cardiac stomach.

Class Insecta

You have studied that the body of insects is divided into head, thorax and abdomen. They bear three pairs of legs in the thorax region and one or two pairs of wings- a feature that distinguishes them from other arthropods. In addition, the head bears a single pair of antennae and a pair of compound eyes.

The insect nervous system is composed of-

- Central nervous system
  - Brain
  - Ventral nerve cord
- Peripheral nervous system
- Stomatogastric nervous system

The brain is a complex of three pairs of fused ganglia located dorsally within the head capsule and is made up of three major regions (Fig. 9), namely

- an anterior 'protocerebrum'
- a median deutocerebrum
- a posterior tritocerebrum

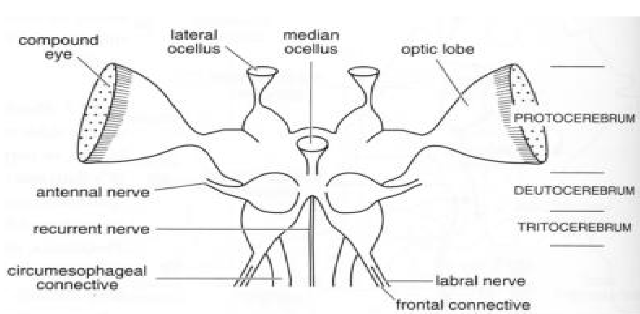


Fig.6.9 Insect brain

Protocerebrum is the anterior most part of the brain that receives the nerves of the eyes and other organs. It bears two lateral protrusions, **optic lobes** which contain one to three pairs of optic centers or neuropiles. In between the optic lobe are located a pair of bilaterally symmetrical neuropils, the **mushroom bodies**. The optic and other neuropiles of the protocerebrum function in integrating photoreception and movements.Protocerebrum innervates the compound eyes and ocelliand is thus associated with vision. These are probably the centers for the initiation of complex behavior.

Deutocerebrum is a bilaterally symmetrical brain region that consists of the antennal lobe and dorsal lobe. This brain region contains the association centers for receiving the antennal nerves for the first antennae and is lacking in those arthropods which lack antennae for example scorpions, spiders, mites etc.Deuterocerebrum processes sensory information collected by the antennae.

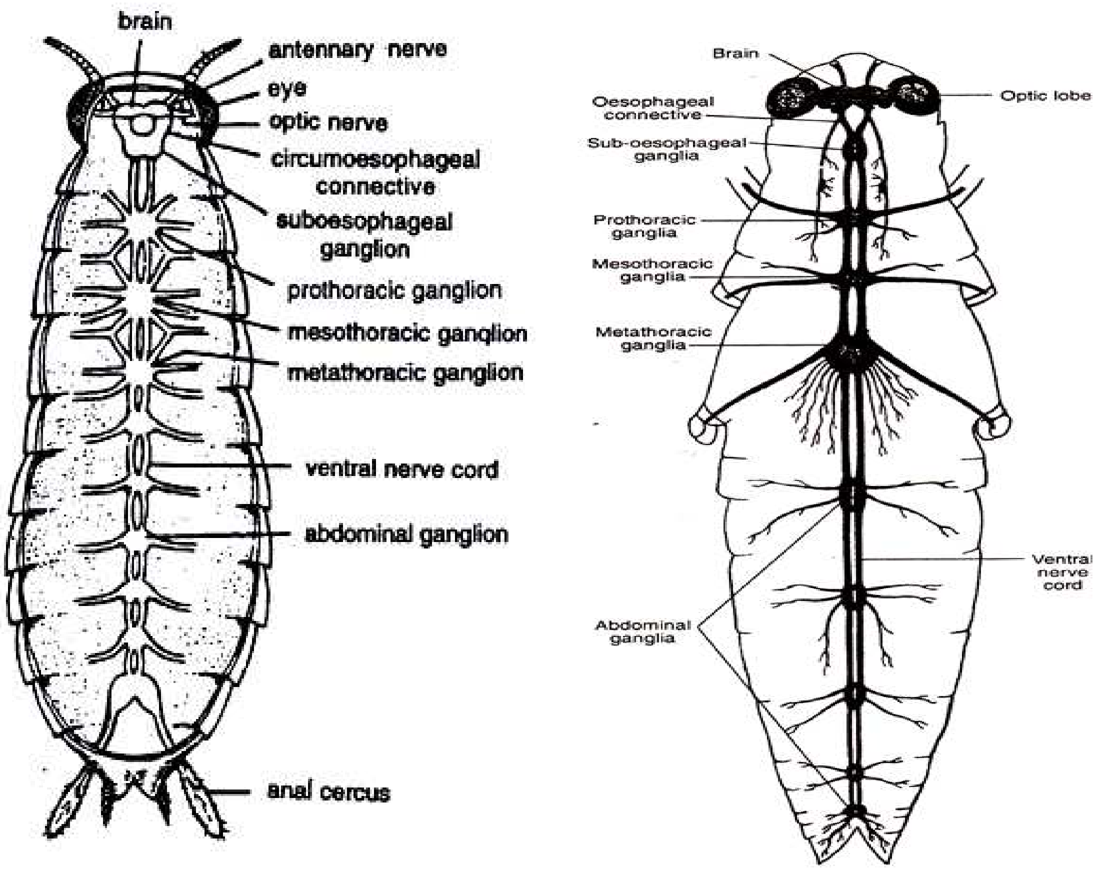
Tritocerebrum is the smallest part of the insect brain which gives rise to the nerves that innervate the labium (lower lip), the digestive tract, and the chelicerae of chelicerates and second antennae of crustaceans. It is connected to suboesophageal ganglion through a pair of connectives, thus also joins the brain with the ventral nerve cord. Tritocerebrum innervates the labrum and integrates sensory inputs from protocerebrum and deuterocerebrum.

The sub-oesophageal ganglionis present below the brain and oesophagus and is formed by the fusion of remaining three pairs of ganglia in the head. Brain and sub-oesophageal ganglion are connected together, on either side of oesophagus, by a circum-oesophageal commissure.

Ventral nerve cord- From suboesophageal ganglion runs posteriorly a double nerve cord along the mid ventral\line of thorax and abdomen. The ventral nerve cord bears thoracic and abdominal ganglia. The thoracic ganglion is a pair of ganglion present one pair per segments. Ganglia within each segment are linked to one another by a short commisure and are also joined by intersegmental connectives to ganglia in adjacent body segments giving it a ladder like appearance. This arrangement is also present in abdominal segments but only in first eightsegments. In some species, ganglia may be fused.

In grasshopper, there are eight paired or bilobed ganglia in the ventral nerve cord, three thoracic and five abdominal ganglia (Fig.10A). The third thoracic ganglion, metathoracic ganglion is the largest as the first three abdominal ganglia are fused with it. Similarly, the fifth abdominal ganglion is the largest abdominal ganglion representing the last four pairs of abdominal ganglia fused together.

In cockroach, the ventral nerve cord bears nine ganglia: three in thorax and six in abdomen. The last abdominal ganglion is comparatively large. The three thoracic segmental ganglia are called prothoracic, mesothoracic and metathoracic ganglia. (Fig.6.10B)



A

B

Fig.6.10 Nervous system of (A) Cockroach (B) Grasshopper

Many species of insects have reduced number of ganglia due to fusion and reduction. In cockroach, there are nine ganglia in the ventral nerve cord. *Vespa crabro*has only two ganglia in thorax and three in abdomen. Some insects like the house fly, *Musca domestica* have all the body ganglia fused into a single large thoracic ganglion. Thoracic ganglia innervate the legs and wings of the insect while abdominal ganglia control movements of abdominal muscle. (Fig. 6.11)

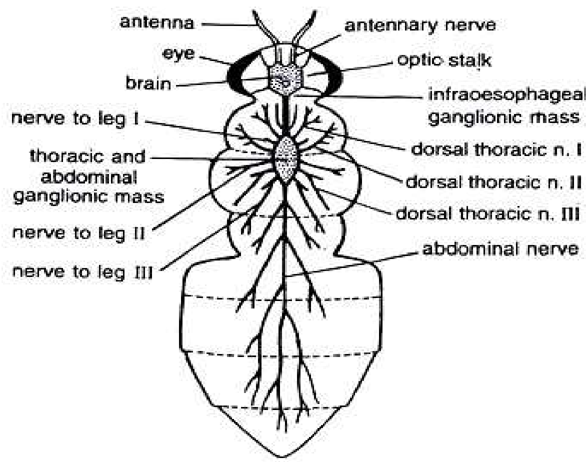


Fig. 6.11 Nervous System of house fly

6.3.3 MOLLUSCA

The phylum Mollusca includes familiar forms as clams, oysters, squids, octopus, snails etc. Their body is divided into head, dorsal visceral mass or hump and a ventral muscular foot modified for crawling, burrowing or swimming. They are soft bodied, primitively bilaterally symmetrical animals with no segmentation. The nervous system in phylum mollusca we will discuss about nervous system of Polyplacophora (Chitan) which is very simple, then gastropods (snail) and then cephalopods which have highly specialized system ranges from relatively simple forms to complex forms, the most complex being in the cephalopods. The basic pattern is a tetraneural nervous system consisting of a cerebral ganglion which gives rise to two dorsal pleurovisceral and two ventral pedal nerve cords. The molluscan nervous system is similar to that of annelids and arthropods but show higher degree of cephalization, particularly in cephalopods and is composed of

- Paired ganglia- cerebral, buccal, pleural, pedal and visceral ganglia
- Unpaired ganglia- supra-intestinal and infra-intestinal ganglions
- Commissures and connectives

Class Cephalopoda

The class cephalopoda contains cuttlefish, squids and octopus etc. They are well adapted for a swimming existence. The head projects into a crown of large prehensile tentacles or arms which are homologous to the anterior part of the foot of other molluscans. In these animals, the nervous system reaches its highest degree of development among invertebrates which is correlated with great cephalization, locomotion and carnivorous habit of these animals. Cephalopods possess well differentiated ganglia that control particular regions or functions of the body.

The cephalopod nervous system is composed of

- Large dorsal ganglionic mass or brain- It is composed of following ganglia
    - Cerebral ganglia
    - Optic ganglia
    - Olfactory ganglia
    - Buccal ganglia
- Sub-oesophageal ganglionic mass
    - Brachial ganglion
    - Pedal ganglion
    - Stellate ganglia
- Pleuro-visceral ganglionic mass
- Connectives
    - Cerebro-buccal connectives
    - Circum-oesophageal connectives
    - brachio-buccal connectives
    - cerebro-brachial connectives
- Nerves- optic, brachial (8-10), branchial and pallial nerves and sympathetic nerves (Fig. 6.12)

The large cerebral ganglia are the part of the brain lying above the oesophagus. They give rise to a pair of buccal nerves that run anteriorly to a pair of superior buccal ganglia and then through the commissure around the oesophagus, to a pair of inferior buccal ganglia. Both pairs of buccal ganglia are situated just behind the buccal mass. A pair of stout optic nerves arises laterally from both the sides of cerebral ganglia which at once expand into large kidney shaped ganglia of the eyes. A small olfactory ganglion lies on the dorsal side of each optic nerve.

In the suboesophageal regions of the brain, the pedal ganglion supplies nerves to the funnel and the anterior part, called brachial ganglia send to each of the tentacles. A pair of pleuro-visceral ganglia is also united to form a single mass lying in contact with the pedal ganglion. They give rise to a pair of visceral nerves from which a pair of brachial nerves arises. As the name indicates, visceral nerves innervate internal organs and brachial nerves innervate gills and bear a branchial ganglion at the base of the gill. A pair of sympathetic nerves innervates the stomach region. The third pair of nerves, pallial nerves is large and supplies the mantle.

Stellate ganglia- Pallial nerves on either side run backwards through the inner surface of the mantle cavity where it divides into two branches- outer and inner branch. The outer branch immediately terminates into a large, triangular stellate ganglion. Nerves arising from the stelatte ganglion innervate the mantle. Two stellate ganglia are present, one in each half of the mantle wall. The inner branch is connected to the stellate ganglion by two commissures and innervates the fin. Many small motor neurons radiating from the two stellate ganglia form a highly organized system of giant motor fibres. These giant fibres are responsible for the rapid escape movements of swimming and muscles contraction.

Like the nervous system, the sense organs of cephalopods are highly developed, particularly the eyes. Eyes in squids, cuttle fish and octopods have cornea, lens iris and retina and thus are almost similar in structure to those of vertebrates. Lens projects an inverted image on the retina as in the vertebrate eye. External muscle attachments enable limited movements of the eye. Cephalopod eye can accommodate itself to light changes both by modifications in the pupil‘s size and by the migration of pigment in the retina. It can probably detect colour.

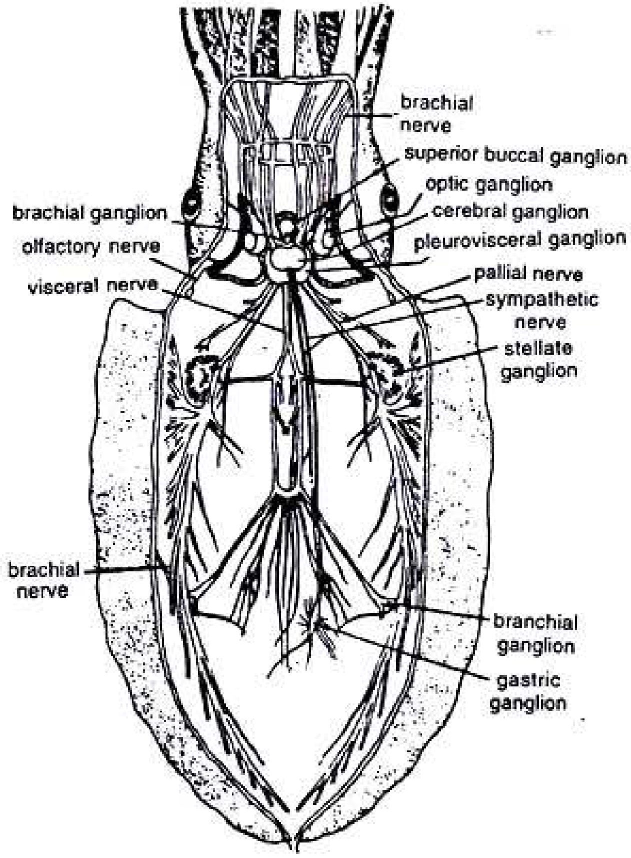


Fig. 6.12 Nervous system of Sepia (dorsal view)

6.5 TRENDS IN NEURAL EVOLUTION

As we have studied in this unit, the nervous system shows diverse patterns of organization among the invertebrates (also true for vertebrates) which run parallel with the increase in the body organization. The trends in neural evolution in invertebrate can be discussed on following points-

- Absence of nervous system- protozoa and porifera
- **Nerve nets**
  - Diffuse nerve nets in coelenterates
  - Complex nerve nets in echinoderms
- **Cephalization-** Condensation of neurons to form anterior ganglion,occurrence of sensory structures in the head due to cephalization
- **Bilateral symmetry/Centralization**
- **Ventral nerve cords** -single or double ventral nerve cord, ganglionated, reduction in the number of ganglia

- **Specialization-** Presence of more highly developed sensory structures that allow the animals to receive, process and respond to the stimuli e.g. from simple eyes to compound eyes in insects

No nervous system is present in protozoa and porifera. First of all, the true neurons appeared to exist in coelenterates which are a part of a simple nervous system of nerve nets consisting of very fine nerve fibers criss-crossing as a diffuse network and making synaptic contacts at points of intersection (**nerve nets**). The flow of nerve impulse in these nerve nets is bidirectional, showing little or no preference in the direction of conduction. We do encounter complex nerve nets in echinoderms with some degree of central coordination conducting nerve impulses from one area to the other. Echinoderms typically have a nerve ring around an axis of secondary radial symmetry and have no brain like ganglion.

The second trend involves **cephalization** i.e. concentration of nervous tissue (anterior ganglion) and receptors in the anterior end (head) of an animal. This led to a formation of a brain. This was the major early advance in the evolution of nervous system.

The third trend in the evolution of nervous system in invertebrates coincides with the evolution of **bilateral symmetry** that required the development of paired neurons, paired sensory structures, brain centers etc.Such nervous system helped to coordinate the complex movements of the animal like crawling, walking, climbing etc. The nervous system in is distinguishable into central, peripheral and sympathetic nervous system.

The fourth evolutionary trend is encountered in annelids (segmented worms), in arthropods with a **centralized brain followed by a ventral nerve cord** bearing segmental ganglia in almost each segment of the body. This type of organization allowed the appearance of extensive interconnections among the neurons. Each body segment bears a ganglion. The ganglia of the successive body segments are joined by nerve fibers, constituting the ventral nerve cord, characteristic of annelids and arthropods. These organisms also have lateral appendages in their body. Thus, such types of nervous system help to coordinate the movements of the appendages. There is a tendency towards the reduction in the number of ganglia in the ventral nerve cord in insects. Among molluscans, the cephalopods like octopus possess the most complex nervous system among invertebrates with high degree of centralization. These organisms have comparatively large number of neurons which are arranged in a series of highly specialized lobes and tracts that evidently evolved from the more dispersed ganglia of the lower mollusca.

6.6 SUMMARY

- Nervous system is one of the two coordinating or integrative systems of the body.
- Nervous system is not present in sponges.
- Primitive nervous system comprising of few nervous and nerve net is found among coelenterates and echinoderms
- Coelenterates possess primitive nervous system consisting of diffuse nerve net with no centralization.
- Advanced nervous system is present in higher invertebrates (except echinoderms).
- In annelids, the nervous system is characterized by the presence of a nerve ring and a ventral nerve cord bearing ganglia and lateral nerves in each segment.
- Nervous system of arthropods is similar to that of annelids. Crustaceans are characterized by comparatively larger nervous system than annelids and have more fusion of ganglia. Insects possess comparatively developed brain with distinct three regions.
- Nervous system of molluscs is composed of paired and unpaired ganglia, connectives and nerves. Ganglia form a ring around oesophagus. The nervous system in cephalopods is well developed among invertebrates.
- There is evolution of neural system among invertebrates. As we were from lower to higer invertebrates, symmetry becomes bilateral (except echinoderms) there is cephalization and ventral nerve cord.
- Like coelenterates, echinoderms also possess primitive nervous system composed of nerve nets. However, these nerve nets are organized into a circumoral ring and radial nerves without a brain.

6.7 TERMINAL QUESTIONS AND ANSWERS

Multiple choice questions and answers:

1. The first invertebrates to possess true nerve cells are

c) flatworms	c) sponges
d) Coelenterates	d) annelids

2. Nerve nets are found in

c) Protozoans	c) Echinoderms
b) Coelenterates	d) both b and c

3. Cephalization originated in phylum…………………for the first time

b) Coelenterata	c) Annelida
d) Platyhelminthes	d) Mollusca

4. Giant fibre system is present in

c) Earthworm	c) squid
d) insects	d) all of these

5. Which of the following is the property of a neuron?

c) Conductivity	c) both of these
d) Excitability	d) none of these

6. Which of the following has the nervous system but no brain?

c) *Nereis*	c) Earthworm
d) Cockroach	d) Hydra

7. How many pairs of ganglia have fused together to form the insect brain?

c) two	c) four
d) three	d) six

8. Which of the following is present in animals with radial symmetry?

c) ventral nerve cord	c) brain

d) nerve nets d) all of these

9. Collection of nerve cell bodies inside the CNS are called

c) nerves c) tracts

d) ganglia d) none of these

10. Terminal ganglionic mass in *Hirudinaria* is formed by the fusion of ……….of embryonic ganglia

c) four c) two

d) three d) seven

Answers: 1 b, 2 d, 3 b, 4 d, 5 c. 6 d, 7 b, 8 b, 9 b, 10 d.

Terminal questions:

(1) Write a note on nerve net.
(2) Describe the various components of nervous system in echinoderms.
(3) What do you mean by the term 'ganglia'?
(4) Describe the nervous system of annelids.
(5) Give an account of central nervous system of insects.
(6) Cephalopods have well developed nervous system among invertebrates. Justify the statement.
(7) Describe the evolutionary trends in invertebrate nervous system.

UNIT 7: INVERTEBRATE LARVAE

CONTENTS

7.1 OBJECTIVES:

After studying this unit, you should be able to:

- Explain the different form of free living invertebrates.
- Explain larval form of parasites (Helminths).
- Discuss the evolutionary significance of larval form.

7.2 INTRODUCTION:

The different stage larva, plural larvae in the development of many animals, occurring after birth and before the adult form are reached. These immature, active forms are structurally different from the adults and are adapted to a different environment. Larvae appear in a variety of forms. Many invertebrates have a simple ciliated larva called a planula. Flukes have several larval stages, and annelids, mollusks and crustaceans have various larval forms.In crustaceans both direct and indirect development. The direct development, adult is attained by progressive growth and differentiation, whereas in the indirect development, there is a larval stage which differs from the adult in many features and acquires adulthood through metamorphosis. Many of the crustaceans undergo indirect development, involving a wide variety of larval forms.

The larval forms of the various insects are called caterpillars, grubs, maggots and nymphs. In some species the larva is free living and adult is an attached or non mobile form, in other the larva is aquatic and the adults lives on land.

7.3 LARVAL FORM OF FREE-LIVING INVERTEBRATES:

The free-living larval forms are following phylum of Invertebrates-

7.3.1Phylum Porifera:

1. Amphiblastula Larva:

Amphiblastula larva occurs in the development of the most Calcarea. The stomoblastula undergoes a process called inversion. Duringthis process, the flagellar ends of micromeres come outside and then it is called amphiblastula larva.Itis more or less oval shape and consists of one half of small narrow flagellated cells and the other half of large rounded granulated cells or non- flellated cells. A fully developed amphiblastula first comes in radial canal and then passto exterior through osculum and then leads swims freely in water. This larva leads to a free- swimming life for some time during which gastrulation takes place by the invagination of the flagellated cells.

Ultimately the amphiblastula settle down and undergoes gastrulation. Gastrula soon attaches itself to some rock or sea-weed by its blastoporal end and develops a central spongocoel and an osculum. Non flagellated cells from the dermal covering and the flagellated cells become the choanocytes lining the spongocoel. After the changes the larva develops into a young sponge. (Fig 7.1)

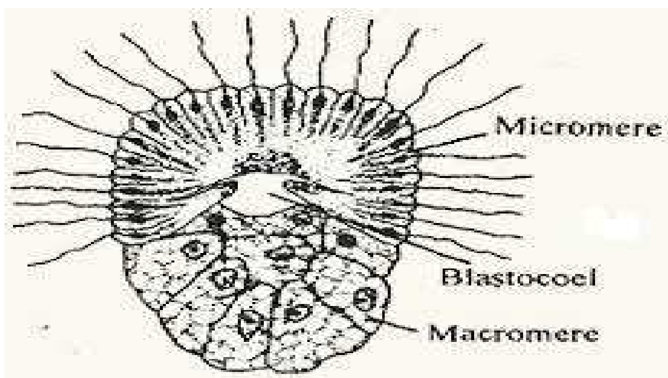


Fig.7.1 Amphiblastula larva

7.3.2 Phylum Coelenterata

1.Scyphistoma Larva:

Scyphistoma is the larva of *Aurelia*. Planula larva metamorphoses in to a small scyphistoma larva. It attaches to rocks by aboral end. The cilia are lost and body becomes elongated. Scyphistoma larva is also known as hydratuba. An oral cone or manubrium is formed, the blastopore opened to become the mouth. Four hollow buds arise become tentacles. Subsequently four inter-radial and eight adradial tentacles are formed. The endoderm of colenteron forms four inter-radial longitudinal ridges called gastric ridges or mesenteries. The mouth becomes square and the manubrium sinks down to form funnel- like depressions called septal funnelsor infundibuls. A root- like stolon arises at the base of hydratuba larva, which feeds and buds new hydratubae from its stolon throughout the summer. After summer the hydratuba cease to bud, it continues feeding and storing food. The hydratuba generally winters over the first year and may bud other hydratubae, but next winter it undergoes a process of transverse fission and called strobilation, the dividing hydratubae is called a scyphistoma or strobila.

The transverse discs of the scyphistoma which have been produced by strobilation looks like a serial pile or saucers and each disc is an ephyra larva. About dozen ephyrae are formed in a single strobilation (Fig 7.2).

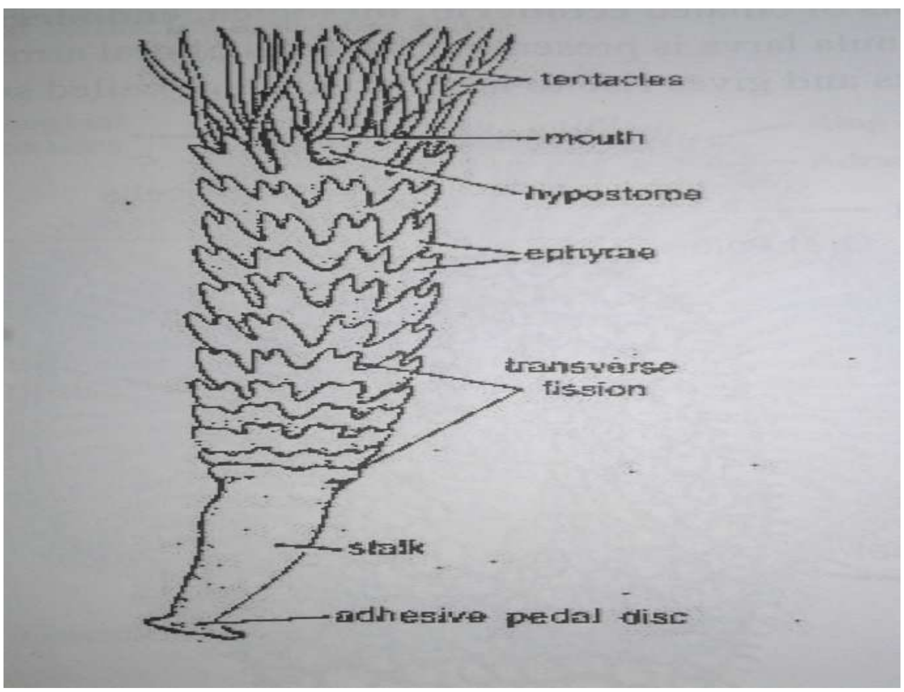


Fig.7.2. Scyphistoma larva ofAurelia.

2. Ephyra Larva:

Ephyra larva is the larva of *Aurelia*. It is a small medusoid form which develops from the scyphistoma larva as a result of transverse fission body is umbrella like and having tetramerous symmetry. The umbrella is divided into eight long forked arms. The distal ends of arms are deeply notched and form marginal lappets. Eight prominent tentaculocysts are present in the notches between the marginal lappets. Manubriummmm with the mouth is present in the middle on the sub- umbrella surface. Gastric filaments, pre- radial and inter-radial canals are also seen. Ephyra larva swims actively in the water and metamorphoses into adult *Aurelia* (Fig. 7.3).

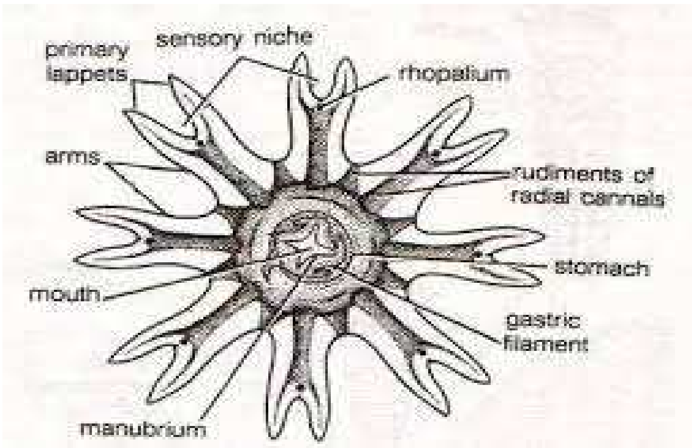


Fig.7.3 Ephyra larva of Aurelia

7.3.3 Phylum - Arthropoda

1. Nauplius Larva:

Nauplius Larva is the first larval stage of many Crustaceans. The body is unsegmented minute oval shaped. It has a broad anterior head region, middle trunk region and bilobed anal region. Head bears a median eye and a pair of antennules bearing terminal setae. Trunk has two pairs of biramous appendages, i.e., antennae and mandibles. Mouth opens at the anterior ends while anus lies on the posterior extremity. Nauplius undergoes a series of mouth to pass through several intermediate larval forms before it reaches the adult stage (Fig. 7.5).

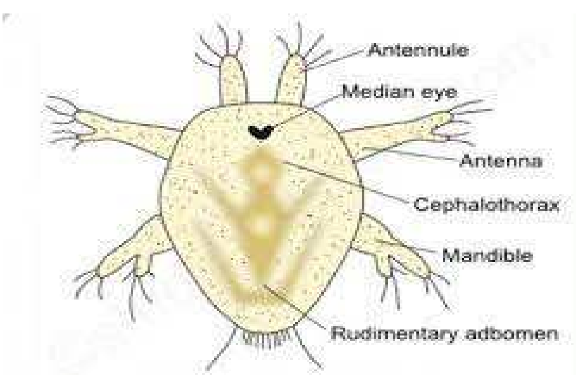


Fig.7.5 Nauplius Larva

2. Metanaplius Larva: Metanaplius is the later nauplius instar andresults by the process of moulting and growth. Its body is divisible into a broad cephalothorax and an elongated abdomen, terminating into a pair of cadual fork.Besides the three pairs of nauplius appendages. It also bears the rudiments of four pairs of appendages, which are two pairs of maxillae and two pair of maxillipedes of the adult. Some decapods and some stomatopods begin their life history with the free swimming metanauplius larva (Fig. 7.6).

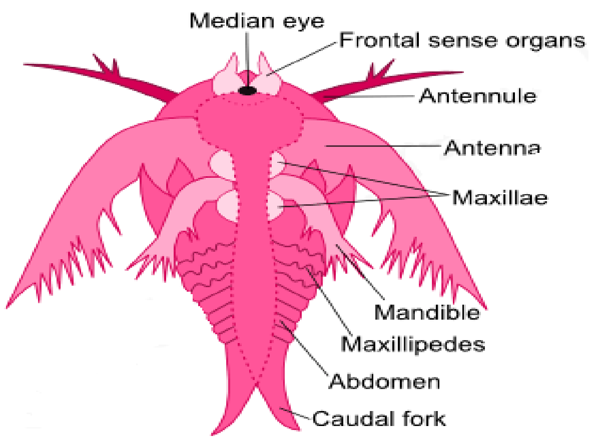


Fig.7.6 Metanaplius Larva ofApus

3. Protozoaea Larva: It body divisible into a cephalothorax, abdomen and telson. Cephalothorax is a broad segmented with a small carapace and a slender abdomen, terminating in a forked telson. A single median nauplius eye is present. The appendages comprise the antennules, antennae, mouthparts and first and second maxillipeds. The later stage protozoaea modified into the zoaea (Fig.7.7)

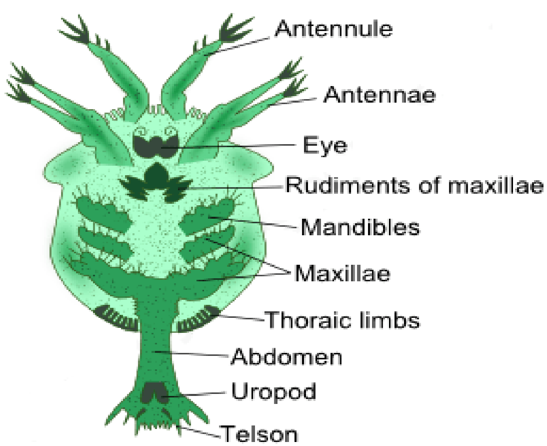


Fig.7.7 Protozoaea larva

4. Zoea Larva:

Zoea larva is the fourth larval stage of the Crustaceans. Nauplius changes into metanauplius, and the latter changed into zoea larva. Body consists of large segmented abdomen and unsegmented cephalothorax. The cephalothorax is covered by carapace, produced long spines of which one is rostral, a median dorsal and two laterals. Compound eyes are paired and movable. Two pairs of maxillipedes are well developed and six pairs of thoracis appendages develop as buds. Abdomen consists of six pairs of thoracic appendages and develops as buds. Abdomen comprises of six segments and the last segment bears caudal fork (Fig.7.8).

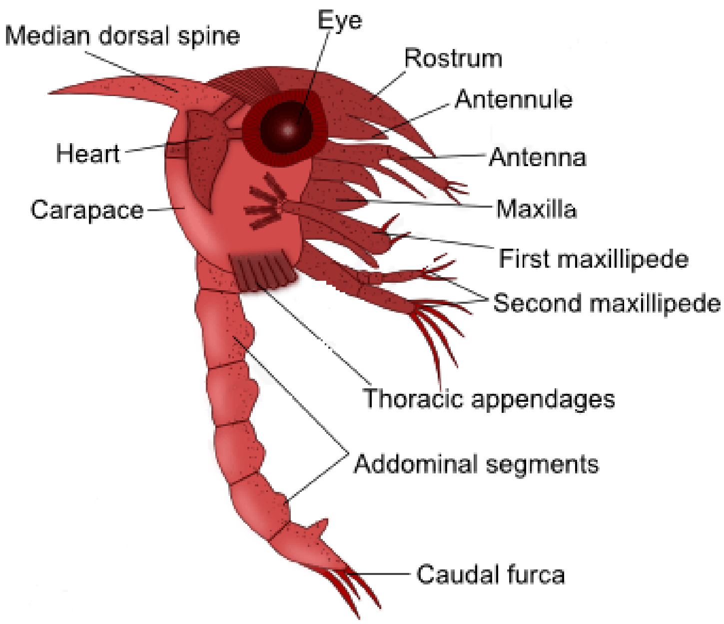


Fig.7.8 Zoea larva

5. Megalopa Larva:

Megalopa larva is the larva of crab and develops from zoea larva through successive moults. It has a broad and crab- like unsegmented cephalothorax bearing a median spine. It has a pair of large and stalked eyes. Antennules are small, while antennae are large. The thoracic appendages are well developed. Abdomen is six segmented bearing biramous pleopods and a telson. Pleopods are used for free swimming. Megalopa leads a pelagic life for some time and later on sinks to the bottom and transforms into adult. (Fig. 7.9)

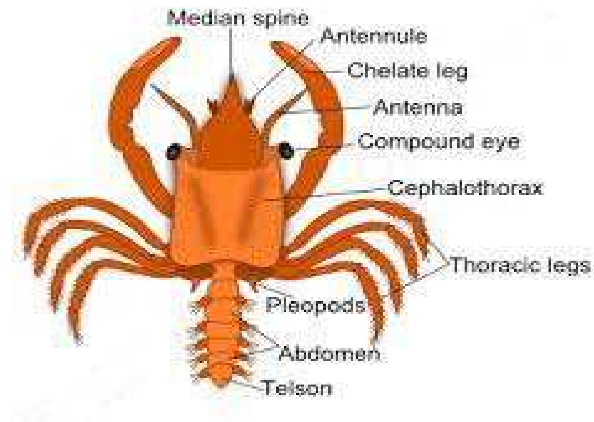


Fig.7.9 Megalopa larva

7.3.4 Phylum-Mollusca

1. Glochidium Larva:

Glochidium larva is found in the development of Pelecypoda or Bivalvia. It is minute larva measuring 0.1 to 0.4 mm, comprises a shell and mantle. The shell consists of two triangular and porous valves united dorsally and free ventrally. The ventral free end of each valve of the shell is produced into a curved hook bearing spines. The shell encloses the body the left and right mantle lobes. Mantle lobes are small and bear brush-like sensory bristle. The adductor muscle is well developed extending between the two valves at the base. The closure of the valve is affected by the large adductor muscle. Byssus gland is situated above the adductor muscle which gives rise to a long sticky thread called provisional byssus. Glochidium larva attached itself to the skin or gills or fins of a fish and leads a parasitic life for about 10 weeks and metamorphoses into adult. (Fig. 7.10)

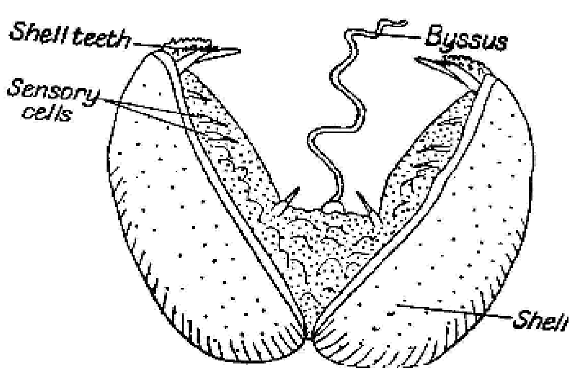


Fig. 7.10 Glochidium larva

7.3.5 Phylum Echinodermata

1. Bipinnaria Larva:

Bipinnaria larva is the characteristic free-swimming larva of Asteridea (star- fish). After gastrulation the egg hatches into a larva which develops cilia and begins a free-swimming life. The free-swimming larva within 2-7 days also develops three lateral lobes on each side and gives rise to bipinnaria larva. At the anterior end dorso-median arm, ventro- median and pre –oral arms are present. On lateral sides antero-dorsal arms, postero- dorsal arms, post- oral arms and postero- lateral arms are present. Alimentary canal consists of mouth, oseophagus stomach, intestine and anus. (Fig. 7.11)

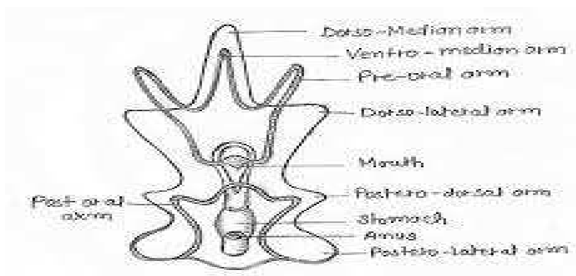


Fig.7.11 Bipinnaria larva

2.Ophiopluteus Larva:

Ophiopluteus larva is the characteristic free- swimming larva of Ophiuroidae. Larva bears four pairs of slender projections, the arms. The postero- lateral arms are formed first and are always the longest and directed forwards, so that the larva has the appearance of a V. Antero-lateral, post- oral and postero- dorsal arms develop after four, ten and eighteen days respectively. Ciliated bands are present on the edges of arms. All the arms are supported by calcareous skeleton. Internally the larva contains coelomic pouches and alimentary canal consisting of mouth, oesophagus, stomach, intestine and anus. The larva metamorphoses into adult after the appearance of skeleton. (Fig .7.12)

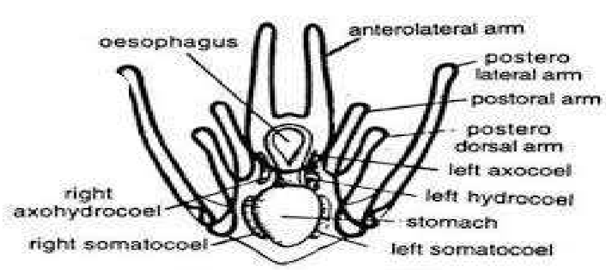


Fig. 7.12 Ophiopluteus larva

3. Echinopluteus Larva:

Echinopluteus Larva ischaracteristic free- swimming larva of Echinoidea. The larva develops after gastrulation. The arms bear five to six pairs, pigmented and supported by calcareous skeleton. The arms which have been named according to their disposition. Pre-oral, antero- lateral, post-oral, postero-dorsal and postero- lateral arms are present. Postero- lateral arms are usually very short and directed backwards. All the arms are supported by calcareous skeleton rods. The locomotion of larva is by ciliated bands. The alimentary canal comprises mouth, oesophagus, stomach, intestine and arms. The larva, after leading a free-swimming life for some time, metamorphosis into the adult (Fig.7.13).

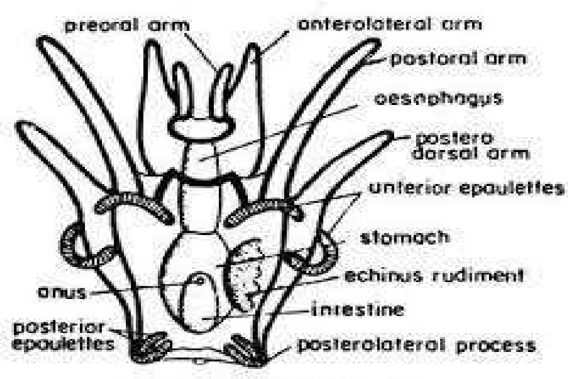


Fig. 7.13 Echinopluteus larva

7.4 LARVAL FORMS OF PARASITE (HELMINTHS):

The larval forms of parasite in Helminths are following types:

1. **(i) Cysticercus Larva of *Tenia solium*:** Cysticercus larva is also known as bladder- worm. It develops in the muscles of pig, the intermediate host. Formation of cysticerci is completed in about 10 weeks in the pig. The cysticercus develops into the adult tapeworm only when ingested by the human host. Onchospheres first reach the stomach of pig with faeces of man. The onchospheres further migrate to the muscles where the hooks are lost and the cells in the centre of the embryo disappears and thus producing a single layered large ovoid bladder known as bladder worm or cystcercus. As the bladder increases in size an invagination takes place at one side. On the invagination suckers and hooks are formed and this part is known as proscolex. The further development of cysticercus larva takes place when it is eaten by man with the muscles of pig. Cysticercus consists of a sac or bladder- like structure, having

invaginated proscolex measuring 6-18 mm in length. The bladder is opalescent made up of asingle layer and filled with a fluid. The contaminated part of pig muscles is called measly pork. Cysticercus in measly pork is found between muscles fibres and connective tissue. (Fig. 7.14)

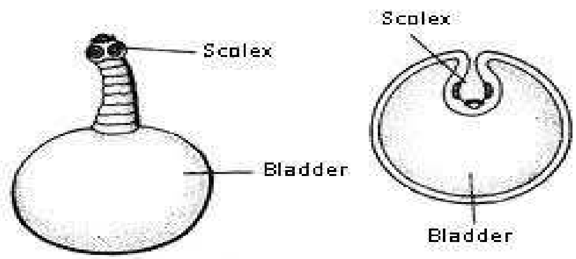


Fig.7.14 Cysticercus larva or bladderworm

2. **(i) Miracidium Larva of *Fasciola hepatica*:** It is the first of a series of larval stages involved in the life cycle. It is a minute, oval, elongate, richly ciliated active creature with its broader and anterior end produced into a mobile and non-ciliated apical papilla or terebratorium. The body is covered with flattened ciliated epidermal plates arranged in five rows. Beneath the epidermal plates is a fine layer of sub-epdermal musculature, consisting of outer circular and inner longitudinal fibres. Below which is a layer of cells forming the sub-epithelium. The epidermal plates, sub- epidermal musculature and sub-epithelium from the body wall of miracidium. (Fig. 7.15)

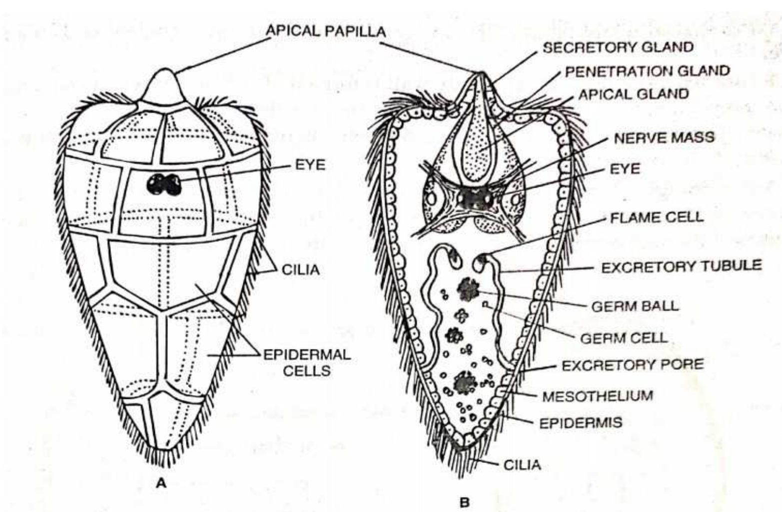


Fig.7.15 Miracidium larva ofFasciola hepatica.A-External structure.

B-Internal structure

ii) Sporocyst Larva: It is the second larval stage involed in the life cycle of Fasciola hepatica. It looks like an elongated sac, about 0.7 mm long. Its body wall retains all the layers of the body wall of miracidium except the ciliated epidermis, which is lost in the process of penetration and soon replaced by a thin cuticle. Glands, brain, eye spot and apical papilla of the miracidium degenerate and disappear in the sporocyst. The protonephridia divide and the two. Thus, formed on each side, open through a common excretory duct.These excretory structures, the sporocyst contain germ cells.

The sporocyst moves about in the tissues of the host, absorbing nutrition from it. Their germ cells multiply and give rise to next larval generation, the rediae. Each sporocyst produces five to eight rediae.Fig. (7.16)

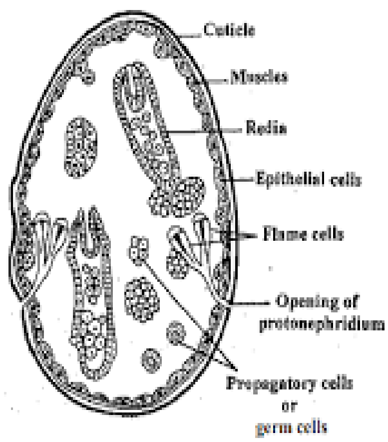


Fig.7.16 Sporocyst ofFaciola hepatica

iii) Redia Larva: The rediae emerge from the sporocyst by rupture of the latter's body wall. Each redia is elongate and normally possesses two or four bud –like, antero- and postero-lateral projections, the ambulatory buds or procruscula. The body wall consists of the usual layers, cuticle, musculature (of outer circular and inner longitudinal fibres) and the subepithelium. The mouth leads into a short muscular pharynx, followed by an elongated sac-like intestine or the gut lined by a single layer of cells. Numerous unicellular pharyngeal glands open into the pharynx. Protonephridia divide further and form a much branched system. All the flame cells of each side open out through a common excretory duct. Body of a larva is packed with germ balls and mesenchyme cells.

The redia moves through the host's tissues which it also feeds. Movements are brought about by muscular contractions of the body. The moving rediae enter various organs of the snail but prefer to migrate to its digestive gland. During summer, when sufficient nourishment is available, the germ balls of the rediae give rise to a second generation of rediae morphologically identical to the parents. Germ balls of rediae of the second generation, during winter, develop into larvae of the next stage known as cercaria larvae.Fig.(7.17).

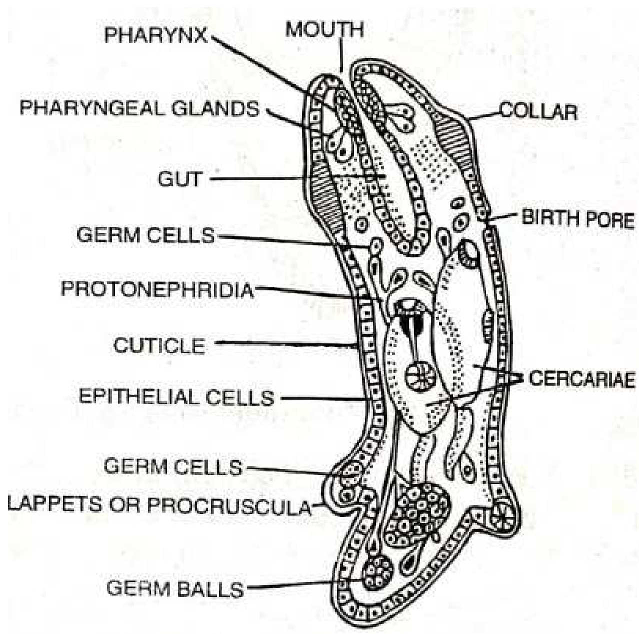


Fig.7.17 Redia larva ofFasciola hepatica

iv)Cercaria Larva: Morphologically, the cercaria bears a close resemblance with the adult fluke. Body of cercaria is flat and oval shaped bearing a tail. Body is covered by cuticle and body wall consists of cuticle, muscles and mesenchyme. It has two sukers and ventral sucker situated in the middle of the body. Digestive system comprises, mouth, muscular pharynx, oesophagus and intestine. Excretory organs of the flame cell type are present. Body space is filled with parenchyma and contains a few cystogenous gland on each side which forms the cyst of the future larva. Rudimentary reproductive organs are also seen. Cercaria larva comes out from the redia through the birth pore and also from the body of snail. It is a free-swimming larva and after swimming for a short period it attaches to the aquatic plants. Finally, cercaria larva undergoes encystment and the encysted larva is known as metacercaria which is swallowed by the final host, sheep.Fig. (7.18).

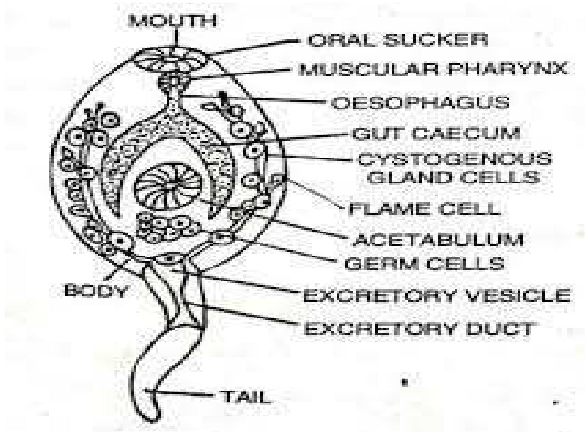


Fig.7.18Cercaria larva ofFasciola hepatica.

7.5 STRATEGIES AND EVOLUTIONARY SIGNIFICANCE OF LARVAL FORMS

Vance (1973) stated that there are three possible paths of development in benthic invertebrates depending on the amount of energy (yolk) available to produce the young.

1. Planktotrophic larvae: produce many eggs with little yolk= energy
2. Lecithotrophic larvae: produce fewer eggs with more yolk= more energy
3. Non- pelagic larvae: produces few eggs with large amount of yolk

By living in a distinct environment, larvae may be given shelter from predators and reduce competition for resources with the adult population. Animals in the larval stages will consume food to fuel their transition into the adult form. In form with nonmobile adult, the mobile larva increases the geographic distribution of the species. Such larvae have well developed locomoter structures. A larva sometimes functions as a food gatherer in many species the larval stage occurs at a time when food is abundant and has a well-developed alimentary system.The significance of larval forms helps in the dispersal of species, help to study the different group. According to the biogenetic law or recapitulation theory of **Haeckel** every organism during its development repeats to some extent its evolutionary history. In other words, successive stages of individual development correspond with successive adult ancestors in the line of evolutionary decent. Due to its occurrence in the development of all Crustacea, the nauplius was previously regarded to be representing the ancestral form of Crustacea. It was presumed that form this ancestral form the present-day crustaceans evolved phylogenetically. The other larval forms show stages of evolution of the higher crustaceans from nauplius-like ancestors. The larval stages are useful for finding out the homologies and the affinities of various groups.

Larvae represent one of the classic problems of evolutionary biology and may explain how new body plans originate. It has often been suggested that many entirely unique bodiesplan first originated as retained larvae of ancestral organisms. The larvae are helpful in the wide distribution of species and in keeping the food reserves of eggs to a minimum.

7.6 SUMMARY:

The larva is a distinct juvenile form many animals undergo before metamorphosis into adults. Animals with direct development such as amphibians, insets typically have a larval phase of their life cycle. The larvae are generally very different from the adult form in appearance including different unique structures and organs that do not occur in the adult form. Larva is the independent and immature animal that undergoes metamorphosis to assume the typical adult form. Larvae occur in almost all of the animal phyla, because most are microscopic, they are rarely seen. They play important roles in the lives of animals.

7.7 SELF ASSESMENT QUESTIONS AND POSSIBLE ANSWERS

1 Multiple Choice Questions:

1. Amphiblastula larva occurs in the class

a) Calcarea b) Hexactinellida

c) Desmospongiae d) None of these

2. Amphiblastula larva belong to which phylum

a) Protozoa b) Porifera

c) Colenterata d) Annelida

3. Scyphistoma is a larve of

a) *Tubipora* b) *Aurelia*

c) *Cyanea* d) *Gorgonia*

4. Ephyra is a larve of

a) Aurelia b) Amoeba

c) Metridium d) Pennatula

5.Ephyra larva belong to which phylum

a) Porifera b)Colenterata

d) Annlida d) Arthropoda

6. Miracidium larva belong to which phylum

a) Arthropoda b) Colenterata

d) Mollusca d) Platyelminthes

7. Mircidium is a larva of

a) *Fasciola hepatica* b) *Schistosoma*

c) *Taenia solium* d) *Planaria*

8. Cercaria larva is a larva of

a) *Tania solium* b) *Schistosoma*

c) *Fasciola hepatica*d) *Planaria*

9. Redia larva belong to which phylum

a) Porifera b) Coelenterata

c) Mollusca d) Platyhelminthes

10. Bipinnaria larva is the free-swimming larva of

a*) Antedon* b) Star-fish

c) *Echinus* d) *Holothuria*

Answers: 1.**a); 2.b); 3b); 4.a); 5.b); 6.d); 7.a); 8.c); 9.d); 10.b)**

2. Write short notes on:

1. Ephyra Larva

2. Carcaria Larva

3. Zoea Larva

4. Glochidium Larva

5. Ophinopluteus Larva

3. Terminal and modal questions

1. Explain the nauplius larva of Arthopoda with digram.

2. Describe the Cercaria larva of helminthes.

3. Describe the larva of phylum Coelenterata.

4. Explain the Bipannaria larva.

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https://www.google.com/search?q=ephyra+larva+diagram

https://www.google.com/search?q=protozoea+larva&safe

https://www.google.com/search?q=glochidium+larva+diagram&safe

https://www.google.com/search?q=ophiopluteus+larva+diagram&safe

UNIT 8: MINOR PHYLA

8.1 OBJECTIVES

- We study about Mesozoa & Gastrotricha.
- We study about Ctenophora & Rhynchocoela.
- General Study of Rotifera & Spincula.
- Study of Protostomes, Entoprocta & Deuterostomes.

8.2 INTRODUCTION

Most of these phyla comprise inconspicuous and little-known animals, which appeared before the two main streams of evolution diverged. They are often grouped together as the ‘minor’ phyla, presumably because their members are generally too small to be seen with the naked, human eye. These animals are rarely seen as they usually live-in secluded aquatic or terrestrial microhabitats or as parasites, hidden away in other animals or plants. In spite of their inconspicuous habits, these animals are both numerous and important — as members of food chains or as parasites of economic, veterinary or medical importance.

The features used to understand how these animals are related to each other and to other invertebrate phyla include the formation of the body cavity and the nature of their larval forms.There are several peculiar animals which constitute separate phylum. Each minor phyla contains a few species such as Nemertinea (Ribbon worms), Nemotomorpha (Horse-hair workm) Rotifera (wheel animalcule) etc.

8.3 ORGANIZATION AND GENERAL CHARACTERS

The concept of major and minor phyla is based on two factors:

(i) The number of species and individuals;

(ii) Their participation in ecological communities. On the basis of the first factor, 11 phyla appear to be clearly major, these are Protozoa, Porifera, Coelenterata, Platyhelminthes, Rotifera, Nematoda, Mollusca, Annelida, Arthropoda, Ectoprocta and Echinodermata.

On the basis of second factor, if the phyla are represented in great majority of ecological communities, they would be regarded as major phyla. Whereas, the minor phyla form only a fraction of animal communities.

On this basis, the two phyla, Rotifera and Ectoprocta, cannot be considered as major phyla. Although they are greater in number of species, but they are included in minor phyla due to their limited participation in animal communities. Thus, keeping in view the utility of the above two factors, we can regard only nine as major phyla and the rest as minor phyla.

Characteristics of Rotifera:-

1) Bilaterally symmetrical.

2) Body has more than two cell layers, tissues and organs.

3) Body cavity is a pseudocoelom.

4) Body possesses a through gut with an anus.

5) Body covered in an external layer of chitin called a lorica.

6) Has a nervous system with a brain and paired nerves.

7) Has no circulatory or respiratory organs.

8) Reproduction mostly parthenogenetic, otherwise sexual and gonochoristic.

9) Feed on bacteria, and protista, or are parasitic.

10) All live in aquatic environments either free swimming or attached.

Characteristics of Mesozoa:-

1) Bilaterally symmetrical.

2) Has no organs or tissues.

3) Body contains no internal cavity.

4) Body possesses no digestive tract (gut).

5) Body only two cell layers in most places.

6) Has no nervous system.

7) Has some cells develop inside other cells.

8) Reproduction quite complex involving both sexual and asexual aspects.

9) All are endoparasites on other marine invertebrates.

8.4.1 MESOZOA

The phylum Mesozoa constitutes a small group of poorly known minute parasites of marine invertebrates. They include small, slender and structurally the simplest metazoans but their life-cycles are complicated. All are tiny in size containing no more than 24 body cells surrounding an elongated reproductive cell. At present no complete life-cycle has been worked out for any mesozoan, and even the taxonomic position of most forms is still unknown.

Distinctive characters

(1) Endoparasites in the internal spaces and tissues of octopuses, squids, flatworms, sea, stars, annelids and other marine invertebrates.

(2) Body small, simple, multicellular, acoelomate and solid, consisting of an outer single syncytical central axial layer of ciliated cells, called somatoderm, enclosing one or more reproductive cells.

(3) Symmetry radial or biradial. Shape somewhat wormlike. Size upto 6 or 7 mm in length.

(4) Locomotion by cilia.

(5) There are no tissues (endoderm and mesoderm), organ, or cavities.

(6) Number of cells is constant for each species.

(7) Life cycle is complicated by an alternation of sexual and asexual generations.

Order 2. Orthonectida

(1) Rare endoparasites of various invertebrates, such as flatworms, nemerteans, brittle star, annelids, and clams.
(2) Body slightly ringed and sexual forms under I am long.
(3) Asexual stages a multinucleate amoeboid plasmodium that can reproduce by fragmentation.
(4) Sexes are separate and dimorphic.

Example: Rhopalura, Staecharthrum.

Affinities

Mesozoa constitute a small but well-define group which have offered a great taxonomic puzzle ever since their discovery in 1869. Their true phylogenetic position is an enigma. Concerning their affinities, there are two principal views. Hyman (1940) and McConnaughey (1963) think that they are truly primitive, representing an offshoot from the early metazoans with a long history of parasitism, and forming a connecting link between the Protozoa and the Metazoa. The other view, perhaps the more popular and held by many zoologists, is that they are degenerate flatworms due to parasitism. Stunkard (1954) has even made them a class of the Platyhelminthes.

1. **Affinities with Protozoa.** The simplicity and primitiveness of Mesozoa can be interpreted by their resemblance to some colonial Protozoa in the following characteristics:

(1) Occurrence of external cilia through much of the life cycle.
(2) Differentiation of cells into somatic and reproductive cells only, as in Volvox.
(3) Endogenous or internal position of sex cells, as in Volvox.
(4) Power of intracellular digestion by the surface cells.
(5) Complicated life cycle with alternation of asexual and sexual phases, as in Sporozoa.

2. **Affinities with Coelenterata.** By some, the Mesozoa are considered to be degenerate coelenterates due to the following reasons:

(1) The adult Mesozoan structure compares with that of the planula larva.

(2) In the development of the dicyemids, the covering over of one cell by the other is similar to epibolic gastrulation found in the coelenterates. Such embryos are regarded by others to remain at a stereoblastula stages.

(3) In the development of the orthonectids, sexual adults are formed by a process identical with endoderm formation by secondary delamination. As the interior cells never differentiate into functional endoderm, the Mesozoa can be regarded to have remained at the morula or stereoblastula stages. However, the structure and life history of the Mesozoa lend very little support to the idea of their coelenterate affinities.

3. **Affinities with Platyhelminthes.** The view that the Mesozoa are degenerate flatworms' rests on the following resemblances:

(1) The complicated life cycle including a ciliated larva and simplified vermiform stages reproducing asexually, as in the digenetic termatodes.

(2) Adult is vermiform, solid and turbellaria-like

But an adult trematode and the micracidium larva do not bear any structural resemblance to the orthonecidium larva do not bear any structural resemblance to the orthonectid sexual adult and the infusiform larva. Also the miracidium comes from a fertilized egg, while the influsiform larva from an agamete.

4. **Affinities with Echiuroides.** Lameere (1922) asserts in vain that the Mesozoa arc degenerate Echiuroidea. He mentions similarity in the occurrence of small ciliated males in the echiuroid Bonellia and the like position of the female genital opening in echiuroids and orthonectids.

5. **Conclusion.** It is clear that the Mesozoa are unlike the typical Metazoa. They have no internal digestive tract and their two-cell layers are not comparable with the ectoderm and endoderm of typical metazoan animals, for the inner layer (often of one cell) is concerned with reproduction and not digestion. Taken at their face value they are of a grade of construction lower than that of coelenterates. Hence they have been placed in an isolated position between Protozoa and Porifera. The name Mesozoa implies they are intermediate between the protozoa and Metazoa.

8.4.2 GASTROTRICHA

The gastrotrichs are common microscopic aquatic animals supposed to be Infusoria by O.F. Muller (1785) and rotifers by Ehrenberg (1838) who also coined the names

Chaetonnt and Iehthydium for some common freshwater forms. Schultze (1853) gave the name Ichthydina to the then known gestrotrichs. Metschnikoff (1864) proposed the name Gastrotricha and placed them with rotifers under a common class. Ludwig (1875) considered them to be intermediate between retifers and nematodes. Butschli (1876) suggested the union of gastrotrichs and echinoderids under the name Nematorhyncha. Zelinka (1889) added much to our knowledge of the group and combined rotifera and gastrotrichs under the phylum Trochelminthes which still continues in some textbooks with addition of the echinoderids. The modern knowledge and classification of the Gastrotricha is due to Ramane. Other valuable contributors are de Beauchamp and Stokes.

HABITS AND HABITAT

Habits and habitat: The gastrotrichs are a small group of minute freshwater as well as marine animals, often abundant among algae and aquatic debris. Benthonic in habitat, they usually occur in the bottom waters, creeping or swimming by means of their cilia or performing leech- like leaping movements among the protozoans, rotifers and plants, which form the populations of such habitats. Pelagic forms are unknown. They feed on minute animals and plant, which are ingested by the sucking movement of pharynx.

Shape and size. These minutes but multicellular organisms resemble some ciliate protozoans in habits and size. But, more typically, they have the same general habits, size, and structural details as rotifers, with which they are sometimes confused. The body is unsegmented, worm-like, elongate and cylindrical, more or less spindle-like, usually ventrally flattened and dorsally convex and measuring from 0.06 mm to 1.5 mm in length.

Coloration. The gastrotrichs are transparent and colourless but the ingested food imparts colour to the digestive tract.

External features. The body is indistinctly divided into head, neck, and thorax. The haed is usually demarcated as a rounded lobe from the rest of the body by a constricted neck. It contains the ventral or sub-terminal mouth and usually bears one or two pairs of lateral eye spots and one or two pairs of sensory and locomotory tufts of cilia or bristles surrounding the mouth. Occasionally, one or two pairs of tentacles or papps may be present. The posterior end of the trunk is generally forked but may be pointed

(Macrodasys), rounded, truncate (Hemidasys) or even drawn out in a slender tail (Urodasys). Highly characterstic structures are the cement glands or adhesive tubules, numbering 2 to 250, opening either at the tips of the forked tail or along the side of the trunk and head. The adhesive secretion of these glands is employed for adhering temporarily to the substratum, as in rotifers.

Locomotion. Small cilia occur on the head. Locomotory cilia are present on the ventral surface, arranged in one or two longitudinal bands or in transverse bands or in localized patches. In some forms they become fused to form cirri for jumping as in hypotrichous ciliates. Dorsal and lateral sides of the body are either naked or covered by imbricate scalesof the body are either nacked or covered by imbricated scales, spines or bristles.

Body wall. The surface cuticle is thin and usually forms scales, spines or bristles. The hypodermis or epidermis is syncytial. Continuous two six pairs of unstriated longitudinal muscles traverse the body.

Body cavity. The body cavity is a pseudocoel, without any special lining and containing a fluid without amoeboid cells. The pseudocoel is narrow and may be divided by membrances into a central and two lateral compartments containing the gut and gonads, repectively.

Digestive system. The alimentary canal is a straight tube. The anterior or slightly ventral mouth may be bordered by numerous small curved hooks or bristles. It leads into a long, muscular pharynx lined by cuticle, which has a triradiate lumen and is remarkably similar similar to that of the nematodes in the orientation of its angle and histology, etc. the pharynx may contain one to four bulbous swellings. It projects behind into the midgut as pharyngeal plug. The midgut wall is made of a single layer of epithelial cells. The wider anterior stomach is not clearly demarcated from the narrow posterior intestine. The latter is separated by a sphincter or constriction from a posterior rectum, which opens to the outside by mid-dorsal anus at the hinder end, usually provided by a sphinecter. Unicellular glands occur in the wall of midgut and their secretions digest bacteria, diatoms, protozoans and other minute organisms sucked in by the pharynx. Little is known about gastrotrich digestion. It probably occurs in the midgut extracellularly.

Nervous system:A large saddle-shaped or bilobed cerebral ganglion, or brain, lies antero-dorsally in head, giving off a pair of ventro-lateral longitudinal nerves posteriorly, and fibers to muscles and sensory, bristles, anteriorly.

Reproduction system: The marine species are usually hermaphroditic, mostly protandric. In freshwater species only pathenogenetic females as known. The gonads may be single or paired and situated in the pseudocoel and produces 1 to 5 large oval eggs, sometimes about one-half of the length of the body. Each egg is enclosed in a tough shell. The connections of ovary, oviduct and uterus are not clear. The female gonopore opens ventrally anterior to or in common with the anus. Seminal vesicle and a copulatory bursa may br present or absent. Some eggs are provided with hooks for attachment with objects or substratum.

The male reproduction system includes a single or a pair of testes, from each of which a sperm duct runs either posteriorly or anteriorly. The male gonopores open in variable position, near or anterior to or in common with the female pore.

Development: Development is directly with no larva or metamorphosis; development is directly with no larva or metamorphosis. Cleavage is holoblastic, spiral and determinate. The young individual hatch as miniatures of adults.

Distinctive characters of Gastrotricha.

1. Minute aquatic mostly freshwater, metazoan animals.

2. Body worm-like, unsegmented and without corona.

3. Locomotion performed by cilia variously arranged on the ventral surface.

4. Cuticle often forming dorsal scales, spines and bristles.

5. Hypodermis syncytial, with 2 to several adhesive tubules.

6. Muscles usually 6, delicate and longitudinal. Continuous muscles absent.

7. Body cavity is a pseudocoel, with no special lining.

8. Digestive tract straight with an anterior mouth, a posterior anus, a muscular pharynx of nematode type but without trophi, and with a midgut without diverticula.

9. Respiratory and circulatory organs lacking.

10. Excretion by two protonephridia each with a flame cell.

11. Nervous system consists of a large cerebral ganglion and two lateral cords.

12. Freshwater forms are with only parthenogenetic females, while marine forms are hermaphroditic. Eggs are large.

13. Development is direct and cleavage total.

Classification of Gastrotricha

About 200 species are known, grouped in two orders.

Order 1. Macrodasyoidea

1. Marine, mostly in sand.

2. Anus slightly ventral.

3. Adhesive tubules several along the body.

4. Protonephridia absent.

5. a pair of external lateral pharyngeal pores present.

6. Hermaphroditic.

Example: Cephalodasys, Macrodasys.

Order 2. Chaetonotoidea

1. Mostly freshwater, a few marines.

2. Anus slightly dorsal.

3. Adhesive tubules, present, one or two pairs at posterior end.

4. Protonephridia present.

5. Pharyngeal pores wanting.

6. Only parthenogenetic females occur.

Example : Chaetonotus, Depidoderms, Ichthydium.

Affinitiesof Gastrotricha

I. Affinities with Rotifera. The gastrotrichs are often treated as an appendix to the Rotifera. No doubt they are about the size of rotifers and usually occur with them in the same places. Some of the most important resemblances of the two groups are as follows

1. External ciliation of the body.

2. Syncytial integument and simple musculature.

3. Presence of protonephridia with flame cells.

4. The bifid foot containing cement glands.

5. Pharynx resembles the mastax of Rotifera even to minute histological details.

But detailed study shows that two groups are not closely related. The gastrotrichs differ from rotifers in their digestive system, lack of corona, cuticular spines and presence of adhesive tubes.

II. Affinities with Nematoda. The gastrotrichs differ from Rotifera but resemble Nematoda in the following characters:

1. Cuticular specialiazation, such as spines and bristles.

2. Adhesive tubules.

3. Lateral sense organs of head correspond to amphids of nematodes.

4. Shape and relation of brain are similar.

On the other hand, gastrotrichs differ from the nematodes particularly in possessing cilia.

III. **Conclusion.** Gastrotrichs show greater affinities with nematodes than with any other invertebrate group. Both the groups, along with Rotifera, seem to have a remote turbellarian ancestor

8.4.3 CTENOPHORA

The phylum ctenophore includes a small group of free swimming or, planktonic marine animal with transparent, delicate, gelatinous bodies. They generally resemble the eoelenterates and are often grouped with them in some classification. They are among the most beautiful of all creatures. Their transparent bodies glisten like fine glass, brilliantly iridescent during the day and luminescent at night. They are even more nearly transparent than the coelenterate jelly-fish and are often termed the comb-jellies, sea-walnuts, sea-gooseberries, or etenophores. They are extensively used in various experimental works, but they have no direct economic value.

Derivation of name

The name Ctenophora (Gr., ktenos, comb; phoros, bearing) first coined by Eschscholtz in 1929, means "comb-bearers". It refers to the locomotory comb-like plates plates on the body. They are commonly called sea walnuts because of their shape; and comb jellies because of comb-like locomotor organs characteristic of the phylum.

Definition

The Ctenophora are marine, pelagic or free, solitary and biradially symmetrical Radiata, with transparent gelatinous bodies; notreducible to either polyp or medusa type; without nematocysts but having special lasso cells; and with characteristic eight locomotory, meridional comb-like, ciliary plates.

Habits and habitat

Ctenophores are very common marine animals often occurring in enormous groups. They are widely distributed, being especially abundant in the warmer seas, though some occur in temperate or arctic regions. They are of planktonic habit, floating in the surface water, mostly near shores, but a few live up to a depth of even 3000 meters, leading a benthonic or creeping existence. They rest vertically in the water and are propelled but feebly by the rhythmic water-like movements of the paddle plates. Being feeble swimmers, they are carried about by currents and tides, often accumulating in vast numbers.

Ctenophores are noted for their delicacy, beauty and luminescence. When seen in sunlight their vibrating comb-plates, refracting the light, show a rapid play of changing colours, giving the effect of successive series of rainbow colours. Many are highly phosphorescent in the dark and glow like electric light bulbs at night. Production of light occurs in the walls of the meridional canals, but externally, the comb-plates appear to emanate light.

Ctenophores are voracious carnivores feeding on plankton. They feed on small marine animal including the eggs and larvae of molluscs, crustaceans and fish .as the animal swims, the tentacles, trailing behind the body, capture the food that comes in contact with them.

External features

The general plan of body resembles that of a coelenterate medusa.

Shape. A typical ctenophore, such as Pleurobrachla, is somewhat spherical, pear shaped or cylindrical in shape. They are commonly termed gooseberries or sea-walnuts because of their shapes. The outer surface is without hard skeletal parts. The spherical body can be divided into two hemispheres. The mouth lies at one end or pole (oral) and a sense organ at the opposite end or pole (aboral) of the body.

Symmetry. A ctenophore is said to possess biradial symmetry. The parts of the body are radially disposed but lie half on one side and half on the other side of a median longitudinal plane or oral-aboral axis. Thus, structures are tetramerously arranged in a radial fashion around the oral –aboral axis.

Size: Ctenophores are of moderate size ranging from a few millimetres to 20 cm but a few species of Cestus reach up to 125 cm in length.

Colour: Ctenophores are usually transparent, but various structures such as the tentacles and the comb rows are tinged with white, orange or purple.

Comb-plates: The ctenphore swims about in the water with help of 8 equally spaced rows of paddle plates arranged on the side of the body like meridian from pole on a globe, thus further dividing the body into 8 equal sections. Each paddle plate is a slight ridge composed of a transverse band of long fused cilia. When viewed from side, the paddle plates appear like the teeth of a comb, so that they are termed the comb-jellies.

The rows of comb-plates from roughened ridges, similar to those on a walnut, hence the other common name sea-walnuts, for the ctenophores. The comb rows may be various tinged with white, orange or purple.

Locomotion: The planktonic ctenophores are feeble swimmers. The cilia of the comb rows beat in a wave-like action beginning at the aboral end. The effective sweep of each comb is toward the aboral pole, so that the animal is propelled with the mouth or oral pole forward or upward. The ciliary beat can be temporarily reversed on meeting obstacles. The animal can right itself when titled by water currents. The ciliary waves are synchronized and coordinated by the nervous system and the apical organ.

Tentacles: Nearer the aboral end, on opposite sides of the body are two extremely long, solid and retractile tentacles. However, some species are without tentacles. They are not attached to the body surface, as in the coelenterates, but each tentacle emerges from a deep ciliated epidermal blind pouch or tentacular sheath, into which it can be wholly or partially withdrawn. Each tentacle bears a single row of short lateral branches or pinnae. The tentacles are highly contractile, each made of a solid mesenchymal core covered with epidermis.

Colloblasts: Nematocysts are absent; instead, the tentacles are armed with peculiar glue-secreting adhesive cells, called lasso cells or colloblasts. (Gr, kola, glue; blastos, germ), typical of the phylum. They correspond to the nematocysts of coelenterates in capture of prey, but are quite different structures;A colloblast is a modified epidermal cell. It has a hemispherical head, situated on the surface of the epidermis, and connected to the core of the tentacle by a stiff, non-elastic straight filament which was originally the nucleus of the cell.

An elastic, spring-like spiral filament is coiled around the straight filament. The surface of the head is covered with secretory granules that produce an adhesive material to entangle and kill small organisms which are then conveyed to the mouth.

The colloblasts cannot sting as they the mechanism for penetration. The colloblasts are absent in at least one ctenophore, Euclora rubra, which, however, posseses the nematocysts, thus pointing to a common origin of Ctenophora with the Coelenterata in the distance past.

Sensory organ: An outstanding anatomical peculiarity of the ctenophores is the apical sensory organ. It consists of a deep pit or depression, the statocyst at the aboral pole. It is lined by tall, ciliated epithelial cells. The cavity of the statocyst contains a tiny rounded mass of calcareous particles, the statolith (Gr., statos, standing; lithos, stone), which is supported by four tufts of long, stout and fused cilia, the balancers. The statocyst is covered by a roof, like a dome or bell, formed of fused cilia. Eight ciliated grooves or furrows lead out from the sense organ to the eight rows of comb-plates. Two furrows extend from each balancer to the comb-rows of that quadrant of the animal. Two ciliated tracts or polar fields extend outwards, in the sagittal plane; from two opposite sides of the statocyst. A strong sphincter, surrounding the sense organ, serves to close off the statocyst.

The sensory organ serves as an organ of equilibrium. If the body is inclined, the statolith presses more heavily the ciliary tuft of the inclined side and the stimulus is carried by the ciliated furrow to the comb-plates which beat faster, thus righting the animal. If a ciliated furrow is severed, the beating of the corresponding comb row becomes independent and no longer coordinated with that of the other rows.

Economic importance: The ctenophores are of no direct economic importance to man except that they may consume large number of oyster larvae at spawning time. Like jelly-fish, the ctenophores, are eaten by many marine animals. They serve as food even for such large animal as whales. The ctenophores have been used in various experimental works in the phylogeny of animal and their divergence from the coelenterates, the other great phylum of the division Radiate.

Distinctive characters

(1) Exclusively marine, solitary, free-swimming or pelagic, without colony-formation, very active, carnivorous and often phosphorescent, multi-cellular animal of tissue grade organization.
(2) Body soft, delicate, transparent and gelatinous, like coelenterate jelly-fishes, without segmentation, head or tail regions.
(3) From typically spherical, pear-shaped or cylindrical, flat in some.
(4) Symmetry definitely biradial (radial+ bilateral) along an oral-abroal axis.
(5) Body acoelomate but triploblastic, with-developed mesoderm including muscles and connective cells.

(6) Most characterstic feature is the presence on the surface of eight meridional rows of comb-like ciliary plates or ctenes, forming locomotor organs; hence the common name comb-jellies.
(7) Generally, a pair of long, solid and retractile tentacles present, projection from blind pouches in opposite sides of the body.
(8) Nematocysts are absent but the tentacles bear special adhesive cells, called lasso cells or colloblasts, which help in food capture.
(9) Skeletal, excretory, circulatory and respiratory systems are absent.

(10).The mouth, lying at one end, leads into a large ectodermal stomodaeum connected with a series of endodermal gastrovascular canals and two aboral anal pores.

(11) Nervous system is diffuse and the aboral end bears a sensory organ of equilibrium, the statoeyst.
(12). All are hermaphroditic, Testes and ovaries formed side by side from endoderm of gastrovascular canals.
(13). Development usually includes a complex metamorphosis with a characteristic cydippid larva, but there is no asexual reproduction and alternation of generations; monomorphic.
(14). Regeneration and paedogenesis are common. Asexual reproduction does not occur.
Classification : The phylum Ctenophora contain about 100 species grouped in two classes, as follow:

Class 1. Tentaculata (L., tentaculum, feeler)

Adult with two aboral tentacles. In certain cases, only the larva tentacles, while the adult has oral lobes.

Order 1. Cydippida

(1) Body simple, rounded or oval.
(2) Tentacles long, branched and retractile into sheaths.
(3) Ends of digestive canals blind.
Example: Cydippr, pleurobrachia, Hormiphora.

Order 2. Lobata

(1) Body laterally compresses and ovate.
(2) Adult with reduce tentacles without sheaths. Two large oral lobes and four slender flaplike ciliated auricles surrounding mouth.
(3) Ends of digestive canals anastomosed.
Examples: Mnemlopsis, bolinopsis.

Order 3. Cestida

(1) Body elongated and compressed in tentacular plane, ribbon-like.
(2) Two main tentacles reduced, with deep sheaths many small, simple tentacles along oral edge.
(3) Four rows of comb-plates rudimentary.
Example: Cestus, Velamen

Order 4. Platyctenea

(1) Body greatly flattened, compressed in oral-aboral plane.
(2) Two well-developed primary tentacles with sheaths.
(3) Comb plates only in larva.
(4) Creeping, aberrant ctenophores.
Example: Ctenoplana, Coeloplana, Vallicula, Gastrodes.

Class 2.Nuda. Body large, conical or thimble-shaped and compressed in lateral plane. Tentacles and oral lobes absent even in larval stages. Mouth wide and pharynx large, voracious.

Order 5.Beroida. : Characters same as in the class.

Example: Beroe.

Affinities

The ephemeral (short-lived) nature of ctenophores remained a handicap in their fossilization. In the absence of their fossils, their origin remains obscure.

[I] Affinities with Coelenterata

Ever since the time of Escboltz (1829-1833), ctenophores have been regarded as a class of the phylum Coelenterata. Some writers still continue to group them as subphylum Acnidaria together with the subphylum Cnidar in the phylum Coelenterata.

1. **Resemblance with Coelenterata** Ctenophores are believed to be an offshoot from the ancestral medusoid coelenterate. No doubt, they resemble the coelenterates in several characters, such as:

(1) Biradial (tetramerous) symmetry and tentacles. With Coelenterata, they form the group Radiata.
(2) Arrangement of parts along an oral-aboral axis.
(3) A well developed gelatinous ectomesodern (collenchyma).
(4) Absence of coelom or other internal spaces except the digestive cavity.
(5) General lack of organ systems. Only tissue grade of organization.
(6) Endodermal gastrovascular cavity with branches.
(7) A single aperture or mouth leads from the gastrovascular cavity to the outside.
(8) Diffuse nerve plexus.
(9) Presence of statocys.

(10). Endodermal origin of gonads.

(11) Absence of nephridia.

(12). Presence of lasso cells similar to the nematoblasts of the coelenterates. Existence of nematoblasts on a ctenophore (Euchlora rubra) is additional evidence of the coelenterate origin of the Ctenophora.

(13) No excretory, respiratory and circulatory system present. On account of these similarities, they are considered by many zoologists to be a class of Coelenterata.

2. Differences from Coelenterata. Although ctenophores remain at the tissue grade of organization, they show greater development of tissue patterns than the coelenterates. They differ from the coelenterates in the following advancements:

(1). Oppositely placed tentacles and gastrovascular canals suggest a pronounced biradial symmetry.

(2). Presence of 8 locomotory meridional ciliated bands of comb plates over the body.

(3). Absence of nematocysts. Instead, presence of special adhesive and sensory cells, the colloblasts, over the tentacles.

(4). Presence of an aboral sense organ for equilibrium and coordination.

(5). With the development of a cellular mesoderm, the ctenophores are definitely triploblastic.

(6). No epithelia-muscular fibres; the muscles cells are entirely mesodermal and muscle fibres gathered into bundles.

(7). Complicated branched gastrovascular cavity with anal pores is more definitely organized.

(8). Cleavage of the egg is determinate.

(9). Endoderm is formed by the invagination of the blastula.

(10). There is no planula, but a higher form of larva, the cydipped, which develops directly into the adult.

(11). The poly stage, so characteristic of Cnidaria, does not occur.

(12). Polymorphism and colony-formation so common in coelenterates, are not found in ctenophores.

3. Resemblance with Hydrozoa. Attempts have been made to demonstrate affinities of Ctenophora with Hydrozoa. An anthomedusan form, Ctenaria, presents remarkable similarities with a cydipped, such as Hormiphora, in the following characters:

(1) The general body surface of a ctenophore corresponds with the ex-cumbrellar surface of a medusa.

(2) The general body surface of a ctenophore corresponds with the ex-cumbrellar surface of a medusa.

(3) Both possess a thick, gelatinous mesoglea.

(4) Presence of a simple gastrovascular cavity.

(5) Presence of two opposite tentacles in sheath.

(6) Eight radical canals given off from stomach, and corresponding with them are eight bands of nematocysts diverging from the apex of ex-umbrella.

But these similarities are superficial and Haeckel's claim, that Ctenaria represents a form directly intermediate between the Hydrozoa and the Ctenophora, seems to be untenable due to the following objections:

(1) The tentacles of Ctenaria have no muscular base.

(2) Eight rows of nematocysts of Ctenaria are not homologous to rows of comb-plates of a ctenophore.

(3) Ctenaria is radially symmetrical, whereas a ctenophore is biradially symmetrical.

(4) No trace of aboral sense organ in Ctenaria.

A narcomedusan, Hydroctena, also present some striking, though superficial ctenophoran

Resemblance, in the possession of an aboral sense organ and a pair of opposite tentacles in sheaths.

4. Resemblance with Anthozoa. The ctenophores also present certain characteristics.

(1) Ciliated ectoderm of Anthozoa is probably a forerunner of the ciliated band of ctenophore.

(2) Presence of a well-developed stomodaeum.

(3) Gonads develop in connection with gastrodermis and sexual elements passed out through the mouth.

(4) The gut in embryos of both is 4-lobed, thus presenting biradial symmetry.

(5) Mesogloea is cellular, hence triploblastic animals.

But the aboral sense organ and rows of comb-plates of a ctenophore have no parallel parts in an anthozoan, lasso cells differ structurally from the nematocysts, and the tentacles are hollow in an anthozoan while solid in the ctenophore.

[ii] Affinities with Platyhelminthes

The following resemblances between the Platyctenea ctenophore (Coeloplana and Ctenoplana) and the polyclad turbellarians are of considerable importance:

(1) Dorso-ventrally flattened body.

(2) Crawling mode of life.

(3) Ciliation of epidermis.

(4) lobed gastrovascular cavity, especially in the embryos.

(5) Similar earlier stages of segmentation and gastrulation.

(6) Gelatinous mesenchyme with muscle fibre and cells.

On account of these similarities, Ctenoplana and Coeloplana have been considered the "missing link" between Coelenterata and Platyhelminthes. This view is no more supported because Ctenoplana and Coeloplana are now considered typical; ctenophores adapted for the creeping mode of life. Moreover, the Acorla, and not Polyelada, are now considered more primitive amoung the flatworms. But the Platyctenca are more similar to Polyclada than to acorla, so that the suggested line of ascent, ctenophores-Platyctenca-Polyclada, becomes untenable.

8.4.4 RHYNCHOCOELA

The animal belonging to phylum Nemertea or Nemertinea or Rhynchocoela are commonly known as the ribbon warms or bootlace worms or proboscis worms. They are the highest acoelomate bilateral animals, having a solid construction without coelomic spaces between the organ systems. They possess some structural advances over the flatworms. They are the simplest animal to have a blood vascular system and a complete digestive system with anus but, they are a small group not usually seen by visitors to the seacoast. They have no economics or medical importance. They are not used by man as food or for any other purpose.

General account

Habits and habitat. Nemerteans are found more in temperate climate than in tropical and subtropical regions. They are mostly marine, non-parasitic and free-living, common along seasbores coiled up under stones in semi-permanent burrows lined with mucus or even distinct tubes in the mud or sand, and among the seaweeds, some inhabit deeper water, some are pelagic, while one genus occurs in freshwater (Prostoma) and one genus in moist earth (Geonemertes). Malacobdella and a few other live commensally in the mantle cavity of marine pelecypods, while some others are found as commensals in ascidians Parasitic forms are unknown.

Locomotion occurs by cilia, which cover the surface of the body, by gliding over the substratum on a trial of slime, by contrictions of the body muscles, or by using the proboscis for attachment. Most of them seem to be carnivorous feeding on smaller annelids, molluscs, crustaceans, etc., both dead and alive. They secrete a great deal of mucous tube. The body is extraordinarily extensile, soft and liable to break into pieces. Consequently, they possess great powers of regeneration and fragmentation (autotomy) or a ability to break body into pieces.

Colouration: The outer body surface is often brightly and contrastingly coloured. They are variously coloured with red, brown, yellow, green, white and some bearing stripes or cross-bands. A few pelagic forms are even transparent. The colours tend to resemble those of the surroundings

Shape: The body is filiform, elongated, vermiform, cylindrical or dorsoventrally tlattened, unsegmented, bilaterally symmetrical and without appendages.

Size: The nemerteans shows a greater diversity of size than in any other "worms" ranging from 5 mm (Pelagonemertes) to about 30 meters (Lineus longissimus) the body is soft and highly extensile. A worm 1 meter long at rest may stretch to 3 meters and assumed almost hair-like thinness.

External feature: The distinct head is absent. Anterior end is pointed and posterior end tapers at one point. Body is unsegmented but internal parts display pseudometamerism. Anterior end forms ceohalic lobe having cephalic eyes and cephalic grooves and is unarmed. Cephalic lobe contains 2 to a few hundred eyes which are arranged laterally. There is a small proboscis pore situated at the anterior extremity above the mouth, through which the soft proboscis may be protruded. Mouth lies immediately behind the brain and in unarmed forms it lies ventrally or it may form a common aperture with proboscis pore. Posterior body end may be provided with a tail-like caudal cirrus with anus at its base.

Body cavity: The coelom is absent Spaces between the gut and the body wall are occupied by a gelatinous mesenchyme. However, a reduced and fluid-filled coelomic space is present; the rhynchocoel is mesodermal in origin and is lined by mesothelium. It represents a true coelom.

Digestive system: The mouth is situated ventrally near the anterior tip. The digestive tract is a ciliated tube, extending the whole length of the body. In majority of the cases, it is divided into foregut and mid-gut or intestine. foregut includes buccal chamber, oesophagus and glandular stomach. In some hoplonemertines, mouth is lost during development and oesophagus directly opens into the rhynchodaeum intestine may be a simple, unconstructed tube, or may be constricted at intervals by paired gonads forming two rows of lateral caeca or diverticula. Giving impression of pseudometamerism intestine open into the terminal anus lying at the hinder end of the body.

Classification

Phylum Nemertinea is represented by nearly 700 species, grouped in 2 classes and 4 orders, as follows:

Class I. Anopla (Gr, anoplos, unarmed)

(1) Proboscis is unarmed.

(2) Mouth posterior to brain.

(3) Muscular layer of inner and outer longitudinal and middle circular fibers.

(4) Intestinal pouches absent or rudimentary.

(5). Ventral nervous system situated among the muscle layers or just below the epidermis

Order 1. Palaeonemertini

1. Body wall muscles of two or three layers.

2. Innermost muscle layer circular.

3. Dermis gelatinous, poorly developed.

4. Eyes usually absent.

Example: Tubulanus, Cephalothrix, Carinoma.

Order 2. Heteronemertini

1. Musculature of body wall three-layered.

2. Innermost muscles layer longitudinal.

3. Dermis fibrous, well developed.

4. Eyes usually present.

Examples: lineus, Micrura, Cerebratulus.

Class II. Enopla (Gr., enoplos, armed)

1. Proboscis often armed with stylets.

2. Mouth anterior anterior to or below the brain.

3. Muscular layer of outer circular and inner longitudinal fibres.

4.Eyes usually present.

Example: Lineus, Micrura, Cerebratulus.

Class II. Enopla (Gr., enoplos, armed)

1. Proboscis often armed with stylets.

2. Mouth anterior to or below the brain.

3. Muscular layer of outer circular and inner longitudinal fibres.

4. Intestinal caeca present.

5. Central nervous system internal to body muscles. No nerve plexus.

Order 3.Hoplonemertini.

1. Proboscis armed.

2. Intestine straight with paired lateral diverticula.

3. Mouth in front of brain.

Example: Prostoma, Paranemertes, Geonemertes, Amphiporous.

Order 4. Bdellonemertini

1. Proboscis unarmed.

2. Intestine sinuous without diverticula.

3. Parasitic having a posterior adhesive or sucking disc.

Example: Malacobdella.

Affinities

The nemerteans hold no definite position in the animal kingdom. They belong to the acoelomate Balateria and Protostomia. They show affinities with vertebrates, lower chordates and the Platyhelminthes.

1. Affinities with verbrates. Nemerteans are considered to be the ancestral forms of vertebrates due to the following homologies:

1. The proboscis sheath suggests the notochord of vertebrates.

2. Red blood cells, generally considered characteristics of vertebrates, present. Invertebrates such as earthworms also have haemoglobin, but it is dissolved in the blood fluid rather than being present in blood cells.

3. The median dorsal nerve is supposed to indicate the spinal cord of the vertebrates.

4. Lateral nerves represent the nerves of lateral lines of fishes.

5. The cerebral ganglion corresponding to a vertebrate brain.

2. Affinities with lower chordates. Nemerteans have several characters in common with a typical lower chordate, such as Balanoglossus.

1. Vermiform, elongated body.

2. No external metamerism.

3. Skin smooth, containing unicellular glands.

4. Ectodernal nerve plexes.

5. Terminal anus.

6. Metamerically arranged simple gonads.

7. Retactile proboscis of nemerteans is equivalent to the non-retractile proboscis of balanoglossus.

3. Affinities with Platyhelminthes. Nemertinea are often placed near or with the Platyhelminthes. Phylogenetically, they appear to be an offshoot from the free-living flatworms. They are supposed to be related to the turbellaria and were include previously in that class.

(a) Resemblance. The following resemblances are found in both the groups:

1. Body is flat, ribbon or tape-like, contractile, bilaterally symmetrical and without external segmentation.

2. Body is covered completely with a ciliated epidermis containing glands cells.

3. Beneath the integument are thick and highly contractile muscles.

4. The spaces between the gut and the body wall is filled with a solid mass of mesenchyme. True coelom is absent.

5. Like Muller's larva or adult flatworms, pilidium larava of marine nemerteans is ciliated, has a ventral mouth but no anus.

6. Respiration system is absent.

7. Excretory system consists of excretory tubules with flame cells.

8. Nervous system is similar to that of flatworms, Longitudinal nerve cords run the length of the worm each side.

9. Proboscis apparatus is equivalent to proboscis of Kalptorhynchus, a rhabdocoel.

10. Rhabdites are present in the proboscis wall of some nemerteans, indicating a flatworm origin for them.

11. Ocelli, front glands, pits cerebral organs, etc., may be derivatives of corresponding structures present in flatworms.

12. Three primary germinal layer and cephalization.

8.4.5 ROTIFERA

The rotifers are very common and abundant freshwater animals, commonly designated as the “wheel animalcules”. Generally speaking, they are the smallest animal amongst the Metazoa. The transparency of their body reveals the internal organs clearly: they can be seen functioning in living specimens.

Definition

Usually microscopic, unsegmented, bilaterally symmetrical, free-living aquatic animal; typically having a ciliary apparatus called corona at the anterior end for locomotion and food collection; with a muscular pharynx containing movable jaws ; with typical flame-bulb nephridia opening into the cloaca ; dioecious, sexually dimorphic and without specialized circulatory and respiratory systems.

Ecology

The rotifers are cosmopolitan as their eggs are easily distributed by the wind and the animals. The same species may occur in similar environment in America, Africa, Eurasia and Australia. They are the most common inhabitants of fresh water, a few are marine, some found in damp moss but very rarely parasitic. Whenever a body of fresh water is examined for Protozoa, one is almost certain to find the rotifers. They have adopted a variety of habitats and ways of life. Thus, they may be free or fixed, solitary or colonial (e.g. Conochilus), creeping or swimming or pelagic, epizoic or parasitic, and carnivores or bacteria-feeders. They are ecologically divided into three groups:

(a) Alkaline fauna Found in hard water. Eggs of amictic females can tolerate alkaline conditions.

(b) Acid fauna Found in soft water. Eggs produced by mictic females can withstand acidic conditions.

(c) Transcursion fauna. Some forms produce dormant eggs which can tolerate both alkaline and acidic conditions.

Rotifers move either by creeping on the bottom in a leech-like manner aided by foot, or by active swimming by the beating cilia of the corona. They feed on unicellular algae, other microscopic organisms and particles which are caught in the whirlpool made by the lashing cilia. In turn, they may serve as food worms, crustaceans, eventually through fish for man, thus becoming an important part of the freshwater food-chains, especially in ponds and lake.

Incapable of regeneration they are very tenacious of life and can withstand drying even for years. They undergo desiccation becoming shrivelled and wrinkled and reduced much in volume. Generally, there is no secretion of a protective cyst. Resistance to low temperatures and lack of moisture in the desiccated condition is remarkable. The creature survives in such a dormant state for 3 to 4 years. Upon the advent of water, the dried creatures swell, unfold, resume normal activities and start reproduction. The capacity to resist drought has made it possible for them to live in place which are only temporarily damp, such as roof gutters, cemetery urns, rock crevices, and similar other the contained eggs may survive until moisture returns. Their small size and resistance to drought facilitate their dispersal by wind and birds, resulting in a more cosmopolitan distribution, than shown by any other group of animals.

General morphology

Colouration: Usually they are transparent and colourless. The enclosing cuticle may impart a slight yellowish colour. The rotifers of Alpine and polar regions may show brown, red and orange colours usually localized in their digestive tracts.

Shape and size: The rotifers are small aquatic creatures many of them not larger than protozoans. Many species are much smaller than amoeba and may be engulfed by it. Superficially they resemble the ciliates, with which they were classed by earlier workers. They range from 0.04 to 3 mm, in length. In spite of their minute size, they are true metazoan with an enteric canal, nephridia, gonads, ganglia and sense organs etc. the body is bilaterally symmetrical but extremely variable in shape. it may be slender and worm-like (Rotaria), broad (Polychaetus), flattened sacciform (Asplanchna), or even spherical (Trochosphaera). More typically it is of elongated form (Epiphanes), Microscopic in size and of no direct importance to man, these abundant animals are little knows except to zoologists and amateur microscopists, who are fascinated by their active movement, bright colours, fantastic shapes and interesting habits.

External features: The elongated or saccular body of a typical rotifer is divisible into three regions an anterior head, a middle trunk and a posterior foot.

(a) Head: The blunt anterior end of the body is not distinctly delimited as head. It may be narrow or lobed but it is typically broad and truncate. The head consists chiefly of a characteristic retractile ciliary crown or disc called the corona or trochal disc, with a central unciliated apical field. The distribution of crown cilia varies in different rotifers. In some cases (e.g. Epiphanes), the corona is surrounded by a double ciliated ring, the velum, made of an outer ciliary band or cingulum, and an inner ciliary band or trochus. Frequently, certain cilia become modified to form cirri, membranelles or bristles. In the common type of crown (e.g. Philodina), the cilia are arranged in two lobes or discs. Their cilia beat in a circular manner, one clockwise and the other anticlockwise, and look like wheels spinning, hence the name 'Rotifera'. The beating of cilia helps in locomotion, in drawing water currents containing oxygen and food towards mouth, and in carrying off wastes.

The trochal disc is the most characteristic organ of the rotifers, which have often been called Trochelminthes (G., trochos, wheel; helminthos, worm).

(b) Trunk: The trunk is the middle, elongated region containing the chief visceral organ. It may be cylindrical or various flattened and broadened. It is generally surrounded by a shell-like transparent, flexible, cuticular covering, into sections that can be telescoped one into the other when the animal contracts.

(c) Foot: The post-anal or terminal, gradually tapering region of the body forms the tail or foot. Its cuticle is sometimes ringed. It may be long or short and terminates either in an adhesive disc or in one-to-four-pointed, movable finger-like projections, the toes. The foot contains cement or pedal glands, the duct of which open at the tips of the toes. The mucilaginous or viscous secretion of these glands serves to anchor the animal temporarily during feeding or constructs vase-like cases in sessile rotifers. Besides being a clinging organ, the foot also serves for locomotion.

Body wall: It consists of cuticle, hypodermis or epidermis and sub-epidermal muscles. The protective noncellular and thin cuticle, secreted by the hypodermis, consists of scleroproteins. In some species it forms a rigid shell or lorica around the trunk. It may be various sculptured or ornamented. The cuticle may be ringed or annulated to permit telescoping the body. The hypodermis is a thin syncylium containing a constant number of scattered nuclei. Epidermal glands are rare. The duct of a retrocerebral organ, lying near the brain, open on the apical filed; while those of pedal glands, located in the foot, open on the tips of the toes. Definite or continuous muscles are absent. There are several bands of unstriped muscles passing from lorica to trochal and tail and serving as retractors for them.

Pseudocoel: The spacious cavity, between the body wall and the gut, is a pseudocoel derived from the embryonic blastocoel. It is without an epithelial lining. It is filled with fluid containing a loose syncytial mass of amoeboid cells, presumably phagocytic and excretory in nature.

Digestive system: The food, consisting of Protozoa, other minute organisms and organic debris, is swept by ciliary action into the mouth, situated in the centre or near the ventral edge of corona. The mouth leads, by a short buccal cavity, into a rounded, elliptical or elongated and highly muscular pharynx or mastax. Which is an efficient chewing apparatus characteristic of rotifers alone. It is provided internally with hard chitinous teeth or jaws, called trophi, projecting into the lumen. The trophi consist of seven main pieces, six paired and one unpaired. In the median line is a forked structure, the incus consisting of a small, mid-ventral base, called fulcrum, bearing two antero dorsal branches, the rami. On either side of incus lies a hammer-shaped malleus, consisting of a handle like manubrium, embedded in the muscles, and a toothed claw or incus. The posterior pointed end of manubrium is known as cauda. Small pieces called subinci may be intercalated between unic and rami**.**

Excretory system: It consists of pair of laterals, convoluted excretory canals or protonephridia, one on each side of the alimentary canal, giving off irregular tag- like processes ending in two to eight flame cells. Anteriorly the canals connect by a transverse renal commissure called Huxley's anastomose, above the mouth. Posteriorly, they open into a common pulsating vesicle or urinary bladder, which contracts periodically to expel its fluid contents to the outside through the cloaca. In some freshwater species, the bladder eliminates a bulk of fluid equal to that of the animal about every 13 minutes. Such a high rate of discharge is evidence of the osmoregulatory function of the protonephridia. Water enters through the mouth by swallowing rather than penetration of the body wall. Respiration takes place through the general body surface.;

Nervous system The brain consist of a bilobed suprapharyngeal ganglion, situated above the mastax in head. Various nerves radiate from the brain to various organ and sensory centres of the body. The great activity of rotifers indicates that the nervous system is well-coordinated with the musculature.

Sense organ: Sense organ includes bristles, membranelles, styles or feelers, ciliated pits, papillae, antennae and eyes spots. The antero-middorsal antenna (someties two), just behind the trochal disc, and the lateral antennae, one on each side of the trunk, are small, cylindrical and finger like processes tipped with stiff, sensory tufts. Dorsal eye spots or ocelli containing red pigment occur. These may be 1 to 3 or may be entirely absent. A retrocerebral organ of unknown function, present inside head, is regarded homologous to the frontal organ of flatworms, by Hyman.

Reproduction

Reproduction is sexual,the sexes are separate with a well-marked sexual dimorphism. The reproduction organs are simple.

The males are usually smaller than females and often degenerate, without digestive organs. They are seldom seen, partly perhaps because of their brief existence and partly because few are produced. They die after mating. They may be totally absent in some cases. The greater part of their body cavity contains a large, sacciform testis, which opens by a ciliated sperm duct either dorsally in prostatic glands open into the sperm duct.

The female are most common, numerous and normal individuals. Each contains a single, bulky syncytial ovary below the stomach. It is divided into a small ovary proper or germarium, and a large yolk gland or vitcllarium, which supplies the eggs with yolk. A short oviduct leads from the ovary into the cloaca.

Life history: Fertilization is internal. It is preceded by a hypodermic impregnation in which the male stabs the female on any part of her body with is penis, so that the sperms are injected through her body wall into the pseudocoel. Two types of sperms are produced; one type serves for fertilization, the other type for penetration. In a very few rotifers copulation may occur by the insertion of the copulatory, apparatus into the cloaca.

The life cycle in rotifers is related to seasons. Eggs are laid on the substratum or glued to the body of the female or other animals. In the order Seisonida, all eggs require to be fertilized and hatch as either male or female. In the order Bdelloida the males are unknown, and the eggs develop pathenogenetically inro females. In the order Monogonontida, two kinds of females occur without external distinction:

(a) Amicitic females: During most of the year the amictic females produce large, thin-walled and diploid eggs, referred to as amictic, parthenogenetic or summer eggs. They are incapable of being fertilized and develop into females. Many such generations of females are produced.

(b) Mictic females: Later in the year, as the sexual season approaches, some of the females lay mictic eggs which are small, thin-walked, haploid and capable of being fertilized. If not fertilized, they develop parthenogenetically into males. If fertilized they become thick-walled and diploid and called the dormant, resting or winter eggs, which can survive unfavourable conditions, such as drought and cold, etc. after remaining quiescent during winter, they finally hatch during spring, into amictic females, whose progeny may be amictic as well as mictic females. The word “mictic”, derived from Greek miktos, means mixed. It refers to the fact that mictic female produces both unfertilized male-producing eggs, and fertilized female-producing eggs if males are available. Any given female is either mictic or amictic and cannot produce eggs of both kinds. The alternation between parthenogenetic and sexual reproduction is termed heterogonous, and is characteristic of the order monogonontida.

Development: Cleavage is spiral and determinate. Gastrulation is epibolic. Stomodaeum and proctodaeum are formed by ectodermal invaginations. The embryo develops into the adult stage without metamorphosis. Mostly oviparous, some rotifers (e.g., Philodina) are viviparous, the living young born by breaking through the parental body resulting in death of the parent.

Importance of Rotifera

The rotifers have a small size and reproduce rapidly, which makes them convenient for experimental studies by zoologists in the laboratories.

The abundance of rotifers may pose a problem in water filtration. But they also play a useful role in cleaning up pollotional and natural wastes. They form a part of the food chains leading to men. The rotifers are a source of food for other animals, such as small crustaceans, which are eaten by small fish. These small fry in turn are eaten by larger fishes that are devoured by various animal and also relished by man.

An outstanding significance is the striking resemblance of some adult rotifers to the trochophore larva of some higher animals, leading to the view that the early an cestors of higher animals were rotifer like in nature.

Rotifers are said to be “cell constant” animals because the number of cells in the adult individual remains fixed and surprisingly constant, except in the gonads. Since cells of the adult do not divide, rotifers have no power of regeneration.

Distinctive characters of Rotifera

1. Mostly microscopic and freshwater animal; rarely marine or parasitic.

2. Body bilaterally symmetrical, unsegmented, triploblastic, non-coelmate, and divisible into 3 parts-head, trunk and tail.

3. Anterior end or head modified into a retractile, variously ciliated trochal disc or corona, for locomotion and food

4. Posterior and terminal foot region or tail is mobile, telescopically segmented, usually forked and containing pedal (cement) gland.

5. Body-wall syncytial, covered with a cuticular exoskeleton forming lorica, that is often ringed, especially over the foot.

6. In the adult, most tissues syncytial. Total member of nuclei in the bodies of different species quite constant.

7. Body cavity spacious and devoid of epithelial lining.

8. Digestive system with a modified muscular grinding pharynx or mastax bearing internal jaws.

9. Special respiratory and circulatory systems are absent.

10. Excretion by a pair of protonephridial tubes, provided with flame cells and ending in a cloaca.

11. Nervous system simple, with a dorsal cerebral ganglion and several nerves (no cords).

12. Sense organ tuft-like or as eye spots.

13. Sexes separate and sexually dimorphic; males usually smaller than females and degenerate; females oviparous or viviparous; parthenogenesis or sexual reproduction ; development direct without a larva.

Classification of Rotifera

The phylum Rotifera includes nearly 2000 species grouped under 3 orders, as follow:

Order 1. Seisonoida

1. Epizoic marine rotifers.

2. Elongated body with reduced corona.

3. Lateral antennae and toes absent.

4. males fully developed, no sexual dimorphism.

5. Ovaries two without vitellaria.

Example: Seison, commensal on crustaceans.

Order 2. Bdelloida

1. Swimming or creeping freshwater rotifers.

2. Corona retractile with two trochal discs.

3. Lateral antennae absent; toes 0 to 4.

4. Mastax adapted for grinding.

5. Males absent. Ovaries two, with vitellaria.

6. Reproduction parthenogenetic.

Example: Philodina, Rotaria, Rotifers, Embata, Adineta.

Order 3. Monogonontlda

1. Swimming or sessile freshwater rotifers.

2. Two lateral antennae; toes 0 to 2.

3. Mastax most often of grinding type.

4. Male'sdegenerate; sexual dimorphism well marked.

5. Ovary single, with vitellarium.

6. Reproduction heterogonous.

Example: Epiphanes (=Hydatina), Asplanehna, Brachionus, Polyarthra, Natommata, pedalia, Synchaeta, Chanochilus.

Affinities of Rotifera

The relationship of rotifers is quite obscure. They have been allied with almost every invertebrate group in the past.

1. Affinities with Arthropoda. It was based on the following resemblances:

i. Body covered by a cuticle.

ii. Superficial metamerism.

iii. presence of two jaws (trophi).

iv. The moving bristle-hearing arms of pedalia suggest the appendages of a crustacean larva.

2. Affinities with trochophore. Some adult rotifers bear a close resemblance with the free-swimming trochophore larva of annelida, Mollusca, nemertinea and Bryozoa. The peculiar rotifer, Trochosphaera, appears almost like a sexually mature trochophore, with a mastax. Its ciliary girdle, bent intestine and excretory organs are topographically similar to corresponding parts of the trochophore. This striking resemblance led Hatschek to propound his famous trochophore theory, which maintains that the living rotifers are closely related to the ancestral Mollusca, Annelida and certain other groups. In brief, the annelid theory concludes that the rotifers are simply annelids that remained in a larval condition. But this hypothesis falls to ground, when it is cstablished that Trochosphaera is merely a peculiar rotifer with a modified girdle type corona, only superficially resembling prototroch of the trochosphere. On the other hand, the primitive, large and ventrally ciliated corona of a rotifer is altogether different from the ciliary circlets of the trochophore. It is noedays are merely coincidental, the result of adaptive radiation and bear no evolutionary significance. The rotifers certainly do not seem to be the aneestors of any other group. Rather, they are simplified forms showing persistence of many larval characters.

3.Affinities with Platyhelminthes. The anatomy and embryology of rotifers combine to suggest their origin from a low grade creeping bilateral type, such as a primitive turbellarian. The inference is based on the following primitive characters of rotifers:

i. The primitive type of corona may have derives from a complete or ventral ciliation, as in turbellarians.

ii. Formation of cuticularized parts, such as trophi, is also common in turbellarians.

iii. The protonephridial system with flame bulbs, recalling that of rhabdococls, is definitely against the derivation of rotifers from any higher group.

iv. The retrocerebral organ is probably homologous with the frontal organs of turbellarians.

On the other hand, rotifers differ from the flatworms in the following respects:

i. Presence of an anus.

ii. Lack of sub-epidermal continuous muscles.

iii. Lack of sub-epidermal nerve plexus. Probably is becomes unnecessary due to the small size of the rotifers. However, the nervous system bears a general resemblance to that of flatworms.

4. Affinities with Nematoda. The rotifers resemble the nematodes in being composed of a relatively few cells, having a nuclear constancy, a syncytial epidermis and a body cavity without a special lining.

Relation with the Gastrotricha have also been suggested.

5. Conclusion. The embryology of rotifers, without any trace of coelom or endo-mesoderm during development, suggests that they have not been derived by retrogression of higher groups. They show the greatest resemblance, among invertebrate groups, to the Turbellaria. But, they display an amazing variety in structure and do not resemble any one group of animal. Therefore, the status of an independent phylum to rotifers seems to be justified.

8.4.6 SPINCULA

The generic name Sipunculus was created by Linnaeus (1767) who placed it in the vermes intestina. Lamarck (1816) considered them to be holothurians because of large and unsegmented body and placed them with Radiaires, Echinodermes. Cuvier also supported Lamarck's view. Later workers regarded sipunculoids to be allied to annelids or parasitic worms. Quatrefages (1847) created the group Gephyrea to include Echiurus, Sternaspis, Sipunuculus and Priapulus. He conceived Gephyrea as a bride between Echinodermata and Annelida and regarded Sipunculoids to be degenerate echiuroids. Lankester (1885) combined Sipunculida, Bryozoa and Phoronida under the name Podaxonia Hatschek (1888) made Sipunculoidea an appendage to Annelida, while Sedgwick (1898) raised it to phylum rank. Despite rejection by eminent worked the group Gephyrea has been used in zoological textbooks and faunal works even upto 1955, probably because it offers an easy way of disposing of three group (Sipunculida, Echiurida and Priapulida) of very uncertain affinities. Sipunculida is treated here as a distinct phylum by itself.

General account

Habits and habitat. Sipunculoids are sometimes called "peanut worms". They are exclusively marine and found in all seas at all latitudes, from the inter-tidal zone to depths of about 5000 meters. They are sedentary, living free or in burrows in the sand and ooze, in empty shells and seaweeds, among corals, in sponges and other protected situations. When removed from their burrows, they show little movements except running the introvert in and out. The introvert is thrust out of the burrows or refuges and the tentacles spread out for ciliary feeding and repiration, as well as for exploring the surrounding surface. When disturbed, the introvert instantly retracts and the animal retreats in the burrow. Little is known about the feeding habits. Sipunculoids are eaten up by fish, large sea anemones, crabs and cephalopods, etc.

Shape and size. The sipunculoids are elongated, usually cylindrical, vermiform animals, without any trace of segmentation in the adult condition, non-ciliatted and without parapodia and setae. The skin is often thrown into transverse and longitudinal ridges. The size varies from 2 mm to about 60 cm (Sipunculus nudus) in length, although most are from 15 to 30 cm long.

Colour. They are drab-coloured, greyish or yellowish.

External feature: The cylindricsl body has two distinct regions-a slender anterior part or introvert greatly in different forms.

(a) Introvert: The introvert can be completely invaginated into the trunk by meansof special retractor muscles. It is not simply a proboscis and represents the head and anterior part of the body. In a fully extended introvert, the mouth is seen to be placed in the centre of the anterior tip, called oral disc, surrounded by a tentacular fold. The tentacles are hollow, ciliated, mere bulges (Golfingia) to conical, digitiform or filiform, and simple to branched. They may be arranged in a circle or in the form of a double horseshoe, the concavity of which is dorsal. In Phascolosoma, the tentacles do not encircle the mouth. A preoral lobe is absent.

There is generally present on the mid-dorsal region of the oral disc a teo or four-lobed ciliated cushion, the nuchal organ. It is absent in Sipunculus. Just ventral to the nuchal organ, or in the same location in its absence, may open one or two opening of cephalic tube or tubes leading toward the brain.

The introvert is often covered, in whole or in part, by rows of horny hooks and spines, or by small, scale-like, chitinous papillae, directed backwards and overlapping one another. Usually, the oral disc is followed by a short smooth zone, which is devoid of papillae and spines, etc. in Phascolosoma, two projecting girdles or ridges bound the smooth zone. The anterior girdle is termed the cephalic collar and posterior girdle the cervical collor.

(b) Trunk. The trunk is a simple cylinder. It usually bears papillae of various kinds, glandular eminences or scalelike thickenings, but is devoid of hooks or spines. In some genera, the anterior end of trunk becomes modified into a hard, calcareous, cone-like shield (Lithacrosiphon) or into irregular, polygonal, calcareous plates (Cloeosiphon). In Aspidosiphon, the posterior end of the trunk has a circular cap-like shield composed of radiating pieces. In other, the trunk usually terminates bluntly, but in abyssal species Golfingia flagrifera and G. murlcaudata it is drawn out into a slender tail.

The anus opens mid-dorsally on the anterior end of the trunk, but in Onchnesoma, it is placed on the introvert near the mouth. The two-minute nephridiopores lie mid-ventrally on the trunk at the level of the anus. In some species, a temporary invagination at the tip of the trunk forms the so-called terminal pore.

Body wall. The body wall is highly muscular. The external, chitinoid cuticle has an iridescent lustre. The underlying epidermis is single layered and abundantly supplied with sensory organs and glands that may be unicellular or multicellular. The dermis is a thin or thick layer of connective tissue containing pigment and amoeboid cells. In some genera (Sipunculus) it also contains coelomic canals and spaces communicating by pores with general coelom. The musculature includes an outer circular laryer and an inner longitudinal layer, often arranged in bundles, and between them a thin oblique layer, which however, is not present in the introvert. Lastly, there is peritoneum consisting of flat coelomic epithelial cells, which are ciliated here and there.

Coelom. The coelom is spacious, lined by ciliated epithelium and without septa, although remnants of mesenteries are present. It is traversed in all directions by connective tissue strands and muscle fibres attached to the gut. The coelom is filled by a richly corpusculated fluid, often of a pink colour. Elevated coelomic fluid pressure brings about the protrusion of the introvert, assisted by the contraction of the bodywall. The elements floating in the coelomic fluid are.

(i) Colourless amoeboid cell;

(ii) Round biconcave corpuscles faintly coloured by an iron-pigment, hemerythrin;

(iii) Reproductive element;

(iv) Peculiar fixed or free unicellular ciliated bodies, the urns, which are apparently budded off from the coelomic epithelium overlying the dorsal blood vessel.

The lumens of tentacles are not connected to the coelom, but to one- or two-blind tubular sacs connected to the oesophagus. They supply or receive fluid to and fro tentacles when they expand or contract.

Digestive system. The alimentary canal is a thin-walked cylindrical tube of unform character. It is long, U-shaped and much coiled. The mouth, occupying the centre of the oral disc surrounded by the tentacular fold, leads into a straight and uncoiled oesophagus. From the beginning of the oesophagus, often termed pharynx, extend retractor muscles to the trunk wall. Their number may be one (Onchnesoma), two (Aspidosiphon) or four (Sipunculus) and their contraction cause the invagination of the introvert. The oesophagus leads into a long intestine,

Which descends to the hind end of the trunk and then turns forwards, the two limbs being twisted in a single spiral coil? On the top of the coil, the intestine straightens up to form the rectum, which opens to the exterior through the anus usually lying mid-dorsally near the anterior end of the trunk. Delicate muscles strands pass from the body wall to the intestine. Often a spindle muscle extends along the axis of the intestinal spiral from the hind end of the body to the rectum. A narrow ciliated groove runs along the inner surface of the entire length of the intestine. A narrow blind diverticulum or eaccum of variable length often opens into the beginning of the rectum. Two tuft-like groups of rectal glands may also occur close to the analopening. Epithelial gland cells are present in the descending absorption. The ascending intestine probably serves for faecal formation.

Circulatory and repiration system. Blood vascular and respiration organs are absent. The coelomic fluid serves for circulation and respiration. It contains abundant corpuscles bearing hemerythrin which is a respiratory pigment with iron as the metallic base. Amoebocytes are also present.

Excretory system. One or two metanephridia, often called brown tubes, are situated ventrally in the anterior part of the trunk. They are elongated, somewhat V-shaped tubular sacs, brownish or yellowish in colour and very mobile in the living condition. A narrow terminal canal leads to the external opening, or nephridiopore situated ventrally near the anterior end. Close to this, a narrow ciliated canal leads to the internal opening, or nephrostome, into the perivisceral coelom. The nephridia have glandular walls and also serve as gonoducts for conveying the reproductive cells to the exterior. Harms (1921) has also ascribed a hormonal function to the nephridia.

Peculiar cell clusters, called urns, are also associated with excretion. Fixed urns are vase-like clusters of peritoneal cells, each capped by a ciliated cell. when detached, they become free urns, moving about in coelomic fiuid, accumulating waste material and eventually eliminated through the nephridia.

Nervous system. The central nervous system is of the annelid type. The brain or supra-oesophageal ganglion is a bilobed mass situated dorsally just behind the attachment of the retractor muscles. From brain arise two circumoesophageal connectives, which embrace the oesophagus and unite ventrally to form a single ventral nerve cord, which continues along the mid-ventral line without ganglionic swellings. The brain and the ventral corf giben off several nerves to the adjacent parts.

Sensory organ seems to be well developed on the tip of the introvert, the dorsal end of which bears a pair of ciliated pits, the nuchal organs, which may be chemoreceptive. One or two cerebral organs, lead from mid-dorsal surface just behind the tentacular fold, towards the brain. In many sipunculoids, a pair of brown or black pigment spots. Or ocelli, remains embedded in the brain.

Reproductive system. The sexes are generally separate. Gonads are not definite but arise during breeding seasons, as inconspicuous proliferations of peritoneum breeding season, as inconspicuous proliferations of peritoneum at the point of attachment of retractor muscles to the body wall. The sex cells are shed before they are ripe into the coelom, where they undergo maturation while floating in the coelomic fluid. They are then passed out of the body through nephridia which act as gonoducts.

Development. Spawning generally takes place during summer. Fertilization is external, taking place in sea water. Cleavage is of the spiral type. Gastrulation occurs partly by epiboly and partly by invagination. The blastopore close and the mouth and anus arise as new formations. The embryo develops into a typical trochophore larva. After a month of free-swimming existence in the plankton, the larva settles down to metamorphose into the sedentary adult. Metamorphosis is not marked by any definite evidence of temporary metamerism as evident in the development of Echiurus. Sipunculoids do not reproduce asexually but show a great power of regeneration.

Distinctive characters

(1) Elongated, marine and worm-like animals, living in sand, mud or coral reefs, either free or in tubes or in snail shellsand capable of show-creeping movements.

(2) Body usually cylindrical, without segmentation in the adult, non-ciliated and without metameric appendages, spines, bristles and parapodia.

(3) The slender anterior part of the body forms as introvert, which can br invaginated into the thicker binder region called the trunk.

(4) When fully everted, the introvert bears the terminal mouth surrounded by short and hollow tentacles, either distinct or more or less united.

(5) Anus lies antero dorsally, near the base of the introvert.

(6) Coelom is voluminous, lined by ciliated peritoneum, filled by corpusculated fluid and dividedinto chambers by mesenteries or septa.

(7) The alimentary canal includes the oesophagus followed by a long recurved and spirally coiled intestine, hanging free in the body cavity.

(8) Blood-vascular system is absent or poorly developed with an oesophageal ring canal, tentacular canal and one or two contractile caeca or hearts.

(9) One or two metanephridia, called brown tubes, hang freely in coelom with their nephridiopores opening ventrally near anus.

(10) Central nervous system includes a dorsal brain with or without pigmented ocelli, a pair of circumcenteric commissures and unganglionated ventral nerve cord.

(11) Sexes are seprate but alike in appearance. Ovaries and testes are simple masses of cells shed into the coelom. The nephridia serve as gonoducts.

(12) Cleavage is spiral. Development shows typical trochophore larva.

Classification

The phylum includes about 250 described species belonging to about 13 genera, which have not been assembled into families. The common genera are Sipunculus, Phascolosoma, Siphonosoma, golfingia, Dendrostoma, Phascolion, etc.

Affinities

Affinities with Annelida. It was Hatschek (1888) who showed Sipunculida to be closely related to Annelida. The relationship is based on similarity in the following feature of development and anatomy of the adults:

1. Body wall is dermo-muscular.

2. Central nervous system is of the annelidan type.

3. Cleavage is typically spiral.

4. Origin of entomesoderm from teloblast cells.

5. Origin of coelom is shizocoelous.

6. Presence of nephridia.

7. Larva is a typical trochosphere with an apical tuft, prototroch and metatroch.

However, Sipunculida differ from phylum Annelida in the following respects:

1. Total lack of body segmentation both in the adult and larval stages.

2. Presence of an introver with tantacular fold.

3. Coelom spacious and undivided by mesenteries or septa.

4. Ventral nerve cord is without ganglia and single.

5. Nephridia are only one pair.

6. Anus is nearer the oral end and dorsal.

7. Absence of parapodia and setae.

8. Rectal glands opening in the rectum.

2. Affinities with Echiuroidea. Quatrefages (1847) placed the sipunculoids and echiuroids together under the group Gephyrea as a class of Annelida. But apart from some similarities (sec Echiuroidea), the two groups differ in many important respects such as the anterior end, the position of the anus, and the presence or absence of the setae.

Conclusion. Sipunculids are not metameric, yet they are clearly related to annelids as shown by their bodywall, nervous system and embryology. They probably diverged from the line leading to annelids, before metamerism had developed.

The sipunculids are protostomatous coelomates with stomodaeum arising at or near the anterior end of the larval blastopore. They may be looked upon as an intermediate stage in the evolution of segmented protostomatous coelomates such as Annelida, Mollusca and Arthropoda.

8.4.7 ENTOPROCTAOR ENDOPROCTA (CALYSSOZOA)

The Entoprocta or Endoprocta is a small group of sessile aquatic animals, in which the body cavity is belived to be a pseudocoel by some zoologists. They were formerly included in the phylum Bryozoa which, however, are coelomate animal.

General account

Habits and habitat. The entoprocts are a group of minutes, simple and archaic animals. They are solitary or colonial and all marine, except the single freshwater genus Urnstells. They live in shallow coastal water attached to seaweeds, sticks, stones, shells, or are epizoic on sponges, crabs and other animals.

Shape and size. The entoprocts are small animals with their size ranging from microscopic to 5 mm. in general appearance they look like the hydroid polyps, but are easily distinguished by the ciliation of their tentacles.

External morphology. The body proper is vase-like or cup-like and called the calyx. It is slightly flattened laterally and contains the viscera.

Calyx. The free upper edge or rim of calyx is oval or round, called lophophore, which bears an encircling of crown of tentacles, ciliated on their inner surface. The tentacles are usually equal-size and their number varies from 8 to 30 in different species. A ciliated vestibular groove runs along the inner side of the tentacular bases, which are connected outwardly by a tentacular membrance provided by a sphincter muscle. The depression or cavity, surrounded by the tentacular crown is called the vestibule or atrium, into which open the mouth, anus, nephridiopore and the gonopore. The mouth and anus are placed at opposite ends, which mark the anterior and posterior ends of the animal. The crown of tentacles is retractile and can be withdrawn into the vestibule, partly covered by the integumental fold or tentacular membrance. The free concave or tentacular surface of calyx is originally ventral and the attached convex surface of calyx is originally ventral and the attached convex surface is dorsal.

Stalk. Basally, the calyx joints a contractile stalk or pedicel and an attachment disc with adhesive glands. The stalk presents much variation and is of taxonomic value. It may be simple (Loxosoma), smooth or beaded and spiny. The base may give out slender, lateral extensions or stolons (Pedicellina), running over the substrate. The stalk is separated from the calyx by a septum-like fold of the body wall.

Body wall. The structure of body wall is simple. The surface of the body, except the tentacles and the vestibule, is covered by a cuticle of varying thickness. Below it lies a single –layered epidermis consisting of cuboid cells and gland cells. To the inner side of the epidermis are present longitudinal muscles fibres. Muscle strands run along the inner wall of the tentacles, which are simply epidermal tubes filled by loose mesenchyme. A sphincter of circular fibre is present in the tentacular membrane. The calyx is traversed by a transverse bundle of muscles ventral to the digestive tract. The stalk has a rather complex musculature.

Pseudocoel.A definite body cavity is lacking. The interior of the tentacles and the stalk and the space between the body wall and the alimentary canal, are filled by a loose, gelatinous parenchyma with free wandering amoeboid cells. The space is the remnant of the embryonic blastocoel.

Digestive system. The alimentary canal is a simple but strongly curved U-shaped tube, occupying most of the space inside the calyx. It includes a small funnel-shaped buccal cavity, a narrow tubular oesophagus, an enlarge sacciform stomach, a narrow intestine and a terminal rectum opening by the anus. The mouth and the anus placed close together inside the tentacular circle. The mouth opening is surrounded often by two lips, upper, and lower, with the angle being continuous with the vestibular groove. The anal opening often lies on an elevation called the anal cone. The digestive tract is mostly by a ciliated epithelium.

The entoprocts are ciliated epithelium. The entoprocts are ciliary feeders and their food consists of diatoms, desmids, protozoans and organic debris in the water. The frontal cilia of tentacles entrap the suspended food particles and pass them on to the ciliated vestibular grooves leading into the mouth. Stomach glands are believed to secrete enzymes for extracellular digestion.

Nervous system. Nervous system consists of a rectangular to bilobular ganglionic mass situated between the stomach and the vestibule. It represents a subenteric ganglion, as the cerebral ganglion is lost during larva metamorphosis. Nerves radiate from this ganglion to supply the crown of tentacles, the calyx wall, the stalk and gonad, etc. tactile sensory nerve cells, ending in bristles, are found scattered in the epidermis.

Reproduction system. Some entaprocts are hermaphroditic and others diecious, though, in the latter case, some may be actually protandric hermaphrodites. Two simple, rounded gonads are placed between the vestibule and the stomach, each with a simple gonoduct. The two gonoducts join to open by a common gonopore just behind nephridiophore. In hermaphroditic species there are two testes and two ovaries, and all four gonoducts open by a single gonopore. In males, the common sperm duct forms a swelling, the seminal vesicle, for the storage of ripe sperm which are flagellate.

Embeyogeny. Entoprocts reproduce sexually by the fusion of ova and sperm. The small and rather yolky eggs are fertilized in the ovaries or gonoduct and become surrounded by a loose membrane formed by a secretion of the gonoduct. The membrane is drawn out into a stalk, by which the zygote adheres to the embryophore or the vestibular wall in front of the anal cone. The calyx surface between the gonopore and the anal cone is depressed into a genital recess serving as a brood chamber for the developing embryos in the hermaphrodites and the females.

Cleavage is equal or spiral, resulting into a ciliated free-swimming larva. It breaks through the enclosing membrane and escapes from the maternal brood pouch. It is known as trochophore because of its superficial resemblance with those of Annelida and Mollusca. It has an apical tuft of cilia at the anterior end and a ciliated girdle around the ventral margin of the body. After a short period of free-swimming existence, the larva fixes itself by the oral surface and undergoes a complex metamorphosis in which the future calyx rotates 180 degrees. The alimentary canal rotates in the same manner as seen in the barnacles. The vestibule with mouth, anus and the developing tentacles are carried to occupy their permanent position on the free surface and the larva transforms into the inverted adult form.

Asexual reproduction and regeneration. Asexual reproduction takes place extensively by extensively by external budding from the sides of calyx, stalks and stolons. When completed, the buds may become separated from the parent and attached elsewhere. When the buds remain attached, colony formation results.

The endoprocts possess a great power of regeneration. During unfavourable conditions, the calyces may be shed, though stolons and stalk remain alive and regenerate new calyces upon return of favourable conditions.

Distinctive characters of Endoprocta

1. Simple, archaic, minute, sedentary, stalked freshwater or marine, and solitary or colonial forms.

2. Body triploblastic, unsegmented and bilaterally symmetrical.

3. An individual consists of calyx, stalk and stolon.

4. The edge of calyx or lophophore is circular supporting a single row of several, minute, slender, active and retractile ciliated tentacles.

5. Both mouth and anus open inside the crown of tentacles.

6. A true body cavity is absent. The space within the body is a pseudocoel filled with gelatinous parenchyma.

7. Digestive tube is U-shaped and ciliated.

8. Retractor muscles are present.

9. Circulatory and respiratory organ are absent.

10. Excretion occurs by a pair of protonephridia, each ending in a flame bulb Single nephridiopore near the mouth.

11. The central nervous system consists of a ganglionic mass, located below in the concavity of the digestive tract.

12. Some are dioecious, others hermaphroditic. Gonads are two, simple and with special ducts. Some are protandric hermaphrodite

13. Development include a free-swimming ciliated larva, which attaches to grow into the adult.

Affinities

In their external appearance, the Entoprocta recall the Hydroidea among the Coelenterata, with which, however, they are not related. They are readily distinguishable by the presence of cilia on tentacles, and possession of a looped alimentary canal, with both mouth and anus opening inside the ring of tentacles.

1. Affinities with Ectoprocta. Previously, Entoprocta were supposed to be closely related to the Ectoprocta, both included as classes under the phylum Bryozoa. This relationship was based mainly in possession by both groups of a crown of ciliated tentacles and a looped digestive tract. But such features occur in common in all the sessile animals. The distal tentacular circlet serves as food-castching device, while approximation of mouth and anus prevents the accumulation of faces around the animal. The larvae in the two groups bear a marked resemblance, but sharply differ in their further development.

2. Affinities with annelid-molluscan types. The spiral determinate cleavage and Similarityof Trochophores shows relationship of Entoprocta with annelid-molluscan types. However, the endoproct larva differs from a typical trochophore in the presence of preoral organs and vestibular depression, shape and relations of the digestive tract, displacement of ciliary girdle and origin and nature of coclom.

3. Affinities with Rotifera. The Entoprocta bear a closer affinity with Rotifera among the pseudocoelomate groups. The following resemblances between a loxosomaid endoproct and a sessile coelothecacean rotifer are noteworthy:

1. Body trumpet-like.

2. The ciliated or bristle-bearing projections are simple extensions of body wall.

3. Stalk develops post-embryonically and has pedal gland at least temporarily.

4. Mouth lies within the crown of tentaculate projections.

5. Digestive tube is curved, so that anus comes nearer to mouth.

6. The mastax (phaynx) of Rotifera shows degeneration in coelothecacean rotifers, being totally absent in Endoprocta.

7. Protonephridia of the flame-bulb type occur.

8. The juveniles possess a pair of eyes.

9. Ciliar rim of entoproct larva and the rotifer corona are derived from a large ventral ciliated surface.

10. The preoral organs of entoproct larva and loxosomatid adult are homologous with the lateral antennae of Rotifers.

Thus, it is fair to conclude that the nearest affinities of Entoprocta lie with the Rotifera.

8.4.8 PROTOSTOMES V/s DEUTEROSTOMES

The term Protostomia (from the Greek "proto," meaning first, and "stoma," meaning mouth) was coined by the biologist Karl Grobben in 1908. It distinguishes a group of invertebrate animals based upon the fate of the blastopore (the first opening of the early digestive tract) during embryonic development. Animals in which the blastopore becomes the mouth are called protostomes; those in which the mouth develops after the anus are called deuterostomes (from the Greek "deutero," meaning second, and "stoma," meaning mouth).

Protostomia and Deuterostomia are considered super-phyletic taxa, each containing a variety of animal phyla. Traditionally, the protostomes include the Annelida, Arthropoda, and Mollusca and the deuterostomes comprise the Echinodermata and Chordata.Grobben was not the first biologist to recognize the distinction between these two groups, but he was the first to place importance on the fate of the blastopore as a major distinguishing criterion. Historically, the two groups are distinguished by the following criteria:

1. Embryonic cleavage pattern (that is, how the zygote divides to become a multicellular animal)
2. Fate of the blastopore
3. Origin of mesoderm (the "middle" embryonic tissue layer between ectoderm and endoderm that forms various structures such as muscles and skeleton)
4. Method of coelom formation
5. Type of larva

These developmental features are different in the two groups and can be summarized as follows:

Developmental features of protostomes

1. Cleavage pattern: spiral cleavage
2. Fate of blastopore: becomes the mouth
3. Origin of mesoderm arises from mesentoblast (4d cells)
4. Coelom formation: schizocoely
5. Larval type: trochophore larva

Developmental features of deuterostomes

1. Cleavage pattern: radial cleavage
2. Fate of blastopore: becomes the anus
3. Origin of mesoderm: pouches off gut (endoderm)
4. Coelom formation: enterocoely
5. Larval type: dipleurula

Cleavage pattern refers to the process of cell division from one fertilized cell, the zygote, into hundreds of cells, the embryo. In protostomes, the developing zygote undergoes spiral cleavage, a process in which the cells divide at a 45° angle to one another due to a realignment of the mitotic spindle. The realignment of the mitotic spindle causes each cell to divide unequally, resulting in a spiral displacement of small cells, the micromeres that come to sit atop the border between larger cells, the macromeres. Another superphyletic term used to describe animals with spiral cleavage is Spiralia. Spiral cleavage is also called determinate cleavage, because the function of the cells is determined early in the cleavage process. The removal of any cell from the developing embryo will result in abnormal development, and individually removed cells will not develop into complete larvae.

In deuterostomes, the zygote undergoes radial cleavage, a process in which the cells divide at right angles to one another. Radial cleavage is also known as indeterminate cleavage, because the fate of the cells is not fixed early in development. The removal of a single cell from a developing embryo will not cause abnormal development, and individually removed cells can develop into complete larvae, producing identical twins, triplets, and so forth. The fate of the blastopore has classically been used as the defining characteristic of protostomes and deuterostomes. In protostomes, the blastopore develops into the mouth, and the anus develops from an opening later in development. In deuterostomes, the blastopore develops into the anus, and the mouth develops secondarily.

Mesoderm and coelom formation are intimately tied together during development. In protostomes, the mesoderm originates from a pair of cells called mesentoblasts (also called
4d cells) next to the blastopore, which then migrate into the blastocoel, the internal cavity of the embryo, to become various internal structures. In coelomates, the mesentoblasts hollow out to become coeloms, cavities lined by a contractile peritoneum, the myoepithelium. In protostomes, the process of coelom formation is called schizocoely. In deuterostomes, the mesoderm originates from the wall of the archenteron, an early digestive tract formed from endoderm. The archenteron pouches out to form coelomic cavities, in a process called enterocoely.

Protostomia and Deuterostomia are also characterized by different larvae. In most protostomes, the larval type is a trochophore, basically defined by the presence of two rings of multiciliated cells (prototroch and metatroch) surrounding a ciliated zone around the mouth. Most deuterostomes have a dipleurula-type larva, defined by the presence of a field of cilia (monociliated cells) surrounding the mouth.

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