SYSTEMATIC AND ANATOMY OF INVERTEBRATES

(DZO001)

(MSC ZOOLOGY)

ACHARYA NAGARJUNA UNIVERSITY

CENTRE FOR DISTANCE EDUCATION

NAGARJUNA NAGAR,

GUNTUR

ANDHRA PRADESH

FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining a B++ (80-85) grade from the NAAC in the year 2003, the University has achieved recognition as one of the front rank universities in the country. At present Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from about 300 affiliated colleges spread over the three districts of Guntur, Krishna and Prakasam.

The University has also started the Centre for Distance Education with the aim to bring higher education within reach of all. The Centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even housewives desirous of pursuing higher studies. With the goal of bringing education to the doorstep of all such people, Acharya Nagarjuna University has started offering B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A. and L.L.M. courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise within the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn facilitate the country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will grow from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Co-ordinators, Editors and Lesson - writers of the Centre who have helped in these endeavours.

Prof. V. Balamohandas
Vice - Chancellor,
Acharya Nagarjuna University

DM - PAPER - 1
SYSTEMATICS AND ANATOMY OF INVERTEBRATES
Syllabus

UNIT - 1

General organization and classification of the Phylum Protozoa upto orders. Various types of reproductive processes in protozoa.

General organization and classification of the Phylum Porifera upto orders. Development in sponges.

UNIT - II

General Organization and classification of Phylum Coelentarata upto orders. Polymorphism in coelenteratas

General organization and classification of Phylum Platyhelmnthes upto orders. Parasitic adaptations in platyhelminthes

General organization and classification of Phylum Nemathelminthes upto orders.

UNIT - III

General organization and classification of Phylum Annelida upto orders.

General organizaton and classification of Phylum Arthropoda upto classes.

Trochophore larva and its evolutionary significance.

UNIT - IV

General organization and classification of Phylum Mollusca upto orders.

General organization and classification of Phylum Echinodermata upto orders. Larval forms in echinoderms.

UNIT - V

Minor Phyla - the general organization of Rotifera, Ectoprocta, Sipuncula, Chaetognatha.

LIST OF TEXT BOOKS :

1. T.J. Parker & W.A. Haswell, 1972. A Text book of Zoology, Vol.I, Invertebrates. (Eds.), A.J. Marshall & W. D. Williams ELBS. and Macmillan.
2. A. Kaestner, 1967. Invertebrate Zoology Vols. I to III, John Wiley & Sons Inc., New York.
3. V. Frrettar & A. Graham, 1976. A Functional Anatomy of Invertebrates. Academic Press Inc. (London) Ltd.
4. Hyman, L.H. 1953. The Invertebrates, Vols. I to VI. McGraw-Hill Book Company, New York, London
5. Borradaile, F., Potts, 1962. The Invertebrates. Asia Publishing House.
6. Robert, D. Barnes, 1980. Invertebrate Zoology. W.B.Saunder's Company, Japan.
7. A. Sedgwick, 1972. A text book of Zoology. Vol. I&II, Central Book Depo, Allahabad.
8. E.J.W. Barrington, 1971. Invertebrate structure and function. ELBS.

M.Sc., Degree Examination, December 2004

PAPER - I : SYSTEMATICS AND ANATOMY OF INVERTEBRATES

1st Year, Zoology

Time : Three hours | Max. Marks : 100

All questions are compulsory
Each question carries 20 marks
Draw the diagrams wherever necessary

1. a) Classify the Phylum Porifera upto orders giving their general characters and suitable examples.

   or

   b) Write short notes on :

   i) Reproductive processes in protozoa

   ii) Development in sponges.

2. a) What are the salient features of Phylum Nemathelminthes? Classify upto orders.

   or

   b) Write shortnotes on :

   i) Polymorphism in coelenterates

   ii) Parasitic adaptations in platyhelmenthis.

3. a) Write in detail the general features of different classes in Phylum Arthropoda.

   or

   b) Write shortnotes on :

   i) Trochophore larva.

   ii) Excretion in earthworm.

4. a) Describe the general characteristics of Phylum Mollusca. Classify upto orders with examples.

   or

   b) Write shortnotes on :

   i) Bipinaria larva.

   ii) Echinopluteus larva.

5. a) Give an account of general organization of Rotifers.

   or

   b) Write shortnotes on :

   i) Reproduction in Ectoprocta.

   ii) Chaetognatha - Habit, Habitat and External features.

M.Sc., Degree Examination, December 2005

PAPER - I : SYSTEMATICS AND ANATOMY OF INVERTEBRATES

1st Year, Zoology

Time : Three hours | Max. Marks : 100

All questions are compulsory
Each question carries 20 marks
Draw the diagrams wherever necessary

1. a) Describe the general characteristic features of phylum protozoa and classify it upto class level with examples.

or

b) Write short notes on :

i) General organization of phylum Porifera.

ii) Types of reproduction in phylum Protozoa.

2. a) What are the salient features of Phylum Coelenterata and explain in detail the polymorphism in it.

or

b) Write shortnotes on :

i) Parasitic adaptations in Platyhelminthes.

ii) Classification of Nematyhelminthes.

3. a) Mention the classes of phylum Arthropoda and describe their salient characteristic features with suitable examples.

or

b) Write shortnotes on :

i) Evolutionary significance of Trochophore larva.

ii) General organization of phylum Annelida.

4. a) Classify the phylum Mollusca and explain the general characteristic features of it.

or

b) Write shortnotes on :

i) Water Vascular system in Echinoderms

ii) Larval forms of Echinoderms.

5. a) Give an account on the general characters of Rotifera and add a note on its affinities.

or

b) Write shortnotes on :

i) Characters of Chaeognatha.

ii) Affinities of Ectoprocta and Sipunculoidea.

M.Sc. (ZOOLOGY) (Previous) DEGREE EXAMINATION :: MAY 2006

Paper - I : SYSTEMATICS AND ANATOMY OF INVERTEBRATES

Time: Three hours Maximum : 100 Marks

Answer ALL Questions
Each question carries 20 marks

1. (a) Write an essay on reproduction in protozoa.

Or

(b) Write notes on:
(i) Parasitic protozoa
(ii) General organization of Porifera.

2. (a) Discuss on the parasitic adaptations in Platyhelminthes.

Or

(b) Write notes on:
(i) Polymorphism in coelenterate
(ii) General organization of Nematyhelminthes.

3. (a) General organization of Arthropods.

Or

(b) Write notes on:
(i) Reproduction in Annelida
(ii) General features of Insects.

4. (a) Describe the general organization of Echinodermata.

Or

(b) Write notes on:
(i) Bipinnaria larva
(ii) Classify Mollusca upto orders.

5. (a) Write an essay on the general characters of Rotifera.

Or

(b) Write notes on:
(i) Sipunculoidea
(ii) Chaetognatha.

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CONTENTS

UNIT - 1

1.1 GENERAL ORGANIZATION OF PHYLUM PROTOZOA

1.1.1 OBJECTIVES

The purpose of this lesson is to:

- understand the general characters of protozoans
- exemplify the various groups of protozoans with the help of diagrams.
- study the general physiology of protozoans

1.1.2 INTRODUCTION

Protozoans are unicellular eukaryotic organisms. The Phylum Protozoa is a heterogeneous assemblage of some 80000 single-cell organisms. Protozoans possess typical membrane-bound cellular organelles. Hence, they are called as eukaryotes. Many of the protozoans are animal like, motile and heterotrophic.

1.1.3 HABIT AND HABITAT

Protozoans occur as solitary individuals and colonial forms. Some colonial forms, such as *Volvox* attain a degree of cellular interdependence, they approach a true multicellular level of structure. Both solitary and colonial species may be either free moving or sessile. Majority of protozoa are microscopic. *Anaplasma,* a blood parasite is so small that it occupies 1/6 to 1/10th of a RBC. A fresh water ciliate, *Spirostomum* may reach a length of 3 mm and may be seen with the naked eye. Gas exchange occurs by diffusion across the cell membrane. Protozoa that live in the digestive tract of other animals can exist with little or no oxygen is present. Metabolic wastes diffuse to the outside of the organism. Ammonia is the principal nitrogenous waste material, and the amount eliminated varies directly with the amount of protein consumed.

The protozoa occur in the free-living state and as parasites. Free-living protozoa occur wherever moisture is present. They are found in both fresh and salt water, in the soil and decaying organic matter. It has been observed that they can tolerate excessive cold but easily killed by extreme heat.

Most of the protozoans live either in fresh or salt water, some groups live in both. Radiolarians are exclusively marine forms. Foraminiferans are mostly marine forms. Heliozoans are typically fresh water forms with few marine representation. Protozoans in the soil encyst during unfavorable conditions and they excyst under favorable conditions. Parasitic forms occur in all classes of protozoa-Mastigophora, Sarcodina, Sporozoa and Ciliata. The class Sporozoa contains exclusively parasitic forms.

1.1.4 STRUCTURE

The body of protozoans is usually bounded by cell membrane. The rigidity of the body and its shape are largely dependent on the nature of cytoskeleton. The cytoskeletons are not always located immediately below the cell membrane. The cytoskeleton together with the cell membrane and other organelles, forms the pellicle (a sort of protozoan cell wall). Protozoan skeletons can also be exoskeletons. They may be secreted onto the outer surface of the cells. Exoskeletons are usually called testa.

The majority of protozoa have a single nucleus. One nucleus is large and is called as macronucleus. The other is smaller and is called as micronucleus. The micronucleus lies close to the macronucleus. The macronucleus is associated with the vegetative function and the micronucleus with the reproductive function.

The protozoan locomotor organelles include flagella, cilia or flowing extrusions of the body called pseudopodia. These are the distinguishing characters of the protozoans.

1.1.5 NUTRITION

All types of nutrition occur in protozoa. The modes of nutrition are of four types: holozoic, holophytic, saprozoic and parasitic. In holozoic nutrition, small organisms like bacteria, algae, diatoms and other protozoa form the food. Many protozoans ingest food particles or prey and digest them intracellularly within food vacuoles. Food reaches the food vacuole often through a cell mouth or by engulfment. In flagellates, there is a definite mouth or cytostome at the base of the flagellum. The food particles are driven towards mouth by the lashing movements of the flagellum. In choanoflagellates, there is a funnel like structure surrounding the base of the flagellum. The flagellar movements waft the small organisms into the funnel. In sarcodines, mouth or digestive tract is absent. Small organisms are caught by the pseudopodia. Food is digested in the food vacuole.

In ciliates, there is a well-developed mouth or cytostome leading into a specialized part, the gullet or cytopharynx. Ingested food enters a vesicle or food vacuole. The food binds in the food vacuole and fuses with the primary lysozymes already present in the cell (Fig.1-1). Fusing results in the release of lysosomal and hydrolytic enzymes into the vacuole. Digestion occurs in the food vacuole and products of intracellular digestion diffuse into the cytoplasm. The undigested material is released from the cell to the exterior. The residual vesicle fuses with the cell membrane and are discharged to the exterior of the cell in a process called exocytosis.

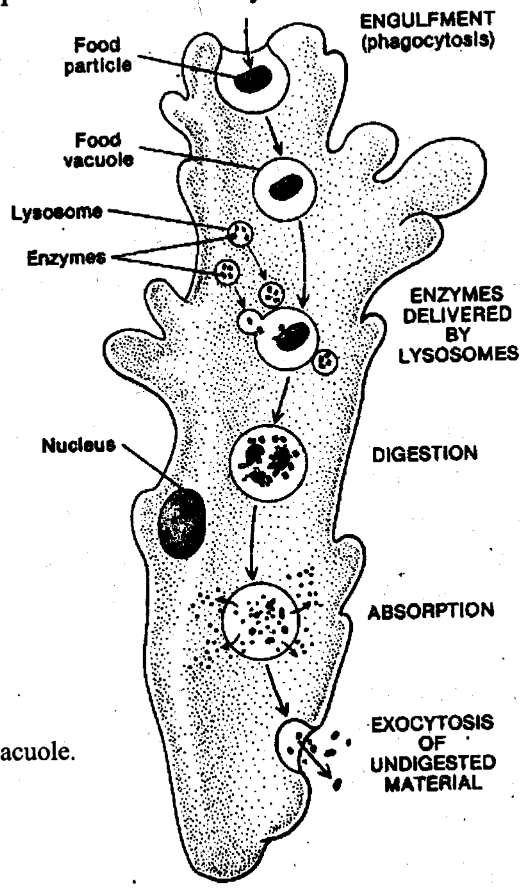

Fig. 1-1.
Digestion within a food vacuole.

In holophytic nutrition, the nutrition process is effected with the help of chlorophyll. This process is similar to that of photosynthesis in plants. This type of nutrition is characteristic of phytomonadin flagellates. Pyrenoids are associated with this nutrition. They help in the formation of reserve food.

In saprozoic nutrition, the food, which is not solid, is absorbed by diffusion through body surface. Saprozoic animals live in media containing decaying organic matter. Mouth is absent in them. The nutritive substances enter protozoan cells in a variety of ways. The extra cellular materials enter the cell in minute pits on the cell membrane. Later these pits pinch off internally, a process called endocytosis. The nonspecific form of endocytosis (in which the rate of uptake is in proportion to the external concentration of the material being absorbed) is called pinocytosis. Water, ions and smaller molecules may be taken in through pinocytosis. The engulfment of bacteria and other small protozoa is known as phagocytosis.

1.1.6 LOCOMOTION

Several types of locomotor organelles occur in the Phylum Protozoa. In most of the protozoa, the locomotor organelles also serve for food capture. Flagella and cilia are the locomotor organelles in the flagellates and ciliates. The flagellum is an whip like extension of the cytoplasm. It contains an axial filament, axoneme surrounded by a contractile protoplasmic sheath. The number of flagella may vary from 1 to 8 or more in various groups. When there is a single flagellum, it arises from the anterior end or from near the posterior end (*Trypanosoma*). Numerous flagella are present in hypermastigotes (*Trichonympha*). In parasitic flagellates (*Trypanosoma*), an undulating membrane extends between the flagellum and to the extreme anterior end (in addition to flagellum). In some dincflagellates (*Ceratium*), there is a longitudinal flagellum and a transverse flagellum. Both flagella and pseudopodia occur in some mastigophorans (*Mastigamoeba*). Few of these possess pseudopodia in one phase of life cycle and flagellum in another phase.

Pseudopodia occur in the sarcodines. Pseudopodia are the temporary extensions of the cytoplasm. Basing on the difference in form and structure, pseudopodia are classified into 4 types:

Lobopodia, lobe like pseudopodia with broad, round ends having both the ectoplasm and the endoplasm (as in *Amoeba*)

Filopodia, more or less filamentous and composed of ectoplasm only (as in *Allogramia*)

Reticulopodia, also filamentous and thread like (as in *Globigerina*). They branch and anastomose to form network. This type occurs in foraminiferans.

Auxopodia, more or less straight and radiating pseudopodia and composed of ectoplasm. The fine and needle like pseudopodia are called auxopodia. (as in *Actinophrys* and *Actinospherium*). These are characteristic of heliozoans.

In the ciliates, the locomotor organelles are the cilia. These are like flagella. These are the protoplasmic projections. These are shorter and many arising from basal granules lying in the cortex. In Holotricha, cilia are usually arranged in longitudinal, oblique or spiral rows and cover the whole body. In Hypotricha and Peritricha, cilia are restricted to certain regions. Also, in Hypotrichia, cilia are fused to form cirri. They are restricted to ventral region. In Suctoria (sessile forms), cilia are present in the young stage and absent in the adult. The locomotor organelles in various groups serve the active locomotion and food catching function.

1.1.7 REPRODUCTION

In Protozoa reproduction takes place by asexual and sexual methods. Asexual reproduction takes place by a process of binary fission, budding and multiple fission.

Binary fission – in this process the parent divides into two nearly equal daughter cells. This occurs in *Amoeba, Arcella, Difflugia* etc.

In flagellates the division is longitudinal. This occurs in *Paramecium.* The division is transverse in few forms (*Polystoma* etc. and certain dinoflagellates).

In ciliates the division is usually transverse. In *Opalina* and *Actinosphaerium,* the body divides into two without any relation to the number of nuclei. This kind of division is known as plasmotony.

Budding may be exogenous (as in *Noctiluca* etc) or endogenous (*Tokophyra* and in certain suctorians).

Multiple fission (or spore formation or schizogony) occurs typically amongst sporozoans. In this process the parent nucleus divides into a number of daughter nuclei. Then, the cytoplasm aggregates around the bits of nuclei, resulting in a number of daughter cells. Thus, the parent gives rise to a number of daughter individuals by multiple fission. Many protozoa reproduce by sexual mode in a manner, which is comparable to the reproduction of higher animals. Two individuals or gametes unite and their nuclei may fuse into one. This fusion is known as syngamy and the cell resulting from such union is called a zygote. Its nucleus is called synkaryon. If the uniting gametes are similar in size and form, they are called isogametes and if they are dissimilar, they are called anisogametes. The union of isogametes is termed isogamy and the union of anisogametes is anisogamy. The larger anisogamete is known as macrogamete and the smaller is the microgamete. The temporary union of two individuals for the nuclear exchange is known as conjugation. This is found in ciliates. The uniting individuals known as conjugants, may be unequal as in *Vorticella* and equal as in *Paramecium.* The occurrence of nuclear reorganization in an individual (without nuclear contribution from another individual) is known as endomixis.

1.1.8 MASTIGOPHORANS (FLAGELLATES)

The flagella of some species of phytoflagellates, such as *Ochromonas*, bear stiff lateral fibrils, called mastigonemes, which cannot be seen with ordinary light microscope. Mastigonemes probably function to reverse water propulsion.

Mastigophorans that have thin, flexible pellicles are often capable of amoeboid movement. Some forms, such as Chrysomonads, may cast off their flagella and assume an amoeboid type of locomotion entirely. Many flagellates cannot be classified as strict autotrophs or heterotrophs, because intermediate condition exists in some forms.

For instance, some species such as *Euglena* are strictly photoautotrophic and can synt[illegible] organic compounds from inorganic sources. It can also become saprophytic in the absence of light and even loses its pigments. *Haematococcus* is holophytic in the light and also saprophytic in the dark.

A number of chrysomonads and some dinoflagellates are both autotrophic and heterotrophic. Strict heterotrophic nutrition occurs in zooflagellates.

Biology of flagellata groups:

Flagellates vary so greatly in structure and have distinct anterior and posterior ends. Most are free swimming but there are some sessile forms. There are also many species that are colonial.

Euglenophyceae:

Marine and fresh water for[illegible]. Contain chlorophyll and are classified with the green algae in the chlorophyta. The genera *Pera[illegible]a* and *Euglena* (Fig. 1-2) contain perhaps the familiar flagellates. Body is elongated with an evagination (reservoir) at the anterior end, two flagella arise from its wall. One flagellum is very small and it terminates at the base of the long flagellum. In the colorless *Peranema*, both flagella are long but one trails backwards. Nutrition in *Peranema* is holozoic and it can ingest living organisms including *Euglena.*

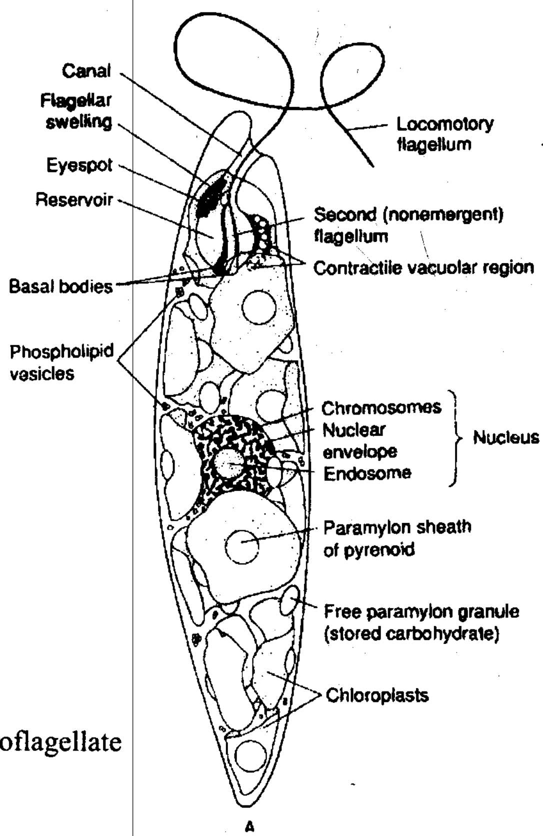

Fig. 1-2.
Structure of the phytoflagellate *Euglena gracilis.*

Chlorophyceae:

The large group of marine and fresh water green algae. It includes non-motile filamentous and thalloid forms, as well as some flagellates. The cells are bounded by a cellulose wall and are similar in organization to those of multicellular green plants. Among the flagellate groups, some are solitary, such as *Chlamydomonas,* and others are colonial. In colonial forms such as *Gonium, Pandorina* and *Eudorina*, the cells composing the colony varies from 4 to 64 and are held together by mucoid material.

Dinoflagellates:

Marine and fresh water dinoflagellates. These are allied with the brown algae and diatoms by the presence of xanthophyll pigment (that gives them a brown or golden brown color) and by the absence of chlorophyll b (chlorophylls a and c are present). They are roughly ovoid and typically possess two flagella. *Gymnodinium,* is said to be unarmored **and naked.** Armored dinoflagellates have well developed theca. The armor is like projections in ***Ceratium***. ***Noctiluca*** is large and aberrant.

Choanoflagellida:

Marine and fresh water zooflagellates that contain a **number of colonial forms.** These are peculiar in having a cylindrical collar around the base of the single flagellum (Fig. 1-3A). The collar is composed of rod like pseudopodia and filter fine particles from the water current produced by the beating of the flagellum. The particles are then engulfed. Many of these colonies are sessile and attached to the substratum directly or by a stalk. In *Proterospongia* (Fig. 1-3B), however, the colony consists of a gelatinous mass into which the flagellated collar cells are embedded. These are of particular interest as being the possible ancestors of sponges, which also possess collar cells.

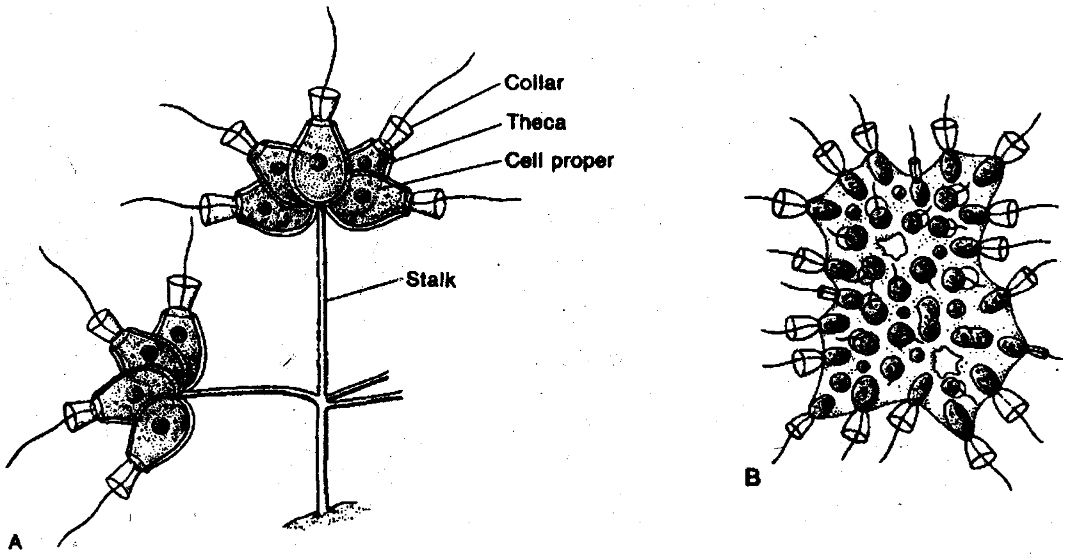

Fig. 1-3. Choanoflegellates, in which the flagellum is surrounded by a collar of microvilli. **A,** A stalked species. The stalk is an extension of a vaselike theca that surrounds the cell proper. ***B, Proterospongia,*** a colonial species, in which the individuals are connected by a jelly-like matrix.

Kinetoplastida:

Free living species as well as important parasites. All possess an organelle called a kinetoplast. Trypanosomids are gut parasites of insects and blood parasites of vertebrates. Only the anterior flagellum is present, the second flagellum being represented by a basal body. Commonly the flagellum trails and is connected along the sides of the body by an undulating membrane.

Man is the primary host for *Leishmania.* It is transmitted by sand flies and causes the disease leishmaniasis, or kala-azar, characterized by loss of hair, enlargement of the spleen and liver and other symptoms. Species of *Trypanosoma* (Fig. 1-4) cause African sleeping sickness and tropical American

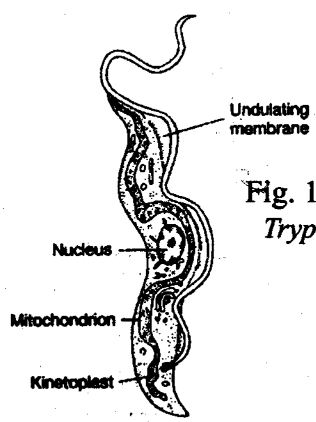

Fig. 1-4. Kinetoplastid- *Trypanosoma brucei.*

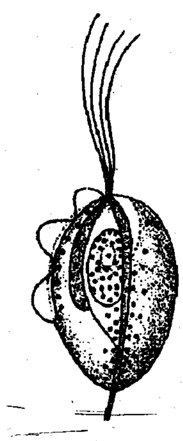

Fig. 1-5. *Trichomonas vaginalis,* a trichomonad, parasitic in the human vagina and male reproductive tract. In addition to the four anterior flagella, there is a trailing flagellum bordering an undulating membrane.

Chagas' disease. The infected person is afflicted with fever and brain symptoms, such as lethargy. Transmission is by blood-sucking bugs (Chagas' disease) and tsetse flies (Afrcian sleeping sickness).

Metamonad flagellates:

Few free living species (*Hexamita*) and some are parasitic in the gut or genital tract of vertebrates (*Trichomonas*) (Fig. 1-5).

1.1.9 SARCODINES

Adults possess flowing extensions of the body called pseudopodia. Pseudopodia are used in capturing prey in all Sarcodina, and in benthic groups, pseudopodia are also used as locomotor organelles. It includes the familiar amoebas as well as many other marine, fresh water and terrestrial forms. However, the skeletal structures, which are found in the majority of species, reach a complexity and beauty that is surpassed by few other animals.

There is an evidence of a close phylogenetic relationship between the Sarcodina and the Mastigophora. As already mentioned, many mastigophorans undergo amoeboid phases in which the flagellum is lost and movement is achieved by pseudopodia. The presence of flagellated gametes among many sarcodines and the tendency of loosing flagella during their life cycle in flagellates would seem to indicate that the Mastigophora is the ancestral group.

Amoebae are naked or enclosed in a shell. The naked amoebas, which include the genera *Amoeba* (Fig. 1-6), *Pelomyxa* live in sea, fresh water and soil. Asymmetrical and constantly change their body shape. Some giant species reach several mm in length. Cytoplasm is divided into stiff ectoplasm and fluid endoplasm. Pseudopodia are off 2 types:

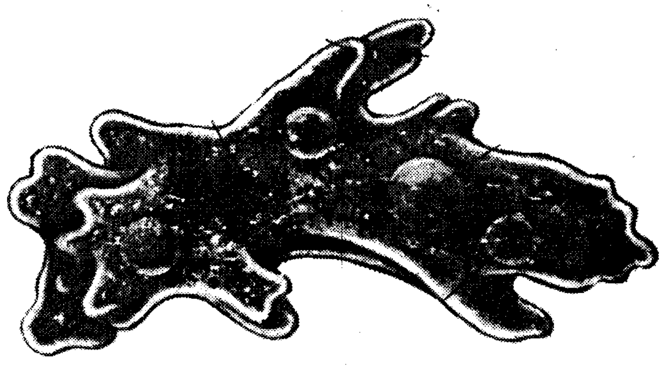

Fig. 1-6. *Amoeba*

Lobopodia – typical of most amoebas, wide with rounded or blunt tips or tubular composed of both ectoplasm and endoplasm.

Filopodia – present in small amoebas. Tend to have pointed ends. Consist of ectoplasm only.

In shelled amoebas, which are inhabitants of fresh water, damp soil, the shell is secreted by the cytoplasm, it is either chitinoid or siliceous or is composed of foreign materials embedded in a cementing matrix. The amoeba is attached to the inner wall of the shell by protoplasmic strands and there is a large opening through which the pseudopodia or body can be protruded. In *Arcella* (Fig. 1-7A and B),

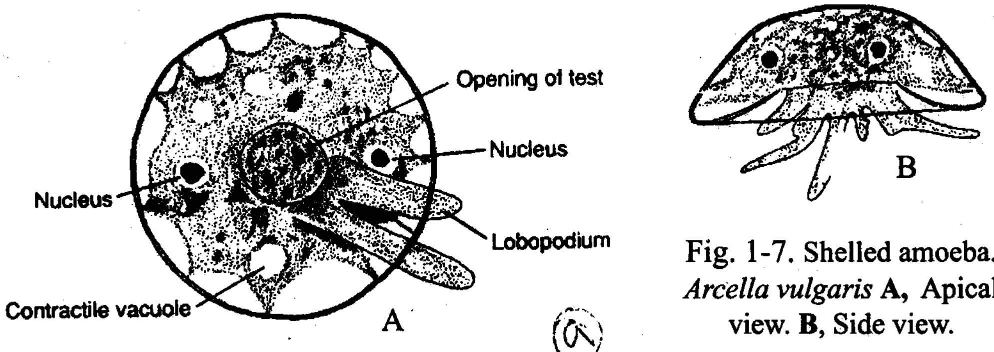

Fig. 1-7. Shelled amoeba. *Arcella vulgaris* **A**, Apical view. **B**, Side view.

one of the common fresh water amoeba, the chitinoid shell has the shape of a flattened dome with the aperture underside. In *Euglypha* the secreted shell is constructed of round siliceous, often spiny scales. In *Difflugia* the shape of the shell is like an egg with an aperture located at one end.

Foraminiferans are primarily marine forms. They occur in great number in the sea. Pseudopodia are thread like, branched and interconnected and are called reticulopodia. Shell is composed of foreign material or secreted calcium carbonate. The structure of the shell is quite different from that of the shelled amoebas. Some species live within a single chambered shell (unilocular). Some species live within a shell having many chambers (multilocular). Multiclocular form begins life as a single chambered form, but as growth increases the protoplasm overflows through the opening of the first compartment and secretes another. This results in a series of chambers, each longer than the preceding one. The shells may look like an onion, or a string of beads or like a snail. Multiclocular forms are not colonies but represent single individuals. Many are visible to the naked eye, planktonic forms have more delicate shells than benthic forms and the shells commonly bear spines.

Heliozoans are called Sun animalcules. Fresh water and may be floating or benthic. Benthic forms are stalked. Fine needle like pseudopodia, called axopodia radiate from the surface of the body. Each axopod contains a central axial rod, which is covered with a granular, adhesive cytoplasm. The body of a heliozoan consists of 2 parts: outer ectoplasmic sphere called cortex which is greatly vacuolated and inner endoplasm called medulla which has 1 to many nuclei and bases of axial rods. The axial rods may be attached to the membranes of a single nucleus as in *Actinophrys* or to numerous nuclei as in *Actinospherium* (Fig. 1-8) and *Camptonema.* Or they may have no connection with the nuclei, the axopodia originating from a central granule, called a centroblast. When the skeleton is

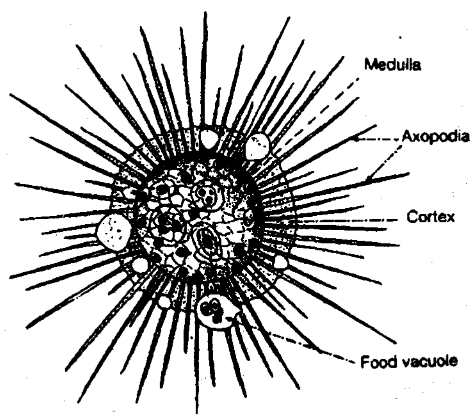

Fig. 1-8. A multinucleate heliozoan, *Actionsphaerium eichomi.*

Asexual reproduction by multiple fission and sexual reproduction by syngamy, followed by spore formation.
Sporozoites/spores are the infective stages.
Polar filaments are absent.

1.2.5.1. CLASS TELOSPOREA OR SPOROZOEA

Pseudopodia are absent and locomotion by gliding or body flexion.
Spores without capsules or filaments, naked or encysted.
Adult trophozoites with one nucleus.
Reproduction is both asexual and sexual.

ORDER – 1 GREGARINIA

These are the parasites of gut and body cavity of invertebrates.
Mature trophozoites are large and extra cellular (in the host's gut and body cavities).
Reproduction is sexual with progeny, spores contain eight porosities.
Gregarina, Monocystis (common parasite of earthworm's seminal receptacle)

ORDER – 2 COCCIDIA

Mature trophozoites are small and intracellular.
Female gametes hologamous.
Sporozoites multiply by schizogony in tissue cells.
Eimeria, Plasmodium, Isospora

1.2.5.2. CLASS TOXOPLASMEA

Spore formation is absent.
Reproduction asexual by binary fission.
Cysts with many naked sporozoites. No flagella or pseudopodia.
Toxoplasma, Sarcocystis

1.2.5.3. CLASS HAPLOSPOREA

Spores are present.
Pseudopodia may be present but flagella absent.
Reproduction only by asexual means.
Parasites of fish and invertebrates.
Ichthyosporidium, Haplosporidium

1.2.6 SUB PHYLUM CNIDOSPORA

All species are parasitic.
Adult trophozoite has many nuclei.
Spore formation occurs throughout life.
Spores with polar filaments. The polar filaments are coiled threads and can be shot out.
Zygote gives rise to one or more trophozoites without sporogony.

1.2.6.1. CLASS MYXOSPORIDEA

Spores develop from several nuclei and enclosed in two or three valves.
Polar capsule is present.

ORDER – 1 MYXOSPORIDA

Spores are large with a bivalved membrane.
Trophozoite amoeboid and not intracellular.
Polar capsule with one, two or four filaments.
Myxidium

ORDER – 2 ACTINOMYXIDA

Spores large with a trivalved membrane.
Polar capsule with three filaments.
Triactinomyxon

1.2.6.2. CLASS MICROSPORIDEA

Spores develop from one nucleus.
Spores small and enclosed in a single valve.
Polar capsule absent or if present with one or two filaments.
Nosema

1.2.7 SUB PHYLUM CILIOPHORA

The ciliates comprise the largest subphylum of Protozoa. Some 8000 species have been described and many groups are still not well known. They are also the most animal like and exhibit a very high level of organelle development.

They posses a definite body shape. The body wall is a complex living pellicle. It contains alveoli, trichocysts and other organelles, in addition to infraciliature.

The body surface is covered with uniform cilia, which help in locomotion.

The cilia around the cytostome region have become specialized to become membranelles and undulating membranes in many ciliates that employ in filter feeding.

Most of them have two types of nuclei – a larger macronucleus and smaller micronucleus.

One or more contractile vacuoles are present in fresh water forms.
Reproduction asexual by transverse binary fission.
Conjugation also takes place with fusion of nuclei.
The anal aperture or cytopyge is permanent.
No alternation of generation in the life cycle.

1.2.7.1 CLASS CILIATA

Cilia are present during whole or part of their life cycle.
Mouth or cytostome and cytopharynx are often present.
Nutrition is holozoic.

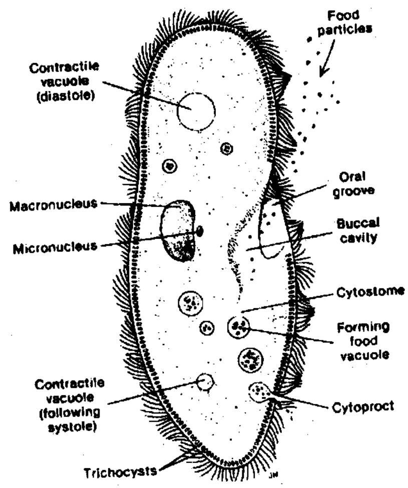

Fig. 1-10.
Structure of *Paramecium.*

1.1.12 SUMMARY

The protozoa are a heterogeneous assemblage of some 80,000 single-cell organisms. Because most are motile and many are heterotrophic, this assemblage was treated as a single Phylum Protozoa.

They inhabit the sea or fresh water, but there are many parasitic, commensal and mutualistic species.

The protozoan cell possess all typical cellular structures and carries out all basic cellular processes. But a protozoan, although unicellular, is also a complete organism, carrying out all functions found in multicellular animals.

Digestion occurs intracellularly within a food vacuole and food reaches the vacuole through a cell mouth or by engulfment.

Excess water is usually eliminated by a contractile vacuole, which is characteristic of many protozoa.

Contractile vacuoles are water-balancing structures, acting as pumps to remove excess water from the cytoplasm. They periodically contract, releasing their fluid contents to the outside. One to several contractile vacuoles may be present and the position and structure vary in different groups.

Contractile vacuoles are more common in fresh water forms. However, they are also present in some marine groups and in certain parasites.

Their type of locomotor organelles, flagella, pseudopodia or cilia distinguish most of the members of the protozoan phyla, in part.

Reproduction by fission occurs at some time in the life history of almost all protozoa. Meiosis, gamete formation and fertilization have been observed in many species, but the nature of these events and their occurrence in the life cycle of the organism is highly variable.

Encystment is common.

Flagellates are distinguished by the presence of one or more flagella.

They have been conveniently divided into phytoflagellates and zooflagellates.

Phytoflagellates usually bear one or two flagella and typically possess chloroplasts. These organisms are thus plant like and usually holophytic or autotrophic, such as chrysomonads, euglenoids and volvocids. In addition to the chlorophyll they contain color pigments, xanthophylls. When other pigments do not mask the chlorophyll, a flagellate appears green in color as in phytomonads and euglenoids. If the xanthophylls dominate, the color is red, orange, yellow or brown.

Zooflagellates possess one to many flagella, lack chloroplasts and are either holozoic or saprozoic (heterotrophs).Few are free living but most are parasitic, commensal or mutualistic in other animals.

Flagella (and cilia) are composed of microtubules surrounded by the plasma membrane. The arrangement of microtubules in which 9 pairs surround the two central microtubules is with few exceptions characteristics of flagella and cilia in all eukaryote organisms. Movement of the organelle is thought to result from the gliding of microtubules relative to each other. Each flagellum (or cilium) arises from a basal body or kinetosome.

Phytoflagellates store reserve foods, such as oils or fats, or they may store carbohydrates in the form of typical plant starch (as in phytomonads), paramylum (in euglenoids) or leucosin.

In zooflagellates, glycogen is the usual reserve food product.

Three zooflagellate groups of special note are:

a) Marine and fresh water choanoflagellates, which have the base of the flagellum surrounded by a collar.
b) Trypansomes, blood parasites of mammals, which are responsible for leishmaniasis, African sleeping sickness and Chagas' disease.
c) Hypermastigotes, gut symbionts of wood roaches, termites and cockroaches which digest the cellulose of the wood consumed by their host.

Fission is longitudinal in most flagellates. Life cycles involving sexual reproduction are highly variable.

Amoeboid protozoa are distinguished by the presence of psuedopodia. The pseudopodia are used in feeding and, in some, for locomotion. Depending on their shape and structure, the pseudopodia are named as lobopodia, filopodia, reticulopodia and auxopodia.

Naked amoebas are the marine, fresh water and parasitic forms. They have no special skeletal structures and possess commonly tubular lobopodia.

Shelled amoebas, which are found in the sea, fresh water and soil are covered by a shell. A large opening permits the protrusion of lobopodia or filopodia.

The benthic foraminiferans posses a calcareous test, which is usually multichambered. They possess long, delicate and often anastomosing reticulopodia.

Heliozoans, which are benthic fresh water and marine species, possess long, needle like pseudopodia (axopods). The axopods arise from the inner medulla and extend through outer cortex. The cortex often contains a siliceous skeleton of plates, tubes and needles.

The fresh water, marine and naked amoebas have no special skeleton. They are with tubular pseudopodia used for both locomotion and feeding.

The shelled amoebas are restricted to freshwater. They possess long, delicate pseudopodia. Foraminiferans are marine forms. They possess a calcareous test, which is usually multichambered.

The radial, floating, fresh water, benthic heliozoans possess long, radiating, needle like pseudopodia (radiating). The body shows an inner medulla and outer cortex. The cortex contains a siliceous skeleton of needles, tubes or plates.

The spherical, marine, planktonic, relatively larger radiolarians contain radiating pseudopodia.

Body shows a central cortex that can be separated from extracapsular cytoplasm.

Their skeleton is made of silicon dioxide.

The Superclass Sarcodina is divided into two Classes Rhizopodea and Actinopodea, which in turn divided into five orders: Amoebida, Arcellinida, Foraminiferida, Radiolaria and Heliozoida.

The third class is Piroplasmea.

Piroplasmeans are parasites in RBC of vertebrates. They do not produce spores.

The subphyla Sporozoa and the Cnidospora contains parasitic protozoa.

The Sporozoa contains the gregarines, which are parasites of insects and vertebrates and the coccidians, which are intracellular parasites of gut and blood cells of vertebrates and invertebrates.

Some species possess spore like infective stages. Life cycle is complex. It involves fission (schizogony), sexual reproduction (gamogony) and spore formation (sporogony).

It is divided into three classes, the Telosporea, theToxoplasmea and the Haplosporea. The class Telosporea is divided into two orders: Gregarinia and Coccidia.

The Subphylum Cnidospora includes amoeboid extracellular parasites of fish and intracellular parasites of insects.

The name Cnidospora is derived from the spore that contains evertible filaments.

It is divided into two classes: Myxosporidea and Microsporidea. The class Myxosporidea is divided into two orders, the myxosporida and the actinomyxida.

The Subphylum Ciliophora is the largest of the Phylum Protozoa.

Ciliates are widely distributed in both fresh and marine waters. There are also many ecto- and endo commensals and some parasites.

The body wall of ciliates is a complex living pellicle containing alveoli, trichocysts and other organelles.

The buccal cilia have become specialized as compound ciliary organelles called membranelles and undulating membranes.

In many ciliates these are employed in suspension feeding.

Suspension feeders feed on bacteria and other particles.

Carnivorous forms feed on other protozoa and microscopic animals.

The cell mouth or cytostome and cytopharynx open into a food vacuole. The undigestible matter is discharged through a fixed cell anus (cytoproct).

Ciliates reproduce asexually by transverse fission and sexually by conjugation.

Exchange of micronuclei, fusion of migratory micronucleus and non-migratory macronucleus to form a zygote nucleus are observed in conjugation.

Meiotic divisions of one micronucleus precede conjugation. Meiosis is followed by reconstitution of normal nuclear condition that may involve fission.

The Subphylum Ciliophora is divided into a Class Ciliata.

Ciliata is divided into four orders, the Holotricha, the Peritricha, the Suctoria and the Spirotricha.

1.2.9 KEY TERMINOLOGY

Blepheroplast: Basal body in flagellates from which the flagellum arises.

Choanoflagellate: A flagellate, which is peculiar in having a collar around the base of the single flagellum.

Flagellum (Cilium): Characteristic of any protozoans and metazoan cells. It is typically long and its motion is a complete whip like undulation.

Mastigophoran (Flagellata): Protozoan that possess flagella in adult organelles.

Phytoflagellate: Usually bear one or two flagella and typically possess chloroplasts. Plant like organism.

Trichocysts: Peculiar, rod like or oval organelles characteristic of many ciliates. These are used in defense or food capturing prey.

Zooflagellate: Usually bear one to many flagella. Lack chloroplasts. Animal like organism.

1.2.10 SELF ASSESSMENT QUESTIONS

1. Classify the Phylum Protozoa upto orders with two examples for each order.
2. Classify the Subphylum Sarcomastigophora upto orders with two examples for each order.
3. Classify the Subphylum Sporozoa upto orders with two examples for each order.
4. Classify the Subphylum Ciliophora upto order level with suitable examples.
5. Write short notes:

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1.2 CLASSIFICATION OF PHYLUM PROTOZOA

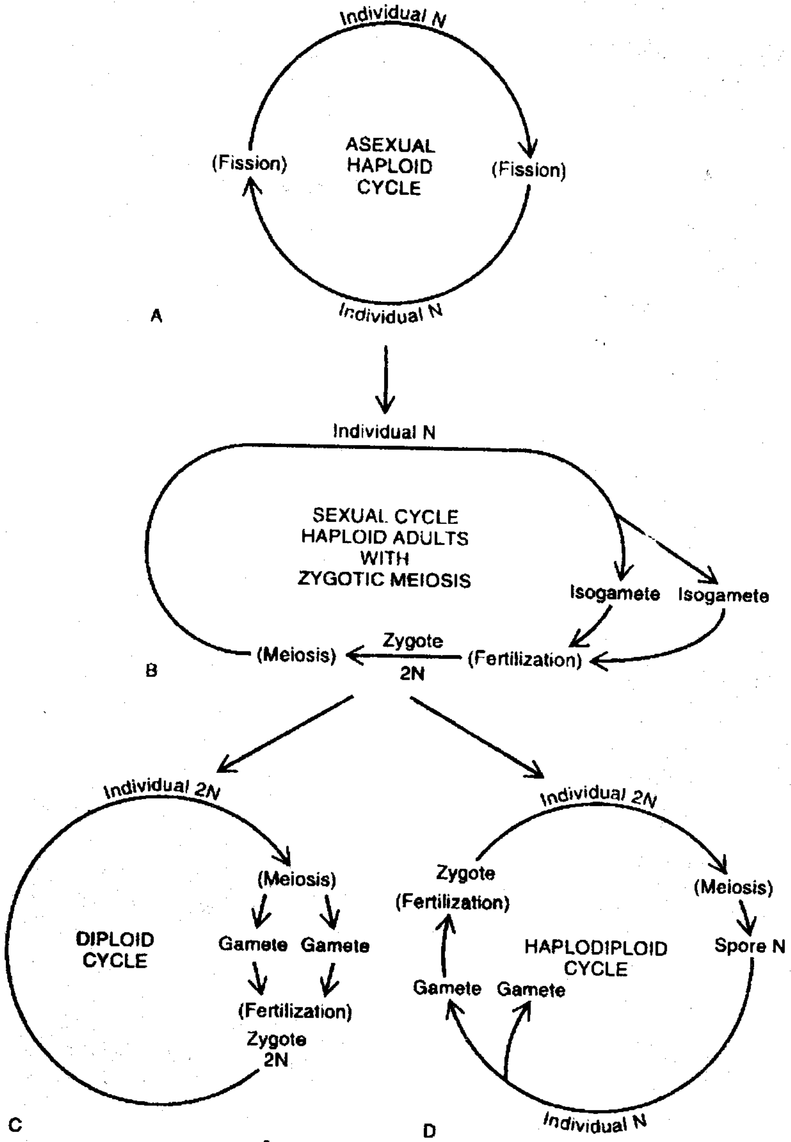

Fig. 1-15. Protistan life cycles. **A,** A primitive eukaryote life cycle in which new individuals are produced solely by fission. Illustrated among living species by the trypanosomatids. Fusion of two individuals could have led to life cycles **(B)** in which isogametes form a diploid zygote. The zygote then undergoes meiosis to form haploid individuals. Protists with this type of life cycle include the volvocids, many dinoflagellates, hypermastigids, and sporozozoans. Extension of the diploid phase could have led to a diploid cycle and a haptodiploid cycle. In the diploid cycle **(C)** which characterizes opalinids, some hypemastigids, heliozoans, many green algae, diatoms and ciliates, the adults are diploid and meiosis occurs in the formation of gametes. Citiates do not produce gametes but exchange haploid nuclei, which fuse. In the haplodiploid cycle **(D)**, found in coccoliths, many forams, and many algae, the formation of spores and diploid individuals alternate with haploid individuals.

In many protozoa, sexual reproduction has never been recorded. In others where sexual reproduction occurs it is not a common process. In primitive protozoans, haploid individuals may be reproduced only by fission (Fig. 1- 15A). Fusion of two similar haploid individuals results into a diploid zygote. The zygote may divide by meiosis to restore the haploid number and may produce 4 new cells. These are identical, flagellated gametes (isogametes) among protozoans. There are many protozoans in which adults are diploid and the life cycle involves fusion of isogametes to form a diploid zygote (Fig. 1- 15B). In these the zygote quickly divides by meiosis to produce haploid adults. When meiosis is delayed the diploid condition dominate in the life cycle. The haploid phase may be restricted to gametes and then they fuse to form a diploid zygote (Fig. 1- 15C). Such diploid life cycle is characteristic of ciliates.

In other protozoans haploid individuals alternate in the life cycle with diploid individuals (Fig. 1- 15 D). In such a haplodiploid life cycle meiosis does not occur in the formation of gametes.

But meiosis occurs in the formation of haploid spores. Haploid individuals arise from the spores and diploid individuals arise from the zygotes.

Encystment occurs commonly in the life cycle of many protozoa. Majority of fresh water species reproduce by encystment. The protozoan secretes a cyst around itself and becomes inactive. Depending on the species, the cyst protects the animal to withstand the unfavorable conditions like desiccation or low temperature. Encystment is a process of the simplest life cycle. It includes only two phases: an active phase and a protective, encysted phase. However, in the complicated life cycles, the encysted zygote undergoes special reproductive processes such as fission, gametogenesis or other processes.

Protozoa may be dispersed long distances in either the motile or the encysted stage. Wind, water currents and mud of water bodies and debris on the body of water birds and other animals are common vehicles of dispersal.

1.3.3 FLAGELLATED PROTOZOA

In the majority of flagellates, asexual and sexual reproduction occurs.

1.3.3.1 ASEXUAL REPRODUCTION

Majority of flagellates undergo asexual reproduction by binary fission. Most commonly they divide by longitudinal fission. When mirror-image daughter cells are produced, division is thus said to be symmetrogenic (Fig. 1- 16). In multiflagellate species the flagella are divided between the daughter cells. In some other species with few flagella, one or more flagella may duplicate prior to cell division. Flagella may be equally or unequally apportioned to each daughter cell in some species. In the same way other organelles are also distributed unequally. Thus, division in many flagellates is not perfectly symmetrogenic.

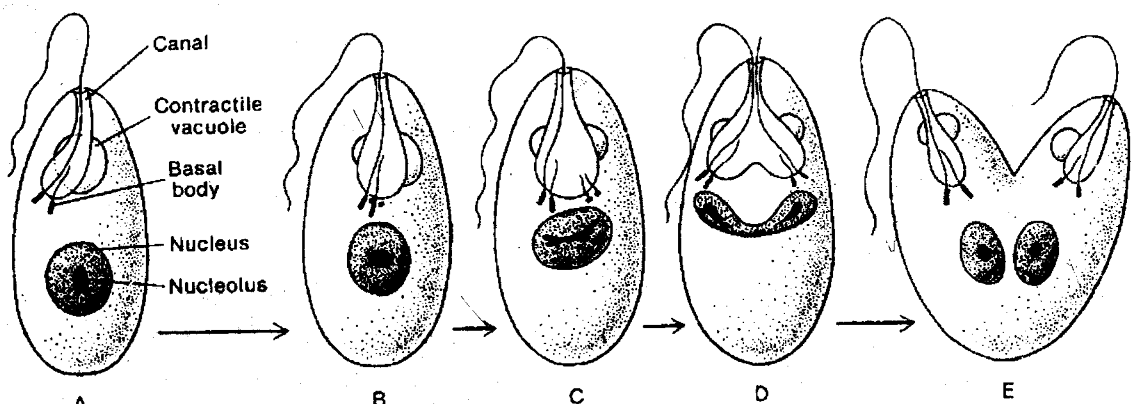

Fig. 1-16. Asexual reproduction (symmetrogenic division) in *Euglena*. **A,** The centriole has already divided. **B,** Each centriole produces a new basal body and flagellum, The nucleus is in prophase, and the contractile vacuole is double. **C,** The old pair of flagellar roots separate and fuse with the new roots. **D,** Mitosis proceeds, and the gullet begins to divide. **E,** Anterior end dividing following duplication of organelles.

In dinoflagellates, division is oblique. In armored species the two fission products regenerate the missing plates are regenerated in the two daughter cells. But in few species, such as *Glenodinium*, division occurs inside the parental envelope and the two naked daughter cells escape by rupturing the

***ORDER – 1 CHRYSOMONADIA (CHRYSOPHYTA)**

Small flagellates with yellow or brown chromoplasts.
One to three flagella.
Gullet is absent; stigma is present.
Nutrition is holophytic. Starch is absent but leucosin and fat droplets are present.
Siliceous cysts. Marine and fresh water forms.
Chromulina, Ochromonas, Synura

***ORDER – 2 COCCOLITHOPHORIDA (HAPTOPHYTA)**

Tiny marine flagellates covered by calcareous platelets called coccoliths.
Two flagella and yellow to brown chromoplasts.
No endogenous siliceous cysts.
Coccolithus, Rhabdosphaera

***ORDER – 3 HETEROCHLORIDA (XANTHOPHYTA)**

Two unequal flagella and yellow-green chromoplasts.
Siliceous cysts.
Heterochloris, Myxochloris

***ORDER – 4 CRYPTOMONADIDA (CRYPTOPHYTA)**

Compressed body with an anterior depression or reservoir.
A rigid pellicle.
Gullet reaches upto the middle of the body.
Two unequal flagella.
Green, yellow, brown or colorless chromatophores.
Stigma often presents.
Marine and fresh water.
E.g *Chilomonas* (a common colorless genus in polluted water), *Cryptomonas*

***ORDER – 5 DINOFLAGELLIDA (PYRROPHYTA)**

Small and planktonic.
Body naked or they possess a complex thickened pellicle, or theca that contains deposits of cellulose.
Distinguished by the presence of two flagella. An equatorial flagellum is located in a transverse groove called girdle and a posterior longitudinal flagellum is located in a longitudinal groove called sulcus.
Chromatophores are green, yellow or brown in color.
Reserve food is starch or oil.
There are complex vacuoles, which are not contractile.
Some are bioluminescent.
Mostly marine, some are parasitic.
Gymnodium, Ceratium, Noctiluca

*ORDER – 6 CHLOROMONADIDA (CHLOROMONODOPHYTA OR RHAPHIDOPHYTA)

Small and dorso-ventrally flattened.
Body covered with a delicate pellicle.
Two flagella, one trailing.
Numerous green chromatophores.
Reserve food is oil.
Stigma absent; complex.
Contractile vacuole present.
These are largely fresh water.
Gonyostomum

*ORDER – 7 EUGLENIDA (EUGLENOPHYTA)

Large and elongated. Body covered with thick and firm pellicle.
Anterior end with gullet leading into reservoir.
One or two flagella arising from an anterior recess.
Stigma present in colored forms.
Chromatophores green and numerous, sometimes colorless.
Reserve food is paramylon and oil.
Mostly fresh water forms.
Euglena, Peranema, Rhabdomonas

*ORDER – 8 VOLVOCIDA (CHLOROPHYTA: ORDER VOLVOCALES)

Small with rigid cellulose covering, theca.
Gullet absent.
Two or four apical flagella for cell.
Body with green, usually single cup-shaped chromoplast.
Reserve food is starch and oil.
Stigma present.
Some colorless forms.
Mostly fresh water forms. Many colonial species.
Volvox Chlamydomonas, (Fig 1-11) Pandorina, Eudorina

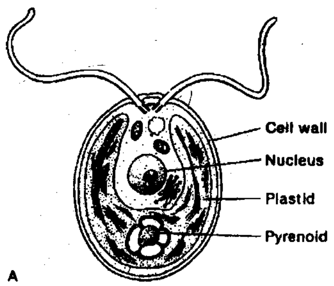

Fig. 1-11. *Chlamydomonas reinhardtii*, a noncolonial species.

Note: * Those groups treated as algae are preceded with an *, and the name of the algal phylum to which they belong is given in parentheses

1.2.4.1.B. CLASS ZOOMASTIGOPHOREA

Flagellates with neither chromoplasts nor leucoplasts.
One to many flagella, in most cases with basal granule complex.
Reserve food is glycogen.
Sexual stage is unknown.
Many commensals, symbionts and parasites

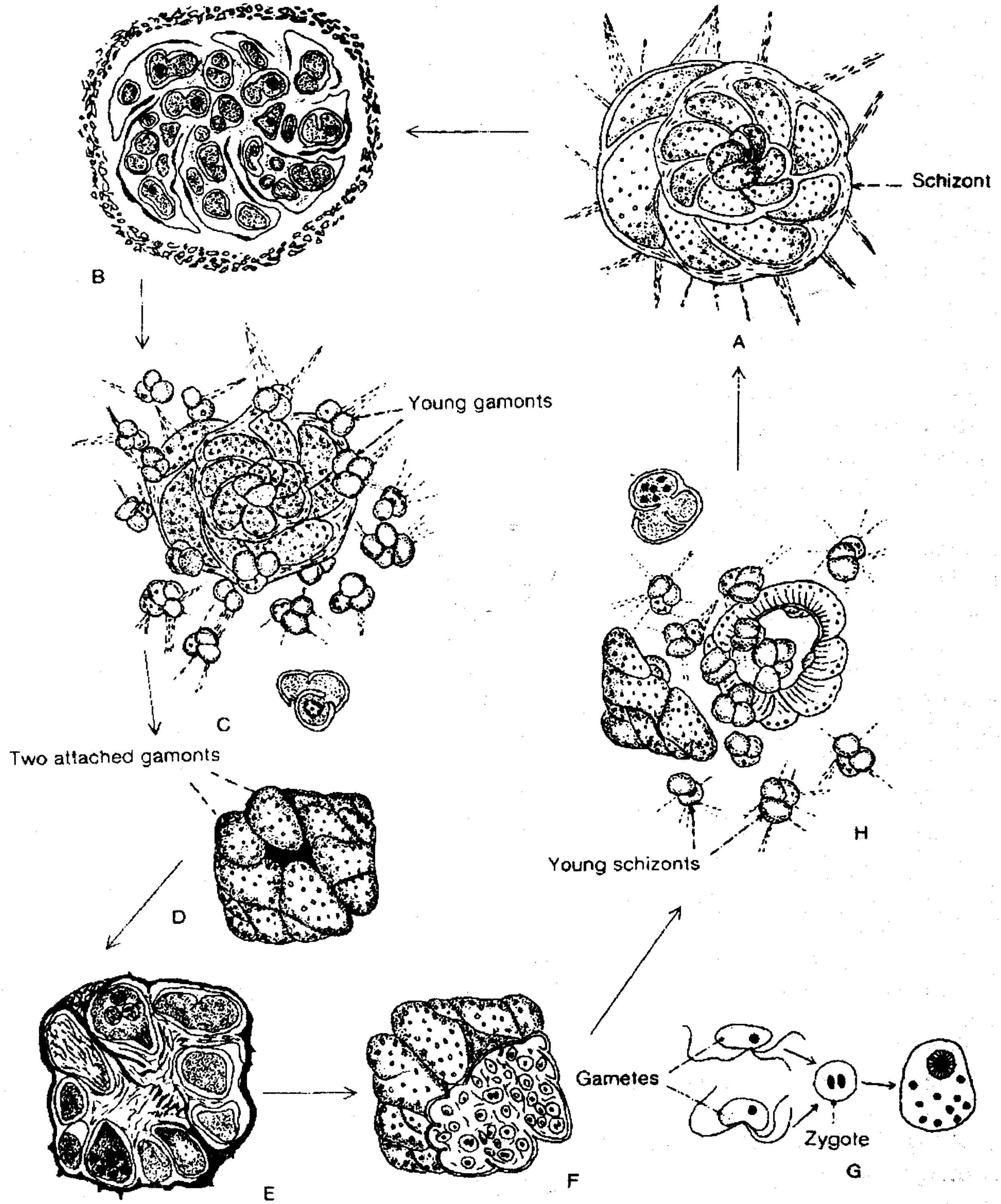

Fig. 1-18. Life cycle of the formainiferan, *Discorbis patelliformis,* **A,** Schizont. **B,** Asexual development of gamonts within chambers of schizont. **C,** Liberation of young gamonts from parent schizont. **D-G,** Formation and fusion of gametes within two attached gamonts. **H,** Separation of attached gamonts accompanied by liberation of young schizonts.

1.3.5 SPORE FORMING PROTOZOA

1.3.5.1 LIFE CYCLE

The life cycle is complex. It usually involves asexual and sexual generations (Fig. 1-19A) and sometimes two hosts. Generally the life cycle begins with the infection by a sporozoite into the host. The sporozoite develops into a trophozoite, which moves by gliding or flexion of the body. In some sporozoans, the trophozoites undergo multiple fission called schizogony. The resulting daughter cells known as merozoites, continue the infection of the host. Each merozoite may go through several additional cycles of schizogamy (schizogamy is repeated for a number of times at least in some well-known sporozoans). Each merozoite becomes a feeding trophozoite. Eventually the trophozoite divides by multiple fission to form gametes, which is called gamogony. These gametes may be similar or different, with male cell commonly flagellated. Gametes unite (zygosis) to form zygote. The zygote undergoes the meiotic division (sporogony) to form sporozoites. In some kinds thousands of sporozoites are formed. Thus, the life cycle can be divided into three phases: schizogony, an asexual multiplication of the parasite (trophozoite) following infection of the host; gamogony, the development of gametes; and sporogony, multiplication and formation of infective stages, typically sporozoites (Fig. 1-19A). The above pattern generally occurs, but innumerable variations are seen in this class. Sporozoa also possess some organelles of still uncertain function that are not encountered in other protozoa. Complex, rings, bands, and microtubes called polar organelles, are located at one end of the body.

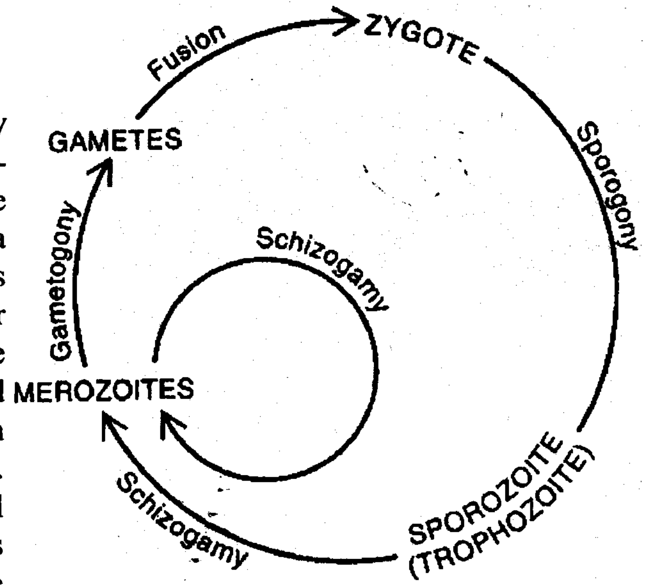

Fig. 1-19 **A**. Life cycle of coccidean sporozoans. All stages are haploid except the zygote, which undergoes meiosis in the formation of spores (sporogony). The ability of merozoites to produce more merozoites (merogony) constitutes an asexual cycle within the sexual life cycle.

The gregarines attain the largest size among the sporozoans. These members of the Sporozoa are extracellular parasites inhabiting the gut and other cavities of invertebrates, especially annelids and insects. Intracellular parasitic species are only a few microns long, but those that inhabit the body or gut cavities may reach 10 millimeters in length. The body of a gregarine trophozoite is elongate and may be divided into anterior and posterior portions by a membrane. Sometimes the anterior part possesses hooks, sucker or suckers, or simple filament or knob for anchoring the parasite into the host's cells. The host becomes infected through ingesting spores containing sporozoites of the parasites. Depending on the species, the liberated sporozites either remain in the gut of the host or penetrate the gut wall reach other areas of the body. In some species schizogony is present, but in many, including *Gregarina blattarum* of cockroaches and termites there is no schizogony. So these are unusual among Protozoa reproducing only by sexual reproduction. Whether there is schizogony or not, the trophozoite becomes a sexual form called a gammont. Two gammonts unite and is called syzygy. Then they form a common cyst. Formation of gametes and syngamy occur within the cyst, after which each zygote

Largely fresh water, some marine; many parasites.
Amoeba (Fig. 1-6), *Entamoeba*

ORDER – 2 ARCELLINIDA OR TESTACIDA

Body enclosed in a shell or test with an aperture through which the pseudopodia protrude.
Free living. Mostly fresh water forms.
Arcella, Euglypha, Difflugia

ORDER – 3 FORAMINIFERIDA

Chiefly marine species with mostly multi-chambered shells.
Delicate and granular reticulopodia.
Shells may be composed of tectin, which may incorporate foreign particles, but most commonly the shells are calcareous.
Shells with one or more openings through which reticulopodia emerge.
The reticulopodia are fine and branched forming a network.
Elphidium, Globigerina (Fig 1-12)

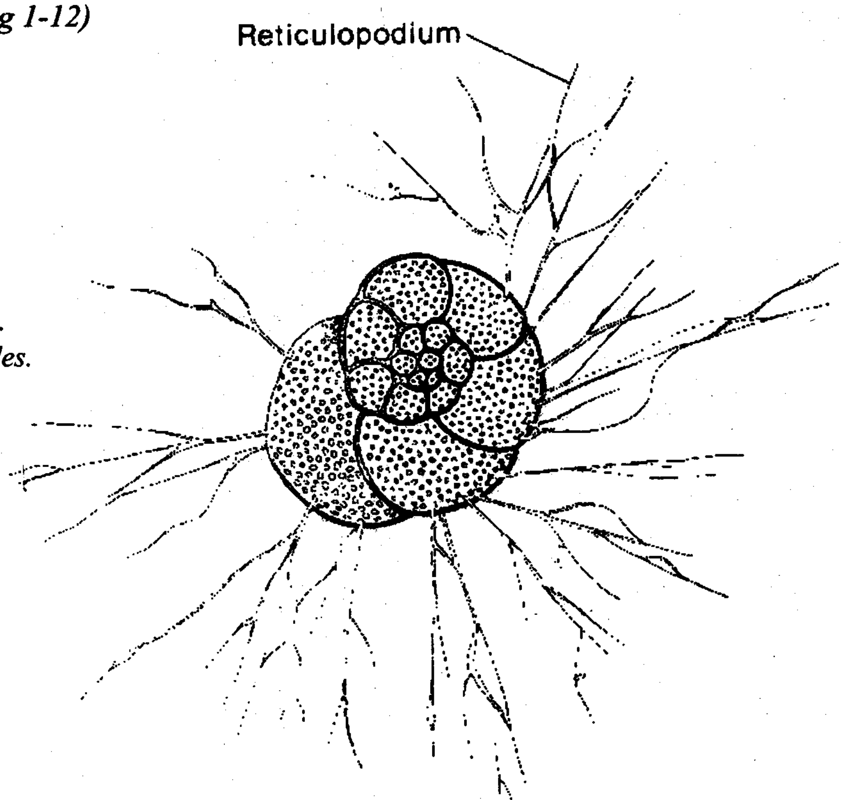

Fig. 1-12. Forminiferan.
Living *Globigerina bulloides*.

1.2.4.3.b. CLASS ACTINOPODEA

Sarcodines with pseudopodia radiating from a spherical body.
They are primarily sessile or floating forms.
The locomotory organelles are delicate axopodia with axial filaments.

Test may be present or absent.
Reproduction by both asexual and sexual methods.

ORDER – 1 RADIOLARIA

Body comparatively larger. One or more pores perforate central capsule.
Siliceous skeleton.
Axopodia or sometimes reticulopodia or filopodia are present.
Exclusively marine.
In *Acanthometra* non-chitinoid capsule is without pores. (Fig.1-13)
Collozoum, Sphaerozoum, Aulacantha

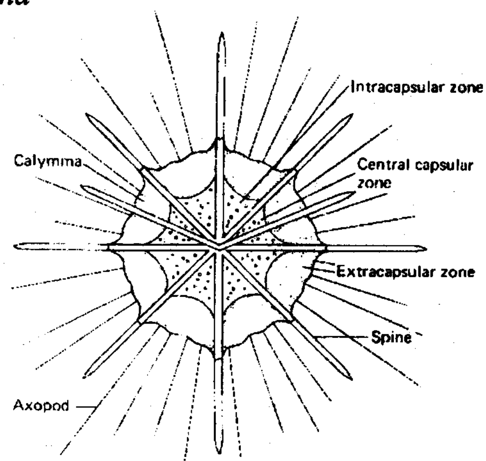

Fig. 1-13. *Acanthometra,* a radiolarian with a skeleton of radiating strontium sulfate rods.

ORDER – 2 HELIOZOIDA

Spherical animals without central capsule. Commonly called Sun-animalcules.
Radiating axopodia or filopodia.
Body cytoplasm is differentiated into outer vacuolated ectoplasm and inner dense endoplasm.
Naked or skeleton is absent. If skeleton is present, it is made up of siliceous scales and spines.
Primarily present in fresh water.
Actinophrys, Camptonema, Actinosphaerium

1.2.4.3.C. CLASS PIROPLASMEA

Small, round, rod-shaped or amoeboid.
Parasites in red blood corpuscles of vertebrates
Do not produce spores.
Babesia

1.2.5 SUB PHYLUM SPOROZOA

The Sporozoa is also referred as Apicomplexia. Sporozoans with apical complex at some stage. All species parasitic.
The locomotory organelles are absent in adults.
Cilia or flagella may be present in gametes.
Nutrition saprozoic.

secreted, the siliceous pieces assume a great variety of forms, such as plates, spheres, tubes or needles. Openings are present in the skeleton through which the axopods may project and is without any regard to the nature and arrangement of skeleton.

Radiolarians are entirely marine and primarily planktonic. They are relatively large protozoa. Some species are several mm in diameter. Some colonial forms attain a length of 20 cm (*Collozoum)*. Body is divided into outer and inner regions. The inner region has one to many nuclei and is bounded by a central capsule with a membranous wall of still uncertain but varying organic composition. The capsule membrane is perforated by openings, which may be evenly distributed or may be restricted to one to three regions (called pore fileds) of the membrane. The perforations allow the cytoplasm of the central capsule to be continuous with the cytoplasm of the outer divisions of the body. This extra capsular cytoplasm forms a broad cortex, called the calymma that surrounds the central capsule. Two types of skeletal structures are found. In one type, the skeleton is composed of long spines and needles that radiate from the capsule and extend beyond the outer surface of the body. In the second type, the skeleton is constructed in the form of lattice sphere, the lattice network is sculptured or ornamented with barbs and spines.

1.1.10 SPOROZOANS

They are parasitic. Some species possess spore like infective stage, from which the name Sporozoa was derived. It includes gregarines (parasites of insects and annelids) and coccidians (intracellular parasites of gut and blood cells of vertebrates and invertebrates). ***Plasmodium***, the causal agent of malaria is the most familiar coccidian. Cnidospora includes amoeboid extracellular parasites of fish or intracellular parasites of insects. Cnidspora is derived from the spore, which contains filaments that can be everted.

The life cycle is complex. It usually involves asexual and sexual generations (Fig. 1-9) and sometimes two hosts. A generalized life cycle might be described as beginning the infection with the trophozoite, which is taken into the host. The sporozoite develops into a trophozoite, which may move by gliding or flexion of the body. The trophozoite undergoes multiple fission called schizogony.

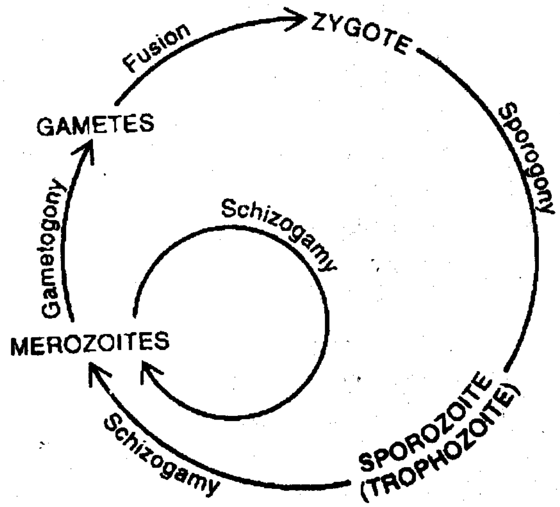

Fig. 1-9. Life cycle of coccidean sporozoans. All stages are haploid except the zygote, which undergoes meiosis in the formation of spores (sporogony). The ability of merozoites to produce more merozoites (merogony) constitutes an asexual cycle within the sexual life cycle.

The resulting daughter cells or merozoites, continue the infection of the host. Schizogony, at least in well-known sporozoans repeated number of times. Eventually, some merozoites give rise to gammonts, a process called gamogony. The gammonts ripen to gametes, with the male cell commonly flagellated. Gametes enter to form zygote and undergoes sporogony and thousands of sporozoites may be resulted. Thus the life cycle may be divided into 3 phases: a) Schizogony (asexual multiplication following the infection of the host), b) Gamogony (development of gametes) and c) Sporogony (multiplication and formation of infective stages, typically spores).

Although this pattern of life cycle is more or less basic for the class, there are innumerable variations. Complex rings, bands and microtubes called polar organelles, are located at one end of the body providing the origin for a new name for the subphylum, Apicomplexia.

Gregarines attain the largest size among sporozoans. These are the parasites of invertebrates, especially annelids and insects. Intracellular parasites are only a few microns long whereas parasites inhabiting body or gut cavity attain about 10 mm in length. The body of a gregarine trophozoite is elongated and may be divided into an anterior and posterior portion separated by a membrane. The anterior part possess hooks, suckers or simple filament or knob for anchoring the parasite into host cells.

Coccidians are intracellular parasites of vertebrates and invertebrates. They attack the intestinal epithelium, blood or other cells of the host. In many gut parasites, the zygote, enclosed within a cyst wall is liberated in the feces of the host. Sporogony takes place within the cyst, each zygote produces number of sporozoites characteristic of its genus. Another host ingests the infective spores and the sporozoites are liberated in the gut. Host cells are invaded. *Eimeria, Isopora* infect the intestinal epithelium of the host and include many economically important pathogenic forms.

1.1.11 CILIATES

Ciliates comprise the largest phylum of protozoa. They are also the most animal like and exhibit a very high level of organelle development. They possess cilia for locomotion and in many species cilia are used for suspension feeding. The body wall of ciliates is a complex living pellicle, containing alveoli, trichocysts and other organelles, in addition to the infraciliature. The body surface is covered with uniform cilia, which function in locomotion. There has been tendency, however, for this somatic ciliature to become reduced or in some groups to become specialized as well (cirri). The cilia around mouth region have become specialized as compound ciliary organelles called membranelles and undulating membranes in many ciliates that employ suspension feeding. In addition to suspension feeding on bacteria and other particles, some ciliates feed on algae and many are carnivorous feeding on other protozoa and microscopic animals. In forms like *Paramecium* there is a vestibule in front of the buccal cavity (Fig. 1-10). The cytostome and cytopharynx open into food vacuole. The undigestible remains are discharged through a fixed cell anus (cytoproct). Ciliates reproduce asexually by transverse fission and sexually by conjugation. Conjugation involves an exchange of micronuclei, each of which fuses with a non-migratory macronucleus to form a zygote nucleus. Conjugation is preceded by meiotic divisions of one micronucleus and is followed by reconstitution of the normal nuclear condition, which may involve fission.

Reproduction takes place asexually by binary fission or by budding. Sexual reproduction occurs by conjugation.
Mostly free living in fresh water and marine water. Many parasitic species. Colonial and sedentary forms also occur.
It is divided into four orders: Holotricha, Peritricha, Suctoria and Spirotricha.

ORDER – 1 HOLOTRICHA

Cilia usually short and uniform. They are arranged in longitudinal rows all over the body.
Long cilia or membranelles are lacking.
Oral structures not conspicuous.
Buccal ciliature is absent. If present, it is usually inconspicuous.
Balantidium, Paramecium (Fig. 1-10)

ORDER – 2 PERITRICHA

Adults with reduced body ciliation or without body cilia.
The apical end of the body typically bears a conspicuous buccal ciliature.
Mostly sessile bearing a stalk.
Vorticella (Fig. 1-14), Carchesium, Epistylis, Zoothamnium

ORDER – 3 SUCTORIA

Sessile forms. Generally stalked.
Cilia are completely absent in adults.
Adults have few to many tentacles.
Cilia are present in the free-swimming larval stages.
Most of the suctorians are ectosymbionts on aquatic invertebrates.
Ephelota, Acineta

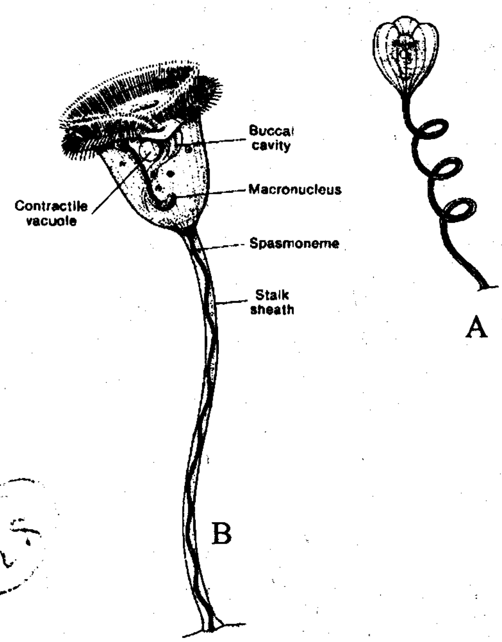

Fig. 1-14. *Vorticella convallaria.* **A,** in contracted state; **B,** in expanded state.

ORDER – 4 SPIROTRICHA

Mostly large ciliates with uniform body ciliation in *Stentor* and *Spirostomum.* Or laterally compressed ciliates with reduced body ciliation in *Saprodinium.* Or dorsoventrally flattened ciliates with cirri on the ventral side in *Euplotes* and *Urostyla.*
Buccal ciliature is conspicuous and well developed.
Stentor, Euplotes

1.2.8 SUMMARY

Protozoa are unicellular organisms.

They possess typical membrane bound organelles. The major groups of protozoa are commonly treated as separate subphyla. The old phylum name protozoa can be used as a convenient term to refer any member of these subphyla.

Most protozoa inhabit the sea or freshwater.

They also lead their life as commensals, parasites and mutualistic forms.

Protozoans possess specialized cell organelles or skeletal structures. Although, a protozoan is a single cell, it performs al the functions as a complete organism.

Food reaches the food vacuole by engulfment or through a cell mouth. Intracellular digestion occurs within the food vacuole.

Elimination of excess of water is by contractile vacuole.

Almost all the members of Phylum Protozoa are distinguished by their locomotory organelles: flagella, pseudopodia and cilia.

Most of the members of protozoa reproduce asexually by fission at sometime in their life history.

Many species exhibit meiosis, gamete formation and fertilization. But variation is seen in the occurrence and nature of these processes. Encystment occurs commonly in protozoans.

The Phylum Protozoa is divided into four subphyla: Sarcomastigophora, Sporozoa, Cnidospora and Ciliophora.

The presence of flagella and pseudopodia is the distinguishing feature of Sarcomastigophorans.

The Sub Phylum Sarcomastigophora is divided into three super classes: Mastigophora,Oplainata and Sarcodina.

The mastigophorans or flagellates are characterized by the presence of one or more flagella as adult organelles. The Superclass Mastigophorea has been conveniently divided into Phytoflagellates and Zooflagellates. Phytoflagellates usually bear one or two flagella and typically possess chloroplasts. These are plant like and usually holophytic. Zooflagellates usually bear one to many flagella. Chloroplasts are absent. Usually holozoic or saprozoic. The Class Phytomastigophorea is divided into 8 orders: Chrysomonadida, Coccolithophorida, Heterochlorida, Crytomonadida, Dinoflagellida, Chloromonadida, Euglenida and Volvocida. The Class Zoomastigophorea is divided into 9 orders: Choanoflagellida, Bicosoecida, Rhizomastigida, Kinetoplastida, Retortamonadida, Diplomonadida, Oxymonadida, Trichomonadida and Hypermastigida.

The Super class Opalinata consists of gut commensals of anurans, less commonly of fish, salamanders and reptiles.

The body of opalanids is covered by longitudinal, oblique rows of cilia. They are characterized by two or more monomorphic nuclei, symmetrogenic binary fission, involvement of flagellated gametes and syngamy in sexual reproduction.

The Superclass Sarcodina includes those protozoans in which adults possess pseudopodia.

The Sarcodina contains four distinct groups – the amoebas, the foraminiferans; the radiolarians and the heliozoans.

Radiolarians, which are marine planktonic species possess spherical bodies and radiating axopods. They possess a central cortex and extracapsular cytoplasm. The skeletons are composed of silicon dioxide or strontium sulfate.

The endoparasitic protozoa or the Sporozoa have spore like infective stages in the life cycle. They lack cilia, flagella or pseudopodia and live within or between cells of their invertebrate or vertebrate hosts. The sporozoa includes the gregarines, which are extracellular parasites of insects and annelids and other worms and the coccidians, which are intracellular parasites of gut and blood cells of vertebrates and invertebrates. *Plasmodium,* the causal agent of malaria, is the best known coccidian parasite. The life cycle of sporozoans involve fission (schizogony), sexual reproduction (gamogony), and spore formation (sporogony).

The ciliates are widely distributed in both fresh and marine waters and in the water films of soil. About one third of ciliate species are ecto– and endo–commensals or parasites. All possess cilia or compound ciliary structures as locomotor or food-acquiring organelles.

Most ciliates possess a cell mouth or cytostome. In contrast to other protozoans, ciliates are characterized by the presence of two types of nuclei: one vegetative (the macronucleus) and the other reproductive (the micronucleus).

In addition to suspension feeding on bacteria and other particles, some ciliates feed on algae, and many are carnivorous. The carnivorous forms feed on other protozoa and microscopic animals.

Fission is transverse and sexual reproduction never involves the formation of free gametes.

1.1.13 KEY TERMINOLOGY

Autogamy: Nuclear reorganization without conjugation or exchange of micro nuclear material between two protozoans.

Autotrophic nutrition: A type of nutrition in which organic compounds used in metabolism are obtained by synthesis from inorganic compounds.

Axopodium: Fine, needle like pseudopodium, which contains a central bundle of microtubules.

Axoneme: Microtubules and other proteins that compose the inner core of flagella and cilia.

Binary fission: Asexual division that produces two similar individuals.

Bud: The smaller of two progeny cells resulting from fission.

Cilium: Characteristic of many protozoans and metazoan cells. A motile outgrowth of cell surface in ciliates.

Commensalism: A type of symbiotic relationship in which one species benefits form the relationship and the other species (host) is neither benefited nor harmed.

Conjugant: One of the pair of fused ciliates in the process of exchanging genetic material.

Cytopharynx: Permanent oral canal of ciliates.

Cytoproct: Cellular anus of ciliates.

Cytostome: Cell mouth.

Encystment: Forming resistant cysts in response to unfavorable conditions.

Flagellum: Characteristic of any protozoans and metazoan cells. It is typically long and its motion is a complete whip like undulation.

Food vacuole: Cellular vesicle containing ingested food.

Heteotrophic: Refers to the type of nutrition. In this process organic compounds used in metabolism are obtained by consuming the bodies or products of these organisms.

Macronucleus: Large, usually ciliate nucleus responsible for the phenotype of the cell.

Mastigoneme: One of the many fine branches of some flagella.

Metabolism: A type of symbiotic relationship in which both species benefit from the relationship.

Micronucleus: Small, usually diploid ciliate nucleus responsible for the synthesis of DNA.

Pellicle: Protozoan body wall composed of cell membrane, cytoskeleton and other organelles.

Phytoflagellates: A flagellate typically possess chloroplasts. Usually bears one or two flagella.

Pseudopodia: A flowing extension of a cell.

Vegetative nucleus: Macronucleus.

1.1.14 SELF ASSESSMENT QUESTIONS

1. Write an account of the general organization of protozoans.
2. Write an account of locomotor organelles in protozoa.
3. Write short notes on
    a. Nutrition in flagellates
    b. Sarcodina
    c. Cnidospore
    d. Phytoflagellates

a. Choanoflagellate.
b. Dinoflagellate
c. Foraminiferan
d. Heliozoan
e. Radiolarian
f. Coccidia
g. Suctoria

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1.3 VARIOUS TYPES OF REPRODUCTIVE PROCESSES IN PROTOZOA

1.3.1 OBJECTIVES

The purpose of this lesson is to:

- ➡ understand the different methods of reproduction in protozoa
- ➡ describe the advantages of reproduction in protozoa.

1.3.2 INTRODUCTION

Reproduction in protozoa may be considered under two heads, Asexual and Sexual. In most protozoa asexual reproduction occurs by mitosis. In some species, asexual reproduction is the only known method of reproduction. Asexual reproduction takes place by a process of binary fission, budding, and multiple fission.

Division of the organism into two or more progeny cells is called fission. When fission results in two similar progeny cells, it is termed binary fission. When fission results in two dissimilar progeny cells; when one progeny cell is much smaller than the other cell, it is called budding. In some protozoa, multiple fission (schizogony) takes place as general rule in the life cycle. In multiple fission or schizogony, the nucleus divides into many nuclei and the cell divides into a number of progeny cells.

1.2.1 OBJECTIVES

The purpose of this lesson is to:

* classify the Phylum Protozoa upto orders
* understand the distinguishing characters of sarcomastigophorans
* study the important characters of sporozoans
* describe the marked characteristics of cnidosporans
* exemplify the common characters of ciliophorans

1.2.2 INTRODUCTION

The protozoa are unicellular organisms possessing typical membrane bound cellular organelles. They are a heterogeneous assemblage of some 50,000 organisms. They are the most primitive or first animals (Gr. *Protos-* first; *zoon-* animal). They occur wherever moisture is present. There are commensal, mutualistic, and many parasitic species. Sporozoans are entirely parasitic. Most of the protozoa are solitary but there are a few colonial forms such as *Volvox*. Body symmetry is nonradial, spherical or bilateral. The body is either naked or covered by pellicle. Sometimes an exoskeleton is also present. The shape of the body is usually constant or in some it may change with the environment or age. Locomotory organelles are pseudopodia, flagella, and cilia or absent as in sporozoans. Nutrition may be holozoic, holophytic, saprozoic or parasitic. The organelles of ingestion and egestion may be present or absent. Digestion occurs intracellularly. No specific respiratory and excretory organs. Both the functions are carried through general body surface by diffusion. In some excretion is carried with the help of contractile vacuole. But contractile vacuoles are mainly osmoregulatory in function. Asexual reproduction by binary fission, multiple fission or budding occurs at some time in the life history of almost all protozoa. Encystment is common. Life history is often complicated in some cases with alternation of asexual and sexual phases.

1.2.3 CLASSIFICATION INTO FOUR SUB PHYLA

Protozoa are unicellular organisms. They are animal-like being heterotrophic and motile. In all other aspects, protozoans display extreme diversity. Protozoa exhibit al types of symmetry. A protozoan cell can attain an extreme complexity. They exhibit adaptations for all types of environmental conditions. The major groups of animals are now commonly treated as separate phyla of eukaryote protistans (Barnes, 1980). The old phylum name protozoa can be employed as a convenient term of reference for any number of these groups. The classification given by "Committee on Taxonomy and Taxonomic problems of the protozoologists" (Honiberg et. al., 1964) is followed for the classification of protozoa. According to Honiberg et al. (1964) the Phylum Protozoa is classified into four sub phyla – Sarcomastigophora, Sporozoa, Cnidospora and Ciliophora.

1.2.4 SUB PHYLUM SARCOMASTIGOPHORA

Organelles of locomotion are pseudopodia or flagella.
Nucleus is monomorphic (single type).
Nutrition is either holozoic or holophytic.
Asexual reproduction is by binary or multiple fission.
Sexual reproduction by syngamy. There is no spore formation.
This subphylum is divided into 3 super classes – Mastigophora, Opalinata and Sarcodina.

1.2.4.1 SUPER CLASS MASTIGOPHORA

The mastigophorans or flagellates include those protozoa, which possess flagella as adult organelles.
Simple and primitive. Body surrounded by firm pellicle.
One to many flagella for locomotion.
Asexual reproduction by binary, more or less symmetrogenic fission.
Autotrophic, heterotrophic or both.
This has been conveniently divided into two classes – Phytomastigophora and Zoomastigophora.

1.2.4.1.A. CLASS PHYTOMASTIGOPHOREA

Mostly free-living.
Plant like flagellates with or without chromoplasts.
Usually one or two flagella
Nucleus is vesicular
Reserve food is either starch or paramylum.

parental envelope. In species of *Ceratium* and *Gymnodinium,* incomplete fission occurs resulting in a chain of individuals. Multiple fission is typical in some dinoflagellates.

In colonial volvocids, asexual reproduction is complex. For instance, in *Volvox*, any one of the cells at the posterior of the colony may undergo fission to form a daughter colony. As fission continues, the daughter cells arrange themselves in the form of a hollow ball, called a plakea. In this stage, the flagellated ends of the cells are directed towards the interior. The plakea then everts or turns inside out. The eversion of plakea occurs through an opening in one side of the sphere. Following eversion, the hollow spherical form is resumed. In the resumed spherical form the flagellated ends of the cells are directed to the exterior. This is now called a daughter colony. The daughter colonies usually escape by rupturing the parent wall.

1.3.3.2 SEXUAL REPRODCUTION

Sexual reproduction in flagellates has rarely observed except in Chlorophyceae and the metamonads. In some species such as the haploid trypansomids, reproduction is entirely asexual. In Chlorophyceae, formation of isogametes to more advanced heterogametes and the occurrence of meiosis after the formation of zygote are observed. In some species of *Chlamydomonas*, the cells act as gametes (isogametes). Sex determination is seen in some species by having gametes that slightly differ in size. In *Platydorina*, heterogamy is well developed, but the large macrogametes still retain flagella and are free-swimming. In *Volvox,* true eggs and sperm develop from special reproductive cells at the posterior of the colony. The egg remains stationary and is fertilized within the parent colony. Colonies may be either monoecious or dioecious. In metanomads gametes may not be markedly different but meiosis timing varies. In species of *Trichonympha,* reduction divisions are post zygotic, but in other genera such as *Macrospironympha,* they occur in the formation of gametes. Autogamy, the fusion of gametes derived from the same parent cell, is also common.

Palmella (nonflagellated) stages are characteristic of phytoflagellates. In the palmella stage, the organism looses its flagellum and becomes a ball-like, non-motile, undifferentiated cell. The palmella stages are found floating in the water. These are protected inside the parental envelope, if present Fission occurs in palmella resulting in a cluster of cells. Many species of dinoflagellates, may remain in the palmella stage for a long time. The symbiotic zooxanthellae, the yellow-brown unicellular algae that occur in some invertebrates are actually the palmella stage of certain dinoflagellates.

In many flagellated groups cysts are formed. Cysts of chrysomonads typically have siliceous walls. Cysts of dinoflagellates are crescent shaped. In *Volvox,* the zygote secretes a thick, tuberculate wall. After disintegration of the parent colony, the zygote sinks to the bottom, and remain for many months in the encysted stage.

1.3.4 AMOEBOID PROTOZOA

1.3.4.1 ASEXUAL REPRODUCTION

Asexual reproduction in most amoebas, heliozoans and radiolarians is by binary fission In amoebas with a soft shell, the shell divides into two parts, and each daughter cell forms a new half (Fig. 1-17A).. In *Arcella,* in which shell is dense and continuous, a mass of protoplasm extrudes from the opening before division; this mass secretes a new shell. The double-shelled animal now divides (Fig.1-17B).

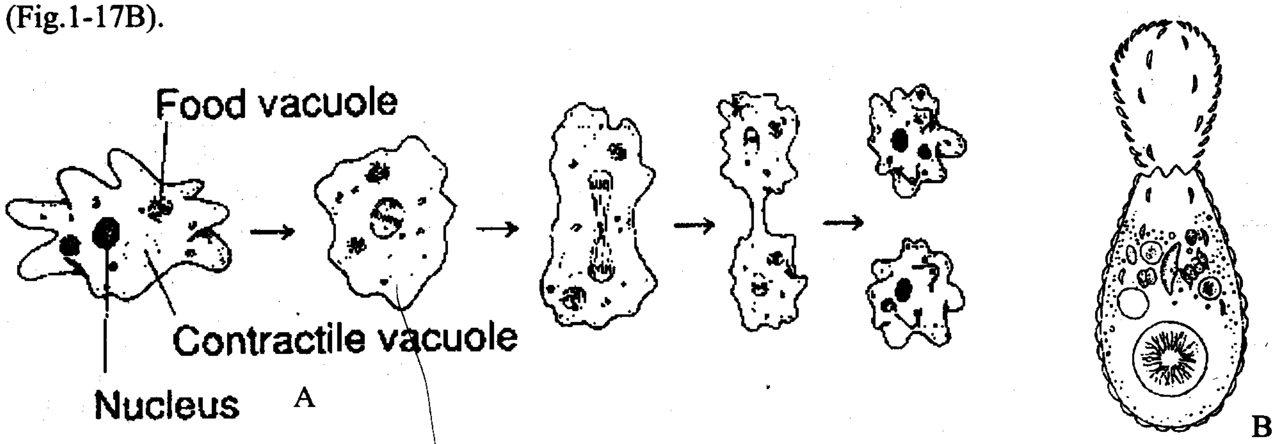

Fig. 1-17. **A,** Fission in a naked amoeba. **B** A stage in the division of *Euglypha*, a shelled amoeba. Formation of skeletal plates on protoplasmic mass protruding from aperture.

Division in the radiolarians is somewhat similar to that in the shelled amoebas. Either, the skeleton itself divides and each daughter cell forms the lacking half; or one daughter cell receives the skeleton and the other secretes a new one.

Multiple fission is also seen in some multinucleated amoebas and heliozoans. In certain shelled amoebas the parent animal sporulates a large number of little, naked amoebas. In the process of growth the little ones produce a new shell.

1.3.4.2 SEXUAL REPRODCUTION

Sexual reproduction occurs in Sarcodina. It is more frequent and better known in some groups. Sexual reproduction is rare in amoebas, but hologamy –the fusion of two individuals, each acting as gamete has been reported in some species.

Among heliozoans, sexual reproduction is observed in *Actinosphaerium* and *Actinophrys*. In *Actinophrys,* the axopods are withdrawn and a cyst is formed. Inside the cyst, the animal divides into two daughter cells. Only the nuclei of each daughter cell undergo two meiotic divisions. The chromosome number is reduced from 44 to 22. After each division the contents of one nucleus are extruded as a sort of polar body. The two gametic nuclei now fuse to form a single diploid zygote nucleus. In *Actinosphaerium,* similar process occurs but is more complicated.

Radiolarians form flagellated cells, but except in one species their sexual nature and fate is uncertain.

In foraminiferans, reproduction is complex but relatively uniform in the species observed. It involves a definite alternation of asexual and sexual generations. Each species is dimorphic and in most multilocular species, the two types of individuals differ in the size of proloculum. One type of individual, known as schizont, reproduces asexually and has a shell with small proloculus, called a microspheric shell. The other known as gammont reproduces sexually and has a megalospheric shell (Fig. 1- 18).

ORDER – 1 CHOANOFLAGELLIDA

Fresh water flagellates, with a single flagellum surrounded by collar.
Sessile, sometimes stalked and sometimes with lorica.
Solitary or colonial.
Proterospongia (Fig. 1-3B), Codosiga

ORDER – 2 BICOSOECIDA

Largely fresh water flagellates encased within a lorica.
Two flagella, one free, the other attaching posterior end of body to shell.
Bicosoeca, Poteriodendron

ORDER – 3 RHIZOMASTIGIDA

Small and amoeboid forms.
Flagella one to many.
Locomotion by pseudopodia and flagella.
Chiefly fresh water.
Mastigamoeba, Dimorpha

ORDER – 4 KINETOPLASTIDA

Small and more or less amoeboid forms. No gullet.
Basically one flagellum. But upto four flagella are present.
Mostly parasitic forms. Some are fresh water. Fresh water forms are usually sessile, or sometimes stalked.
Trypanosoma (Fig. 1-4), Leishmania

ORDER – 5 RETORTAMONADIDA

Gut parasites of insects or vertebrates.
One to four flagella. One flagellum associated with ventrally located cytostome.
Chilomastix.

ORDER – 6 DIPLOMONADIDA

Small forms and often with a cytostome.
Body is covered with a pellicle.
Bilaterally symmetrical flagellates, with two nuclei.
Each nucleus associated with four flagella.
Mostly parasites.
Giardia, Hexamita

ORDER – 7 OXYMONADIDA

Symbiotic flagellates having one to many nuclei.
Each nucleus is associated with four flagella.

Some flagella are turned posteriorly and adhere to the body surface.
Oxymonas, Pyrsonympha

ORDER – 8 TRICHOMONADIDA

Symbiotic flagellates.
Four to six flagella, one flagellum is trailing.
Parasites in genital passage.
Trichomonas (Fig. 1-5)

ORDER – 9 HYPERMASTIGIDA

Highly specialized forms with numerous flagella.
Kinetosomes arranged in a circle, plate or longitudinal or spiral rows.
Uninucleate or multinucleate but never binucleate.
Pseudopodia are employed for the ingestion of food.
Symbionts in the guts of termites, cockroaches and wood roaches.
Lophomonas, Trichonympha

1.2.4.2 SUPER CLASS OPALINATA

Body covered by longitudinal, oblique rows of cilia arising from anterior sub terminal rows.
Cytostome is absent.
Two to many monomorphic nuclei.
Binary fission generally symmetrogenic.
Sexual reproduction involves syngamy with flagellated gametes (anisogamous).
Parasites in the gut of frogs and toads, less commonly in fish, salamanders and reptiles.
Opalina, Zelleriella

1.2.4.3 SUPER CLASS SARCODINA

Protozoans with pseudopodia as feeding and locomotory organelles.
Flagella are present in developmental stages.
Asexual reproduction by binary fission.
Mostly solitary and free-living.
Some are colonial forms. Some others are parasites.
Skeletons of various forms and composition characteristic of some groups.

1.2.4.3.A. CLASS RHIZOPODEA

The locomotory organelles are lobopodia, filopodia, reticulopodia, but never axopodia.
Generally creeping forms.

ORDER – 1 AMOEBIDA

Body is naked without any exoskeleton.
Typically uninucleate, ectoplasm and endoplasm are clearly differentiated.
Nucleus with honeycomb lattice.

undergoes sporogony to form sporozoites enclosed within a spore. The spore is liberated from the host in the feces.

The coccidians are intracellular parasites of vertebrates and invertebrates. They attack the intestinal epithelium, blood, or other cells of the host. In many gut parasites the zygote, enclosed within cyst wall is liberated in the feces of the host. Sporogony occurs within the cyst, each zygote producing a number of sporozoites is characteristic of its genus. The infective sporozoites when ingested by another host are liberated in the gut. They invade the host cells. Each sporozoite becomes a feeding trophozoite. Schizogony occurs, increasing the number of merozoites. Some of these form two types of gametes; the microgametes and macrogametes. Microgametes are small and flagellated, and they move to macrogametes, which are large and stationary (within the ho t cells). Gametes fuse to form a zygote. The zygote undergoes meiosis to form sporozoites.

The asexual stage of other coccidians infects blood cells or gut cells. Coccidians cause a number of diseases in domesticated animals. Species of the coccidian genera *Eimeria* and *Isospora* are the economically important pathogenic forms. Coccidioses from species of *Eimeria* in chickens, turkeys and calves is especially destructive. *Isospora,* usually attack fish, also occur in man, but the resulting coccidiosis is not serious.

1.3.6 CILIATE PROTOZOA

Ciliates differ from almost all other organisms in possessing two distinct types of nuclei -a large macronucleus and one or more small micronuclei. The micronuclei are small, rounded bodies and vary from one to as many as 80, depending on the species. They are diploid with little RNA. The micronucleus is a store of genetic material, is responsible for genetic exchange and nuclear reorganization, and also gives rise to the macronuclei. The macronucleus is sometimes called the vegetative nucleus, since it is not critical in sexual reproduction. However, the macronucleus is essential for normal metabolism. It is essential for mitotic division and for the control of cellular differentiation. It is also responsible for the genetic control of the phenotype through protein synthesis.

1.3.6.1 ASEXUAL REPRODUCTION

Asexual reproduction is always by means of binary fission. The binary fission is typically transverse. Fission is described as homothetogenic type of fission, in which the plane of division cuts across the kinetics – the longitudinal rows of cilia or basal bodies (Fig. 1-19B). These are certain elements (kinetics/kinetic elements) in the cell. The exact structure and function of which are unknown. They are compared to the central bodies of metazoan nucleus and supposed to initiate the mitosis. The kinetic elements are in the form of granules or filaments or massive bodies. Some of which lie in the nucleus and other in the cytoplasm. Those lying in the nucleus are distinguished as intra nuclear or endobasal bodies. Those lying in the cytoplasm as the extra nuclear or cytoplasmic kinetic elements. The cytoplasmic kinetic elements are usually the basal granules, the rhizoplasts and the parabasal bodies. This is in contrast to the symmetrogenic fission of flagellates, in which the plane of division occurs between the rows of basal granules. Mitotic spindles are typically formed within each of the micronuclei. The behavior of macronuclei is more variable. A spindle is not formed, and division is accomplished by constriction. When more macronuclei are present, they fuse as a single body before dividing. This is true in some forms with beaded or elongated macronuclei. In *Stentor,* the macro nuclear chain condenses into a single mass and then divides.

Modified fission in the form of budding is seen in some ciliate groups like Suctoria In most members of Suctoria, the parent body buds off a varying number of daughter cells from the outer surface; or there is an internal cavity or brood chamber, and the buds form internally from the chamber wall. Though the adults lack cilia, the daughter cells or buds are provided with several circlets of cilia and are free-swimming. After a few hours of free existence, the larva attaches and assumes the characteristics of the sessile adults.

Although there are no centrioles, the kinetosomes of many ciliates, like the basal granules of flagellates, divide at the time of fission. The kinetosomes play a primary role in the re-formation of organelles. All organelles can be reformed if the cell contains a piece of macronucleus and some kinetosomes. In primitive ciliates, where cilia have a general distribution over the body surface, the kinetosomes have equal potentials in the reformation of organelles. However, in specialized ciliates there is a corresponding specialization of the kinetosomes; only few kinetic elements are involved in the re-formation of new cellular structures during fission.

Most ciliates undergo encystment during unfavorable conditions, such as lack of food or desiccation. The encysted cysts can be transported by wind or in mud on the feet of birds or other animals. Encystment is typical of most ciliates. However, encystment is absent in some ciliates, including *Paramecium.* They remain in the active state and transported from one water body to another.

1.3.6.2 SEXUAL REPRODCUTION

Sexual reproduction takes place by conjugation, in which an exchange of nuclear material takes place. In the course of swimming, by random contact, two sexually compatible members of a particular species adhere in the oral or buccal region of the body. Cilia secrete a sticky substance, which helps in adhesion. There is a fusion of protoplasm in the region of contact. Two such fused ciliates are called conjugants; attachment lasts for several hours. During this period a reorganization and exchange of nuclear material occurs. Only the micronuclei are involved in conjugation; the macronucleus breaks up and disappears either in the course or following micro nuclear exchange.

After two meiotic divisions of the micronuclei, all but one of them degenerates. This one often divides, giving rise to gametic micronuclei that are genetically identical. One is stationary and is considered as female nucleus; the other is male nucleus, it is wandering and will migrate into the opposite conjugant. It moves through the region of fused protoplasm. There the male and female nuclei fuse with one another to form a zygote nucleus or synkaryon.

Shortly after nuclear fusion the two animals separate and each is now called an exconjugant. After separation, a varying number of nuclear divisions occur in each exconjugant resulting in the reconstitution of the normal nuclear condition, characteristic of the species. This reconstitution usually, but not always involves a certain number of cytoplasmic divisions. In some forms where there is a single macronucleus and a single micronucleus, the synkaryon divides once. One of the daughter nuclei forms micronucleus, the other forms the macronucleus. Thus, normal nuclear condition is restored without any cytosomal divisions.

However, in *Paramecium caudatum* (Fig. 1-19C), which also has single nucleus of each type, the synkaryon divides thrice, producing 8 nuclei. Four become micronuclei and remaining four become macronuclei. Three of the micronuclei are then reabsorbed. The animal now undergoes two cytosomal divisions, during the course of which each of the resulting four daughter cells receive one macronucleus. The single micronucleus in each daughter cell undergoes mitosis at each cytosomal division. Restoration of the normal nuclear state in *Paramecium aurelia*, which has one macronucleus and two micronuclei, occurs differently. Here the synkaryon divides twice to form two micronuclei and two macronuclei. The exconjugant then undergoes binary fission, in which each micronucleus divides mitotically. Each daughter cell receives one macronucleus and two micronuclei. In those species that have numerous nuclei of both types, there is no cytosomal division; the synkaryon divides a sufficient number of times to produce the requisite number of macronuclei and micronuclei.

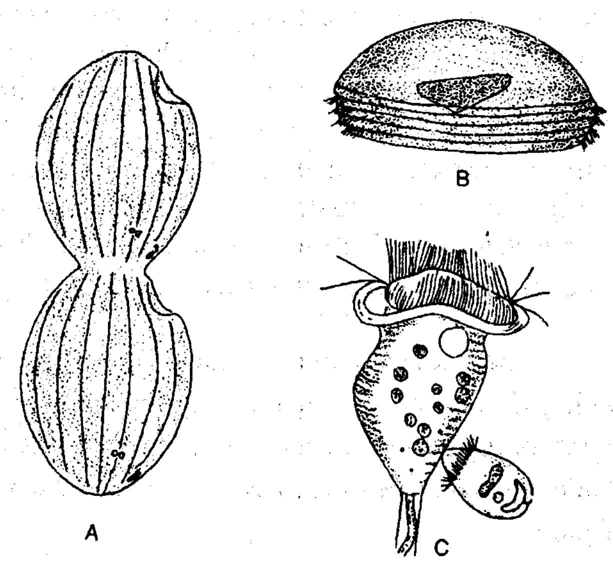

Fig. 1-19 B: **a,** Homothetogenic type of fission, in which the plane of division cuts across the kineties, **b,** Detached bud of *Dendrocometes*. **c,** Conjugtion in *Vorticella*. Note the small nonsessile microconjugant.

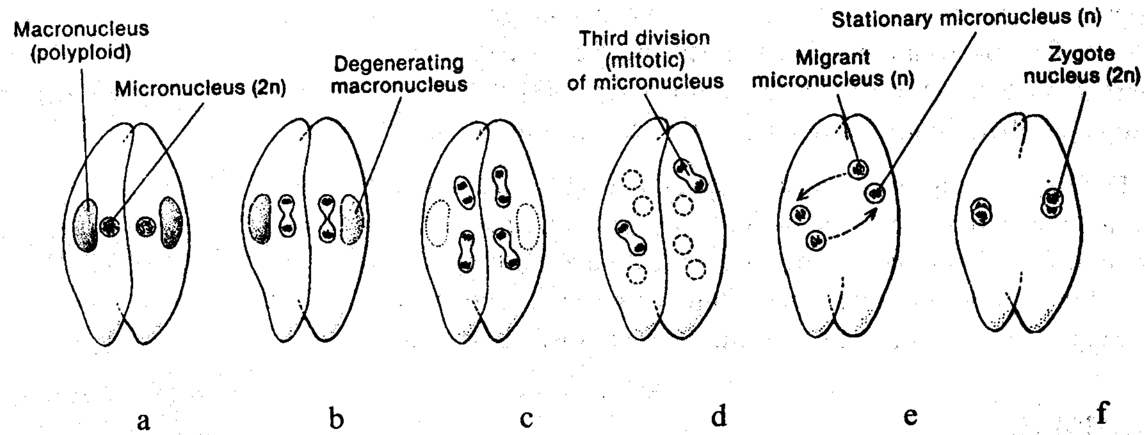

Fig. 1-19 C. Sexual reproduction in Paramecium caudatum, in which there is one macroucleus and one micronucleus. **a,** Two individuals are uniyed in conjugation. **b-d,** The micronucleus of each undegoes three divisions, the first two of which are meiotic. **e,** Migrant micronucleui are exchanged. **f,** they fuse with the stationary micronucleus of the opposite conjugant to form a synkaryon or "zygote" nucleus.

In some of the more specialized ciliates, the conjugants are a little smaller than the no conjugating individuals. Or the members of the conjugating pair are of strikingly different sizes. Such dioecious macro and micro conjugants are seen in *Vorticella* (Fig. 1- 19B) and represents an adaptation for conjugation in sessile species. The female or macroconjugant remains attached, while the small bell of the male or micro conjugant breaks free from its stalk and swims in water. On contact with an attached macroconjugant the two bells adhere. A synkaryon is formed only in the macroconjugant from one gametic nucleus contributed by each conjugant. However, there is no separation after conjugation, and the male conjugant degenerates. In the Suctoria, conjugation takes place between two attached individuals located side by side. This type of conjugation is also seen in chonotrichs and ectocommensal ciliates attached to crustaceans.

The frequency of conjugation is extremely variable: Ciliates ot some species rarely undergo conjugation, others conjugate every few days or weeks. In some species a period of "immaturity" in which only fission occurs, precedes a period in which individuals are capable of conjugation. Conjugation may be influenced or induced by many factors such as temperature, light and availability of food.

Conjugation brings about shuffling of hereditary characteristics and renewal of macronucleus. The latter is an important event during conjugation. In some ciliates this nuclear reorganization has a rejuvenating effect and is necessary for continued asexual fission. In some species of *Paramecium* about 350 asexual generations occur and if nuclear reorganization does not occur, the asexual line (or clone) will die out. There are many species in which fission can occur indefinitely. In such cases conjugation becomes an unnecessary adjunct for asexual fission.

Although conjugation is not seen in some species, another type of nuclear reorganization called autogamy may take place. Autogamy, which has the same effect on fission as, does conjugation. In autogamy, there is no conjugation and no exchange of micro nuclear material between two individuals. The macronucleus degenerates and the micronucleus divides a number of times to form eight or more nuclei. Two of these nuclei fuse to form a synkaryon; the others degenerate and disappear. The synkaryon then divides to form a new micronucleus and macronuclei as in conjugation.

Definite mating types exist in species of *Paramecium, Tetrahymena, Euplotes, Stylonchia,* and a few other ciliates. For example, there are a number of varieties or syngens, or *Parameicum caudatum* and *P.aurelia,* each with two or more mating types. Conjugation is always restricted to a member of the opposite mating type within the same syngen and does not occur between members of the same type. This may be due to the failure of the surfaces to adhere. The mating types are hereditary.

1.3.7 SUMMARY

Almost all protozoa reproduce by fission.

Fission (mitosis) occurs at sometime in the life history of protozoa.

In the majority of flagellates, asexual reproduction occurs by binary fission.

It is a longitudinal fission producing mirror image daughter cells. Division is thus said to be symmetrogenic.

In many flagellate groups, sexual reproduction is still poorly known.

Nonflagellated (palmella) stages are characteristic of some phytoflagellates, such as dinoflagellates. In the palmella stage the organism loses its flagellum and becomes non motile. Usually it floats on water. It is encircled by parental envelope. Fission occurs and the palmella consists of a cluster of cells. The symbiotic dinoflagellates inhabit their host at the palmella stage.

Sexual reproduction is poorly known. When sexual reproduction occurs, isogametes are common.

Amoebas, heliozoans and radiolarians reproduce asexually by binary fission.

Multiple fission is common in multinucleated amoebas and heliozoans.

Division in radiolarians is somewhat similar to that in shelled amoebas.

Sarcodines reproduce sexually. But sexual reproduction has rarely been observed among the amoebas.

The mode of sexual reproduction is known among heliozoans such as *Actinosphaerium* and *Actinophrys*. During sexual reproduction, in *Actinophrys*, the axopods are withdrawn and a cyst is formed. Within the cyst the animal undergoes two meiotic divisions.

Four nuclei are formed. The contents of two nuclei are extruded as polar bodies. The two remaining gamete nuclei fuse to form a single, diploid zygote nucleus.

Formation of flagellated cells is reported in radiolarians. The mode of sexual reproduction and the fate of flagellated cells are still uncertain.

Foraminiferans are dimorphic. Two types of individuals are seen in foraminiferans. One type of individual, known as a schizont (microspheric shell) reproduces asexually. The other type that has a megaspheric shell, known as a gammont, reproduces sexually.

The parasitic sporozoans (some species) possess spore like infective stages.

Parasitic forms have a complex life cycle. The life cycles usually involve fission (schizogony), sexual reproduction (gamogony) and spore formation (sporogony).

Ciliates exhibit both asexual and sexual mode of reproduction.

They reproduce asexually by transverse fission and sexually by conjugation.

The transverse binary fission in some ciliates is described as homothetogenic.

In suctorians, modified fission occurs in the form of budding.

In most ciliates encystment occurs as a common method of reproduction.

Conjugation involves an exchange of micronuclei.

Each micronucleus (active, migratory) fuses with a macronucleus (inactive, non migratory) to form a zygote nucleus.

Meiotic divisions of one micronucleus precede conjugation.

In this type of conjugation, the normal nuclear condition is reconstituted.

1.3.8 KEY TERMINOLOGY

Conjugant: One of the pair of fused ciliates in the process of exchanging genetic material.
Conjugation: Sexual reproduction takes place in most ciliates for exchange of nuclear material through conjugation.
Exconjugant: Conjugating animals shortly after nuclear fusion separate and each is now called an exconjugant.
Palmella: Nonflagellated stage, which is characteristic of phytoflagellates. Fission occurs in the palmella stage.
Symmetrogenic: In majority of flagellates, the animal divides by longitudinal binary fission producing mirror image daughter cells. Such division is said to be symmetrogenic.
Synkaryon: Zygote nucleus.

1.3.9 SELF ASSESSMENT QUESTIONS

1. Describe the mode of asexual and sexual reproduction in protozoa with suitable examples.
2. Describe the process of conjugation in ciliates with the help of diagrams.
3. Describe the basic life cycle of sporozoans.
4. Write short notes:
    a. Symmetrometric division.
    b. Schizont.
    c. Conjugation.
    d. Gammont.
    e. Homothetogenic division.

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1.4 GENERAL ORGANIZATION OF PHYLUM PORIFERA

1.4.1. OBJECTIVES :

The purpose of this lesson is to :

- describe the structure of sponges
- understand their physiology.

1.4.2. INTRODUCTION :

Phylum Porifera includes sponges which are lowly organized multicellular animals. They are kept under a separate sub-kingdom Parazoa. These animals are distinct from protozoans in having multicellular body, and from other metazoans in the absence of true tissues and organs. The sponge body is a collection of loose cells without any coordination of the body function and the cells perform a variety of functions independently. Sponges are specialized in being sessile and in having an unusual body plan built around a system of water canals. Their sessile nature and lack of movement of body parts convinced Aristotle, Pliny and other ancient naturalists that sponges were plants. In 1765, when internal water currents were first observed, the animal nature of sponges became clearly established.

1.4.3. DISTRIBUTION :

The poriferans are marine except for a single family Spongillidae which inhabits fresh waters. Approximately 5000 marine species and about 150 fresh water species of sponges are described at present. All members are sessile in adult stages. They abound in all seas, wherever rocks, shells, submerged timbers, or coral provide a suitable substratum. Some species even live on soft sand or mud bottoms. Most sponges prefer relatively shallow water, but some groups, including most glass sponges, live in deep water.

Many sponges are hosts for other animals. Some large leuconoid sponges are veritable apartment houses for certain shrimps and brittle stars. Some spider crabs put algae, sponges, and other sessile animals on their backs. These grow on this mobile substratum, providing the crab with an effective camouflage.

Sponges are economically useful in many ways. They are used as food for animals, for ornamental purposes and are of medicinal value. Their multivarious uses lead to the development of sponge industry on a high scale.

1.4.4. SPONGE STRUCTURE :

The general organization of sponges varies considerably. The sponges are cylindrical like *Leucosolenia,* vase-shaped like *Scypha and Grantia,* tree-like *Microciona*, finger-like *Haliclona,* leaf-like *Phyllospongia,* cushion-shaped like *Euspongia,* rope-like *Hyalomema,* bowl-shaped like *Pheronema,* etc. Some sponges are solitary, while others are colonial. The sponges are mostly attached forms; they are found attached to stones, shells, sticks, sea weeds, etc., Some are boring sponges like *Cliona.* Some are radially symmetrical, but the majority are irregular, and exhibit massive, erect, encrusting, or branching growth patterns. Sponges vary greatly in size. Certain calcareous sponges are about the size of a grain of rice, but a large loggerhead sponge may exceed a meter in height and diameter.

Most of the common species are brightly colored. Green, yellow, organge, red and purple sponges are frequently encountered, but the significance of the coloration is uncertain. Protection from solar radiation and warning coloration have been suggested for some species. The green color of the sponge is usually due to the presence of a symbiotic algae, *Zoochlorella,* in them.

Sponge architecture is unique, being constructed around a system of water canals – an arrangement that is correlated with sponge sessility. This architecture is the key to understanding many aspects of sponge biology. The basic structure and histology of sponges is most easily understood by beginning with the simplest radial forms. Such sponges are called asconoid sponges.

1.4.4.1.STRUCTURE OF ASCONOID SPONGE :

The asconoid sponge is tubular and always small. *Leucosolenia,* which is one of the few living genera of asconoid sponges, rarely exceeds 10 cm in height. Asconoid sponges are not usually solitary but are composed of clusters of tubes attached together along their long axes or at their bases (Fig. 1-20).

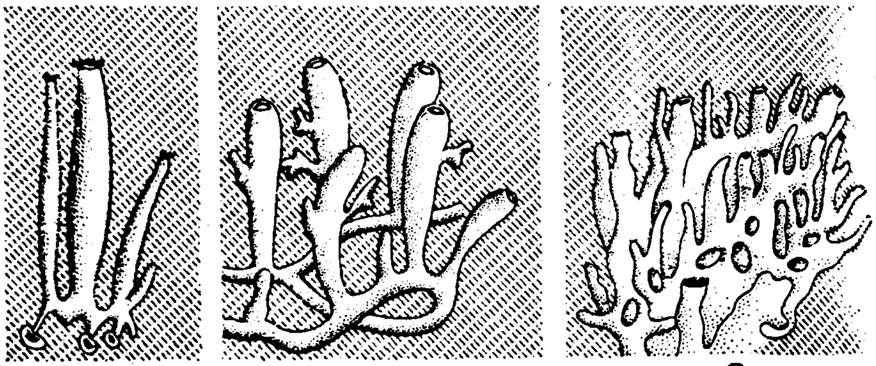


Fig. 1-20 Types of *Leucosolenia* A-Simple; B-Branching; C-Reticulate.

The surface of an asconoid sponge is perforated by many small openings, called ostia (or incurrent pores) from which the name Porifera (pore-bearer) is derived. These pores open into the interior cavity, the spongocoel (atrium) (Fig. 1-21 and 1-24A) which in turn opens to the outside through a large opening called osculum, at the top of the tube. A constant stream of water passes through the incurrent pores into the sponeocoel and out through the osculum.

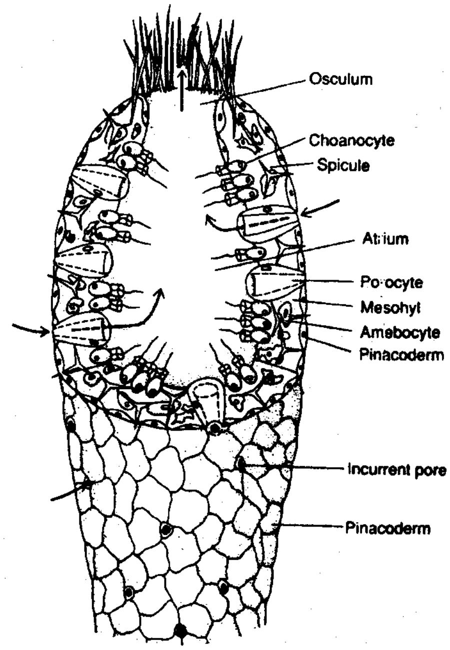


Fig. 1-21, Diagram of a partially sectioned asconoid sponge.

1.4.4.2. HISTOLOGY OF THE BODY WALL :

Body wall is diploblastic with an outer pinacoderm and an inner choanoderm. In between the two layers lies a thick gelatinous mesohyl (mesenchyme) with different kinds of amoeboid cells and skeletal material.

1.4.4.2.A. PINACODERM :

The body wall is relatively simple. The outer surface of the body is covered by epithelial-like flattened cells, known as the pinacocytes, which together make up the pinacoderm. Unlike the epithelium of most other animals, however, a basal lamina and intercellular junctions are absent. The pinacocytes are highly contractile and their contraction and relaxation can reduce or increase the surface area of the sponge body. The basal pinacocytes secrete material that fixes the sponge to the substratum. Each pore is formed by a cell called porocyte. It shaped like a ring that extends from the external surface to the spongocoel. The bore, or lumen, of the porocyte forms the incurrent pore or ostium, and can be closed or opened by contraction.

1.4.4.2.B. MESOHYL :

Beneath the pinacoderm lies the mesohyl (sometimes referred to as mesenchyme), which consists of a gelatinous proteinaceous matrix containing skeletal material and amoeboid cells. The mesohyl is equivalent to the connective tissue of other metazoans. Mesohyl is of two types. (a) collenchyma and (b) parenchyma. In collenchyma, the matrix is more and the cells are less while in parenchyma, matrix is less and cells are more.

a) *Skeleton :* The skeleton is relatively complex and provides supporting framework for the living cells of the animal. (This discussion applies to the phylum in general, not just to the asconoid sponges). The skeleton may be composed of calcareous spicules, siliceous spicules, protein spongin fibres, or a combination of the latter two. The spicules exist in a variety of forms and are important in the identification and classification of species (Fig. 1-22). An extensive nomenclature has developed through the use of these structures in sponge taxonomy. The suffix axon, refers to the number of axes of a spicule has, while actine, refers to the number of rays or points. Monoaxon spicules are shaped like needles or rods and may be curved or straight with pointed, knobbed, or hooked ends, while triaxons may have either three rays or six (hexactines). These terms apply to megascleres (monaxons, tetraxons, triaxons, polyaxons and spheres), the larger spicules forming the chief supporting elements in the skeleton, and microscleres (spires and asters), spicules that are considerably smaller, have their own specialized terminology.

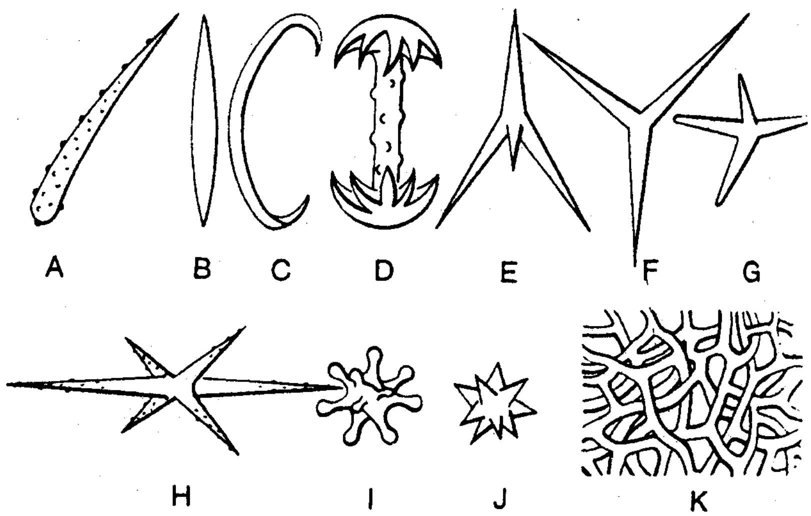


Fig. 1-22. Spicules and spongin. A-Monactinal monaxon; B-Diactinal monaxon; C-Curved monaxon; D-Monaxon with hooked ends; E-Tetraxon; F-Triradiate; G-Calthrops; H-Hexactinal triaxon; I and J - Polyaxon; K-Spongin fibres.

The skeleton is located primarily in the mesohyl, but spicules frequently project through the pinacoderm. The arrangement of spicules is organized, with various types often combined in distinct groupings. They may be interlocked or be fused together. The organization in one part of the body may differ from that in another. Microscleres, for example, support the pinacoderm lining the water canals.

The mesohyl of all sponges contains dispersed collagen fibrils, but many sponges also possess a skeleton of coarse interconnecting fibres. The fibres are composed of spongin, a fibrous protein similar to collagen. Some sponges contain so much spongin that they are tough and rubbery, and in many species siliceous spicules are embedded partially or completely in the fibres to help stiffen them.

b. Amoeboid cells : The amoeboid cells occurring in the mesohyl include a number of types which are as follows :

Archeocytes: Large cells with large nuclei. These are phagocytic and play a role in digestion. Archeocytes are said to be totipotent, that is, they are capable of transforming themselves into other types of cells when needed.

Collencytes : Fixed cells, anchored by long, cytoplasmic strands and secrete the dispersed collagen fibers. Many sponges possess mobile cells, which also secrete these fibers.

Sclerocytes : The spicule skeleton is secreted by ameboid sclerocytes. One to several sclerocytes are usually involved in the secretion of a single spicule in the calcareous sponges, and the process is relatively complex. A three pronged spicule, for example, originates in three sclerocytes derived from an amoebocyte, called a scleroblast. The three sclerocytes partially fuse to form a trio of cells (Fig. 1-23). Each member of the trio then divides, and between each pair of daughter cells one prong, or ray, of the spicule is secreted. The three prongs fuse at the base. Each of the three pairs of sclerocytes now moves outward along a ray, one cell secreting the end and one thickening the base of the spicule (Fig. 1-23). The spongin skeleton is secreted by spongocytes.

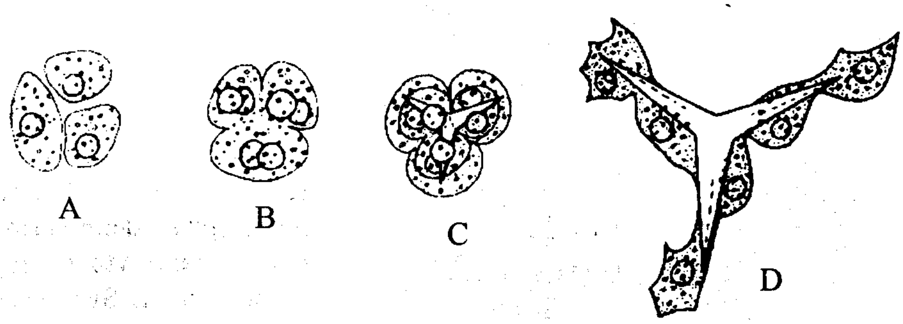


Fig. 1-23. Secretion of a calcareous triradiate spicule.

1.4.4.2.C. CHOANODERM :

On the inner side of the mesohyl, and lining the spongocoel, is a layer of cells, the choanocytes which are very similar in structure to choanoflagellate protozoa. The choanocyte is ovoid, with one end adjacent to the mesohyl. The opposite end of the choanocyte projects into the spongocoel and bears a flagellum surrounded by a collar or microvilli. The choanocytes are responsible for moving water through the sponge and for obtaining food. It is important to understand that the spongocoel and its choanocyte lining are not homologous to the gut of other animals, and the choanocytes are not an endodermal derivative. Indeed, there is no endoderm in sponges. Sponges are gutless, and the gutless condition is primary.

1.4.4.3. MORPHOLOGICAL TYPES OF SPONGES :

The primitive asconoid structure imposes very definite size limitations. An increase in the volume of the spongocoel is not accompanied by a sufficient increase in surface area of the choanocyte layer to provide for water movement. Thus, asconoid sponges are always small.

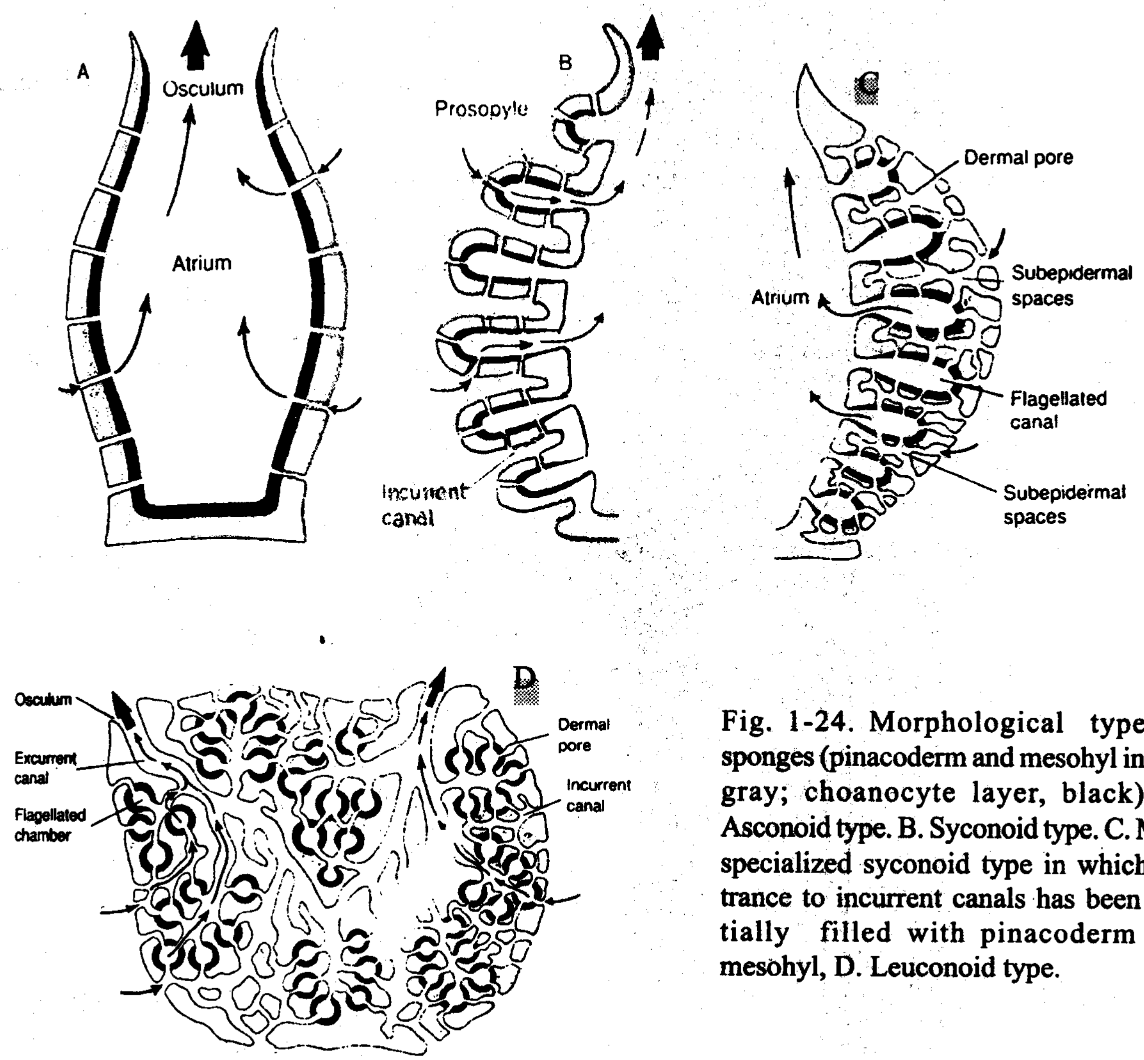


Fig. 1-24. Morphological types of sponges (pinacoderm and mesohyl in pale gray; choanocyte layer, black). A, Asconoid type. B. Syconoid type. C. More specialized syconoid type in which entrance to incurrent canals has been partially filled with pinacoderm and mesohyl, D. Leuconoid type.

The problems of water flow and surface area have been overcome during the evolution of sponges by the folding of the body wall, and in many species by the reduction of the spongocoel. The folding increases the surface area of the choanocyte layer, and the reduction of the spongocoel lessens the volume of water that must be circulated. The net result of these changes is a greatly increased and more efficient water flow through the body. A greater size now becomes possible, although the primitive radial symmetry is commonly lost. Sponges display various stages with regard to the folding of body wall and reduction of the spongocoel.

Sponges that exhibit the first stages of body wall folding are called syconoid sponges and include the well-known genera *Grantia* and *Scypha* (=*Sycon)*. In syconoid structure, the body wall has become folded, forming external pockets extending inward from the outside, and evaginations, extending outward from the spongocoel (Fig. 1-24 B). The many pockets produced by folding do not meet but by pass each other and are blind.

In this more advanced type of sponge, the choanocytes no longer line the spongocoel but are now confined to the evaginations, which are called flagellated, or radial canals. The corresponding invaginations from the pinacoderm side are known as incurrent canals and are lined by pinacocytes. The two canals are connected by openings called prosopyles, which are equivalent to the pores of asconoid sponges. Water now flows through the incurrent canals, the prosopyles, the flagellated canals, and the spongocoel and flows out the osculum. Thus water current takes the following route:

Water ⟶ incurrent canals ⟶ prosopyles

↓

Osculum ⟵ Spongocoel ⟵ Flagellated canals

A slightly more specialized stage of the syconoid structure develops when pinacocytes and mesohyl plug the open ends of the incurrent canals (Fig. 1-24 C). Ostial openings remain to permit entrance of water into incurrent canals. Despite the folding of the body wall, syconoid sponges still retain a radial symmetry.

The highest degree of folding takes place in leuconoid sponges (Fig. 1-24 D). The flagellated canals have transformed to form small, rounded, flagellated chambers and the spongocoel has commonly been reduced to water canals leading to an osculum. Water enters the sponge through the ostia and passes into subdermal spaces leading into branching incurrent canals. These eventually open into the flagellated chambers through prosopyles. Water leaves the chamber through an apopyle and courses through excurrent canals, which become progressively larger as they are joined by other excurrent canals. A large canal eventually open to the outside through the osculum. The canals are lined by pinacocytes. The number of flagellated chambers may be enormous, for example *Microciona prolifera* contains some 10,000 chambers/mm each 20 to 39 μm in diameter and containing about 57 choanocytes. The mesohyl is usually thicker than in asconoid sponges. Porocytes can form the ostia as well as prosopyles and apopyles in the endopinacoderm.

Most sponges built on the leuconoid plan, which is the evidence of the efficiency of this type of structure. Leuconoid sponges can reach a large size because any addition to their mass increases the number of flagellated chambers necessary to propel water through the addition. Leuconoid sponges may be encrusting or erect with flattened or branching bodies, although many species are vase-shaped and tubular forms in which the excurrent canals empty into a large, central chamber. Rather than a single osculum, there may be many oscula.

Most leuconoid sponges have one of two general internal designs, regardless of the external forms. In one type the body is solid, and adjacent incurrent and excurrent canals commonly run parallel to each other, conducting water inward to flagellated chambers and outward to oscula, which are scattered over the surface. In the other type, the body is hollow, with the oscula comfined to the upper or distal parts of the body. Excurrent water canals do not return to the surface but open into the interior cavity, which leads to a distal osculum. The leuconoid plan clearly evolved more than once within sponges and, in some instances, may have involved a preceding syconoid sponge.

1.4.5. PHYSIOLOGY :

1.4.5.1. WATER CURRENT :

The physiology of a sponge largely depends on the current of water flowing through the body. The current of water brings in food and oxygen and removes waste products. Even sperm are moved in and out and larvae released by the water currents. Under normal conditions all the apertures of a sponge are widely open and a current of water flows through the animal and out at the oscula. The volume of water pumped by a sponge is remarkable. A specimen of *Leuconia (Leucandra)*, a leuconoid sponge, 10 cm in height and 1 cm in diameter, has roughly 2,250,000 flagellated chambers and pumps 22.5 l of water per day through its body. The flow velocity is greatest through the osculum and slowest through the flagellated chambers, because these two regions have respectively, the smallest and the largest total cross-sectional areas of the various passageways. By regulating the size of the osculum and closing the ostia, the animal can control the rate of flow and even stop it altogether. In some Demospongiae, control of the osculum is facilitated by a special type of mesohyl cell called a myocyte, which exhibits similarities to a smooth muscle cell in shape and contractility. However, unlike true muscle cells, the myocytes surrounding an osculum do not touch each other. The water current is produced by the beating of the flagella of the choanocytes, but there is neither coordination nor synchrony of the flagella in a particular chamber. The choanocytes are oriented toward the apopyle, and each flagellum beats from base to tip, driving water from the flagellated chamber (Fig. 1-25). As

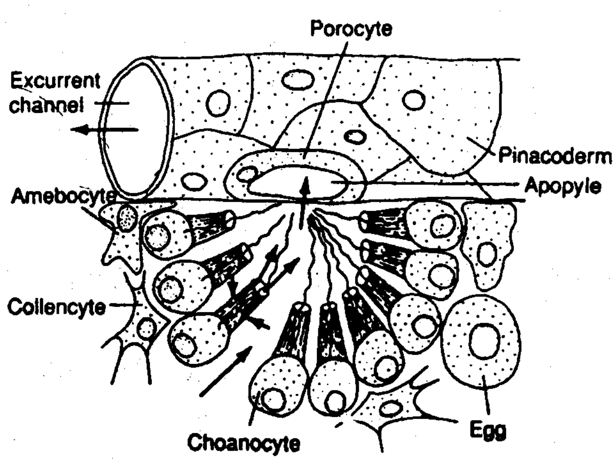


Fig. 1-25. Section through flagellated chamber of freshwater sponge, *Ephydatia*. Arrows indicate direction of water currents.

a result, water is sucked into the chamber from the incurrent canals through the small prosopyles located between the bases of the choanocyte. It is then driven to the center of the chamber and out the larger apopyle into an excurrent canal.

When a sponge is exposed to an external current, water flows passively through the body of a sponge, with an elevated oscula. This hydrodynamic effect undoubtedly contributes to water passage in those sponges that live in strong to moderate currents. However, many sponges reach their greatest development in relatively quiet water or even in confined spaces.

1.4.5.2. NUTRITION :

Sponges are filter feeders that depend on the stream of water passing through the body as a source of food. The nutrition is of holozoic and saprozoic types. They feed on extremely fine particulate material. The food consists of about 80% of fine organic matter 20% of bacteria, dinoflagellates, and other fine plankton.

Food particles are apparently selected largely on the basis of size and are screened in the course of their passage into the flagellated chambers. Only particles smaller than a certain size can enter the ostia or pass through the prosopyles. Screening is also provided by cytoplasmic strands stretched across the incurrent canals. The finest particles are removed by the choanocytes, perhaps by filtration across the choanocyte collar.

All sponge cells can phagocytize particles. Large particles (5-50 μm) are phagocytized by pinacocytes lining the inhalant pathways or by archeocytes that move out of the mesohyl. Indeed, populations of archeocytes have been reported cleansing the outer pinacoderm surface. Particles of bacterial size and below (<1μm) are removed and engulfed by the choanocytes on the surface of the cell and not on the microvillor collars (Fig. 1-26). Both choanocytes and archeocytes can transfer

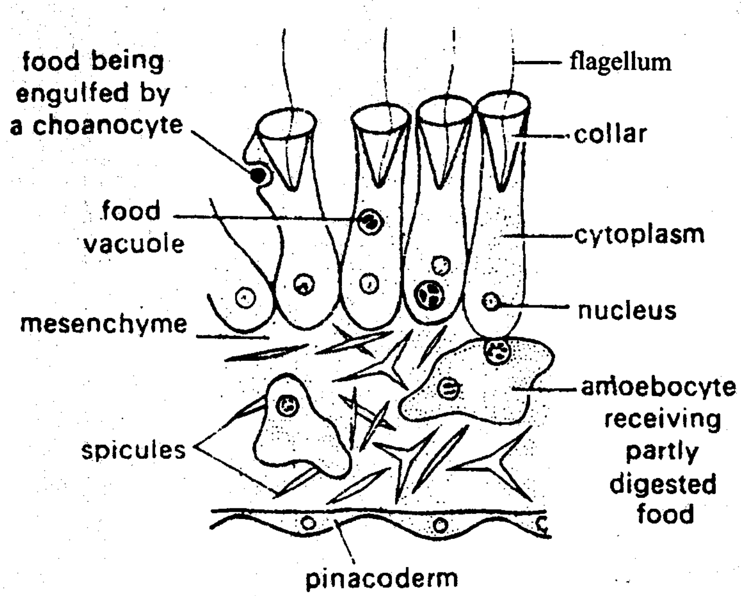


Fig. 1-26. *Scypha*. Ingestion of food by choanocytes and its digestion.

their engulfed particles to cells. Archeocytes rather than choanocytes appear to be the principal sites of digestion. Digestion takes place inside the food vacuole, thus digestion is intracellular as in Protozoa. Sometimes the partly digested food is conveyed to thesocytes (amoebocytes) where it is digested fully and stored in the form of glycogen and fats. The archeocytes probably also act as storage centers for food reserves. The digested food is distributed throughout the body by diffusion. The undigested food is passed into the spongocoel from there to outside through the osculum.

Many marine sponges, both Demospongiae and Calcarea, are now known to harbour symbiotic photosynthetic organisms. A few species contain non motile dinoflagellates *(Zooxanthellae)*, but the most common symbionts are cyanobacteria (blue-green algae), which live within the mesohyl or within specialized amoebocytes. The zooxanthellae may give the sponge a yellowish hue and the cyanobacteria a green, violet, or brown colour. The cyanobacterial symbionts of some keratose sponges, including *Verongia,* may make up more than 33% of the sponge. Such sponges live in shallow, well-lighted habitats and may have their symbiotic cyanobacteria restricted to the outer layers of the body. Excess photosynthate in the form of glycerol and a phosphyorylated compound are utilized by the sponge host. Sponges studied on the Australian Great Barrier Reef obtain from 48 to 80% of their energy requirements from their cyanobacteria. Some sponges also contain intra-and extracellular bacteria, in addition to the cyanobacteria. However, the significance of such bacteria is still uncertain.

1.4.5.3. RESPIRATION :

Special respiratory organs are absent in sponges. Gaseous exchange occurs by simple diffusion, between the cells of sponge and the current of water. Oxygen dissolved in water is taken in by diffusion through the general body surface by the pinacocytes and internally by the choanocytes. Amoebocytes distribute the oxygen throughout the mesenchyme and take away the carbon dioxide. The process of respiration is entirely intracellular as in Protozoa. Sponges prefer places where water contains plenty of oxygen.

1.4.5.4. OSMOREGULATION :

The pinacocyte and choanocyte layers lack intercellular junctions and most other ultrastructural connections that make epithelial layers of other animals controlling barriers between internal and external environments. Sponges have sometimes been described as "leaky animals". Their interstitial fluid (the fluid between cells) must be very similar to that of the environment even in fresh water species. Most cells of freshwater sponges possess contractile vacuoles, but the contractile vacuoles are osmoregulating for individual cells, not for extracellular compartments.

1.4.5.5. EXCRETION :

Egested waste and nitrogenous waste (largely ammonia) leave the body in the water currents. Some observers claim that amoebocytes containing excretory granules and inclusions are discharged into spongocoel. From there they are sent out along with the water currents.

1.4.5.6. NERVOUS SYSTEM :

Sponges have no nervous sytem and sense organs, and reactions are largely local. Coordination depends on transmission of messenger substances by diffusion within the mesohyl, by wandering amoeboid cells, and along fixed cells in contact with each other. Electrical conduction, which does not involve action potentials, appears to take place by the latter route.

1.4.5.7. DEFENCE :

Many sponges produce metabolites that may prevent other organisms from settling on their surfaces or may deter some potential grazing predators. Nine out of 16 Antarctic sponges and 27 of 36 Caribbean species were found to be toxic to fish. However, compounds that repel fish do not necessarily deter other grazers. Turtles commonly feed on sponges, and 95% of their feces may consist of glass spicules. Some sponges utilize excreted metabolites in competing for space with other animals. For example, the Caribbean "Chicken liver" sponge can kill adjacent stony corals and overgrow their skeletons. Some species have very distinctive odors (garlic odor), and a few, like the red Caribbean fire sponge *Tedania ignis,* can cause a rash when handled. Various sponge biochemicals are being investigated for potential medical and commercial benefits.

1.4.5.8. REGENERATION :

Many sponges have remarkable powers of regeneration. Any cut part or piece of sponge is capable of growing into a complete sponge, but the process is so slow that it takes months or years. Individual cells or all masses that are distributed at random can also aggregate and develop into a complete sponge. If the sponge is macerated and squeezed through silk cloth, and the resulting pieces or clustures of cells are kept in water, each piece will develop into a new sponge (Fig. 1-27).

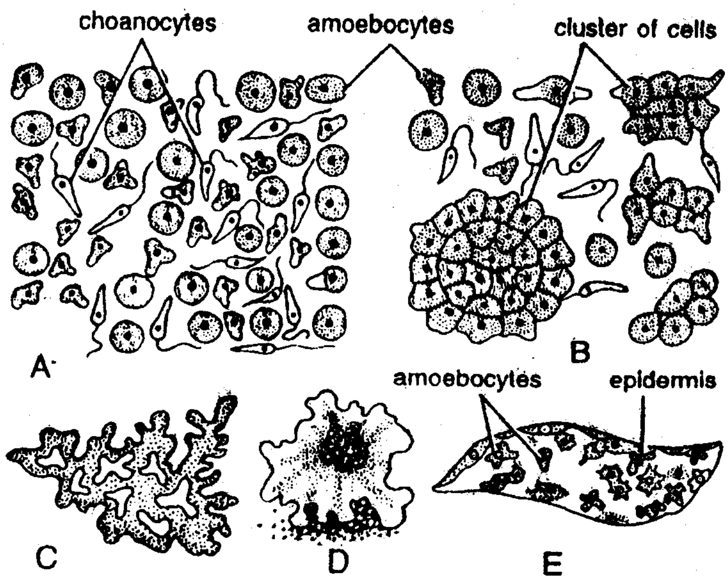


Fig. 1-27 . Wilson's experiment on regenerataion in sponges. A—Cells of *Microciona* separated by squeezing living sponge through bolting cloth; B—Cells aggregating into small masses; C—A reticulate reunion mass; D—Later stage forming a young sponge or spongelet; E—Section through a stage like D.

Regeneration was emplyed in the propagation of commercial sponges in overfished areas off the Florida coast. Pieces of sponge called cuttings were attached to cement blocks and dumped into the water. These regenerate and after several years of growth produced into a sponge of marketable size.

1.4.5.9. REPRODUCTION :

The sponges reproduce both asexually and sexually.

1.4.5.9.A. ASEXUAL REPRODUCTION :

It takes place by the formation of reduction bodies, exogenous budding and gemmulation.

a) Reduction bodies : Most of the freshwater and marine sponges disintegrate themselves leaving some rounded bodies called reduction bodies, in adverse conditions. The bodies are covered by pinacoderm enclosing an internal cell mass constituting all types of amoebocytes. In favourable conditions, these bodies develop into new sponges. In some sponges the tips of the branches break off regularly and become rounded, which latter develop into new sponges.

b) Exogenous budding : The formation of buds that are liberated from the parent is not common in sponges, although it does occur in some species. Masses of archeocytes migrate to the surface of the sponge body where they develop into buds, resembling the parent in all respects. Later they may constrict off from the parent to develop into a new sponge, or remain attached to the parent forming a colony as in *Leucosolenia* (Fig. 1-28). The buds detached from the parent body and attached themselves to the substratum by the terminal end but not with the cut end.

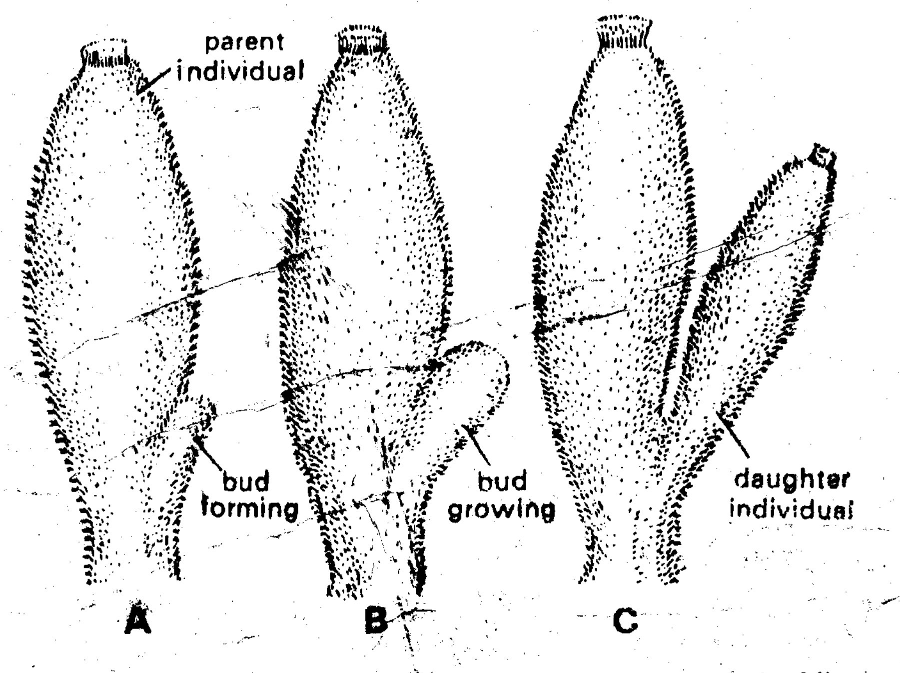


Fig. 1-28. *Leucosolenia*, Diagram showing stages in budding.

c) Gemmulation (endogenous budding): Some what different from exogenous budding is the formation and release of packets of essential cells called gemmules (Fig. 1-29). Gemmules are regularly formed internally in all freshwater sponges and few marine forms. The archeocytes which are filled with food reserves are grouped together inside the body of the sponge. Other amoebocytes encircle this cell mass in a columnar layer which secrete a hard double layered shell. Then some scleroblasts secrete spicules which are placed radially between two layers of the shell, some spicules project outside the shell. The spicules in *Spongilla* are monaxon spicules but in others they are amphidisks. Thus a completely formed gemmule is a small hard ball consisting of a mass of food laden archeocytes enclosed in a wall composed of two membranes with spicules in between, and pierced by an outlet called the micropyle. (Fig 1-29)

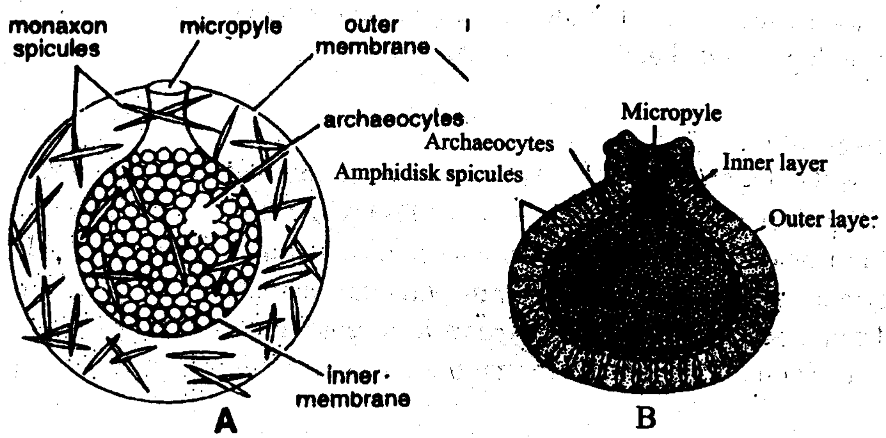


Fig. 1-29. A-Gemmule of *Spongilla*; B-Gemmule of *Ephydatia*.

Gemmules are formed in large numbers in autumn after which the sponge disintegrates. The gemmules remain in the remnants of the sponge body or fall to the bottom. Gemmules being highly resistant can withstand all adverse conditions of the nature and on the onset of favourable conditions hatchout into new sponges. While hatching, the inner cell mass flows out through the micropyle and by differentiation and rearrangement produce a young sponge.

The large multinucleate archeocytes divide into small uninucleate histoblsts, and arrange to form an epidermis. They further differentiate into choanocytes, porocytes, etc. Spicules are also secreted and in about a week after hatching, a small complete sponge is formed surrounding the empty gemmule shell.

1.4.5.9.B. SEXUAL REPRODUCTION :

It occurs in all sponges except some Tetractinellida. Sponges have no sex organs but specialized amoebocytes (archeocytes) give rise to germ cells, both ova and sperms.

Sponges are hermaphroditic or monoecious, that is, both gametes are formed in the same individual. Sex cells are formed at different times, thus self fertilization is prevented. Some sponges like *Scypha* are protogynous in which eggs produced earlier than sperms and hence cross fertilization takes place.

a) Eggs and sperms :

Eggs arise from archeocytes or choanocytes. The egg mother cell or oocyte is first derived from an enlarged archeocyte with a large nucleus and conspicuous nucleolus. It grows and accumulate food reserves by engulfing adjacent amoebocytes or may receive supplies from special trophocytes. Upon attaining full size, it undergoes the usual maturation divisions to form the ovum which lies in the wall of the radial canal in the mesohyl and ready to be fertilized by a sperm from another sponge.

The sperm mother cells or spermatogonia are differentiated from choanocytes or archeocytes Each spermatogonium divides many times and gives rise to the spermatocytes. Finally the spermatocytes divide and transform into the sperms. A mature sperm consists of a round nucleated head and a long vibratile tail by which it moves in the water to reach another sponge, some authors state that spermatogonia are transformed choanocytes, and Gatenby has described the transformation of an entire flagellated chamber into spermatozoa.

b) Fertilization :

Fertilization is internal. The sperm enter the body of other sponge along with the water current. (Fig. 1-30). But the sperm does not fuse with the ovum directly. It enters into a choanocyte adjacent to ripe ovum. The choanocyte loses its collar and flagellum and becomes amoeboid. This choanocyte is called a carrier which transports the sperm to the egg. The sperm loses its tail at this stage. The amoeboid cell with the sperm head goes and attaches to the ovum at a special conical depression. Then it transfers the sperm to the ovum, and fertilization takes place.

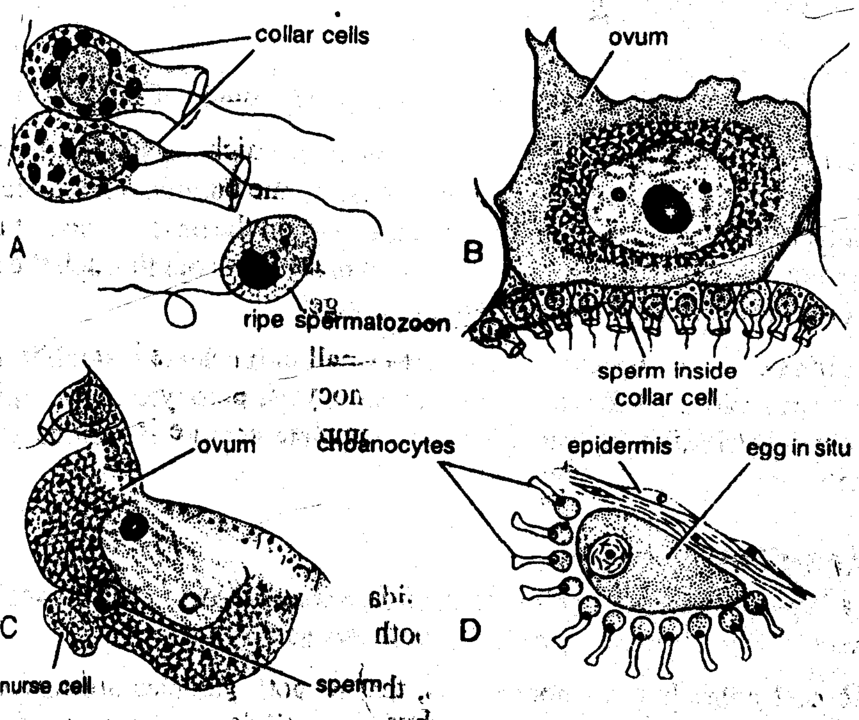


Fig. 1-30. Fertilization in *Grantia*. A-A ripe spermatozoon near two choanocytes; B-Sperm enters a collar cell adjacent to an ovum; C-Nurse cell giving up sperm into ovum; D-Fertilized egg *in situ*.

c) Development :

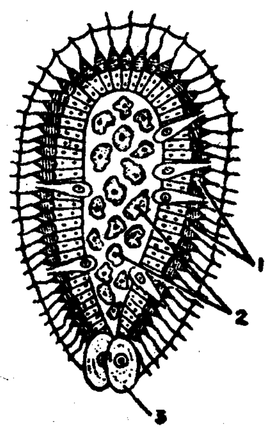
The fertilized egg undergoes equal or unequal holoblastic cleavage and develops *in situ* into a blastula. This becomes flagellated and develops into a larva which escapes out through the osculum into the surrounding water. It swims for sometime, finally attaches to a substratum and develops into an adult.

d) Larvae :

Two types of larvae are found in the life history of sponges (1) Parenchymula and (2) Amphiblastula.

i) Parenchymula :

It occurs in simple calcareous sponges like *Leucosolenia* and *Clathrina*. The blastula in this case is called a *coeloblastula* with a large central cavity surrounded by flagellated cells. In the later stages the central cavity is filled with amoeboid cells formed by the outer flagellated cells, and this stage is called *stereogastrula*. A pair of large granular cells appear at the posterior side of the body and the larva is known as Parenchymula (Fig. 1-31). The larva swims freely for sometime and attaches to the substratum by the anterior end, and metamorphosizes into an adult sponge.



1. Flagellated cells
2. Amoeboid cells
3. Posterior granular cells

Fig. 1-31. Parenchymula larva.

During metamorphosis an inversion of germ layer takes place causing the migration of the inner amoebocytes to the outer surface and they give rise to the pinacoderm and the mesohyl. The flagellated cells develop into a choanocyte layer which forms an internal lining of the spongocoel The spongocoel develops an osculum soon.

ii) Amphiblastula :

This larva occurs in highly evolved calcareous sponges like *Scypha*. The vertical an horizontal cleavage results in the formation of 8 macromeres and 8 micromeres which give rise t future dermal (pinacoderm) and gastral layers (choanoderm) respectively. The flattened disc lik embryo with an internal blastocoel, is now called, a blastula. The micromeres that are arranged on th upper side, multiply and produce flagella on their inner ends facing towards the blastocoel. The lower side is occupied by undeveloped large macromeres which develop a small mouth opening in between them. This stage of embryo is called a stomoblastula. (Fig. 1-32A). An inversion of cell layers takes place, the macromeres also multiplying resulting in a little elongation of the larva as well as the closure of the mouth. An eye spot develops at the anterior end and now the larva is called an *Amphiblastula*, enclosed in an trophic membrane drawn from the maternal choanocytes. The larva is oval in shape having one half made up of small flagellated micromeres and the other half having large rounded non-flagellated macromeres (Fig. 1-32B). The larva now escapes from the parent body along with the water currents through osculum. It swims in water with the help of flagella for sometime and then attaches to the substratum.

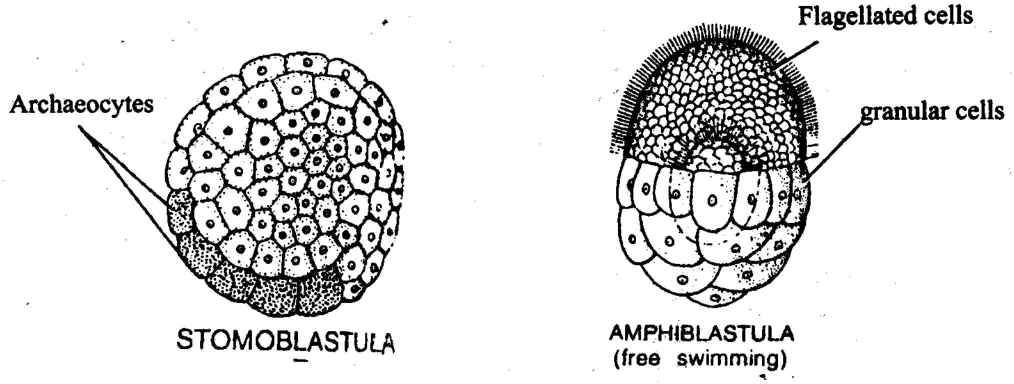


Fig. 1-32. A-Stomoblastula and B- Amphiblastula

e) Metamorphosis :

The larva now elongates developing an osculum at the free end. Dermal and gastral layers with the mesohyl in between develop. Dermal ostia also make their appearance. The embryo now reaches *olynthus stage* (Fig. 1-44) which gradually develops into an adult by complicating its body with different types of canals and chambers.

1.4.6. SUMMARY :

1. Sponges are lowly organized multicellular animals.

2. They are primitive in their lack of organs, including mouth and gut. There are different kinds of cells, but tissue differentiation, except for connective tissue, has not followed the common designs of other animals.

3. Sponges are sessile aquatic animals. They are mostly marine and largely found on hard substrata.

4. The bodies of sponges are organized around a system of water canals, a specialization correlated with sessility.

5. They vary in shapes and sizes. Most species are brightly coloured.

6. The surface of sponge is perforated by many small openings called ostia which open into the interior cavity called spongocoel. It opens to the outside through the osculum.

7. The body wall is diploblastic with an outer pinacoderm and an inner choanoderm with mesohyl in between. Mesohyl consists of skeletal material and amoeboid cells.

8. Support is provided by a complex connective tissue, containing a skeleton of organic spongin fibrers or siliceous or calcareous spicules, or a combination of spongin fibres and siliceous spicules.

9. The small, vase-shaped asconoid body form, in which flagellated chanocytes line an interior spongoel, is the primitive sponge form. The evolution of the common leuconoid form, in which the flagellated cells are distributed within a vast number of minute chambers, has permitted the attainment of much larger size and greater diversity of shape, because each addition to the sponge body brings with it all of the units necessary to provide the required additional water flow.

10. Feeding, gas exchange and waste removal depend on the flow of water through the body. The ability of the choanocyte collar to remove minute particles from the water stream has probably been an important factor in the long, successful history of sponges.

11. There are neither neurons nor true muscle cells.

12. Most sponges are hermaphrodites. Sperm leave one sponge and enter another in the currents flowing through the water canals. Eggs in the mesohyl are fertilized *in situ*. They may then be released by way of the water canals or brooded until they reach the larval stage. In most sponges the flagellated larva is a blastula, and reorganization equivalent to gastrulation occurs following settling.

1.4.7. KEY TERMINOLOGY :

Amphiblastula : Sponge larva which is hollow, one hemisphere is composed of small flagellated cells and the other is composed of large non flagellated macromeres.

Asconoid: A sponge body that is a simple cylinder and always small.

Atrium (pl. Atria): Internal cavity through which water flows in asconoid sponges (Spongocoel).

Blastula: A sphere of blastomeres created by repeated cleavage divisions of the zygote.

Coeloblastula: Blastula having a well developed blatocoel.

Collencyte: A fixed cell of sponges that is anchored by long, cytoplasmic strands and secretes dispersed collagen fibers (not spongin).

Contractile vacuole: Large spherical vesicle responsible for osmoregulation in protozoans and some sponge cells.

Food vacuole: Cellular vesicle containing ingested food.

Incurrent canal: Tubular invagination of the sponge.

Incurrent pore/Ostium: Small opening on the surface of sponges that leads into an incurrent canal.

Leuconoid: Refers to a type of sponge body organization built around flagellated chambers and an extensive system of canals.

Mesohyl: Sponge connective tissue. Lies beneath the pinacoderm and consists of a gelatinous proteinaceous matrix containing skeletal material and amoeboid cells.

Parenchymula: A sponge larva that lacks an internal cavity and bears flagellated cells over all over its outer surface except, often, the posterior pole.

Porocyte: A sponge cell that surrounds an opening which extends from the external surface to the spongocoel.

Prosopyle: Internal opening of a sponge through which water flows from the incurrent canal into a radial canal or flagellated chambers.

Spongin: A large, collagenous, connective tissue fiber of sponges.

Spongocoel: Interior cavity of asconoid sponges. Atrium.

Syconoid sponge: A radially symmetrical sponge that has a body wall folded into radially oriented canals.

1.4.8. SELF ASSESSMENT QUESTIONS :

1. Give an account of the general organization of Phylum Porifera.
2. Describe the different morphological types of sponges.
3. Write notes on :
   a) Amoebocytes
   b) Choanocytes
   c) Mesohyl
   d) Spicules
   e) Genmmule
   f) Parenchymula

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1.5 CLASSIFICATION OF PHYLUM PORIFERA

1.5.1 OBJECTIVES

The purpose of this lesson is to:

- ➡ understand the characters of sponges
- ➡ classify the Phylum Porifera upto order level

1.5.2 INTRODUCTION

Phylum Porifera includes sponges, which are the most primitive of the multicellular animals. Robert E. Grant coined the term Porifera. The term Porifera (L. porous=pore; ferro=to bear) is derived due to the presence of pores in the body. True tissues or organs are absent. Cells display a high degree of independence. They perform a variety of functions. There are about 150 fresh water species. Approximately 500 species of sponges are marine animals. They are found in all seas. They are found attached to rocks, shells, submerged timbers or corals. Most species prefer relatively shallow water. Some species (glass sponges) live in deep water. They are sessile, solitary or colonial. They have asymmetrical or radially symmetrical bodies. The body is cylindrical, tubular or vase-like. They vary in size. Most of the common species are brightly colored. They exhibit green, yellow, red, orange and purple color. But the significance of coloration is not known. The body wall is diploblastic with outer dermal epithelium and inner gastral epithelium with a gelatinous non-cellular mesenchyme in between. The body wall is relatively simple. Flattened cells, the pinacocytes, cover the outer surface. The pinacocytes together make up the pinacoderm. The basal pinacocytes secrete material. It is with the use of this material the sponge fixes to the substratum. The body surface bears numerous minute pores known as ostia for ingression of water. A type of cell, called a porocyte, forms the pores. The porocyte is shaped like a short tube. The porocyte extends from the external surface to the spongocoel. The bore or lumen of the porocyte forms the incurrent pore or ostium. Sponges possess peculiar canal system through which water current flows drawing food and oxygen inside the body and carrying away excretory and reproductive products. Beneath the pinacoderm lies a layer called the mesohyle. The mesohyle consists of a gelatinous protein matrix that contains amoeboid cells and skeletal material. Internal skeleton is present in the mesenchyme in the form of calcareous or siliceous spicules or of proteinous sponging fibres. Digestion is entirely intracellular. Nervous system and sensory cells are absent. Sponges show a high power of regeneration. Both hermaphroditic and dioecious sponge species exist. But most are hermaphroditic. Hermaphroditic forms produce eggs and sperm at different times. Reproduction takes place both by asexual and sexual methods. Asexual reproduction takes place by budding, fission or gemmule formation and sexual reproduction by sperms and ova. Fertilization is internal and generally cross fertilization takes place. Cleavage is holoblastic and development is indirect followed by a free swimming ciliated larva, the amphiblastula or parenchymula.

1.5.3 CLASSIFICATION

Approximately 5000 species of sponges have been described. The classification of sponges is based on the type of skeleton. Phylum Porifera is divided into four classes namely Calcarea (Calcispongiae), Hexactinellida (Hyalospongiae), Demospongiae and Sclerospongiae.

1.5.4 CLASS CALCAREA OR CALCISPONGIAE

The members of this class possess the skeleton with calcareous spicules made of calcium carbonate (L. Caleis = lime, Gr. Sponges = sponge). They are smaller in size, certain calcareous sponges are approximately the size of a grain of rice. Some sponges may measure less than 10 cm in length;

Solitary or colonial forms occur.

Shape of the body usually cylindrical or vase-like.

All the three grades of structures are encountered; they are asconoid, syconoid and leuconoid type of sponges.

The canal system is ascon, sycon or leucon type.

Osculum is narrow, terminal and fringed with spicules.

Spicules may be monaxon, triradiate or tetraradiate.

The color of the body is white or dull-brown or brilliant yellow or red or lavender.

Collar cells or choanocytes are comparatively large.

1.5.4.1 ORDER HOMOCOELA

Body is small, cylindrical. Asconoid sponges. Thin and simple body wall without any foldings.

Canal system is ascon type.

Spongocoel is lined throughout by choanocytes.

Leucosolenia (Fig. 1-33), Clathrina

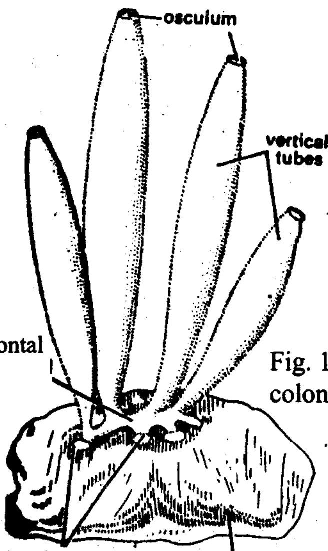

Fig. 1-33 *Leucosolenia* colony

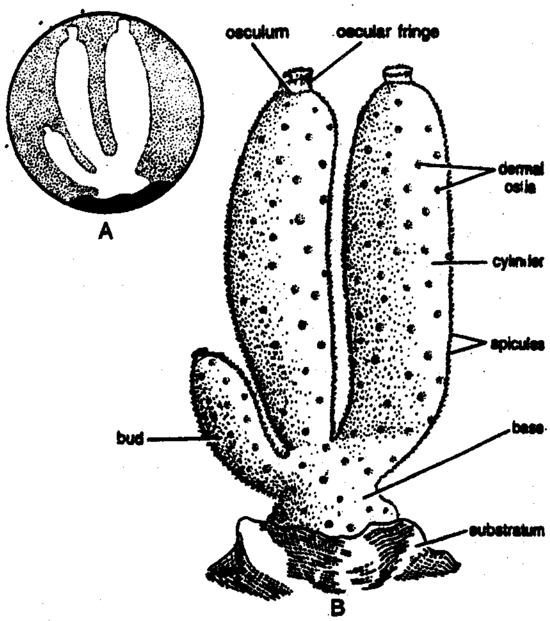

Fig. 1-34 *Scypha* A-Colony in natural size; B-Colony magnified.

1.5.4.2 ORDER HETEROCOELA

Body is comparatively bigger, vase-like. Body wall is thick with internal foldings.

Canal system may be sycon or leucon type.

Choanocytes are restricted to the flagellated chambers or radial canals.

Spongocoel is lined by dermal epithelium.

Scypha (Fig. 1-34), Grantia

1.5.5 CLASS HEXACTINELLIDA OR HYALOSPONGIAE

The members of this class are commonly known as glass-sponges.

The name Hexactinellida is derived from the fact that the spicules are of hexaxon or six pointed type (Fig. 1-22H)

Some of the spicules are fused to form a lattice like structure showing long siliceous fibers. Thus they are called glass sponges.

These are deep-water sponges. They live between depths of 450 and 900 meters.

Members of this class are of moderate size, extending upto 1 meter in length and are usually solitary.

The body shape is usually cylindrical, cup-shaped or funnel-shaped or vase shaped or urn like.

There is a well-developed atrium and a single osculum.

The osculum is wide and usually covered by a siliceous sieve plate.

The skeleton consists of triaxon or hexactinal spicules made up of silica, often fused resembling spun glass.

Dermal epithelium is absent. There is no epidermis of pinacocytes.

A net like syncytium formed by the interconnecting pseudopodia of amoebocytes covers the body surface.

Long spicules project through the net giving a beautiful appearance.

The canal system is somewhat asconoid type.

The choanocyte cells are restricted to finger-like flagellated chambers.

Glass sponges are exclusively marine and occur chiefly in tropical deep-sea water.

1.5.5.1 ORDER HEXASETROPHORA

Members of this order, retain the general body structure.
The body is glass-like, very beautiful, light and attached to the substratum directly.
The white, filmy skeleton looks as if it were emerged from a rock wool.
The spicules are hex asters having star-like appearance.
The flagellated chambers are radially and regularly arranged.
Species of *Euplectella* display an interesting commensal relation with certain species of shrimp (*Spongicola*). A young male and a young female shrimp enter the atrium, and after growth, are unable to escape through the sieve plate covering the osculum. They spend their whole life in the sponge prison. They feed on plankton brought in Sponge's water currents. The sponges with its imprisoned shrimp formerly were used in Japan as a wedding present, symbolizing the idea "no separation till death". A spider crab (*Chlorilla)* and isopod (*Aega)* are also found as commensals with some *Euplectella.* species.

Euplectella (Venus's flower basket) (Fig. 1-35)

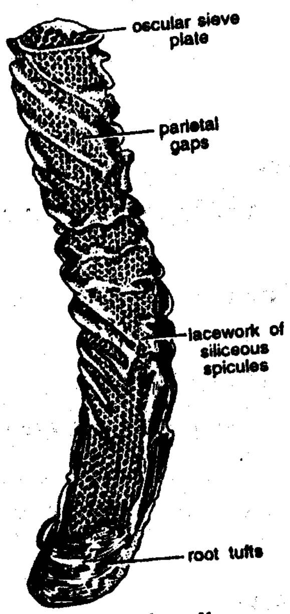

Fig. 1-35. *Euplectella.*

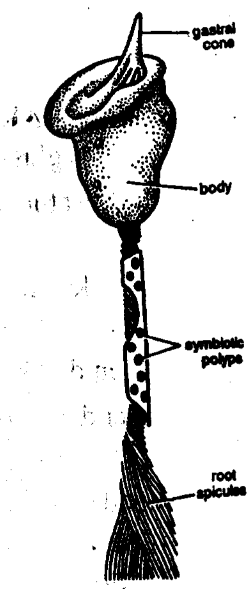

Fig. 1-36. *Hyalonema*

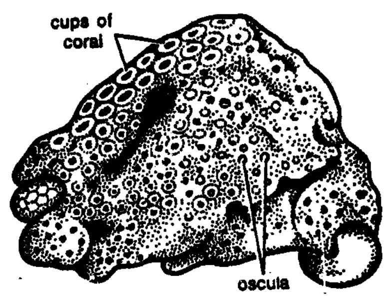

Fig. 1-37. *Cliona*

1.5.5.2 ORDER AMPHIDISCOPHORA

Members of this order has rounded or oval body.
Sponge is attached to the substratum by root tufts.
The spicules are amphidiscs having a convex disc. The spicules possess a crown of backwardly directed marginal teeth at both ends.
The flagellated chambers are irregularly arranged.
Hyalonema (Glass rope sponge) (Fig. 1-36).

1.5.6 CLASS DEMOSPONGIAE

This large class consists of diverse and complicated sponges.
They range in distribution from shallow water to great depths.
They are mostly marine but few sponges are fresh water.
They exhibit brilliant colors because of pigment granules located in the amoebocytes.
Different species exhibit different colors.
The skeleton is made up of siliceous spicules or spongin fibres or a combination of both. In some they are totally absent. (Gr. demos = frame; sponges = sponge).
The members are highly organized, varying from small to large size.
They may be solitary or colonial. They exhibit all types of growth patterns.
The body may be rounded, oval, cup-like or funnel-like.
Spicules are monaxon or tetraxon. Spicules are never hexaxons.
Canal system is complicated and leucon type. Majorities are irregular.
Choanocytes are restricted to small flagellated chambers.

1.5.6.1 ORDER TETRACTINELLIDA

Body is rounded or flattened.
Spicules are made up of silica.
Demospongia with tetraxon spicules.
Spongin fibres are absent.
Oscarella, Chondrilla

1.5.6.2 ORDER MONAXONIDA

Body form is variable. Species such as *Poterion* are goblet or urn-shaped, others such as *Callyspongia* are tubular.
Occur in shallow and deep water.
The skeleton consists of monaxon spicules.
Spongin fibers may or may not be present.
Cliona (Boring sponge) (Fig. 1-37), *Halichondria* (Fig. 1-38).

1.5.6.3 ORDER CERATOSA

Common bath sponges.
The body form is usually rounded and massive with a leathery surface and dark color.
Generally occur in warm, shallow water.
The skeleton is exclusively composed of spongin fibers.

The spicules are totally absent.

Euspongia (Bath sponge) (Fig. 1-39), *Hippospongia* (horse sponge)

1.5.6.4 ORDER MYXOSPONGIA

Demospongia devoid of skeleton.

Oscarella (Fig. 1-40).

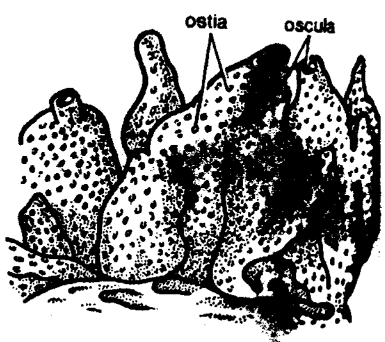

Fig. 1-38. *Haliclona*.

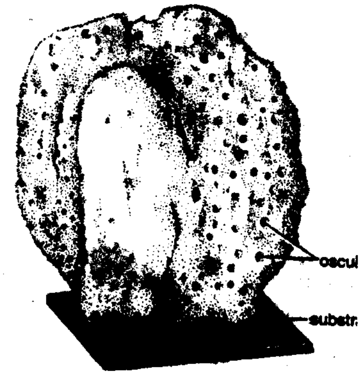

Fig. 1-39. *Euspongia*

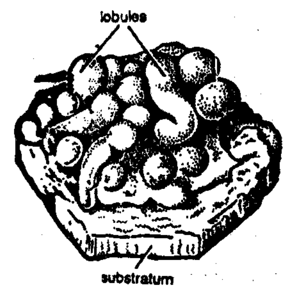

Fig. 1-40. *Oscarella.*

1.5.7 CLASS SCLEROSPONGIAE

This class contains a small number of species.
These sponges are found in tunnels associated with corals.
Leuconoid sponges.
They have an o[illegible]ent of calcium carbonate.
Internal skeleton of siliceous spicules and spongin fibers.

1.5.8 SUMMARY

The Phylum Porifera contains sponges.
Sponges are the primitive multicellular animals.
True tissues and true organs are absent.
The cells display a considerable degree of independence.
All members of the phylum are sessile.
Sponges exhibit little movement.
Sponges vary greatly in size.
Asconoid sponges exhibit the simplest and most primitive type of structure.
The surface of an asconoid sponge is perforated by many small openings, called incurrent pores. Because of the presence of incurrent pores, the name Porifera (pore-bearer) is derived. These pores open into the interior cavity, the atrium (spongocoel).
The atrium opens to the outside through a large opening at the top of the sponge, called osculum.
The osculum is covered by a sieve plate in *Euplectella* (glass sponge).
The skeleton is complex and provides support for the living cells of the animal.
The skeleton may be composed of calcareous spicules, siliceous spicules, and protein spongin fibers

or a combination of the last two. The spicules exist in a variety of forms. The spicules are important in the identification and classification of sponges.

Spicules are monaxons, triaxons, tetraxons, hexaxons and polyaxons.

Sponges exhibit three types of canal system- ascon, sycon and leucon.

In sponges, all the three grades of structures are encountered – asconoid, syconoid and leuconoid.

The Phylum Porifera is divided into 4 Classes, the Calcarea or Calcispongiae, the Hexactinellida or Hyalospongiae, the Demospongiae and the Sclerospongiae.

The Class Calcarea is divided into 2 orders: the Homocoela and the Heterocoela.

The Class Hexactinellida is divided into 2 orders: the Hexasetrophora and the Amphidiscophora.

The Class Demospongiae is classified into 4 orders: the Tetracinellida, Monaxonida, Ceratosa and Myxospongia.

1.5.9 KEY TERMINOLOGY

Atrium: The interior cavity of sponge body.

Hexaxon spicules: Six rayed spicules

Incurrent pore: Ostium (see ostium)

Monaxon spicules: a single rayed form. Shaped like needles, rod and may be curved or straight.

Osculum: The large opening of the atrium (present at the top of the sponge).

Ostium: The bore or lumen of the tubular porocytes forms the ostium.

Polyaxon spicules: Many rayed spicules

Porocytes: A type of cell in sponge body forms the pores. These are shaped like tubes.

Tetraxon spicules: Four rayed spicules

Triaxon spicules: Three rayed spicules

1.5.10 SELF ASSESSMENT QUESTIONS

1. Classify the Phylum Porifera upto orders with at least two examples for each order.
2. Classify the Phylum Porifera upto order level with suitable examples and diagrams.
3. Write notes on:
   a. Calcareous sponges
   b. *Euplectella*
   c. Demospongiae

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Dr. V. Viveka Vardhani

1.6. DEVELOPMENT IN SPONGES

1.6.1. OBJECTIVES :

The purpose of this lesson is to :

* understand the development of sponge from fertilized egg to young one in general and
* describe a detailed development of the two common asconoid and syconoid sponges such as *Leucosolenia* and *Scypha* respectively.

1.6.2. INTRODUCTION :

Sponges reproduce both asexually and sexually. Sexual reproduction and development of sponges display a number of peculiar features. Both hermaphroditic and dioecious sponge species exist, although most are hermaphroditic. They usually produce eggs and sperms at different times.

Fig. 1-36. Sperm release from a specimen of the tubular West Indian sponge *Verongia*.

The sperm arise from choanocytes and also from archeocytes. For example, the choanocytes of an entire flagellated chamber lose their collars and flagella and form spermatogonia or sperm mother cell, which then undergo meiosis. The cluster becomes surrounded by a cellular wall forming a spermatic cyst. Alternatively, a spermatic cyst may be derived from the division of a single sperm-mother cell.

Eggs arise from archeocytes or choanocytes. Egg generally accumulate their food reserves by engulfing adjacent nurse cells and are usually located within a cluster of surrounding cells. Gamete production appears to be initiated by changes in water temperature, photoperiod, or cellular regression depending on the species.

Sperm leave the sponge by means of exhalant water currents and are taken into other sponges in the inhalant stream. Certain tropical sponges have been observed to release their sperm suddenly in great milky clouds (Fig. 1-33) and sudden sperm release may be characteristic of most sponges.

After a sperm has reached a flagellated chamber, it is engulfed by a choanocyte, called a carrier. It transports the sperm to the egg.

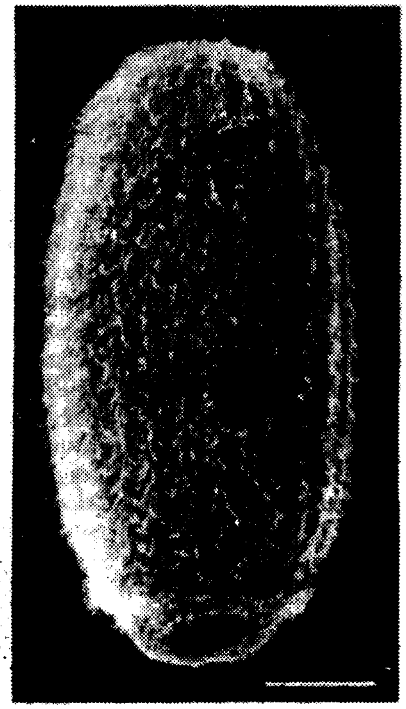
Both cells lose their flagella. After the carrier with its sperm has reached an egg (which would be in the surrounding mesohyl), the carrier either transfers the sperm nucleus, or the carrier and sperm nucleus are engulfed by the eggs. Fertilization thus occurs *in situ*. Only one species of sponge is known to liberate eggs outside that are then fertilized externally. The fertilized egg undergo development in several stages and finally transform into a young sponge.

1.6.3. DEVELOPMENT IN SPONGES :

In the majority of sponges, development to the larval stage takes place within the body of the parent. Among the Demospongiae, there are some species that liberate fertilized eggs, which develop in the sea water. Cleavage is complete and generally radial.

Development leads to a larval stage, which displays various degrees of differentiation. The larva is usually at the blastula stage of development. The majority of sponges possess a parenchymula (=Parenchymella) larva and a few calcareous sponges such as *Grantia, Scypha*, and among the Demospongiae, *Oscarella*, have an amphiblastula larva.

The parenchymula larva is covered by monociliated or flagellated cells all over the surface except, often, the posterior pole (Fig.1-42). Spicules are often present, and the interior of the larva commonly contains most of the cell types found in the adult, with the usual exception of choanocytes. The Parenchymala larva breaksout of the mesohyl, exits through the excurrent canal system, and has a brief free-swimming existence.



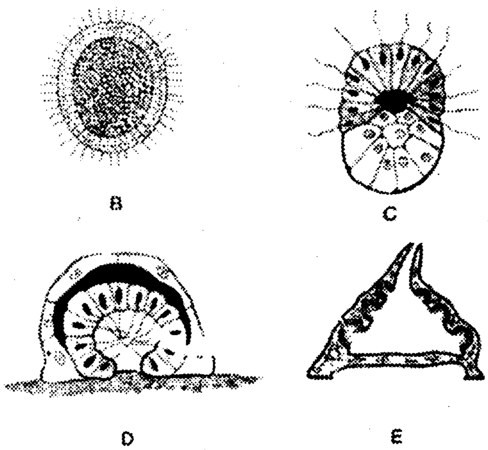


Fig. 1-42 Sponge larvae and postlarval development. A, Scanning electron microphotograph of parenchymella larva of *Haliclona*. Bar = 50 μm. B, Parenchymella larvae in section. C, An amphiblastula larva. D, Gastrulation of an amphiblastula larva following settling. E, Postlarval rhagon stage.

The amphiblastula larva is hollow, and one he isphere is composed of small flagellated cells (micromeres) and the other of large non-flagellated (macromers).

After settling and attachment by the anterior pole, the sponge larva undergoes an internal reorganization that is comparable to gastrulation in other animals. In the parenchymula, the external flagellated cells lose their flagella and move to the interior, where they regrow flagella and form choanocytes, and interior cells move to the periphery to form pinacocytes. The parenchymula larva of freshwater sponges and some marine species develops choanocytes before leaving the parent sponge. In these species, the external flagellated cells are sloughed off or move to the interior but are then phagocytized by amoebocytes. In the hollow amphiblastula larva, reorganization following settling occurs either by epiboly or by invagination, or by both, but the macromeres overgrow the micromeres (Fig. 1-42); in other metazoans the macromeres typically become internal. The macromeres in these sponges give rise to the pinacoderm and the micromeres to the choanocytes. Both these layers produce the amoebocytes of the mesohyl. There is nothing equivalent to endoderm in sponges.

In many of those calcareous sponges having a leuconoid structure, the final stages of development after attachment of the larva are preceded by stages resembling the asconoid and syconoid structures. In other leuconoid sponges, especially the Demospongiae, the leuconoid condition is attained more directly. The first stage is known as a rhagon (Fig. 1-42E). It resembles either the asconoid or the syconoid structure except that the walls are quite thick. The leuconoid plan develops directly from the rhagon stage by means of the formation of canals and flagellated chambers.

1.6.4. DEVELOPMENT IN *LEUCOSOLENIA* :

The fertilized egg undergoes equal and holoblastic cleavage and develops *in situ* into a blastula. The first three divisions are vertical but the fourth is horizontal passing just above the equatorial plane resulting in 16 cells or blastomeres. The upper eight cells are small and called micromeres and the lower eight cells are large and called macromeres. Soon many vertical and horizontal divisions take place resulting in a many celled hollow blastula (Fig.1-43) The blastula at this stage is called coeloblastula. The coeloblastula is composed

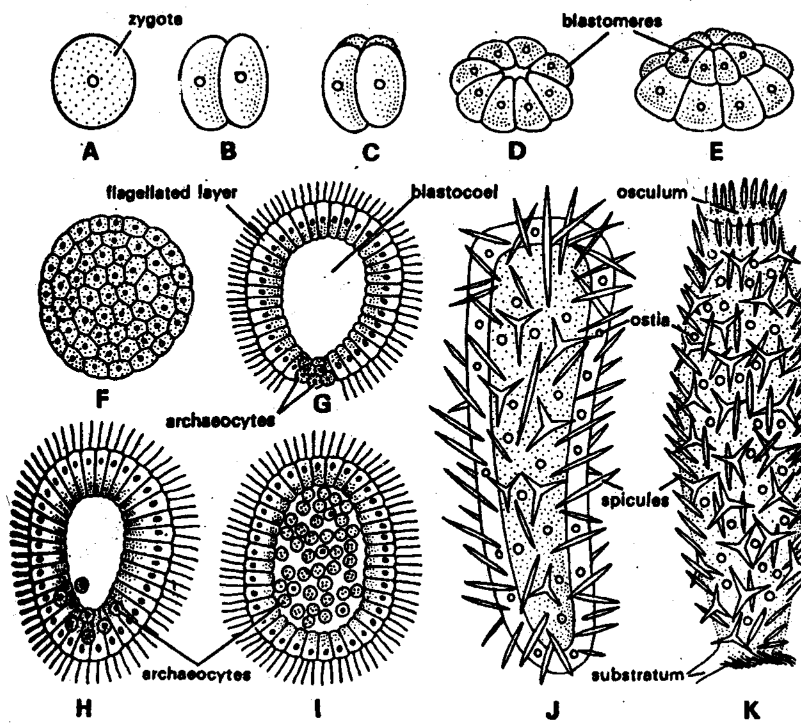


Fig. 1-43. *Leucosolenia.* Stages in development A-Zygote; B to E - Cleaving stages; F- Early blastla; G-H Coeloblastula; I - Parenchymula; J & K young sponge.

entirely of a narrow flagellated cells except at the posterior pole, where there is a group of rounded non-flagellated cells. These are believed to be archaeocytes which form all future archaeocytes of the sponge. These together with adjacent flagellated cells (by loosing their flagella) wander into the interior and fill it with a mass of cells. The resulting larva is, thus, a stereogastrula or parenchymula with an inner mass of amoeboid cells.

The parenchymula breaks the mesohyl and comes out through excurrent canal system and swims freely for some hours. Then it attaches to the substratum by the anterior pole and develops into a flat plate with an irregular outline and metamorphosizes into an adult sponge. During metamorphosis, an inversion of germ layers takes place causing the migration of the inner amoebocytes to the outer surface and they give rise to the epidermis (pinacoderm) and mesohyl. The outer flagellated cells move to the interior and develop into a choanocyte layer which forms an internal lining of the spongocoel. An osculum develops through a central spongocoel and spicules are secreted. After a few days of attachment, the larva is converted into an adult asconoid sponge.

1.6.5. DEVELOPMENT IN *SCYPHA (SYCON)* :

a. *Early embryonic development :*

The fertilized egg undergoes maturation and holoblastic cleavage and develops *in situ* into a blastula. The first three cleavages are vertical and produce a disc of eight pyramidal cells or blastomeres. A horizontal cleavage then divides the blastomeres unequally, yielding eight large cells, macromeres which produce the future epidermis (pinacoderm) and eight small cells, micromeres which give rise to future choanocytes. At the 16 cell stage the embryo lies just beneath the maternal choanocyte layer as a flattened disc-shaped body. The micromeres increase rapidly, elongate and each acquires a flagellum on its inner end facing the blatocoel (Fig. 1-44). The large cells remain undivided for sometime, become rounded and granular and in their middle an opening forms that functions as a mouth to ingest adjacent maternal cells. This stage is called stomoblastula.

The stomoblastula, thus, is the blastula stage of *Scypha,* consisting of many small, elongated and flagellated micromeres and 8 spherical granular macromeres. It bears a blastocoel which opens out by an aperature, the mouth which is formed in the macromeres. The mouth is used for engulfing the surrounding maternal cells for nutrition. The stomoblastula undergoes a process of inversion in which the embryo turnsout through its mouth, so that the flagella become directed towards the outside. Now, the embryo is called amphiblastula larva.

Amphiblastula larva: It occurs in the development of most of the calcarea. It is more or less oval in shape and consists of one-half of small, narrow flagellated cells and the other half large rounded granular cells. The amphiblatula larva forces its way into the adjacent radial canal and escapes through the osculum of the parent. It swims for some hours with the flagellated cells directed forward. After swimming for a few hours, further changes take place resulting in the formation of a double walled structure called gastrula with an outer layer of non-flagellated and an inner layer of flagellated cells. Thus gastrulation takes place by the invagination of the flagellated cells. Now the larva becomes a typical gestrula with a blastopore at the invaginated side.

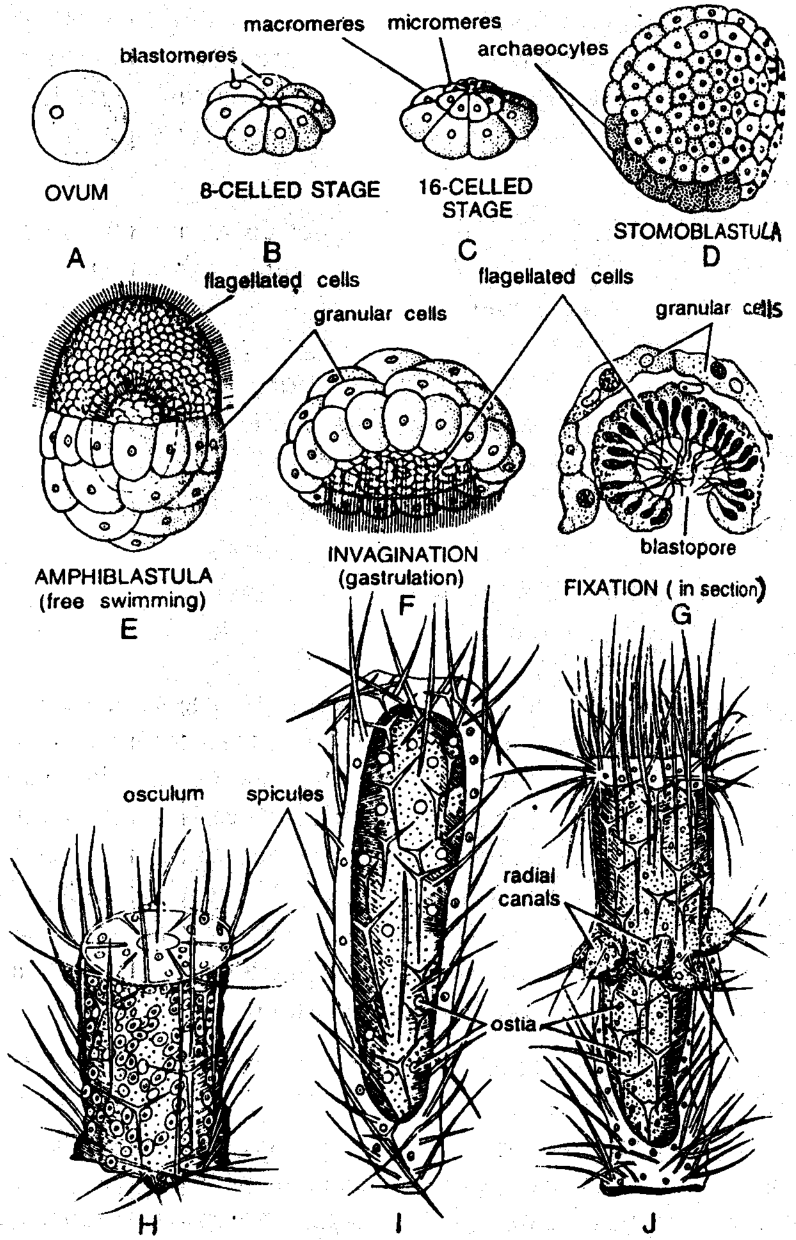


Fig. 1.44. *Scypha*. Development. A-Ovum; B-8-celled stage; C-16- celled stage; D-Blastula; E-Amphiblastula; F-Beginning of invagination; G-Gastrula showing fixation (in section); H-Young sponge; I-Asconoid (olynthus) stage; J-Syconoid stage.

B. Post embryonic development (metamorphosis) :

The gastrula soon gets attached to some substratum by its blastoporal end and develops into a cylinder. At the free end of the cylinder an osculum is formed. The outer non-flagellated cells give rise to the dermal epithelium, scleroblasts and porocytes. The inner flagellated cells develop into choanocytes and amoebocytes. The mesohyl arises from both the layers. A large number of small perforations, the ostia are formed on the cylinder. The young *Scypha* now reaches the olynthus stage resembling the asconoid type of sponge (Fig. 1-45). The adult or syconoid stage develops from the olynthus stage by pushing out of the wall , first at the middle, into radial canals. The choanocytes are shifted in these radial canals and the body wall increases in thickness. Thus, the adult *Scypha* is formed and its colony develops later on by further branching.

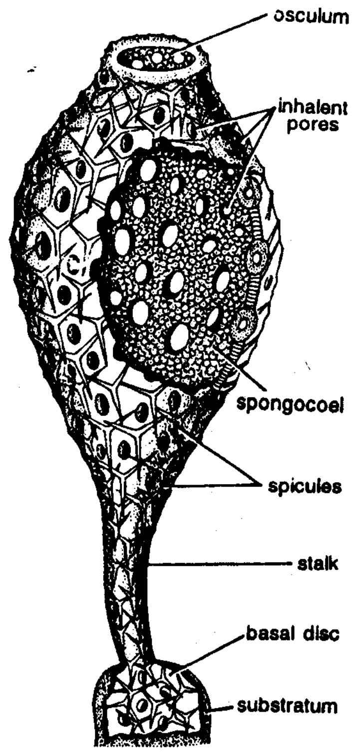


Fig. 1-45
Olynthus stage of *Clathrina* (a calcareus sponge) with a portion of the wall cut to show the spongocoel.

1.6.6. SUMMARY :

1. In sponges sexual reproduction and development exhibit a number of peculiar features. Majority are hermaphroditic but self fertilization is prevented because an individual produces eggs and sperms at different times.

2. Eggs in the mesohyl are fertilized *in situ*. Thus fertilization is internal. The fertilized egg undergoes equal and holoblastic cleavage and develops *in situ* into a blastula. The larva is usually at the blastula stage of development.

3. The majority of sponges (e.g. *Leucosolenia, Clathrina*) possess parenchymula larva and a few sponges (e.g. *Scypha Grantia, Oscarella*) have an amphiblastula larva during their development.

4. Parenchymula larva is covered by monociliated or flagellated cells enclosing an inner mass of amoeboid cells. It exits from the mesohyl through excurrent canal system. After short free swimming period, it attaches to the substratum by the anterior end and metamorphosizes by a process of inversion and finally develop into an adult sponge.

5. Amphiblastula larva is hollow, and one hemisphere is composed of small flagellated cells called micromens and the other of large non-flagellated macromeres. Following settling and attachment to the substratum reorganization equivalent to gastrulation occurs i.e. by epiboly or invagination.

6. In syconoid sponges, the gastrula develops and the young *Scypha* reaches the olynthus stage, resembling the asconoid type of sponge and then develops into adult syconoid stage.

7. In calcareous sponges having leuconoid structure, the final stages of development after attachment of the larva are preceded by stages resembling the asconoid and syconoid structures. In other leuconoid sponges, especially the Demospongiae, the leuconoid condition is attained more directly through rhagon stage.

1.6.7. KETY TERMINOLOGY :

Amphiblastula : Blastula-like sponge larva; large- celled vegetal pole, small-celled flagellated animal pole; free swimming.

Asconoid: Type of sponge structure in which canals pass directly from the ostia to the spongocoel, which is lined with collar cells.

Asexual reproduction: Reproduction without involving gametes.

Blastocoel: Cavity of the blastula.

Blastula: The early embryo in which the cells form a hollow ball.

Coeloblastula: Blastula having a well developed blastocoel.

Epiboly: Posterior growth of a fold of the blastoderm over the surface of an embryo in the process of forming the enteron during gastrulation.

Gastrula: An embryonic stage with two germ layers, ectoderm and endoderm.

Holoblastic: Cleavage in which an entire egg cell divides, also referred to as complete cleavage.

Invagination: Infolding. In gatrulation, this refers to a type of morphogenetic movement in which the cells of the vegetal hemisphere fold into the interior to form the archenteron.

Macromere: One of several large blatomeres located in the yolky vegetal hemisphere of early embryos.

Micromere: One of many small blastomeres located in the animal hemisphere of the cleaving zygote.

Radial cleavage: Type of cleavage pattern in which the cleavage spindles or cleavage planes are at right angles or parallel to the polar axis of the egg.

Self-fertilization: Fertilizing an egg by a sperm from the same individual.

Sexual reproduction: Reproduction involving the gametes.

1.6.8. SELF ASSESSMENT QUESTIONS :

1. Give a detailed account of development in sponges.
2. Describe the process of development in *Scypha*
3. Write notes on :
   a) Parenchymula
   b) Amphiblastula
   c) Olynthus stage
   d) Rhagon stage

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Dr. P. Padmavathi

UNIT - II

2.1. GENERAL ORGANIZATION OF PHYLUM COELENTERATA

2.1.1 OBJECTIVES :

The purpose of this lesson is to :

* describe the coelenterates
* understand the body forms of coelenterates and
* to understand the physiology of coelenterates.

2.1.2. INTRODUCTION :

Coelenterates are regarded as primitive Metazoans in which the cells reached the tissue grade of organization. As the members of this phylum possess specialized cells called cnidocytes or cnidoblasts in their body wall, these are also called 'cnidarians'. Coelenterates are aquatic, radially symmetrical and diploblastic animals. The body wall is composed of two layers of cells, the outer epidermis and inner endodermis or gastrodermis with mesoglea in between. The mesoglea may be thin or thick, cellular or acellular. All the coelenterates possess an internal cavity called coelenteron or gastrovascular cavity lined by endodermis. This single large cavity has only one opening, the mouth. The phylum includes familiar hydras, jelly fishes, sea anemones and corals. The brilliant colouring of marine species combined with the radial symmetry gives beautiful appearance to these animals. The phylum is composed of about 9000 living species. Fossils are known from the pre-cambrian and a rich fossil record dates from the Cambrian period.

2.1.3. DISTRIBUTION :

Coelenterates are marine except for the hydras and a few other freshwater hydrozoans. Most are inhabitants of shallow water. They may be pelagic, free-swimming or sedentary in their habit. Sessile forms abound on rocky coasts or on coral formations in tropical waters. They are solitary or colonial. Some colonial forms like *Obelia, Physalia, Porpita* and *Velella* are polymorphic and free-swimming.

2.1.4 BODY ORGANIZATION :

2.1.4.1. BODY FORM :

In contrast to sponges, coelenterates possess a gut cavity lined by endoderm and is referred to as the coelenteron or gastrovascular cavity (Fig. 2-1), because it functions in digestion and circulation. The gastrovascular cavity opens to the outside at one end to form a mouth. Thus, mouth is the only opening to the gut cavity. Mouth is surrounded by a circle of tentacles, representing evaginations of the body wall and aid in the capture and ingestion of food.

Although all cnidarians are basically tentaculate and radially symmetrical, two basic forms are encountered within the phylum. One form, which is generally sessile, is the polyp. The other form is generally free swimming and is called the medusa.

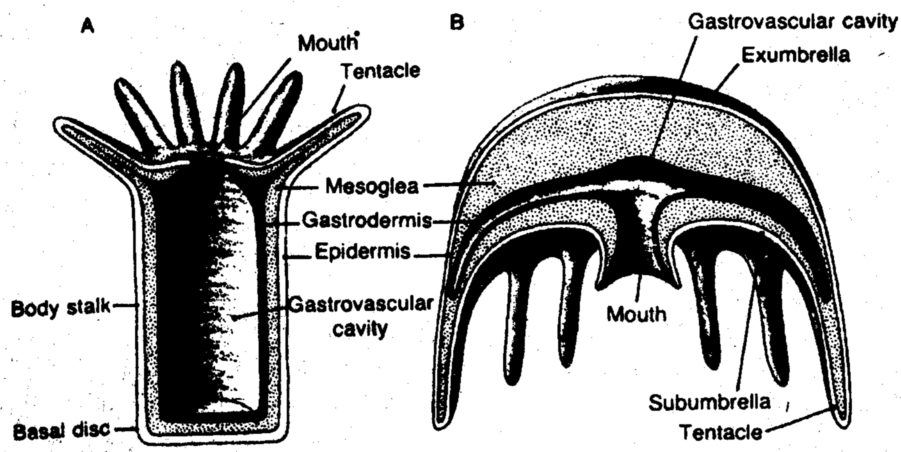

Fig. 2-1 - A, Polypoid body form B, Medusoid body form.

Typically, the body of a polyp is tubular or cylindrical, with the oral end bearing the mouth and tentacles directed upward, while the opposite or aboral end is attached (Fig.2-1A). The medusoid body resembles a bell or umbrella, with the convex side upward and the mouth located in the center of the concave undersurface (Fig.2-1 B). The tentacles hang down from the margin of the bell. In contrast to the polypoid mesoglea, which is more or less thin, the medusoid mesoglea is extremely thick and constitutes the bulk of the animal. Because of this mass of jelly-like mesogleal material, these cnidarian forms are commonly known as jelly fish. The interesting point to note that the medusoid and polypoid body forms are more or less inversions of each other. Some coelenterates exhibit only the polypoid form, some only the medusoid form, and others pass through both in their life cycle. Colonial organization has evolved numerous times within the phylum, especially in polypoid forms.

The following explanation to the body organization of coelenterates is primarily based on the familiar freshwater hydras, but the variations and the more important exceptions to the other coelenterates are also discussed.

Hydras are cylindrical, solitary polyps that range from a few millimeters to 1cm or more in length and about 1mm in diameter (Fig.2-1C). The aboral end of the cylindrical body stalk forms a basal disc, by which the animal attaches to the substratum. The oral end contains a mound, or cone, called the hypostome with the mouth at the top. Around the base of the cone is a circle of about six tentacles.

2.1.4.2 BODY WALL :

Coelenterates are diploblastic i.e. their body wall consists of two cellular layers, an outer epidermis derived from ectoderm and an inner gastrodermis derived from endoderm. In between these two layers, cellular or non-cellular layer called mesoglea is present. The mesoglea ranges from a thin non-cellular basal lamina (in hydras and many other hydrozoans) to a thick, fibrous, jelly-like connective tissue with or without mesenchymal cells (in scyphozoans and anthozoans). Epidermis and gastrodermis are made of a number of cell types showing a division of labour. The cells form poorly organized body tissues. All functions of the body are performed by the tissues and never by organs. Hence, histologically, the coelenterates have remained primitive.

2.1.4.3. HISTOLOGY OF BODY WALL :

A) The Epidermis : It is made up of small cubical cells and forms a sensory, muscular and protective layer. It is covered by a delicate cuticle secreted by the epidermis itself. It forms a thin layer, about one-third of the thickness of the body wall. Various types of cells that are found in the epidermis are as follows :

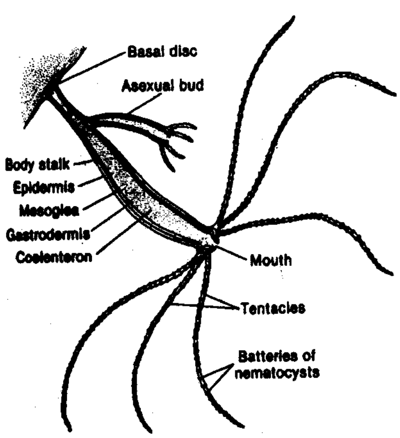

Fig. 2-1C. *Hydra*

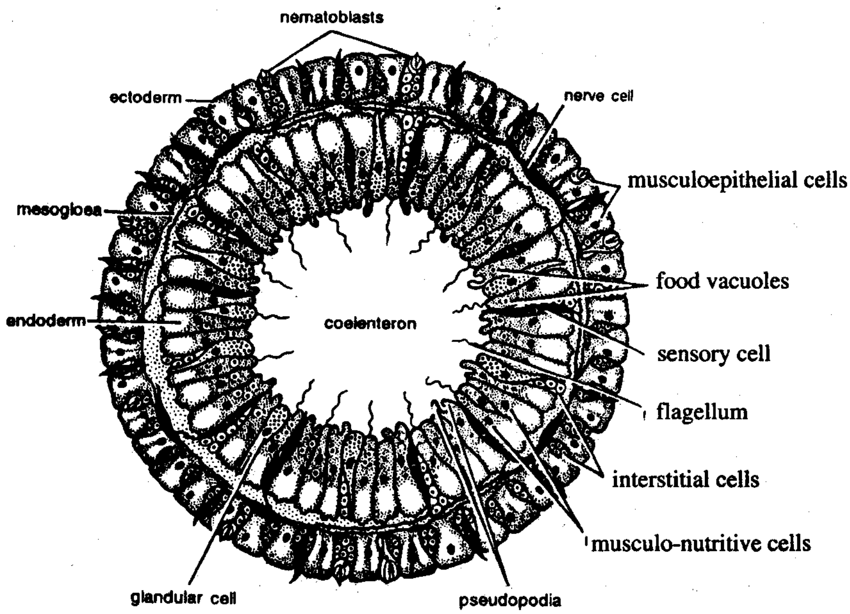

Fig. 2-2. A. *Hydra*. T.S.

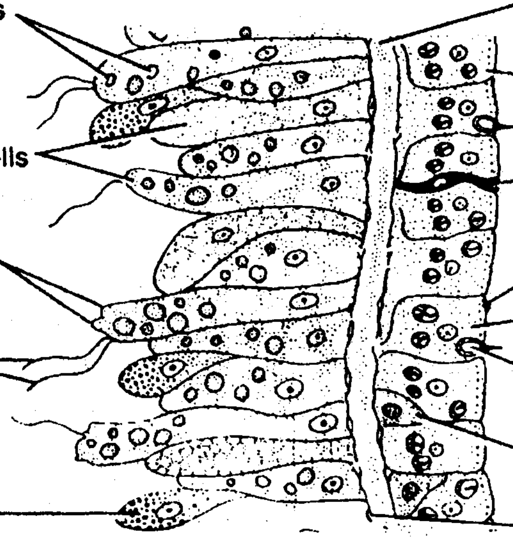

Fig. 2.2 B. *Hydra.* A portion of body wall in longitudinal section

i) Epitheliomuscular cells : The epitheliomuscular (myoepithelial) cells are the most common type of cells in cnidarians. These are cylindrical or columnar in shape with the broader epidermal part directed outwards whereas the muscular part faces inwards and resting on the mesoglea. (Fig. 2.2A and 2.2 C) The inner end is drawn into two or more processes, which have myonemes or unstriped muscle fibres. The myonemes extend along the longitudinal axis of the body and tentacles. These are highly contractile and bring about contraction of the body. The epitheliomuscular cell has a large nucleus and along the border there is a row of granules which secrete the cuticle.

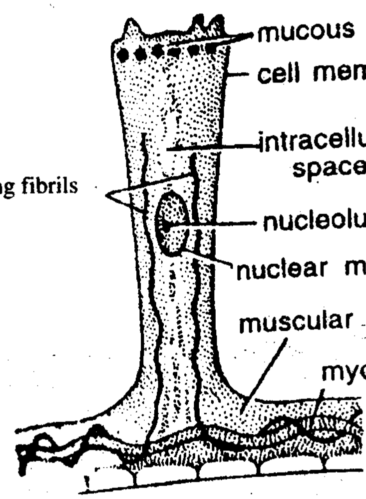

Fig. 2.2 C. *Hydra.* Epitheliomuscular cell

ii) Interstitial cells : In between the basal ends of the epitheliomuscular cells are lodged the interstitial cells. These are small, rounded cells with relatively large nuclei (Fig. 2-2 D). These cells can give rise to any other kind of cells (e.g. germ cells – sperms and eggs, nematocysts, epitheliomuscular cells). Hence these cells are said to be totipotent.

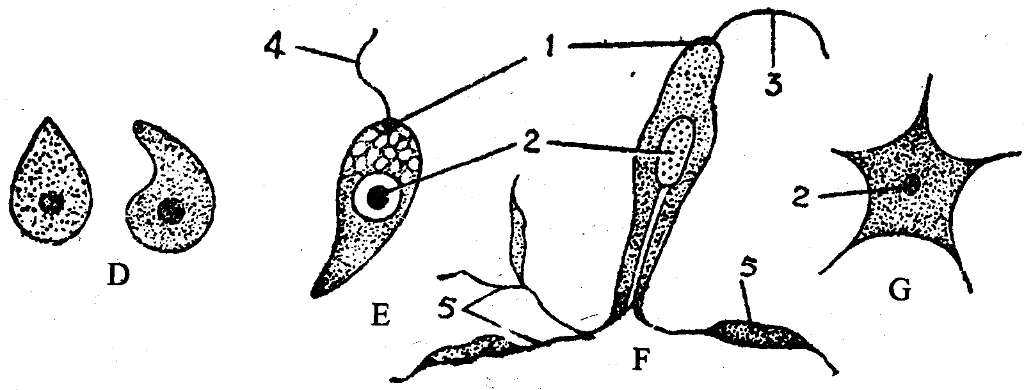

Fig. 2-2 Hydra cells D. Interstitial cells. E. Secretory cell. F. Sensory cell. G. Nerve cell

1. Basal granule, 2. Nucleus 3. Sensory hair, 4. Flagellum, 5. Nodulated process

iii) Gland cells or mucus secreting cells : These are modified epithelial muscular cells located abundantly in the basal disc region. (Fig. 2-2E). They secrete an adhesive substance by which the animal attaches to the substratum. The cytoplasm of the cell is filled with mucous bodies, more numerous at the apical region. They also produce a gas babble sometimes by which the animal can float on the surface of the water.

iv) Sensory/Receptor Cells : These are small columnar cells which lie scattered in the epidermis among the epithelio muscular cells. (Fig. 2-2F). The base of each cell gives rise to a number of neuron processes, and the distal end terminates in a sphere or a sensory bristle (modified cilium). These are found in abundance on the tentacles, hypostome and the basal disc. These are called receptors as they receive and transmit the impulses. These are specialized to receive impulses from different stimuli like touch, temperature, light, chemical and so on.

v) Nerve cells : These are superficially similar to multipolar neurons of other animals and are located at the base of the epidermis next to the mesoglea (Fig. 2-2 G). Each cell is broad and polygonal, and the ends are drawn into long nerve processes which lie close to each other forming a net.

vi) Cnidocytes or Cnidoblasts : These specialized cells are unique and characteristic of all cnidarians. Cnidocytes contain everting organelles known as cnidae. About 30 kinds of cnidae occur in coelenterates. The commonest type are the stinging structures called nematocysts. The other two types, spirocysts and ptychocysts are found only in anthozoans.

Cnidocytes are found throughout the epidermis and are more abundant on the tentacles. These cells develop from the interstitial cells of the epidermis. These are the organs of offence as well as defence. Cnidocytes also help in food capture, locomotion and anchoring with the substratum. A cnidocyte is a rounded or an ovoid cell with a basal nucleus (Fig. 2-2 H&I). The outer end of the cell contains a short, stiff, bristle like process called a cnidocil (modified cilium) and is exposed to the surface. It is conspicuous in hydrozoans and scyphozoans. In anthozoans, the cnidocil is not present, although a ciliary cone complex of similar function is associated with atleast some of the types of cnidocytes found in anthozoans.

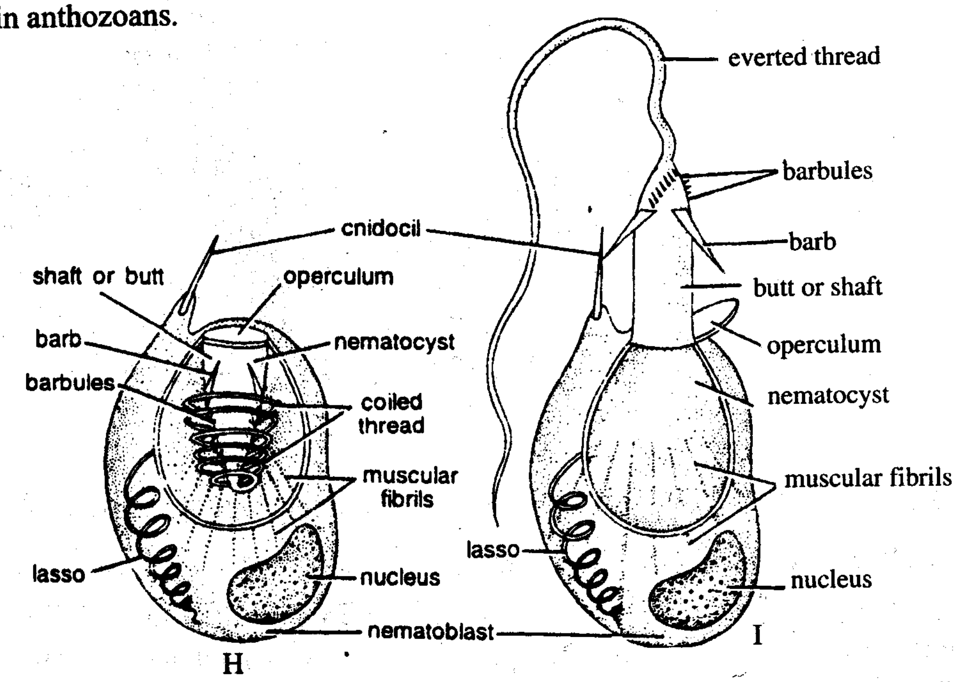

Fig. 2-2 (H & I) *Hydra* Cnidoblast with nematocyst. H- A cnidoblast at rest; I- A cnidoblast with nematocyst discharged.

Each cnidocyte or cnidoblast cell contains a thin rim of cytoplasm surrounding a centrally placed oval sac like capsule called the stinging capsule or nematocyst. The nematocyst sac is filled up with a poisonous fluid called hypnotoxin, which is of proteinaceous nature. The outer end of this capsule is drawn into a coiled, usually pleated tube, and is covered by an operculum or lid like flaps. The tube has a basal swelling called a butt or shaft and a long coiled tube which may be opened or closed at the tip. The base of the butt shows 3 large spines called barbs or styles, and 3 rows of small spines called barbules. On the wall of the capsule are contractile muscle fibrils running into the cnidocyte. Some nematocysts have a coiled restraining thread like structure called lasso which is attached to the base of the cnidoblast. It prevents the falling of the nematocyst from the cell. The base of the cnidocyte is anchored to the lateral extensions of one or more epitheliomuscular cells and may also be associated with a neuron terminal.

Different species of cnidarians possess one to seven structural types of nematocysts. The number and type of nematocyst vary depending on the nature of the prey they trap. *Hydra*, for example, possesses four types, namely Penetrants or Stenoteles, Volvents or Desmonemes, Large glutinants or Streptoline glutinants and Small glutinants or Stereoline glutinants (Fig. 2-2J). These are arranged on the tentacles in groups of batteries. Each battery represents a large number of cnidocytes that have become invaginated within one epitheliomuscular cell (a battery cell). The batteries appear as bumps or warts when the tentacles are extended.

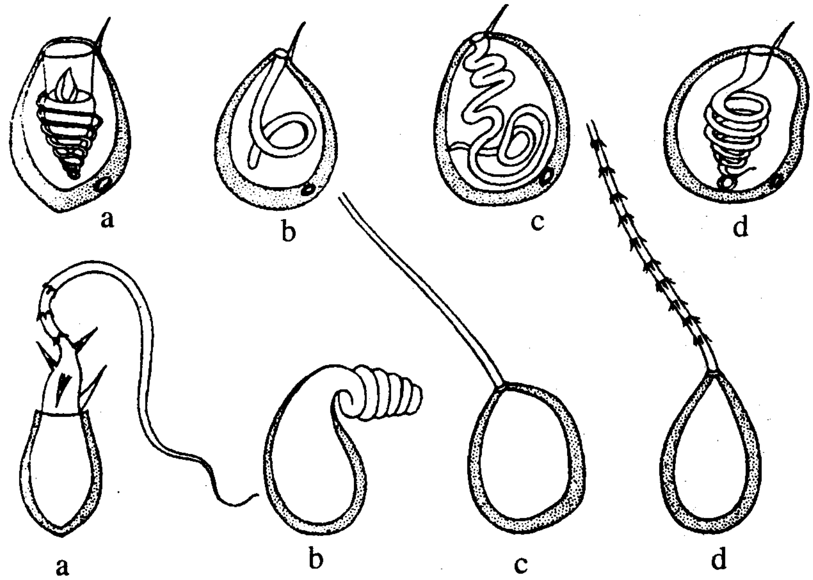

Fig. 2-2 J, Hydra. Types of nematocysts (upper figures undischarged; lower figure dicharged).
a - Penetrant; b - Volvent; c - Small glutinant; d - Large glutinant.

The mechanism of discharge of nematocyst is interesting Due to the increased osmotic pressure inside the capsule and due to the contraction of the walls of nematocyst, the lid or operculum is opened forcibly. It results in the sudden eversion of the thread and turns inside out. Thus the entire nematocyst is drawn out. The contractile fibrils also contract and help the discharge. The discharge is also brought about by mechanical stimulation such as contact with the prey or the enemy. In hydras, the entire discharge process takes 3 minutes. Sea anemones have shown that chemical and mechanical stimuli may interact to discharge nematocysts.

The coiled thread penetrates the body of the victim and the fluid is released into the body by which the victim gets paralyzed. Nematocysts like Desmonemes do not possess any known toxic properties; instead, they function by adhesion or by wrapping and entangling small prey. The thread is closed at the end and may be unarmed and coiled or have a long spiny shaft (Fig.2-2 H and I). The spines appear to be an adaptation for adhesion to the prey surface. The glutinants produce a sticky substance that is used in locomotion (of somersault type) to fasten the tentacles to the substratum. The filament of nematcyts once drawn can not be withdrawn. Hence, the nematocysts or other cnidae are used but once and new cnidocytes are formed from nearby interstitial cells. The discharged nematocysts are replaced within 48h.

B. The Gastrodermis : The histology of the gastrodermis is somewhat similar to that of the epidermis. It forms the main bulk of the body in its thickness i.e. about two-thirds of the body wall. It is mainly nutritive in function. The following are the main types of cells found in the gastrodermis.

i) Nutritive-muscle cells or Endotheliomuscular Cells : These cells are corresponding to the epitheliomuscular cells in the epidermis. These are more numerous forming the main bulk of the gastrodermis. They are elongated and club shaped. (Fig. 2-2A & B and 2-3). Their outer ends are drawn into a pair of muscular processes which are at right angles to the body. The contraction and

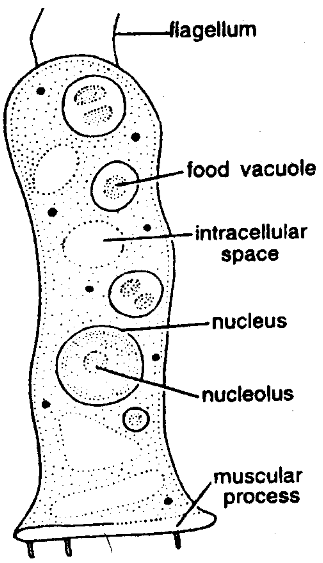

Fig. 2-3 *Hydra* Nutritive muscle cell.

relaxation of these bring about the change in the diameter of the body. The free ends projecting into the enteron are provided with a pair of flagella which keep the food in constant motion and help in digestion. The cells are highly vacuolated and often filled with food vacuoles.

ii) Gland cells : The gland cells lie singly in between the endothelial cells (Fig. 2-2A and B). These are small and club-shaped with their broader ends facing the coelenteron. These cells do not possess the basal muscular processes. Gland cells are of two types :

a) Enzymatic gland cells : These cells secrete the digestive enzymes to digest the food. These are absent in the tentacles and basal disc.

b) Mucus-secreting gland cells : These are abundant around the mouth and hypostome and helps in swallowing the solid food.

iii) Interestitial cells : These are present in between the spaces of gastrodermal cells.

Nerve cells also exist but in far fewer numbers than in the epidermis. Although nematocy are lacking in the gastrodermis of hydrozoans, they are present in restricted areas of this layer in the other classes of cnidarians.

In many cnidarians, the gastrodermal cells contain symbiotic algae. Some species of *Hydra* harbour green *zoochlorellae*, as do certain freshwater sponges. However, the symbiotic alg[illegible] marine cnidarians are zooxanthellae. The green or yellow colour of these algae gives a sin[illegible] to the cnidarian host.

2.1.5. MOVEMENT :

The body and tentacles of cnidarians can extend, contract, or bend to one side or the other. In hydras the gastrodermal fibres in most parts of the body are so poorly developed that movement is almost due to the contractions of the longitudinal, epidermal fibres. The fluid within the gastrovascular cavity plays an important role to work as a hydraulic skeleton. By taking in water through the mouth as a result of the beating of the gastrodermal flagella, a relaxed hydra may stretch out to a length of 20mm, whereas contraction of the epidermal fibres can reduce it to a mere 0.5mm. Hydras can detach and shift locations by somersaulting or floating or looping or gliding movements.

In scyphozoans and cubozoans, a band of powerful circular muscle fibres (the coronal muscle) and radial fibers in the subumbrella produce swimming pulsations similar to those of hydromedusae.

In sea anemones, the muscular system is much more specialized than that in the other cnidarian classes. It is highly developed and is primarily gastrodermal. Bundles of longitudinal fibers in the septa form retractor muscles for shortening the column. Circular muscle fibers in the columnar gastrodermis are well developed (Fig. 2-6). Also important are radial muscles in the complete septa that, on contraction, open the pharynx. Although sea anemones are essentially sessile animals, many species are able to change locations by slow gliding on the pedal disc, by crawling on the side of the column, or by walking on the tentacles.

2.1.6. NUTRITION :

Almost all cnidarians, including hydras, are carnivorous and feed mainly on small crustaceans. If any food material comes in contact with the tentacles, the nematocysts immediately discharge and paralyze the prey by injecting hypnotoxin. The tentacles then pull the captured animal toward the mouth, which opens to receive it. The contraction of the hypostome and the body wall, forces the food into the gastrovascular cavity. All of these feeding responses are initiated by various aminoacids and peptides liberated from the prey, presumably through nematocyst puncture wounds.

Digestion takes place both by extracellular and intracellular methods. In the gastrovascular cavity, enzymatic gland cells secrete proteolytic enzymes that begin the digestion of proteins, and the tissues of the prey are gradually reduced to a soupy broth. Due to the lashing movements of the flagella of the nutritive muscle cells, the food is thoroughly mixed up with the digestive enzymes. The digestion thus occurring in the coelenteron is termed as extracellular digestion, a characteristic of higher animals.

After this initial extracellular phase, digestion continues intracellularly. The nutritive muscle cells produce pseudopodia that engulf small fragments of tissue. Continued digestion of proteins and the digestion of fats occur within food vacuoles of the nutritive muscle cells, and the food vacuoles undergo the acid and alkaline phases, characterestic of lower organisms like Protozoa. Products of digestion are distributed by diffusion. Indigestible materials are ejected from the mouth on contraction of the body.

In colonial hydrozoans (eg. *Obelia*) (Fig. 2-4), the gastrozooids capture and ingest prey, as in *Hydra*, and thus provide nutrition for the colony. Extracellular digestion takes place in the gastrozooid itself, the partially digested broth then passes into the common gastrovascular cavity of the colony, where intracellular digestion occurs.

In hydrozoan medusae, the gut cavity consists of a series of canals, arranged to resemble the hub, spokes and rim of a wheel (Fig.2-5). The mouth leads into a central stomach, from which extend four radial canals. These join with a ring canal running around the margin of the umbrella. The processes of their nutrition are essentially the same as in the polyp.

Anthozoans are either solitary or colonial polypoids. They differ considerably from hydrozoan polyps. The mouth leads into a tubular pharynx that extends more than half way into the gastrovascular cavity (Fig. 2-6). The gastrovascular cavity is divided by longitudinal mesenteries, or septa, into radiating compartments, and the edges of the mesentery bear nematocysts. The free edge of the septum is triboled and is called a septal filament. The middle lobe contains cnidocysts and enzymatic gland cells. The middle lobes continue beyond the base of the septa as threads called

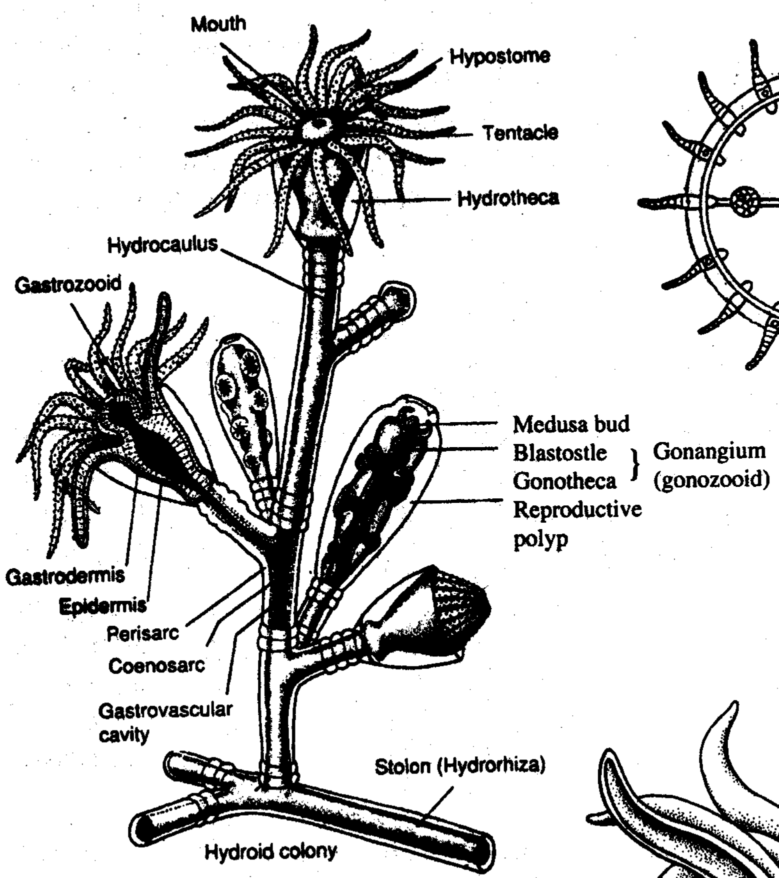

Fig. 2-4. *Obelia* colony.

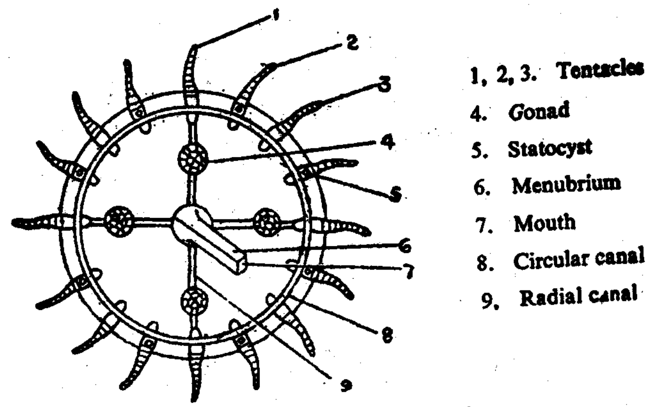

Fig. 2-5. *Obelia* medusa

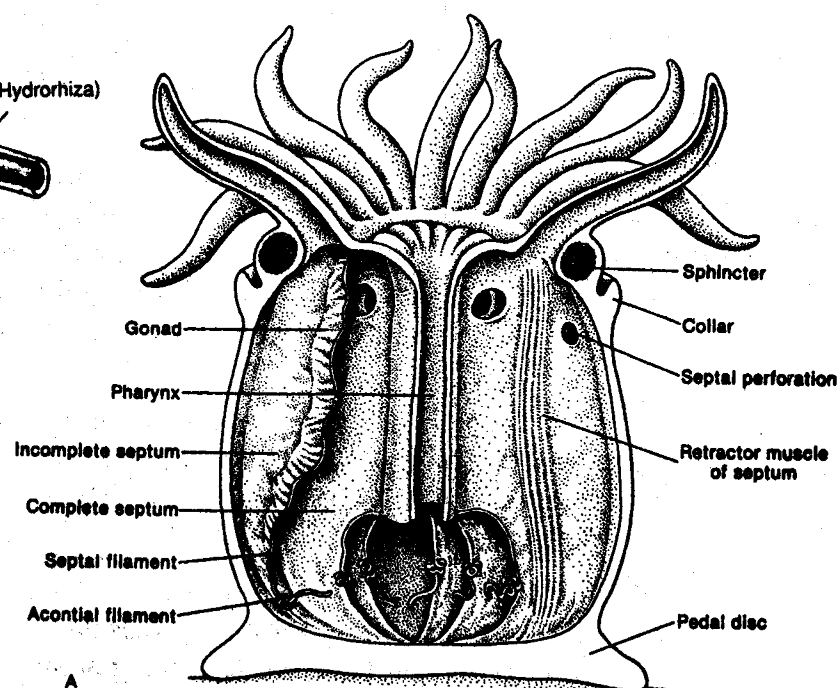

Fig. 2-6. Structure of a sea anemona - Longitudinal section

acontia. The septal filaments form a closely fitting bag around the food. They produce the enzymes for extracellular digestion of proteins and fats. The septal filaments are the principal sites of intracellular digestion and absorption.

2.1.7. GAS EXCHANGE AND EXCRETION :

Gas exchange occurs across the general body surface. Nitrogenous wastes (ammonia) also diffuse through the general body surface. As in many other freshwater animals, there is a continuous influx of water into the bodies of hydras through the body wall. Excess water, which is hypoosmotic to the tissue fluids, is removed periodically from the gastrovascular cavity via the mouth. The gastrovascular cavity thus acts like a giant contractile vacuole or a nephridium of a higher animal.

2.1.8 NERVOUS SYSTEM :

The nerve cells are arranged in an irregular nerve net, or plexus, in the base of the epidermis and gastrodermis and are particularly concentrated around the mouth. The nerve cells which may be bipolar or multipolar, form a sort of irregular net work by forming synaptic junctions. The nerve cells of the ectoderm and gastroderm form two separate net works and they are interconnected. Moreover, their processes are also connected with the sensory cells, epitheliomuscular and endotheliomuscular cells, thus forming a neuromuscular system.

A double nerve net system in the same body layer is common in cnidarians other than hydras. One nerve net acts as a diffuse, slow-conducting system of multipolar neurons; the other as a rapid, through-conducting system of bipolar neurons.

2.1.9 REPRODUCTION :

Hydras reproduce both asexually by budding, and sexually by producing gametes or sex cells.

Asexual budding is the usual means of reproduction during the warmer months of the year when the food material is abundant. A bud develops as a simple evagination of the body wall and contains an extension of the gastrovascular cavity (Fig. 2-7). The mouth and tentacles form at the distal end, and eventually, the bud detaches from the parent to become an independent hydra. Budding occurs in many other cnidarians and is the means by which colonies form in colonial species. (Fig. 2-7).

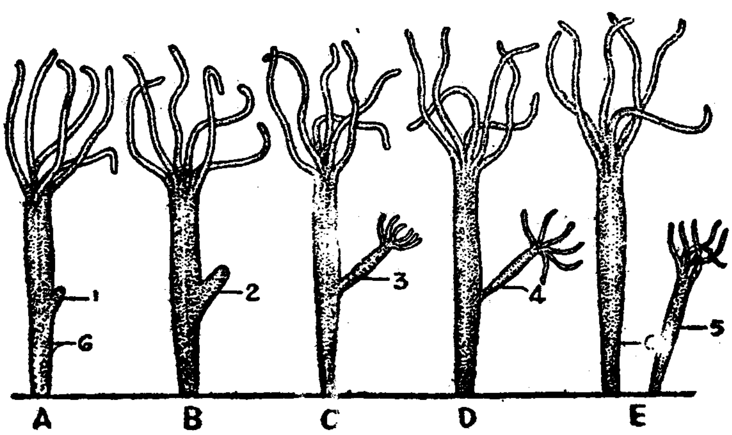

Fig. 2.7 Hydra – Budding
A, B, C, D E Stages in budding
1, 2, 3, 4 Formation of Bud 5. Young hydra 6. Parent

Sexual reproduction occurs during unfavourable conditions, and more common in autumn and winter seasons. Hydras may be hermaphroditic or dioecious. As in all cnidarians, the germ cells originate from interstitial cells, which aggregate in the stalk to form ovaries and testes. Fig. (2-8). A single egg is produced in each ovary. As the egg enlarges, the overlying epidermis ruptures exposing the egg. The testis is a conical swelling with an opening through which the sperms escape. Sperm liberated into the surrounding water and penetrate the exposed surface of the egg, which is thus fertilized *in situ.*

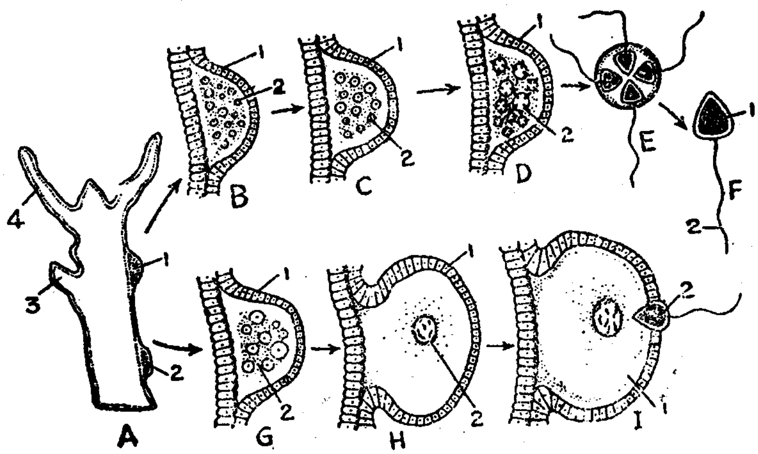

Fig. 2-8. Hydra-formation of sex cells. A. Adult hydra 1. Testis 2. Ovary 3. Bud 4. Tentacle

B, C, D - Formation of Spermatozoan 1. Ectoderm 2. Developing spermatid

E - Spermatids F. Sperm 1. Head 2. Tail G, H. Developing oogonia 1. Ectoderm 2. Oogonia I- Fertilization.

The egg then undergoes cleavage and simultaneously becomes covered by a chitinous shell. When shell formation is complete, the encapsulated embryo drops off the parent and remains in its protective casing through the winter. With the advent of spring the shell softens, and a young hydra emerges. Because each individual may bear several ovaries, a number of eggs may be produced in each season.

The reproductive pattern described for hydras is not typical of most marine cnidarians. Eggs, as well as sperm, may be liberated into the sea water, where fertilization occurs. Cleavage is complete and usually radial. The primitive blastula is hollow (coeloblastula). But a yolky solid blastula (stereoblastula) has evolved in many species. Following gastrulation, a planula larva develops. The planula is an elongated and radially symmetrical larva. It swims for sometime, settles to the bottom and attaches by the anterior end and develops into an adult.

2.1.10. REGENERATION :

Like many other cnidarians, hydras have considerable powers of regeneration. When hydra is cut into pieces, each bit develops into a young individual (Fig.2-9).

7)

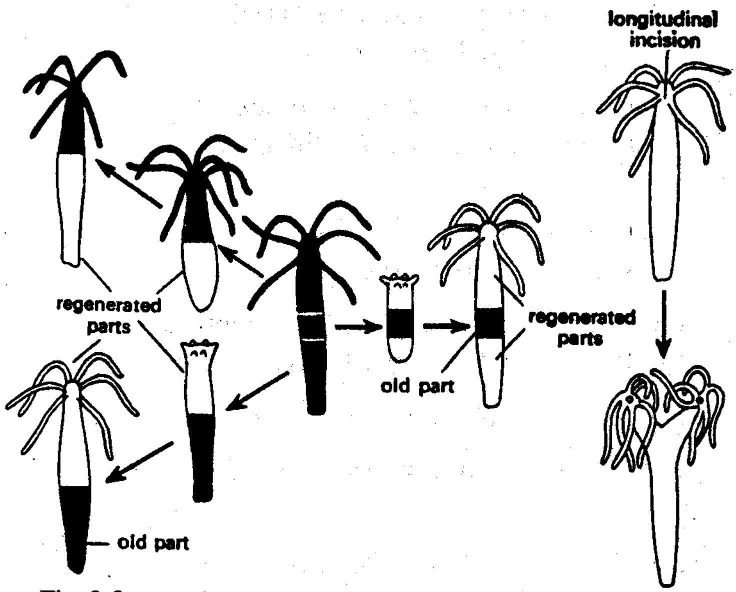

Fig. 2-9. *Hydra.* Diagrams to show the process of regeneration.

2.1.11. SUMMARY :

1. Coelenterates are primitive metazoans showing cell-tissue grade of organization. These are called cnidarians as they possess specialized cells called cnidocytes.

2. Coelenterates are aquatic, radially symmetrical animals with tentacles encircling the mouth at one end of the body. The mouth is the only opening into the gut cavity.

3. They exhibit two types of body forms : the medusa, which is bell or umbrella shaped, adapted for a pelagic or free swimming existence and the polyp, which is tubular or cylindrical, adapted for a sessile, benthic existence.

4. Cnidarians are diploblastic – the body wall consists of an outer epidermis and inner gastrodermis with an intervening mesoglea. Mesoglea may be thin or thick, cellular or acellular connective tissue.

5. Cnidarians are primitive in the absence of organs. Instead, a variety of cells constituting the body wall are highly specialized and show division of labour. The cells are integrated for different functions.

6. Body movement is aided by the contraction and relaxation of the epidermal and gastrodermal muscle fibres.

7. Most of the cnidarians are carnivorous. Some feed on zooplankton and others on large animals. Some are suspension feeders of fine particulate matter. Prey is caught with the tentacles and paralyzed by cnidocytes, which are unique to the phylum. Digestion is initially extracellular followed by intracellular process.

8. Gas exchange and excretion of nitrogenous wastes occur through the general body surface. Excess of water in the gastrovascular cavity is removed periodically via the mouth.

9. The neurons are usually arranged as nerve nets at the base of the epidermal and gastrodermal layers, and impulse transmission tends to be radiating

10. Cnidarians reproduce both by asexual and sexual means. A ciliated, free-swimming stereogastrula, called the planula larva, occurs in the life cycle of most cnidarians.

2.1.12. KEY TERMINOLOGY:

Acellular : Without cellular organization.

Acontium (pl. Acontia) : A thread originating from the middle lobe of an anthozoan septal filament that projects freely into the gastrovascular cavity.

Asexual reproduction : Reproduction without involving gametes.

Basal lamina : Thin, collagenous, fibrous sheet secreted by epithelial cells and on which they rest. .

Blastula: The early embryo in which the cells form a hollow ball.

Budding: Production of offspring by development of a lateral branch from part of the body. It is a form of asexual reproduction

Carnivorous : Eating on other animals.

Cellular: Pertaining to or consisting of cells.

Cnida (pl. cnidae): An eversible cnidarian organelle that occurs in a cnidocyte.

Cnidocil: A short, stiff, bristle-like cilium projecting from the outer margin of the cnidocyte.

Cnidocyte: A cnidarian cell that contains an eversible cnida.

Coelenteron: The body cavity and gut of cnidarians. Also called gastrovascular cavity.

Coeloblastula : Blastula having a well developed blastocoel.

Dioecious: Having the male and female reproductive organs in separate individuals.

Diploplastic: Derived from two embryonic germ layers, ectoderm and endoderm or Body wall showing two layers- an outer epidermis and an inner gastrodermis.

Extracellular digestion: Digestion which occurs outside the cells. In coelenterates it occurs in the gastrovascular cavity.

Exumbrella: Aboral, upper surface of the bell of a medusa.

Gastrodermis: Cellular epithelial lining of the gastrovascular cavity of coelenterates.

Gastrovascular cavity: The internal body cavity of coelenterates. It serves the function of both digestion and circulation including distribution of food.

Gastrula: An embryonic stage with two germ layers, ectoderm and endoderm.

Hermaphroditic: Having both male and female reproductive organs in the same individual.

Hypostome: A mound or cone that bears the mouth of hydropolyps.

Intracellular digestion: Digestion which occurs within the cells. In coelenterates it occurs in the food vacuoles of nutritive muscle cells.

Metazoa: Multicellular animals in which there is a differentiation of the body cells as opposed to the unicellular animals.

Mesoglea: A gelatinous, cellular or acellular layer present between epidermis and gastrodermis. Acellular in hydrozoans and cellular in scyphozoans and anthozoans.

Nematocyst: One of the stinging capsules or cnidae found in the cnidocyte of coelenterates.

Pelagic: Inhabiting the open water, away from shore, as in the oceans or Living, floating or swimming above the water column.

Planula: The citiated free-living larval form of most coelenterates.

Polymorphic: Colony consisting of more than 2 or 3 structurally and functionally different types of individuals – gastrozooids, gonozooids and dactylozooids.

Polyp : Generally sessile, tubular and asexual form of coelenterate.

Septal filament: The free edge of an anthozoan septum that is trilobed.

Sessile: Attached, not free-moving, sedentary.

Sexual reproduction: Reproduction involving the gametes.

Solitary: Living alone, not a member of the colony or group.

Stereogastrula: A solid gastrula, lacking an archenteron cavity.

Tentacle: Evagination of the body wall surrounding the mouth which aids in the capture and ingestion of food.

Zoochlorellae: A green algal symbionts of certain animals, especially freshwater sponges and freshwater and marine cnidarians and turbellarians.

Zooplankton: Microscopic animals that are free-swimming or suspended in the water of both oceans and freshwater lakes.

2.1.13. SELF ASSESSMENT QUESTIONS :

1. Describe briefly the general organization of coelenterates.
2. Give an account of the histological structure of the body wall of *Hydra.*
3. Give a detailed account on the modes of reproduction in *Hydra.*
4. Briefly explain the patterns of feeding and digestion in coelenterates.
5. Write notes on :

a) Cnidocytes
b) Gastrovascular cavity in coelenterates
c) Nutrirtive muscle cells
d) Sexual reproduction in *Hydra.*

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Dr. P. Padmavathi

2.2 CLASSIFICATION OF PHYLUM COELENTERATA

2.2.1 OBJECTIVES :

The purpose of this lesson is to :

- understand the general characters of phylum Coelenterata and
- classify the Phylum Coelenterata upto orders.

2.2.2. INTRODUCTION :

Coelanterates are the primitive group of individuals which show the typical metazoan characters and tissue grade of organization. Unlike the Protozoa and Parazoa, the cells of Coelenterata are highly specialized and integrated for different functions.

The coelenterates possess two basic structural features of metazoa. 1) An internal space for digestion and circulation called gastrovascular cavity; (2) Diploblastic body wall with a mesoglea in between. Although coelenterates are basically tantaculate and radially symmetrical, they exihibit two different structural types. They are stinging animals with the characteristic "Cnidocytes" which are unique for this group.

Basing on stinging qualities of coelenterates, Aristotle considered these organisms as Acalephae or Cnidae (Gr. *akalephe*=nettle; *cnidos*=thread). He also considered these organisms as intermediate between plants and animals, and included them in Zoophyta together with various forms – from sponges to ascidians. Peyssonel (1723) for the first time observed the animal nature of cnidarians and called them coral insects. Linnaeus, Lamarck and Cuvier grouped the coelenterates under Radiata. Leuckart (1847) created the Phylum Coelenterata (Gr. *koilos*=cavity, *enteron*=intestine) including sponges, cnidarians and ctenophores. Hatschek (1888) splitted Leuckart's Coelenterata into three distinct Phyla: Porifera (Spongiaria) Cnidaria (Coelenterata) and Ctenophora. The coelenterates are distinguished from poriferans as metazoans having distinct digestive cavity. The coelenterates differ from ctenophores by having primarily radial symmetry, nematocysts, polyp stage, and asexual and sexual mode of reproduction.

2.2.3 GENERAL CHARACTERS :

1. Coelenterates are primitive metazoan animals with low grade of tissue organization.
2. These are aquatic, mostly marine except few freshwater forms like hydras.
3. These are solitary or colonial and sedentary or free-swimming.
4. Some are polymorphic i.e. many zooids performing different functions exist in a colony.
5. Body is radially or biradially symmetrical with a central gastrovascular cavity communicating to the exterior only by the mouth. Anus is absent.
6. These are diploblastic animals i.e. the body wall is made up of two cellular layers, an outer epidermis and an inner gastrodermis with intervening cellular or non-cellular mesoglea.
7. Acoelomate animals because they do not possess a true body cavity or coelom.
8. Coelenterates exist in two forms - polyp, an asexual phase and medusa, a sexual phase. Polyp is tubular and medusa is umbrella shaped.
9. Skeleton is generally absent but corals have either exoskeleton or endoskeleton made of calcareous or horny material

10. Mouth is encircled by tentacles in one or more whorls. Tentacles are rich in nematocysts useful for food capture and defence.
11. They are usually carnivorous; digestion is extracellular as well as intracellular.
12. Nervous system is in the form of a diffuse network.
13. Respiratory, circulatory and excretory systems are absent.
14. In some, sense organs like statocysts are present.
15. Reproduction is by asexual and sexual methods.
16. Asexual reproduction occurs by budding and sexual reproduction by the formation of gametes.
17. Mostly, cnidarians are hermaphrodites and some are dioecious.
18. Life history usually includes a ciliated planula larva.
19. Usually alternation of generations or metagenesis is observed in the life history i.e. polyp and medusa are developed alternately one from the other.

2.2.4 CLASSIFICATION :

Phylum Coelenterata or Cnidaria is divided into three classes *viz.*, Hydrozoa, Scyphozoa and Anthozoa, basing on the presence or absence of polyp and medusa stage, and cellular or noncellular mesoglea.

2.2.5. CLASS-HYDROZOA :

1. Both medusa and polyp stages occur (Polyps are predominant in life cycle). Exclusively polypoid or medusoid forms are also present.
2. Chiefly marine, a few freshwater. Solitary or colonial.
3. Mesoglea is acellular
4. Cnidocytes confined to the epidermal layer.
5. Medusa is umbrella like with a velum at the margin of the umbrella.
6. Coelenteron or gastrovascular cavity is simple and saclike.
7. Some have an exoskeleton of calcareous material.
8. Polymorphism is common in hydrozoans.
9. Gonads ectodermal and the sex cells are discharged into the water.

2.2.5.1 ORDER HYDROIDA :

1. Polypoid generation well developed, and gives rise to medusae by budding.
2. Medusae stage present or absent.
3. Sense organs of medusae include ocelli and ectodermal statocysts.
4. Solitary or colonial forms

   Examples : *Hydra* (Fig. 2-1C), *Hydractinia, Tubularia, Obelia* (Fig. 2-4), *Companularia, Plumularia.*

2.2.5.2. ORDER MILLEPORINA :

1. Colonial coral-like Hydrozoa without perisarc
2. Calcareous skeleton is secreted by ectoderm, provided with pores through which polyps protrude out.
3. Polyps are dimorphic i.e. colony has two kinds of zooids, the gastrozooid and the dactylozooid.
4. Gastrozooids (nutritive zooids) are short, with mouth and tentacles.
5. Dactylozooids (defensive polyps) are elongate hollow, slender with tentacles but without mouth.
6. Medusae without mouth and tentacles.
7. Stinging coral consists of defensive polyps arising from separate pores encircling a central gastrozooid.

   Example : *Millepora.*

2.2.5.3. ORDER STYLASTERINA :

1. Colonial coral-like Hydrozoa.
2. Hydrocorals having a thick layer of tissue overlying the skeleton
3. Polyps are dimorphic
4. Defensive and feeding polyps located within a star-shaped common pit.
5. Medusae develop in special cavities which are reduced sporosacs.

   Examples : *Stylaster, Allopora.*

2.2.5.4. ORDER TRACHYLINA :

1. Medusoid hydrozoans lacking a polypoid stage.
2. Medusae are large, provided with tentaculocysts, statocysts and lithocysts enclosed in the endoderm.
3. This order contains perhaps the most primitive members of the class.

   Examples: *Geryonia, Cunina.*

2.2.5.5. ORDER SIPHONOPHORA :

1. Highly polymorphic, pelagic hydrozoan colonies with several types of polypoid and medusoid individuals.
2. Colonies with floats (Pneumatophore) or large swimming bells.
3. Polyps without tentacles.
4. Mudusae incomplete and rarely freed.

   Examples : *Diphyes, Physalia, Velella, Porpita* (Fig. 2-27), *Halistemma* (Fig. 2-26).

2.2.6. CLASS SCYPHOZOA :

1. Medusoid form is dominant; the polypoid form is restricted to a larval stage.
2. Completely marine individuals, free-swimming or attached by an aboral stalk and solitary.

3. Mesoglea is thick, gelatinous and cellular.
4. The thick mesoglea constitutes the bulk of the animal, hence commonly called jelly fishes.
5. Some cnidocytes are gastrodermal.
6. Medusae are large, bell or umbrella shaped, without true velum.
7. Gastrovascular cavity is without stomodaeum. But it possess four gastric filaments with or without inter-radial pockets.
8. Sense organs are usually in the form of tentaculocysts.
9. Gonads are endodermal and sex cells are discharged into the gastrovascular cavity.
10. The fertilized egg develops into a planula larva. The planula develops into a polypoid larva called a scyphistoma. Young medusae or ephyrae are budded by transverse fission from the oral end of polypoid larva, a process called strobilation. Buds may form one at a time called monostrobilation or many buds may form simultaneously called polystrobilation. The microscopic ephyrae break from the scyphistoma one by one. Ephyrae feed largely on small crustaceans and may take six months to two years to attain sexual maturity.

2.2.6.1 ORDER STAUROMEDUSAE OR LUCERNARIDA :

1. Sessile polypoid scyphozoans attached by a stalk.
2. Body is globet or trumpet shaped.
3. Mouth cruciform (four cornered) with small oral lobes and a short quadrangular manubrium.
4. Gastrovascular system is divided into central stomach and four per-radial pouches by the four interradial septa.
5. Marginal sense organs are absent.
6. Gonads are elongated band-like borne on the faces of septa.
7. Chiefly in cold littoral waters.

Examples : *Lucernaria* (Fig 2-10), *Haliclystus.*

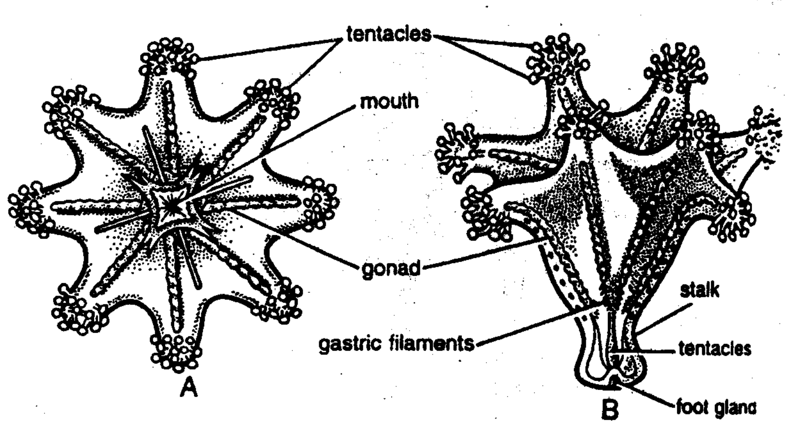

Fig 2-10. *Lucernaria.* A-Oral view; B-Side view

2.2.6.2 ORDER CUBOMEDUSAE OR CARYBDEIDA :

1. Free-swimming Scyphozoa.
2. Bell cubical with four flat sides.
3. Bell margin is not scalloped, possesses a velum-like structure (velarium) and bears four tentacles.
4. Mouth cruciform. Gastric pouches are present.
5. Four tentaculocysts or rhopalia are present.
6. Gonads are leaf-like.
7. Found in warm and shallow waters of tropical and subtropical oceans.

Examples : *Carybdea, Chrinex, Tamoya.*

2.2.6.3. ORDER CORONATAE :

1. Free-swimming forms
2. Bell conical, bowl shaped or dome shaped or flattened.
3. Bell with a deep encircling groove, called coronal groove. This groove is found extending from the central mouth around the exumbrella. The coronal groove divides the exumbrella into an upper cone and a lower crown.
4. The crown consists of pedal lobes, pedalia, which bear solid tentacles.
5. Bell-margin scalloped into lappets alternate with pedalia.
6. Mouth cruciform.
7. About 4 to 32 tentaculocysts or rhopalia are present.
8. Found inhabiting the deep waters of ocean.

Examples : *Pericolpa, Periphylla, Atolla.*

2.2.6.4. ORDER SEMAEOSTOMEAE :

1. Most common free-swimming medusae.
2. Bell bowl-shaped or saucer shaped having scalloped margins.
3. Bell margin is fringed with hollow tentacles.

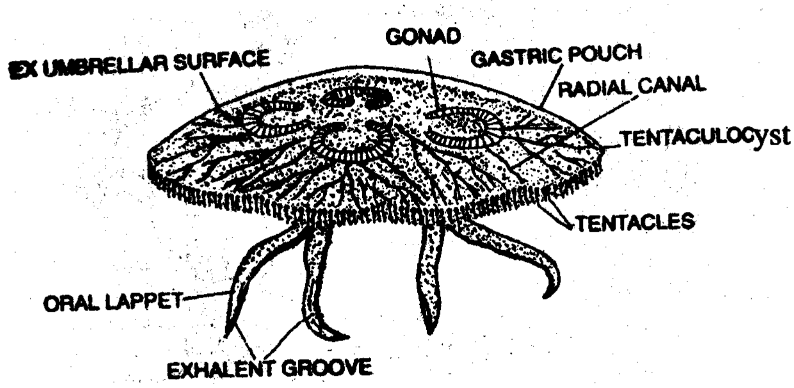

Fig. 2-11 : Aurelia-lateral view

4. Mouth is square.
5. Manubrium divided into four oral arms.
6. Gastrovascular cavity with radial canals extending from central stomach to bell margin.
7. Gastric pouches and filaments are absent.
8. Eight or more tentaculocysts are present.
9. Found inhabiting the coastal waters of all oceans.

Examples : *Aurelia* (Fig. 2-11), *Cyanea, Chrysaora.*

2.2.6.5. ORDER RHIZOSTOMAE :

1. Free-swimming scyphomedusae.
2. Bell is saucer or bowl-shaped or flattened or even concave on the top.
3. Bell margin without tentacles.
4. Manubrium has eight oral arms.
5. The oral arms are branched. The branched oral arms bear deep folds or secondary mouths. Foo is passed into these deep folds. The secondary mouths open into the stomach by way of canals.
6. Original mouth lost through fusion of oral arms, except in *Stomolophus.*
7. Eight or more tentaculocysts are present.
8. Found in shallow waters of tropical and sub-tropical oceans.

Examples: *Rhizostoma* (Fig. 2-12), *Cassiopea, Stomolophus.*

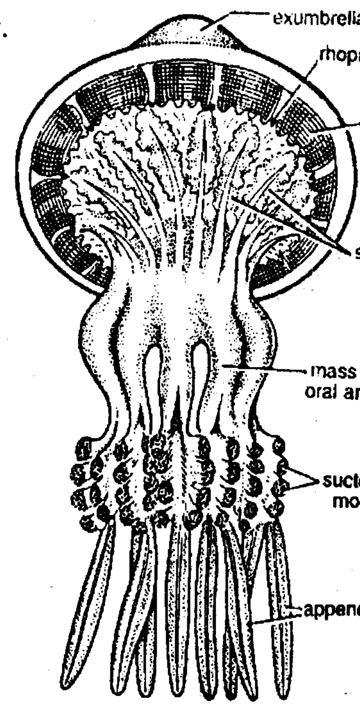

Fig. 2-12. *Rhizostoma.*

2.2.7 CLASS ANTHOZOA :

1. Only polyp stage is present and medusoid stage is absent.
2. Exclusively marine forms; solitary or colonial.
3. Body usually cylindrical with hexamerous, octomerous or polymerous biradial or radiobilateral symmetry.
4. Oral end of the body is expanded radially into an oral disc bearing hollow tentacles around mouth.
5. Stomodaeum is well developed, often provided with one or more ciliated grooves, the siphonoglyphs.
6. Gastrovascular cavity is divided into compartments by complete or incomplete septa or mesenteries.
7. Mesenteries bear nematocysts at their inner free edges.

8. Mesoglea is well developed with fibrous connective tissue.
9. Skeleton either external or internal and may be calcareous or hormy forming massive corals.
10. Nervous system is in the form of typical nerve net.
11. Gonads are endodermal, develop in the mesenteries.
12. Fertilization is external.
13. Planula larva is seen in the development. After a short free life, it settles down and develops into an adult.

2.2.7.A SUB CLASS OCTOCORALLIA OR ALCYONARIA :

1. Colonial marine forms.
2. The polyps of the colony are usually connected by a mass of tissue called coenenchyme.
3. Octocorals with eight pinnate tentacles and with eight complete mesenteries.
4. Tentacles possess side branches as does a feather. Single ventral siphonoglyph is present.
5. Endoskeleton calcareous or horny, derived from mesoglea .
6. Polyps are dimorphic in some forms.

2.2.7.A.1 ORDER STOLONIFERA :

1. No coenenchymal mass; polyps arising from a creeping mat or stolon.
2. Skeleton consists of loose spicules or of compact tubes and platforms.
3. Inhabitants of shallow waters in the tropical and temperate regions.

Examples : *Tubipora* (Organ-pipe coral) (Fig. 2-13), *Clavularia.*

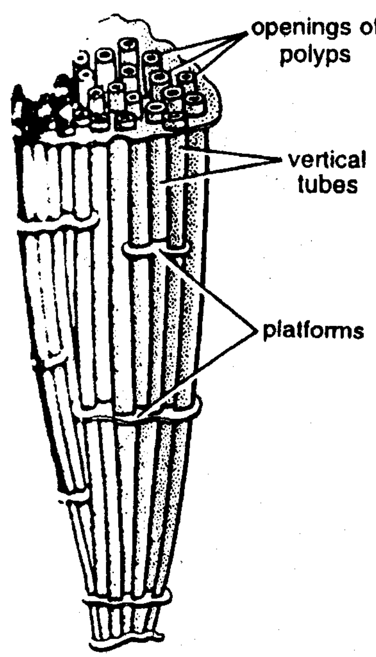

Fig. 2-13. *Tubipora musica.*

2.2.7.A.2 ORDER TELESTACEA :

1. Colony consists of simple or branched stems arising from a creeping base.
2. Lateral polyps on simple or branched stems.
3. Skeleton of calcareous or horny spicules.

Example : *Telesto.*

2.2.7.A.3. ORDER ALCYONACEA :

1. Soft corals.
2. Coenenchyme forming a rubbery mass. Colony may have a massive mushroom shape or an encrusting growth form

3. Lower part of the polyp fused into a fleshy mass with only oral ends protruding.
4. Largely tropical

Examples : *Alcyonium, Xenia, Gersemia.*

2.2.7.A.4. ORDER HELIOPORACEA OR COENOTHECALIA :

1. Blue corals, having a massive blue calcareous skeleton.
2. Skeleton concealed by polyps.
3. Contains only the Indo-pacific blue coral

Example : *Heliopora.*

2.2.7.A.5 ORDER GORGONACEA :

1. Horny corals or gorgonian corals.
2. Commonly known as sea fans, sea feathers and sea whips.
3. Plant-like colonial and highly branched forms.
4. The axial skeleton is composed of separate or fused calcareous spicules or a horny organic material called gorgonin.
5. Found in tropical and subtropical shores.

Examples: *Gorgonia* (Sea fan) (Fig. 2-14) *Leptogorgia* (sea whip); *Corallium* (precious red coral) (Fig. 2-15) *Muricea* (Sea rod).

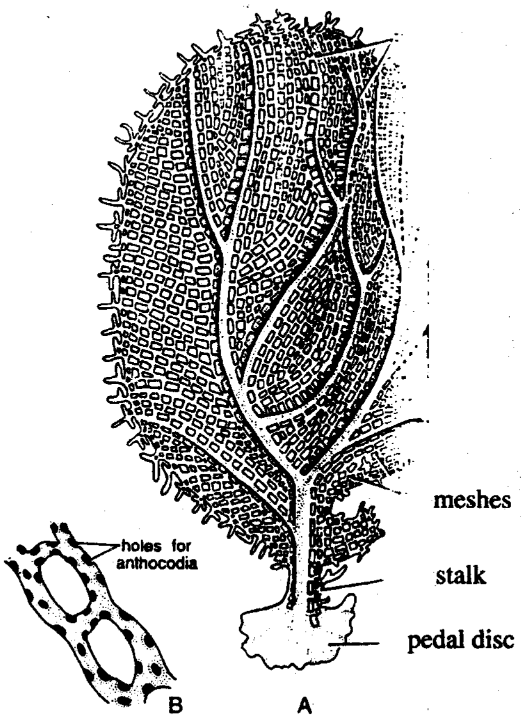

Fig. 2-14. *Gargonia. A-Entire colony; B-A portion*

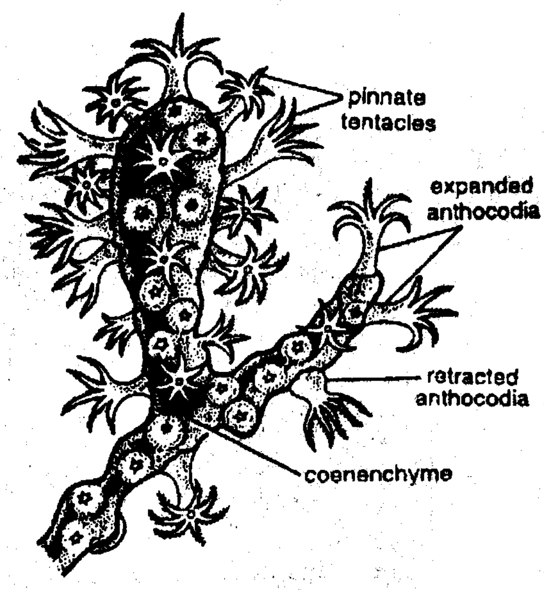

Fig. 2-15. *Corallium rubrum*

2.2.7.A.6. ORDER PENNATULACEA :

1. Sea pens. The colony is elongated and divided into lower stalk or peduncle, and a distal rachis.
2. Peduncle is embedded in the mud and sand.

3. Rachis is the axial polyp that bears numerous dimorphic polyps on its lateral branches.
4. The stem is supported by calcareous spicules or horny skeleton.

Examples : *Pennatula* (Sea pen) (Fig. 2-16), *Renilla* (Sea pansy) (Fig. 2-17) *Pteroides.*

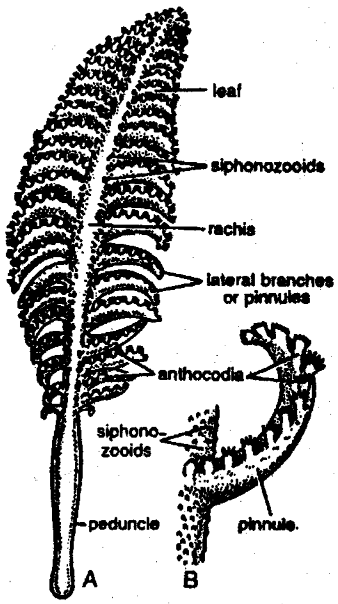

Fig. 2-16. *Pennatula.* A-Entire colony, B-A portion magnified.

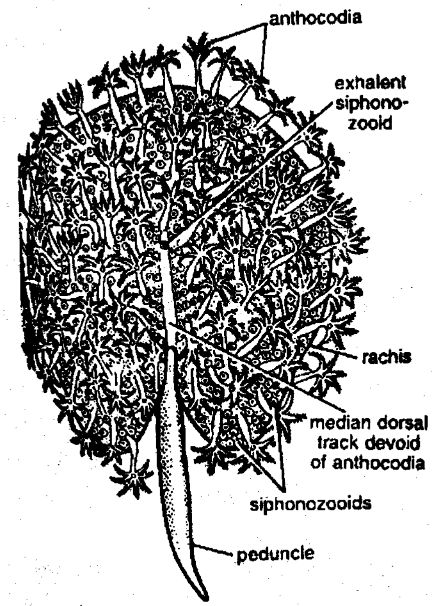

Fig. 2-17. *Renilla.*

2.2.7.B. SUB CLASS HEXACORALLIA OR ZOANTHARIA :

1. Solitary or colonial marine forms.
2. Polyps with more than eight tentacles and rarely pinnate.
3. Septa or mesenteries are typically in cycles of 12.

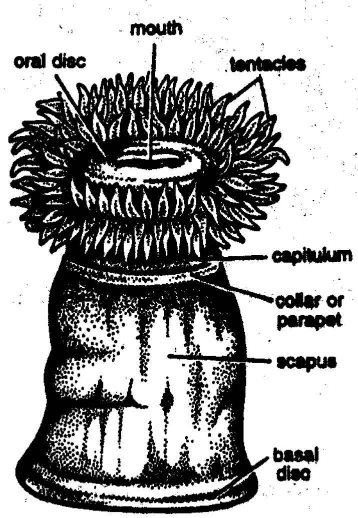

Fig - 2-18. *Metridium*

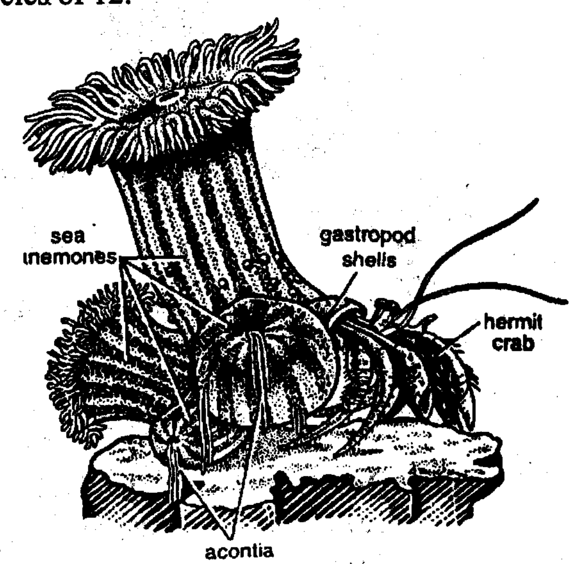

Fig - 2-19. *Adamsia*

4. Two siphonoglyphs are commonly present.
5. Endoskeleton when present is calcareous, derived from ectoderm.
6. Polyps are usually monomorphic.

2.2.7.B.1. ORDER ACTINIARIA :

1. Sea anemones
2. Solitary, large anthozoans with no skeleton.
3. Body cylindrical, divided into oral disc, column and base or pedal disc.
4. Tentacles and mesenteries are numerous in hexermerous cycles i.e., arranged in multiples of six.
5. Usually with two siphonoglyphs.

Examples : *Actinia, Metridium* (Fig. 2-18), *Adamsia* (Fig. 2-19), *Edwardsia.*

2.2.7.B.2 ORDER ZOANTHIDEA :

1. Mostly colonial, small anemone like anthozoans with no skeleton.
2. Pedal disc absent.
3. Mesenteries are paired.
4. Having one siphonoglyph.

Examples : *Zoanthus, Polythoa.*

2.2.7.B.3. ORDER MADREPORARIA OR SCLERACTINIA :

1. Stony corals.
2. Mostly colonial anthozoans secreting a heavy external calcareous skeleton.
3. Sclerosepta arranged in hexamerous cycles.
4. Polyps small, enclosed in the cup-like cavities of the exoskeleton.
5. Siphoglyph usually absent.

Examples : *Fungia* (Fig. 2-20), *Favia, Madrepora* (Fig. 2-21), *Acropora, Astraea* (Fig. 2-22).

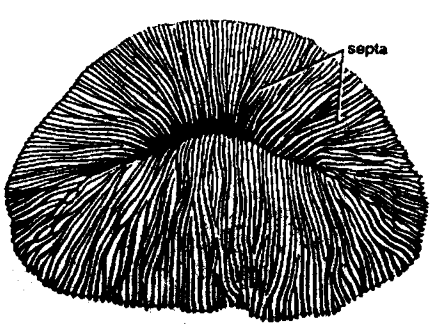

Fig. 2-20. *Fungia*

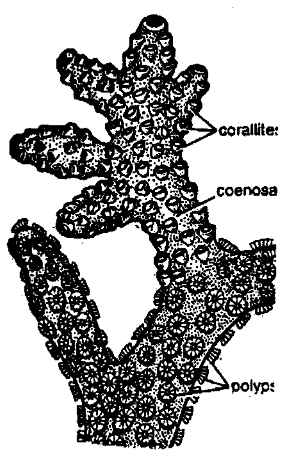

Fig. 2-21. *Madrepora*

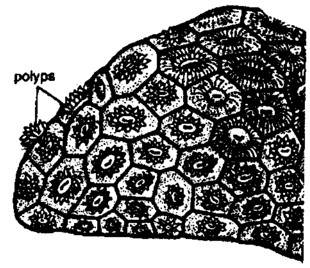

Fig. 2-22. *Astraea*

2.2.7.B.4. ORDER CORALLIMORPHARIA :

1. Coral-like anemones. Solitary or colonial polyps resembling true corals but lack skeletons.
2. Tentacles often in radiating rows.

Examples : *Corynactis.*

2.2.7.B.5. ORDER ANTIPATHARIA :

1. Black or horny corals.
2. Colonial, tree-like black hexacorallian corals.
3. Polyps arranged around an axial skeleton composed of a black, horny material and bearing thorns.
4. Tentacles and mesenteries are 6-24 in number.
5. Two siphonoglyphs are present.
6. Largely in deep water in tropics.

Examples : *Antipathes.*

2.2.7.B.6 ORDER CERIANTHARIA :

1. Burrowing, solitary anemone-like anthozoans.
2. Body greatly elongated, adapted for living with secreted tubes buried in sand or mud.
3. Pedal disc and skeleton absent.
4. Tentacles and mesenteries are numerous. All mesenteries complete.
5. One siphonoglyph.

Examples: *Cerianthus, Ceriantheopsis.*

2.2.8. SUMMARY :

1. Coelenterates are the primitive metazoan animals with tissue grade of organization. Leuckart (1847) created the phylum Coelenterata including sponges, cnidarians and ctenophorans. Hatschek (1888) considered the coelenterates under three distinct Phyla: Porifera (Spongiaria), Cnidaria (Coelenterata) and Ctenophora.

2. Coelenterates are aquatic, radially or biradially symmetrical, diploblastic animals. Some are solitary and some are colonial. The colonial forms mostly exhibit polymorphism.

3. Body cavity called gastrovascular cavity or coelenteron is communicating to the exterior only by the mouth.

4. Skeleton is generally absent but corals have either exoskeleton or endoskeleton made of calcareous or horny material.

5. Most of them feed on zooplankton and carnivorous. Digestion is initially extracellular, then intracellular.

8) 6. Nervous system is in the form of nerve net.

7. Respiratory, circulatory and excretory systems are absent.

8. Reproduction is by both asexual and sexual methods.

9. Phylum Coelenterata is divided into three classes namely Hydrozoa, Scyphozoa and Anthozoa.

10. Class Hydrozoa and Class Scyphozoa are divided into 5 orders each.

11. Class Anthozoa is divided into two sub-classes namely Octocorallia and Hexacorallia based on the number of tentacles and septa. Sub class Octocorallia and Hexacorallia are again divided into 6 orders each.

KEY TERMINOLOGY :

Acoelomate: Animals without coelom, or Body organization of animals in which a fluid-filled cavity is absent between the epidermis and gastrodermis.

Benthic: Bottom-dwelling.

Bilateral symmetry: The arrangement of the body parts into two halves so that the right and left halves are mirror images of each other.

Biradial symmetry: Having similar parts arranged around a central axis, but each of the four arcs or sides of the body is identical to the opposite side but not to the adjacent side.

Ephyra : An immature scyphomedusa.

Manubrium : Tube like extension, bearing mouth at its end, that hangs down from the center of the subumbrella of cnidarian medusae. Hypostome of hydroid polyps.

Radial symmetry: The arrangement of similar parts around a central axis.

Scyphistoma: A scyphozoan polyp.

Siphonoglyph: Ciliated groove in the pharyngeal wall of some anthozoans which serves to create a current of water into the gastrovascular cavity.

Strobilation: Process by which scyphomedusae arise as buds that are released by transverse fission of the oral end of the scyphistoma.

Velum: Shelf formed by the margin of the umbrella projected inward which is characteristic of most hydromedusae.

SELF ASSESSMENT QUESTIONS :

1. Discuss the general characters of phylum Coelenterata and classify upto orders.
2. Write the general characters and classification of class Anthozoa upto orders.
3. Write note on :

   a) Siphonophora
   b) Semaeostomeae
   c) Octocorallia
   d) Hexacorallia.

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Dr. P. Padmavathi

2.3. POLYMORPHISM IN COELENTERATES

2.3.1. OBJECTIVES :

The purpose of this lesson is to :

- ✯ define polymorphism
- ✯ describe the patterns of polymorphism in different groups of coelenterates
- ✯ explain the origin of polymorphism and
- ✯ understand the significance of polymorphism.

2.3.2. INTRODUCTION :

Among the coelenterates, hydrozoans exhibit an interesting and peculiar phenomenon of polymorphism. Coelenterates are the first group of animals in the animal kingdom which showed the division of labour through polymorphism. Coelenterates exhibit low level of body organization. Definite organs and organ systems are absent. Hence they are in need of various zooids to perform different functions. The necessity of division of labour resulted in the onset of polymorphism in coelenterates.

Divison of labour was first seen in *Hydra* where cells are specialized to perform different functions in a single individual. Thus the cells differ in their morphology and physiology. In *Obelia* there is further advancement. Here not only the cells are specialized but the individuals get specialized like polyp and medusa which perform different functions. In other colonial forms, specialization of zooids is further intensified, so that many different zooids take up different functions. A phenomenon in which a single species or a colony represented by more than one kind of individual or zooid which differ both structurally and functionally is known as polymorphism.

2.3.3. PATTERNS OF POLYMORPHISM :

The two main forms of the polymorphic colonies are the polyp and medusa. The polyp is a sessile form. It has a mouth, tentacles and a simple gastrovascular cavity. The medusa is a free-swimming form. It is bell or umbrella or saucer shaped with tentacles hang from the margin and bears gonads. Polyps are concerned with protection and asexual reproduction. Medusae are also feeding zooids but reproducing by sexual mode. Both of them may be derived from one another.

Scyphozoans are typically medusoid forms. Anthozoans are exclusively polypoid. The typical and best examples of polymorphism is evident in hydrozoans.

2.3.4. POLYMORPHISM IN HYDROIDA :

Simple Hydroids like *Hydra* are monomorphic existing only in polypoid form. But the cells exhibit a great division of labour. Most of the thecate hydroids like *Obelia* and *Campanularia* are dimorphic consisting of two types of zooids: the gastrozooids and gonophores represented by polyp and medusa. The gastrozooids or trophozooids are always more numerous in a colony. The medusae or gonophores may arise directly from hydrorhiza (*Hydractina*) (Fig. 2-23) or from manubrium of a gastrozooid (*Tubularia*). Sometimes the medusae are produced from modified polyps called blastostyles or gonozooids, thus making the colony trimorphic. In *Obelia*, the blatostyles with medusae are enclosed in a perisarcal covering called gonotheca and the complete structure is termed as gonangium (Fig. 2-4).

The colonies become more complicated with the appearance of a fourth type of zooids called Dactylozooids. Typically they resemble gastrozooids except they lack a mouth, and their basal tantacle is unbranched They are protective in function. These are provided with nematocysts and adhesive cells useful for food capturing as well as protection. Mouth, tentacles and digestive cavity are absent. Dactylozooids is small in *Plumularia.* It secretes mucous and enclosed in small sacs called nematotheca.

In *Hydractina* the polyps exhibit different morphological forms. Apart from gastrozooids, male and female gonozooids with gonophores, dactylozooids and sporosacs occur. Other zooids are:

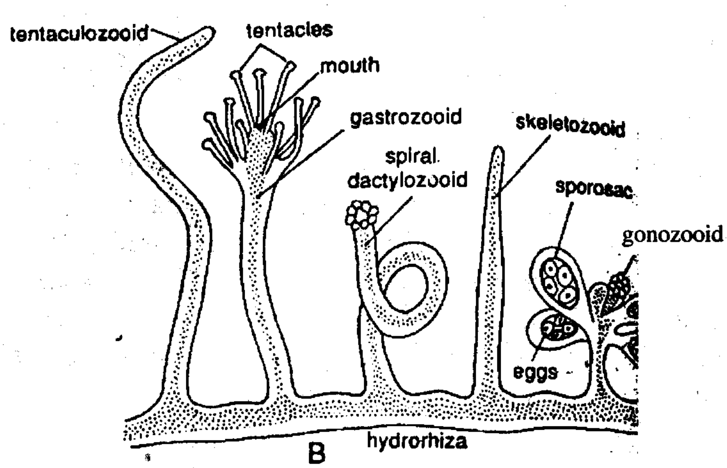

Fig. 2-23. Polymorphic colony of *Hydractinia*

1) long extensive tentaculozooids with sensory cells; (2) spiral zooids with short capitate tentacles fringing from the margins of the colony. The sporosacs are reduced sac like medusae. They produce either male or female gametes.

2.3.5. POLYMORPHISM IN SIPHONOPHORA :

Siphonophores are free swimming colonies which show the highest degree of polymorphism. The polypoid and medusoid forms occur in several modifications which do not resemble the typical hydroid form. They may have three kinds of polypoid zooids and four kinds of medusoid zooids. They are :

1. Polypoid zooids :
   - Gastrozooids - nutritive zooids
   - Dactylozooids - defensive zooids
   - Gonozooids - reproductive zooids
2. Medusoid zooids :
   - Swimming bells - excellent swimming organs which help in locomotion
   - Pneumatophores - gas filled sacs which keep the colony floating.
   - Bracts - defensive in function
   - Gonophores - reproductive medusoids.

2.3.5.1. MODIFIED POLYPOID FORMS :

1. Gastrozooids: Also called siphons. These are the only zooids capable of ingesting food. Hence, the name nutritive or trophozooids or gastrozooid. Gastrozooids have the usual polyp form with a long single hollow tentacle springing up from the base. The tentacle bears lateral contractile branches termed tentilla which terminate with nematocysts. But the tentacles are absent in *Velella* (Fig 2-24).

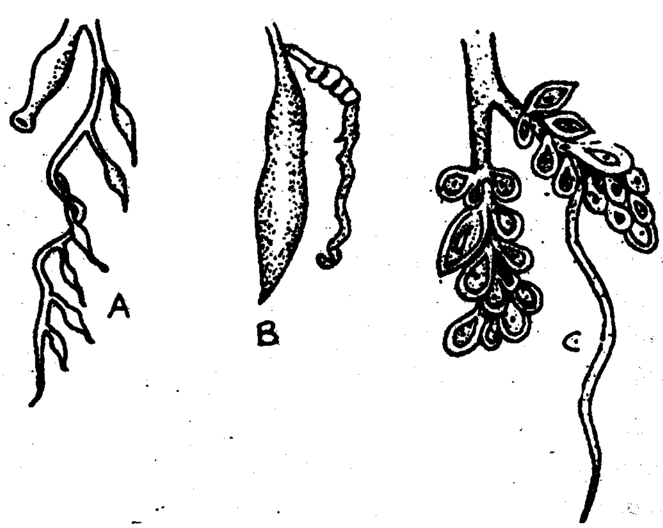

Fig. 2-24. Polypoid zooids A. Gastrozooid, B. Dactylozooid, C. Gonozooid

2. Dactylozooids : Also called palpons, feelers or tasters. These are protective zooids and are actually derived from gastrozooids by the loss of mouth. The body is elongated and highly extensible. A long unbranched tentacle armed with batteries of nematocysts is present. In *Porpita* and *Velella*, a long hollow tentacle–like dactylozooid fringes from the margin of the colony called tentaculozooid (Fig. 2-25). Dactylozooids when associated with gonophores are called gonopalpons as in *Physalia*. Dactylozooids catch the prey and convey it to gastrozooids.

3. Gonozooids : These are reproductive zooids. These are like gastrozooids (*Vellella* and *Porpita)* or blastostyles. Gonozooids produce medusa by asexual budding. Mostly, the gonozooids take the form of a branched stalk called gonodendron having tufts of gonophores with gonopalpons.

2.3.5.2. MODIFIED MEDUSOID FORMS :

These include the swimming bells, the bracts, the gonophores and the pneumatophores which are concerned with floatation, protection and reproduction

1. **Swimming bell or Nectocalyx or Nectophore :** It is a bell shaped medusa with a velum, four radial canals and a ring canal. Mouth, manubruim, tentacles and sense organs are absent. They are varied in shape appearing like flattened or prismatic forms (Fig. 2.26). They are highly muscular. With the use of swimming bells, the colonies are able to swim for long distances.

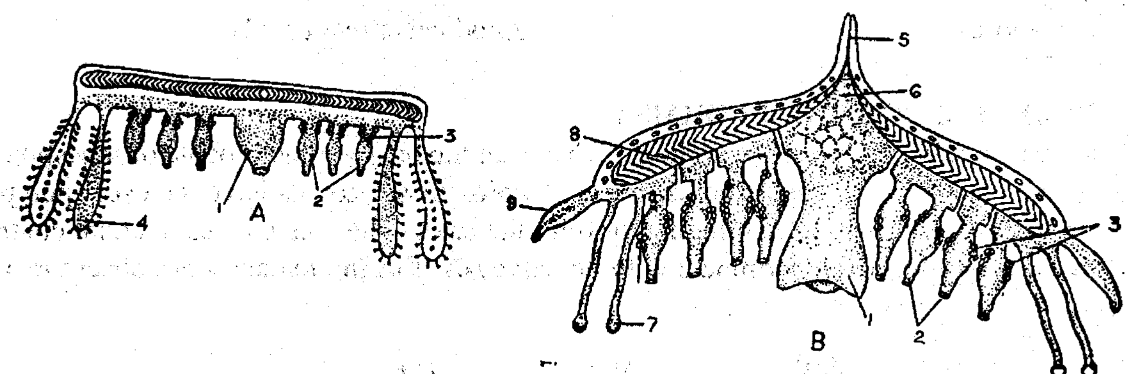

Fig. 2-25 Vertical Section of (A) *Porpita* (B). *Velella*

1. Central gastrozooid 2. Gonozooids 3. Medusae 4. Dactylozooid 5. Crest
6. Liver 7. Tentaculozooid 8. Air chamber, 9. Edge of disc.

2. **Bracts or Hydrophilla or Phyllozooids :** These are thick, gelatinous, leaf-like medusoids containing simple or branched gastrovascular cavity (Fig. 2-26). Though these are medusoid in origin, they never resemble medusa. They may also have helmet-shaped or shield-like body. They are protective in function.

3. **Gonophores :** These are reproductive zooids. They occur on separate stalks or in clustures on polypoid gonozooids *(Velella)* or on simple or branched gonodendron. They are medusa-like with bell, velum, radial canals and a manubrium on which the gonads are borne. Mouth, tentacles and sense organs are absent. Though the colony is hermaphroditic, male and female

gonophores are separate. Male gonophores are sac-like and female gonophores are medusa-like as in *Physalia* (Fig. 2-28). They produce germ cells.

4 **Pneumatophore or float:** The stems of the colonies of all siphonophores become condensed and flat to form a float to which the rest of the zooids are found attached (Fig. 2-26 and 2-27). It shows great variation in its structure and size in different siphonophores. It helps in swimming. It resembles an inverted medusa. Mouth and tentacles are absent. Mesoglea is also absent. The outer ex-umbrellar wall is called Pneumatocodon and the inner sub-umbrellar wall is called Pneumatosaccus or air sac. The air sac is highly muscular. The opening of air sac is directed upwards and is reduced to a small pore, the pneumatopore. This opening is guarded by a sphincter muscle. The air sac is lined internally by chitinous epidermis. The bottom of the air sac is expanded into a chamber called trichter or funnel. The ectodermal lining of this chamber is modified into gas gland. The gas gland secretes the gas. The contents of the gas in air sac are oxygen, nitrogen, argon, etc. The float is absent in *Diphyes,* instead it secretes an oil droplet, which is hydrostatic in function.

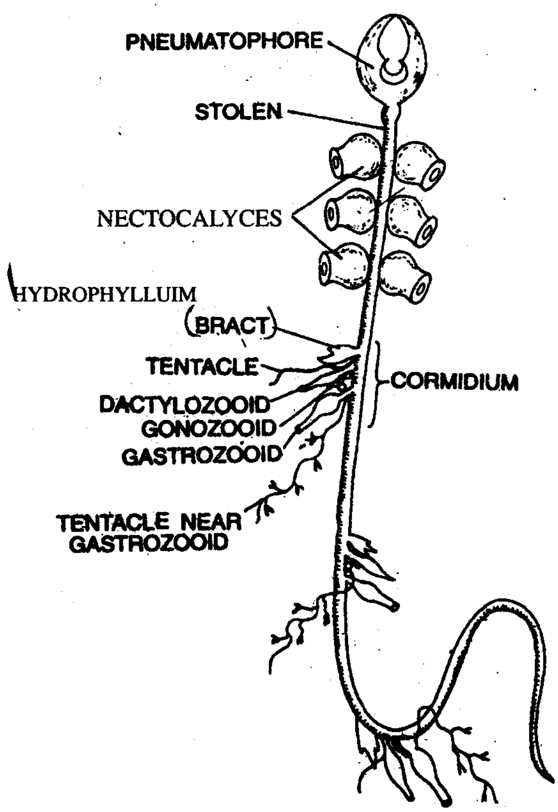

Fig. 2-26. *Halistemma*

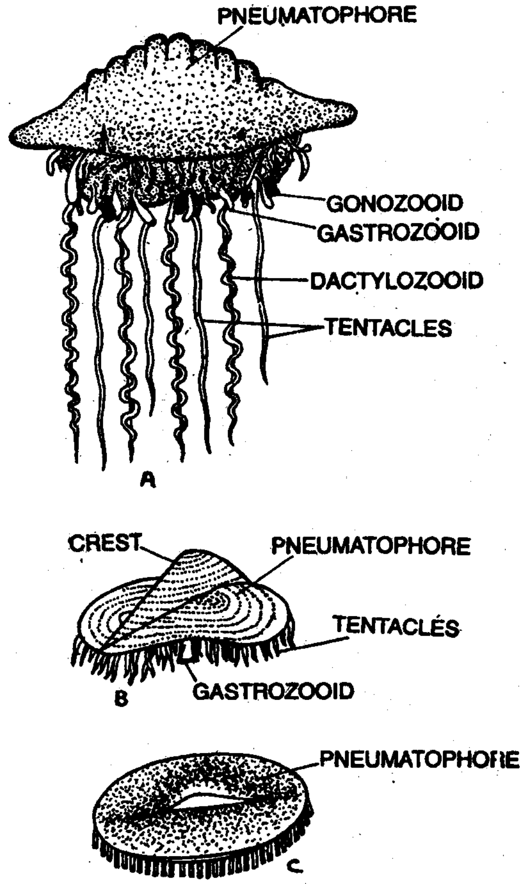

Fig. 2-27. *A. Physalia; B. Velella, C. Porpita*

2.3.6. EXAMPLES OF POLYMORPHISM :

1. Halistemma : It is a typical polymorphic colony consisting of a long, slender floating stem to which zooids are attached. The upper end of the stem has a small gas-filled, invaginated cup like pneumatophore. (Fig. 2-26). Below this pneumatophore there are many nectocalyces or swimming bells. They are transparent and look like medusae without manubria, but they have a velum, muscles and canals. They take in water and pump it out rhythmically so that the colony can be moved. Below these zooids there are several cormidia in groups.

A cormidium has a gastrozooid, dactylozooid, hydrophillium and gonozooids. Gastrozooid is tubular with a large mouth and a long, branched tentacle that bears numerous nematocysts. Dactylozooid is tubular with an unbranched sensory tentacle. Mouth is absent. Gonozooids lie in groups and bear male and female medusae or gonophores. Hydrophillium or bract is a shield shaped leaf which covers and protects the rest of the cormidium.

2. Physalia : (Portuguese man-of-war) : It is a large polymorphic pelagic colony composed of modified polypoid and medusoid members. It possesses a large gas filled pneumatophore or float (about 30 cm length) which exhibits beautiful shades of blue color (Fig. 2-27A and 2-28). It is formed by the fusion of several medusoid forms. It floats and keeps the colony at the surface, and functions as a sail. It contains gas glands which produce a gas having 90% nitrogen, 9% oxygen and 1% argon. Below the pneumatophore hangs a colony of several non-linear cormidia.

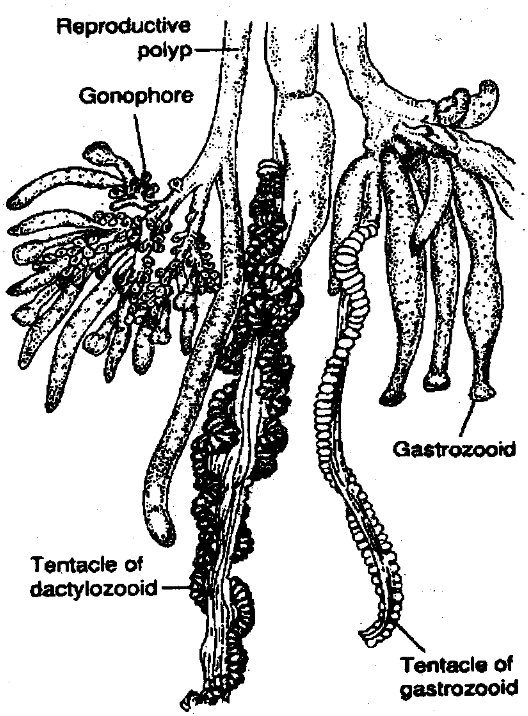

Fig. 2-28. Part of a *Physalia* colony

A cormidium is a group of polymorphic individuals which are modified polyps like dactylozooids, gonozooids and gastrozooids. Dactylozooids are of various sizes, each is a tubular, mouthless individual with a long tentacle having strong muscles and a twisting ribbon of nematocysts Dactylozooids may be upto 12m long, they form a drift net for capturing fish for food. An accidential encounter with the tentacles of this siphonophore can be a painful and even a dangerous experience for a swimmer. Gastrozooids are also tubular with a mouth and a long tentacle. Gonozooids are branching blastostyles having leaf-life gonopalpons and male and female medusae or gonophores. The members of the colony stand as a good example of division of labour.

3. Velella : It is a highly modified siphonophore colony. It looks like a medusa (Fig.2-25B). It has a rhomboidal float containing many air chambers and bearing a vertical sail like ridge on the top. The air chambers open above by pores and below by chitinous canals running between the zooids; they are supposed to have a respiratory function as air is said to be pumped by the contraction of the zooids. A single large gastrozooid with prominant mouth hangs from the middle of the body. It is surrounded by numerous gonozooids or blastostyles which produce free-swimming medusae. On the margin of the body is a circle of long tentacle like dactylozooids having nematocysts.

4. ***Porpita :*** It is a polymorphic colony which resembles closely to *Velella.* The colony resembles a medusa (Fig. 2-25 A and 2-27C). It has a large disc like body with a chitinous, chambered, air filled pneumatophore. Each chamber communicates with the exterior by two pores. On the lower side of the disc, the zooids are massed together; there is a single large gastrozooid in the middle, surrounded by numerous gonozooids; and the margin of the disc is fringed with dactylozooids. Beneath the disc is a large cellular mass traversed by canals, the so called liver, supposed to have an excretory function.

2.3.7. ORIGIN OF POLYMORPHISM :

Various theories were put forward to explain the origin of polymorphism. They are :

1. Poly-organ theory : This theory was proposed by Huxley, Eschscholtz and Metschnikoff. According to this theory, the entire colony is a representation of a single medusoid organism and all the forms of the colony are the organs of the same organism. It results by the individual division of the various parts of the medusa like tentacles, manubruim, umbrella, etc.

2. Poly- person theory : This theory was proposed by Leuckart, Vogt and Gegenbaur. According to this theory a polymorphic coelenterate is a colonial form in which diversified organisms have grouped together to perform different functions. The colony consists of either polyp or medusa but the primitive zooid of the colony was of polyp type.

3. Medusa theory : This theory was put forward by Haeckel, Balfour and Sedgwick. They have agreed that the poly-person theory is more appropriate but the primitive zooid of the colony was a medusa. The medusa produces other medusae by budding. Thus, modified polyps according to this view are nothing more than the parts of medusoid form individual which have shifted their attachment. This theory agrees in asserting the colonial nature of Siphonophora.

4. Moser's theory : This theory has revived the poly- organ theory. According to him, the various zooids of the colony are organs which have not yet attained the grade of polymorphic form. Thus, the siphonophores are the most primitive existing coelenterates. This theory has not been recognized in general because it altogether denies the colonial nature of siphonophores.

Ultimately the identification of the component structures of a colony in siphonophore as organs or individuals is a problem to be enlightened.

2.3.8. POLYMORPHISM AND ALTERNATION OF GENERATIONS :

In a colony, all the members whether polypoids or medusoids are formed from the coenosarc. Polymorphism is associated with the life cycles of hydroid coelenterates. In monomorphic forms like *Hydra,* the polyp reproduces both asexually and sexually, this condition also applies to Anthozoa. The life cycle remains very simple, it may be represented as : Polyp-egg-polyp. The origin and advancement of polymorphism resulted in the division of reproductive power as a part of division of labour. All the polyps reproduce asexually to give rise to medusoid forms (i.e. gonophores) which reproduce sexually to form polyp. The life cycle, thus, becomes complicated and may be represented as polyp-medusa-egg-planula-polyp. Thus, the life cycle of polymorphic forms shows an alternation of generations or metagenesis. The asexual polypoid generation alternates with the sexual medusoid generation.

2.3.9. SIGNIFICANCE OF POLYMORPHISM :

The polymorphism is essentially a phenomenon of division of labour in which different functions are performed by the different members or zooids of the colony, *viz.*, polyps are related to feeding and asexual reproduction while medusae are related to sexual reproduction and so on.

2.3.10 SUMMARY :

1. Polymorphism is a peculiar phenomenon in coelenterates associated with their colonial organization and division of labour.

2. The two main forms of the polymorphic colonies are the polyp and medusa.

3. Hydrozoans offer typical and best examples of polymorphism whereas scyphozoans are typically medusoid forms and anthozoans are exclusively polypoid.

4. Simple hydroids like *Hydra* are monomorphic and colonial hydroids like *Obelia* and *Companularia* are dimorphic with gastrozooids and gonophores. The colonies become trimorphic with the development of medusae over blastostyles. The colony of *Hydractina* is polymorphic with polyps exhibiting different morphological forms.

5. Siphonophores show the highest degree of polymorphism. The polypoid and medusoid forms occur in several modifications. The modified polypoid forms are gastrozooids, dactylozooids and gonozooids. The medusoid forms are modified as swimming bells, bracts, gonophores and pneumatophores. Examples: *Physalia, Velella, Porpita, Halistemma.*

6. The origin of polymorphism was explained with various theories like Poly-organ theory, Poly-person theory, Medusa theory and Moser's Theory.

7. Polymorphism is associated with the life cycles of hydrozoans. The life cycle of polymorphic forms shows an alternation of generations or metagenesis. The asexual polypoid generation always alternates with the sexual medusoid generation.

2.2.11 KEY TERMINOLOGY :

Blastostyle : A reduced, finger-like gonozooid that bears gonophores.

Dactylozooid: A finger-shaped, defensive, hydrozoan polyp.

Dimorphic: Colony consisting of two structurally and functionally different types of individuals – gastrozooids and gonozooids.

Gastrozooid: Nutritive or feeding polyp of cnidarians which is similar to a short hydra.

Gonangium (pl. Gonangia): Type of gonozooid that consists of a central blastostyle bearing gonophores and is surrounded by an extension of the perisarc (gonotheca).

Gonophore: A hydroid reproductive bud that bears the germ cells and may become a free – swimming medusa or a variously modified sessile medusa. Medusoid.

Gonotheca: An extension of the perisarc around a gonozooid.

Gonozooid: A hydrozoan reproductive polyp which is often reduced, lacking mouth and tentacles,and bears gonophores.

Hydranth: The oral end of a hydroid polyp bearing the mouth and the tentacles.

Hydrocaulus: The stalk of a hydroid polyp.

Hydroid colony: A collection of polyps in which each polyp is connected to the others.

Hydrorhiza: Horizontal root like stolon of a hydroid colony that grows over the substratum.

Hydrotheca: A cuticle that encloses the hydranth.

Metagenesis: Alternation of sexual with an asexual generation in reproduction in the life cycle of a coelenterate such as *Obelia.*

Perisarc: A supporting, nonliving chitinous cuticle secreted by the epidermis surrounding most hydroids.

Polymorphism: When two or more members of a species or zooids of a colony are structurally modified for different functions.

Trimorphic: Colony consisting of 3 structurally and functionally different types of individuals – gastrozooids (nutrition), gonozooids (reproduction) and dactylozoids (defense).

2.3.12. SELF ASSESSMENT QUESTIONS :

1. Describe polymorphism in coelenterates. Add a note on its origin.
2. Give a detailed account of the polymorphism in siphonophores
3. Write notes on :
   a) Polymorphism in Hydroida
   b) Pneumatophore
   c) Origin of polymorphism
   d) Polypoid forms in siphonophores
   e) Swimming bells

2.3.13.REFERENCE BOOKS :

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Dr. P. Padmavathi

2.4 GENERAL ORGANIZATION OF PHYLUM PLATYHELMINTHES

2.4.1 OBJECTIVES

The purpose of this lesson is to:

- define platyhelminthes
- know about the free living and parasitic worms
- understand the life cycle of trematode parasite
- study the life cycle of cestode parasite

2.4.2 INTRODUCTION

The term helminth was originally applied to the parasitic worms. Helminthes are the internal (endo) as well as external (ecto) parasites without obvious appendages.

The flatworms are bilaterally symmetrical organisms, usually flattened dorsoventrally, with no body cavity, the various organs within the body being embedded in a spongy parenchyma. In the parasitic forms the external surface of the body is smooth or spiny cuticle. In the free forms is a ciliated epithelium and this occurs also in some of the free larval stages of the parasitic flat worms. Underneath the cuticle is a complicated musculature, which in the absence of any skeletal system permits of great variation of external shape. The excretory system involves a series of tubules, which ramify, and end in a series of flame cells; these are small expansions containing a number of cilia, the movement of which stimulates the flickering of a flame. The system discharges by one or two openings. A digestive system may or may not be present; there is no anus. Digested food material is passed from the intestine to the various organs by a tubular lymphatic system.

There is no blood vascular system.

The flatworms are usually, but not invariably hermaphroditic. The male organs consist of one, two or more solid testes, each with its collecting duct. These ducts unite as a common vas deferens which may be dilated to form a seminal vesicle, and the end of which may be modified to form an extrusible cirrus contained in a muscular cirrus sac. The female organs consist of a single solid ovary, yolk glands, a shell gland, usually a spermatheca and various ducts. A distinct vagina opens in common with the male genital pore. A uterus is also usually present. But one tube may perform both vaginal and uterine functions, or the uterus may be a separate tube or sac. The phylum Platyhelminthes will be discussed here in the following classes:

Turbellaria

Trematoda and

Cestoda

Turbellarians are basically free living, aquatic animals with ciliated bodies. The others are entirely parasitic and do not have ciliated bodies, while the cestodes have no alimentary tract at any stage of their existence.

2.4.3 CLASS TURBELLARIA

This is a widely distributed group of ciliated flatworms, which are mostly free-living. They usually possess a gut but have no anus, although a few, like *Convoluta (Fig.* 2-29), have lost the gut and depend on symbiotic algae for their food. They are classified on the shape of this digestive tract which may be simple or have a number of divisions.

2.4.3.1 EXTERNAL CHARACTERS

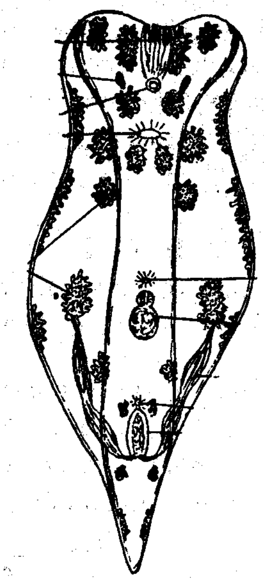


Fig. 2-29. *Convoluta,*

Turbellarians are broad, flat and leaf like in shape.

Free living forms live in fresh or salt water, or in moist soil. There are few pelagic species.

Some turbellarians lead their life as commensals or parasites.

The unsegmented body is dorsoventrally flattened.

Turbellarian body is covered with cilia.

The anterior end is differentiated into head.

Head projections are present in some species.

These projections may be in the form of short tentacles.

Head projections vary in number and position.

The lateral projections of the head are called auricles.

The auricles are frequently found in fresh water planarians.

Most of the turbellarians are black, brown and grey in color.

Some groups display bright color.

A few species are green because of the presence of symbiotic algae.

Turbellarians are microscopic or they range from less than 10 m.m. to more than 60 c.m. in length.

2.4.3.2 BODY WALL

A ciliated epidermis bearing surface microvilli covers the body (Fig.2-30)

Beneath the epidermis lies a muscle layer.

The muscle layer is composed of an outer circular and inner longitudinal layer.

Between these two layers diagonal fibers are present.

In acoels and catanulids, the muscle layers are composed of epitheliomuscular cells as in cnidarians.

But these cells are separate from the overlying ciliated epithelium.

The space between the body wall and internal organs is filled with a loose net like aggregations of irregularly shaped cells called parenchyma.

Numerous gland cells are present in the body wall.

The gland cells may help in adhesion, covering the substratum or enveloping the prey.

There is an anterior aggregation of cells called a frontal gland.

It is the characteristic feature of many turbellarians.

Frontal gland is believed to be a primitive turbellarian feature.

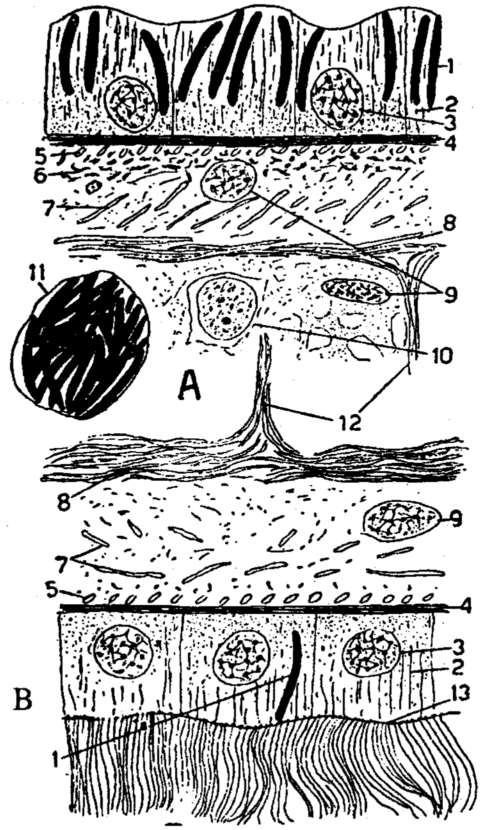


Fig. 2-30. Structure of the epidermis. **A,** Longitudinal section through the dorsal epidermis of a fresh-water planarian, showing also the subepidermal musculature. **B,** Same through the ventral epidermis; note ciliation, paucity of rhabdites.

1. rhabdites; 2. epidermis; 3, nucleus of epidermis; 4, basement membrane; 5, circular muscle layer; 6. pigment; 7, diagonal muscle layer; 8, longitudinal muscle layer; 9, fixed nuclei of mesenchyme; 10, free cell of mesenchyme; 11, rhabdite-forming gland cell; 12, parenchymal muscles; 13, basal bodies of cilla;

Almost all turbellarians possess numerous rod shaped epidermal bodies known as rhabdites

Rhabdites are present at right angles to the body surface.

Epidermal gland cells secrete rhabdites.

The function of rhabdites is uncertain.

Upon discharge, rhabdites may be used in defense or disintegrate to form a slimy covering around the animal.

Few turbellarians possess true nematocysts, which are obtained when the worms eat hydroids. The nematocysts are not digested and travel from the gut to the body wall. They are used in the defense in the body wall.

A small number of marine turbellarians possess calcareous spicules.

These spicules are supportive in function.

2.4.3.3 LOCOMOTION

Minute turbellarians swim about within bottom debris.

Large animals creep upon the ventral surface.

Cilia provide the force for propulsion in aquatic turbellarians.

Muscular undulations are important in the locomotion of large polyclads and terrestrial animals.

Elongated bodies and adhesive glands are common adaptations in maintaining the position of the body and in locomotion.

2.4.3.4 NUTRITION

The intestine of turbellarians is a blind sac.

Mouth is the only opening for ingestion and egestion.

The wall of the intestine is single layered.

The intestinal layer is composed of phagocytic and gland cells.

In the primitive macrostomids, catenulids and some polyclads, the intestine is ciliated (Fig. 2-31). Cilia are absent in the intestine of most of the turbellarians.

Small turbellarians, such as the macrostomatids, catenulids and rhabdocoels have a simple, unbranched, sac like gut. A permanent gut cavity is absent in the members of the order Acoela. A syncytial mass enclosed by a common cell membrane functions like a gut. The name Acoela refers due to the lack of gut cavity. The larger turbellarins have a branched gut with lateral diverticula. The lateral branches increase the surface area for digestion and absorption. The branching system of gut compensates the absence of internal nutrients transport system. In polyclads, the intestine consists of a central tube, from which arise many lateral branches. These lateral branches are further divided into lateral diverticula (Fig. 2-31). In Triclads, the intestine consists of three principle branches - one

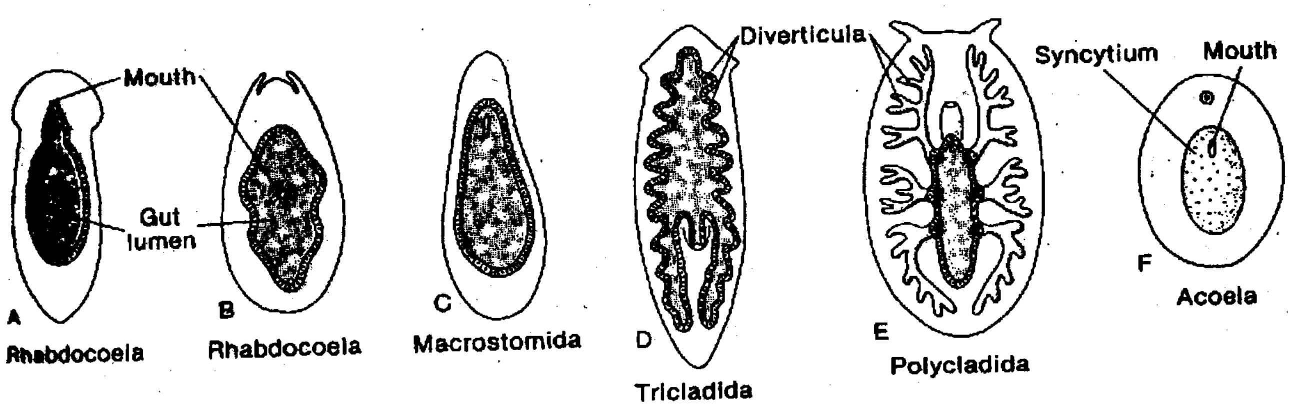


Fig. 2-31. Turbellarian midguts are more or less simple sacs in small turbellarians (A-C) such as most rhabdocoels (A,B) and macrostomids (C), In the acoels (F), the gut is usually a lumenless syncytium, as shown here. The larger turbellarians, such as triclads (D) and polyclads (E), have vessel-like diverticula that increase the area of the gut and distribute nutrients to all parts of the body.

anterior and two posterior. Each of these branches again subdivided into lateral diverticula. These three branches join in the middle of the body, anterior to the mouth and pharynx. The name Tricladida and Polycladida refer to the branching of the intestine. The mouth is commonly present midventrally but may be situated anteriorly, posteriorly or anywhere along the midventral line. In Acoels, mouth opens directly into the digestive syncytium due to the absence of mouth. Mouth opens into a simple, ciliated pharynx in primitive Macrostomids and Catenulids. A complex, ingestive pharynx is present in higher turbellarians (Polyclads and all neophorans). A folded or plicate pharynx is present in triclads and polyclads which are having branched intestines. Rhabdocoels, many predatory and most commensal and parasitic species have bulbous pharynx. Turbellarians are largely carnivorous and feed on various invertebrates which are small enough to be captured. They also depend upon the dead bodies of animals that sink to the bottom. The polyclad *Stylochus frontalis* feeds on living oysters. Hence, nicknamed as "Oyster Leech". Some acoels, macrostomids and polyclads feed on algae. Turbellarians with simple pharynx or with protrusible bulbous pharynx swallow the whole prey. The pharyngeal gland secretions aid the penetration of the prey. Then the body tissues of the prey are ingested by pharynx. The partially digested and liquefied food is driven into the gut by peristaltic action. Digestion occurs extracellularly and intracellularly. Pharyngeal enzymes and endopeptides of intestinal gland cells fragment the food. Then intestinal phagocytic cells engulf the food fragments. Intracellular digestion is completed by endopeptidases within the phagocytic cell. Nutrients may diffuse from the central gut to nearby tissues or may also be transported intracellularly from gastrodermal phagocytes to fixed parencymal cells.

2.4.3.5 NERVOUS SYSTEM

In general, the primitive nervous system consists of a sub epidermal ring like brain and one to several nerve cords. The nerve cords extend posteriorly. The number of nerve cords varies in different species. When, several pairs of longitudinal nerve cords extend from the brain, they maintain equidistance from each other. This arrangement imparts radial symmetry on the nervous system (Fig. 2-32). In all turbellarians, the nervous system is relatively primitive in lacking ganglia.

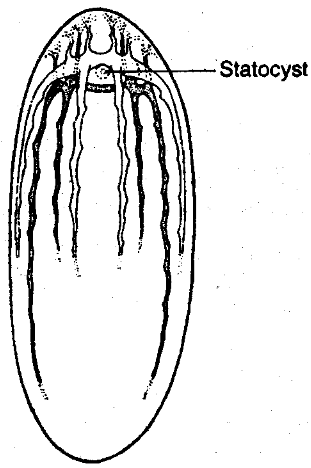


Fig. 2-32. In the acoels nervous system, the brain and nerve cords are more or less radially disposed (peripheral nerve net not shown).

2.4.3.6 SENSE ORGANS

In most turbellarians, the pigment cup type eyes are present. Usually two eyes are present. Many eyes are present in the polyclads and the land planarians. Eyes function only in detecting light. Most of the turbellarians are negatively photo tactic.

2.4.3.7 EXCRETION AND OSMOREGULATION

A pair of protonephridia is present in turbellarians (except in acoels). Each of the protonephridium of the turbellarian is of the flame cell type. It is consisting of many branched tubules. Each tubule terminates in a blind capillary, which possess flagella at the inner end. The terminal structure is composed of a tubule cell and a cap cell having two or more flagella. The number of protonephridia and the position of the nephridiopores are variable. In triclads, the number of protonephridia is of four pairs. The nephridial tubules form an anastomosing network, which open by many nephridiopores.

The turbellarian nephridia are osmoregulatory in function although direct evidence is still lacking. As osmoregulatory organs, the protonephridia function to reabsorb ions of potassium and calcium. The protonephridial system is best developed in fresh water turbellarians, less developed or absent in marine turbellarians.

The nitrogenous waste material is in the form of ammonia in Turbellarians. The wastes may be eliminated by diffusion through the general body surface. Excess of water and other waste metabolites may sent out of the body through a pair of protonephridial tubules bearing multiciliated terminal cells (Fig.2-33). These cells are found scattered throughout the body. The entire terminal cells feed into

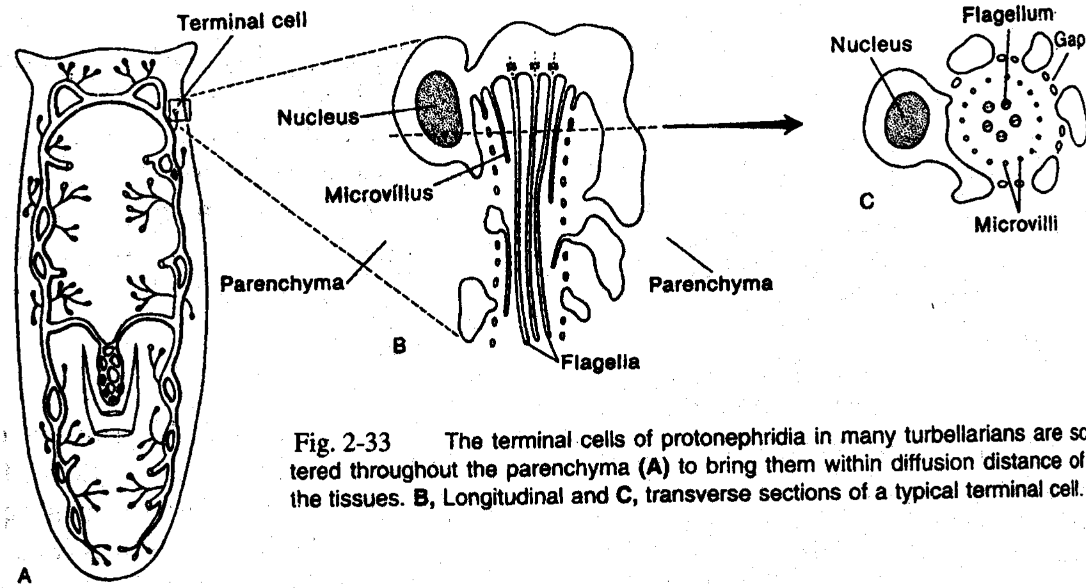


Fig. 2-33 The terminal cells of protonephridia in many turbellarians are scattered throughout the parenchyma (A) to bring them within diffusion distance of al the tissues. B, Longitudinal and C, transverse sections of a typical terminal cell.

anatomizing and sometimes-ciliated ducts. These ciliated ducts open to the exterior by one or more pores, depending on the species. Any recognized excretory system is absent in Acoels.

2.4.3.8 ASEXUAL REPRODUCTION

Most of the fresh water turbellarians reproduce usually by means of fission. In the genera *Catenula, Stenstomum* and *Microstomum,* new individuals are formed by transverse fission. But these individu also remains attached to the parent forming a chain.

In the fresh-water planarians, such as *Dugesia*, new individuals, which are formed by transverse fission, detach from the parent and lead an independent life.

2.4.3.9 REGENERATION

Most planarians have considerable power of regeneration. During asexual reproduction, the newly formed individual (zooid) regenerates the missing parts to form new small forms. When planarians are divided into an anterior, middle and posterior half, each of the half regenerates the missing parts to form an independent individual.

2.4.3.10 SEXUAL REPRODUCTION

In Turbellarians, except in acoels, the gonads are distinct from the surrounding parenchyma. The male and female reproductive systems are complicated and variable. In the primitive type of system, for example in *Macrostomum*, a sperm duct leads from the single pair of testes to the seminal vesicle (Fig. 2-34). The seminal vesicle passes into the penis (without stylet), which opens, by a male gonopore in the posterior ventral surface. The female system consists of a pair of ovaries, a sperm storage center called the bursa, vagina and female gonopore located in front of male gonopore.

In the male system, there may be one to numerous pairs of testes, multiple prostate glands, seminal vesicles and penises (Fig.2-35). The male system terminates into the common gonopore. Most turbellarians have biflagellate sperm.

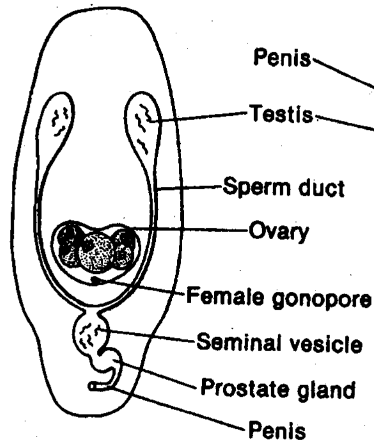


Fig. 2-34. Macrostomid. Small animals with ovaries, testes, and well-developed accessory reproductive organs.

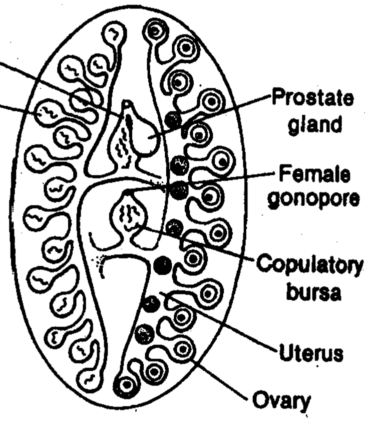


Fig. 2-35. Polyclad. Multiple ovaries and testes scattered among branches of gut. Accessory organs are well developed.

The female system like that of male system consists of one to numerous pairs of ovaries but with only one pair of oviducts. Some turbellarians produce eggs in which yolk material is an integral part of the cytoplasm. In many turbellarians, however, the ovary is of more specialized form. Part of the ovary has become specialized for the production of yolk cells (modified eggs). This part is called the vitellarium. The other part of the ovary has become specialized for the production of yolk less eggs. This part is called germinarium.

Turbellaria is divided into the two levels of organization, the Archophora and Neophora basing on the division of ovaries. In the primitive Archophorans yolk glands are absent and the eggs contain yolk as in other animals. In advanced Neophorans, the yolk glands are present and yolk cells accompany the eggs. The oviducts may dilate to provide a sperm storage center, a seminal receptacle. Another modification in female reproductive system is a temporary storage center, or uterus for ripe eggs. The uterus may be a blind sac. Separate male and female gonopores are characteristic of most Macrostomida, the Acoela and the Polycladida. The common planarian and other many turbellarians possess a single gonopore and a genital atrium into which the female and male systems open. Self-fertilization is uncommon in planarians. Fertilization between male and female worms occurs by copulation.

Fertilized eggs undergo less determinate type of cleavage than that of more typical spiral pattern. Gastrulation is by epiboly and develops to a stereogastrula. The mouth and pharynx form from a stomodeal invagination near the original site of blastopore. This invagination connects enteron. Thus an endodermal mass is formed which later becomes hollow. In some polyclads there is no larva. Some polyclad turbellarians possess a larva called Muller's larva (Fig.2-36). The larva, which is characterized by 8 arms or lobes with long cilia, swims about for a few days and then settles to the bottom as a young worm.

Some polyclad species *Stylochus* pass a larval stage called Gotte's larva. It differs from a Muller's larva in having only 4 ciliated lobes. There is no free-swimming larval stage in the neophorans, triclads and many rhabdocoels. The young worms emerge from the capsule in a few weeks.

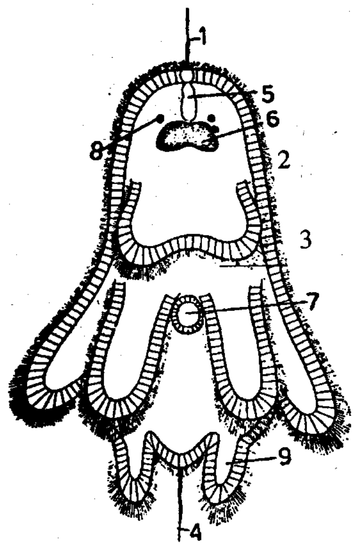


Fig. 2-36. Muller's larva.
1. apical sensory tuft; 2. ectoderm; 3, yolk masses; 4, caudal tuft, 5, frontal gland; 6, brain; 7. mouth; 8, eyes; 9, ciliated lobes.

2.4.3.11 SUMMARY

The Turbellarians are the free-living platyhelminthes.

They are primitive of all bilateral animals.

Their small size, acoelomate condition, low level of cephalization and the absence of anus are probably primitive characteristics.

Majority of turbellarians are primitive marine forms. But there are fresh water and terrestrial species. Terrestrial forms live in humid environments.

Benthos turbellarians live on or beneath stones, algae and other objects.

Small species move by cilia. Larger forms move by cilia and muscular contractions.

In many species duo gland systems make possible temporary attachment.

Turbellarians are predators and scavengers.

Small species have a simple sac like intestine and pharynx. Large species have a branched intestine and folded pharynx. In both small and large species digestion is initially extra cellular and then intracellular.

Presence of rhabdites or epidermal bodies is one of the characteristics of turbellarians. The mucus produced by rhabdites is useful to coat the substratum over which the animal crawls.

Internal transport, gas exchange and excretion are effected by branched intestine in larger forms.

Protonephridia serve as excretory and osmoregulatory organs.

May be numerous pigment cup ocelli meant for sensation.

Four pairs of longitudinal nerve cords are arranged radially. This is the primitive arrangement of nervous system in turbellarians.

The hermaphroditic reproductive system with internal fertilization and egg deposition is found in turbellarians.

In primitive archophorans, the eggs are entolecithal, cleavage is spiral and there is a free-swimming larva. However, in most archophorans development is direct and there is no larval stage.

In advanced neophorans, the eggs are ectolecithal, spiral cleavage is absent and there is no free-swimming larval stage. Development is always direct.

2.4.4 CLASS TREMATODA

The flatworms that belong to the class Trematoda are known as flukes. They represent one of the major groups of metazoan parasites.

2.4.4.1 EXTERNAL STRUCTURE

The external structure of the parasitic trematodes is more like that of free-living turbellarians. They differ in structure from that of the parasitic cestodes. The body of trematodes is oval to elongate. They range in length from less than 1 millimeter to 7 meters. But most of the trematodes are no longer than a few centimeters. Oral and ventral adhesive organs characterize trematodes. Mouth is typically located at the anterior end.

2.4.4.2 TEGUMENT

The body of trematodes is covered by a non-ciliated cytoplasmic syncytium called the tegument. This feature is in contrast to the ciliated epidermis of free-living turbellarians. Below the outer covering lie consecutive layers of circular, longitudinal and diagonal muscles. The tegument plays an important role in the physiology of trematodes. It protects the parasite against the action of host enzymes especially in intestinal parasites. Nitrogenous wastes are eliminated outside through the tegument. It is the site for gas exchange and amino acid absorption.

2.4.4.3 DIGESTIVE TRACT

The anterior mouth leads into a muscular pharynx. The pharynx acts as a pump to push the cells and cell fragments, mucus, tissue fluids, or blood of the host into the digestive tract of the parasites. The parasite feeds on the host tissues as listed above. The pharynx leads into a short oesophagus. From the oesophagus the digestive tract gives rise to one or more commonly – two intestinal caeca. The caeca extend posteriorly along the length of the body (Fig. 2-37). The caeca are generally simple cylindrical tubes but are branched in some species. The physiology of nutrition is still not fully understood. Presence of secretive and absorptive cells has been reported in the caeca. Part of the digestion is apparently extra cellular.

2.4.4.4 RESPIRATION

The ectoparasitic trematodes are aerobic, but the endoparasites are facultative anaerobes. The amount of oxygen utilized in respiration depends upon the location within the host and also upon the developmental stage of the parasite. Lactic acid is the end product of glycolysis.

2.4.4.5 PROTONEPHRIDIA

Trematodes are provided with protonephridia. The number of flame cells varies, but there is typically a pair of longitudinal collecting ducts. There may be two anterior dorso lateral nephridiopores (Monogenea) or a single posterior nephridiopore (Digenea). The collecting system is typically provided with a terminal bladder (Fig. 2-37). In the ectoparasites, the protonephridia are probably osmoregulatory in function. The function of the protonephridia in endoparasites is still uncertain.

2.4.4.6 NERVOUS SYSTEM

The trematode nervous system consists of a pair of anterior cerebral ganglia and usually three pairs of longitudinal nerve cords. These nerve cords arise from the brain and extend posteriorly. The ventral cord is most highly developed, and the dorsal cord is absent in digenetic trematodes. The adhesive organs receive a rich nerve supply. Sense organs are poorly developed, but one or two pairs of ocelli are present in many ectoparasites.

2.4.4.7 REPRODUCTION

The general plan of reproductive system is almost similar in all the trematodes (Fig. 2-37). There are usually two testes, which are probably the primitive number, and the position of the testes is of taxonomic importance. Sperm ducts, one from each testis, unite anteriorly and then enter a copulatory organ or cirrus sac. In digenetic trematodes, the cirrus sac contains a seminal vesicle, prostate glands and cirrus. The cirrus lies at the terminal end of the male system and serves as a copulatory organ if it is an eversible structure and a penis if not eversible. The penis opens into a genital atrium shared with the female system. The gonopore is usually located on the midventral surface in the anterior half of the worm. There are many variations of the general plan just described. In some trematodes, the sperm ducts may enter the cirrus sac separately. In some forms, the seminal vesicle may be located outside the cirrus sac or the sperm duct may open directly to the outside through the gonopore. Also, there may be separate male and female gonopores.

The female system possesses a central small chamber called the ootype. It receives eggs, sperm and yolk cells by way of a short ovovitelline duct (Fig. 2-37). The ovary produces the eggs. Usually there is a single ovary. A duct from the seminal receptacle and a common duct from the right and left yolk glands join the oviduct. Unicellular gland cells collectively called the Mehlis' gland surround the ootype. The uterus leaves the ootype and runs anteriorly to the genital atrium. The atrium has a muscular terminal end that facilitates the expulsion of encapsulated eggs. There may be a vitelline reservoir (dilation of the vitelline duct) and one or two vaginae form a part of the female's system. When present, the vaginae open separately to the exterior on the dorsal, lateral or ventral surface.

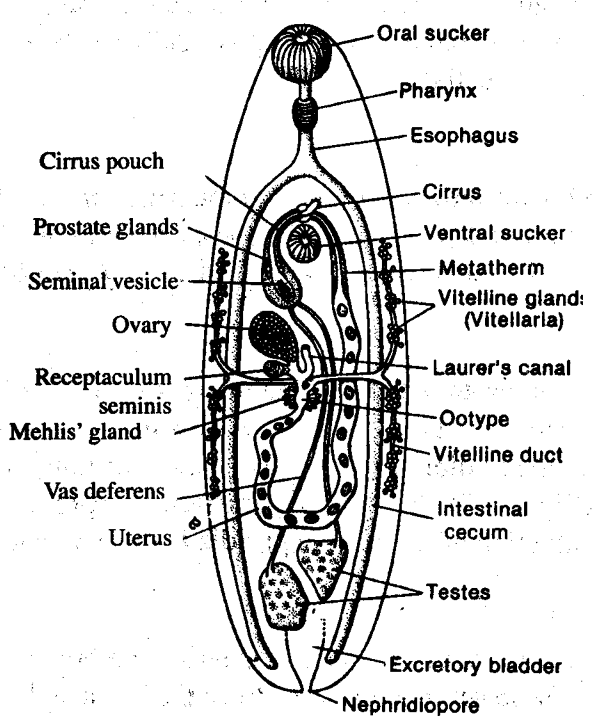


Fig. 2-37. A diagram of a generalized trematode.

In many trematodes there is a special copulatory canal (Laurer's canal) that extends from the duct of the seminal receptacle to the dorsal surface of the worm. Copulation is mutual and cross-fertilization does occur. During copulation the cirrus and penis of the male system of one worm is inserted into the uterine or vaginal opening of the other worm and sperm are ejaculated. The prostate gland provides semen for sperm survival. Sperms travel down the uterus or vaginal canal to be stored in the seminal receptacle.

The egg when released from the ovary is fertilized either en route to the ootype or within the ootype. The egg is ectolecithal. The vitelline glands supply yolk material for the egg and also a material that hardens around the egg to form the shell.

The encapsulated eggs pass through the uterus to be expelled to the exterior. The function of the Mehlis' gland (around ootype) is uncertain, but its secretions may provide lubrication for the passage of eggs through the uterus. The number of eggs produced by trematodes is enormous.

2.4.4.8 ORDER MONOGENEA – LIFE CYCLE

A single host is involved in the life cycle of monogenetic trematodes. There is one form or generation in the life cycle; hence the name monogenetic trematode. They are also different from digenetic trematodes in having a large posterior adhesive organ called an opisthaptor. It is by means of this complex muscular organ or opisthaptor the parasite attaches to the host. The opisthaptor bears sclerotized pieces in the form of hooks, anchors, or bars and sometimes suckers as well (Fig. 2-38). The structures of opisthaptor are variously arranged and modified in different species.

Mostly the monogenetic trematodes parasitize marine and fresh water fish. But amphibians, reptiles and cephalopod mollusks also serve as hosts. The majority are ectoparasites, but some have migrated into body chambers with external openings, such as the mouth, gills, chambers, and urino genital tract. A few are even found in the coelom.

The egg is elongated and its shell is provided with a lid and usually with one or two threads. By means of these threads the egg attaches to the host (Fig.2-39). The egg on hatching release a free-swimming ciliated larva called an onchomiracidium. This larva attaches a new host. The adhesive organ develops in the larva to attach. For example, *Polystoma integerrinum* is found in the bladder of frog and toads. The eggs are shed when frogs or toads come to water to breed. The larval form, onchomiracidium attaches to the gills of tadpoles. When tadpoles metamorphose, the larva leaves the gill chamber, crawls over the belly and enters the bladder. During this migration the larva matures to adult.

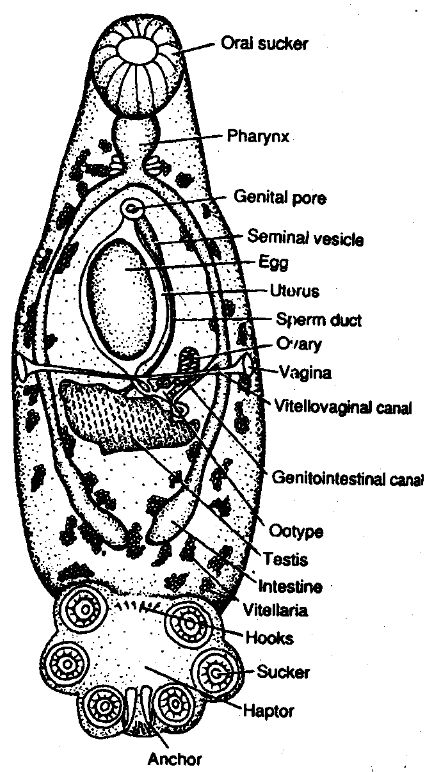


Fig. 2-38. *Polystomoidella oblongum,* a monogenean parasitic in the urinary bladder of turtles.

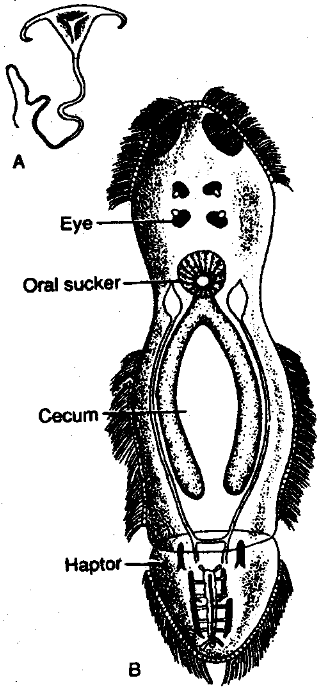


Fig. 2-39. A, Egg capsule and B, oncomiracidium of *Benedenia melleni*, a monogenean parasitic on fish,

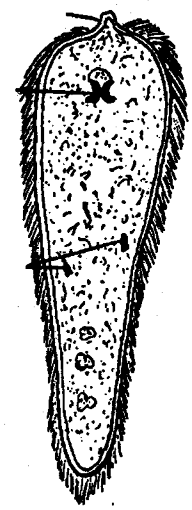


Fig. 2-40. Miracidium larva.

2.4.4.9 ORDER DIGENEA – LIFE CYCLE

Greatest number of parasitic flatworms belongs to this order. The life cycles of the digenetic flatworms involves two to four hosts. The host, which lodges the adult, is the primary host. The hosts, which lodge the developmental stages or larvae, are termed intermediate hosts.

Most digenetic trematodes are endoparasitic. The primary hosts include all groups of vertebrates, and virtually any organ system may be infected. The intermediate hosts are largely invertebrates, commonly snails.

The generalized scheme of life cycle is complex and will be explained in the following manner. The egg is enclosed within an oval shell with a lid, deposited in the gut and passed to the outside with the host's feces. A ciliated, free-swimming miracidium hatches from the egg (Fig. 2-40). This is the first larval stage. It must be either eaten by the snail host or penetrates the host epidermis; in either case, it comes to inhabit the hemocoel.

Later, the miracidium losses its cilia and develops into a second developmental stage called a sporocyst (Fig. 2-41). The sporocyst is hollow and contains numerous

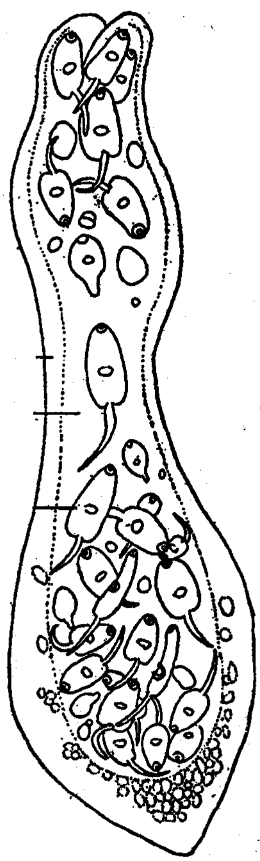
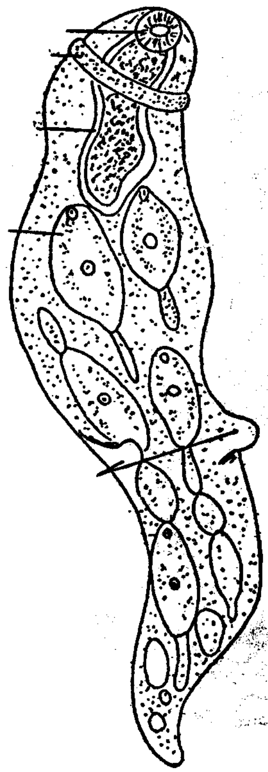


Fig. 2-41. Mature daughter sporocyst.

germinal cells. Each of the germinal cells will develop into an embryonic mass. Each mass develops into another developmental stage called a redia or daughter sporocyst. The redia or daughter sporocyst is a chambered form (Fig. 2-42). The germinal cells within the redia again develop into a number of larvae called cercariae (Fig. 2-43). The cercaria is the fourth developmental stage in this generalized life cycle. The cercaria is the infective stage. A digestive tract, oral sucker, ventral sucker and tail characterize it. After leaving the first intermediate host, is leads its life as a free-swimming larva. If the cercaria comes in contact with a second intermediate host, an invertebrate (usually an arthropod), it encysts into another larva or if it reaches the second intermediate host, a vertebrate it penetrates the host and encysts into another larva. The encysted stage is called a metacercaria (Fig. 2-44). Metacercaria may be found in the second intermediate invertebrate or vertebrate host. If the final vertebrate host eats the host of the metacercaria, the metacercaria actively escapes from its cyst. It migrates and develops into an adult form. The adult is found within its characteristic location of the host.

In the life cycle of Chinese liver fluke, *Opisthorchis (Clonorchis) sinensis* and the sheep liver fluke, *Fasciola hepatica,* the typical larval stages are found. The intermediate hosts are a snail and a fish for the Chinese liver fluke (Fig2-45). The sheep liver fluke has the typical larval stages like miracidium, sporocyst, redia, cercaria and metacercaria. The snail is the only intermediate host. The metacercaria encysted on vegetation along the edges of the ponds and streams.



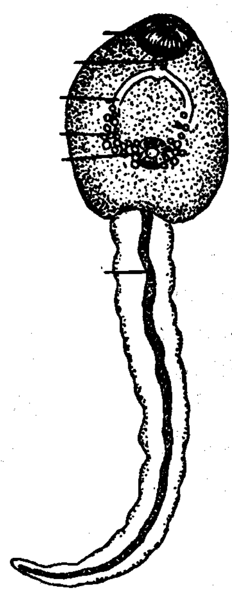


Fig. 2-43. Cercaria

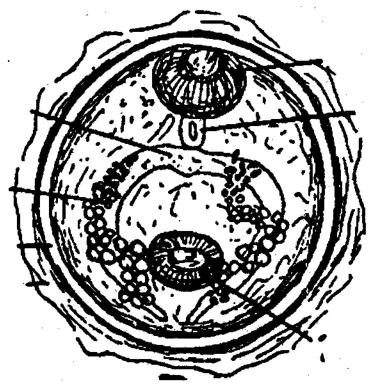


Fig. 2-44. Encysted metacercaria.

Fig. 2-42. Redia of the liver fluke

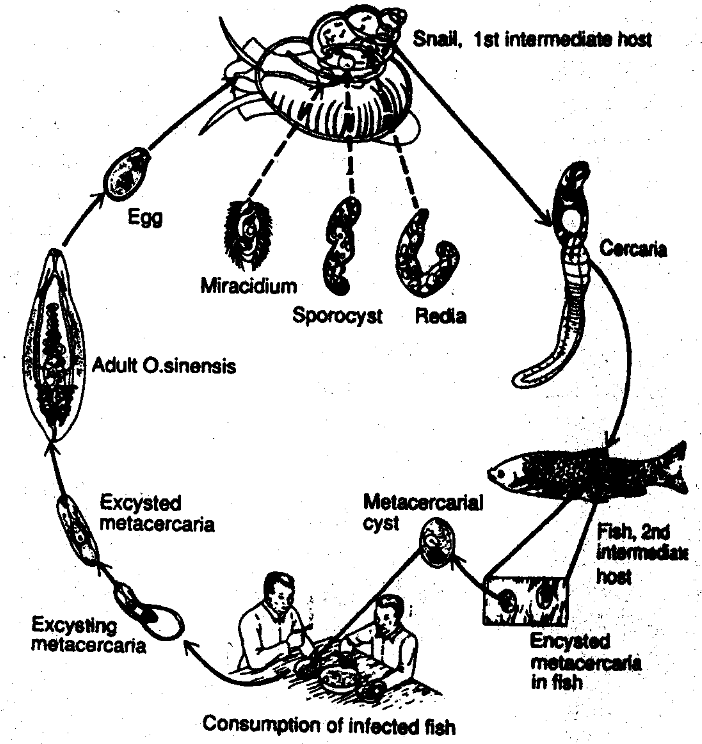


Fig. 2-45. Life cycle of the Chinese liver fluke, *Opisthorchis sinensis.*

2.4.4.10 ORDER ASPIDOBOTHREA

A small group of trematodes are included in this order. Aspidobothreans are similar to monogenetic and digenetic trematodes in structure and life cycle. The distinguishing feature of Aspidobothreans is the single lobulate ventral sucker or the ventral surface is provided with a longitudinal row of suckers. The sucker serves as adhesive organs (Fig. 2-46). The digestive tract contains only one intestinal caecum. Reproductive system is hermaphroditic. But the male system consists of only one testis. Most of the aspidobothreans are endoparasites. They live in the gut of fish and reptiles and in the pericardial and renal cavities of mollusks. They complete their life cycle with one or two hosts.

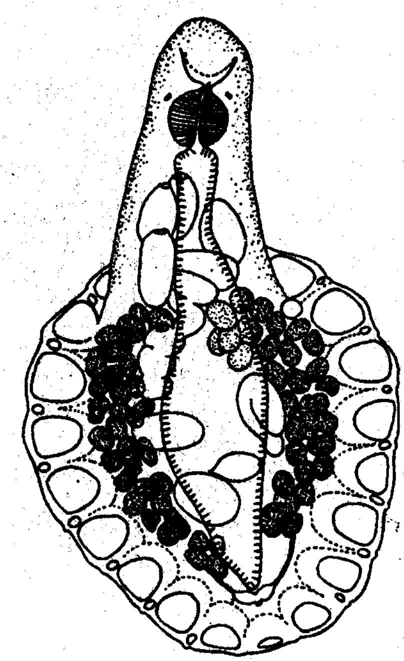


Fig. 2-46. Dorsal view of *Cotyaspis insignis.*

2.4.4.11 SUMMARY

One of the classes of flatworms, the trematoda containing the flukes is entirely parasitic. In contrast to the turbellarians, parasitic trematodes have a non-ciliated body covering, or tegument.

Adult trematodes are ecto (external) or endo (internal) parasites of vertebrates. Trematodes are less modified from the ancestral turbellarian condition than are the tapeworms.

Body is oval to elongate and flattened.

They are provided with a ventral sucker or other attachment organs. A gut is present, and the anterior mouth in some species (Digenea) is associated with a second sucker (ventral sucker or posterior sucker).

The tegument plays a vital role in the physiology of trematodes. It serves as a site of gas exchange. It provides protection against the destructive action of enzymes.

Trematodes are hermaphroditic. The reproductive systems are adapted for copulation, internal fertilization, ectolecithal development and the formation of the egg shells.

The monogenetic trematodes are mostly ectoparasites of fish. They utilize only one host to complete their life cycle. They have a free-swimming onchomiracidium larval stage. It reaches the new host to develop into an adult.

The digenetic trematodes are endoparasites and constitute the largest parasitic flatworms. The life cycle involves two to four hosts. They have a number of different developmental stages, including two types of larvae (miracidium and cercaria)

The primary host is always a vertebrate.

Snails are common intermediate hosts.

Species of blood flukes (*Schistosoma)* are one of the most wide spread and serious groups of human parasites.

2.4.5 CLASS CESTODA (CESTOIDEA)

Cestodes are the most highly specialized flat worms. All are endoparasites. The body is covered by tegument as in trematodes. However, they differ from the turbellarians and trematodes in the complete absence of a digestive tract. The class is divided into two subclasses, the Cestodaria and Eucestoda. The sub class Cestodaria is a small group showing certain similarities to the trematodes and will be discussed briefly after the sub class Eucestoda.

2.4.5.1 Sub class Eucestoda

The great majority of cestodes belong to the subclass Eucestoda and is called as tapeworms. Eucestodes are polyzoic tapeworms.

2.4.5.A. EXTERNAL STRUCTURE

The body of the adult tapeworm is dissimilar to that of turbellarians and trematodes. The anterior region of the worm is called the scolex. The scolex is adapted for adhering to the host (Fig.2-47 and 2-49). A narrow neck follows the scolex. The neck gives rise to the third part of the body. This part sometimes called the strobila. The strobila consists of linearly arranged individual segments called proglottids. The greater part of the worm consists of strobila. Tapeworms are generally long, and some species reach a length of 40 feet. The scolex, neck and strobila (segments) are regarded as comprising the entire body of a single individual and not a colony. The scolex is relatively small when compared to the mature proglottids. In general, the scolex has the form of a more or less four-sided knob. It is provided with suckers and hooks are used for adhering to the host. Although there are generally four large suckers arranged around the sides of the scolex, the scolex is often a more complicated structure than that of the familiar *Taenia* (Fig. 2-47A). The main suckers may be leaf like or ruffled, and there may be terminal accessory suckers in place of or in addition to hooks (Fig.2-47B)

A short neck lies behind the scolex. The neck region produces the proglottids by means of transverse constrictions (Fig. 2-47C). The youngest (immature) proglottids are thus at the anterior end just behind the neck. The youngest proglottids increase in size and undergo maturation. Mature proglottids lie toward the posterior end of the strobila. Gravid or ripe proglottids lie at the terminal end of the worm.

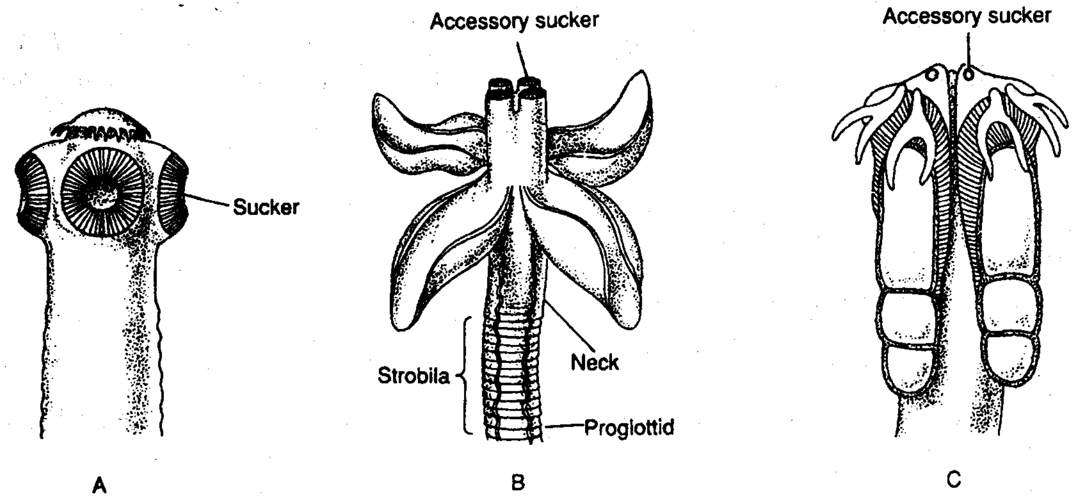


Fig. 2-47. Scoleces of three tapeworms, showing the four principal suckers or sucker like adesive structures, small accessory suckers, and the hooks. **A,** *Taenia*. **B,** *Myzophyllobothrium.* **C,** *Acanthobothrium.*

2.4.5.B. TEGUMENT

A tegument covers the body of cestodes. The tegument is nonciliated cytoplasmic syncytium (Fig. 2-48). The tegument plays a vital role in the physiology of tapeworms. It functions as it does in trematodes. The surface of the outer syncytial cytoplasm is thrown into folds. The outer microtriches utilized to increase the surface area (Fig. 2-48). The tegument assumes additional importance in the absorption of food, since digestive system is absent in tapeworms. An aerobic metabolism apparently predominates in tapeworms. But aerobic metabolism is not their exclusive mode of metabolism. The muscle layer consists of circular and longitudinal muscle layers. There is also a secondary parenchymal musculature having longitudinal, transverse and dorsoventral fibers to enclose the secondary parenchyma.

2.4.5.C DIGESTIVE SYSTEM

Digestive system is completely absent. Tapeworms absorb the food through tegument. They exhibit aerobic metabolism.

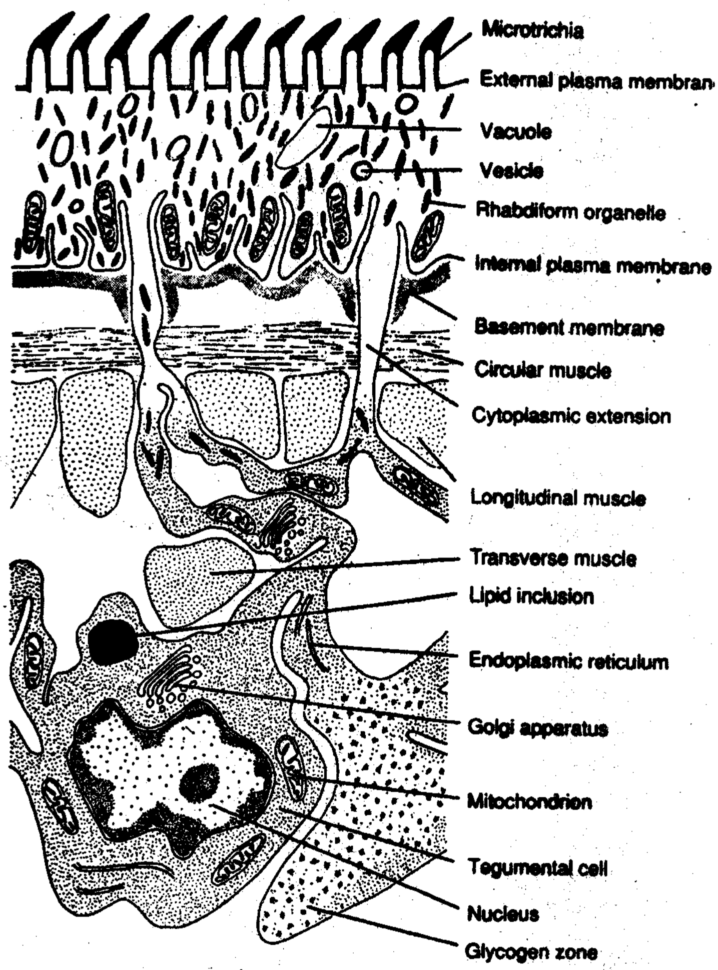


Fig. 2-48. Section through the tegument and body wall of the tapeworm, *Caryophyllaeus.*

2.4.5.D RESPIRATION

The endoparasites are facultative anaerobes. An anaerobic respiration is seen in endoparasitic tapeworms.

2.4.5.E EXCRETION

Extending through the chain of proglottids lies the excretory system. Flame cells and tubules in the mesenchyme drain into four peripheral longitudinal collecting canals. Two protonephridial canals are dorsolateral and the other two ventrolateral (Fig.2-49). All the four longitudinal canals interconnect in the scolex. A transverse canal in the posterior end of each proglottid usually connects the two ventrolateral canals. After proglottids have begun to shed, the collecting ducts open to the exterior through the last proglottid.

2.4.5.F NERVOUS SYSTEM

The nervous system extends through a chain of proglottids. An anterior mass lies in the scolex, and two lateral longitudinal cords extend posteriorly through the strobila (Fig.2-49). There may also be a dorsal and ventral pair of cords and quite commonly accessory lateral cords. Ring commissures connect the longitudinal cords in each proglottid.

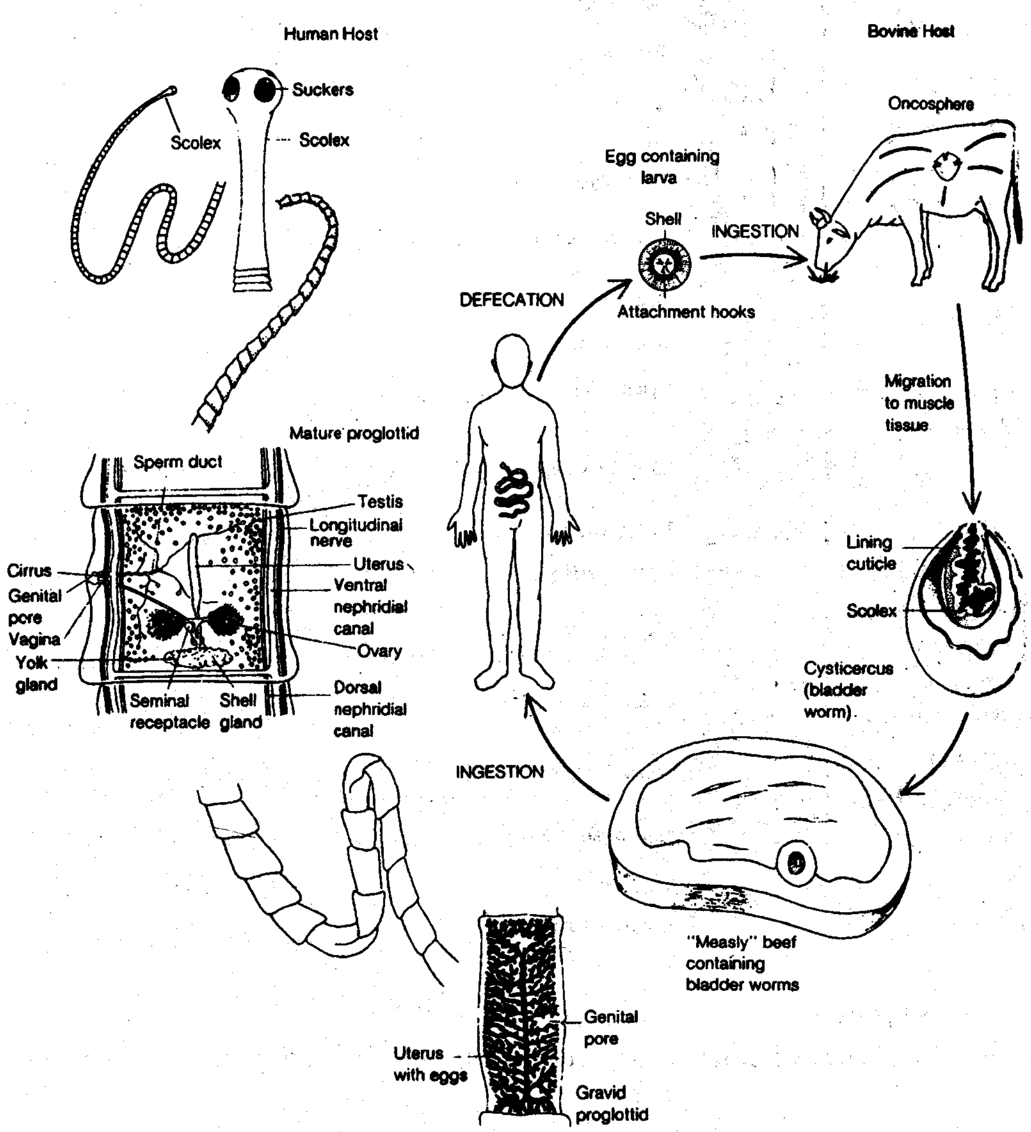


Fig. 2-49. Structure and life cycle of the beef tapeworm *Taenia saginatus.*

2.4.5.G REPRODUCTION

Each proglottid contains a complete reproductive system. It makes up a major part of each of these body sections. The tapeworm reproductive system is basically like that of digenetic trematodes as shown in Fig. 2-49. The reproductive system is hermaphroditic. There are usually a common male and female atrium and gonopore. A vaginal canal extends between the atrium and the ootype. In this way it differs from the condition found in many trematodes. The canal is enlarged as a seminal receptacle. A blind sac like uterus extends from the ootype or atrium. Uterus is a storing organ of eggs.

Cross-fertilization occurs between different adjacent individuals in the host's gut. But self-fertilization between two different proglottids in the same strobila or even within the same proglottid is known to occur. However, in many species self-fertilization within the same proglottid does not occur. This is due to the tendency in the male system to develop before the female system.

At copulation, the cirrus of the male is everted into the vaginal opening of the proglottid of an adjacent worm. Seminal receptacle functions like a storing organ of sperm cells. The fertilization of the eggs occurs in the ootype. The eggs are usually stored in a blind uterus. The terminal proglottids packed with eggs break away from the strobila. The eggs are freed with the rupture of the proglottid, which may occur within the host's intestine or after they leave with the feces.

2.4.5.H LIFE CYCLE

Tapeworms are endoparasites in the guts of vertebrates. Their life cycles require one to two or some time more intermediate hosts. The intermediate hosts are arthropods and vertebrates. The basic developmental stages are an onchosphere larva (Fig.2-49), which hatches from the egg and a cysticercus or plerocercoid stage, which is terminal and develops into an adult.

The basic life cycle of eucestodes can be understood looking into the life cycle of *Dibothrio-cephalus latus*. It is one of the fish tapeworms. It is widely distributed living as parasite in the gut of many carnivores, including man. If the eggs are deposited with feces in water, a ciliated free swimming onchosphere (coracidium) hatches after an approximately 10 day developmental period (Fig. 2-50A). Certain copepod crustaceans ingest the coracidium larva. It penetrates the intestinal wall and develops within the hemocoel of copepod crustaceans into a six-hooked stage called a procercoid (Fig. 2-50B). The second larval stage or procercoid should be ingested by a variety of fresh water fish. The procercoid, like the onchosphere, penetrates the host's gut and eventually reaches the striated muscles of the fish to develop into a plerocercoid stage. The plerocercoid stage is the infective stages to the primary host. The plerocercoid, which looks like an unsegmented tapeworm, develops into an adult tapeworm when ingested by a primary host.

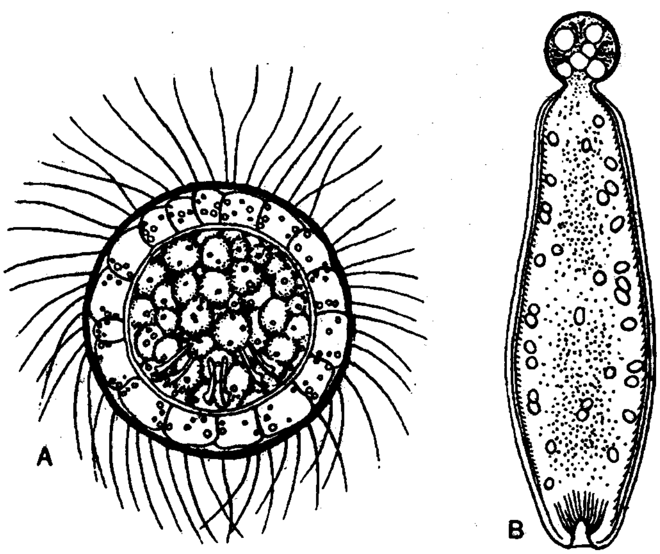


Fig. 2-50. Some stages in the life cycle of the fish tapeworm, *Diphyllobothrium latum*. A, Ciliated oncosphere. B, Mature procercoid.

Species of the genus *Taenia* are among the best known tapeworms (Fig. 2-49). *Taenia solium* is a parasite of man and reaches a length in the human intestine of up to 7 meters. The proglottids are passed in the host's feces. This phenomenon is known as apolysis and the worms as apolytic worms. The eggs do not hatch until a pig or one of several other hosts, even man, eats them. On hatching the onchospheres bore into the intestinal wall. Via blood vascular system, onchospheres are transported to striated muscles. Within the striated muscles, the larva leaves the blood stream and develops into a cysticercus stage. The cysticercus sometimes called as bladder worm. It is an oval stage, which reaches about 10 mm. in length. The scolex invaginated into the interior in the bladder worm. If raw pork or pork is insufficiently cooked to kill the cysticercus is ingested by man, the cysticercus is freed. The scolex evaginates, it fixes to the intestinal wall and an adult worm develops. *Taenia pisiformis* occurs in cats and dogs, with rabbits as the intermediate hosts. The beef tapeworm of man, *Taeniarhynchus saginatus,* belongs to a related genus, and bovine animals are the intermediate hosts (Fig. 2-49). Cyclophyllidean tapeworms are largely parasitic in birds and mammals. Vertebrates, arthropods, annelids and mollusks serve as intermediate hosts for these tapeworms.

2.4.5.2 SUBCLASS CESTODARIA

The subclass cestodaria is a small group of cestodes that show some similarities to trematodes. The body of the adult tapeworm is similar to that of other flat worms such as turbellarians and trematodes. Cestodarians are single segmented and are called monozoic tapeworms (Fig. 2-51). Scolex and strobila are absent. The body contains only one hermaphroditic reproductive system. Trematode like suckers are sometimes present. However, the absence of a digestive system and the presence of a larva that is similar to the larva of many tapeworms would place them with the cestodes.

The cestodarians are intestinal and coelomic parasites of elasmobranches and primitive teleost fish. The intermediate hosts are invertebrates.

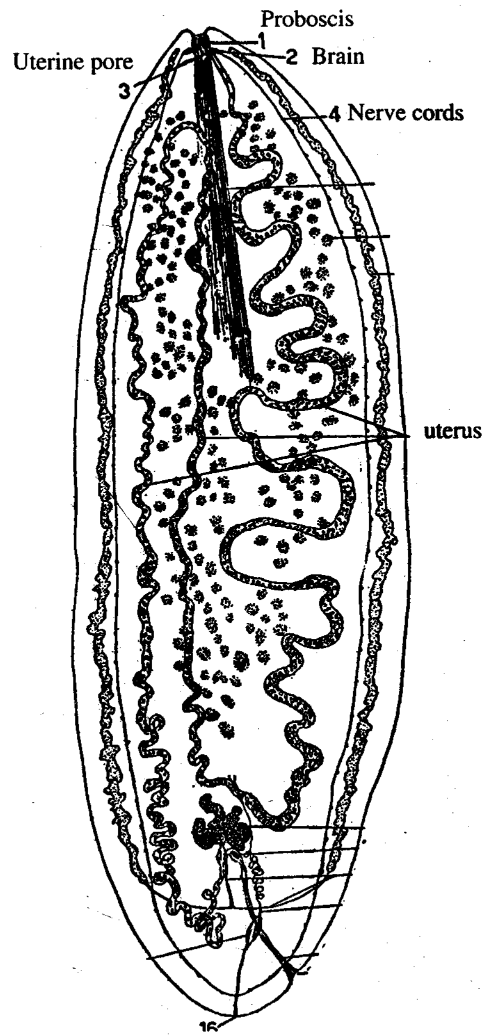


Fig. 2-51. *Amphilina foliacea*

2.4.5.3 SUMMARY

Cestodes or tapeworms are gut parasites of vertebrates. They are structurally more specialized than flukes.

The body is composed of a scolex having adhesive organs, a neck region and a strobila. The strobila consists of a chain of segments (proglottids). The neck produces a chain of proglottids by means of transverse constrictions.

Eucestodes are polyzoic (many segmented) tapeworms. Cestodarians are monozoic (single segmented) tapeworms.

The tapeworm tegument plays an important role in the body physiology. It serves as a site of absorption of nutrients.

Digestive system is absent. Absorption of food occurs through tegument. The nervous and protonephridial excretory systems are present extending through the chain of proglottids in eucestodes.

The reproductive system is hermaphroditic. It is somewhat similar to that of trematodes. It is repeated in each segment in polyzoic tapeworms.

The life cycle involves an onchosphere larva and an intermediate host in eucestodes.

The cysticercus or bladder worm is the infective stage.

The cestodarians are intestinal and coelomic parasites of elasmobranch fish.

The cestodarians are a small group of monozoic tapeworms. In external morphology, they are similar to trematodes.

Typical characters of eucestodes like scolex and strobila are absent.

The tegument covers body.

Gut is absent. The tegument serves as a site of absorption of food.

Protonephridial and nervous systems are present. Reproductive system is hermaphroditic.

Invertebrates are their intermediate hosts (amphipod crustaceans).

The fertilized egg hatches into an onchosphere. When intermediate host eats the onchosphere, it develops into a procercoid. The procercoid transforms into pleurocercoid. The pleurocercoid is the infective stage to the primary host.

2.4.6 KEY TERMINOLOGY

Acoelomate: Animal showing the absence of coelom. The space between the gut and body wall is occupied by mesenchyme.

Bilateral symmetry: Animals showing bilateral symmetry show distinct anterior and posterior ends. They show an upper or dorsal surface and a lower or ventral surface and right and left sides.

Capsule: It refers to the egg found in the ootype of tapeworm. When the capsules are in the ootype the shell glands secrete a shell around them.

Cysticercus: Also called as bladder worm. The infective stage of *Taenia solium*. When hexacanth enters into the intermediate host, it looses its hooks and transforms into cysticercus. It consists of a bladder filled with fluid. Hence, it is called as bladder worm. It is the infective stage to man.

Direct development: Having no larval stage in the course of development.

Genital atrium: a small chamber in parasitic platyhelminthes that receives the openings of both the male and female reproductive systems.

Gravid or ripe proglottids: The last or terminal segments of taenoids. They show a branched uterus filled with ripe eggs. The reproductive system is degenerated. The ripe proglottids detach from the worm and come out through feces.

Gonoduct: Principal duct used for the transport of eggs and sperm in male or female reproductive system.

Gonopore: External opening of male of female reproductive system.

Hermaphroditic: Presence of both male and female reproductive systems in one individual. When both male and female systems are present and function at the same time, it is said to be simultaneous hermaphroditism. When the male reproductive system appears and function first and followed by the female reproductive system, the hermaphroditism is said to be protandric.

Heteromorphosis: When the anterior end of a planaria is cut longitudinally into several parts, each part is able to grow into a complete head. Thus, a multiheaded planarian with a common tail is formed. This process is called as heteromorphosis.

Indirect development: Having a larval stage in the course of development.

Intermediate host: The host for the larval or developmental stage of parasite.

Laurer's canal: Short, inconspicuous canal that extends from the seminal receptacle of trematodes to the dorsal surface, when it may open at a minute pore.

Mehli's gland: Conspicuous, unicellular gland cells associated with the reproductive system of trematodes, which play a role in egg capsule formation.

Metacercaria: It is an encysted form of cercaria. It is the final larval stage in the life cycle of majority of digenetic trematodes.

Miracidium: Ciliated, free swimming, first larva of digenetic trematodes.

Muller's larva and Gotte's larva: Larva of free living turbellarians

Osmoregulation: The maintenance of salt concentration of body fluids at a different level from that of environment.

Oviparous: Egg laying.

Parasitism: A type of symbiotic relationship in which a parasite is benefited and the other host is harmed.

Pelagic worms: Animals, which live floating or swimming in the water column above the bottom.

Pleurocercoid: The infective stage of *Dibothriocephalus latus*. It looks like an unsegmented tapeworm.

Polyembryony: Development of a number of young ones or larvae from a single zygote. In the life cycle of a digenetic trematodes, rediae and cercariae are developed through polyembryony.

Premuntion: When a tapeworm invades the host, the antibodies which are produced against that worm to resist the establishment of fresh infection with the same species. This sort of temporary protective immune response of the host is called as premuntion.

Protonephridium: It functions as an organ of excretion. It is a type of excretory tubule. Flame bulbs or flame cells appear on either side of protonephridium. Flame bulbs or flame cells are the terminal structures of protonephridium.

Pseudometamerism (Pseudo = False): In tapeworm, new segments are proliferated from the neck so that the oldest segment lies at the posterior end of strobila. This type of segmentation is different from annelids and arthropods where new segments are proliferated from anal segment.

Seminal receptacle: A chamber like part of the female reproductive system. It serves as an organ of reception and storage of sperms.

Seminal vesicle: A part of the male reproductive system. In this organ sperms are received and stored.

Spiral cleavage: In this cleavage, the spindle axis is oriented obliquely with respect to the polar axis of the egg.

Viviparous: The phenomenon of producing young ones directly from the mother rather than egg.

2.4.7 SELF ASSESSMENT QUESTIONS

1. Describe the general characters of turbellarians.
2. Explain in detail the arrangement of reproductive system in turbellarians.
3. Describe the protonephridial system in flatworms.
4. Describe the digestive system in turbellarians and trematodes.
5. Describe the life cycle of any monogenetic trematode you have studied.
6. Describe the life cycle of any digenetic trematode you have studied.
7. Describe the external morphology of polyzoic tapeworms.
8. Describe the larval stages of trematodes. Draw the labeled diagrams.
9. Describe the larval stages of cestodes.
10. Describe the life cycle of any eucestode you have studied.
11. The reproductive system of cestodes is similar to that of trematodes. Justify the statement.
12. What characters keep cestodarians under the class cestoda? Explain in detail.
13. Draw a labeled diagram of T.S. of tegument in cestodes. Discuss the role of tegument in the physiology of cestodes.
14. Draw a labeled diagram of Muller's larva. Explain its importance in the developmental process.

2.4.8 REFERENCE BOOKS

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Dr. V. Viveka Vardhani

2.5 CLASSIFICATION OF PHYLUM PLATYHELMINTHES

2.5.10. Self Assessment Questions

2.5.11. Reference Books

2.5.1 OBJECTIVES

The purpose of this lesson is to:

- classify the Phylum Platyhelminthes upto order level
- understand the distinguishing characters of turbellarians
- comment on the adoptive characters of trematodes
- point out the distinct characters of cestodes

2.5.2 INTRODUCTION

Parasitic forms of platyhelminthes are included in two classes, the trematoda and the cestoda. Parasitic trematodes are sometimes called flukes. Cestodes are generally known as tapeworms. The free living worms are included in the Class Turbellaria. The Turbellarians are said to be the ancestors for trematodes and cestodes.

2.5.3 GENERAL CHARACTERS

The following are the general characteristics of the members of the Phylum Platyhelminthes:

Soft bodied animals. Exoskeleton and endoskeleton are absent in these worms. Hence, these are soft worms.

Dorsoventrally flattened worms. Hence, they are called flat worms.

Body is unsegmented in turbellarians and trematodes. In cestodes body is monozoic (having single segment) or polyzoic (consisting of few to thousands of proglottids).

They are oval or rounded or leaf like (turbellarians and trematodes) or ribbon like (polyzoic cestodes) in shape.

They vary in size. Free living worms are less than 50 m.m. in length whereas some polyzoic cestodes measure more than 20 meters.

They exhibit variety of colors. Turbellarians are black, brown, grey or green in color. Parasites are cream or white in color or colorless.

Platyhelminthes are triploblastic animals because they show an outer ectoderm, inner endoderm and middle mesoderm.

Bilaterally symmetrical animals as they show distinct anterior and posterior ends, dorsal and ventral surfaces.

They are called acoelomates as there is no body cavity and a loose parenchymatous tissue occupies the space between the body wall and gut.

An outer ciliated epidermis that covers the body is the characteristic feature of turbellarians. In contrast to the ciliated epidermis, a tegument covers the body of the trematodes and cestodes.

Tegument plays a vital role in the physiology of trematodes and cestodes.

The muscle layer consists of an outer layer of circular muscles and an inner layer of longitudinal muscles.

Excretion is by means of longitudinal excretory canals having a great number of flame cells. Flame cells are meant for excretion and osmoregulation.

Respiratory and circulatory systems are absent. Endoparasitic flat worms respire anaerobically.

The primitive nervous system consists of a pair of cerebral ganglia or brain and 3 to 5 pairs of longitudinal nerve cords. Majority of flatworms possess a ladder like nervous system.

Sense organs are poorly developed in turbellarians. These are reduced or absent in trematodes and cestodes.

Reproductive system is hermaphroditic in all the platyhelminthic worms (with few exceptions).

Biflagellate sperm are present

Fertilization is external.

Development is indirect with one or more varied larval stages.

Life history is complicated with one or more varied larval stages.

Life cycle is involved with one, two or more intermediate hosts.

2.5.4 CLASSIFICATION

Phylum Platyhelminthes is divided into 3 classes: The Turbellaria, the Trematoda and the Cestoda.

2.5.5 CLASS TURBELLARIA

The Class Turbellaria consists of about 3000 species of free living worms. These are commonly called turbellarians or planarians.

The shape of turbellarians varies from oval to elongate.

Turbellarians are primarily aquatic. Majority of them are marine. Few are pelagic. Most of them are bottom dwellers that live in sand or mud under stones and shells or on sea weed. The land planarian, *Bipalium* is the largest of all free living worms.

Fresh water forms such as the microscopic *Steriostomum* (Fig. 2-52C) and the common laboratory planarian *Dugesia* lives in lakes, ponds and streams. Some terrestrial species are confined to very humid areas. During the day they hide beneath logs and leaf mold. They emerge out only at night to feed. The land planarians are called giant turbellarians. Some species may reach about 60 c.m. or more in length (Fig. 2-52). Most of the land turbellarians are tropical. The North American *Bipalium adventitium* and related species live in temperate regions. Some 3000 species of turbellarians have been described.

Body is unsegmented with a distinct head at the anterior end.

Head projections are present in some species. They may be in the form of short tentacles or as lateral projections called as auricles.

The complex body wall of turbellarian is ciliated containing numerous secreting gland cells and rhabdites. Presence of rhabdites is the typical feature of almost all turbellarians. Rhabdites are rod shaped epidermal bodies and are used in defense or forming a slime around the predators (Fig. 2-53).

Life cycle involves an onchosphere larva and an intermediate host. It is divided into two sub classes, the Cestodaria and the Eucestoda.

2.5.7.1 SUB CLASS CESTODARIA

It includes smaller group of worms. Monozoic body resembles to trematodes in some extent and differs to polyzoic tapeworms. Scolex and strobila are absent. Trematodes like suckers are present. Reproductive system is similar to trematodes. Larva with 10 hooks and is known as decacanth.

2.5.7.1.A ORDER AMPHILINIDEA

The amphilinids are flattened oval to elongate monozoic tapeworms. The length of these worms ranges from a few to 30 to 40 cm.

These are endoparasites in the body cavity of ganoid fish.

Frontal gland and protractible pharynx are present in the anterior part of the body.

Suckers are absent.

Male and female pores present in the posterior part of the body.

Uterus is coiled and opens near the anterior end.

Amphilina (coelomic parasite of elasmobranch fish) (Fig. 2-51).

2.5.7.1.B ORDER GYROCOTYLIDEA

These are endoparasites of chimaeroid fish.

Anterior end has cup like suckers.

Eversible proboscis at anterior end.

Male and female pores are situated at the anterior half of the body.

Uterus not coiled.

Gyrocotyle

2.5.7.2 SUB CLASS EUCESTODA

Majority of cestodes belong to the subclass Eucestoda and are known as tapeworms. These are gut parasites of vertebrates. Body is divided into scolex, neck and strobila.

Scolex with suckers, spines and hooks for attachment to host.

Each proglottid with male and female reproductive organs.

Larva with 6 hooks and is known as onchosphere.

Sub class Eucestoda is divided into nine orders: the Tetraphyllidea, the Lecanicephaloidea, the Proteocephalidea, the Diphyllidea, the Trypanorhyncha or Tetrarhynchoidea, the Pseudophyllidea, the Nippotaeniidea, the Taenioidea or Cyclophyllidea and the Aporidea.

2.5.7.2.A ORDER TETRAPHYLIIDEA

Endoparasites. They are found exclusively in the intestine of elasmobranch fish.

Scolex provided with four bothria often with hooks.

Testes lie in front of ovaries.

Cirrus armed with hairs, spines or hooks.

Common marginal genital atrium.

Phyllobothrium, Acanthobothrium (Fig. 2-47 B,C)

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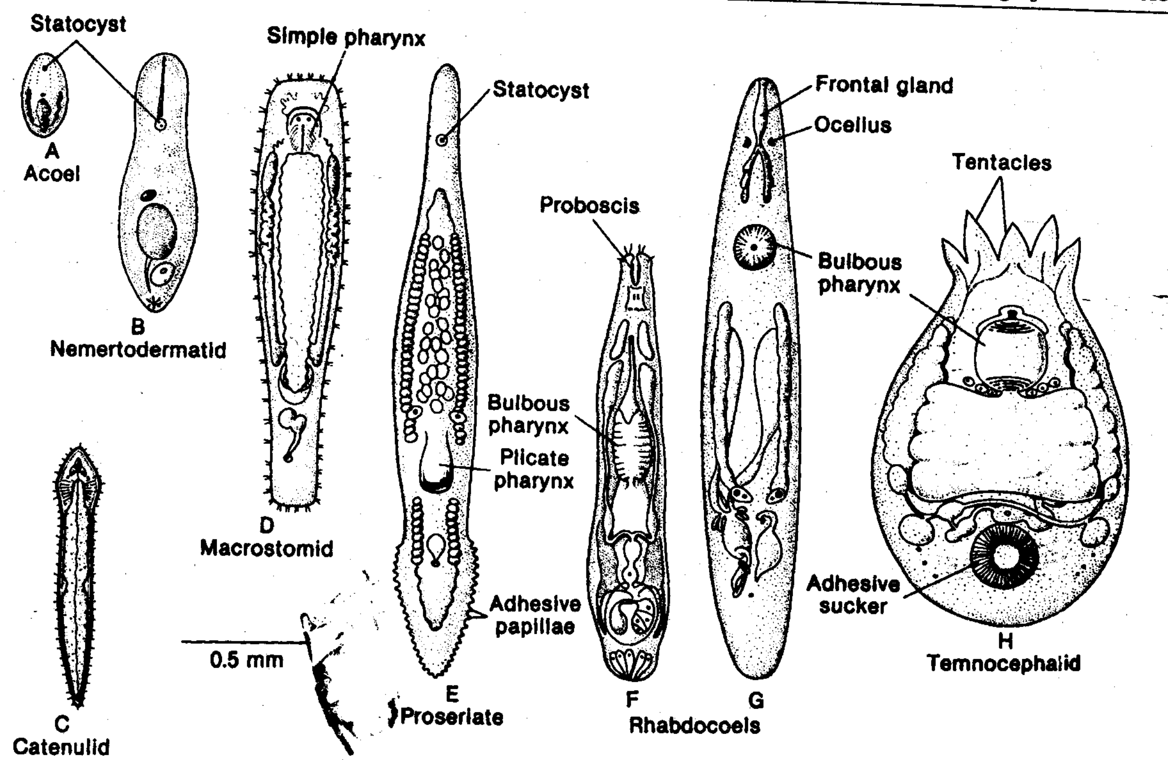


Fig. 2-52. Representative small turbellarians. A, The acoel *Pseudactionoposthia parva*. B, The nemertodermatid *Flagellophora*. C, The catenulid *Stenostomum virginianum*. D, The macrostomid *Macrostomum appendiculatum*. E, The proseriate *Monocelis galapagoensis*. F, The kalyptorthynch rhabdocoel *Karkinorhynchus tetragnathus*. G, The typhloplanoid rhabdocoel *Ceratopera bifida*. H, The temnocephalid *Temnocephala geonoma*.

The intestine of turbellarian is a blind sac with mouth at one end.

Turbellarians are largely carnivores.

Eyes are common in most of the turbellarians. Ciliated pits, grooves and cilia act as sense organs.

They reproduce asexually (fresh water forms) and sexually.

They exhibit remarkable regenerating capacity.

Early development involves spiral cleavage.

Some species pass through a free swimming larval stage called Muller's larva and in some other species, there is a similar larval stage called Gotte's larva.

1. *Dugesia* (Planarian, fresh water form)
2. *Bipalium* (terrestrial form)

According to the modern classification, the turbellarians are divided into three major groups. The turbellarians, which are kept in these groups may or may not be closely related to each other. The three major groups of classification are the Acoelomorpha (Nemertodermatida and Acoela), Catenulida (Catenulida) and Rhabditophora (remaining orders) (see Rieger et. al 1991).

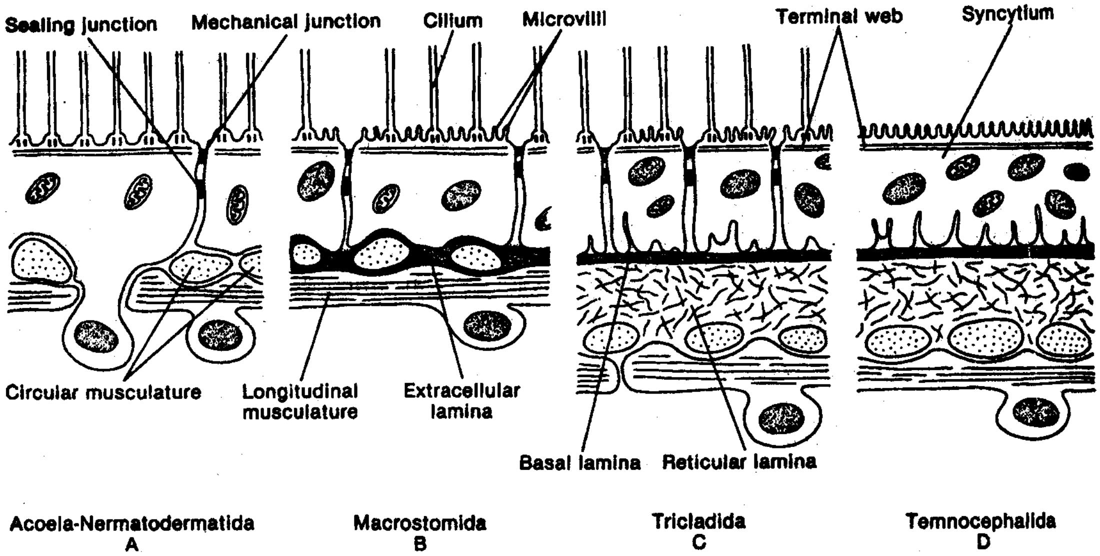


Fig. 2-53 Sections show the body wall organization in acoels and nemertodermatids (A), macrostomids (B), triclads (C), and temnocephalids (D). The amount of extracellular matrix tends to increase with body size from A to D. A syncytial epidermis occurs in some rhabdocoels but is typical of the ectocommensal temnocephalids (D). A similar syncytial tegument is characteristic of trematodes, monogeneans, and tapeworms.

Most of the trubellarians exhibit external simplicity. But they exhibit internal complexity and diversity. The members of the orders Nemertodermatida, Acoela, Catenulida, Macrostomida, Haplopharyngida have a more primitive type of reproductive system. This is referred to as archophoran level of organization. The members of the orders Lecithoepitheliata, Prolecithophora, Proseriata, Temnocephalida, Rhabdocoela and Tricladida have a more advanced type of reproductive system. This is referred to as neophoran level of organization.

2.5.5.1 ARCHOPHORAN TURBELLARIANS

Archophoran Turbellarians exhibit more primitive level of organization. The hermaphroditic reproductive system has more than two testes or ovaries. Vitellaria absent. They produce eggs in which yolk material is an integral part of the cytoplasm of the egg cells. Such eggs are called entolecithal. Fertilized eggs undergo spiral cleavage.

2.5.5.1.A Order Nemertodermatida

Marine species. Small worms They possess an epithelial digestive tract. Uniflagellate sperm. Two statoliths are present in the statocyst.

Nemertoderma (Fig. 2-52B).

2.5.5.1.B Order Acoela

Marine species. Small worms Usually they measure less than 2 m.m. Digestive system shows a mouth and a simple pharynx. Digestive cavity is absent. Gonads often not bounded by a cellular wall. Oviducts are absent. One statolith is present in the statocyst. A few species lead their life as commensals within the intestine of echinoderms.

Anaperus, Convoluta (Fig. 2-29).

2.5.5.1.C Order Catenulida

Fresh water animals. Small in size. Digestive tract is with a simple pharynx and a ciliated sac like intestine. A single ovary and a single testis are present .The male gonopore lies above the pharynx dorsally. Female gonoducts absent. Statocyst usually with one statolith.

Catanula, Stenostomum

2.5.5.1.D Order Haplopharyngida

Marine species. Small in size. The pharynx is protractible as a proboscis. The proboscis is enclosed in a muscular sheath when retracted. Anus may be formed temporarily.

Haplopharynx

2.5.5.1.E Order Macrostomida

Marine and fresh water species. Small in size. Characterized by a simple pharynx and a simple sac like ciliated intestine. Nervous system shows one pair of ventrolateral nerve cords.

Macrostomum, Microstomum

2.5.5.1.F Order Polycladida

Marine forms. Moderate size. Usually 3 to 20 m.m. in length. Greatly flattened worms. More or less oval in shape. Brightly colored. Elongated and centrally located intestine. Folded or plicate pharynx. The intestine has numerous highly branched diverticulae radiating to the periphery. The name Polycladida refers to the branching intestine of this group of turbellarians. Eyes numerous. Testes and ovaries follicular.

Stylochus, Notoplana

2.5.5.2 NEOPHORAN TURBELLARIANS

Neophoran turbellarians exhibit an advanced level of organization. Ectolecithal eggs. Vitellaria present. Development modified from the spiral cleavage pattern.

2.5.5.2.A Order Lecithoepitheliata

Marine and freshwater species. Mouth and folded pharynx at the anterior end of the body. Simple intestine. Follicle like yolk cells surround the eggs.

Prorhynchus

2.5.5.2.B Order Prolecithophora

Marine and freshwater species. Small in size. Plicate or bulbous pharynx. A simple intestine is present. Eggs surrounded by follicle like yolk cells.

Plagiostomum, Hydolimax

2.5.5.2.C Order Proseriata

Mostly marine turbellarians consisting of many interstitial forms. Generally small. Plicate pharynx. Unbranched intestine. Statocyst with one statolith. An advanced type of reproductive system.

Monocelis, Nemertoplana

2.5.5.2.D Order Temnocephalida

Commensal and parasitic forms. Crustaceans, mollusks and turtles act as hosts for commensal and parasitic forms. Leaf like tentacles or projections are developed at the anterior margin. Tentacles are adhesive and tactile in function. An adhesive sucker is present on the posterior ventral surface. With the help of adhesive sucker and tentacles these worms can move like leeches on their hosts. Eyes are present.

Temnocephalus

2.5.5.2.E Order Rhabdocoela

A large group of marine and fresh water species containing free living, commensal and parasitic (on snails, sea urchins and sea cucumbers) and interstitial species. Some of the rhabdocoels are the smallest turbellarians. They vary 0.3 to 3 m.m. in length. Mouth may vary in position. It may be located at the anterior end of the body or in the middle of the body.

Mesostoma, Gnathorhynchus

2.5.5.2.F Order Tricladida

Relatively large, fresh water, marine and terrestrial turbellarians. A tubular, folded (plicate) pharynx directed posteriorly. Intestine shows three principle branches – one running anteriorly in the middle line and the other two lateral branches running posteriorly. . Each of these branches divides and subdivides into many small lateral diverticulae. These diverticulae end blindly in parenchyma. Because of the three main branches of intestine, the name tricladida is derived.

Planaria, Dugesia

2.5.6 CLASS TREMATODA

It includes about 6000 species, which are sometimes called flukes.

Flukes are ecto or endoparasites.

Body is usually unsegmented, dorsoventrally flattened and leaf like. The body of the trematode is oval to elongate and range in length from less than 1 m.m to 7 meters.

Ventral and oral suckers act as adhesive organs. These suckers are the characteristic features of trematodes.

Mouth is typically located at the anterior end.

Epidermis is absent. Rhabdites are absent.

The body is covered by a non-ciliated, cytoplasmic syncytium, tegument. Cilia absent.

Tegument provides protection and it is the site of gas exchange.

Digestive system consists of mouth, muscular pharynx and intestine usually with two main branches. Anus is absent. Intestinal branches (caeca) may extend upto the posterior extremity of the body.

In some flukes, there is a system of parenchymal vessels showing the presence of primitive circulatory system.

Sense organs are poorly developed.

Excretory organs consist of protonephridia. There are three pairs of longitudinal nerve cords.

Ectoparasites are aerobic and endoparasites are anaerobic.

Hermaphroditic reproductive system is uniform throughout the class. The members of the family Schistosomatidae, in contrast to most other flat worms, are dioecious with a male and a female permanently paired throughout life. Bisexual reproductive system in blood flukes (Schistosomes). Single ovary in female and many testes in male. Cross fertilization takes place. Development direct or indirect.

The class Trematoda includes both monogenetic and digenetic trematodes.

The life cycle of monogenetic forms involves a single host for adult and a single free swimming onchomiracidium larva.

The life cycle of digenetic forms involves 2 to 4 hosts and a number of different larval forms. The primary host is always a vertebrate and intermediate hosts are commonly snails.

Parasites cause various diseases in man and domesticated animals.

Some of the examples of trematodes are:

Polystoma - an endoparasite of urinary bladder of frogs and toads.

Gyrodactylus - a common ectoparasite on the gills and body surface of fish and tadpoles.

Fasciola hepatica (liver fluke of sheep) – an endoparasite in liver of sheep

Schistosoma haematobium (blood fluke of man) – an endoparasite in the blood capillaries of humans.

2.5.6.1 Order Monogenea

These are ectoparasites.

These are rather specialized parasites of aquatic animals which live either on the surface of the body or in cavities opening outside directly.

Oral sucker is absent, when present it is poorly developed.

They have in consequence rather elaborate organs of fixation, particularly a posterior organ called a haptor or opisthaptor. The large opisthaptor is provided with suckers or hooks not all of which are functional. Hooks are usually seen in those species living in the gills and the suckers on those on the skin.

Their development is more or less direct.

Nevertheless, the life cycle is not a simple matter of development. The parasite shows gradual developmental stages from a ciliated larva to a sexually mature adult.

Most of the parasitic forms lay large number of eggs suggesting the hazards of development for a parasitic life. Also, it is an adaptation to their parasitic life.

However, some species lay few eggs and a few are viviparous.

The vast majority of genera of Monogenea are fish parasites; on the other hand, only about one third of the Digenea occur in fish and nearly half are in birds and mammals.

Anatomically too, the Monogenea are closer to the temnocephalids and rhabdocoelic turbellarians than they are to the Digenea.

The excretory system consists of two tubules. These tubules are completely separate; each tubule terminates near the mouth on the dorsal side by a nephridiopore.

Male and female genital pores are separate.

A separate vaginal pore or in some cases, two may be present. Some species have a genito-intestinal canal, which runs from the oviduct to one branch of the intestine; it has been suggested that this is homologous with Laurer's canal in the Digenea.

The uterus is small and contains few eggs.

The most striking differences lie in the adhesive organs. An anterior oral sucker and a large posterior attachment organ, the haptor/opisthaptor characterize monogenetic trematodes.

The haptor possess hooks and suckers

The Monogenea is divided into two orders – one containing the forms with a single posterior haptor (Monopisthocotylea), the other, those with several haptors (Polyopisthocotylea).

In Monopisthocotylea, an oral sucker is generally absent or may be weekly developed. The prohaptor consists of a pair of small suckers or pits supplied by adhesive glands. These glands open through one to several thickened bulbous ends known as head organs as in *Dactylogyrus* (Fig.2-54). The single opisthaptor may be a sucker or a disc with one to three pairs of large hooks (anchors) and often with 2 to 16 small peripheral hooks (hook lets). The two anchors of a pair may be connected by a cross piece termed bar (Fig. 2-54).The anterior end has many skin glands with two or four contractile tips.

Gyrodactylus is a member of this group and is unique among the flat worms. It infects gills, fins and skin of fish. It is of considerable economic importance. Its morphology is simple and its haptor is fringed with one pair of anchors and a row of sixteen tiny hook lets, each of which can be moved independently. The large anchors appear to be functionless and play no part in adhesion. The parasite moves over the skin of the fish freely. However, it dies in twenty minutes off the fish, although it will live on the skin of a dead fish for several days.

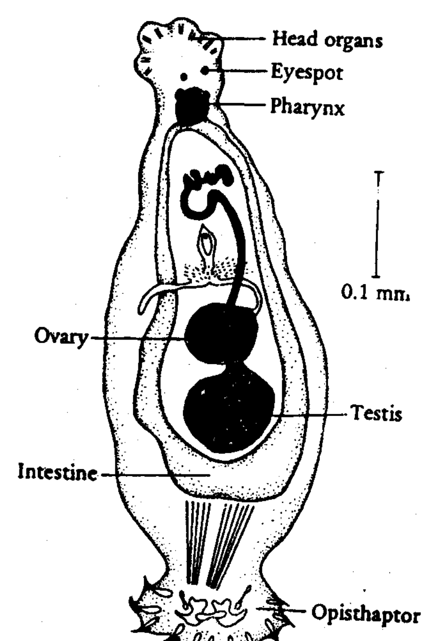


Fig. 2-54. *Dactylogyrus vastator*, a monogenean ectoparasite on the gills of freshwater fishes.

It is viviparous and gives birth to a well developed larva. Moreover, the larva has already another larva within its undeveloped uterus; a single worm may lodge grand daughters and great grand daughters. The larva feeds actively on blood from the internal gills and develops in about a month to maturity, still on the gills; it lays eggs (without cross fertilization).

Polystoma integerrium is found in the bladder of frogs and toads. The eggs are shed when the young frog and toad returns to the water to breed. A ciliated, free-swimming onchomiracidium hatches fioi the egg (Fig.

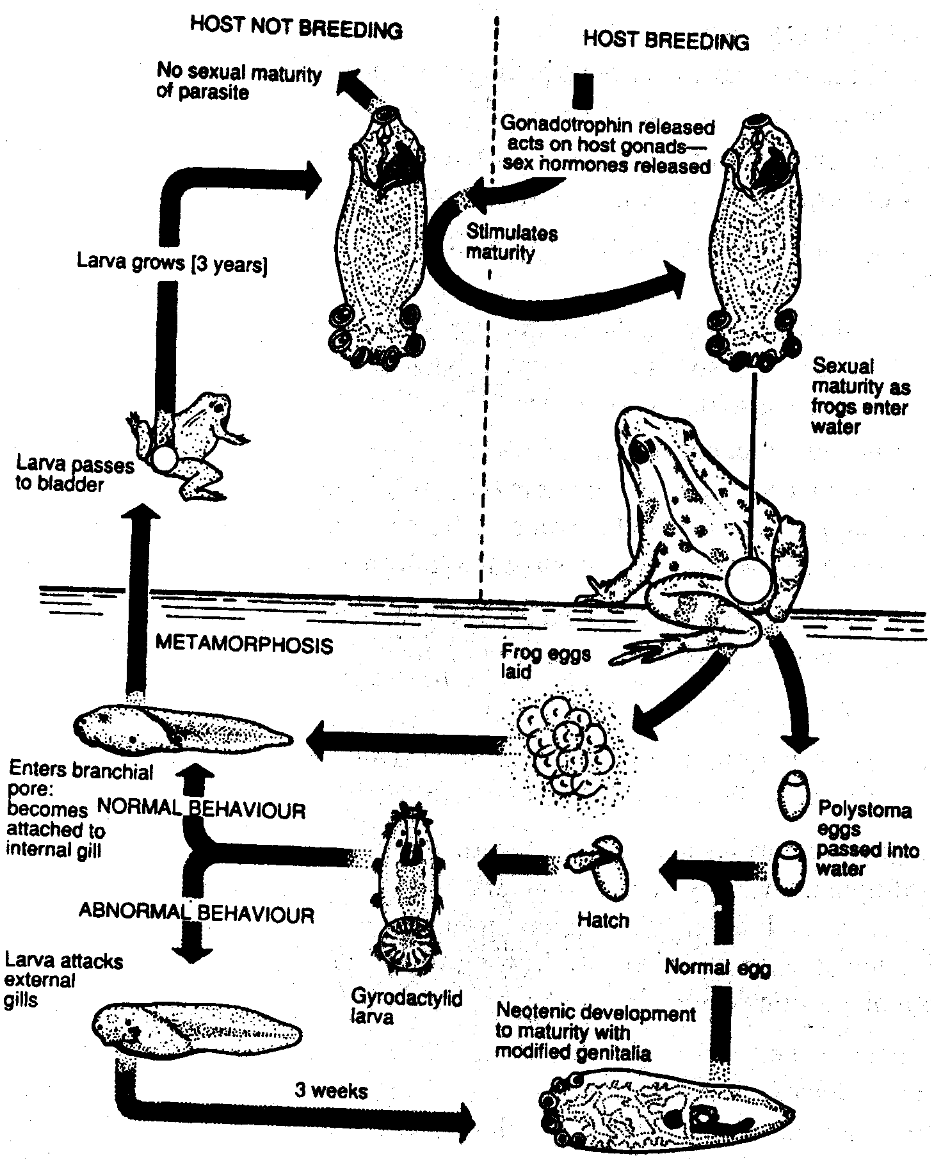


Fig. 2-55. Life cycle of *Polystoma integerrimum,* a monogenean found in the bladder of frogs. Diagram also shows a progenetic population parasitic on the gills of the tadpole.

2-55). It attaches to the gills of the tadpoles. When the tadpoles metamorphose, the larva leaves the gill chamber, crawls over the host's belly, and enters the bladder. When the tadpole is young, some of the larvae may attain sexual maturity and produce eggs.

The effect of Monogenea on the host is usually slight, except under artificial conditions of crowding, but sometimes they cause considerable damage. This is especially true for such forms as *Gyrodactylus*, which can develop without leaving the host at all, and often kill young fish causing irritation and interfering with the normal function of the gills.

2.5.6.2 ORDER DIGENEA

Most of the familiar trematodes belong to the order Digenea. It is a remarkably homogenous group with a basic similarity both in morphology and life history.

These are endoparasitic in vertebrates and invertebrates. Digeneans are common endoparasites of all classes of vertebrates; fishes, amphibians, reptiles, birds and mammals.

In the digenean the body is usually small and leaf like, but some forms are pyriform or thread like (Fig. 2-37).

There is always (except in the gastrostomes) an anterior sucker surrounding the mouth opening and a second, purely adhesive sucker is usually present on the ventral surface, or it may be found elsewhere, or may be absent; this sucker is called the acetabulum.

The digestive tract consists of an oesophagus, a muscular sucking pharynx and two digestive caeca. The intestinal caeca may extend upto the posterior extremity of the animal. In the blood flukes, however, the pharynx is absent and in some of them the intestine bifurcates for part of its length, then reuniting to form a single caecum. Intestine is saciform in bucephalids (gastrostomes).

Digestion is carried out in the caeca. The products of digestion are circulated through special spaces in the parenchyma, which form a lymphatic system.

There is no vascular system.

The excretory system discharges out by a single posterior excretory pore. The number and arrangement of flame cells varies differently in different species.

The great majorities are hermaphroditic and have typical genital systems. There are usually two testes (although this is by no means invariable) and a single ovary. Both testis and ovary are solid but may be spherical, lobulated, branched, or even thread like. They may be situated in a variety of positions related to each other and as they are easily seen, their shape and relative position are of considerable diagnostic value.

The position and extent of the yolk glands, which are usually situated in the lateral fields of the body external to the caeca. All the other organs lie within the caecal field. Both the systems discharge side by side as the common genital pore, which usually opens on the ventral surface of the body.

In the male system, a cirrus and seminal vesicle may be present or absent.

In the female system, a vagina or its place being taken by the uterus, seminal receptacle (which receives spermatozoa and discharges eggs) and a common genital pore are present.

A spermatheca may be present or absent, and so also may a peculiar residual structure called 'Laurer's canal' which passes from the spermatheca to open on the dorsal surface of the body. This structure may represent the remnant of a one separate vagina.

The life cycle may be described as follows: the eggs are compound, containing yolk or nurse cells in addition to an ovum and are usually provided with an operculum or lid. They may be embryonated when deposited or become so after a period of incubation. The embryo is ciliated and is called a miracidium. The miracidium may hatch in water and enter a snail, which it must do quickly because it is unable to feed in water.

Alternatively, a snail may swallow the embryonated egg, which may hatch in the mollusk's intestine. In every case a mollusk is essential for the further development of the parasite.

In the mollusc, the cilia of the miracidium are lost and in most cases, with in the body of the snail, the miracidium becomes a sporocyst; in a few cases it develops directly into redia.

However, the sporocyst usually gives rise to a brood of rediae, but in some cases it gives rise to daughter sporocysts.

The basic difference between these two stages lies in the possession of agent. The redia has a pharynx and a blind sac-like gut; the sporocyst has no digestive tract at all and must, therefore be saprozoic. Whereas the redia is partly at least holozoic.

The final stage in all cases is a brood of cercariae while the number of cercariae developing from a single miracidium varies; it is always very large and may amount to millions.

The embryonic part of the life cycle (that is, the sporocyst – redia part) is extremely host specific, some times so much so that only certain species of a genus of snails can be parasitized.

The cercaria is a larval fluke and usually leaves the mollusk to develop to maturity, it reaches its final host by various means – either directly or indirectly.

The cercaria has some potentially adult and some strictly larval characters.

It has a body and usually a tail.

The body becomes the adult parasite and possesses an oral sucker and a rudimentary digestive system, usually an acetabulum, a genital rudiment and a simplified excretory system, including an excretory bladder, which often is able to pulsate.

It may possess cytogenic or proteolytic glands or both, as well as eyespots and other structures, which are purely larval.

The tail is also a purely larval character and may be vestigial, single or bifid, prehensile or swimming organ with or without spine.

The tail is basically an organ for passing from the snail to the next host

Cercaria with a tail is usually able to swim well, in some cases using the tail as a propeller, in others as a tractor. However, the tail is easily lost and all cercariae are able to creep with the aid of their suckers and general body musculature.

They show some degree of chemotaxis – being attracted towards the next host.

In most cases the cercaria penetrates a second intermediate host (losing its tail) and encysts within the host.

Such cercariae usually possess proteolytic glands opening in the oral region, and may also possess penetration spines; these are useful for gaining entry into the second host.

In addition, they possess mucoid glands, which, are used in the host for the secretion of a cyst in which the young flukes undergo some slight development towards sexual maturity.

In some cases, at least the cyst wall is formed partly from these glands, but partly also from material in the excretory bladder.

The encysted stage is called a metacercaria.

In some cases the metacercaria may become sexually mature while still in the second intermediate host. If the final vertebrate host eats the host of the metacercaria, the metacercaria actively escapes from its cyst, migrates and develops into the adult form within a characteristic location in the host.

Some of the common examples are:

Bucephalus - a fish endoparasite

Opisthorchis sinensis (Chinese liver fluke) - lives in the bile passage of fi... eating birds, reptiles and mammals.

Paramphistomum westermoni- endoparasite in the gut and bile ducts of vertebrates.

Echinostoma granulosoma - a common intestinal parasite of birds.

2.5.6.3 ORDER ASPIDOBOTHREA

Aspidobothrea is a small but peculiar group of trematodes with a direct development, although a 'metacercarian' stage occurs in some as a means of reaching the final host.

Endoparasites in the digestive tract of fish and reptiles and in the renal or pericardial cavity of mollusks.

In its morphology this group resembles to both the Monogenea and Digenea. However, there is no oral sucker and a single, multilobulate sucker covers the entire ventral surface of the body.

Hooks are absent in the ventral sucker.

The digestive tract contains only one intestinal caecum.

Single excretory pore.

The reproductive system is like that of the digenetic trematodes, but there is single testis in the male system.

Its life cycle commences with an egg containing what is actually a small aspidogaster and all the stages upto maturity take place in the same host.

Their life cycle involves one or two hosts.

Aspidogaster, Cotylaspis,(Fig. 2-46), Stichocotyle

2.5.7 CLASS CESTODA

The Cestoda is the most highly specialized of the flatworm classes.

All are endoparasites.

This class includes about 3400 species.

The structure of cestode is more specialized than trematode.

Body is long, flat and ribbon shaped.

Body is monozoic or polyzoic.

Polyzoic tapeworm body is divided into scolex, neck and strobila.

Strobila consists of a chain of immature, mature and gravid segments called proglottids.

Scolex serves as an attachment organ.

A tegument as in trematodes covers body.

Gut is completely absent.

Hermaphroditic reproductive system is repeated in each segment.

11)

Life cycle involves an onchosphere larva and an intermediate host. It is divided into two sub classes, the Cestodaria and the Eucestoda.

2.5.7.1 SUB CLASS CESTODARIA

It includes smaller group of worms. Monozoic body resembles to trematodes in some extent and differs to polyzoic tapeworms. Scolex and strobila are absent. Trematodes like suckers are present. Reproductive system is similar to trematodes. Larva with 10 hooks and is known as decacanth.

2.5.7.1.A ORDER AMPHILINIDEA

The amphilinids are flattened oval to elongate monozoic tapeworms. The length of these worms ranges from a few to 30 to 40 cm.

These are endoparasites in the body cavity of ganoid fish.

Frontal gland and protractible pharynx are present in the anterior part of the body.

Suckers are absent.

Male and female pores present in the posterior part of the body.

Uterus is coiled and opens near the anterior end.

Amphilina (coelomic parasite of elasmobranch fish) (Fig. 2-51).

2.5.7.1.B ORDER GYROCOTYLIDEA

These are endoparasites of chimaeroid fish.

Anterior end has cup like suckers.

Eversible proboscis at anterior end.

Male and female pores are situated at the anterior half of the body.

Uterus not coiled.

Gyrocotyle

2.5.7.2 SUB CLASS EUCESTODA

Majority of cestodes belong to the subclass Eucestoda and are known as tapeworms. These are gut parasites of vertebrates. Body is divided into scolex, neck and strobila.

Scolex with suckers, spines and hooks for attachment to host.

Each proglottid with male and female reproductive organs.

Larva with 6 hooks and is known as onchosphere.

Sub class Eucestoda is divided into nine orders: the Tetraphyllidea, the Lecanicephaloidea, the Proteocephalidea, the Diphyllidea, the Trypanorhyncha or Tetrarhynchoidea, the Pseudophyllidea, the Nippotaeniidea, the Taenioidea or Cyclophyllidea and the Aporidea.

2.5.7.2.A ORDER TETRAPHYLIIDEA

Endoparasites. They are found exclusively in the intestine of elasmobranch fish.

Scolex provided with four bothria often with hooks.

Testes lie in front of ovaries.

Cirrus armed with hairs, spines or hooks.

Common marginal genital atrium.

Phyllobothrium, Acanthobothrium (Fig. 2-47 B,C)

2.5.7.2.B ORDER LECANICEPHALOIDEA

Intestinal parasites of elasmobranch fish.
Scolex divided by a transverse groove into two parts – upper with disc and lower with four suckers.
Vitellaria in two lateral bands.
Lecanicephalium, Polypocephalus (Fig. 2-56 A, B)

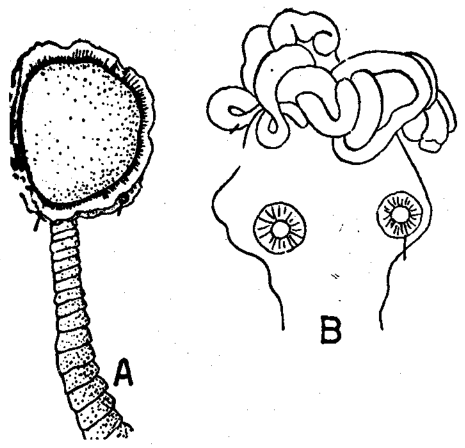


Fig. 2-56 Scoleces of A. *Lecanicephalium, B, Polypocephalus*

2.5.7.2.C ORDER PROTEOCEPHALIDEA

Endoparasites of fresh water fish, amphibians and reptiles.
Scolex with four lateral suckers.
Bilobed ovary. Uterus with many branches and spores.
Scattered vitellaria.
Marginal common genital atrium
Proteocephalus (Fig.2-57 A, B), *Ophiotaenia*

2.5.7.2.D ORDER DIPHYLLIDEA

Endoparasites in the intestine of elasmobranch fish.
Proglottids only 20 or less
Scolex with two bothria.
A spiny head stalk.
Scattered vitellaria
Echinobothrium (Fig. 2-58A)

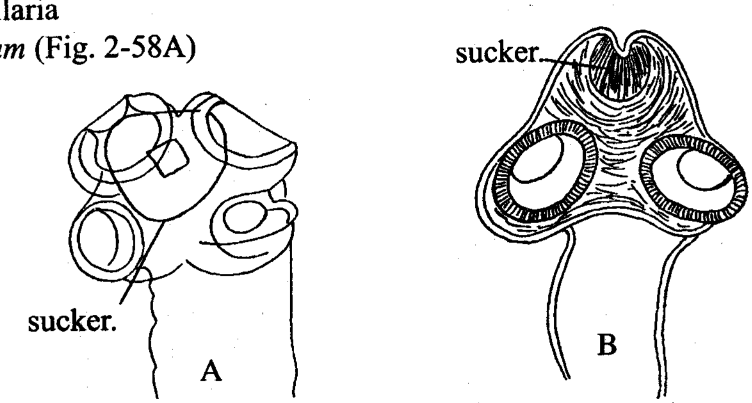
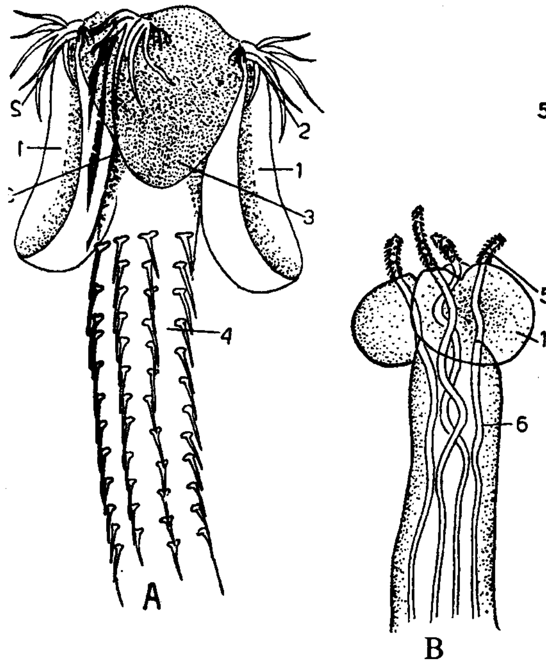


Fig. 2-57 Scolex of *Proteocephalus,* entire A and section B showing terminal sucker.

2.5.7.2.E ORDER TRYPANORHYNCHA OR TETRARHYNCHOIDEA

Endoparasites in the spiral valve of digestive tract of elasmobranch fish.
Moderate size.
Segmented strobila
Scolex with two or four sessile bothria.
Four spiny proboscides are present.
Each of the proboscides is enclosed in a proboscis sheath.
Each proboscis is able to protrude out.
Testes extend beyond ovary posteriorly.
Tetrarhynchus, Haplobothrium, Grilotia, Gilquinia (Fig.2-58 B, C.)



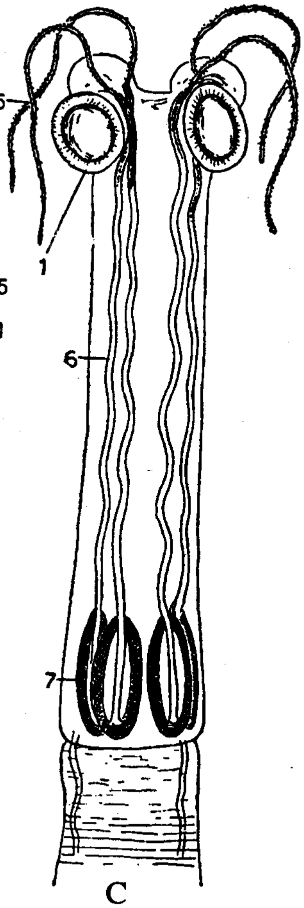


Fig. 2-58 A, *Echinobothrium. B, Grilotia, C, Gilquinia*
1. Bothria, 2. Spines, 3. Rostellum, 4. Head stalk with spines,
5. Proboscides, 6. Proboscis sheath, 7. Proboscis bulb.

2.5.7.2.F ORDER PSEUDOPHYLLIDEA

Endoparasites in the intestine of fish, birds and mammals.
Scolex with six hollow groove like suckers.
Bothria are found on the scolex.
Hooks are absent on the bothria.
Proglottids may be present or absent.
Neck is not well developed.
Yolk glands are many.
Dibothriocephalus, Amphicotyle, Eubothrium (Fig. 2-59)

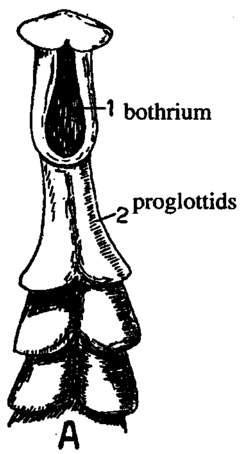


Fig. 2-59. *Eubothrium*

2.5.7.2.G ORDER NIPPOTAENIIDEA

Endoparasites in the intestine of Japanese fresh water fish.
Scolex with single terminal sucker.
Few proglottids.
Each proglottid with one set of genital organs.
Compact vitellaria
Nippotaenia (Fig. 2-60), *Amurotaenia*

2.5.7.2.H ORDER TAENIOIDEA OR CYCLOPHYLLIDEA

Endoparasites in the intestine of birds and mammals.
Body is elongated.
Numerous proglottids.
Scolex bears four suckers often with an apical rostellum.
Rostellum armed with hooks.
Excretory system with four longitudinal vessels and flame cells.
Each proglottid has one set of reproductive organs.
Single compact yolk gland.
Taenia (Fig. 2-49), Echinococcus (Fig. 2-61)

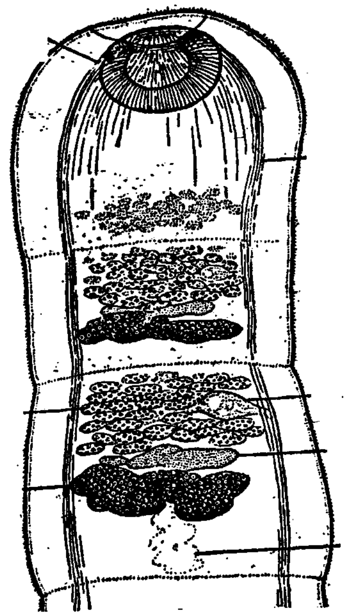


Fig. 2-60. Anterior part of *Nippotaenia.*

2.5.7.2.I ORDER APORIDEA

Endoparasites of birds.
Scolex with four suckers
Rostellum with hooks.
Segmentation is absent.
Reproductive system with simple gonoducts and gonopores.
Nematoparataenia (Fig. 2-62A, B), *Gastrotaenia*

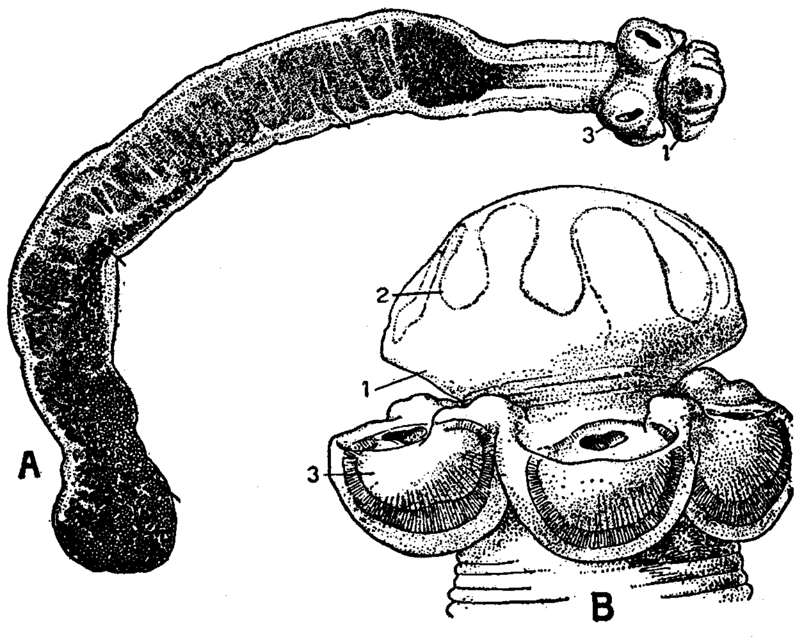


Fig. 2-62. A, Enitire worm of *Nematoparataenia.* B, Scolex enlarged.
1. rostellum; 2. hooks; 3. suckers.

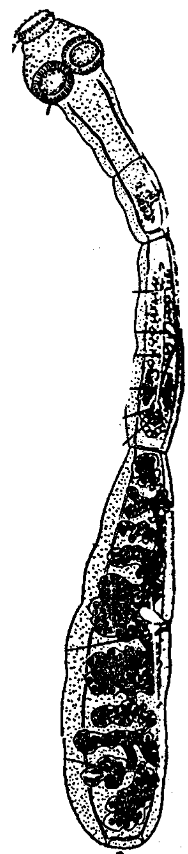


Fig. 2-61. *Echinococcus granulosus*

2.5.8 SUMMARY

The Phylum Platyhelminthes includes three classes: Turbellaria, Trematoda and Cestoda.

The members of the Phylum Platyhelminthes show different habits. Some are free living and many are parasitic having specialized features, which suit their parasitic mode of life.

Free living forms are grouped in the class Turbellaria.

Parasitic forms are grouped in two classes, the Trematoda and the Cestoda.

Turbellarians are generally small animals.

Turbellarians are bilaterally symmetrical animals with poorly developed head.

Turbellarians represent an acoelomate grade of body construction.

Turbellarians are found in salt water (majority), fresh water (few) and on land (very few) in humid environments beneath stones, algae and other objects. Also, there are few interstitial fauna.

Most of the smaller turbellarians move by ciliary action. The more flattened, large animals move by muscular undulations.

Most of the turbellarians lead their life as predators and scavengers. A few are herbivores, commensals and parasites. Small species have a simple sac like intestine with a simple bulbous pharynx. Large species have a branched intestine with a plicate (folded) pharynx.

Extra cellular digestion is followed by intracellular digestion.

A simple ciliated epidermis covers the body of turbellarians. The epidermal glands produce the mucus. It helps in lubricating the substratum over which the animal crawls. Mucus also aids in trapping and swallowing the prey.

The small size, flattened shape and branched intestine of advanced forms compensate the absence of internal transport system and gas exchange organs.

Turbellarians possess protonephridial excretory system. Protonephridia also act as osmoregulatory organs.

A primitive nervous system consists of a brain and a radial arrangement of several pairs of nerve cords. The nerve cords are associated with sense organs.

The sense organs of turbellarians include numerous pigment cup ocelli and statocysts.

Turbellarians possess hermaphroditic reproductive system. They are adapted for internal fertilization and egg deposition.

The two types of ovaries form the basis to identify two levels of organization in the Turbellarians. Primitive archophorans have a simple ovary (acoels, macrostomids, catenulids and polyclads). The advanced neophorans have an ovary and vitellaria (proseriates, rhabdocoels and triclads).

The Archophoran turbellarians are divided into six orders: the Nemertodermatida, the Acoela, the Catenulida, the Haplopharyngida, the Macrostomida and the Polycladida.

The Neophoran turbellarians are divided into six orders: the Lecithoepitheliata, the Prolecithophora, the Proseriata, the Temnocephalida, the Rhabdocoela and the Tricladida.

In archophorans, eggs are entolecithal, cleavage is spiral and sometimes a free swimming larva.

In neophorans, eggs are ectolecithal, spiral cleavage has been lost and development is always direct.

Some polyclads produce free swimming larvae that feed on plankton. There are two kinds of these larvae. One is with eight arms called Muller's larva. Another is with four arms called Gotte's larva. The larvae swim about for a few days and then settle to the bottom as young worms.

Two classes of flatworms, Trematoda and Cestoda are entirely parasitic.

A syncytial, non ciliated body covering, or tegument covers the body of both the trematodes and cestodes.

Monogenetic trematodes are ectoparasites on aquatic vertebrates like fish. They also parasitize amphibians and reptiles. Body is oval or elongate.

Monogeneans are dorsoventrally flattened and have a large, posterior attachment organ called the haptor. The haptor bears hooks and spines. It is with this haptor they attach to the skin of the host.

Mouth lies anteriorly. The sucker does not surround mouth.

Gut is with a mouth, pharynx, oesophagus and a pair of blind intestinal caeca.

There is no intermediate host in the monogenean life cycle.

Development includes a single larva called onchomiracidium. Adults lay eggs.

From the egg the onchomiracidium emerges. It develops into an adult form after attaching to a new host of same species.

Digenetic trematodes are endoparasites of vertebrates and constitute the largest group of helminthes parasites.

Body is oval to elongate. The flattened worm is provided with an oral sucker and a ventral sucker or acetabulum. Both the suckers act as adhesive organs.

A gut is present with mouth, pharynx, oesophagus and a pair of intestinal caeca.

The caeca are simple or branched with closed ends. Mouth is encircled with an oral sucker.

Hermaphroditic reproductive system is adapted for internal fertilization, formation of egg capsule and egg deposition.

The life cycle is indirect in digenetic trematodes. The life cycle involves two to four intermediate hosts and three to four types of developmental stages (miracidium, sporocyst, redia, cercaria). The primary (definitive) host, which lodges the adult, is always a vertebrate. The intermediate hosts (gastropod snails) are invertebrates. Species of *Schistosomes* (blood flukes) are among the most widespread group of human parasites.

The Class Trematoda is divided into three orders, the Monogenea, the Digenea and the Aspidobothrea.

Cestodes or tapeworms are the gut parasites of vertebrates. The polyzoic tapeworms (eucestodes) have a scolex, neck, and a linearly arranged segments called strobila. Scolex is provided with suckers and hooks, which serve as adhesive organs.

Monozoic tapeworms are oval to elongate; they are like that of digenetic trematodes in their shape. Like monogeneans, monozoic tapeworms (cestodarians) are provided with an adhesive rostellum at the posterior end.

Tapeworms are devoid of digestive tract.

Tegument plays a vital role in the absorption of nutrients and in protecting them against the host enzymes.

In eucestodes (polyzoic tapeworms), the hermaphroditic reproductive system (similar to that of monogeneans and digeneans) is repeated in each segment.

The tapeworm life cycle is indirect.

In some eucestodes onchosphere is the only larval form in the life cycle.

In other tapeworms, two to three larval forms (coracidium, procercoid, pleurocercoid) are involved.

Tapeworms utilize one or more intermediate hosts (an invertebrate and/or a vertebrate) to complete their life cycle.

The onchosphere and pleurocercoid are the infective stages.

The Class Cestoda is divided into two subclasses, the Cestodaria and the Eucestoda.

The subclass Cestodaria is divided into two orders, the Amphilinidea and the Gyrocotylidea.

The subclass Eucestoda is divided into nine orders, the Tetraphyllidea, the Lecanicephaloidea, the Proteocephalidea, the Diphyllidea, the Trypanorhyncha or Tetrarhynchoidea, the Pseudophyllidea, the Nippotaeniidea, the Taenioidea or Cyclophyllidea and the Aporidea.

2.5.9 KEY TERMINOLOGY

Auricles: Lateral head projections of some turbellarians.

Cercaria: Infective larval stage of digenetic trematodes

Flatworm: Platyhelminthes are dorsoventrally flattened. Hence, they are called flatworms.

Gravid proglottid: Ripe proglottid of polyzoic tapeworms

Miracidium: First larval form of digenetic trematodes.

Monozoic tapeworm: Single segmented tapeworm.

Onchosphere: Six hooked larval form of tapeworms.

Polyzoic tapeworm: Many segmented tapeworm.

Rhabdites: Rod shaped epidermal bodies of turbellarians. These are used in defense.

Scolex: Head end of tapeworms. Useful for attachment.

Tegument: Body covering of trematodes and cestodes.

2.5.10 SELF ASSESSMENT QUESTIONS

1. Classify the Phylum Platyhelminthes upto orders with at least two examples for each order.
2. Classify the Class Turbellaria upto orders. Draw a well labeled diagram of a typical turbellarian.
3. Classify the Class Trematoda upto orders with two examples for each order
4. Classify the Class Cestoda upto orders quoting 2 examples for each order.
5. Describe the different types of scoleces in polyzoic tapeworms.

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2.6 PARASITIC ADAPTATIONS OF PLATYHELMINTHES

2.6.1 OBJECTIVES

The purpose of this lesson is to :

- define external and internal helminth parasites.
- explain the development of parasitism in flatworms.
- know the various types of parasites
- discuss the adaptations of flatworms for a parasitic existence.

2.6.2 PARASITISM

A *Parasite* is a living form, which lives in or on another species, *host*. The parasite gains its livelihood at the expense of the host. The host furnishes both the habitat and the food for the parasites, which are dependent on it for life. Moreover, the parasite always does damage in some degree to the host.

Parasitology is the study of parasitism. It includes the morphology, classification, biology and physiology of the parasites. In addition it involves the reactions and relationships between each other.

2.6.3 DEVELOPMENT OF PARASITISM

The protozoa, the helminthes and some of the arthropods were the most successful groups of animals that invade hosts. They constitute the important groups of parasites known today. This biotic association is one of symbiosis in which animals live together in varying degrees of dependency between the host and the symbiont.

2.6.4 SYMBIOTIC RELATIONSHIPS

Three degrees of symbiosis are generally recognized. They are mutualism, commensalism and parasitism. Mutualism constitutes one type of relationship in which the host and the symbionts are physiologically dependent upon each other and the relationship is mutually beneficial. Termites and their intestinal protozoa are an example. The termites provide the habitat and the food in the form of wood (cellulose), which they cannot digest. The protozoa in the intestinal habitat, however, are capable of hydrolyzing the wood for their own and the termites use. Ruminants and other herbivorous with their rich flora of bacteria and fauna of protozoa are additional examples of mutualism wherein both the host and the symbionts are physiologically dependent on each other.

2.6.5 PARASITISM AND KINDS OF PARASITES

Parasitism is that relationship in which the symbiont is physiologically dependent on the host for its habitat and sustenance and at the same time may be harmful to it. All of the trematodes, cestodes, acanthocephalans, and many of the protozoa and nematodes are examples of true animal parasites.

Commensalism is the condition in which the host provides the habitat and food for its symbionts, which live without causing harm or benefit to it. The symbionts, however, are physiologically dependent on the host for their existence. The host, on the other hand, is not dependent on them. Certain of the protozoa living in the alimentary canal of man or on the bodies of hydra are examples of commensals.

Several groups of parasites are recognized, depending on their relationship to the host. Depending on the location of parasite in or on the body of the host provides basis for dividing parasitic animals into 2 groups. Ectoparasites live on the external surface of the body of the host or in cavities that open directly to the outer surface. They include monogenetic trematodes, lice, mites and ticks. Endoparasites live in the bodies of the hosts, occurring in the alimentary canal, lungs, liver and other organs, tissues, cells and body cavity. Examples are tapeworms, digenetic trematodes, nematodes and protozoa.

The amount of time, the parasite spent in or on the host serves as temporary basis for dividing parasites into 2 major groups: temporary parasites and stationary parasites.

Temporary parasites visit the host for food. Having satisfied their hunger, they leave. Blood sucking arthropods and leeches are examples.

Stationary parasites spend a definite period of development on or in the body of the host. They may be divided into two groups: periodic parasites and permanent parasites. According to the amount of time spent within the host, those, which remain with the host for only a part of their development, and then leave to continue a non-parasitic life are known as periodic parasites. Boot flies and mermithid nematodes represent this group. Parasites that spend their entire existence in hosts except for the times they occur free while transferring from one host to another are designated as permanent parasites. The trematodes, cestodes, acanthocephalans, nematodes and protozoa are examples.

Parasites found in unusual hosts, or unusual places in normal hosts, are designated by terms indicating the nature of their abnormalities. Parasites, which occasionally appear in unusual hosts under natural conditions, are *incidental parasites.* For e.g.: the common liver fluke of sheep occurs in dogs or cats.

Parasites that wander into unusual places in the normal hosts are erratic or aberrant parasites. Ascarids of swine and man may wander from the intestine into the liver, body cavity or nostrils.

All of the parasites listed in these categories are obligate parasites.

They are unable to exist without some degree of development on or in the host. A few normally free living animals, on the other hand, are able to exist for shorter periods in the bodies of other animals when accidentally introduced into them. They are spoken of as facultative parasites. Certain free living nematodes of the genera *Rhabditis* and *Turbotrix* and some of the blow flies are examples.

2.6.6 PROPERTIES OF PARASITISM

The basic properties of parasitism appear in the adaptations of the parasite to live, to reproduce and to infect new hosts.

2.6.7 ADAPTATIONS FOR PARASITIC LIFE

An interesting aspect in helminthology is to study the basic adaptations of the parasites. The basic physiological requirements of a parasite are similar to those of free-living animals. They are habitat, food and reproduction. The problems in achieving these requirements under the conditions of parasitism are complex and specialized adaptations have evolved to meet them.

1. In order to live on or in the host, the parasite must evolve structures for adhering to it. Monogenetic and digenetic trematodes and cestodes possess suckers and hooks for attachment. For e.g., Monogenetic trematodes possess a large posterior adhesive organ called an opisthaptor. The opisthaptor is a complex muscular organ, which bears sclerotized pieces in the form of hooks, anchors or bars and sometimes suckers (Fig. 2-36). *Gyrodactylus* species on fish gills with two head organs. *Dactylogyrus* species on fish gills with 2 pairs of head organs. *Diplozoon* on gills of numerous fishes. In cestodes the scolex is adapted for adhering to the host (Fig. 2-47).

2. Sense organs are reduced especially in endoparasites.

3. There are various modifications in nutrition. In case of ectoparasites, such modifications include the development of storage areas for ingested food, adaptations of the ingestive organs or direct absorption through body wall in endoparasites. Since tapeworms are devoid of digestive tract, tegument plays a vital role in the absorption of food.

4. The tegument plays a vital role on the physiology of endoparasitic trematodes and cestodes. It provides protection especially against the host's enzymes in gut inhabiting species. In trematodes – it is the site of gas exchange. In endoparasitic forms some amino acid absorption also occurs by the integument.

5. There is an increase in the reproductive capabilities of the parasite through greater egg production, and often asexual reproductive stages that are universal in the life history of the parasite. In some parasites, they exhibit parthenogenetic development. The process is referred as heterogamy.

6. In case of digenetic trematodes, some larval forms develop by means of polyembryony (Fig. 2-41 and 2-42).

7. Numerous larval stages permit passage of the parasite from one host to another. Utilization of intermediate hosts to complete their life cycle.

8. Means of survival and development are essential during the interval of transfer from one definite host to the next. In parasites with direct or indirect life cycles, protective cysts, thick egg shells, or the retained cuticle of larvae are adaptations to protect the stages free in the soil against the unfavorable conditions of environment like desiccation and freezing. Not only this, the adaptation of parasites may be adjusted to the biotic environment of the bodies of survival species. For e.g., the lancet fluke *Dicrocoelium dendriticum* that lives and develops successively in sheep, snails and ants.

9. Transmission of infective stages by active, passive or inoculative parasites of the alimentary canal, liver, lungs and reproductive systems utilize the natural outlets of these organ systems as avenues of exist for cysts or eggs.

10. When cestodes infect the host, they may continue the infection by newly hatched eggs/ larvae. Such fresh infection can be prevented by the action of antibodies of the host. This phenomenon/premuntion is seen in cestode infections only.

Those living on blood stream and tissues generally utilize other means to leave their hosts.

Trematodes and Cestodes depend on the digestive processes of predators, which serve as definite hosts to release them from the tissues of their intermediate hosts. For example in the life cycle of *Dibothriocephalus latus* (fish tape worm of Man) the infective stages are freed in the interstine of man due to the action of digestive enzymes.

The broad fish tapeworm is widely distributed. It parasitizes in the gut of many carnivores, including man. If the eggs are deposited with feces in water, a ciliated free swimming onchosphere (coracidium) hatches after 10 day developmental period. Upon hatching, the six hooked coracidium swim aimlessly in the water. When eaten by copepod crustaceans, the coracidium sheds the ciliated epithelium in the intestine, penetrates the intestinal wall and develops within the hemocoel into a six hooked stage called a procercoid. When infected crustaceans are ingested by a variety of fresh water fish, the procercoid penetrates the host's gut and eventually reaches the striated muscles of fish to develop into a pleurocercoid stage. The pleurocercoid looks like an adult tapeworm. When the primary host ingests fish harbouring pleurocercoids, the digestive process of the primary host will release it. Here the pleurocercoid is depended upon the digestive processes of the host to release in the intestine. They also acts as stimulants to release the pleurocercoid from the tissue of intermediate host, fish.

Means of survival for development are essential during the interval of transfer from one host to the next. In parasites with a direct life cycle protective cysts, thick egg shells or the retained cuticle of larvae are adaptations to protect the stages free in the soil against the environmental hazards of desiccation and freezing.

Species with indirect life cycle may depend upon certain of the above factors during the time of transfer between their survival hosts.

2.6.8 TRANSMISSION OF THE INFECTIVE STAGE

Transmission of the infective stage of the parasite to the next host in the developmental cycle is accomplished by one of three methods. They are passive, active or inoculative. Passive transmission occurs through swallowing of contaminated food or water. Contaminated water contains eggs of ascarids, cysts of *Entamoeba* and larvae of *Trichostrongylus* etc. Contaminated food may contain the larval stages of trematodes, cestodes, acanthocephalans and many nematodes.

Active transfer occurs by the miracidiae and cercariae of trematodes and by the larvae of hook worms. These parasitic larvae actively penetrate the bodies of their hosts upon coming in contact with them. 'Swimmers itch' is an irritation produced by the incomplete penetration into human skin by the cercariae of blood flukes of birds.

When they enter into the host, survival within the host is dependent upon the ability of the parasites to withstand the destructive action of the digestive juices and the immunological reactions of the host against them. If they have to reach microhabitats within the hosts, the required nutrients for growth and reproduction must be available in adequate amounts.

The most successful parasites have evolved a biotic potential of great capacity in order to compensate for the tremendous losses of eggs or larvae or both, incurred in the completion of their life cycles.

a. **Transmission by fish**: Among the better known examples of trematodes are the Opisthorchids. They include a variety of forms living in the liver of fish eating mammals and birds. The adults have a partial host specificity. Adults, which inhabit the liver of birds, do not generally grow in mammalian hosts.

b. **Transmission by water plants**: Some trematodes do not require an animal as a second intermediate host and the cercariae encyst on vegetation or even the surface film of water. In these cases, the larval fluke secretes the cyst. Cercaria encysts as metacercaria (Fig. 2-44). The metacercaria is ingested with herbage or water and excysts in the alimentary tract, reaching the liver either directly or through the blood stream or by penetration of the bowel wall and liver capsule. It sometimes enters the lungs, it can survive for sometime, but it does not mature.

c. **Transmission by herbage:** A small number of *Digenea* use land snail as their first intermediate host. In *Dicrocoelium,* the sporocyst gives rise to daughter sporocysts instead of rediae, and the cercariae. The daughter sporocysts emerge and pass into the mantle cavity of the snail. They are either excreted by the snail into the grass or swallowed by ants. In the ant, they encyst to form a metacercarial stage.

d. **Transmission by bait cercariae:** Some trematodes of fishes and amphibia have to be swallowed in the actively motile cercarial condition, the cercarial body being enclosed in a chamber hollowed out of the tail. Such cercariae offer themselves as bait and are swallowed by aquatic invertebrates in which they form metacercariae.

e. **Transmission by direct penetration:** The *Schistosomes* have no secondary host. Development takes place in aquatic mollusk. The cercariae have bifid tails and a relatively simple excretory system. The cercariae are distinguished from all others by the congenital absence of a pharynx. They actually enter the definite host by piercing the skin and are provided with special penetration glands with proteolytic enzymes for this purpose. Hence they gain entry to the blood stream. In the case of *Schistosomes*, in which the sexes are separate, they pass via the lungs to the liver, here they wait as immature *Schistosomes* until another of the opposite sex arise. The eggs are released in the intestine and reach the exterior partly by the use of proteolytic enzymes developed by the miracidiae and partly by the peristaltic movements of the intestine.

2.6.9 SUMMARY

The basic properties of parasitism appear in the adaptations of a parasite for its living, reproduction and to infect new hosts.

The basic requirements of a parasite are similar to those of free living animals. They are habitat, food and reproduction. It is difficult to achieve these requirements for a parasite. So, special adaptations have evolved in them.

The trematodes and cestodes show most of the adaptations for parasitic life:

a. Adhesive organs are highly developed for attachment for the exterior or interior of the host.

b. In endoparasites, sense organs are reduced.

c. Parasites of alimentary canal, lungs, liver and reproductive system utilize the natural openings of these systems. The cysts or eggs come out of the natural openings of the hosts.

d. Parasites have modified organs of nutrition. Pharynx is modified as pumping or ingestive organ in trematodes or direct absorption of food by body wall in cestodes.

e. The most successful parasites have a greater production of eggs. Duplication of reproductive organs in each segment in cestodes, extension of asexual reproduction for long periods in sporocyst or redia of trematodes and formation of many scoleces in cestodes are some of the adaptations for parasitic life.

f. Utilization of variety of hosts for the transmission of infection.

2.6.10 KEY TERMINOLOGY

Apolytic worms: Tapeworms in which gravid proglottids detach from the posterior end of the strobila.

Anapolytic worms: Tapeworms in which gravid proglottids do not detach from the posterior end of the strobila.

Coracidium: The free swimming, ciliated onchosphere of fish tapeworm, *Dibothriocephalus latus (Diphyllobothrium latum).*

Dimorphic or unisexual blood fluke: *Schistosoma haematobium*

Dibothriocephalus latus (Diphyllobothrium latum): The broad fish tapeworm of man. It completes its life cycle in two intermediate hosts, a vertebrate (fish) and an invertebrate (copepod crustacean).

Flame cells: Cells of the excretory organs of flatworms.

Furcocercous cercaria: Cercaria with forked tail. It is a laryal stage of some digenetic trematodes.

Helminthology: Study of flatworms and round worms.

Heterogamy: Development of larval stages by parthenogenesis

Metacercaria: It is an encysted form of cercaria. It is the final larval stage in the life cycle of majority of digenetic trematodes.

Procercoid: The coracidium transfers into another larval stage known as procercoid. It is found in the first intermediate host (invertebrate), usually a copepod crustacean.

Pleurocercoid: The infective stage of *Dibothriocephalus latus*. It look ike an unsegmented tapeworm. It is found in the second intermediate host (vertebrate).

Polyembryony: Development of a number of young ones or larvae from a single zygote. In the life cycle of a digenetic trematodes, rediae and cercariae are developed through polyembryony.

Premuntion: When a tapeworm invades the host, the antibodies which are produced against that worm to resist the establishment of fresh infection with the same species. This sort of temporary protective immune response of the host is called as premuntion.

Redia: An elongated and cylindrical larval form. It is the third larval stage in the life cycle of most of the digenetic trematodes. It produces daughter rediae during summer and cercariae in winter.

Swimmer's itch: Inflammation or dermatitis of skin produced due to the penetration of furcocercous cercariae of blood flukes.

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2.7 GENERAL ORGANIZATION OF PHYLUM NEMATHELMINTHES

2.7.1 OBJECTIVES

The purpose of this lesson is to:

- understand the general characters of nematodes
- exemplify the nematode structure
- describe the generalized life cycle of nematodes.

2.7.2 INTRODUCTION

The nemathelminthes or nematodes are commonly designated as "unsegmented roundworms, threadworms, or pinworms". The term Nematode is derived from the Greek word *"nema"*, thread; *"eidos"*, form, which means thread like worms.

Typically the nematodes are triploblastic, bilaterally symmetrical, slender and cylindrical. The worm-like animals are without appendages, segmentation, cilia, flame cells, circulatory system and true coelom. They show four longitudinal epidermal chords, a triangular pharynx, a nerve ring, copulatory spicules, and one or two tube-like gonads. Simple gonoducts open separately in female, and into the rectum in the male. Most species are sexually dimorphic, a few are hermaphroditic, fertilization internal, young embryonic stages resemble adults, and the development is direct.

The nematodes are the widespread metazoans living in every conceivable aquatic and terrestrial habitat, from poles to tropics, where life can be supported including deserts, hot springs, high mountain elevations, and great oceanic depths. However, the free-swimming planktonic forms are lacking. Most of the worms are free-living and are found in the moist soils, decaying matter, seas, fresh-waters, and marshes. Many members are parasitic attacking virtually all groups of culture plants, domestic animals and even humans. In plants, animals and human beings they are found dwelling in various types of tissues or fluids of the host body, i.e., in the seeds and roots of plants, gum of tree wounds, and in the intestine, blood and other organs of the animals. Some are obligatory parasites and others are facultative, parasitizing both invertebrates and vertebrates, by displaying all the degrees of parasitism. Out of 560 genera, as many as 364 are parasitic in vertebrates. Although over 50 species have been encountered in humans, only a dozen species are of medical importance. According to Stoll (1947), there are about 2200 millions of humans infected by nematode infection all over the world. The significant parasitic groups causing serious diseases are: the threadworms, eelworms, hookworms, filarial worms, pinworms, whipworms, and trichinia worms.

As per the studies of Natural History Museum (1995), the nematodes represent a very large assemblage of worms in enormous numbers with an estimate of 100 million living species, of which only 13000 - 14000 species are named. Nematodes are of utmost importance to humans for their well being and economy. Many are pathogenic resulting in a tremendous damage to the crop plants and domestic animals, and only a few free-living species are beneficial.

2.7.3 EXTERNAL STRUCTURE

2.7.3.A SIZE AND SHAPE

The nematodes vary much in size. The majority of free-living and terrestrial forms are generally microscopic (0.1 to 2mm), but some marine forms attain a maximum length of 50mm. Some parasitic worms (Fig. 2-63 A, C) are also of small size while many reach considerable size and some are veritable giants visible to naked eye such as *Dracunculus* (2m). The males are always smaller than the females.

The nematodes are cylindrical worms with both ends gradually tapering in most of the species. They exhibit two general types of body form, the fusiform shape where the body is long and spindle-like with tapering ends, and the misinform shape (Mermithidae, Filaridae and trichurid genus *Capillaria*) where the body is thread-like and of uniform diameter throughout. Other variations are the short, plump, pyriform or oval shape (*Heterodera*) and the trichuran shape i.e., filiform anteriorly and fusiform posteriorly. The two sexes differ posteriorly in shape and external features, curved with papillae or alae in males, and straight in females.

2.7.3.B STRUCTURE

Generally the nematodes lack coloration, but some are yellowish. The nematode body has no definite regions. It lacks a distinct head. In some marine forms (Draconematidae), the swollen anterior

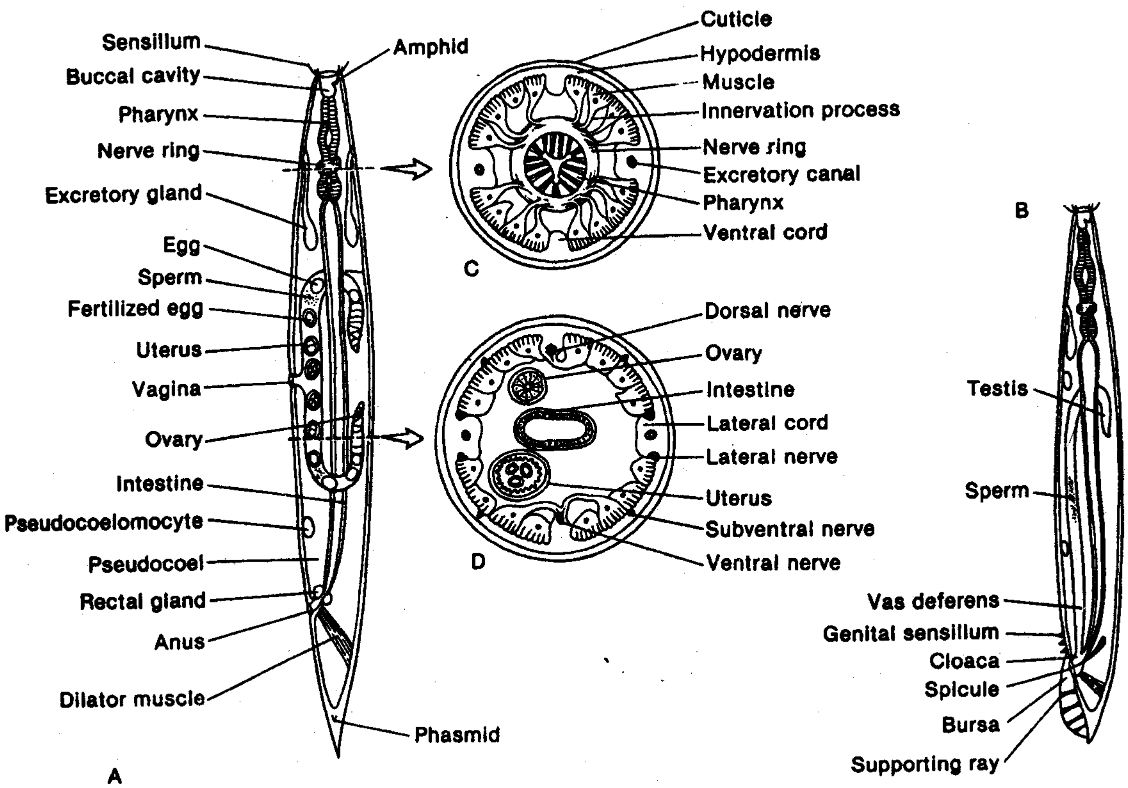

Fig. 2-63 Generalized female nematodes in lateral view (A) and cross sections (C, D). B, Generalized male nematode in lateral view. The volume of the pseudocoel has been exaggerated for clarity.

end simulates head and is differentiated by a circular groove. The mouth is located at the center of the anterior end and is variously modified. In the primitive free-living species, it is encircled by three lips, one dorsal, two ventrolateral, and many sensory papillae, showing a pronounced hexamerous or biradial arrangement. Some specialists (Steiner, 1921) believe that this symmetry is the evidence that the nematodes originally led a semi sessile life attached to the objects by means of adhesive secretions of the caudal glands at their posterior end. This condition is retained by several groups of parasitic forms including the strongyloides, oxyurids, and ascarids. Many marine forms exhibit a primitive condition with six lip-like lobes, each bearing an inner circlet of six sensory papillae and an outer circlet of six labial papillae. A third circlet of four cephalic papillae may be located outside the lips retaining their bilateral symmetry. This primitive pattern is frequently modified to give several variants. In some forms (filaridae and their allies) the lips have disappeared and in others they may be fused into two or three pairs. Sometimes smaller lobes, the interlabia, may present in between the lips. Head sense organs are often reduced in terrestrial and parasitic species.

The body is encased in a very tough, impermeable, non-chitinous cuticle, which is often sculptured or ornamented in different ways. The surface may be pitted, ribbed, ridged, annulated, or striated and has bristles, spines, warts, punctations, scales, or papillae of various patterns. A pair of characteristic sense organs, the amphids, occurs along the sides of the anterior end, just external to the circlet of cephalic sense organs. These are cuticular excavations of three general shapes: cyathiform in marine free-living forms (Enoploidea), spiral form in marine free-living forms (Chromodoroidea and Araeolaimoidea), and circular form in marine free-living forms (Monhysteroidea). They are more conspicuous and well developed in aquatic forms and inconspicuous and reduced in terrestrial and parasitic forms.

A pair of cuticular pouches, the phasmids, appears in many worms, near the posterior end as the outlets of the precaudal glands. Typically most free-living forms have a caudal gland opening at the terminal end of the body. The phasmids occur chiefly in parasitic worms, which form the basis (Chitwoods, 1937) for the classification of Nematoda into Phasmidia and Aphasmidia.

Some parasitic forms have fanlike expansions in the neck region (cervical alae) or in the tail region (caudal alae). In strongylata, there is a bell-shaped cuticular expansion, the bursa, at the posterior end of the males supported by fleshy rays. In Diactophymoidea, the terminal bursa is formed by the expansion of the entire body wall. In the females of Simondsia (Spiruroidea), the caudal end is greatly expanded into a rounded excrescence containing the distended uterus. In males (Fig. 2-63 B, D) and females, the ventral surface is identified by the presence of the excretory pore, the gonopore and the anus. In females the excretory pore is anterior in position, while the gonopore lies in the posterior half of the body. In males the anus, which also serves as the gonopore, lies near the posterior end. The region beyond the anus is the tail.

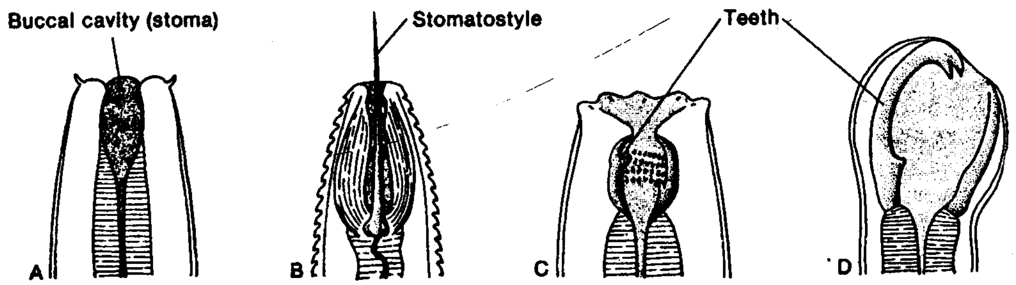

Fig. 2-64 Nematode buccal cavities: **A,** The bacteriovore, *Rhabditis.* **B,** The plant root parasite, *Criconemoides.* **C,** The protozoan and micrometazoan carnivore, *Mononchus.* **D,** The intestinal parasite, *Ancylostoma.*

2.7.4 BODY WALL

The body wall of nematode consists of cuticle, epidermis, and musculature. The epidermis secretes an elastic, complex, flexible, multilayered cuticle (Fig. 2-63 C, D) that molts four times during animal's lifetime. The cuticle is often transparent and may be smooth structure having different histological and chemical construction. In parasitic forms, it may be thicker with obvious annulations strengthened by rows of pits, knobs, ridges, struts, bristles, plates or other ornamentation. The cuticle comprises of three kinds of material, an outer keratinized cortex, a middle matrix, and a basal fiber layer. The cortex is resistant to solvents and to digestive enzymes. The matrix has spongy appearance and consists of fibroid, the matricin. The innermost part comprises of two or three fiber layers of very dense collagen running in different directions in adjacent layers. The cuticle grows continuously and undergoes ecdysis at regular intervals. It is bounded internally by a basement membrane and participates in the formation of outgrowths and hard skeletal structures.

The epidermis or sub cuticle is usually cellular but may be a protoplasmic syncytium with scattered nuclei. The most striking feature is the bulging of the cytoplasm into pseudocoel at four places to form longitudinal chords, one middorsal, one midventral, and two laterals in origin. The chords are better developed anteriorly and tend to disappear posteriorly with an exception to the lateral chords.

The muscles of body wall are exclusively longitudinal fibers arranged as strips in the spaces between the chords. Special muscles occur in the pharynx, ovejector, etc., and for moving the spicules of the male.

2.7.5 BODY CAVITY

The fluid-filled space that occurs between the muscles and the gut wall is the pseudocoel (Fig.2-63C,D). It is not lined by an epithelium. It consists of a small amount of mesenterial tissue and a few large fixed coelocytes, located either against the inner side of the muscle layer or against the wall of the gut or internal organs. The coelocytes are generally smaller and more numerous in free-living forms. The reproductive organs lie in the cavity unattached except at their external openings. The pseudocoelomic fluid serves as a distributing medium for digested food and for the collection of waste products. There may be a frequent occurrence of unicellular glands in free-living forms, but are lacking in parasitic forms. The gland cells usually accompany the amphids, phasmids and other sensory organs. The lateral chords with single or double rows of gland cells have been observed in many marine members (Enoploidea, Chromadoroidea, and Araeolamoidea). The gland cells also accompany warts and other accessory structures of males. A midventral preanal row of gland cells occurs in males of some species. The caudal glands are present in the tail of free-living marine forms, but lacking in others. The cervical or ventral gland is excretory in nature.

2.7.6 LOCOMOTION

The nematodes exhibit a graceful snake-like gliding movement brought about by the alternating contraction of dorsal and ventral longitudinal muscles acting on the cuticle and opposed by hydrostatic pressure in the body tissues. The elasticity of the cuticle and the hydrostatic skeleton of the pseudocoelomic fluid are the key factors in locomotion. The movement is greatly facilitated in aquatic environment compared to the terrestrial environment. A few species having sculptured cuticle can crawl, where a caterpillar-like, earthworm-like, or looping movement is facilitated by means of adhesive glands and elongated ventral bristles. Some species show the thrashing movements involving an alternate bending and straightening of the body.

2.7.7 NUTRITION AND DIGESTION

Many free-living nematodes are carnivorous and others are phytophagous. A large number of terrestrial forms are parasitic. There are many microbivorous and saprophagous worms feeding on dead organic matter or decomposing plant and animal matter. Some species feed on bacteria and fungi associated with the dead matter.

The mouth is terminal and variously modified, and is frequently armed with spines. The lips, 6 or fewer in number, sometimes altogether wanting, and sometimes augmented by interlabia, border it. The mouth opens into a cuticularized, cylindrical or prismatic tube, the buccal cavity, which shows varied size, shape, and degree of differentiation in different species (Fig. 2-64). The teeth that are the characteristic structures of the carnivores may be small and numerous or limited to a few large jaw-like processes (e.g., *Enoplus)*. In the terrestrial carnivores like *Monanchus*, there is one large dorsal tooth and two smaller ventrolateral teeth. In Rhabditoids, the buccal capsule is divisible into three sections, viz., an anterior vestibule enclosed by the lips, a middle sclerotized protostome, and a smaller terminal telostome. It is small and weakly developed in many marine species. In many phytophagous and some predacious forms (Aphelenchoids), it is armed with a long conspicuous spear or stylet that serves as a pierce as well as a path of food intake. In some of the strongylata, the buccal capsule may be supplied with crowns of leaf-like processes, cutting ridges, teeth, and lancets.

The buccal capsule leads into a simple tube consisting of the pharynx and the intestine. The pharynx is a cylindrical tube with a marked chitinized triradiate lumen. The pharyngeal wall is composed of a syncytial epithelium, gland cells and radial muscle fibers. Frequently the middle or posterior part of the pharynx contains one or more muscular swellings, which may be truly valved bulbs or unvalved pseudobulbs. Basing on the shape and the presence of bulbs, pharynges are classified as: cylindrical, when of same diameter throughout; dorylamoid, when slender anteriorly and wider posteriorly; oxyuroid, when provided with an end bulb; rhabditoid, when an anterior wide region leading into a median pseudobulb followed by a narrow region; diplogasteoid, with an anterior muscular region terminating in a median bulb succeeded by a posterior glandular region; tylenchoid, similar of diplogasteroid, except for the more slender region; aphelenchoid, similar to tylenchoid, except that the pharyngeal gland protrude posteriorly from the pharynx, and mermithoid, with a very long tubular non-muscular pharynx. In Trichurates, the pharyngeal wall is greatly reduced and the lumen appears to pass like a capillary tube through a column of large cells that open into the pharynx. In Spiruroidea and Filaroidea, the pharynx is muscular anteriorly and glandular posteriorly. In Ascaroids, the posterior part gives off one or more blind diverticula. There are three long and greatly branched uninucleate or multinucleate pharyngeal glands present in the wall of the pharynx. In Ancylostoma, a pair of pear-shaped cervical glands, of unknown function, is present one on either side of the pharynx.

The pharynx opens into a long straight non-muscular tube, the intestine, extending the entire length of the body (Fig. 2-63 A, B). It has valves at both the ends. The number of columnar or cubical cells of the intestine is either limited (18 to 20) as in Strongyles or about a million as in Ascaris. In many smaller parasitic worms these cells are present only in two rows. The digestion occurs extracellularly in the intestine.

The intestine is connected to the anus by a short flat cuticularized rectum (cloaca in male). The anus is located near the posterior end, with a short or long post-anal tail. The rectum of many parasitic worms is provided with unicellular rectal glands, three in females and six in males. Most marine forms have mucous-secreting caudal glands in the tail for anchorage. They are long-stalked, pyriform cells open at the tip of the tail by a single pore.

2.7.8 RESPIRATION

Most of the aquatic and terrestrial nematodes are aerobic, while many of the parasitic forms and some free-living species inhabiting the mud bottoms of the deep lakes are anaerobic. The respiration is possibly through the cuticle or alimentary canal.

2.7.9 CIRCULATORY SYSTEM

The circulatory system is wanting, and the pseudocoelomic fluid takes the role of distribution of the digested food, elimination of the metabolic wastes, and transport of the respiratory gases.

2.7.10 EXCRETION AND OSMOREGULATION

The excretory system is variable, and the only constant feature is a pore opening on the midventral surface in the pharyngeal region, which seems to be lacking in some forms. The nematodes possess a peculiar system of two sorts of non-ciliated structures, the gland cells and the tubules, which are devoid of the flame bulbs and the internal openings (Fig. 2-65). In free-living forms, the system is primitive, reduced and glandular, consisting of a single large gland cell, the renette, located ventrally in the posterior end of the pharynx or the anterior part of the midgut. The renette gland has a long or short neck, which runs forward and opens in midverntal line by a pore. Little information is available as to its occurrence in fresh-water and terrestrial forms. It may not present in all free-living marine worms. It is lacking in Dorylaimoidea. In Mermithidae, a renette is present only in parasitic juvenile stage. A two celled renette occurs in *Rhabdias* and in many rhabditoids. Excretion may also take place through the cuticle and the real excretory system is secretary.

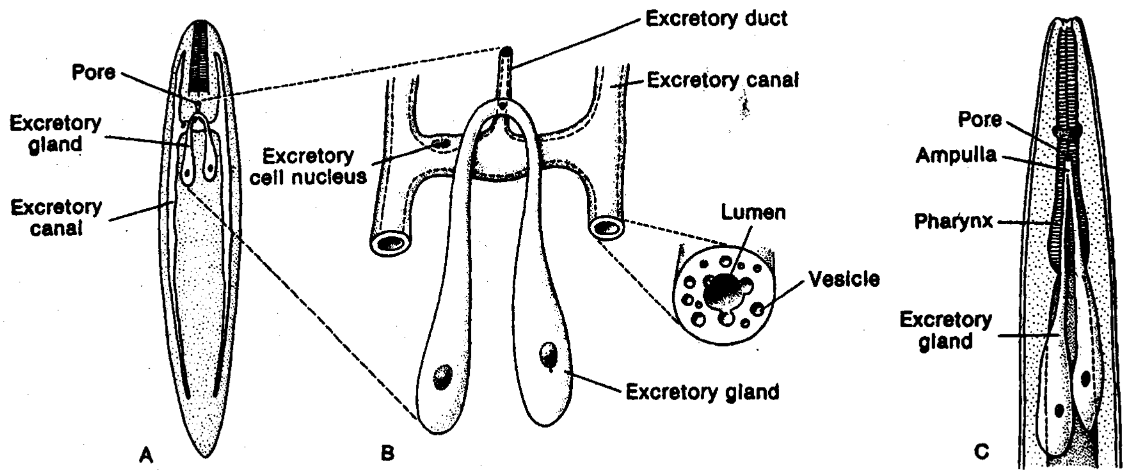

Fig. 2-65 **A, Generalized anatomy of the binucleate excretory gland cell and excretory canal system of secernentean nematodes; ventral view. B, Enlargement of the system in A. C, The excretory gland of the adenophorean nematode, *Rhabdias*.**

From this a more specialized and well developed tubular system is believed to have evolved. It has three long canals arranged in the form of "H" as seen in the adults of Strongyloidea and Spiruroidea.Two canals extends inside the lateral chords and these are interconnected by a transverse canal, which gives out a short common excretory canal leading to the excretory pore.

The vessel of the canal system is lined by a firm membrane outside of which is a layer of syncytial cytoplasm. The whole system bears a single large nucleus along the transverse canal. The common stem may be enlarged into a bladder-like structure. The posterior limbs are usually much longer than the anterior ones. In many forms (Filarioidea), the system is shaped like an inverted "U" with the loss of the anterior limbs. In some (tylenchoids), it is developed on one side only, and in others (Trichuroidea and Diactophymoidea), it is absent in the adult stage. A transitional system is found in a number of forms as in Rhabdias, where two renette cells exist with their necks join together to form a common excretory canal leading to the outside. In some (juveniles of Ancylostomidae), each cell possesses a long slender canal-like extension, and in some (*Oesophagostomum* and *Rhabditis*), a transverse tubular connection occurs between the two renette cells, in some (*Contracaecum*), one renette cell and one canal, and in others, a tubular system in the adult and renette cells in the parasitic juvenile stage. The existence of the transitional types strongly indicates that the canals are intracellular outgrowths from the renette, probably necessitated by increasing body size. The renette and the canal systems are wholly independent structures, but may establish the connection secondarily. Chitwoods consider the canal system to be the original one from which the renette type can be derived by way of transitional forms, and the lateral canals represent the protonephridia that have lost their flame bulbs. The importance of the renette varies with the environment. The principal nitrogenous waste is of ammonia, which is readily removed through the body wall and digestive tract in fresh-water and terrestrial species. Therefore the primary function of renette is osmoregulatory serving in the removal of the water and ions. However, Ascaris can excrete urea under the osmotic stress.

2.7.11 NERVOUS SYSTEM

The nervous system consists of mainly a conspicuous circumenteric nerve ring encircling the pharynx and of associated paired lateral ganglia and the single or paired ventral ganglia (Fig. 2-63C). Other ganglia may be a small dorsal ganglion, a pair of sub dorsal ganglia, a pair of post lateral ganglia, and a pair of post ventral ganglia. The lateral ganglia correspond to the cerebral ganglia and the ring represents the dorsal and ventral connectives between them. The ring gives off six radially arranged anterior papillary nerves, two dorsolateral, two laterals, and two ventrolateral, innervating the labial papillae and cephalic papillae or bristles. Although primarily sensory, these nerves also contain motor fibers for the muscles that operate bristles. In addition, a pair of nerves runs to the amphids.The species usually differs in the number of nerves behind the ring. A number of nerves extend posteriorly from the brain through the longitudinal chords. Of these, two are of considerable size, and run in the dorsal and ventral chords respectively. Transverse commissars connect them with one another. The midventral nerve is the main body nerve arising as a double cord, which fuses in the region of the excretory pore, and continues posteriorly as a ganglionated cord to end as single or paired anal ganglia just in front of the anus. The anal ganglion gives off fibers extending into the tail region. There may be a pair of caudal ganglia in the tail. The innervations of the posterior end are more complicated in males than in females. The middorsal nerve is a motor nerve having a small ganglion located near its origin and proceeds posteriorly in the dorsal chord. One to three pairs of lateral nerves arise from the lateral ganglia of the brain, and are sensory and ganglionated. They extend inside the lateral chords and their terminal ganglia innervate the tail. Some forms have even ventrolateral and dorsolateral nerves. There are two visceral nervous systems one in the pharynx and the other in the rectum. The pharyngeal system consists of three long nerves extending from the brain to the wall of the pharynx and the rectal system comprises of a pair of anorectal commissures extending from the anal ganglia to the dorsal surface of the rectum.

2.7.12 SENSE ORGANS

The free-living nematodes are abundantly supplied with sense organs, chiefly in the form of bristles and papillae, which are tactile. The principal sense organs are the papillae and the amphids. The labial and cephalic papillae are jointed by cuticular projections innervated by the papillary nerves. Sensory bristles may be supplied with the gland cells. The *Ascaris* has six outer labial papillae, four cephalic papillae and two amphids. The genital papillae are wart-like cuticular elevations with a central circular opening.

The amphids are blind cuticular invaginations of various shapes (Fig 2-66 A,B). They are highly developed in free-living marine worms with one amphid located on each side of the head. It has a cluster of nerve endings and also the opening of the unicellular gland in its bottom. The amphids are believed to be chemo receptive in function. The nature of the amphid invagination varies considerably. It may resemble a small pouch or a spiraled or looped blind tube. The sensory processes of the amphids are actually ciliary in nature. In primitive forms, the amphids are greatly reduced and have lost the cuticular cavity.

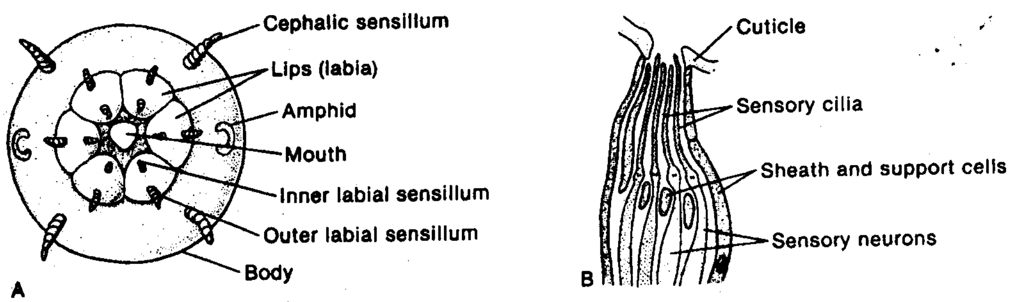

Fig. 2-66 **A,** Oral view of a generalized nematode, showing typical sensory structures. **B,** Longitudinal section of an amphid of *Caenorhabditis elegans*.

There are pair of unicellular caudal glands, the phasmids, which open separately on either side of the tail (Fig. 2-63A, 2-67 A). These are glandular-sensory organs meant for chemoreception. They reach their best development in parasitic forms. It is certain that they are absent wherever the caudal glands are present. A pair of eyes is located one on each side of the pharynx of a few marine and fresh-water nematodes. The eyes are pigmented cups with lenses derived from the cuticle. The nematodes are also abundantly supplied with free sensory nerve endings on the general body surface.

2.7.13 REPRODUCTION

The nematodes are dioecious. Males are externally distinguishable from the females by their size, curvature of the posterior end, and the presence of bursae (Fig. 2-67B), genital papillae and copulatory structures. The males are typically smaller than females and their terminal end is curved like a hook. In marine and most parasitic forms, the males and females occur in equal proportions, where as in terrestrial and fresh-water species there is a preponderance of females. The scarcity or absence of males indicates a tendency towards hermaphroditism or parthenogenesis.

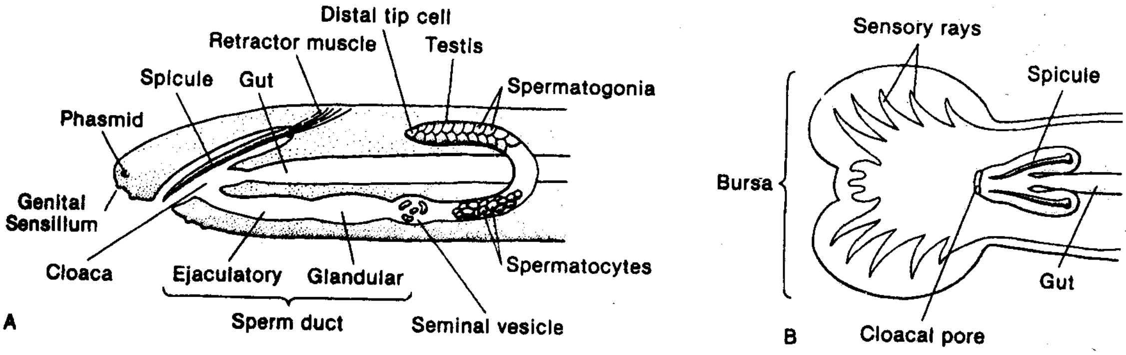

Fig. 2-67. A, B. A Lateral view of the male reproductive system of a generalized nematode with one testis. B, Copulatory bursa of a parasitic trichostrongle nematode.

The reproductive organs are formed on a peculiar and very characteristic pattern. In both sexes the gonads are tubular, varying greatly in length, and may be straight, sinuous, reflexed, or coiled (Fig 2-63 A, B). In smaller forms the entire genital tube is short and not coiled. The anterior end of the testis consists of solid mass of sex cells.

In all parasitic forms the male system is reduced to a single tubule extending anteriorly (monarchic). However, two testes occur in many forms (diarchic). The males usually have a long, coiled thread-like testis, an elongated sperm duct and a wide seminal vesicle, which is connected with the rectum by a short narrow muscular ejaculatory duct containing varying number of prostrate glands (Fig. 2-63B). These glands secrete an adhesive that helps in copulation. The wall of the rectum or cloaca is evaginated to form two muscular pouches, each containing one or two short curved sclerotized rods, the copulatory spicules, which may be equal in size and alike in shape, or may exhibit various degrees of dissimilarities. They may be of styli form, curved, flattened, or blade-like, and are used to open the vulva and to guide the sperms into the vagina of the female during copulation. In a few forms one or both spicules may be missing. Sometimes, there may be a third sclerotized body, the gubernaculums. The copulatory spicules are absent in *Trichinella*. In Trichuroidea, the cloaca of the male is long and eversible, the cirrus, accompanied by a single spicule.

The females have straight or coiled thread-like ovaries, two (didelphic) or many (polydelphic) in number, oriented in opposite direction (Fig. 2-64A). Each ovary extends into a long, tubular oviduct and a long, wide uterus. The two uteri unite into a short, common muscular tube, the vagina, which leads to the outside through the vulva located on the midventral line, anywhere between the head and anus. The walls of the uterus appear to supply the yolk and shell material for the egg. The upper end of the uterus functions like a seminal receptacle. In many strongyloids and spiruroids, the terminal part of the vagina is heavily muscularized forming an ovejector, which helps in the expulsion of the eggs. The female tract is much longer and more complicated in parasitic forms compared to free-living forms.

The sperms are round cells devoid of flagellum and move in amoeboid manner into the body of the female. The sperm travels up the female tract to the seminal receptacle to fertilize the ripe oocytes.

The entire sperm enters the egg. The fertilization occurs in the upper end of the uterus. After fertilization a membrane appears around the egg and this forms the chitinous shell. A thin, delicate, lipoid membrane develops on the inner side of the shell, and during its passage the uterus adds a protein membrane outside the shell, which furnishes sculpturing, filaments, etc. The shell is usually rounded, oval or elliptical in shape with a smooth, spiny, or warty surface. The eggs are stored in uterus prior to deposition.

The marine species lay a small number(less than 50) of relatively large eggs into their habitat and usually deposit them in clusters. The terrestrial species may produce several hundreds of eggs in the soil. The phytoparasites lay their eggs inside the plant body. Many parasitic and some free-living species (vinegar eel) are viviparous, i.e., the eggs hatch to juvenile stage in the maternal uterus.

The embryonic development usually starts while the eggs are still in the female. Some terrestrial forms (rhabditoids) are hermaphroditic, where the sperms develop before the eggs do and are stored (protandrous), and later fertilize the eggs subsequently developed by the same gonad, a condition known as syngony. The syngonic forms have the external appearance of females. Parthenogenesis also occurs in some terrestrial forms like *Heterodera*. In *Rhabditis*, after copulation their sperms only initiate cleavage and do not fuse with the nucleus of the eggs that are destined to develop into females.

Little is known is about the reproductive habits of free-living marine forms.

Though parthenogenesis and syngonic reproduction occur in nematodes, the insemination by a male is necessary in most species for the development of the eggs. At the time of copulation, the male is oriented at an angle to the female and often coils around her to insert the spicules in the vulva. In bursate males, the bursa folds over the female body.

2.7.14 LIFE CYCLE

The nematodes hatch as juvenile worms, which are fully developed. They differ from the adults in size and the absence of the reproductive system. The juveniles undergo some changes in form, especially of the posterior end and of the buccal capsule. The marked feature of the post embryonic development is the occurrence of molts in which the entire cuticle, including the lining of the buccal capsule, pharynx, rectum, and vagina is shed. There are four molts separating four juvenile stages preceding sexual maturity. The first two molts may occur within the shell before hatching and the fully developed worm emerges from the fourth molt. Sometimes, the adults may continue to grow substantially even after the last molt. In some cases (*Ascaris* and *Trichiuris*), the deposited eggs may leave the mother's body unsegmented; some (*Ancylostoma*) in an early stage of segmentation; some (*Enterobius*) in the tadpole stage, and some (*Trichinella, Strongyloides*, and *Filaria*) as fully developed embryos.

Many forms have a curious and complex life history. The eggs undergo further development only after reaching a new environment or intermediate host. In the simplest type of life cycle, the host swallows the embryonated eggs, e.g., *Enterobius* and *Trichuris* or they may make an extra-intestinal journey through the host's body (*Ascaris*). In hookworms, the embryos hatch outside the body and grow and develop as free-living larvae, then re-enter the host by burrowing through the skin. In *Trichinella*, the embryos penetrate into the host's body and encysted in the muscles to be taken by another host. The filariae require an invertebrate as an intermediate host as a place for partial development. A few like Gnathostoma needs two intermediate hosts.

Majority of the aquatic species are limited to the substratum, and the marine forms are found, in enormous numbers, everywhere in the bottom mud rich in organic matter, from the shore to great depths. Free-living nematodes occur in all types of fresh-water habitats. Some live in fast flowing mountain streams using the adhesive caudal glands, the largest populations live in the shallow waters around lakes. Fresh-water forms seem to have evolved from the terrestrial species, which came in turn directly from the marine forms. The terrestrial species are actually aquatic as they live in the water film that surrounds each soil particle. They live in enormous numbers in the upper few inches of soil, but decreases rapidly at greater depths. Further, the numbers are greater in the vicinity of plant roots. They have been also reported to exist in the accumulations of detritus in leaf axils and in the angles of tree branches. Lichens and mosses maintain a characteristic nematode fauna that can withstand extreme conditions of desiccation and temperature.

A great many fresh-water and terrestrial forms have a cosmopolitan distribution. The birds, animals, and floating debris are important agents of spreading. The nematodes present all degrees of endoparasitism. The stage at which the juveniles enter the host is termed as the infective stage. In many unsheathed juveniles, the molted cuticle remains as a protective covering enabling them to withstand adverse conditions. Juveniles inside the egg membranes are referred to as the ovic juveniles. Basing on the shape of the pharynx, juveniles may be designated as rhabdiform, or filariform, etc.

Many parasitic forms attack almost all groups of animals and plants. They exhibit all degrees of and types of parasitism. In completely free-living forms, life cycle is direct and all stages are free-living as in aquatic and terrestrial species. In ectoparasites of plants, juveniles may attach to the roots or other parts of plants, piercing the tissues by using the stylets and feeding on the plant sap and external cells, but do not enter the plant. In endoparasites of plants, the juveniles are obligatory endoparasites. For example in *Heterodera*, the juveniles penetrate into the plant body and feed on the living cells, cause the death of tissue or evoke gall-like structures. They also reproduce asexually within the host and release the cysts into the soil after the disintegration of the plant tissue. The juveniles after hatching migrate through the soil to infect new plants. In endoparasites of animals, the young and adult forms (merminthids) are free-living in soil or mud and do not feed, but the former on reaching the infective stage require to be transported as parasitic unsheathed juveniles by insects, crustaceans, arachnids or mollusks to fresh food supplies. Some animal parasites are saprophagous. The adults lead a free existence in the soil. In the absence of adequate organic food, late juvenile stages enter an invertebrate host and feed on the dead tissue when the host dies from other causes, and develop to maturity. Some parasites show a combination of saprophagous juveniles and zoo parasitic adult life. The worms mature in the invertebrate host, mate, and produce offspring, and remain in the host until it dies, the unsheathed juveniles infect the host. Some forms have a combination of phytoparasitic juveniles and zoo parasitic adult life. The female worm produces juveniles within an insect host that feeds on plants. When the insect punctures the plant tissue, the juveniles enter the plant and remain as endoparasites. After maturation and copulation, the female enters the larva of the host in the same plant (*Herotylenchus*, a parasite on onion flies). Some forms have a combination of phytoparasitic adult and zoo parasitic juvenile life. The worms develop in the host, and the juveniles leave the host and enter the plants on which the host feeds, and complete development and reproduce in the plants. A new generation of larvae then enters the host. Some nematodes have zoo parasitism in adult females only. The larvae develop into adults in the soil, after copulation, the male dies, and the female enters an invertebrate host to produce the next generation.

In addition to these, there are some special features exhibited by the juvenile and adult parasitic nematodes. For example:

Alteration of zoo parasitic, hermaphroditic or parthenogenetic females with free-living adults: the offspring of the parasitic females on reaching the exterior may develop into a free-living generation of sexual adults as in *Strongyloides*.

Optional use of transport host in zoo parasitism: the ingested infective juveniles may undergo encystations in invertebrate transport host, and reaches maturity only when this host is ingested by the definitive host.

Adult zoo parasitism with one host: in a typical zoo parasitic cycle is seen an alteration of parasitic and free-living stages. Adults of both the sexes are parasitic within a host. Transmission from one host to another is by eggs or larvae, which may be free-living during their development. The oxyuroid, *Probstmayria* continuous zoo parasitism is seen without free stage. It inhabits the intestine of horse and lives without the necessity of passing any stage to the exterior. Other illustrations are the ascaroids, the internal parasites of man (*Ascaris lumbricoides*), horse (*Parascaris*), cat, dog (*Toxocara canis*), chicken, cattle and other vertebrates, the strongyloids (hookworm, *Ancylostoma duodenale*), the oxyuroids (pinworm, *Enterobius vermicularis*), and the trichuroids, infecting man (whipworm, *Trichuris trichiura*) and mammals (hookworm, *Trichinella spiralis*).

Zoo parasitism with an obligatory intermediate host: the juveniles develop in intermediate host, and then a reinfection occurs to primary host for reproduction as seen in the filarial worm (*Wuchereria bancrofti*), African eye worm (*Loa loa*), guinea worm (*Dracunculus medinensis*), etc. Here some young stage of the worm is swallowed by the intermediate host, reaches an infective stage in their host, and develops further only if it gains access to the definitive host.

Zoo parasitism with two obligatory hosts: in *Gnathostoma*, the first intermediate host is Cyclops, the second a fish, frog, or snake, and the definitive host a carnivorous mammal. The nematode, *Dioctophyma* parasitizes the kidney and coelom of mammals. The female can destroy the kidney, resulting in host's death. The eggs leave the body of the host through urine into water. If ingested by certain fresh-water annelid (branchiobdellid), that is epizootic on crayfish gills, the eggs hatch out larvae, which penetrate the worm's intestine and enter the coelom and undergo encystations. If a certain fish eats this crayfish, the nematode encases in the fish's coelom, and reaches the primary host when it happens to eat the infected fish.

Zoo parasitic adults alternating with free-living adults: a strange life cycle occurs in a few worms like *Rhabdias bufonis*, which lives in the lungs of frogs. In the parasitic phase, the worms are hermaphroditic, and the sperms are produced before the eggs. The eggs are coughed up into pharynx and thus swallowed by the frog. They hatch in the intestine, and the larvae leave the host in the feces. The liberated larvae develop into dioecious forms; their adults are soil-inhabiting forms. Larvae of the free-living worms penetrate the frog's skin, and are finally carried to the lungs.

2.7.15 SUMMARY

Pseudocoelomate protostomes with triploblasitic nature and bilateral symmetry.

Aquatic, terrestrial, or parasitic.

Body is minute to quite large, elongate, cylindrical, and unsegmented.

Body covered by a tough, transparent, collagenous, protective cuticle.

Epidermis is syncytial, non-ciliated, and is thickened to form two main lateral lines and less evident mid-dorsal and mid-ventral lines.

Anterior end is narrow and contains the mouth, which is characteristically guarded by lips and sensory papillae.

Body cavity is a pseudocoel and is a remnant of the embryonic blastocoel.

Movement is muscular with a characteristic whipping flexure, which is due to the animal possessing only longitudinal muscles in the body wall.

Gut is a simple, complete, and straight tube opens posteriorly through anus, which is sub terminal.

Digestive tract is devoid of muscles and glands.

Respiratory and circulatory systems are absent, and the pseudocoelomic fluid facilitates absorption and transport of nutrients and gases.

Excretion is typically by renette cells or tubular system.

Nervous system is with a circumenteric nerve ring, ganglia, and one or more nerve cords extending anteriorly as well as posteriorly.

Sense organs like bristles, amphids, phasmids, etc., are present.

Well-marked sexual dimorphism, the males are smaller with a curved posterior end having a cloaca and copulatory spicules, and the females are generally larger with a distinct vulva and a straight and pointed tail.

Gonads and their ducts form continuous tubes, didelphic or monadelphic.

Majority of nematodes are oviparous and a few are ovo-viviparous.

Fertilization is internal and the eggs are laid in large numbers.

Development is direct and cleavage is determinate.

Asexual reproduction and regeneration are lacking.

Parthenogenesis may occur.

Larvae are very similar to the adults.

Life history is often complex. Many nematodes are parasitic either in the adult or in the larval stages, or throughout the entire life cycle.

2.7.16 KEY TERMINOLOGY

Amphid: Paired, anterior chemo receptive organs of many nematodes. They reach their highest development in the aquatic nematodes, especially in the marine species.

Blastocoel: The fluid filled embryonic cavity beneath the germ layers. It is the embryonic connective tissue compartment.

Buccal cavity: Cavity within the mouth opening.

Determinate cleavage: Mosaic development. In this type of developmental process the fate of the blastomeres are fixed or determined early in cleavage.

Direct development: During the course of development, larval stage is absent. On hatching the young ones have the adult body forms.

Endoparasite: Parasite that lives inside the body of the host.

Flame bulb: A protonephridial terminal cell that has many flagella which beat synchronously and resemble a minute flickering flame; its nucleus is offset to one side of the flame.

Flame cell: A protonephridial terminal cell that has many flagella, which beat synchronously and resemble a minute flickering flame; its nucleus is at the base of the flame.

Gonoduct: Principal duct providing for the transport of sperm or eggs in any reproductive system.

Gonopore: External opening of any reproductive system.

Indirect development: Having a larval stage in the course of development.

Phasmid: Paired unicellular glands; posterior (in the tail region). Chemo receptors of nematodes. They open separately on either side of the tail. Best developed in parasitic nematodes.

Protonephridium: A ciliated excretory tubule that is capped internally by one or more terminal cells, which are specialized for ultrafiltration.

Pseudocoel: Fluid filled cavity that occupies the connective tissue compartment. Differs from the hemocoel only in the lack of a heart.

Sexual dimorphism: Having separate sexes. Some individuals contain the male reproductive system and other individuals contain the female reproductive system.
Syncytium: Tissue in which nuclei are not separated by cell membrane.

2.7.17 SELF ASSESSMENT QUESTIONS

1. Describe the general organization of nematodes.
2. Give an account of parasitic nematodes.
3. Discuss eight general characteristic features of nematode.
4. Mention the nematode parasites causing diseases in man.
5. Explain the detailed structure of body wall in nematodes.
6. Give the salient features of the phylum Nemathelminthes.
7. Describe the reproductive system of nematodes.
8. Write short notes on
    a. degrees of parasitism in nematodes.
    b. nervous system and sense organs in nematodes.

c. digestive system and nutrition in nematodes.
d. structure of a typical nematode.
e. renette cells in nematodes.
f. amphids and phasmids

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Shri B.V. Krishna Rao

2.8 CLASSIFICATION OF PHYLUM NEMATHELMINTHES

2.8.1 OBJECTIVES

The purpose of this lesson is to:

- classify the Phylum Nematoda upto orders.
- study the life cycle of nematodes
- exemplify the free-living and parasitic nematodes

2.8.2 INTRODUCTION

. The nematodes, called round worms, form the largest Nemathelminthes phylum. There are about 12000 described species. But there are probably many more undescribed than described species. Nematodes include wide spread free living and parasitic forms. Free-living nematodes are found in the sea, in fresh water, and in the soil. Parasitic nematodes display all degrees of parasitism and attack virtually all groups of plants and animals. This phylum is considered as one of the most important of the parasitic animal group as the numerous nematode species infect food crops, domesticated animals and humans.

Nematodes have slender, elongated bodies with both ends gradually tapered in most species (Fig. 2-63). Nematodes possess a perfectly cylindrical body, hence the name round worm. A cuticle encloses the body of a nematode. Mouth lies at the somewhat rounded anterior end and is surrounded by lips and sensilla.

In most small free-living species pseudocoel is small or absent. In large forms, such as parasitic *Ascaris,* the coelom may be large. The coelomic fluid contains a variety of organic metabolites, including hemoglobin in some species and a few phagocytic cells. Nematodes move forward and backward by means of eel like undulations of the body.

Many free-living forms are carnivores feeding on small metazoans, including other nematodes. Some are phytophagous. The mouth of the nematode opens into a buccal cavity (Fig. 2-68). The buccal cavity leads into a tubular pharynx, intestine and rectum. The rectum opens outside by anus.

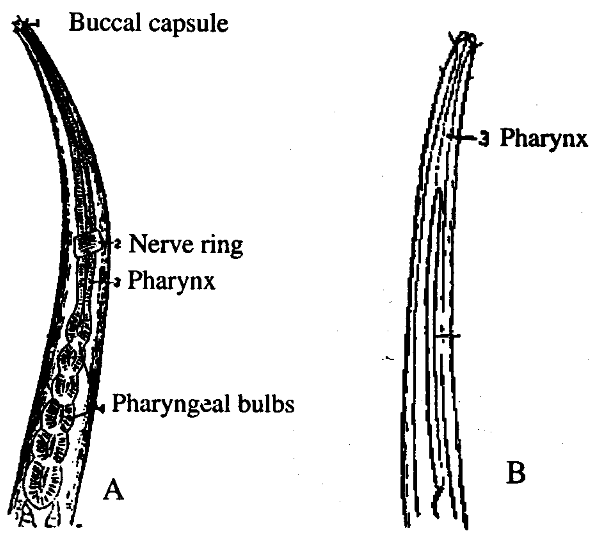


Fig. 2-68. A, *Polygastrophora,* B, *Enoplus*

Digestion occurs both extracellularly and intracellularly by the digestive enzymes. The pharyngeal glands and the intestinal epithelium produce these enzymes. The intestine plays an important role in nutrient storage and yolk synthesis for developing oocytes.

The nitrogenous waste is in the form of ammonium ions. These ions may be diffused across the body wall. The excretory gland cell, also called a ventral or renette cell is meant for excretion in marine and fresh water nematodes. Osmoregulation, ionic regulation and excretion seem to be associated with specialized excretory canal system. Generally, the excretory system is laid out in the form of an H, which opens outside by a pore. A few nematodes lack any excretory organs.

The nervous system consists of a brain or pharyngeal nerve ring. From the brain, nerves extend anteriorly to innovate the anterior sense organs or amphids. Dorsal, lateral and ventral nerves extend posteriorly.

Most of the nematodes are dioecious. Males are often smaller than females. The posterior end of the male may be curved like a hook or broadened into a fan-shaped copulatory aid called bursa. The paired reproductive system opens at cloaca in males and vulva in females. Some nematodes are oviparous and others are viviparous. Development is determinate and is direct or indirect. In zooparasitic nematodes one to 3 larval forms are found in the life cycle. In viviparous forms, when juveniles hatch, they have all adult structures except certain parts of the reproductive system.

2.8.3 CLASSIFICATION INTO TWO CLASSES

The Phylum Nemathelminthes or Aschelmithes has been elevated to a separate phylum status. Chit Wood (1933) has evolved a classification that embraces both the free-living and parasitic forms. He divided the entire nematodes into two classes, the Phasmidia and the Aphasmidia. In this classification, the classes are further divided into seventeen orders of unfamiliar names, seven of which contain mostly free-living species.

2.8.4 CLASS PHASMIDA

It includes the nematodes, which are equipped with the phasmids, but lack caudal glands. These are often parasitic. The sensory bristles or papillae are either reduced or wanting. The amphids are simple pores. The excretory system is well developed and not rudimentary. The mesenterial tissue and the coelomocytes (6 or less) poorly developed.

2.8.4.A ORDER ENOPLOIDEA.

These are the free-living, chiefly marine, nematodes which are of small to moderate size with a smooth cuticle and typical cyathiform amphids. The cuticle is provided with bristles and is not ringed. The anterior end has a narrow, strongly cuticularized cephalic capsule containing a full complement of sensory organs, six labial palps, one circlet of ten or two circlets of six bristles each, and a pair of cephalic slits. The buccal capsuie is weak or well developed. The pharynx is a simple straight tube lacking bulbous enlargements (6-8 in Polygastrophora). A one-celled renette and three caudal glands are present. The female is usually didelphic with refiexed ovaries and the male bears a few genital papillae.

Leptostomatids have weekly developed lips and buccal capsule and exemplified by the genera *Anticoma, Synonchus*, and *Thoracostoma.*

Thoracostomatids are represented by a single genus, *Thoracostomopsis*, characterized by exceptionally long cephalic bristles and a long spear in the buccal cavity.

Oxystomatids are filiform worms without a buccal capsule such as *Oxystomatina, Thalassolaimus*, *Trefusia*, *Halalaimus*, etc.

Enoplid worms have a mouth with three lips and a buccal cavity armed by three strong movable jaws and are represented by *Enoplus, Enoploides* and ***Enoplolaimus***.

Oncholaimids comprise of about 30 genera and nearly 100 marine species, including *Pelagonema, Monocholaimus, Paroncholaimus, Metoncholaimus, Adoncholaimus,* etc., in which there is a large buccal capsule with 1-3 immovable teeth and a head with six papillated lips.

Enchelidiids body is markedly slender anteriorly, without lips, but with six labial papillae, and 6+4 bristles in the outer circlet. The important genera are *Polygastrophora, Parasymphlocostoma,* and *Enchelidium.*

Trilobids are non-marine genera, *Tripyla* and *Triloba*, which live in brackish and fresh-water habitats. They possess three lips and a weak buccal capsule with 1 or 2 teeth.

Mononchids is represented by a single genus. It is a predatory form. *Mononchus,* which lives in fresh-water and moist soil. It has six lips, six inner and six outer papillae, but the cephalic circlet is lacking. The buccal capsule with one dorsal tooth.

2.8.4.B ORDER DORYLAIMOIDEA.

These are the most common soil and fresh-water nematodes The cuticle is smooth and devoid of bristles. The head sense organs are in two circlets of 6 and 10 each. The pharynx is dorylaimoid type. The buccal capsule has a protrusible hollow spear to suck plant or animal juices. Renette is absent or rudimentary. The caudal glands are lacking. Many exist only as females, apparently parthenogenetic rather than syngonic. The females are with 1 or 2 reflexed ovaries. The males are with two equal spicules, genital papillae, and gubernaculum of three pieces.

Dorylaimus, Tylencholaimus, Actinolaimus, Nygolaimus, Xiphinema (Fig. 2-69), *Axonchium.*

2.8.4.C ORDER MERMITHOIDEA.

These are smooth filiform worms (up to 50 cm) leading a parasitic life in juvenile stage in fresh-water or in terrestrial invertebrate host (insect) but free-living in soil or water in the adult condition. The head possesses all the 16 papillae. The amphids vary from cyathiform to minute pores. As the buccal capsule is lacking, the mouth proceeds directly into pharynx, which is a long cuticularized tube reaching half of the body, but is unconnected to the intestine. The intestine is a peculiar trophosome consisting of two or more rows of greatly enlarged food reserve cells. The trophosome lacks an anal outlet and serves to nourish the adults, which do not feed. Excretion is by an anteriorly located renette gland. The female is didelphic. The male has 1 or 2 spicules and numerous genital papillae at the posterior end. The reproduction is by sexual or parthenogenesis.

Tetradonema, Paramermis

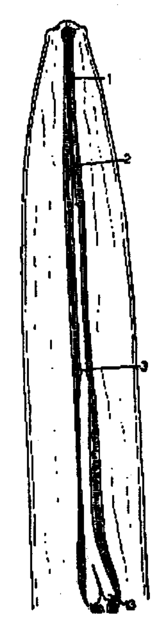


Fig. 2-69. *Xiphinema* 1. pharynx 2. spear 3. nerve ring.

2.8.4.D ORDER CHROMADOROIDEA.

Mostly marine forms with a ringed cuticle and round or oblong punctuations. Amphids are spirally wound. The buccal capsule is often armed with teeth. The pharynx has a posterior bulb. The female system shows reflexed ovaries. The male has a preanal row of genital papillae.

Cyatholaimus, Desmodora

2.8.4.E ORDER ARAEOLAIMOIDEA.

This order includes several families characterized by four conspicuous cephalic bristles well set off from the labial circlets, which consist of papillae or reduced bristles. Other features are the spiral or loop-like amphids, the absence of cuticular ornamentation as well as preanal copulatory aids. Pharyngeal end bulb is lacking except in the Plectidae.
Axonolaimus, Araeolaimus, Plectus (Fig. 2-70).

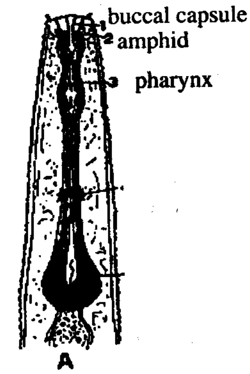
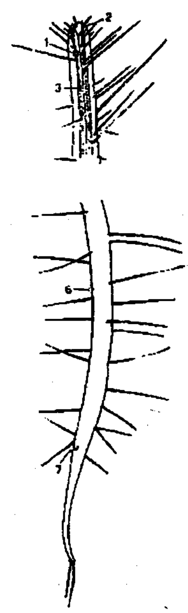


Fig. 2-70. *Plectus*

2.8.4.F ORDER MONHYSTEROIDEA.

It is characterized by circular amphids and includes aquatic and terrestrial nematodes with smooth or slightly ringed cuticle, often bearing scattered bristles. Females with single or double outstretched ovaries, and males with preanal papillae.
Siphonolaimus, Linhomeus, Steineria (Fig. 2-71).



(Fig. 2-71) *Steineria*

2.8.4.G ORDER DESMOSCOLECOIDEA.

It comprises of plump, marine forms with heavily ringed and bristled body having hemispherical amphids and armored head. A defined buccal capsule is lacking.
Desmoscolex, Tricoma

2.8.4.H ORDER RHABDITOIDEA OR ANGUILLULOIDEA.

It is a large group of small to moderately sized forms with all the head sense organs in the form of papillae, and the amphids are reduced to small pockets. These are usually terrestrial, saprophagous, or partial or complete phyto- or zooparasites, but rarely found as free-living in aquatic habitats. The pharynx is with one or two bulbs, of which one is a pseudobulb and other is a valvulated bulb. The excretory system is with or without two renette cells and with lateral and transverse canals. The female is didelphic with reflexed ovaries, but sometimes monodelphic. The males have caudal alae forming a bursa supported by genital papillae and the spicules are equal and similar and accompanied by a gubernaculum.

The life cycle is may be direct, but frequently includes an infective juvenile stage transported by an insect. Some forms exhibit free-living generation alternating with a parasitic generation of parthenogenetic females.
Rhabditis (Fig. 2-72), Anguillula

2.8.4.I ORDER RHABDIASOIDEA.

Though anatomically resemble the Rhabditoidea, these forms have a complicated life cycle, including a free-living stage alternating with a parasitic phage, which may be a protandrous hermaphrodite or a parthenogenetic female. The eggs may develop either directly into a parasitic form (homogonic), where males are wanting or into free-living males and females, the offspring of which proceed to the parasitic phase (heterogonic).

Rhabdias bufonis (Fig. 2-73), *Strongyloides stercoralis*

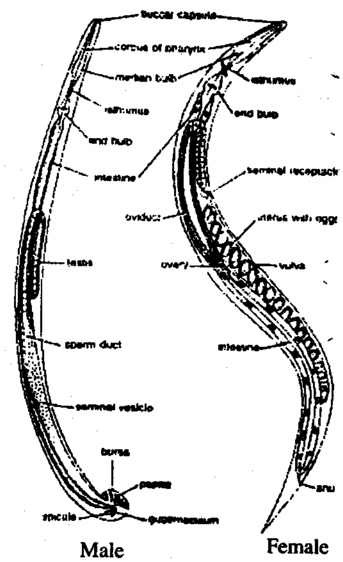


Fig. 2-72. *Rhabditis elegans*

2.8.4.J ORDER OXYUROIDEA.

It includes obligatory zooparasites with only one host, almost exclusively living in the cecum and colon of vertebrates, with simple life cycle. These are small to medium transparent meromyarian worms of fusiform shape with a slender pointed tail. The head is with 3 or 6 simple lips and a single circlet of 8 or 10 papillae. The amphids are shaped like tubular pockets. The small buccal capsule leads into a rhabdiform pharynx with a conspicuous valvulated end bulb, and often also with a corpus and isthmus. The excretory system is of "H" type and the renette cells are lacking. The females are monodelphic or didelphic and oviparous. The males are with none, one or two spicules, and also with genital papillae accompanied by caudal alae.

Enterobius vermicularis(Fig. 2-74) is the common pinworm of children, *Aspiculuris* and *Syphacia* are found in rats and other rodents.

2.8.4.K ORDER ASCAROIDEA.

It represents relatively large and stout worms that are obligatory parasites of the intestine of vertebrates. The mouth has three or six prominent lips, four double papillae and a lateral papilla on each side accompanied by the amphid. The buccal capsule is absent. The pharynx is simple cylindrical and usually lacks the bulbous enlargements, with an end bulb in some cases. The excretory system is of the "H" type with a reduction of the anterior branches. The male is with a spirally coiled tail bearing two equal or nearly equal spicules and numerous genital papillae, but is devoid of caudal alae and gubernaculum. The female is didelphic with two uteri and a long vagina, and is oviparous, producing a large number of unsegmented eggs. The eggs undergo complete development to the juvenile stage outside the host.

Ascaris lumbricoides, Toxocara canis

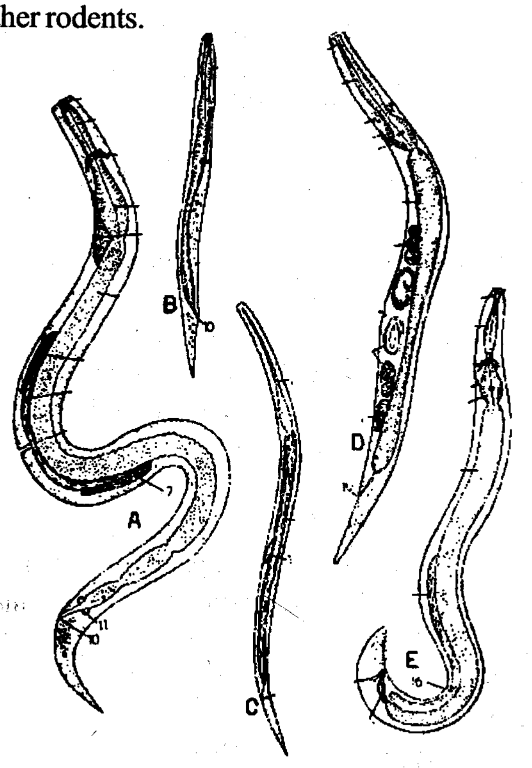


Fig. 2-73. *Rhabdias bufonis*
A, Parasitic female. B, Rhabditiform young, C, Filariform young. D, Free-living female. E, Free-living male.

2.8.4.L ORDER STRONGYLOIDEA.

These include the hookworms, strongyles, gapeworms, and lungworms, which are the obligatory parasites of the digestive tract of vertebrates. These are recognized as the most injurious blood-sucking parasites, of man and domestic mammals, characterized by the presence of a conspicuous expanded **bursa** in the male. The bursa is composed of two large lateral lobes, each supported by six muscular rays, and a small median lobe containing one main ray. The pattern of branching of the rays is of importance in the taxonomy of nematodes. The mouth is simple without distinct bulging lips but provided with leaf crowns, the pharynx is club-shaped or cylindrical without bulbs or glands, and the digestive tract is devoid of caeca. The excretory system is H-shaped with two renette cells. The female is didelphic with highly developed muscular ovejectors. The life cycle is direct involving two free-living juvenile stages. The eggs are thin-shelled and are in some stage of segmentation or embryonated, hatch in the external environment into free-living larvae, which may enter the host by burrowing through the skin or by ingestion along with water or vegetation, or by an intermediate or transport host. Basing on the structure of the pharynx, the order is divided into three groups: the strongyloids proper, which have a cuticularized buccal capsule and a typical 3-lobed bursa, but are devoid of lips; the trichostrongyloids, which are small slender worms, without leaf crowns or cutting plates, with a buccal capsule either rudimentary or wanting, and with a well developed bursa, in which the dorsal lobe is small or wanting, and the metastrongyloids, which resemble the trichostrongyloids except that the bursa exhibits reduction or disappearance.

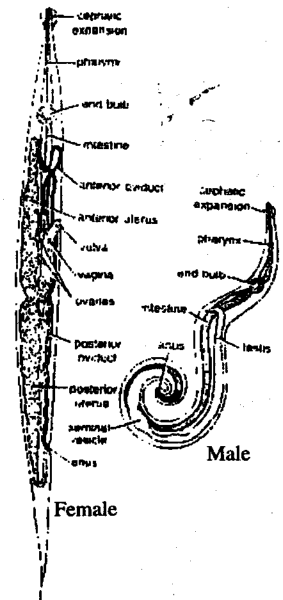


Fig. 2-74. *Enterobius vermicularis*

Strongyloides stercolaris, Ancylostoma duodenale

2.8.4.M ORDER SPIRUROIDEA.

These are mostly slender worms of moderate size. They live as the obligatory parasites in the digestive tract, respiratory system, and eyes, nasal cavities and sinuses of vertebrates The mouth is simple with two unlobed or trilobed lateral lips, sometimes with 4 or 6 small lips. The sense organs are an inner circlet of 6 reduced papillae, and an outer circlet of four double or eight single papillae. The buccal capsule is cuticularized and the cylindrical pharynx is differentiated into an anterior muscular and a posterior glandular portion. The cuticular ornamentation is varied at the anterior end or along the entire body. The excretory canals are U-shaped and renette cells are lacking. The vulva is present near the middle of the body. The female is with an ovejector. The males have two unequal and dissimilar spicules, well developed caudal alae and genital papillae on the spirally coiled tail. The bursa is lacking. The life cycle is often complicated involving one or two intermediate hosts. The eggs contain fully developed juveniles. Some worms are viviparous. The systematic position is still doubtful for many species.

Thelazia (eye worm), *Camallanus* (intestinal worm of fish)

2.8.4.N ORDER DRACUNCULOIDEA.

These are filiform worms without definite lips or buccal capsule. They live in the connective tissue or coelom and its membranes of the vertebrates. The life cycle involves a copepod as an intermediate host. The head bears an inner circlet of six labial papillae, and an external circlet of eight separate or four double papillae. The pharynx is divisible into an anterior narrow muscular part and a posterior broader glandular part. The vulva is near the middle region of the body. The females are didelphic and viviparous. The males are with equal and filiform spicules, and a gubernaculum but the bursa is lacking. The worms are arranged into one Dracunculidae with three main genera: Dracunculus in man, Philometra in fishes, and Micropleura in crocodiles. The most spectacular form is *Dracunculus medinensis*, the guinea worm or fiery serpent, inhabiting the deeper subcutaneous tissues of man and other mammals in tropical countries of Asia, Arabia, North America, and Africa. There are about 48 million human guinea worm infections all over the world. These are the largest filiform nematodes; the males are 12-40 mm. long while the females attain a length of 3-4 meters. The head end of both the sexes are bluntly rounded with a thick cuticular ring surrounding the mouth and bears 6 labial papillae and four double papillae of the outer circlet. The pharynx is long and differentiated into a muscular and a glandular portion. The anus, vulva, and intestine degenerate in females but a spine-like projection at its tail end. The males are fewer in number and contain a conical pointed tail bearing ten pairs of papillae; two nearly equal spicules, and a gubernaculum. The females are didelphic and viviparous. In the gravid female the body space is occupied by much enlarged uterus filled with embryos. After the copulation, the males seem to disappear. The mature female migrates to the more superficial layers of the skin (limbs), which frequently comes in contact with water. They exude toxins that evoke small blisters under the epidermis. The blister breaks and the female force its uterus through the ruptured area, and emit the juveniles into the water. The female dies after discharging all her young. The tiny microfilariae (0.6 mm.) have a long filamentous tail. They swim freely in water for a short period and develop further only when ingested by Cyclops. After two molts the juveniles become infective and reach the definitive host through drinking water containing the infected Cyclops. Asthma, urticaria, itchiness, nausea, vomiting, diarrhea, dyspnea, and eosinophilia, etc characterizes the guinea disease. The guinea worm is also reported in a variety of mammals and snakes.

Dracunculus medinensis

2.8.4.O ORDER FILARIOIDEA

These are slender, delicate, thread-like worms of moderate to large size, inhabiting the blood or lymphatic system, connective tissues, coelomic cavities, muscles, nasal cavities, etc. in vertebrates. The life cycle of filarial worms depends on two hosts, a vertebrate and an arthropod. The mouth is simple without lips but rarely contains a vestibule. The buccal capsule is reduced or wanting. The males are with coiled tails with two unequal and dissimilar spicules, with or without alae, but always with papillae. The true bursa is lacking. The females are ovi or viviparous, and the vulva is located far anterior. They give birth to embryos, which swarm in blood and are transmitted by blood-sucking insects. They gain access to a new host through the skin by the insect bite. Many filarial infections are diagnosed by the "microfilaria" in blood or skin of humans. They are colorless, transparent and may or may not be enclosed in "sheaths", and are characterized by the presence of a nerve ring anteriorly, an excretory pore or "V" spot and a renette cell farther back, a few genital cells posteriorly, and an anal pore or tail spot. The filariae cause diseases collectively known as filariasis. The filaria endemic to parts of Africa, Spain, South America, East Asia, the Caribbean islands, and various Pacific islands,

reaches a maximum length of 10 cm. Infection either manifests no clinical symptoms or may be indicated in various ways. This order is endowed with parasites of medical or veterinary interest.
Loa loa (the African eye worm), *Wuchereria bancrofti* (the human filarial worm)

2.8.5 CLASS APHASMIDIA.

It includes, usually, the free-living forms and a few parasites, which are devoid of phasmids. There are conspicuous sensory bristles in the head region and caudal glands in the anal region. The amphids are much modified with an exception to parasitic forms. The excretory system is lacking or rudimentary. The mesenterial tissue and pseudocoelomocytes are well developed.

2.8.5.A ORDER TRICHUROIDEA OR TRICHINELLOIDEA

The trichuroides or trichinelloideas are heavily infective causing anemia, abdominal pain and bloody stool in humans, which can be treated by latex of Ficus and prevented by sanitary disposal of human feces. They live as endoparasites in the digestive tract of birds and mammals, but also occur in other vertebrates. The pharynx is long, slender, delicate and non-muscular. The anterior part of the body containing the pharynx is always slender and may be sharply demarcated from the coarse posterior part containing the intestine and reproductive organs. The mouth is simple without lips. The females are with a single long and tubular ovary and the vulva is variously placed near the end of the pharynx. The males either lack a copulatory apparatus or provided with an eversible spicule sheath, the cirrus, armed with or without one spicule. These are mostly oviparous, laying unsegmented eggs enclosed in a barrel shaped shell. The juveniles have a buccal stylet. The life cycle is simple involving no intermediate host.
Trichuris trichiura (the human whipworm), *Capillaria hepatica* (rodent liver worm), *Trichinella spiralis* (intestinal parasite of man).

2.8.5.B ORDER DIOCTOPHYMOIDEA

It includes the large endoparasitic worms parasitizing birds and mammals and using fish as intermediate hosts. The lips are lacking, but the mouth is bounded by one or two circlets of papillae The pharynx is cylindrical without a bulb. The female has one ovary, a vulva, and a terminal anus. The male has a bell-shaped bursa without rays and a single spicule. The excretory system is completely lacking. Female is oviparous, and the eggs have thick shells.
Eustrongylides, *Soboliphyma*

2.8.6 SUMMARY

The Phylum Nemathelminthes contains some of the most widespread animals.
Free-living nematodes are found in the sea, in fresh water, and in the soil.
In addition to the free-living species, there are many parasitic nematodes.
The parasitic forms attack virtually all groups of plants and animals.
Nematodes have a slender, elongated body with both ends gradually tapered in most species.
Nematodes are cylindrical in shape.
The nematode cuticle consists of secreted collagen, which appears to be unique to nematodes.
A great many fresh water and terrestrial nematodes exhibit a cosmopolitan distribution.

Many free-living nematodes are carnivorous and feed on small metazoan animals, including other nematodes.

They possess a simple, straight digestive tract.

The mouth of the nematode opens into a buccal capsule. The buccal capsule leads into a tubular pharynx (sometimes referred to as the oesophagus).

From the pharynx, a long tubular intestine extends the whole length of the body. A short cuticle-lined rectum (cloaca in males) connects the intestine with the anus.

The pharyngeal glands and the intestinal epithelium produce digestive enzymes.

Extracellular and intracellular digestion occurs within the intestinal lumen.

Protonephridia are absent in nematodes.

A specialized glandular system is meant for excretion.

Ammonia is the principal nitrogenous waste in nematodes.

The nervous system consists of a brain and many lateral nerves.

Most of the nematodes are dioecious. Males are typically smaller than females.

The young, sometimes called larvae, have adult features except certain parts of the reproductive organs.

Nematodes are oviparous or viviparous.

The principal sense organs in nematodes are papillae, setae, and amphids.

The amphids are well developed in aquatic nematodes (especially in the marine species). The amphids are believed to be chemoreceptors.

A pair of unicellular glands, called phasmids are present in the tail region of nematodes.

The presence of phasmids forms the basis to classify the Nemathelminthes into two classes, the Phasmida and the Aphasmida.

The Class Phasmida is divided into fifteen orders: the Enoploidea, the Dorylaimoidea, the Mermithoidea, the Chromadoroidea, the Araeolaimoidea, the Monhysteroidea, the Desmoscolecoidea, the Rhabditoidea or Anguilluloidea, the Rhabdiasoidea, the Oxyuroidea, the Ascaroidea, the Strongyloidea, the Spiruroidea, the Dracunculoidea and the Filarioidea.

The Class Aphasmida is divided into two orders: the Trichuroidea or Trichinelloidea and the Dioctophymoidea.

2.8.7 KEY TERMINOLOGY

Amphid: Blind invaginations of the cuticle. Commonly located just posterior to cephalic setae. The amphids are believed to be chemoreceptors. They reach their highest form of development in aquatic nematodes.

Buccal cavity: Cavity just within the mouth opening.

Bursa: A pouch like structure. Commonly refers to a female reproductive chamber for the reception and temporary storage of sperm received at copulation.

Dioecious: Having separate sexes; i.e. certain individuals possess the male reproductive system and other individuals possess the female reproductive system.

Oviparous: Egg laying.

Parasitism: A type of symbiotic relationship in which one species (parasite) is benefited from the relationship and the other (host) is harmed.

Phasmid: A pair of unicellular glands in the tail region of nematodes. Glandular sensory structures that function in chemoreception. They reach their best development in parasitic nematodes.

Viviparous: Nutrition of embryo is provided directly by mother rather than by yolk of egg. Young are released at birth.

2.8.8 SELF ASSESSMENT QUESTIONS

1. Mention any three main orders of Phylum Nemathelminthes in detail with examples.
2. Classify the phylum Nemathelminthes up to orders with suitable examples.
3. Give an account of Aphasmid nematodes with two important human parasites.
4. Explain different groups of Phasmids.
5. Write an essay on strongyloid nematodes.
6. Write short notes on:
   a. Filarioidea
   b. Dracunculoidea
   c. Pharynx in nematodes

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Shri. B.V. Krishna Rao

UNIT - III

3.1 GENERAL ORGANIZATION OF PHYLUM ANNELIDA

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3.1.1 OBJECTIVES

The purpose of this lesson is to:

- study the general characters of annelids.
- exemplify the annelids with suitable examples.
- know about the general structure of the polychaete, oligochaete and hirudinid
- study the general physiology of the annelid.

3.1.2 INTRODUCTION

The Phylum Annelida consists of the segmented worms. The familiar earthworms, leeches and a great number of marine and fresh water forms belong to this phylum. In general, the annelids attain the largest size among worm like animals and display the greatest structural differentiation. The most important character of the annelid is metamerism, the division of the body into similar parts or segments. The segments are arranged in a linear series along the anteroposterior axis. Metamerism is probably evolved as an adaptation for peristaltic burrowing in soft substrata. The primary metameric structures are the body wall muscles and the coelomic compartments. Chitinous, paired, lateral bristles or setae on each segment increase friction with the substratum. Annelids possess a more or less straight digestive tract running from anterior mouth to the posterior anus. Digestion is extracellular. There is a usually a dorsal blood vascular system. The nervous, circulatory and excretory systems are metameric.

The phylum contains more than 8700 described species, which are placed into three cla Polychaeta, Oligochaeta and Hirudinea.

3.1.3 CLASS POLYCHAETA

3.1.3.A EXTERNAL STRUCTURE

Polychaetes are common marine animals. Over 5300 species have been described. The majorities are less than 10 cm. in length. The generalized polychaete is perfectly metameric. Each segment is identical and bearing a pair of lateral, fleshy, paddle like appendages called parapodia (Fig. 3-1). A typical parapodium is a fleshy projection extending from the body wall and is more or less laterally compressed (Fig. 3-1). The parapodium is basically biramous, consisting of an upper (dorsal) division, the notopodium and a lower (ventral) division, the neuropodium. One or more chitinous rods, or acicula supports each division internally. A cirri form process extends from the notopodium and from the neuropodium. At the anterior end of the worm is a well-developed prostomium. The prostomium bears eyes, antennae and a pair of palps. The post oral region is called peristomium. The mouth is located on the ventral side of the body between the prostomium and peristomium. The terminal non-segmented region of the worm is called pygidium. Anus is located in the region of pygidium. Polychaetes can be errant (free moving) or sedentary. The body segments of polychaetes are generally similar. In many species, a trunk follows the head region.

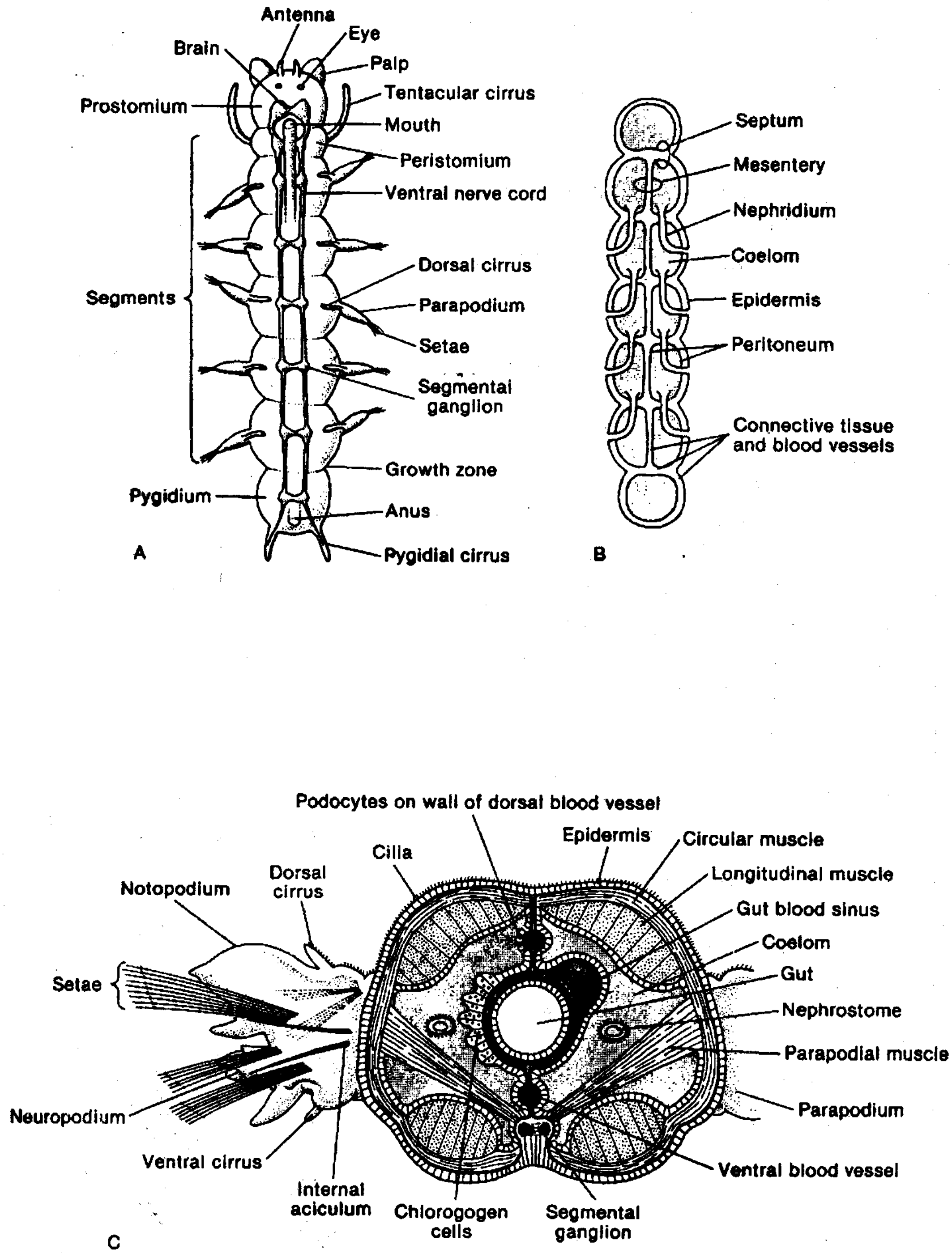


Fig. 3-1. Polychaete organization. **A, B,** Dorsal views. C, Cross section of trunk.

3.1.3.B INTEGUMENT

An integument covers many polychaetes. It is composed of a single layer of columnar epithelium, which is covered by a thin layer of cuticle. Beneath the epithelium lie in order a thin layer of connective tissue, a thin layer of circular muscles and a thick layer of longitudinal muscles and a thin layer of peritoneum. The longitudinal fibers are broken up into four bundles- two dorsolateral and two ventrolateral. Oblique muscles are commonly present at the level of parapodia.

3.1.3.C COELOM

The coelom is spacious. It is compartmented by transverse septa. Each septum is composed of a double layer of peritoneum. The gut penetrates the septa. The gut is suspended dorsally and ventrally by longitudinal mesenteries. Thus each coelomic compartment is divided into right and left halves.

3.1.3.D THE ALIMENTARY CANAL

Polychaetes are raptorial feeders, herbivores, omnivores, scavengers, browsers and non-selective deposit feeders (consume sand or mud). Raptorial feeders feed upon various small invertebrates, including other polychaetes.

Typically the alimentary canal of polychaetes is a straight tube. It is present between the mouth and anus. The most common regions of alimentary canal are the proboscis or pharynx or buccal cavity (when the proboscis is absent), a short oesophagus, a short stomach, an intestine and a rectum. In *Neries,* stomach is absent and the oesophagus opens directly into the intestine (Fig.3-2). In case of bamboo worms such as *Owenia* and *Euzomes,* the digestive tract behind the pharynx is a simple uniform tube.

The epithelial lining of stomach or intestine (when the stomach is absent) secretes enzymes for extracellular digestion. Two large glandular caeca open into the oesophagus through two-caecal openings .They along with the intestine secretes digestive enzymes. In omnivorous *Neries*, the epithelial lining of gut elaborates cellulose. Intestine is the main site of absorption.

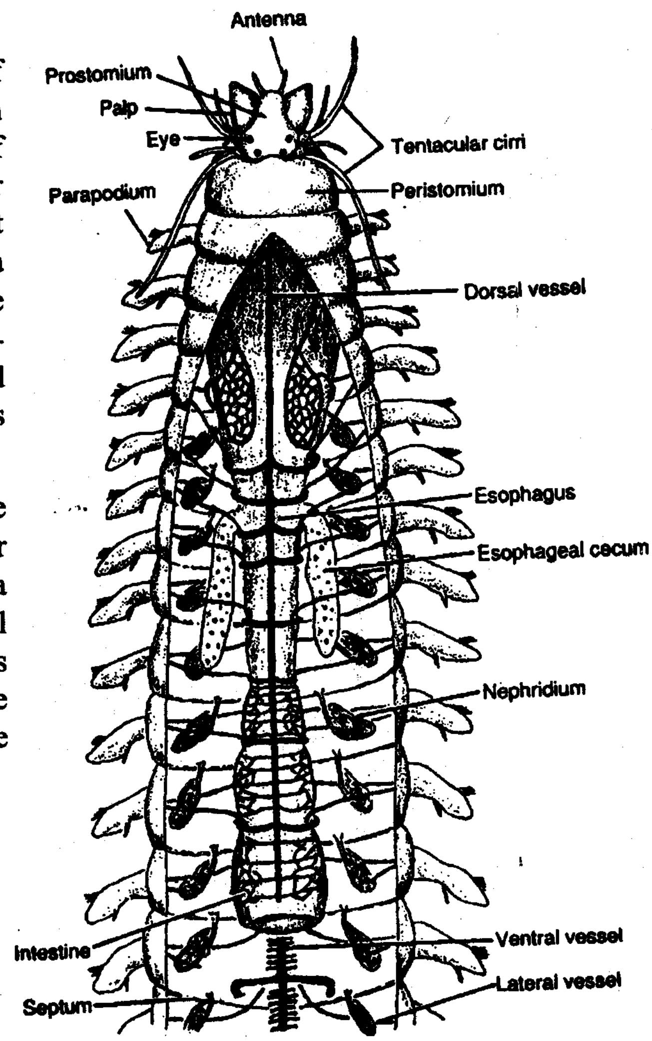


Fig. 3-2. *Nereis* - Dorsal view.

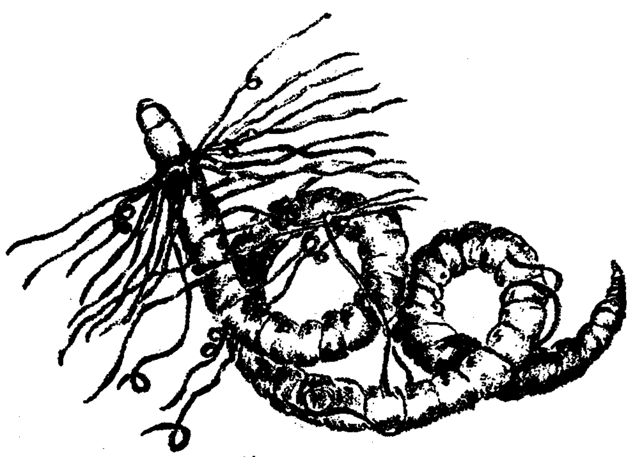
In some worms such as *Amphitrite,* intestine is the main site for digestion and absorption. In *Arenicola,* oesophageal caeca are known to produce lipase and propase.

Some polychaetes produce fecal pellets or strings. Defecation appears to follow a rhythmic cycle. It is under the control of an internal muscular system.

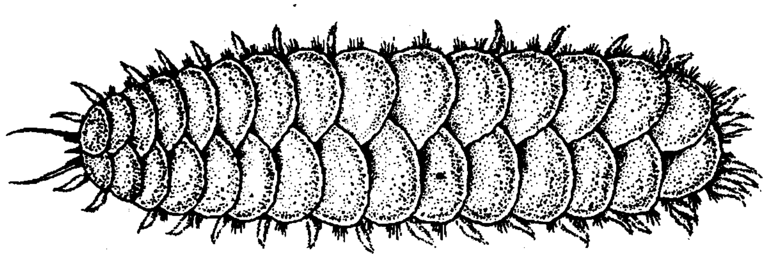
3.1.3.E GAS EXCHANGE

Gills are the gas exchange organs. They vary greatly in both structure and location. They are never enclosed in protective chambers. In ancestral polychaetes gills are absent and diffusion of gases occurred through the general body surface.

In the polynoid scale worms, gas exchange occurs through the general dorsal body surface; which is roofed by the electra (Fig.3-3). In some forms like *Sabellaria* and *Scolelepis* the gills are associated with parapodia. In these the dorsal surface of the notopodium is modified to serve as a gill and the cirrus is like a long inverted cone (Fig.3-4A). The dorsal cirrus is modified into a large flattened lobe in *Phyllodocids* (Fig. 3-4B), or irregularly branched filaments in *Arenicola* or spirally branched in *Dioptera.*



A



B

Fig. 3-3. **A,** *Cirratulus cirratus,* a polychaete with long, threadlike, dorsal cirri (gills). **B,** A free living polynoid scaleworm, *Harothoe aculeata.* The elytra bear many low sensory papillae on their upper surface.

The gills in *Amphitrite* are not associated with parapodia. They are arborescent and are located on the dorsal surface of the anterior segments. The gills can thus be projected from the openings of the burrow or tube. In the scale worm, *Aphrodita* (called a sea mouse) the entire dorsal surface is covered by hair like setae (Fig. 3-5). The sabellid and serpulid fan worms do not have gills associated with parapodia. The bipinnated radioles composing the fans serve as sites of gas exchange. Ventilation may be provided by gill cilia or by contractions of gills. Gas exchange occurs by interior vascular supply in gills.

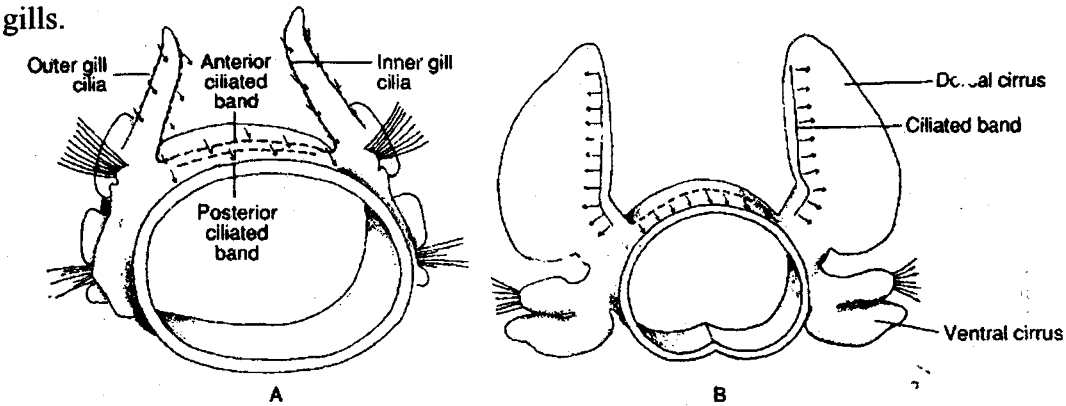


Fig. 3-4 Surface cilation in two polychaetes. Arrows indicate direction of water currents. Flows on trunk surface are directed posteriorily. **A**, *Scolelepis squamata.* **B**, *Phyllodoce laminosa.*

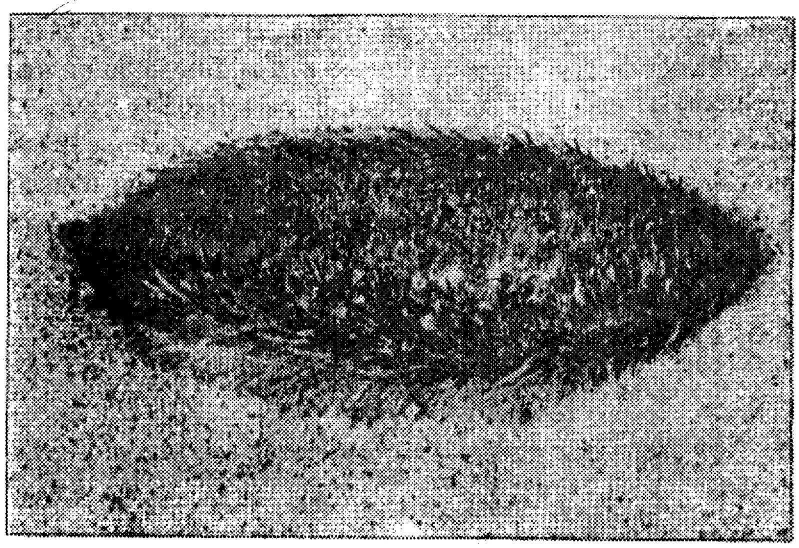


Fig. 3-5 The sea mouse, *Aphrodita aculeata.* Dorsal view.

3.1.3.F INTERNAL TRANSPORT

Most commonly circulation occurs by means of fluid movement in both the blood vascular system and the coelom. A blood vascular system and sometimes also the coelomic cavities are absent in small species. In most polychaetes, a well developed blood vascular system is present in which blood is confined to vessels. In a typical blood vascular system blood flows anteriorly in a dorsal

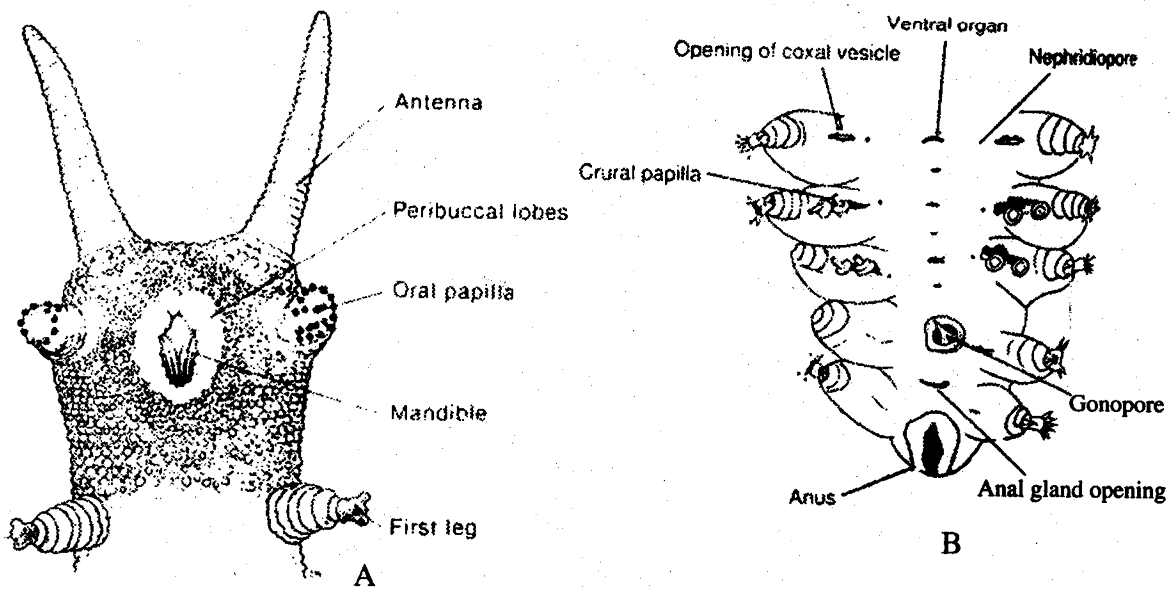


Fig. 3-23. Onychophora. **A,** *Peripatus* - Anterior end (ventral view) **B,** Posterior of a male *Peripatus corradoi* (ventral view).

3.3.6 COELOM

The coelom or body cavity is a haemocoel. The arthropod blood vascular system is composed of a heart vessel and the haemocoel. The heart varies in position and length in different arthropodan groups. In all the arthropods the heart is a muscular tube perforated by a pair of lateral openings called ostei. The contraction of the heart muscle is referred as systole and the expansion and filling of heart is referred as diastole. A large sinus known as pericardium surrounds the heart (Fig. 3-24). The heart is filled with blood during diastole through the ostei. The blood after leaving the heart flows into coelomic sinuses through arteries. The blood then returns by various vessels to the pericardial sinus. The blood of arthropods contains many types of cells. In some species a respiratory pigment haemocyanin or hemoglobin is present.

3.3.7 NUTRITION

Horseshoe crabs are scavengers and dependent on worms, mollusks and other organisms. They pick up the food by chelate appendages. The mouth located just behind the chelicerae, opens into an oesophagus, crop, gizzard and midgut (stomach and intestine) (Fig. 3-25). The gizzard acts as a grinding chamber. The food that is ground in the gizzard pass into the stomach. Opening into each side of the stomach is one or two pairs of glandular hepatic caeca. Enzyme production and digestion occurs within the midgut region and hepatic caeca. Digestion is entirely extracellular. The hepatic caeca are the main sites of absorption of digested food materials. Intracellular digestion of dipeptides occurs within the hepatic caeca. Wastes are passed out through rectum and anus. Anus lies on the ventral side of abdomen in front of the telson.

Arachnids are carnivores and feed on small arthropods. Pedipalps and chelicerae are used in capturing and killing the prey. Digestion occurs partly outside the body. Fluids and partly digested tissues are sucked into the gut. The anteriorly situated mouth leads to pharynx and oesophagus of the

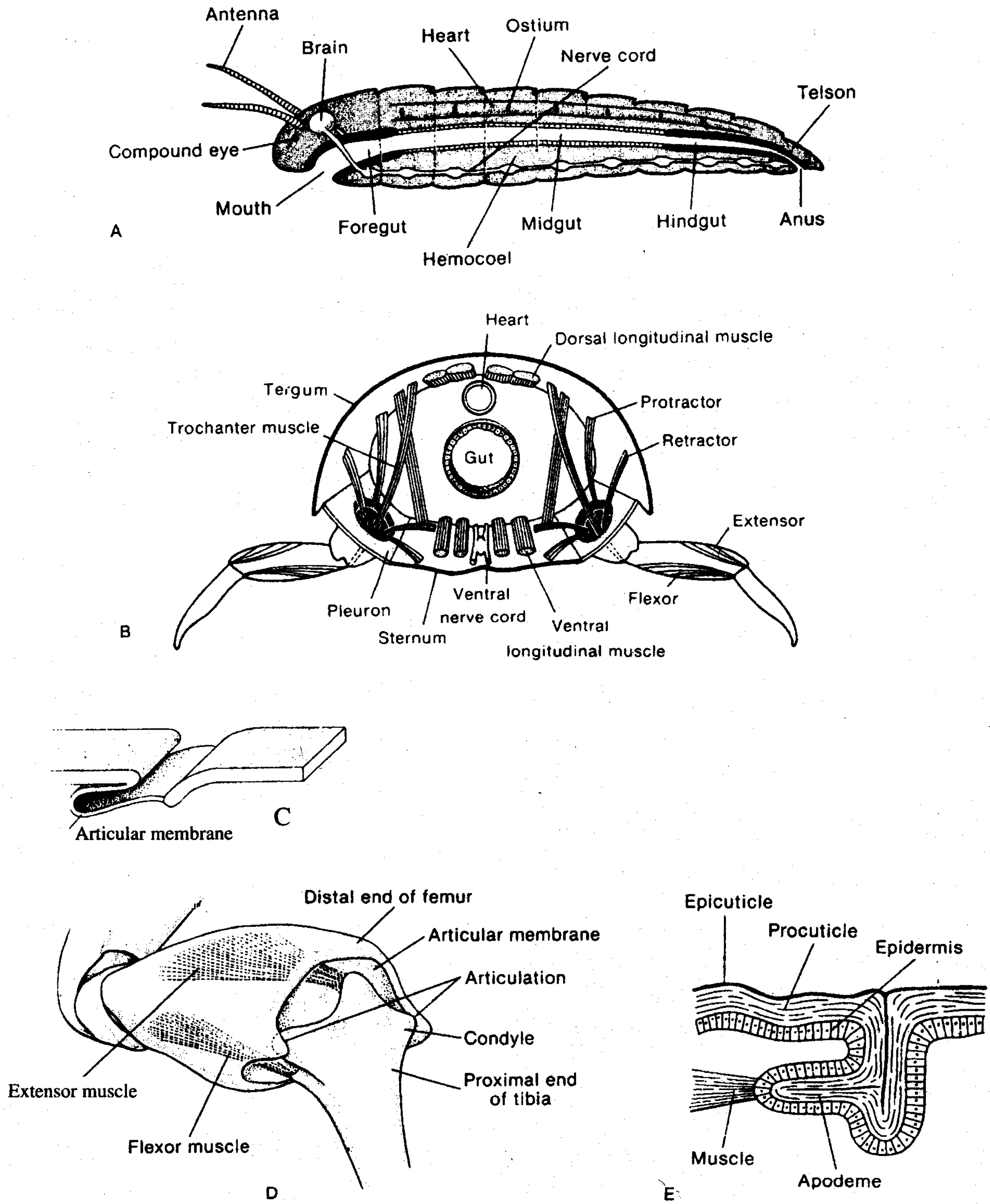


Fig. 3-24. **A** and **B**, Structure of a generalized arthropod. **A**, Sagittal section. **B**, Cross section. **C**, Intersegmental articulation. Note articular membrane folded beneath segmental plate. **D**, Leg joint of an insect showing condyles and muscle attachments. **E**, An apodeme.

3.1.3.I SENSE ORGANS

Eyes, nuchal organs and statocysts are the principal sense organs. Two, three or four pairs of eyes are found on the surface of the prostomium. The nuchal organs consist of a pair of ciliated sensory pits or slits. These sense organs are important for detecting the food. Statocysts are found in many sedentary burrowers and tube dwelling polychaetes. These are found within the body wall of the head opening laterally on the body surface.

3.1.3.J REPRODUCTION

Polychaetes reproduce by means of budding. Body may be divided into 2 parts or into a number of fragments. Majority of the polychaetes are dioecious and reproduce sexually. Gonads are usually distinct organs. The number and position of gonads varies in different species. In general they are found in the connective tissue associated with septa, blood vessels and lining of the coelom. In some species the gonads may be restricted to the genital segments. Among the few hermaphroditic polychaetes, some anterior abdominal genital segments produce eggs and posterior segments produce sperms. Immature gametes shed into the coelom and maturation occurs in the coelomic fluid. When the worm is matured the coelom is packed with eggs or sperm. Gametes exit outside by separate coelomoducts or gonoducts. In some forms the nephridial ducts serve as gonoducts.

Many polychaetes shed their eggs into the seawater. The eggs become plank tonic. Some polychaetes, however retain the eggs within the tubes or burrows. Some polychaetes brood their eggs in the cavity of the operculum or some others brood their eggs within a secreted sac attached to the ventral surface of the body. Few species such as *Neries, Limnicola* brood their eggs within the coelom.

3.1.3.K DEVELOPMENT OF THE EGG

The fertilized egg undergoes a typical spiral cleavage and is holoblastic. Gastrulation takes place by invagination, epiboly or both resulting in to a stereo-gastrula. The stereogstrula or the embryo rapidly develops into a top shaped trochophore larva (Fig.3-8). The trochophores of *Owenia, Polygordius,* phyllodoscids, serpulid fan worms have a planktotrophic trochophores that feed on plankton. The trochophores of nereids and eunicids are lecithotrophic, i.e. yolky and non-feeding. These larvae have a brief larval existence. The trochophores undergo metamorphosis to transform into the jevunile body form. The most important feature of metamorphosis is the gradual lengthening of the growth zone. This region lies in between the mouth and telotroch. During metamorphosis the segments develop from anterior to posterior and the germinal region remains just in front of the terminal pygidium. Thus, in adult polychaetes the oldest segments lie close to the head region.

3.1.3.L REGENERATION

Most polychaetes have great power of regeneration. Tentacles, palps and even heads torn off by predators are soon regenerated. In general serpulid worms, burrowers and tube dwellers show regeneration.

3.1.3.M EPITOKY

It is a reproductive phenomenon characteristic of many polychaetes. The formation of a pelagic reproductive individual is called as epitoky. And the reproductive individual is referred as epitoke.

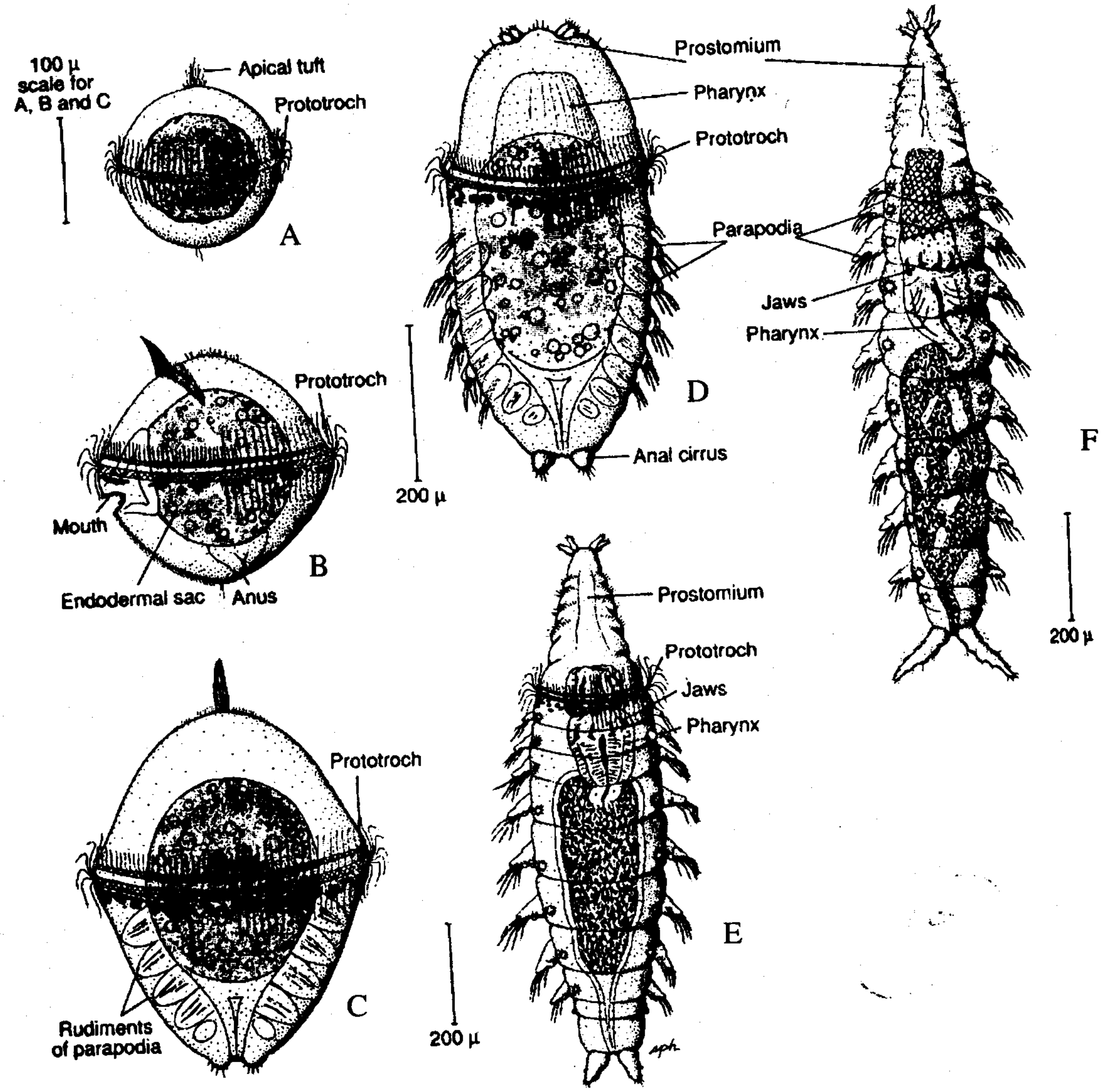


Fig. 3-8. Larval stages of *Glycera convoluta.* **A**, Early trochophore (15 h). **B**, Later trochophore (10 days), **C**, Young metatrochophore (4 weeks). **D**, Metatrochophore at 7 weeks. Although still a swimming stage, it frequently comes to rest on the bottom,. **E**, Postlarva at 8 weeks. Metamorphosis follows metatrochophore illustrated in **D**, Larva becomes benthic and raptorial. **F**, Young worm at 2 months.

The epitoke is adapted for leaving bottom burrows, tubes and other habitations. Generally epitokes arise form a non-reproductive individual, atoke. Epitokes may arise either by direct transformation of entire individual or by the transformation of the posterior end of atoke. The epitoke of nereids have large eyes and reduced prostomial palps and tentacles (Fig.3-9). The anterior segments are not greatly modified. The posterior segments are packed with gametes and each segment shows swimming setae.

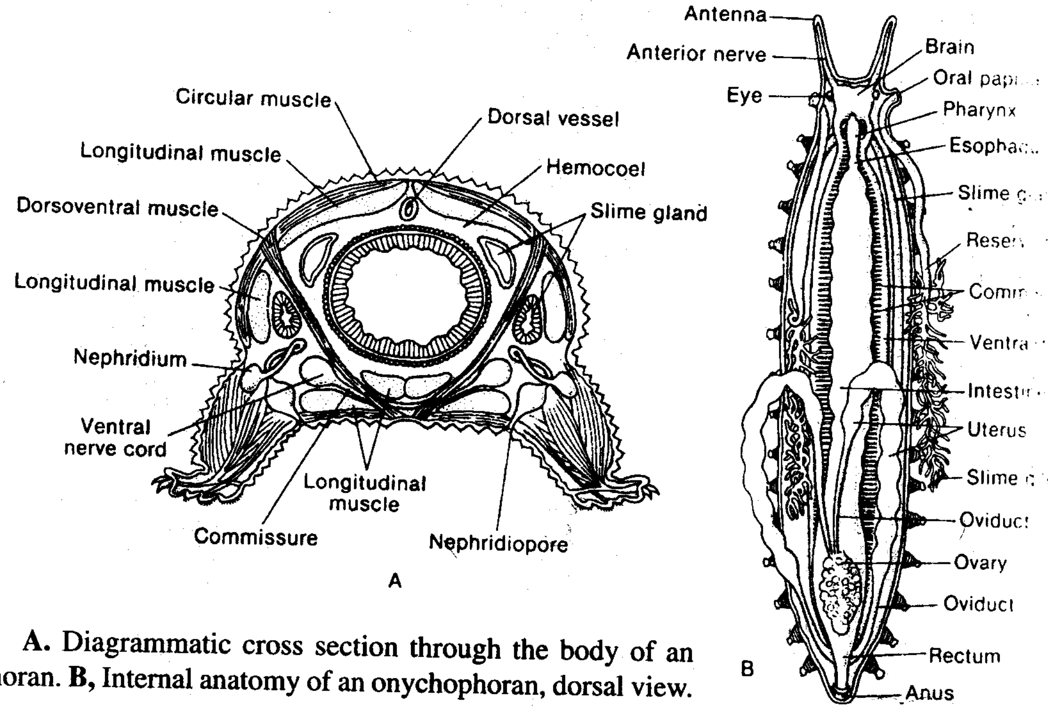


Fig. 3-28 **A.** Diagrammatic cross section through the body of an onychophoran. **B,** Internal anatomy of an onychophoran, dorsal view.

of glycogen, fat and calcium. Hence, absorption is confined to these cells. An intestine composed in part or entirely of hindgut, comprises the posterior portion of the gut.

Onychophorans are predaceous and feed on small invertebrates, such as snails, insects and worms. They possess a simple straight digestive tract (Fig. 3-28). The mouth is located at the base of the pre buccal depression. Part of the digestion occurs outside the body. The digested tissues are then sucked into the mouth. It opens into the chitin-lined foregut, composed of a pharynx and an oesophagus. A large, straight intestine is immediately posterior to the oesophagus. The intestine is the main site of the remaining digestion and absorption. The hindgut is composed of rectum and intestine. The intestine opens into an anus that lies on the ventral side at the posterior end of the body.

Chilopods are predaceous. In chilopods, the digestive tract is a straight tube. Depending on the species, the foregut lies from one seventh to two-thirds of the body (Fig. 3-29). The hindgut is short. The secretions of salivary glands help in the digestion of food material.

Symphylans feed on decayed vegetation. They possess a simple, straight digestive tract.

Most diplopods (millipedes) are herbivores, feeding on decaying vegetation. Some are carnivorous or omnivorous. The digestive tract is typically a straight tube with a long midgut. Salivary glands open into the pre oral cavity. The midgut is separated from the long hindgut (rectum) by means of a constriction.

The diet and feeding habits of pauropods are very poorly known.

Insects have adapted to all types of diets. They have highly modified mouthparts. The digestive tract is divided into three parts, the foregut, the midgut and the hindgut. Food taken into the mouth

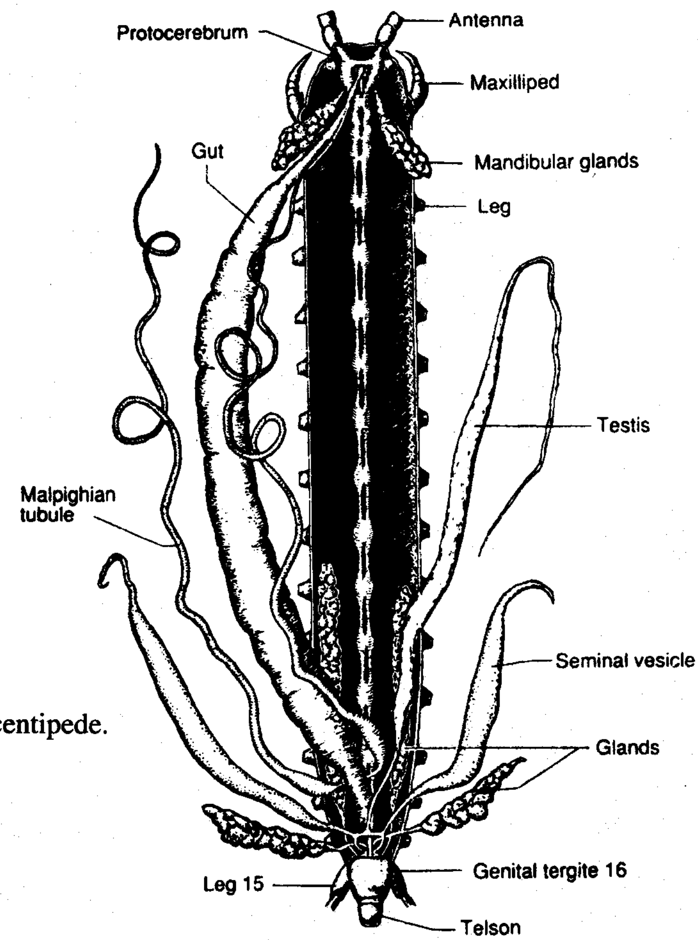


Fig. 3-29. Internal structure of the centipede. *Lithobius.*

passes into the foregut. The foregut is commonly subdivided into an anterior pharynx, and oesophagus, a crop and a narrowed proventiculus (Fig. 3-30). A pair of salivary glands open into the buccal cavity. These glands secrete saliva, which moistens the mouth; they may also produce enzymes that are mixed with food before it is swallowed. The foregut leads into the midgut. A stomodeal valve separates the foregut and midgut. The midgut or stomach is tubular. Most insects possess outpocketings of the midgut called gastric caeca. The position of the caeca varies. The function of the midgut is poorly known. The hindgut or proctodeum, consists of an anterior intestine and a posterior rectum. Both the intestine and rectum are lined by cuticle. The hindgut functions in the egestion of waste. It also maintains the water and salt balance. In most insects, the rectum consists of rectal pads in the epithelium. These organs are thought to be principle sites of water reabsorption. Fat bodies are present in hemocoel in various insects. These are the principal storage areas for glycogen. Certain cells of the fat body may contain deposits of uric acid or urates. In some insects, these cells temporarily store excretory products during molting, when the malpighian tubules are inactive.

3.3.8 RESPIRATION

In case of horseshoe crabs the abdomen bears 6 pairs of appendages. The first pair is fused forming a genital operculum. Posterior to the genital operculum are 5 pairs of flap like appendages modified as gills. The undersurface of each flap is modified to form many leaf like folds called lamellae.

calciferous glands in certain parts of the oesophageal wall. The calciferous glands secrete calcium carbonate, which may not be re-absorbed by the gut. The calciferous glands do not play a role in digestion. Their function is uncertain. It has been suggested that these glands function to eliminate the excess calcium taken in with blood. The remainder of the digestive tract is the intestine. The anterior half of this straight intestine is meant for secretion and digestion and the posterior half is primarily absorptive. The intestinal epithelium secretes digestive enzymes and cellulose and chitinase (in earthworms). The absorption area of the intestine is increased by a ridge or hold called typhlosole.

A layer of yellowish peritoneal cells called chloragogen cells surround the intestine and dorsal vessel. These cells play a vital role in the intermediate metabolism similar to the role of liver in vertebrates. Synthesis and storage of glycogen and fat is found in this tissue. The storage and detoxification of toxins, hemoglobin synthesis, protein metabolism and formation of ammonia and synthesis of urea also occur in these cells.

3.1.4.F GAS EXCHANGE

Diffusion of gases occurs through general body integument in both aquatic and terrestrial oligochaetes. The small aquatic forms possess gills at the anterior of the body. The large oligochaetes have plasma hemoglobin.

3.1.4.G CIRCULATORY SYSTEM

Basically the circulatory system of oligochaetes is similar to that of polychaetes. The dorsal blood vessel is contractile. In each segment segmental vessels send blood into the capillaries of the segment and the various segmental organs.

3.1.4.H EXCRETION

There is one pair of metanephridial tubules per segment except the extreme anterior and posterior ends. Each metanephridium is with a ciliated nephrostome and with a ventrolateral nephridiopore (Fig. 3-12).

Many earthworms of the families Megascolecidae and Glossoscolecidae possess a single typical pair of nephridia called holonephridia in each segment. These additional nephridia are multiple or branches. These typical or modified nephridia may open to the outside through nephridiopores or they may pen into the various parts of the digestive tract. In such a case they are termed as enteronephric nephridia. A single worm may possess a number of different types of these nephridia. The different nephridia may be restricted to certain parts of the body.

In fresh water and terrestrial oligochaetes salt and water balance will be maintained by the nephridia. The urine of these forms is hypo osmotic and considerable reabsorption of salts may take place as fluid passes through

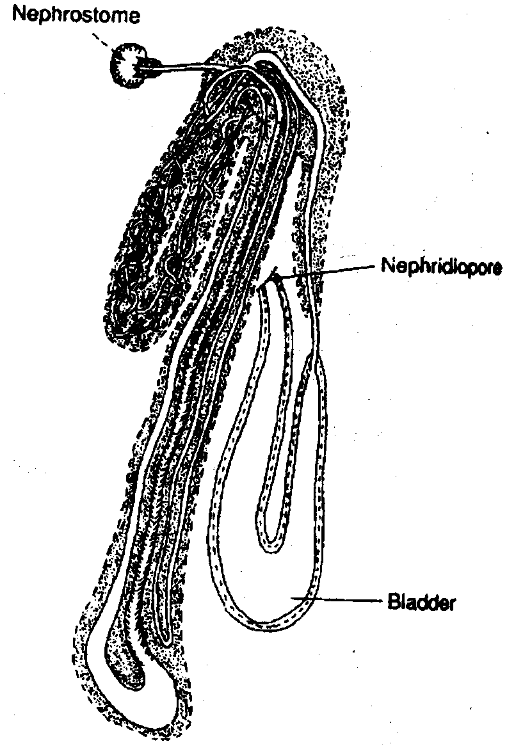


Fig. 3-12. Metanephridial tubule of *Lumbricus*

the nephridial tubule. Earthworms excrete urea. Worms with enteronephric nephridia are able to tolerate much drier conditions.

A few aquatic oligochaete species are capable of encystment during unfavorable conditions. They form summer cysts or winter cysts. The activity of these animals will be resumed when the conditions become favorable.

3.1.4.I NERVOUS SYSTEM

The nervous system consisting of a brain lying above the anterior margin of the pharynx (third segment) and two fused ventral nerve cords lying inside the muscles of the body wall. Also there is a sub pharyngeal ganglion, which is the center for motor control.

3.1.4.J SENSE ORGANS

Eyes are absent. Few aquatic forms have pigment cup ocelli. The integument is well supplied with photoreceptors. Clusters of sensory cells lying above the cuticle act as a chemoreceptor. Numerous sensory tubules may also appear to be chemoreceptors in function.

3.1.4.K REPRODUCTION

Oligochaetes are hermaphroditic with well-developed reproductive system limited to few segments. Both the ovaries and testes are typically paired and are situated in the genital segments on the lower part of the anterior septum. The gonads project into the coelom. Immature gametes fall into the coelom. Maturation will be completed in the coelom and in the coelomic pouches called the seminal vesicles and ovisacs. The sperm or eggs will be released outside through gonopore via a pair of sperm ducts or oviducts. In the female reproductive system there is a simple pair of sacs called spermathecae (seminal receptacles for the storage of sperm). Glandular tissues called prostrate glands are found in connection with the male reproductive system. In some oligochaetes there is no gonoducts and the sperm exit outside through nephridial duct.

The clitellum is a reproductive structure characteristic of oligochaete (Fig. 3-10) The number of segments comprising the clitellum varies considerably. The glands of clitellum produce mucus for copulation, secrete the wall of the cocoon and secrete the albumin in which the eggs are deposited within the egg cocoon. Sperm are deposited in the cocoon and fertilization occurs externally within the cocoon. The eggs of aquatic forms contain relatively large amounts of yolk. On the other hand terrestrial forms have much smaller eggs with much less yolk. In both the aquatic and terrestrial forms development is direct and there are no larval stages. All developmental processes occur within the cocoon and the young ones emerge from the end of the cocoon. The developmental period may range from 8 days to several months. They may reach the sexual maturity in six months to year depending on the environmental conditions and the species.

3.1.5 CLASS HIRUDINEA

3.1.5.A EXTERNAL STRUCTURE

The worms, which belong to Class Hirudiunea are commonly known as leeches. Some are marine leeches. Most of them are aquatic living in fresh water. They prefer to live in shallow water ponds, lakes and sluggish streams. Leeches are the most specialized annelids. Leeches share some

Crustaceans possess nephrocytes. These cells are capable of picking up and accumulating waste products.

In branchiopods, the maxillary glands are usually called shell glands. The ducts of these glands can be seen coiled within the carapace wall. The brine shrimp *Artemia* can tolerate extreme salinity. Antennal (or green) glands are the excretory organs of decapods. These glands reach their highest degree of development in decapods. The excretory organs are malpighian tubules in uniramian arthropods including centipedes, millipedes and insects. Much of the nitrogenous waste is excreted as ammonia. Malpighian tubules lie more or less free in hemocoel. The proximal end usually found in between mid gut and hindgut. The tubules must be short and often grouped in bundles. Uric acid is the nitrogenous waste. In onychophorans such as *Peripatus,* each segment contains a single pair of nephridia located in the ventrolateral sinuses. The nephridium is composed of a ciliated funnel, nephrostome and a tubule, which opens by a nephridiopore. The nephridiopore is located on the inner base of each leg. The nature of excretory waste is not known. Millipedes possess coxal sacs, which are meant to take up water such as dewdrops. In pycnogonids (sea spiders), excretory organs are absent.

3.3.10 NERVOUS SYSTEM

In chelicerates (Horse shoe crabs), the nervous system displays a large degree of fusion (Fig. 3-19). The brain forms a collar around the oesophagus. A ventral nerve cord with five ganglia and the lateral nerves (extending through the abdomen) issue from the brain. The brain directly innervates all

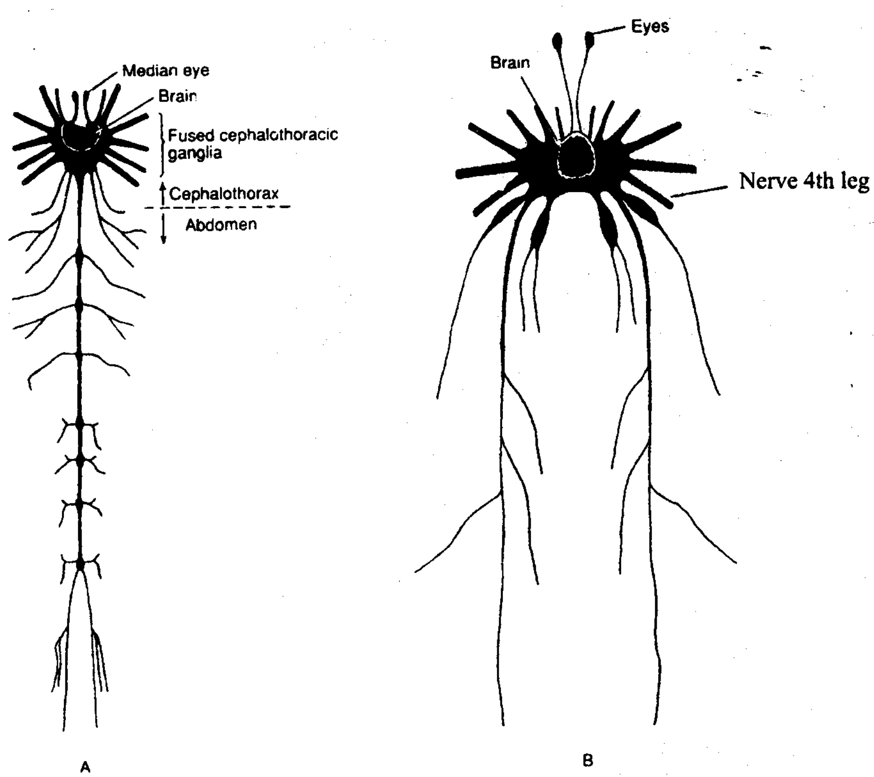


Fig. 3-31. **A**-Scorpion nervous system, in which abdominal ganglla are distinct. **B,** An opilionid nervous system, in which all ventral gangila have migrated forward and fused.

the appendages anterior to the operculum. In arachnids, the nervous system is greatly concentrated (Fig.3-31). The arachnid nervous system is composed of a collar or ring surrounding the oesophagus. The posterior ventral half of this nerve ring gives rise to nerves to innervate the appendages. A single posterior nerve bundle extends back into the abdomen, which arises from the nerve collar. In pycnogonids, the nervous system consists of a brain and a pair of ventral nerve cords. From the brain extend nerves to anterior parts of the body. The paired ventral nerve cords bear a pair of fused ganglia in each of the trunk segments. The nervous system of crustaceans displays the usual tendency toward concentration and fusion of ganglia. In primitive forms, the ventral nerve cord displays a ladder like configuration. In onychophorans, the nervous system is composed of a large bilobed brain lying over the pharynx and a pair of ventral nerve cords connected together by commisures (Fig.3-28). The brain supplies nerves to the anterior parts of the head. The ventral nerve cord contains a ganglionic swelling and give rise a number of paired nerves to innervate legs and body wall. In case of myriapodous arthropods, which include centipedes (class Chilopoda), millipedes (class Diplopoda), symphylans (class Symphyla) and pauropods (class Pauropoda), the nervous system consists of a brain and paired ganglionated ventral nerve cords. The insect nervous system is basically like that of other arthropods. It is composed of a brain and a ventral nerve cord with median segmental ganglia (Fig.3-30). The thoracic and abdominal segmental ganglia are often fused. The sub esophageal ganglion is composed of three pairs of fused ganglia, which innervate the mouthparts, salivary glands, and some of the cervical muscles.

3.3.11 SENSE ORGANS

In chelicerates, the sense organs include a pair of lateral eyes and a pair of median eyes. The lateral eyes are compound eyes made up of units of 8 to 14 retinal cells grouped around a random (Fig. 3-25C). Each unit has a lens and a cornea and is called an ommatidium. The ommatidia are not compactly arranged. The median eyes are invaginated cups. The lens of the eye is continuous with an exterior cornea and is surrounded by retinal cells. The frontal organ is chemo receptive in function.

Although, most of the arachnids possess eyes, a relatively small number of arachnids are capable of discriminating objects. Trichobothria and slit sense organs are important sense organs to capture prey. In spiders, usually, there are eight eyes arranged in two rows of four each. The eyes are present along the dorsal anterior margin of the carapace. Among these, the anterior large median eyes are of the direct type and all the remaining eyes are indirect. In most spiders, the eyes are unable to form an image owing to the insufficient number of receptors. In all spiders, chemosensitive tubular hairs on tips of appendages, trichobothria, slit sense organs and tarsal organs are very important sense organs. Tarsal organs, cap like structures situated near the tips of the legs are probably olfactory receptors.

The sense organs of crustaceans include two types of eyes, a pair of compound eyes and a small, median, dorsal nauplius eye, composed of three or four closely placed ocelli. Compound eyes are absent in some groups. The nauplius eye, which is characteristic of the crustacean larva, does not persist in the adult in many groups.

In onychophorans, a small eye lies at the base of each of antenna. They avoid light and usually nocturnal. Sensory cells are present on the large tubercles and some areas on the integument. In centipedes (Chilopoda), millipedes (Diplopoda), pauropods (Pauropoda) and symphyllans (Symphyla)

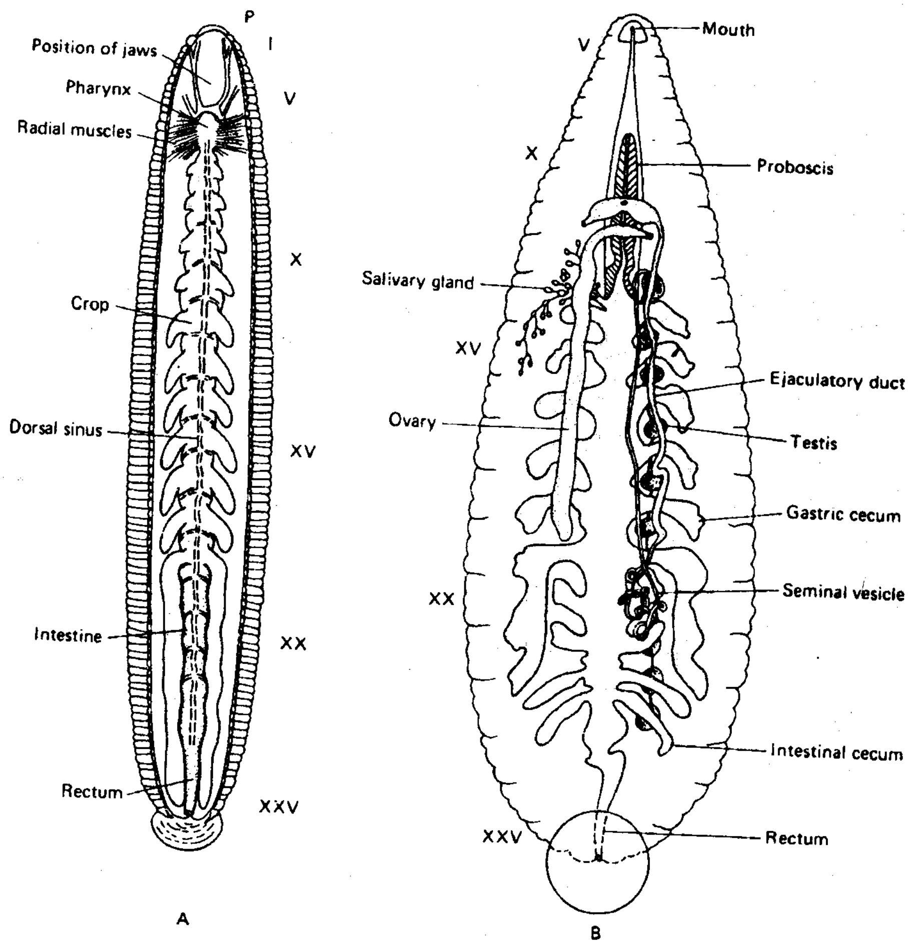


Fig. 3-15. Internal structure of the arhynchobdellid, *Hirudo medicinalis* (dorsal view). **B**, Internal structure of the rhynchobdellid, *Glossiphonia complanata* (ventral view).

mammals including humans. The mammalian blood suckers such as *Hirudo* is able to attack the skin of the host. Penetration of the host's tissues is not well understood in the jawless leeches. Digestion in leeches is peculiar in a number of aspects. The gut secretes exopeptidases that are useful in the digestion of blood. Digestion in blood sucking leeches is so slow. Another characteristic feature of leech gut is the presence of symbiotic bacteria flora. These bacteria produce vitamins and other compounds, which are used by the leech host for considerable part of digestion.

3.1.5.H EXCRETION

Leeches possess 10 – 17 pairs of metanephridial tubules. These are situated in the middle third of the body, one pair per segment. The nephridial tubules are embedded in the connective tissue and the nephrostomes project into the coelomic channels. The leech nephridium differs from the oligochaete nephridium in structure. Each nephridium consists of a ciliated nephrostome, a non-ciliated capsule, a nephridial duct and nephridiopore. In the leech nephridium the ciliated nephrostome opens into a non-ciliated capsule (Fig.3-16). The cavity of the capsule does not open into the nephridial canal. The nephridial tubule consists of a main duct. The main duct expands into a urinary bladder before it opens to the exterior as a ventrolateral nephridiopore.

The nephridia act as important organs of osmoregulation by reabsorbing the water and salts when the urine is passing along the nephridial duct.

The non-ciliated capsule contain a population of amoeboid phagocytes which engulf RNA material and cellulose material. Some of the amoeboid phagocytes may be released into the hemocoelomic circulation as coelomocytes. The botryoidal tissue of the leeches may also pick up the waste. In some species the nephrostomal cilia beat inverts carrying the waste into the capsule. In some other species the nephrostomal cilia beat outward away from the capsule and are believed to promote the circulation of coelomic fluid.

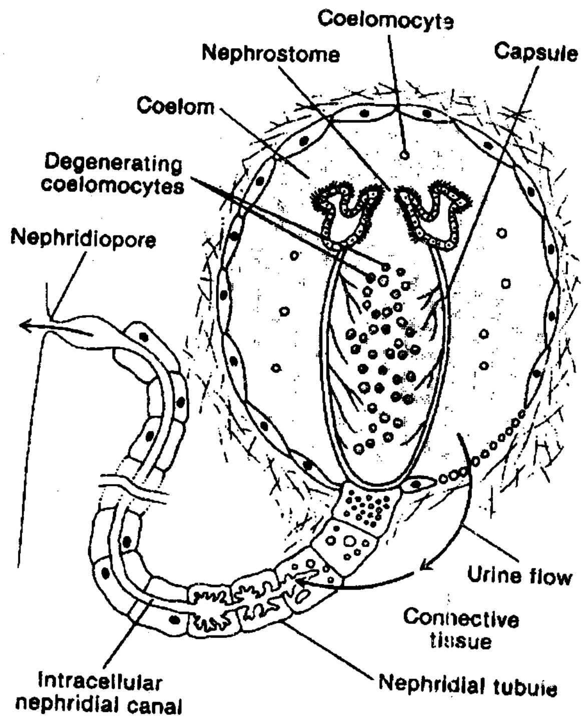


Fig. 3-16. Nephridium of the arhychobdellid leech, *Trocheta*. The nephrostome and capsule do not communicate with the tubule but rather collect and break down spent coelomocytes. Urine formation (arrows) apparently results from ultrafiltration of coelomic fluid across the wall of the botryoidal capillary into the connective tissue, followed by secretion into the nephridial tubule.

3.1.5.I NERVOUS SYSTEM

The nervous system in leeches consists of a brain and a ventral nerve cord. The brain consists of a mass of neural tissue in the prostomium. The supra oesophageal ganglion and the fused first four pairs of ventral segmental ganglia forming the sub-oesophageal ganglion. The ventral nerve cord of the trunk consists of a series of 21 ganglia. The last 7 ganglia are fused to form the caudal ganglion associated with the posterior sucker.

3.1.5.J SENSE ORGANS

The specialized sense organs in leeches consist of 2 – 10 pigment cup eyes and sensory papillae. The sensory papillae are small projecting disks arranged in a dorsal row or in a complete ring in each segment. Each papilla consists of a cluster of numerous sensory cells. Some species are able to change their colors because of the large chromatophores.

3.1.5.K REPRODUCTION

Asexual reproduction and regeneration are absent in leeches. All leeches are hermaphrodites (Fig. 3-17). They are protandric but not simultaneous hermaphrodites. Separate seminal receptacles (spermathecae) are absent. Fertilization internal. Sperm transfer is by hypodermic impregnation. Eggs are released from 2 days to many months after copulation. At this period the clitellum becomes conspicuous and in most species a cocoon is secreted. The cocoon is filled with nutritive albumin

In onychophorans, the sexes are always separate. The males are little smaller than females. Males have fewer legs. Both males and females have special glands called crural glands, which are thought to have some sort of sexual function. The female system contains a pair of fused ovaries located in the posterior part of the body. Single common female genital pore is situated ventrally near the posterior end of the body. The male system consists of nonfused testes located at the posterior part of the body. The male pore is ventral and posterior (Fig.3-23).

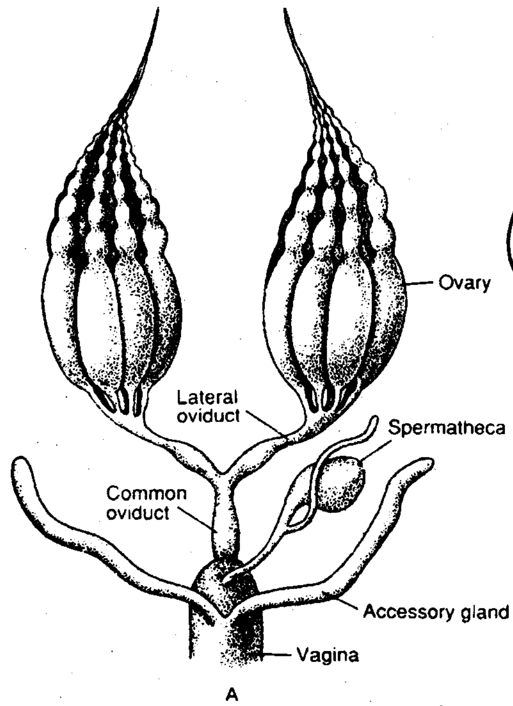
Onychophorans are oviparous, ovoviviparous or viviparous. The eggs of viviparous forms are having little yolk.

Centipedes are dioecious. In female, the ovary is single, trilobular organ located above the gut. The female aperture lies on the ventral surface of the posterior, legless segment. In the male, 1 to 24 testes are located above the midgut. A median male gonophore lies on the ventral side of the genital segment (Fig.3-29). Sperm transfer is indirect in centipedes.

Some centipedes brood their eggs in clusters of 15 to 35. The female guards the eggs by winding itself around the egg mass. When the young one hatches from the egg it displays the full complement of segments. In Symphylans, the genital openings are located on the ventral side of the fourth trunk segment. Female lays eggs in clusters like those of centipedes. Parthenogenesis is common in the small claws of symphylans. Like those of centipedes the males and females possess paired fused tubular ovaries and testes located on the ventral side of the body. Ovaries and testes lie between the midgut and the ventral nerve cord. Sperm transfer is indirect by means of copulation. Development is anamorphic. The eggs of millipedes hatch in several weeks and the newly hatched young possess the first three pairs of legs and not more than seven trunk rings. It undergoes several molts to obtain maturity. Parthenogenesis is common in some population and males are rare. In pauropods, males and females are distinct. As in diplopods, the third segment is the genital segment. A single ovary lies below the gut. Testes are located above the gut. Sperm are transferred via a spermatophore. Development is anamorphic and as in diplopods the young hatch with only three pairs of legs. The young one may become sexually mature within 14 weeks.

In case of insects, the reproductive system is well developed in both males and females. The female reproductive system includes a pair of ovaries and a pair of lateral oviducts one on each side of the body. The two-paired oviducts unite to form common oviduct, which leads into vagina (Fig.3-34). The vagina in turn opens on the ventral surface. The male reproductive system consists of a pair of testes, a pair of lateral ducts and a median duct opening through a ventral penis (Fig.3-35). Sperm are transferred in spermatophores. Sperm transfer is by copulation. During insemination, spermatophores may be deposited in the vagina. Superficial cleavage is the characteristic of insects. Insect young vary in the degree of development in hatching. Insects show two types of metamorphoses: incomplete and complete metamorphosis.

Newly hatched grasshoppers, cockroaches resemble the adults except the absence of genitalia and small size of wings. The adult form is reached gradually with successive molts. Such type of development is called gradual or incomplete metamorphosis (hemi-metabolous); all the immature stages from hatching to the adult are termed nymphs or when aquatic, naiads. In many insects, including bees, wasps, flies and beetles, the wing rudiments develop internally; the wings seem to appear suddenly



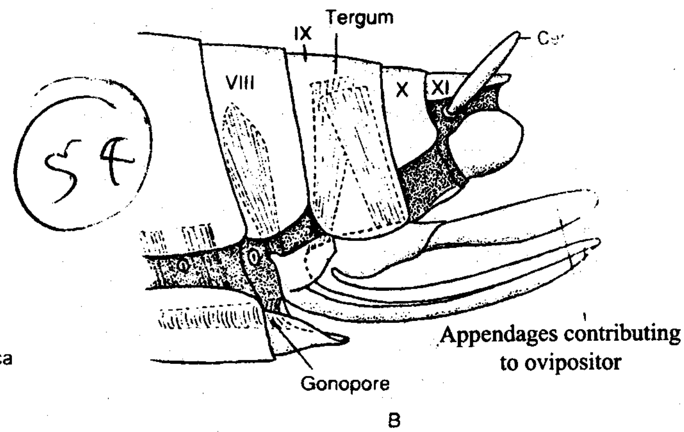


Fig. 3-34. **A,** Reproductive system in a female insect. **B,** Lateral view of the posterior end of the abdomen, showing reproductive opening and appendages, forming ovipositor.

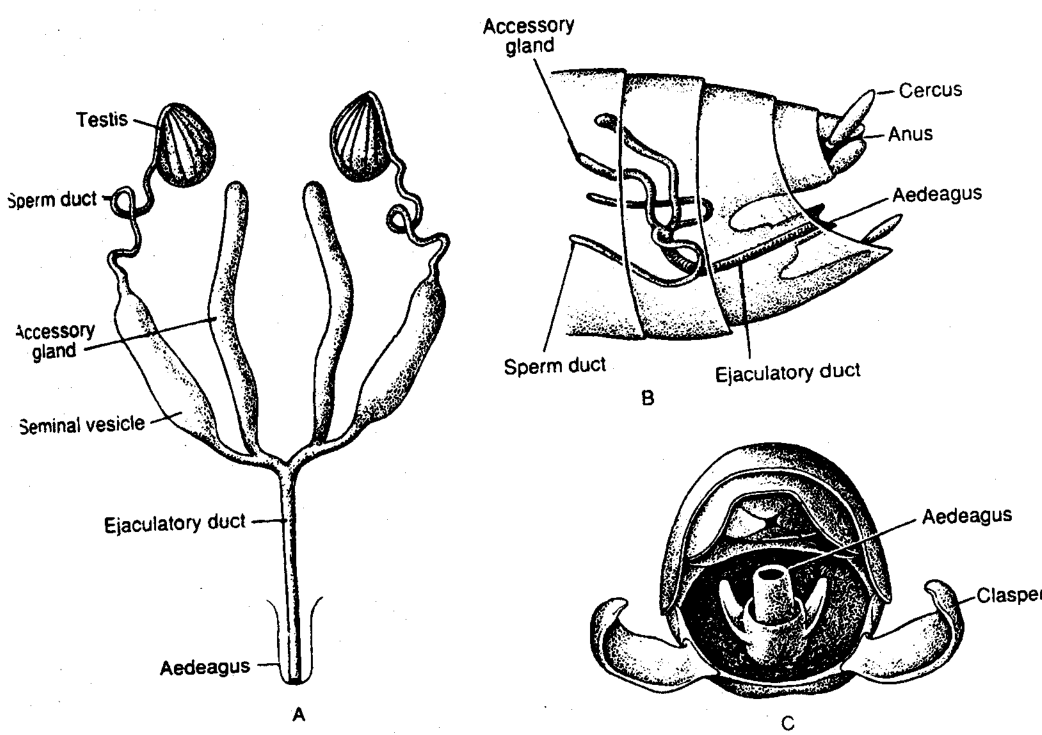


Fig. 3-35. Reproductive system in a male insect. **A,** General plan of the system, **B,** Lateral view of the posterior and of the abdomen, showing reproductive opening and other structures. **C,** Posterior view of the abdomen, showing aedeagus and claspers.

A proboscis or jaw is employed to obtain food.

The ectoparasitic or blood sucking leeches utilize vertebrates as hosts.

Digestion of blood, which is slow occurs by exopeptidase enzymes and a symbiotic bacterial gut flora.

The internal arrangement of the nephridia and ganglia, ventral nerve cord reflects external body segmentation.

Gills are absent.

Blood vascular system is similar to that of other annelids or has been replaced by coelomic channels.

Reproduction is similar to that of oligochaetes.

Sperm transfer by hypodermic impregnation with spermatophores.

3.1.8 KEY TERMINOLOGY

Atoke: The non-reproductive individual (polychaete) adapted for benthic existence.

Blood vascular system: Circulatory system of bilaterally symmetrical animals. It develops within the connective tissue.

Brood: To care for the eggs during at least in the early part of development. The development may take place inside or outside the female body. The male may be involved in brooding in some animals.

Chlorocruorin: Type of polychaete hemoglobin that is green in color.

Chromatophore: A pigment cell in the body wall that can expand or contract to expose or conceal its pigment.

Chromatophototropin: A hormone. The functioning of the chromatophores is under the control of this hormone.

Coelom: Body cavity line by a mesodermally derived epithelium.

Coelomoduct: A mesodermally derived duct leading from coelom to exterior, usually a gonoduct.

Commensalism: A type of symbiotic relationship in which one species benefits from the relationship and other species (host) is neither benefited nor harmed.

Commissure: a nerve that transversely joins two ganglia or some other part of the nervous system.

Connective tissue: Body layer between epithelia. It is composed of a fluid or gel extracellular matrix. Cells may or may not be present.

Enteronephric nephridia: The typical of modified nephridia, which open into various parts of the digestive tract of earthworms.

Epitoke: A reproductive individual, which is adapted for a pelagic existence.

Epitoky: Reproductive phenomenon in some polychaetes. The phenomenon of production of a reproductive individual (epitoke) either by transformation or by budding.

Hemal system: Blood vascular system.
Hermaphrodite: Having both male and female reproductive systems in the same individual. When both the systems are present at the same time, the hermaphroditism is said to be simultaneous; when the male system appears and functions first and is followed by the female system, the hermaphroditism is said to be protandric.

Metamerism: The division of an animal's body into a linear series of similar parts or segments.

Metanepridial system: Excretory system composed of a vascular ultra filtration site, a coelomic cavity and a metanephridium (metanephridial tubule).

Metanephridium (Pl. Metanephridia): An excretory organ that opens into the coelom by a ciliated funnel, nephrostome and to the exterior by a nephridiopore.

Notopodium (Pl. Notopodia): The dorsal branch of a polychaete parapodium.

Nuchal organ: The chemoreceptive organs of polychaetes. There are pair of pits or slits, which are present in the head margin.

Ocellus: A small cluster of photoreceptors, i.e., a simple eye.

Proboscis: Any tubular process of the head or anterior part of the gut, usually used in feeding and often extensible.

Seta: Chitinous bristle.

Spiral cleavage: Type of cleavage pattern in which the cleavage spindles or cleavage planes are oblique to the polar axis of the egg.

Terminal anchor: Anchor at the leading end of a burrowing animal.
Trochophore: Type of larva found in polychaetes.

3.1.9 SELF ASSESSMENT QUESTIONS

1. Describe the general characters of annelids with suitable examples
2. Write an account of polychaetes.

3. Write in detail about the general organization of Oligochaeta.
4. Describe the general organization of Class Hirudinea.
5. Write short notes on:
    a. Metanephridium.
    b. Gas exchange organs in polychaetes.
    c. Reproduction in oligochaetes.
    d. Excretion in leeches.
    e. Nutrition in polychaetes.

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Dr. V. Viveka Vardhani

3.2 CLASSIFICATION OF PHYLUM ANNELIDA

3.2.1 OBJECTIVES

The purpose of this lesson is to:

- classify the Phylum Annelida unto orders
- understand the distinguishing characters of Class Polychaeta
- exemplify the distinct features of Class Oligochaeta
- understand the distinguishing characteristics of Class Hirudinea
- study the complete definition of Class Archiannelida

3.2.2 INTRODUCTION

The invertebrate animals, which have a soft-body usually resembling the common earthworm are known as worms. In general, the annelids attain the largest size of any of the worm like invertebrates. The term Annelida is derived from two words: one is Latin (annulus = a ring) and the other is Greek (eidos = form). The phylum Annelida comprises the segmented worms and includes the familiar earthworms and leeches, plus a number of unknown marine and fresh water species. Annelids burrow or crawl upon the bottom in the ocean or in fresh water. Some are free swimming, at least during breeding season, and others are adapted to live in moist soil. Many marine species build permanent tube to inhabit. Tubicolous polychaetes live in tubes composed of secreted materials or of sand grains or shell fragments cemented together. Few species lead their life as sedentary burrowers. They occupy more or less fixed, simple vertical or U shaped burrows excavated in the substratum. Some annelids are actively predaceous, seizing the prey with well-developed jaws. Tube dwelling polychaetes feed upon microscopic particles brought in by ciliated tentacles.

3.2.3 GENERAL CHARACTERS

Annelids are bilaterally symmetrical with elongate vermiform body.

The smallest annelids are interstitial polychaetes (measuring few mm in length). The largest are the giant 3m long earthworms of Australia.

The distinguishing character of the phylum is segmentation (metamerism).

The body is metamerically segmented with ringed appearance. The segments are similar in structure internally as well as externally. The segments are arranges in a linear series along the anteroposterior axis. Segmentation of the body is limited to the trunk. The head, or acron is represented by the prostomium and contains the brain. The pygidium,which is the terminal part of the body tha carries the anus.

Body wall consists of layers of circular and longitudinal muscles.

The body wall consists of a fibrous cuticle, a glandular epidermis in which the nerve fibers are situated and a connective tissue dermis (cutis) of varying thickness.

The underlying epidermis with unicellular gland cells secrete the cuticle.

Appendages are unjointed and minute. They are usually chitinous, paired, lateral bristles or setae. Few to many lateral bristlesor setae are present in each segment. Setae are generally absent in Hirudinea.

Coelom is well developed and extensive. It is separated into segmental compartments by transverse partitions or septa.In addition to the segmentation of coelom and body wall musculature, lateral nerves, blood vesselsand excretory organs are also segmentally arranged..Each septum is composed of two layers of peritoneum. But, in Hirudinea coelom is reduced.

The digestive tract is tube like, extending through the body between the anterior mouth and posterior anus.

Respiration is by epidermis, or by gills in some tube dwellimg polychaetes and primitive leeches.

Excretion is by filtration nephridia (metanephridia and protonephridia), which characteristically occur as a single pair per segment. Each nephridium removes waste from the coelom and blood stream directly to the exterior.

Circulatory system is closed. Well-developed blood vascular system with longitudinal blood vessels having lateral branches in each segment. Blood plasma contains dissolved hemoglobin and free amoebocytes.

Nervous system consists of a dorsal brain and a long double or single ventral nerve cord. Ventral nerve cord is composed of paired ganglia and lateral nerves in each segment. These are connected to the brain by a pair of circum pharyngeal connectives.

Sense organs include sensory cells and organs of chemoreception.

In few sexes are separate, while in others sexes are united (hermaphrodite).

Gonads may be simple; they develop only during breeding season. In some forms gonads are well developed.

Cleavage is spiral and determinate.

Development is direct or indirect through a larval stage called trochophore.

Process of regeneration is common.

3.2.4 CLASSIFICATION

There are about 12,000 known species of segmented worms. Phylum Annelida is divided into 4 classes as Polychaeta, Oligochaeta, Hirudinea and Archiannelida. The classification is primarily based on the presence or absence of setae, parapodia and metamerism. The Class Polychaeta contains most of the living marine species. The Class Oligochaeta contains fresh water, marine and terrestrial earthworms. The Class Hirudinea, which includes the leeches, may arose from the stock of fresh water oligochaetes.

3.2.5 CLASS POLYCHAETA

Polychaeta means presence of many bristles (Gr. *Poly*= many; *chaete*= bristles).

These are common marine and carnivorous animals.

Body is usually elongated, cylindrical and distinctly segmented into numerous similar segments or metameres.

Majority of polychaetes are less than 10 cm long. Some interstitial forms are less than 1 mm.

Species of *Eunice* and *Neries* may attain a length of greater than 1m.

Many polychaetes exhibit beautiful colors – red, pink or green or a combination of these colors.

Depending on their body design, polychaetes have either protonephridia or metanephridial systems.

The head or acron represented by the well developed prostomium, which bears eyes, tentacles, cirri and ventrolateral palps. The post oral region is called peristomium (Fig. 3-1).

Each segment bears a pair of fleshy, lateral paddle like appendages called parapodia.

Setae are numerous and are borne up on parapodia.

Clitellum is absent.

Parapodia are highly vascular and respiratory in function.

Coelom is spacious and usually divided by intersegmental septa.

Alimentary canal is a straight tube extending from the mouth at the anterior end of the worm to the anus situated in the pygidium. The gut is differentiated into a pharynx (or buccal cavity if pharynx is absent), short oesophagus, stomach, intestine and rectum (Fig. 3-2).

The blood vascular system is well developed and does not communicate with coelom.

Polychaetes have great power of regeneration.

Sexes are separate. Gonads are simple and developed by active proliferation of coelomic epithelium.

Fertilization is external.

Development is indirect with a free swimming trochophore larva.

Asexual reproduction is by lateral budding.

Class Polychaeta is divided into two orders – Errentia and Sedentaria

3.2.5.1 ORDER ERRENTIA

Crawling, swimming, burrowing and tube dwelling worms. Free swimming forms are often pelagic while some are tubicolous. Segments numerous and all segments are similar except the head and tail regions. Parapodia are well developed Parapodia provided with acicula and setae. They are used for locomotion. The head is usually definite with eyes, tentacles and cirri. Pharynx is protrusible. Pharynx is provided with chitinous jaws and teeth. Clitellum is absent. The branchiae or gills are restricted to the anterior part of the body.

Aphrodita(Fig, 3-5), Nereis(Fig. 3-2), Glycera, and Syllis

3.2.5.2 ORDER SEDENTARIA

Sedentary in habit. Burrowing and tube dwelling. Body is distinguished into two or three regions due to differences in shape of segments, parapodia and setae. Parapodia reduced, without acicula or compound setae. Head is small without eyes. But head commonly provided with palps, tentacles and other structures for feeding. Prostomium indistinct and without sensory appendages. Gills when present are situated only in the anterior part. Pharynx is non-protrusible, without jaws or teeth. Feed on plankton or organic detritus. Parapodia are peculiar, without cirri and present only in the posterior region.

Chaetopterus, Sabella, Arenicola

3.2.6 CLASS OLIGOCHAETA

Oligochaetes have few bristles (L., Oligos = few, chaete = bristles). Mostly terrestrial, some live in fresh water.

Body with conspicuous external and internal segmentation (Fig. 3-10).

Head is not distinct. Prostomium is usually small. Eyes and tentacles are absent.

Parapodia and cirri are absent. Setae are usually arranged segmentally. Gills are also absent. But cutaneous net works are well developed.

Pharynx is not protrusible and without jaws.

Hermaphroditic with well developed ovaries and testes. Usually a clitellum is present.

Development direct without larval stage. Fertilization and development occur with in a coccon secreted by the clitellum.

The following classification is based on that of Brinkhurst and Jamieson (1972), modified by Jamieson (1978). Oligochaeta is divided into three orders – Lumbriculida, Tubificida and Haplotoxida.

3.2.6.1 ORDER LUMBRICULIDA

This order contains of fresh water forms. Body has few segments. Four pairs of setae per segment. Gizzard is either absent or poorly developed. Simple clitellum with single layer of cells situated forwards. Eye spots are usually present. Reproduction is both asexual and sexual. Male

reproductive openings lie in front of female reproductive openings.
Lumbriculus

3.2.6.2 ORDER TUBIFICIDA

Marine, fresh water and terrestrial forms. Setal bundles usually with two or more setae, rarely absent. Setae often hair like. One pair of testes followed by one pair of ovaries. Testes and ovaries lie in adjacent segments. Clitellum includes male and female gonopores.
Tubifex, Chaetogaster

3.2.6.3 ORDER HAPLOTOXIDA

Mostly terrestrial forms found in moist soil. Body is large with many segments. Setae are arranged in lumbricine manner. Gizzard well developed. Clitellum after 12th segment and is composed of two or more layers of cells. Eye spots are well developed. One pair of testes or ovaries or both often absent. Female genital apertures before male genital pore and usually lie in 14th segment. Reproduction by sexual method. No free larval stage.
Pheretima, Lumbricus (Fig. 3-10), Megascolex

3.2.7 CLASS HIRUDINEA

The Class Hirudinea contains more than 500 species.

They are marine, aquatic, terrestrial or free living worms, commonly known as leeches. Some are ectoparasitic and popularly considered to be blood-sucking annelids. But, a large number of leeches are not ectoparasites. The smallest leeches are 1 cm in length; but most species are 2 to 5 cm long.

Body is typically dorsoventrally flattened and tapered at the anterior end (Fig. 3-13).

Leeches have a fixed number of segments, 32 (or 34 according to some authorities who report that two segments have fused with the prostomium).

Body is segmented and is marked externally be ring-like annuli.

The number of annulations per segment varies not only in different regions of the body but also on different species.

Parapodia and head appendages are absent.

Anterior and posterior cup-shaped suckers are present. They help in adhesion and locomotion.

Mouth is ventral and surrounded by anterior sucker.

Anus is dorsal and situated just above the posterior sucker.

Coelom is greatly reduced due to the presence of connective tissue and is represented by haemocoelomic sinuses. The true blood vessels with definite muscular walls present.

The body wall consists of a cuticle, epidermis and a thick fibrous connective tissue beneath the epidermis.

Gills are found only in the Piscicolidae(Fish leeches).

In other leeches, the general body surface provides the site for gas exchange.

Leeches possess either an eversible proboscis or noneversible sucking pharynx and jaws. Unicellular salivary glands open into the proboscis. Salivary glands secrete an anticoagulant called hirudin. The buccal cavity opens into a muscular pharynx and then to oesophagus. The short oesophagus either opens directly into a relatively large stomach, or a crop. The stomach is provided with 1 to 4 pairs of lateral caeca. The stomach opens into an intestine and the intestine opens into short rectum. The rectum opens outside by a dorsal anus. Leech digestion is slow because the gut secretes only exopeptidases. Also, leech gut possess symbiotic bacterial flora that is important in nutrition. The bacterial flora also produces vitamins and other compounds that are used by leech host.

The nervous system consists of a brain united by small oesophageal connectives to a double ganglionated ventral nerve cord.

Nephridia are the excretory organs. Leeches contain 10 to 17 pairs of metanephridial tubules, situated in the middle third of the body. Nephridia are segmentally arranged and open independently to exterior by nephridiopore. Nephridia are the important organs of osmoregulation.

Unlike many other annelids, leeches do not reproduce asexually, nor they can regenerate lost parts.
Hermaphroditic. The testes are many and segmentally arranged, whereas the ovary is single, paired.
Eggs are laid in cocoons.
Fertilization is internal.
Development is direct without larval stage.
Hirudinea is divided into 4 orders – Acanthobdellida, Rhynchobdellida, Gnathobdellida and Pharyngobdellida.

3.2.7.1 ORDER ACANTHOBDELLIDA

A primitive order contains a single species. Mostly ectoparasitic on the fins of salmon fishes. Anterior sucker absent, posterior sucker well developed. Proboscis small and not well developed. Nephridia without internal openings. Body generally composed of twenty or twenty-one segments. It forms a connecting link between Oligochaeta and Hirudinea.
Acanthobdella

3.2.7.2 ORDER RHYNCHOBDELLIDA

Aquatic leeches, parasitic on snails, frogs and fishes. The anterior part of body may be protruded and retracted so as to form a proboscis or introvert. Jaws are absent. Each typical body segment consists of 3, 6 or 12 rings. The mouth is minute slit-like opening. It lies inside the anterior sucker. Blood is colorless. Coelom is reduced to sinuses without botryoidal tissues.
Glossiphonia, Pontobdella

3.2.7.3 ORDER GNATHOBDELLIDA

Fresh water and terrestrial forms. Amphibious or aquatic blood sucking leeches. Ectoparasites and blood sucking. Each typical segment consists of five rings or annuli. Anterior sucker has three jaws, one median dorsal and two ventro-lateral. Proboscis is non-protrusible or absent. Blood is red in color. Coelom is reduced. Botryoidal tissue is present.
Hirudo, Hirudinaria, Haemopis

3.2.7.4 ORDER PHARYNGOBDELLIDA

Fresh water, amphibious, carnivorous leeches. Each body segment is divided into five rings or annuli. Pharynx non-protrusible. Jaws are absent.

Dina, Erpobdella

3.2.8 CLASS ARCHIANNELIDA

Most modern authorities on the annelids agree that the old phylum or class Archiannelida represents a group/collection of different examples of one class of modified annelids. These modified annelids probably belong to the class Polychaeta. Most are members of the interstitial fauna.

This group may represents the primitive members or modified forms of Annelida.

Mostly marine forms.

Body is elongated, cylindrical with internal segmentation.

The head is distinct bearing the tentacles, eyes and ciliated pits.

Parapodia are wanting.

Hermaphroditic or dioecious. Gonads are simple and develop temporarily only during breeding season by active proliferation of coelomic epithelium.

Polygordius, Protodrilus, Nerilla

3.2.9 SUMMARY

Phylum Annelida is divided into 4 classes as Polychaeta, Oligochaeta, Hirudinea and Archiannelida.

Annelids are bilaterally symmetrical with elongate vermiform body.

The Class Polychaeta is divided into two orders: Errantia and Sedentaria.

Polychaetes are marine and carnivorous.

Surface dwelling, errant polychaetes possess well developed heads with sense organs.

Head shows prostomium and peristomium with eyes and tentacles in Polychaetes.

Most are predaceous, but some are herbivorous or scavengers. They typically possess an eversible pharynx equipped with jaws.

Permanently tube dwelling polychaetes feed upon microscopic particles brought in by ciliated tentacles.

Respiration is by epidermis, or by gills in some tube dwellers.

Parapodia are well developed in Polychaetes. They crawl with the parapodia using them as leg like appendages.

Excretion takes place with the help of a pair of nephridia. Polychaetes that lack a blood vascular system possess protonephridia.

Circulatory system is closed. Blood plasma contains dissolved hemoglobin and free amoebocytes.

Nervous system consists of a dorsal brain, a ventral nerve cord and a pair of circum pharyngeal connectives.

The sexes are separate in most polychaetes.

A free swimming trochophore larva is seen in Polychaetes.

The Class Oligochaeta is divided into three orders: Lumbriculida, Tubificida and Haplotoxida.

Oligochaetes are mostly terrestrial, some are fresh water species.

In oligochaetes head is not distinct with a small prostomium, devoid of eyes and tentacles.

Parapodia are absent in oligochaetes.

A clitellum is usually present in oligochaetes.

Development is direct in oligochaetes without a larval stage.

The Class Hirudinea is divided into four orders: Acanthobdellida, Rhynchobdellida, Gnathobdellida and Pharyngobdellida. Hirudinids are commonly known as leeches.

Some hirudinids are ectoparasites and blood sucking annelids.

The body of leeches is marked externally by ring-like annuli.

Coelom is greatly reduced in Hirudineans.

Fertilization is internal and development is direct without a larval stage.

Archiannelids are primitive annelids.

The body of Archiannelids shows internal segmentation only.

Parapodia are absent in Archiannelids.

Gonads develop temporarily only during breeding season in Archiannelids.

3.2.10 KEY TERMINOLOGY

Botryoidal tissue: A tissue present in Hirudinids beneath the longitudinal muscles. It consists of a network of large branching tubular cells, which are loaded with a dark brown pigment.

Clitellum: In earth worm, 14^{th} to 17^{th} segments are swollen into a ring-like structure called clitellum.

Determinate cleavage: Developmental process during which the fate of the blastomeres are fixed in early cleavage.

Hermaphrodite: Having both male and female reproductive systems in one individual.

Metamerism: The divisions of an animal's body into a linear series of similar parts or segments.

Nephridium : An excretory tubule, which usually opens to the exterior by a nephridiopore. The inner end of the tubule may be blind, ending in flame bulbs or flame cells(protonephridium) or may open into coelom through a ciliated fummel (metanephridium)

Nephrostome: A ciliated funnel through which the excretory tubule of a metanephridium communicates with the coelom

Oligochaete: Annelid having well developed metamerism and a simple prostomium. Parapodia are absent. Few bristles or setae are present.

Parapodia: Lateral, fleshy, paddle like appendages in polychaete annelids.

Peristomium: The post oral region of polychaete annelid (the first true segment)

Polychaete: Annelid having many similar segments. Parapodia are well developed with bristles or setae. Head with sensory structures.

Prostomium: The head or a crown of polychaete and oligochaete is represented by prostomium.

Protostome : Member of a major branch of the Animal Kingdom, in which the blastopore contributes to the formation of mouth.

Pygidium: The terminal nonsegmented region, which carries the anus.

Setae: Chitinous, lateral bristles. Useful to increase traction with the substratum.

Spiral cleavage: Type of cleavage pattern in which the cleavage spindles or cleavage planes are oblique to the polar axis of the egg.

Trochophore: Larval stage found in Polychaete annelids.

3.2.11 SELF ASSESSMENT QUESTIONS

1. Classify the phylum Annelida unto orders.
2. Write short notes:

    a. Classification of Class Polychaeta.
    b. Classification of Class Oligochaeta.
    c. Classification of Class Hirudinea

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3.3 GENERAL ORGANIZATION OF PHYLUM ARTHROPODA

3.3.1 OBJECTIVES

The purpose of this lesson is to:

- understand the general characters of Phylum Arthropoda.
- to study the general physiology of arthropods.

3.3.2 INTRODUCTION

Phylum Arthropoda includes a vast assemblage of animals. They are adapted to different types of habitats. Arthropods like annelids are segmented animals. They are probably evolved from annelids or at least from some common ancestor forms. The annelidan ancestry of arthropods is evident in their segmentation, the plan of the nervous system and the determinate type of cleavage. Arthropods make their appearance in the fossil record during the Cambrian along with many other invertebrates. One of the most common groups of fossil arthropods was included in the sub phylum trilobita. The marine Paleozoic trilobites are a group of extinct primitive arthropods.

Most zoologists today agree that there are probably 4 main lines of arthropod evolution: extinct Trilobita, the chelicerata, the Crustacea and the Uniramia. The Chelicerata contains the horseshoe crabs, scorpions, spiders and mites. The Crustacea contains the copepods, barnacles, shrimps, lobsters and crabs. The Uniramia includes centipedes, millipedes and insects.

3.3.3 FOSSIL ARTHROPODS

The fossil arthropods are kept in a separate Phylum Trilobita. More than 3,900 species have been described from fossil specimens. Trilobites ranged from 3 – 10 cm in length. The largest trilobites are less than 1 meter in length. The trilobite body was somewhat oral and flattened. The body was divided into 3 more or less equal sections: a solid anterior cephalon, an intermediate thorax or trunk region and a posterior pygidium (Fig. 3-18). Each of these body divisions was again dividec into 3 regions by a pair of furrows. These furrows extend from anterior to posterior end of the body. These furrows divide body segments to form a median axial lobe planked on each side by a lateral lobe. The name trilobita refers to the transverse trilobation of the dorsal body surface. Trilobites exhibit diversity in size, shape, spination, eye size and positions. The variation in the body form indicates that they lived in a variety of habitats. The majority were bottom dwellers such as burrowers, epibenthic crawlers, planktonic forms and swimmers. The Cambrian fossil record, especially that of the Bergies Shale of British Columbia contains a number of arthropods that are trilobites and do not fit into any of the existing arthropod taxa.

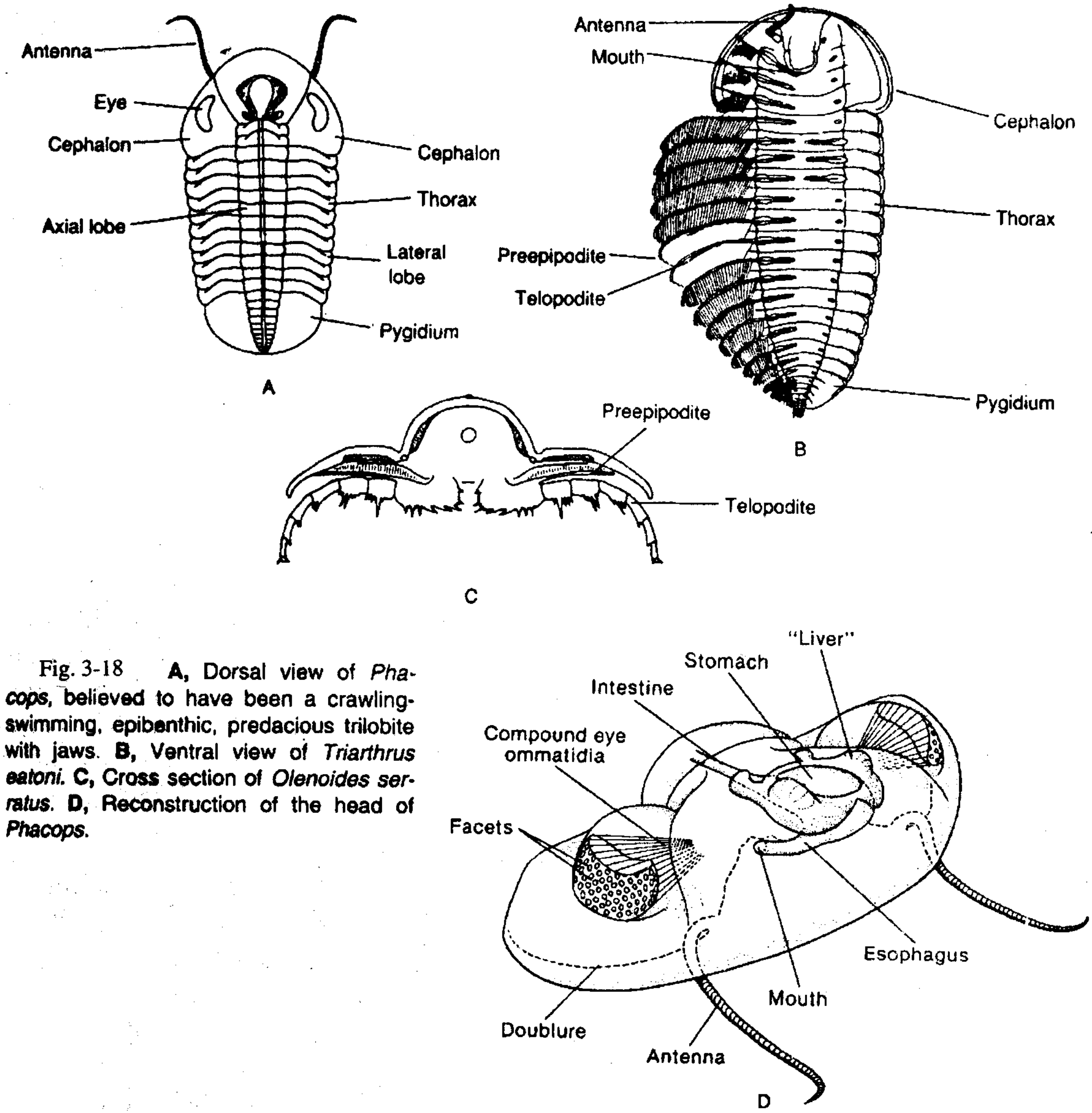


Fig. 3-18 **A,** Dorsal view of *Phacops,* believed to have been a crawling-swimming, epibenthic, predacious trilobite with jaws. **B,** Ventral view of *Triarthrus eatoni.* **C,** Cross section of *Olenoides serratus.* **D,** Reconstruction of the head of *Phacops.*

3.3.4 EXTERNAL STRUCTURE

Segmentation of the body is the characteristic feature of arthropods. Segmentation is evident in the embryonic development of all arthropods. Growth in arthropods results from the addition of new segments to the region immediately anterior to the terminal section of the body (telson). Annelid prostomium and pygidium correspond respectively to a crown and telson of arthropods. In some forms, such as mites, the segmentation is almost disappeared. The distinguishing feature of arthropod is the chitinous exoskeleton, or cuticle that covers their entire body (Fig. 3-24). Basically the cuticle of each segment is divided into 4 primary plates: a dorsal tergum, a ventral sternum and two lateral pleura. In all arthropods some degree of fusion and grouping of segment skeletal plates has occurred. As a result the body shows 3 regions. For example, in bees the body is divided into three segments: head, thorax and abdomen. The cuticle skeleton of the appendages has also been divided into tube like sections. Articular membranes connect these sections to one another. Thus at each junction a joint is created. Such joints help the sections of the appendages and the body to move. Hence the name of the phylum arthropod "jointed feet". In addition to the exoskeleton, the endoskeleton has also been developed in some forms. Arthropods exhibit different colors. The color of arthropods commonly results from the deposition of brown, yellow, orange and red melanin pigments with in the cuticle. Body coloration is also produced by sub-cuticular pigment cells (chromatophores) or is caused by blood and tissue pigments. Arthropods are able to shed their skin periodically, a process called molting or ecdysis. The number of segments forming the head varies in the different classes but is constant for each class. The head consists of fused segments of the anterior region. The head bears sense organs like the antennae and eyes, and also the brain and the mouthparts. The number of segments of the thorax or abdomen also varies in different classes.

The body of a chelicerate is divided into a cephalothorax (prosoma) and an abdomen (opisthosoma). Only in the sub phylum of arthropods, Chelicerata, antennae are absent. This is the most distinguishing feature of the sub phylum. The first pair of appendages is feeding structures called chelicerae. The second pair is called pedipalps. These are modified to perform different functions in different arthropods. 4 pairs of legs usually follow the pedipalps.

In horseshoe crabs, a large horseshoe shaped carapace covers the prosoma. The abdominal segments are fused together. A posterior spike like telson is used for pushing (Fig. 3-19). The scorpion body consists of carapace covered prosoma and a long abdomen ending in a stinging apparatus. A pair of large elevated median eyes and 2 – 5 pairs of small lateral

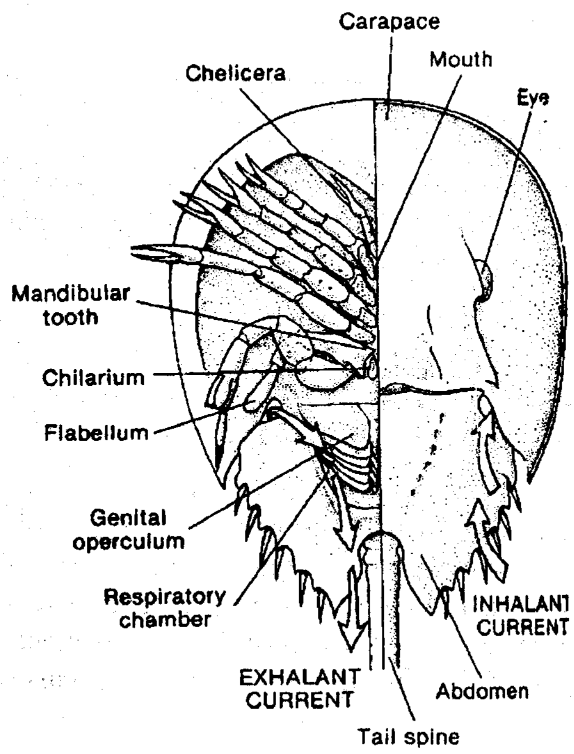


Fig. 3-19. A horseshoe crab. *Limulus polyphemus*, in combined ventral (left) and dorsal (right) views. Arrows show water currents.

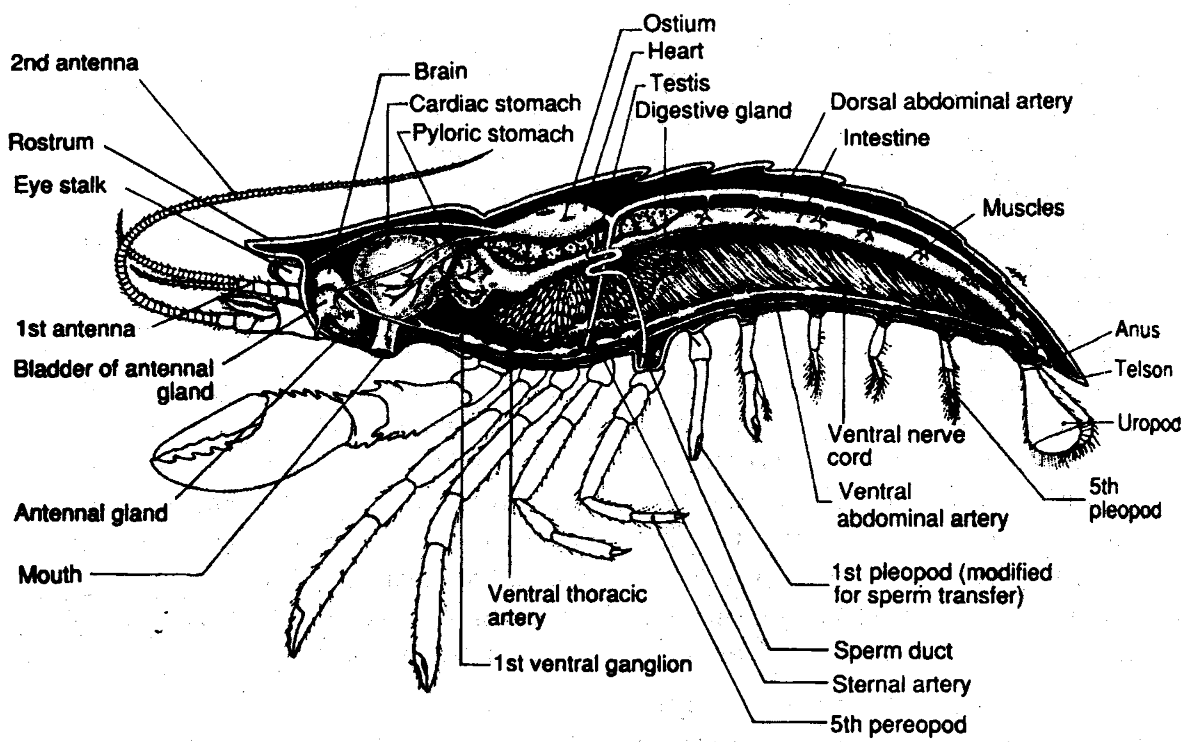


Fig. 3-20. Crustacean structure. Internal structure of a crayfish (lateral view).

eyes are present on the head (Fig. 3-32). In pycnogonids or sea spiders, the body is narrow and is composed of the head or cephalon and prosoma. The appendages consist of a pairs of palps, a pair of ovigerous legs and 4 pairs of walking legs (Fig. 3-27).

Crustaceans are the only major group of aquatic arthropods. The body of a crustacean is divided into a head and trunk. The head appendages are: 1 pair of mandibles and 2 pairs of maxillae. A carapace covers all parts of the body. Crustacean appendages are typically biramous and the appendages have become modified to perform different functions (Fig. 3-20).

In the 4 groups of uniramian arthropods the body is divided into an anterior head and a long trunk. They possess one pair of antennae and the mouthparts including a pair of mandibles. They are called uniramians because of the apparent unbranched nature of their appendages. The long trunk shows many segments and appendages. Centipedes possess 1 pair of legs per segment (Fig. 3-21). Millipedes possess 2 pairs of legs per segment (Fig. 3-22). Onychophorans possess a pair of antennae, a pair of claw like mandibles and many pairs of non-jointed, peg like legs (Fig. 3-23)

3.3.5 BODY COVERING

In all arthropods except *Peripatus* the body is covered with thick cuticle or chitinous exoskeleton. The underlying epidermis secretes the cuticle. The exoskeleton (cuticle) is segmented corresponding to the segmentation of the body. The segments are intervened by soft skin. The

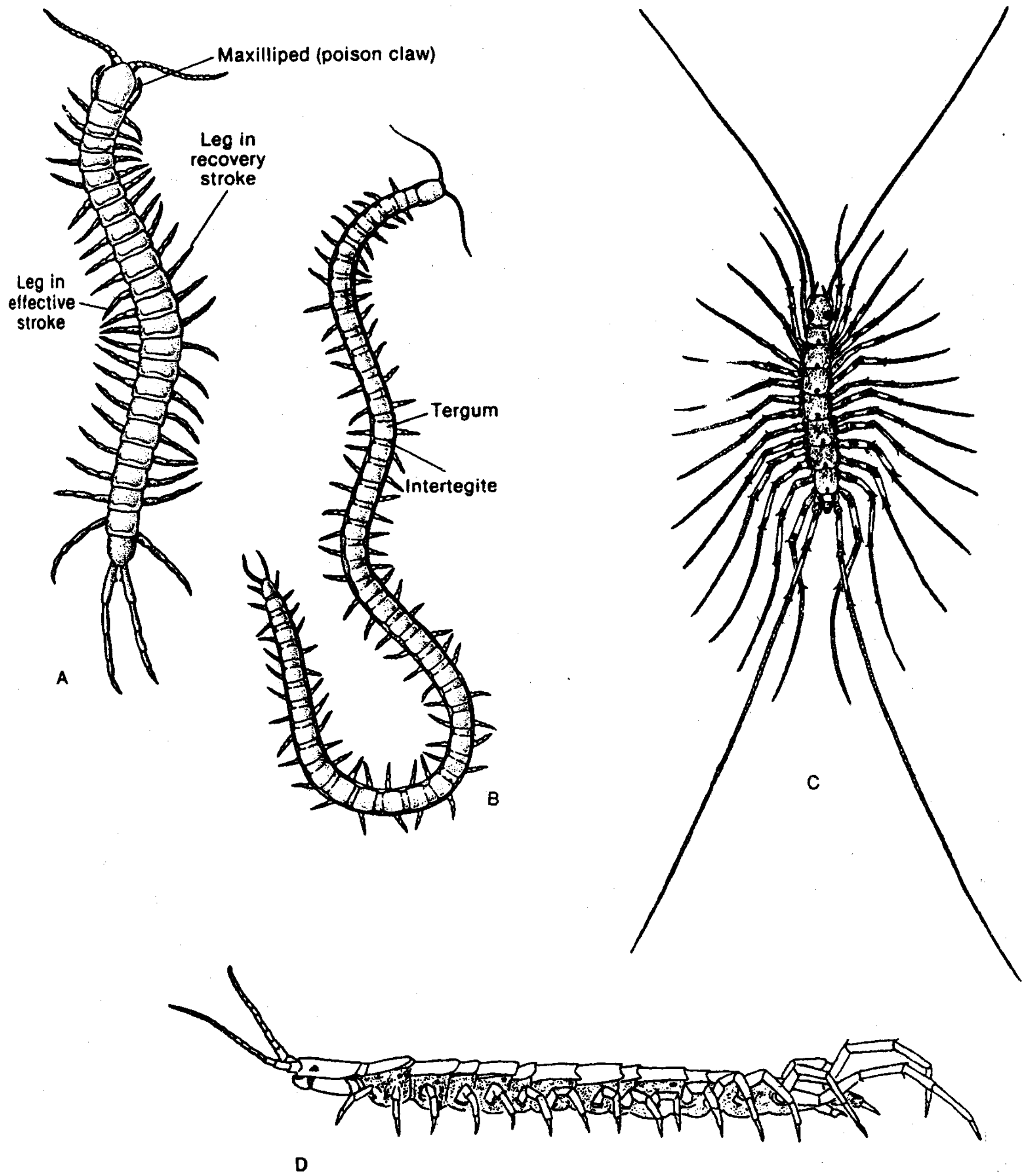
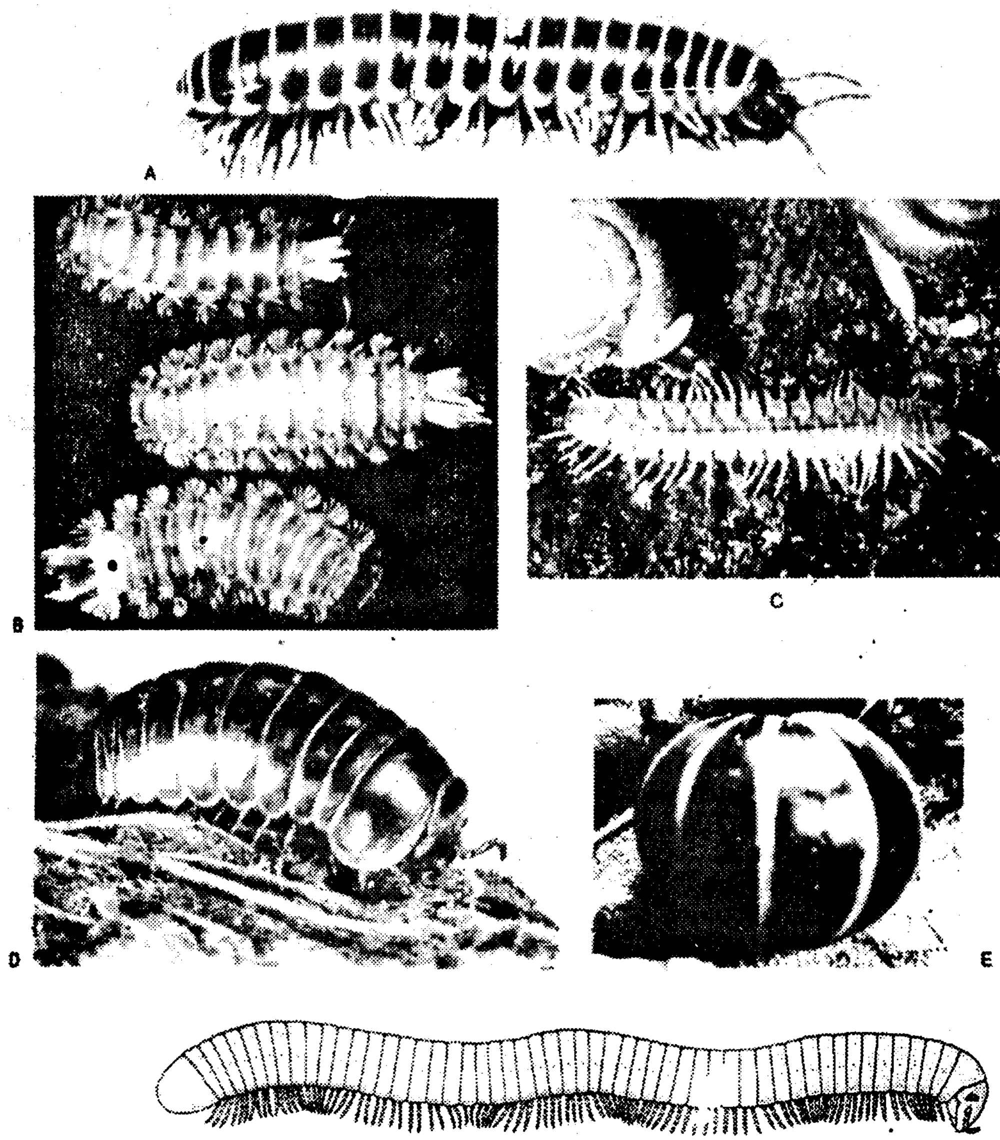


Fig. 3-21. Chilopoda. **A,** *Otocryptops sexspinnosa,* a scolopendromorph centipede. **B,** A geophilomorph centipede. **C,** *Scutigera coleoptrata,* the common house centipede, a scutigeromorph. **D,** *Lithobius*, a lithobiomorph centipede.

exoskeleton protects the body. The exoskeleton is secreted by the underlying epidermis or hypodermis. It is composed of a thin outer cuticle and a much thicker procuticle. The epicuticle is composed of proteins and in many terrestrial arthropods, wax (hydrocarbons). The fully developed procuticle is composed of an outer exocuticle and an inner endocuticle. Both the exo and endo cuticle layers are composed of chitin and protein bound together to form a complex glycoprotein. The exoskeleton may become tanned by stabilizing the organic molecules. In most terrestrial arthropods the waxy epicuticle



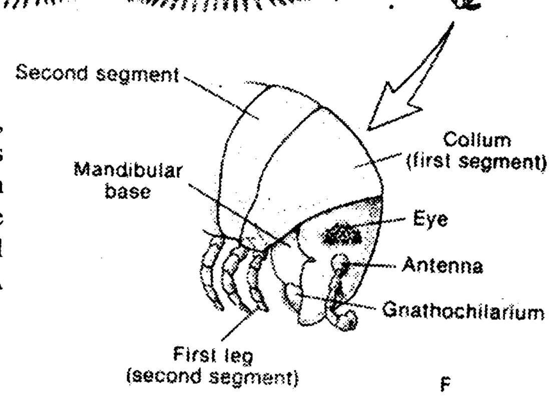


Fig. 3-22. Diplopoda. A, A polydesmid millipede, *Sigmoria.* B, Pselaphognath millipedes of the genus *Polyxenus.* These tiny millipedes are only 4 mm in length. The legs are obscured by the large, scalelike spines. C, A flat-backed millipede. D, The pill millipede. *Glomens,* E, *Glomens* rolled up. F, A juliform millipede.

plays an important role in reducing the water loss and in acting as a water repellent preventing from the submersion in drops of rain or dew.

blood vessel situated above the digestive tract and posteriorly in a ventral blood vessel situated below the digestive tract. At the anterior end of the body the dorsal blood vessel is connected to a ventral vessel by one or two or several vessels. In each segment the ventral vessel gives rise to one pair of ventral parapodial vessels and to several intestinal vessels. Parapodial vessels supply the parapodia, the body wall and the nephridia. The ventral intestinal vessels supply the gut. The dorsal vessel, in turn, receives a corresponding pair of dorsal parapodial vessels, and a dorsal intestinal vessel. A network of smaller vessels interconnects all these paired dorsal and ventral vessels.

The blood contains few cells compared with coelomic fluid. The blood also contains the respiratory pigment, hemoglobin. In the majority of polychaetes, the hemoglobin function in oxygen transport. In *Glycera,* the hemoglobin may also store glycogen during the resting period.

3.1.3.G EXCRETION

Polychaete excretory organs are either protonephridia or metanephridia. Generally nephridia are distributed as one pair per segment. Polychaetes that are in lack of blood vascular system (nine families and all larvae) and those with reduced blood system (five families) have protonephridia. All others have metanephridia (Fig. 3-6).

The protonephridia have terminal cells called solenocytes (Fig. 3-7). Each solenocyte has a single flagellum and a long tubular filtration collar which empties into the lumen of protonephridial

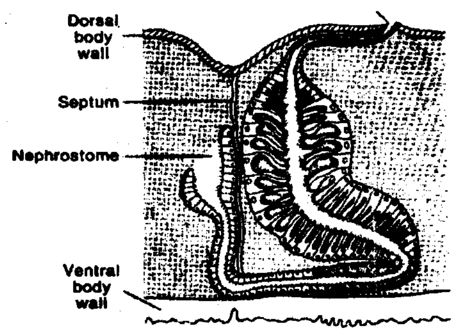
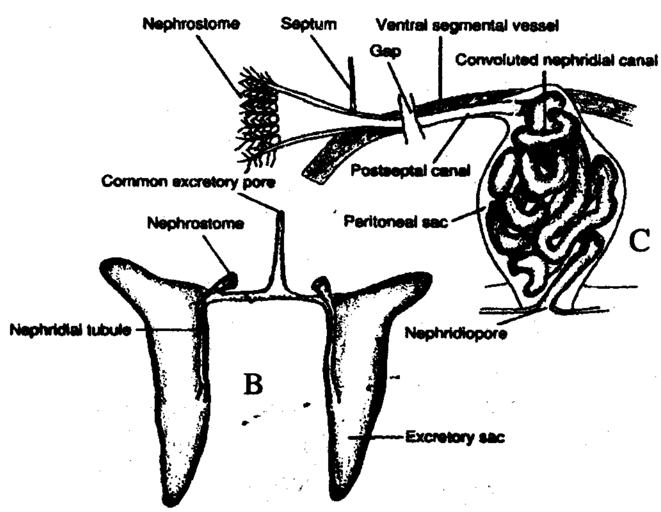


Fig. 3-6. Polychaete metanephridial systems. **A-C,** Metanephridia of three polychaetes: **A,** The spionid, *Polydora* (this nephridium also fabricates spematophores); **B,** The serpulid fan worm, *Pomatoceros;* **C,** *Nereis vexillosa.*



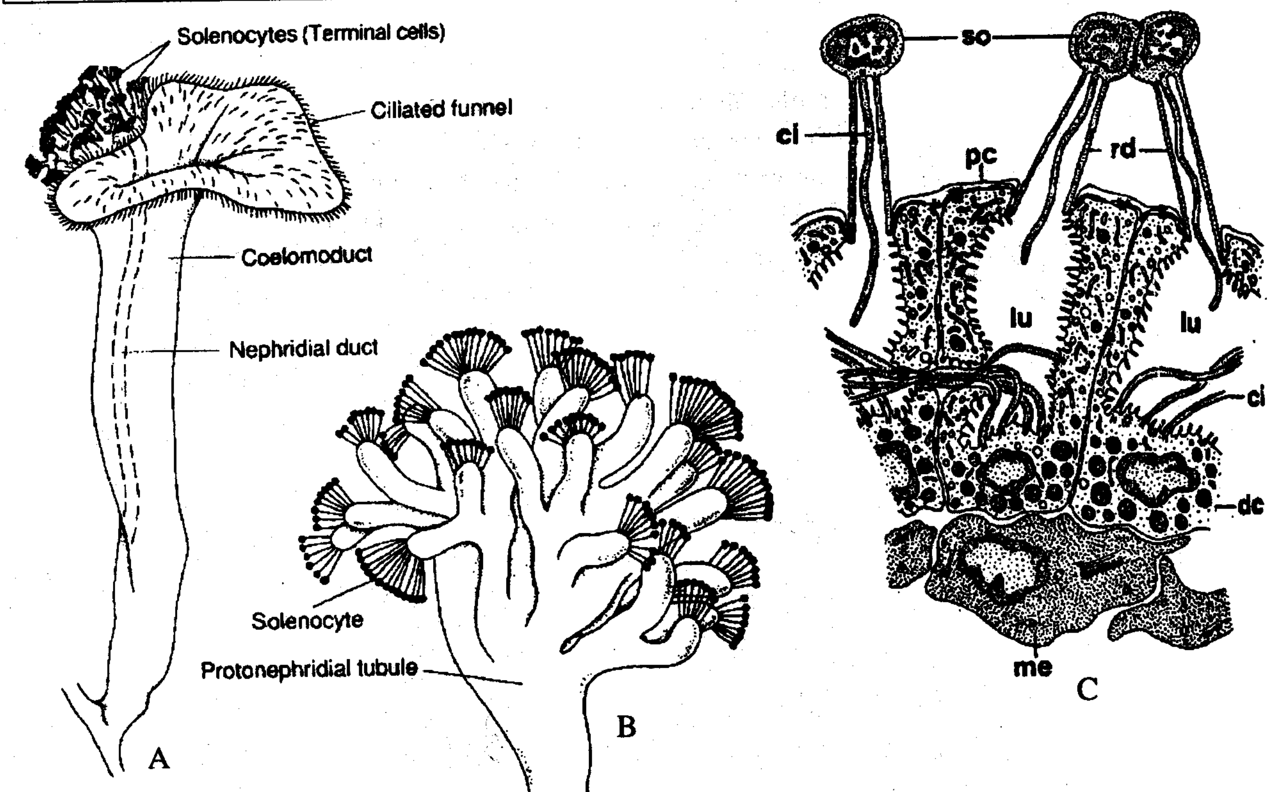


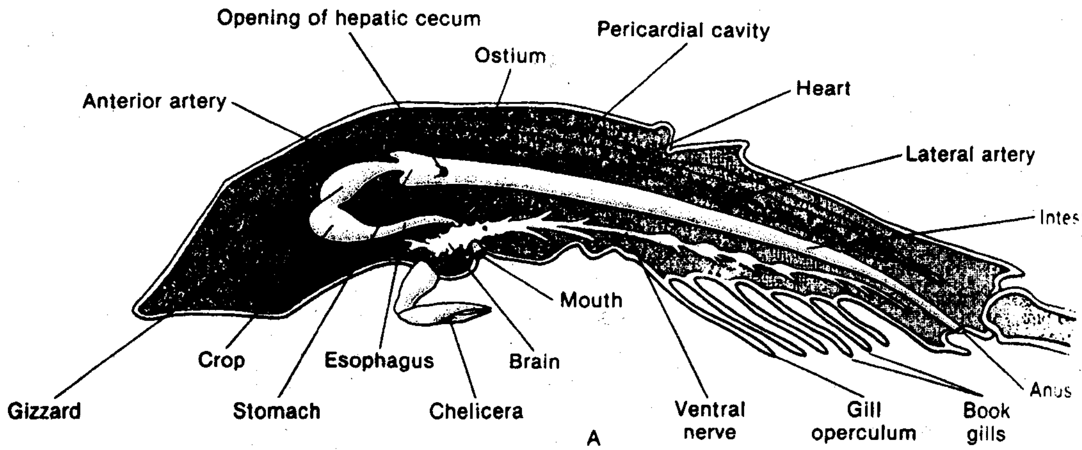
Fig. 3-7. **A**, Protonephridium and coelomoduct (gonoduct) of *Phyllodoce paretti*. **B**, Branched end of protonephridium of *Phyllodoce paretti*. **C**, Ultrastructure of three terminal cells and the collecting protonephridial tubules (lu) of the bloodworm, *Glycera dibranchiata*.

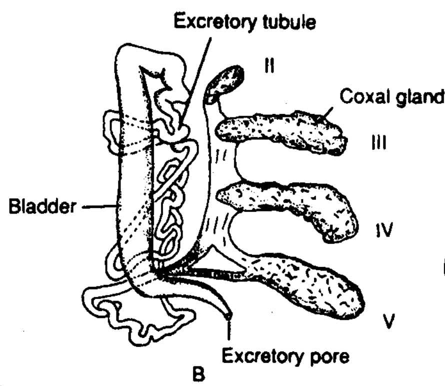
tubule. Reabsorption of salts occurs in the protonephridial tubule, which is identical histologically to a metanephridium. Each nephridium is a coiled tube, opening by one end into the body cavity, and by the other to the exterior on the surface of the skin. The internal ciliated funnel is known as the nephrostome and the external opening is called the nephridiopore. The nephrostome lies in one segment and the coiled nephridial duct and nephridiopore lie in the succeeding segment. The metanephridia of most other polychaetes differ only in minor details. A well-developed nephridial blood supply is absent in fan worm and arenicolids. The waste from the blood to the metanephridia is removed by coelomic fluid.

Chloragogen tissue, coelomocytes and the intestinal wall play a secondary role in excretion. This tissue is present on the wall of the intestine and the wall of the blood vessel. Chloragogen tissue is composed of brown or greenish peritoneal cells. It is an important center of hemoglobin synthesis and nutrient synthesis and storage.

3.1.3.H NERVOUS SYSTEM

The nervous system consists of a bilobed brain and a ventral nerve cord with metamerically arranged ganglia. The brain lies beneath the dorsal epithelium. The brain supplies nerves to the palps, antennae, eyes and nuchal organs. A pair of circumpharyngeal or circumoesophageal connectives surrounds the anterior gut and interconnects the brain and the ventral nerve cord.





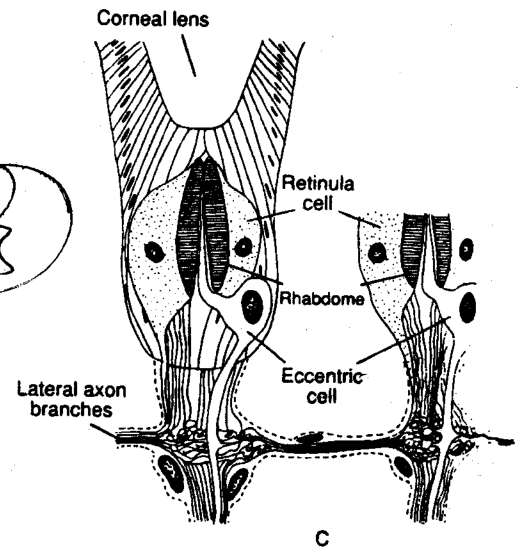


Fig. 3-25 **A,** Sagittal section through *Limulus*. **B,** Coxal glands and ducts of *Limulus*. **C,** Longitudinal section through two ommatidia of the eye of *Limulus*.

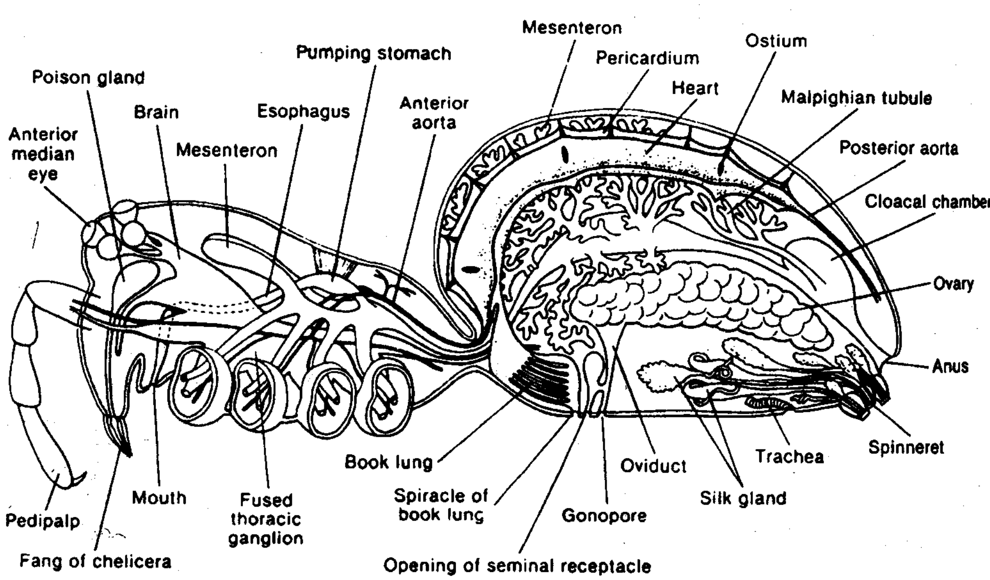


Fig. 3-26. Internal anatomy of an araneomorph spider.

foregut (Fig. 3- 26). The pharynx serves as the chief pumping organ to pump the liquid food into the foregut. The oesophagus conveys the food to the midgut. The central, tube like midgut possesses lateral diverticula. These diverticula become filled with the partially digested liquid pumped into the foregut. The midgut wall consists of secretory cells and absorptive cells. Extra cellular digestion occurs by the enzymes produced by secretory cells. The interstitial cells, which are present surrounding the diverticula, store much of the digested food. Waste is egested by anus.

Pycnogonids are carnivorous and feed on hydroids, soft corals, anemones, bryozoans and sponges. The cylindrical proboscis, which lies at the anterior of the head, is used to directly penetrate the prey and suck the tissues. Mouth lies at the tip of the proboscis. From the mouth a tubular pharynx extends through the proboscis (Fig. 3 - 27). The pharynx macerates the food and also acts as a pump. The pharynx opens into an oesophagus and then into an intestine. The intestine constitutes the midgut of the digestive tract. A long lateral caecum extends into each appendage and in the legs. Intracellular digestion occurs in the walls of the intestine and the caeca. Undigestible waste materials are ejected by anus that lies at the tip of the abdomen.

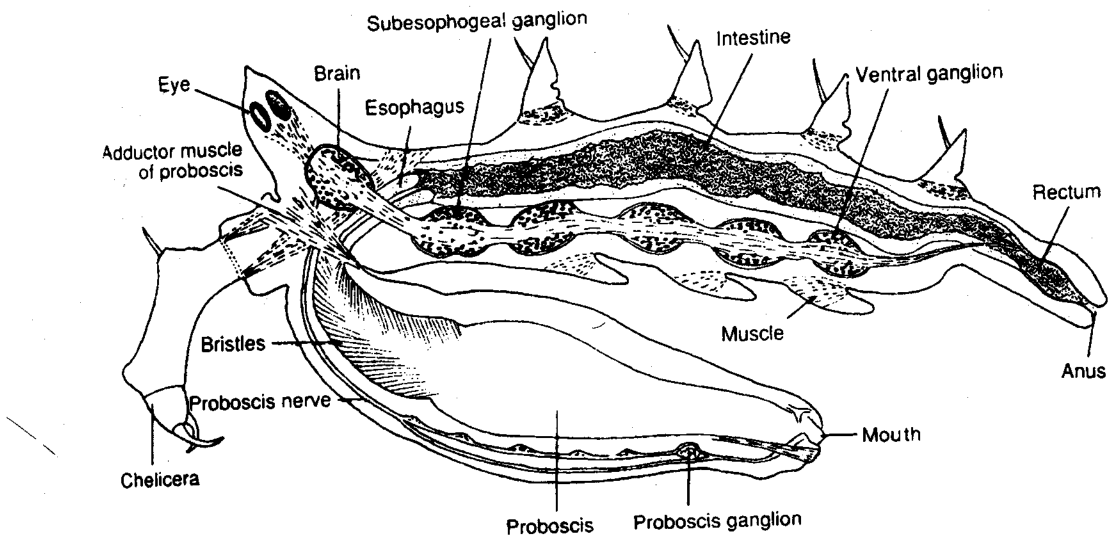


Fig. 3-27. The pycnogonid, *Ascorhynchus castelli* (sagittal section).

The crustaceans use a great range of diets and feeding mechanisms. The mouth is ventral and the digestive tract is almost straight (Fig.3 -20). The foregut may only be a simple tubular oesophagus. The oesophagus functions as triturating stomach. The walls of the stomach bear opposing chitinous ridges, denticles and calcareous ossicles. The size of the midgut varies. The midgut possesses one to several pair of caeca. In malacostracans, one pair of caeca, has always modified to form large solid digestive glands (the hepatopancreas) composed of ducts and sensory tubules. The secretory tubes are blind and without openings. The secretions of these tubes are composed of digestive enzymes. Digestion of food material occurs in the midgut and in the stomach of triturating stomach of the foregut when this chamber is present. The midgut walls and the tubules of hepatopancreas contain cells for storage

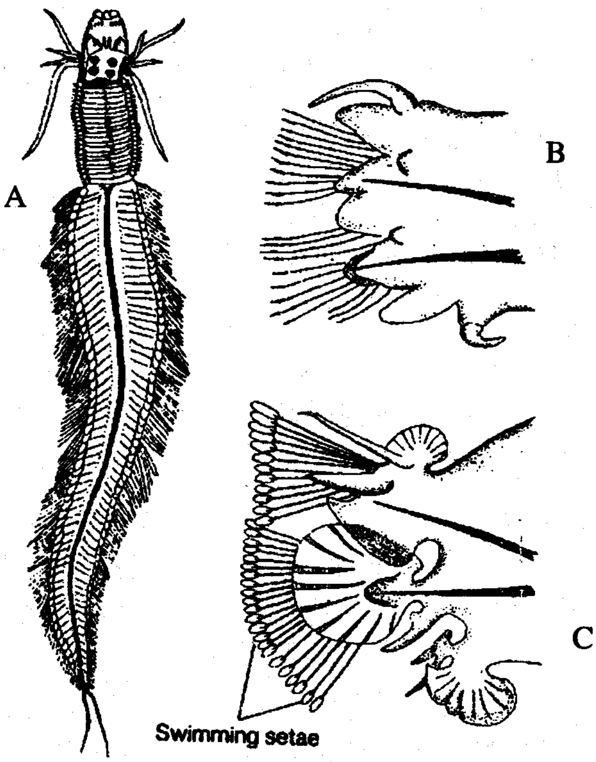


Fig. 3-9. **A,** Epitokous male of *Nereis irrorata*. **B** and **C,** Parapodia of atoke (**B**) and epitoke (**C**) of *Nereis irrorata* male.

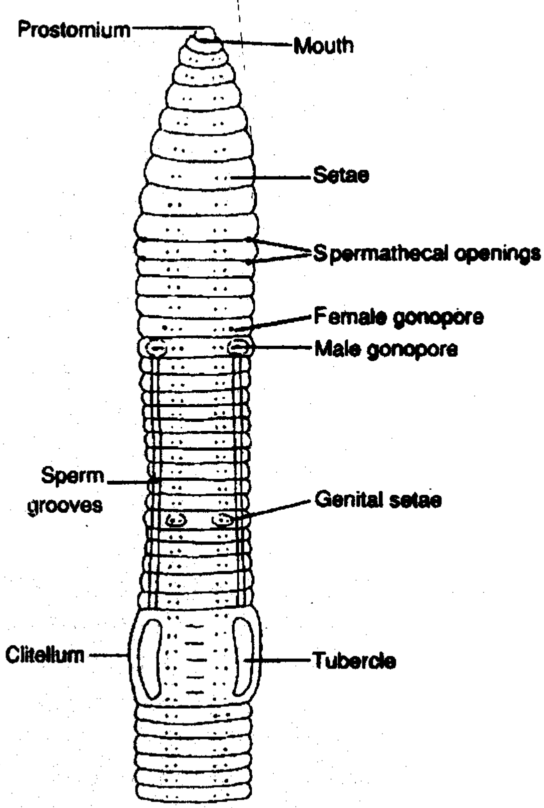


Fig. 3-10. Anteroventral surface of the earthworm, *Lumbricus terrestris.*

3.1.4 CLASS OLIGOCHAETA

The class Oligochaeta contains about 3100 species. It includes the familiar earthworms and many species, which live in fresh water.

3.1.4.A EXTERNAL STRUCTURE

In the oligochaetes segmentation is well developed. Parapodia are absent. The prostomium is usually a small, rounded lobe or a small comb. Sensory appendages are also absent (Fig.3-10). In *Stylaria,* the prostomium is drawn out into a tentacle. Oligochaetes have setae and in general, the longer setae are characteristic of aquatic species. Setae are found in groups or bundles. Two of these groups are ventral and two are ventrolateral or dorsolateral. The number of setae per bundle varies from 1 to 25. In any case the number of setae are few when compared to that of polychaetes. The name Oligochaeta is derived because of the presence of "few setae". In the familiar earthworm such as *Lumbricus,* the setae are limited to 8 with two setae in each bundle. In mature forms, in the anterior half of the body certain adjacent ridges are thickened and swollen. The mucus glands of these secrete mucus for copulation and also for cocoon formation. The glandular area of these segments is collectively called the clitellum. The distinguishing characters of the Oligochaeta include:

- The presence of clitellum
- Hermaphroditic reproductive system
- Eggs lying in a cocoon.
- The restriction of gonads in a few genital systems.

3.1.4.B BODY WALL

The body of oligochaetes is covered by means of a cuticle. Beneath the cuticle lies an epidermal layer consisting of mucus secreting gland cell. The circular muscles are well developed and the septa dividing the coelom are relatively complete.

3.1.4.C COELOM

Coelom is compartmented except at the extreme anterior and posterior ends. The coelom is connected to the outside by a mid dorsal pore, which is provided with the sphincter. These pores exude coelomic fluid, which helps in keeping the segments moist.

3.1.4.D LOCOMOTION

Oligochaetes exhibit crawling and burrowing movements. Circular muscle contraction and the consequent elongation of the segments are most important in crawling.

3.1.4.E NUTRITION

Majority of the aquatic, terrestrial and scavenger oligochaete feed on dead organic matter. The digestive tract is straight and relatively simple (Fig. 3-11). The mouth situated beneath the prostomium opens into a small buccal cavity, which in turn opens into more spacious pharynx. The pharynx opens into a narrow tubular oesophagus. The oesophagus may be modified at different levels to form a gizzard or crop. The gizzard is used for grinding food particles and is lined with cuticle. The gizzard is highly muscular. The crop if thin walled acts as a storage chamber.

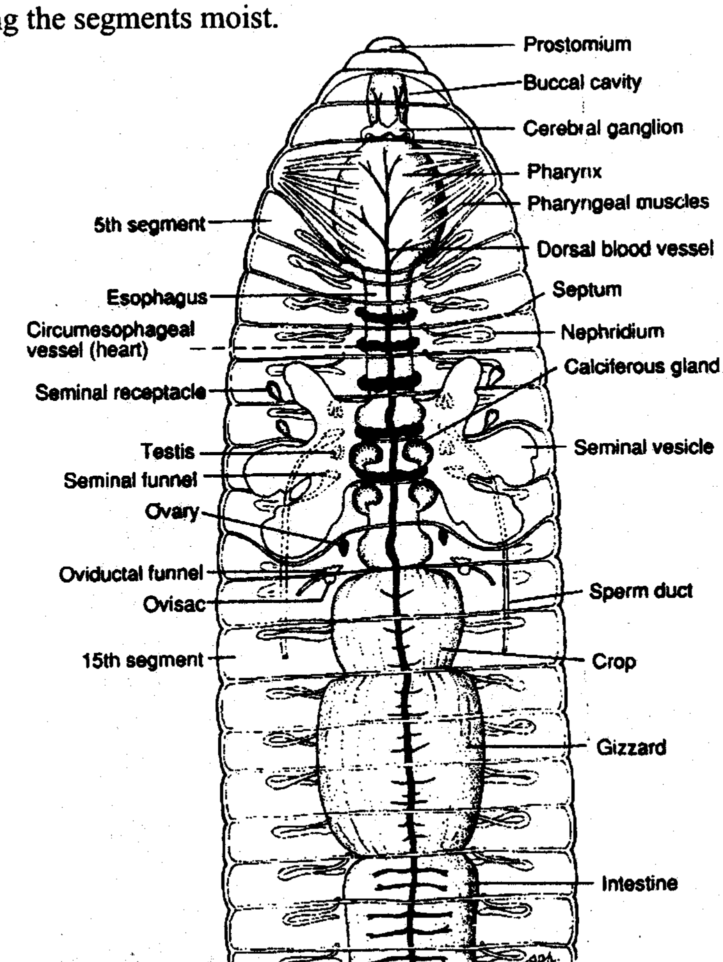


Fig. 3-11. Dorsal view of the anterior internal structures of the earthworm, *Lumbricus*.

The oliogochaete gut characteristically shows the presence of

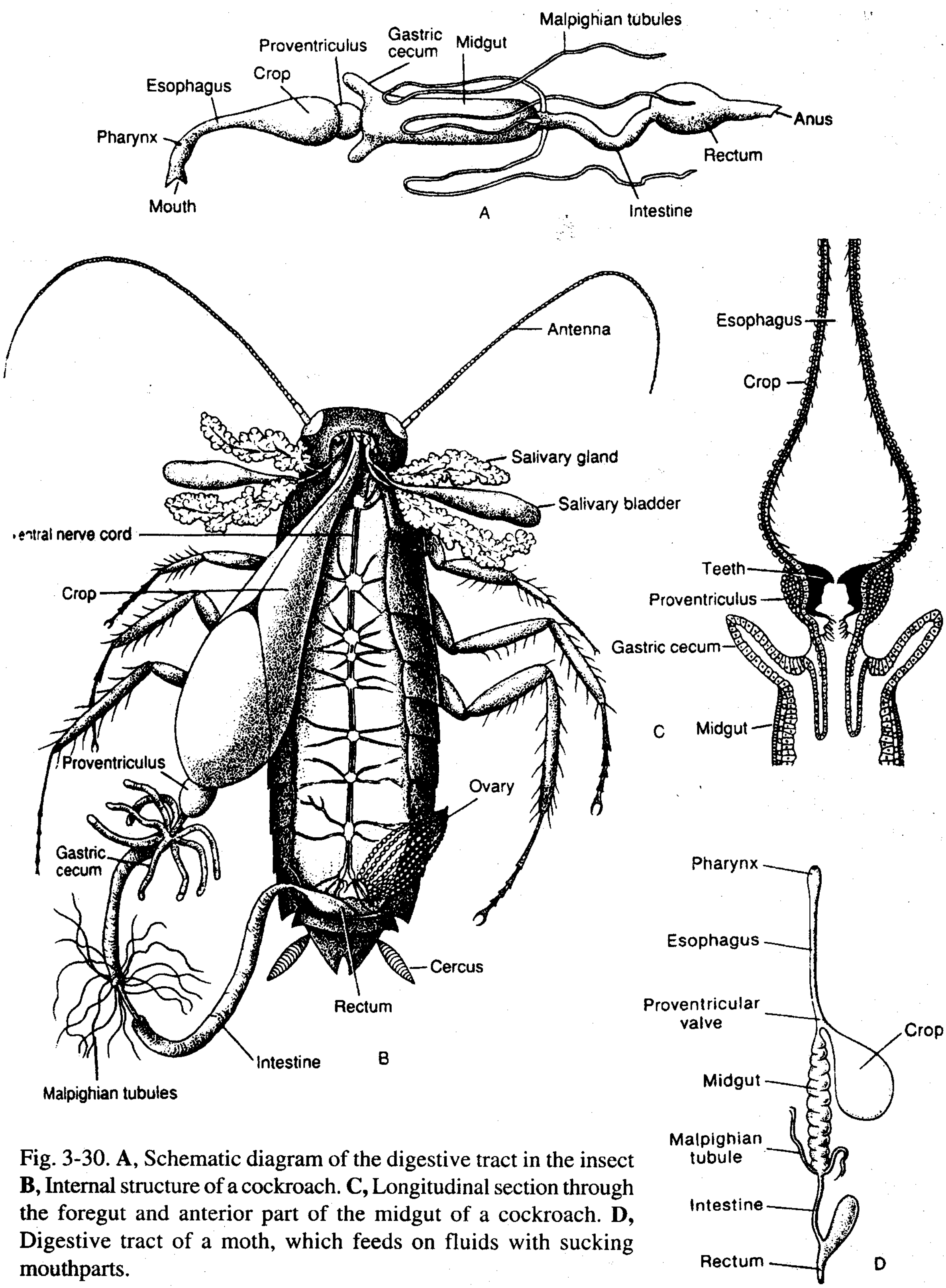


Fig. 3-30. **A**, Schematic diagram of the digestive tract in the insect **B**, Internal structure of a cockroach. **C**, Longitudinal section through the foregut and anterior part of the midgut of a cockroach. **D**, Digestive tract of a moth, which feeds on fluids with sucking mouthparts.

These lamellae are the sites for gas exchange (Fig.3-19). The arrangement of leaf like lamellae has caused the appendages to be called the book lungs. The lamellae are covered with water constantly due to the gill movement. The gills also function as paddles during swimming. Arachnid possesses book lungs or trachea or both. Book lungs are probably the modification of trachea. They are always two in number. Each book lung consists of a sclerotized pocket, which is an invaginated abdominal wall. The wall on one side of the pocket is folded into lamellae. Diffusion of gases occurs between the blood circulating within the lamellae and the air in the interlamellar spaces. The non-folded side of the pocket opens outside through a slit like opening (spiracle).

In arachnides trachea are highly developed in pseudoscorpions and in some sea spiders. A sieve tracheal system is present. In this type the spiracle opens into an atrial or tube like chamber from which arises a great bundle of trachea. In mites and other spiders the trachea are simple, branched or unbranched tubes terminating in the haemocoel. Some arachnids such as scorpions and many spiders with book lungs have the respiratory pigment haemocyanin. There are no special organs for gas exchange in pycnogonids. In the higher malacostracans the brancheae are adopted for respiration. In case of insects, aquatic respiration occurs with tubes called trachea. They branch extensively all over the body. The trachea open to the exterior by stigmata. The stigmata are valvular and lead into short tubes, which are connected with longitudinal trunks. From the longitudinal trunks, branches are given off as tracheoles. These tracheoles penetrate the tissues. The air from outside enters the tracheal tubes by the stigmata and is passed to the tissues directly. The alternate contractions and expansions of abdomen help the air to come inside and exit outside. Diffusion of respiratory gases occurs via tracheoles. The oxygen of the air passes into the tissues. The exchange of CO_2 occurs in tissues simultaneously. As the O_2 is directly passed to the tissues blood is not involved in respiration. A tracheal system functions to exchange gases in the uniramian arthropods.

3.3.9 EXCRETION

In aquatic chelicerates, excretion takes place through four pairs of coxal glands, two pairs located on each side of the gizzard (Fig.3-25B). The waste collected within a common sac like chamber exit outside through an excretory pore, which lies at the base of the last pair of walking legs. The coxal glands contribute to osmoregulation by producing dilute urine. When the animal is in brackish water coxal glands act as organs of osmoregulation.

In arachnids, excretion takes place by coxal glands and malpighian tubules. Guanine is the most important nitrogenous waste of arachnids. The waxy epicuticle contributes to the successful survival of terrestrial arthropods by conserving water. In addition to malpighian tubules and coxal glands, arachnids possess certain large phagocyte cells called nephrocytes.

The excretory organs of crustaceans are a pair of blind sacs in the head. They open onto the bases of the second pair of antennae (antennal glands) or the second pair of maxillae (maxillary glands). Both antennal and maxillary glands are present in some crustaceans.

In most crustaceans, the antennal and maxillary glands do not play an important role in osmoregulation. Ammonia is the principal nitrogenous waste in terrestrial forms.

characters with oligochaetes. Both leeches and oligochaetes lack parapodia and head appendages. Both are hermaphrodites with gonads and gonoducts restricted to a few segments. Both leeches and oligochaetes possess direct development within cocoons secreted by clitellum.

Leeches are commonly larger than polychaetes and oligochaetes. The smallest leeches are 1 cm in length. But most species are 2 – 5 cm long. Some species, including the medicinal leech (*Hirudo medicinalis*), may reach a length of 12 cms. The giant leeches may attain a length of 30 cms.

The body of leech is typically dorsoventrally flattened with a tapered anterior end (Fig.3-13). The segments at the anterior and posterior ends have been modified to form suckers. The anterior sucker is usually smaller than the posterior sucker. The anterior sucker frequently surrounds the mouth. The posterior sucker is disc shaped and turned ventrally. Leeches have a fixed number of segments, 32 (or 34 according to some authorities who claimed that two segments have fused with the prostomium).

The head or cephalic region contains the reduced prostomium (and perhaps 2 fused segments) and 4 body segments (Fig.3-13). The head bears a number of eyes dorsally and an anterior sucker ventrally. The trunk consists of 21 segments. It includes the preclitellar region, clitellum and post clitellar region. The clitellum (covering 3 segments) is conspicuous during reproductive periods. The large ventral posterior sucker is derived from 7 segments. The anus opens dorsally on or near the last trunk segment.

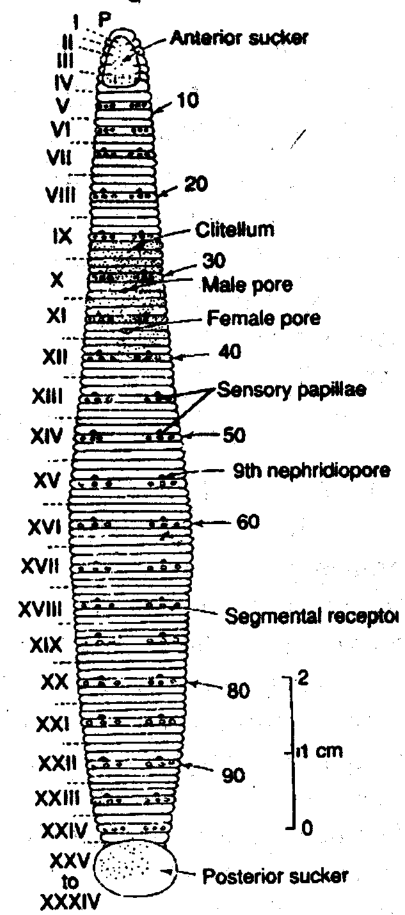


Fig. 3-13. External ventral surface of the medicinal leech, *Hirudo medicinalis.*

3.1.5.B BODY WALL

The body of leeches is covered by a cuticle and epidermis. Beneath the epidermis lies the connective tissue. The peripheral connective tissue layer is sometimes referred as dermis. Below the dermis is a layer of circular muscles, diagonal muscles and longitudinal muscles. Dorsoventral muscles are also present.

3.1.5.C COELOM

Coelom and coelomic septa are reduced. In the primitive *Acanthobdella* only the five anterior segments contain coelomic compartments and separating septa. Interestingly anterior sucker is absent in this leech. Also the anterior segments with coelomic compartments have setae in this same leech. *Acanthobdella* provides additional evidence connecting leeches and oligochaetes. In all other leeches septa are absent and the coelom is reduced. The circulatory system is composed of interconnected sinuses and channels.

3.1.5.D LOCOMOTION

The loss of septa, setae and coelomic compartments in leeches is correlated with a change from peristomatic burrowing to locomotion. Leeches crawl or swim in the water.

3.1.5.E INTERNAL TRANSPORT

In all the leeches except in *Acanthobdella* septa have disappeared and coelom has become reduced and specialized into a circulatory system. The circulatory system is composed of coelomic sinuses and coelomic fluid. These have become the internal transport system, which is also termed the coelomic system. There is no distinct body cavity. The space between the body wall and alimentary canal is filled with a kind of large nutrient tissue called the chloragogen tissue in rhynchobdellids and the botryoidal tissue in arhynchobdellids.

Certain longitudinal channels, their branches and a large number of spaces filled with a blood red fluid called the hemocoelomic fluid, represent the reduced coelom. This fluid may bring the muscular contractions of the body.

3.1.5.F GAS EXCHANGE

Gills are found only in the piscicoloid leeches. The piscicolid leech is leaf like (Fig.3-14). The piscicolid gills are lateral leaf like or branching outgrowths of the body . In all other leeches the general body surface serves as a site of gas exchange. In Arhynchobdella leeches, an extracellular hemoglobin (the respiratory pigment) is responsible for about one half of the oxygen transport.

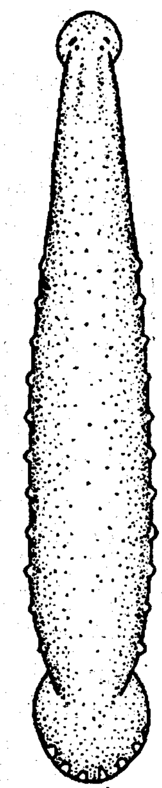


Fig. 3-14. External dorsal view of *Piscicola.*

3.1.5.G NUTRITION

In both the predacious and ectoparasitic leeches an eversible proboscis and a non eversible-sucking pharynx is present. During feeding the animal is able to extend its proboscis from the mouth forcing it into the tissues of the host. Salivary glands open into the proboscis. In the Arhynchobdellid leeches the proboscis is absent and the mouth is situated in the anterior sucker. In many leeches 3 large, oval, blade like jaws each with a large number of small teeth are present within the mouth cavity. The 3 jaws are arranged in a triangle, one dorsally and two laterally. During feeding the animal attaches to the surface of the host by means of anterior sucker. The edges of the jaws slice the integument of the prey. Salivary glands secrete an anticoagulant called hirudin.

The proboscis or the pharynx opens into a short oesophagus. The oesophagus either opens directly into a relatively long stomach or into its first expansion as crop. Following the stomach is an intestine. The intestine may be simple tube or may have 4 pairs of intestinal lateral caeca. (Fig. 3-15) The intestine opens into a short rectum, which again opens outside through the dorsal anus. The anus is situated in front of the posterior sucker. In the erpobdellids the stomach may be provided with 1 – 4 pairs of lateral caeca.

The blood-sucking leeches attack a variety of hosts. They feed on invertebrates such as snails, oligochaetes, crustaceans and insects and vertebrates such as amphibians, snakes, crocodiles and eyes may be totally absent. Organs of Tomosvary are present in many centipeds, millipedes, eyes may be totally lacking or there may be 2 or 80 ocelli. In insects, sense organs other than eyes and ocelli are present on the appendages. The sense organs in crustaceans are chemo receptive in function.

3.3.12 REPRODUCTION

Horseshoe crabs are dioecious. The reproductive system has the same structure in both the male and female. The gonad is located adjacent to the intestine. The sperm or egg pass to the outside through short ducts. The gonopores are present medially and the underside of the base of the genital operculum. The eggs are entolecithal and covered by a thick envelope or chorion. Cleavage is total. A trilobite larva emerges from the egg. It is called trilobite larva because of its superficial similarity to trilobites. The larva of merostomes is approximately 1 cm long and actively swims for sometime and burrows in sand. The little caudal spine does not project beyond the abdomen. The larva shows five pairs of book gills and all anterior appendages. The remaining book gills appear during the successive molting. The caudal spine increases in length. At the end of molting the young crab assumes the adult form. The adult may become sexually mature at the end of second year. In Japanese species, it was found that the sexual maturity requires 13 instars in the male and 14 instars in the female.

In arachnids, the genital orifice is present on the ventral side of the second abdominal or eighth body segment in both male and female (Fig.3-32). Gonads may be either single or paired. In many arachnids, indirect sperm transmission with a spermatophore is reported. The eggs are yolky and centrolecithal. Scorpions exhibit little sexual dimorphism. Males may be little larger than females. The male scorpions can be distinguished by the presence of hook on the opercular plate. In females, the ovarian tubules are located between the midgut and diverticula in the preabdomen. The genital atrium opens to the outside between the genital opercula. In males, the reproductive system occupies a position in the preabdomen, corresponding to that of female. The lower part of genital tract lodges the spermatophores. Fertilization occurs by mating. All scorpions are either ovoviviparous or truly viviparous. Viviparous forms brood their eggs within the female reproductive tract. The eggs of viviparous forms have little yolk. At birth the young are only a few millimeters long and they immediately crawl upon the mother's belly. The young ones leave the mother gradually and become independent. They attain maturity in about one year.

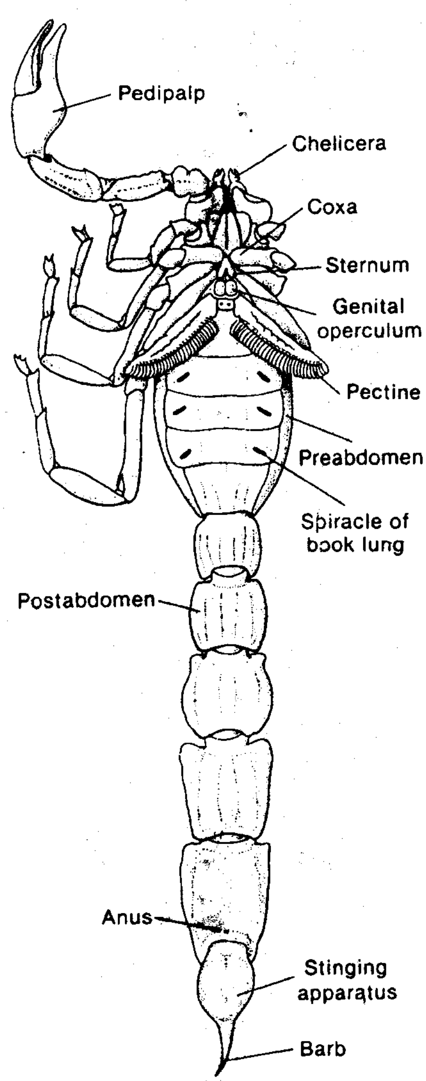


Fig. 3-32. *Androctonus australis* (ventral view)

Sexes are separate in most crustaceans. Few are hermaphroditic. The male reproductive system consists of a pair of lobular testes, located in the mid region of the body. The two vasa deferentia join ventrally to open through a gonopore. The female reproductive system consists of a pair of elongated ovaries. The sperm ducts and oviducts are simple, paired tubules. The gonoducts open either at the base of a pair of trunk appendages or on a sternite. However, the genital segments, which carry gonopores, vary from one group to another. Copulation is the general rule in crustaceans. In many crustaceans, the sperm lack a flagellum and non motile. The sperm are transmitted as spermatophores. Most crustaceans brood their eggs for different length of time. The eggs may be attached to appendages. The eggs of many higher crustaceans are large, centrolecithal and cleavage is superficial .The eggs of lower crustaceans are small and the cleavage is holoblastic.

A free-swimming planktonic larva is characteristic of most marine species and even some fresh water species. Nauplius larva is the earliest and basic larva of crustaceans (Fig.3-33). Only three pairs of appendages are present – the first antennae, the second antennae and the mandibles. A single median or nauplius eye is borne on the front of the head. No trunk segmentation is evident in nauplius larva. Swimming setae are present on second antennae and mandibles.

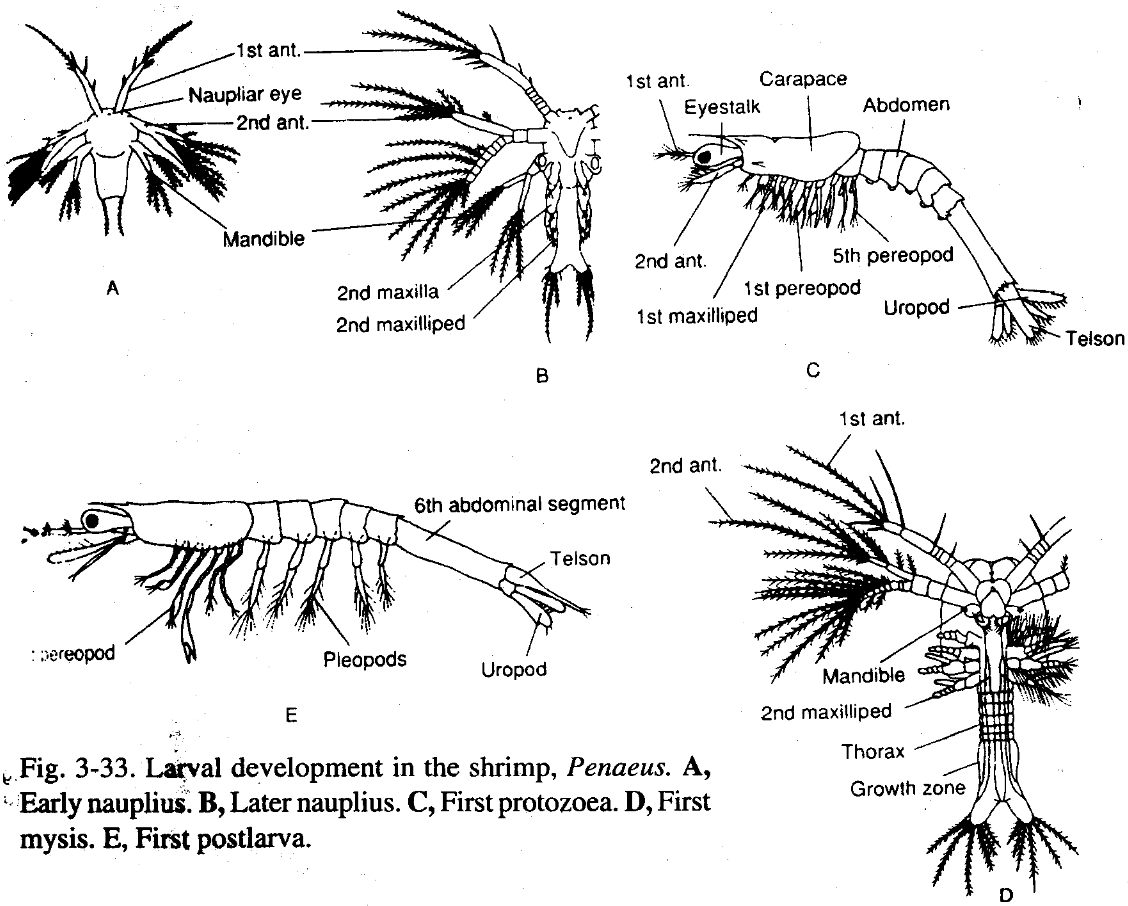


Fig. 3-33. Larval development in the shrimp, *Penaeus*. **A,** Early nauplius. **B,** Later nauplius. **C,** First protozoea. **D,** First mysis. **E,** First postlarva.

produced by some of the clitellar glands. The cocoon then receives the fertilized eggs and transfers them to female gonopore. The eggs are secondarily small and relatively yolkless. The glossiphonid leeches brood their eggs internally. In some species the cocoons are attached to the bottom and covered and ventilated by the ventral surface of the leech. In others the cocoons are membranous and transparent. Such cocoons are attached to the ventral surface of the parent. As the development advances the embryonic leeches break the cocoons and come outside. They attach themselves directly to the ventral surface of the parent. In case of arhynchobdellid leeches the larva develops within the cocoons and is called crypto larva. It has a pair of provisional protonephridia and a mouth. The developing larvae use the nutritive fluid within the cocoon. Most leeches have a one year or two year life cycle. They breed in spring or summer and mature in the following year.

3.1.6 BRANCHIOBDELLIDA

The branchiobdellidans are annelids, which are parasitic or commensal on the cray fish. Parasitic forms are found on the gills and commensals are depended upon the accumulated organic debris and microorganisms on the cray fish. They show similarities to both oligochaetes and leeches. Hence they are treated as a separate group of worms as Branchiobdellida (within a separate class or sub class). Branchiobdellidians are very small (1 to 10 mm) and are composed of only 17 segments. An anterior sucker and posterior sucker are present. The terminal mouth leads to buccal cavity having two

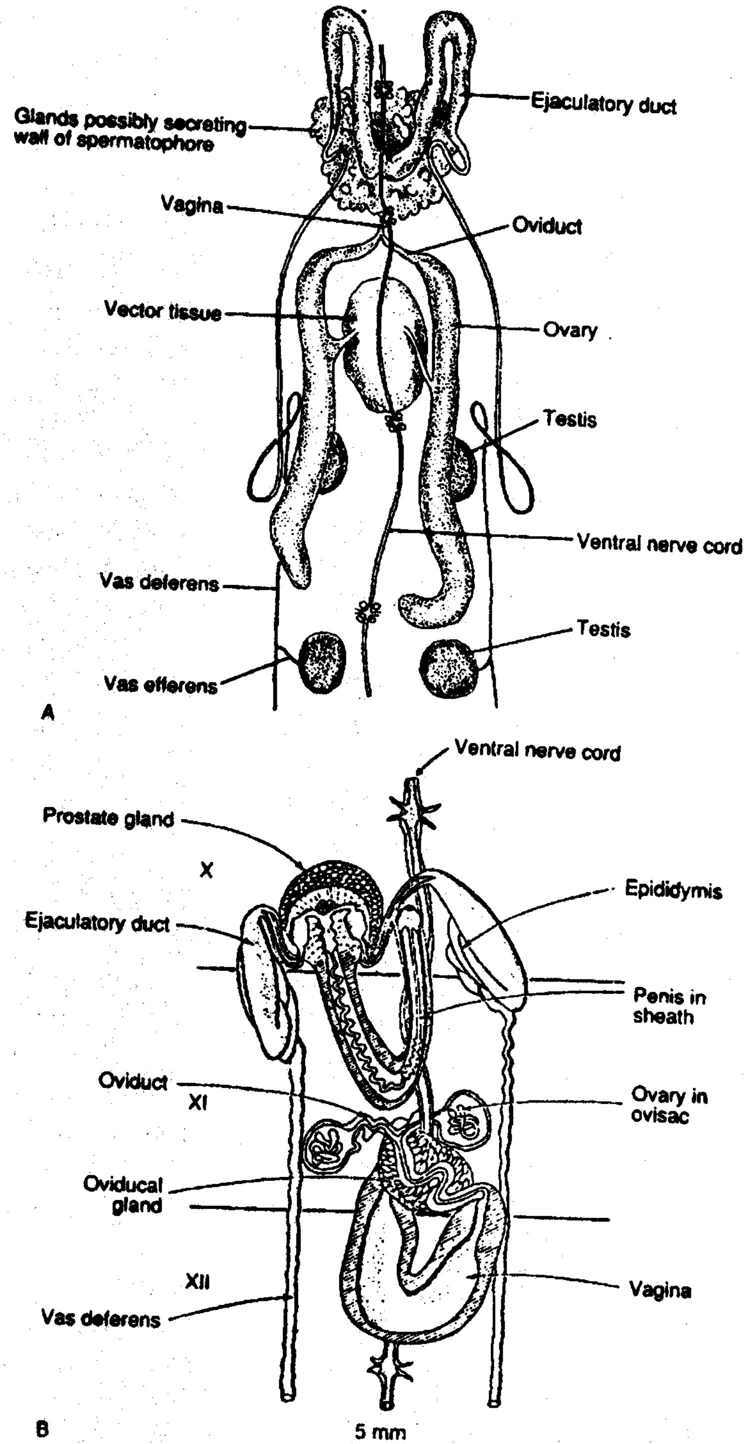


Fig. 3-17. A, Reproductive system of *Piscicola geometra*. B, Reproductive organs of *Hirudo*. Testes are associated with vas deferens in more posterior segments.

teeth. Anus is dorsal on segment 14. Branchiobdellidans have a segmented coelom, a more or less typical annelidan blood vascular system and two pairs of metanephridia. These are hermaphrodites with internal fertilization. Zygotes are deposited in the cocoon. Cocoons are found attached to the host. The embryos develop into cryptolarvae as in Arhynchobdellid leeches. Setae are absent.

3.1.7 SUMMARY

In polychaetes, the blood vascular system or the coelomic fluid or the combination of both provides the internal transport. Gas transport frequently involves respiratory pigments, of which hemoglobin is the most common.

But some polychaetes possess hemerythrin. Blood vascular hemoglobin and chlorocruorin are always extracellular and large molecules. Blood vascular hemerythrin and coelomic hemoglobin are always intracellular and small molecules.

Most polychaetes possess paired, segmental organs called metanephridia. The metanephridial system is composed of a nephrostome, which opens into the coelomic compartment that is anterior to the one housing the nephridial tubule.

Polychaetes that lack a blood vascular system possess protonephridia.

Primitively, polychaetes have a ladder-like ventral nervous system.

The sexes are separate in most polychaetes. The gonads are in the connective tissue. Immature gametes are often released into the coelom for maturation and storage. After maturing in the coelom, they exit by coelomoducts joined to nephridia alone. Or they leave the body by rupturing the body wall.

Copulation is rare. Synchronous emission of sperm and eggs takes place.

Dispersed benthic population and a brief pelagic existence are evidenced by epitokes.

The shedding of gametes increases fertilization.

A trochophore larva is the basic larval stage of polychaetes.

Oligochaetes have well developed segmentation and a simple prostomium.

Oligochaetes are aquatic and adapted for living in loose debris and algae.

The digestive tract is simple and straight. It is adapted for a diet of decomposing organic matter largely plant material.

Gills are generally absent. Gas exchange occurs by well-developed cutaneous vascular net works.

Oligochaetes have a segmentally arranged metanephridial system as in polychaetes.

Most of the oligochaetes are characterized by the presence of calciferous glands, enteronephric nephridia, the production of urea, encystment and egg deposition in cocoons.

Oligochaetes are hermaphroditic. Well-developed reproductive organs are limited to a few segments.

Copulation by reciprocal sperm transfer.

Fertilization by direct development takes place within a cocoon secreted by the clitella.

The class Hirudinea consists of marine, fresh water and terrestrial forms commonly known as leeches. They have an anterior and a posterior sucker.

Setae and external segmentation are absent.

Coelom is reduced but specialized into a circulatory system.

Feeding habits are like that of predacious and ectoparasitic forms.

in the adults. This type of development is called complete metamorphosis and consists of three distinct stages. The newly hatched larval stage, which has no wings, is the caterpillar of butterflies, the maggots of flies, and the grub of beetles. This is an active feeding stage, although the food is usually quite different from that of the adult. In some species, the larvae and the adults have different kinds of mouthparts. For example, caterpillar larvae have chewing mouthparts, whereas the adults have sucking mouthparts. Some parasitic groups have low or more different larval habits and structures (hypermetamorphosis). At the end of larval period, the young becomes nonfeeding and quiescent. This stage is called pupa (Fig.3-36). The pupa is usually passes in the ground, cocoon, or plant tissues. Adult structures are formed during pupation. Few larval structures are carried over to the adult stage. The number of molts and the time required for each molt varies from species to species.

Endocrine glands control metamorphosis by the release of hormones. The brain hormone stimulates the prothoracic gland to release ecdysone, which stimulate the growth and molting. During the larval stage, another hormone called juvenile hormone (JH) is secreted by the corpora allata of the brain. This hormone maintains the larval structures and inhibits metamorphosis. When high levels of JH is present in the blood, molt occurs form larva – larva. When the level of JH is lower, molt occurs from larva to pupa. And in the absence of JH, molt occurs from pupa to adult.

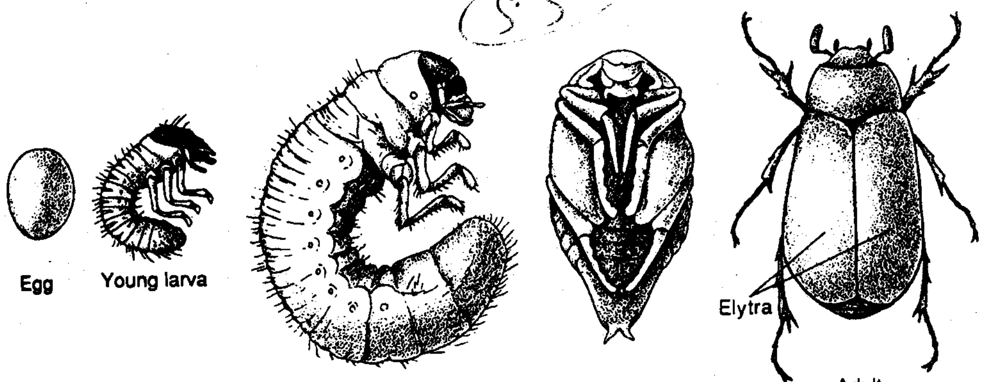


Fig. 3-36. Stages in the complete metamorphosis of a beetle.

Several groups of insects display several methods of reproduction. Aphids have remarkable power of reproduction. Eggs laid in the autumn hatch in the spring and develop into parthnogenetic females. The females sometimes called stem mothers. These stem mothers are ovoviviparous and give birth to parthenogenetic females. One of these generations may produce a new generation of both males and females with the appearance of fall. Such reproductive abilities appear to be adaptations for rapid increase of their population.

3.3.13 SUMMARY

The Phylum Arthropoda contains largest number of species within the animal kingdom.
Arthropods move by jointed, segmented appendages.
Members of the Class Arachnida are terrestrial chelicerates.
Scorpions, the most primitive arachnids have long segmented abdomen.

The highest specialized mites have lost the external segmentation and the cephalothorax and abdomen are broadly joined together.
Pycnogonids are marine arthropods, which appear to be chelicerates.
They are commonly found on sessile animals especially hydroids and bryozoans.
In crustaceans, the six anterior segments are fused with the presegmental region to form the head, while the rest are usually divisible into two regions, the thorax and the abdomen.
With the exception of antennules, the appendages are typically biramous.
The body of crustacean is covered externally by a chitinous cuticle.
Respiration takes place either by the general surface of the body or by gills in crustaceans.
The renal organs are peculiarly modified coelomocytes.
The nervous system consists of a brain and a double nerve cord with paired ganglia.
The sexes are separate or united.
Parthenogenesis occurs frequently.
The insects are air breathing Arthropoda.
The body of insects show three well marked regions – head, thorax and abdomen.
Head is bearing compound eyes, a pair of antennae, mandibles and two pairs of maxillae.
Respiration by means of trachea.
The nervous system and sense organs reach a high level of complexity.
Excretory organs are a number of blind tubes, the malpighian tubules.
The sexes are separate.
Development is sometimes direct; complicated by metamorphosis.
Myriapods, including the Centipedes and Millipedes present many features similar to insects.
There is a distinct head, bearing many jointed antennae, a pair of eyes and two or three pairs of jaws.
Body is not divisible into regions. Body consists of similar segments, each bearing one pair of legs or two pairs.
The nervous system consists of a brain and a ventral nerve cord consisting of a series of a paired ganglia.
Respiration by means of trachea.
Alimentary canal is straight. There are salivary glands, and one or two pars of malpighian tubules.
The sexes are always separate.

3.3.14 KEY TERMINOLOGY

Aciculum: Chitinous rod that internally supports the division of the pauropodium
Biramous: Refers to the division of annelid and some arthropod appendages into two branches.
Compound eye: An image forming eye of many arthropods composed of multiple lenses and photoreceptors called ommatidia.
Coxa: The basal article of an arthropod appendage.
Cuticle: The nonliving, extra cellular layer. It is protective or supportive in function.
Cypris: A larval stage of barnacles. It follows the nauplius larva. It is a settling larval stage. It has six pairs of appendages and resembles an ostracod.
Ecdysis: Molting or the periodic shedding of the skeleton.
Ecdysone: Hormone responsible for molting process.
Epicuticle: An outer layer of arthropod skeleton. It is composed of proteins and sometimes wax.

Epigastric furrow: A transverse groove found on the ventral side of the abdomen of arachnids. It contains the reproductive openings.

Gnathobase: Spiny medial surface of the basal articles of many crustacean limbs.

Gnathochilarium: The floor of the preoral chamber formed by a fused pair of maxillae. It is a brood flattened plate attached to the posterior ventral surface of the head of millipedes.

Hemal system: Blood vascular system.

Hemocoel: A voluminous, blood filled cavity. It may occupy the entire body.

Hepatopancreas: Large, spongy, digestive diverticula from the arthropod mid gut. It is composed of ducts and blind secretary tubules.

Malpighian tubules: Arthropod excretory organs. These are blind, tubular and contractile. Evagination of the mid gut. They lie in hemocoel.

Mandibles: Third pair of oral appendages of crustaceans. Useful for chewing or grinding.

Megalopas: The post larval stage of crabs. It has a large of flexed abdomen with fully developed appendages.

Metamerism: The division of animal's body into a linear series of similar parts or segments. Metamerism is also known as segmentation.

Metamorphosis: Transformation of a larva into an adult.

Molt: Shedding of old cuticle. A new cuticle is secreted to replace the old cuticle.

Nauplius eye: The eye of a nauplius larva of crustaceans. It is simple and lies median to the larva.

Nauplius: Earliest and basic type of crustacean larva. It has three pairs of appendages.

Organ of Tomosovary: Present in pairs at the base of the head antennae of some centipedes. Sensory in function.

Ovigerous legs: Present in male Pycnogonids. One of the third pair of appendages. Male use these legs to brood the fertilized eggs.

Oviparous: Egg laying.

Parthenogenesis: The embryonic development of unfertilized, usually diploid eggs.

Protozoea: Third larval stage of a decapod (shrimp). The preceding larval stage of protozoea is zoea. It follows the metanauplius larva.

Spermatheca: The other name for a seminal receptacle.

Spiracle: Slit like opening to the outside of the arthropod tracheal system.

Sternum: The primary ventral plate of the cuticle of each segment of an arthropod.

Subchelate: It refers to an arthropod appendage. In this the terminal piece of the appendage folds against the sub terminal piece. A movable finger is absent in the sub terminal piece.

Vessel: A small tubular blood channel.

Viviparous: Embryos brooded internally within the female. The parent supplies supplement nutrition.

Zoea (Pl. Zoeae): The post larval stage of decapod crustaceans transforms to zoea. It is the penultimate larval stage of many decapod crustaceans.

3.3.15 SELF ASSESSMENT QUESTIONS

1. Write an account of the general characters of arthropods.
2. Write an essay on the mode of nutrition in arthropods.
3. Give an account of the respiratory and excretory organs in arthropods.
4. Write an essay on the mode of reproduction in arthropods.
5. Write short notes on:

    a. Fossil arthropods.
    b. Horse shoe crabs.
    c. Sense organs in arthropods.
    d. Respiratory organs in arthropods.
    e. Malpighian tubules.

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3.4 CLASSIFICATION OF PHYLUM ARTHROPODA

3.4.1 OBJECTIVES

The purpose of this lesson is to:

- classify the Phylum Arthropoda upto classes.
- understand the distinguishing characters of extinct arthropods.
- study the distinct features of living arthropods.

3.4.2 INTRODUCTION

Phylum Arthropoda contains the great majority of animals, about one million species. It is derived from two Greek words (arthros = joint; pods = foot). Many of the species are enormously abundant as individuals. It includes crabs, shrimps, insects, spiders, scorpions, ticks, centipedes etc.

3.4.3 GENERAL CHARACTERS

The following are the general characteristics of Phylum Arthropoda:

The arthropods are the largest assemblage species within the Animal Kingdom.

They most probably evolved form annelids or at least from some common ancestral form.

Many zoologists now believe that the arthropods are a polyphyletic grouping and that there are three or four independent arthropod lines of evolution. In the evolution of the arthropod condition, the chitin-protein exoskeleton was a central development.

Arthropoda are triploblastic, bilaterally symmetrical, metamerically segmented animals.

There has been a tendency among arthropods for metamerism to become reduced through fusion, loss, and differentiation of segments.

Body is covered with a thick chitinous cuticle forming an exoskeleton.

The division of the skeleton into plates and cylinders makes possible movement and periodic molting of the exoskeleton permits growth.

Body segments usually bear paired lateral and jointed appendages.

The number of locomotor appendages, has, in general become reduced as a consequence of differentiation of appendages for other functions

Body cavity is haemocoel. The coelom has become vestigial in the adult, and the musculature is organized as bundles attached to the inside of the skeleton.

Musculature is not continuous but comprises separate striped muscles.

The skeleton and muscles operate together as a lever system.

Muscle contraction is governed by a system of multiple motor innervations – tonic, phasic and inhibitory.

Digestive system is complete. Mouth parts are adapted for various modes of feeding.

Circulatory system is open with a dorsal, primitively tubular heart, arteries and blood sinuses.

Paired lateral ostia permit the passage of blood into the heart. Hemocyanin is the usual respiratory pigment

Respiration is by general body surface, gills, trachea or book-lungs.

Nephridia have been replaced with new types of excretory organs, due to the reduction of coelom. Excretory organs are green glands or Malphigian tubules.

Nervous system shows a dorsal nerve ring and two ventral nerve cords.

The sense organs usually involve some specialization of the exoskeletal barrier, which permits monitoring of environmental stimuli.

Cilia are completely absent.

Sexes are separate or dioecious. Sexual dimorphism is often exhibited by several forms.

Copulation and internal fertilization are characteristic of the majority of species.

The eggs of most arthropods are centrolecithal and cleavage is commonly superficial.

Development is usually indirect through larval stages.

Parental care is also often well marked in many arthropods.

3.4.4 CLASSIFICATION

Living arthropods traditionally have been divided into two subphyla. Those that lack antennae have been commonly placed in the sub phylum Chelicerata, which got its name from the fact that the postoral appendages are feeding appendages called chelicerae. Crabs, scorpions, spiders, mites and ticks belong to this group. Arthropods with antennae have been placed in the sub phylum Mandibulata. All of the insects, shrimp, crabs, millipedes and centipedes are included in this group.

Most zoologists today agree, however, that the Mandibulata is an artificial assemblage of unrelated groups and that there are probably four main lines of arthropod evolution rather than two as the Mandibulata and Chelicerata. These lines are believed to be represented by the extinct Trilobitomorpha, the Chelicerata, the Crustacea and the Uniramia. The uniramians include the centipedes, millipedes and insects. In contrast to the marine origin of the other three arthropod lines, the uniramians appear to have evolved on land. They are mandibulate and antennate, but the name uniramian refers to the fact that the appendages are basically unbranched, and there is no evidence that they were derived from a branched condition.

3.4.5 SUBPHYLUM TRILOBITOMORPHA

The marine Paleozoic trilobites are the group of extinct primitive arthropods. Each of the post oral segments carried a pair of similar appendages, which included a filament bearing branch of uncertain function.

The body of trilobites was composed of an anterior cephalon, a middle trunk region of unfused segments, and a posterior pygidium.

The cephalon carried a pair of antennae and a pair of dorsolateral eyes. The mouth was located in the middle of the underside of the cephalon (Fig. 3-18).

The trunk consisted of varying number of separately articulating segments. Each segment bore a pair of appendages ventrally.

The pygidium was constructed on the same plan as the thorax except that the segments were fused and formed a solid shield.

The medial bases of the appendages move food forward to the posteriorly directed mouth.

Variations in form indicate that there was some diversity in trilobite life styles, such as burrowing, epibenthic crawling, planktonic, and swimming modes of existence.

Triarthrus, Phacops, Megalaspis, Radiaspis

3.4.6 SUBPHYLUM CHELICERATA

The body of chelicerates is divided into an anterior cephalothorax (or prosoma) and a posterior abdomen (or ophisthosoma).

The subphylum Chelicerata contains the only non-antennate arthropods.

Chelicrates lack antennae and are the only subphylum of arthropods in which they are absent. This is the most distingwishing character of the subphylum chelicerata.

The first pair of appendages is feeding structures called chelicerae.

The second pair of appendages is called pedipalps and is modified to perform various functions in different classes.

Pedipalps are followed by four pairs of legs.

The marine origin of chelicerates is evidenced by a long fossil history beginning in the early Paleozoic, but only five species exist today (horseshoe crabs)

There are three classes of chelicerates. Two small classes, the Merostomata and the Pycnogonida, contain marine species. The third class Arachnida containg terrestrial species.

3.4.6.1 CLASS MEROSTOMATA

Horseshoe crabs are included in this class.

These are soft bottom, shallow water, and marine chelicerates.

The prosoma is covered by a large horseshoe-shaped carapace, and the abdominal segments are fused together (Fig. 3-19).

The pedipalps are not differentiated from the posterior legs except in mature males, in which they are used in clasping the female.

A posterior spike like telson is used for pushing and righting.

The ventral side of the abdomen carries five pairs of book gills.

Fossil evidence indicates that some species of the extinct Paleozoic eurypterids (merostomes) invaded fresh water and may have given rise to the class Arachnida.

Limulus, Eurypterus

3.4.6.2 CLASS ARACHNIDA

The arachnids comprise the largest and the most important of the chelicerate animals. The class Arachnida includes many common and familiar forms such as spiders, scorpions, mites and ticks.

These are terrestrial chelicerates that lack book gills. The species that are aquatic (some mites) represent a secondary return to fresh water or the sea.

Scorpions, the most primitive arachnids, have long segmented abdomens. The highly specialized mites have lost all external evidence of metamerism, and the cephalothorax and abdomen are broadly joined together.

Arachnids are largely predatory chelicerates, other arthropods form the principle prey. The pedipalps of scorpions and pseudoscorpions are used in seizing and holding the prey. Poison is used to immobilize prey in some groups like spiders, scorpions and pseudoscorpions. Some spiders use silk in capturing the prey.

Harvestmen and many mites are the principal exception to the arachnid predatory habit. The great diversity of feeding habits among the mites is in part related to the miniaturization that is characteristic of the group.

Trichobothria and slit sense organs are important sense organs in prey capture. Although most arachnids possess eyes, a relatively small number are capable of object discrimination.

Large arachnids like scorpions, some spiders possess book lungs as gas exchange organs. Small forms such as pseudoscrpions, some spiders possess tracheae.

The heart is most highly developed in large species with book lungs, and the blood contains haemocyanin.

Excretory organs are the coxal glands and Malphigian tubules. A waxy epicuticle is an important adaptation for water conservation. They excrete guanine, and many are secretive or nocturnal in habit. Leaf mold is the habitat for many small species , especially pseudoscorpions, mites and spiders.

Primitively arachnids transfer sperm indirectly by spermatophores. The unique indirect sperm transfer of spiders is probably derived from handling of spermatophores by the male with pedipalps. Sperm transfer is direct in harvestmen and many mites.

Androctonus (Scorpion) (Fig. 3-32), *Araneus* (Spider)

3.4.6.3 CLASS PYCNOGONIDA

The pycnogonida also known as Pantopoda is a small group of some 500 species of marine animals known as sea spiders.

The name sea spider is derived from the somewhat spider-like appearance of these animals, which crawl about slowly on legs.

Members of this group are aberrant marine arthropods that appear like chelicerates, although their relationship to other chelicerates is uncertain.

The often narrow body bears an anterior proboscis and very long legs. The number of legs may be a four, five or six pair (Fig. 3-27).

Pycnogonids are commonly found on sessile animals, especially hydroids and bryozoans. Some species are carnivorous on sessile animals; others feed on detritus or flora growing on such animals.

The circulatory system is composed of a heart, or dorsal vessel and a haemocoel.

The absence of gas exchange and excretory organs may be correlated with their large surface and aquatic existence.

Pycnogonids are dioecious. Females can be distinguished from males by the poorly developed condition of ovigerous legs or by their complete absence.

The eggs are carried by the male with a pair of ovigerous legs that are located in front of the first walking legs.

Nymphon, Ascorhynchus

3.4.7 SUBPHYLUM CRUSTACEA

There are about 31,312 known species in the subphylum Crustacea.

It is the only large class of arthropods that are primarily aquatic. Most are marine, but there are many fresh water species and there have been a number of invasions of the terrestrial environment.

Crustaceans are extremely diverse in structure and habit, but they are unique among arthropods in having two pairs of antennae.

Other characteristic head appendages are one pair of mandibles, two pairs of maxillae. The trunk specialization varies greatly, but a carapace that covers all or part of the body is common (Fig. 3-20).

Crustacean appendages are typically biramous and depending upon the group, they have become adapted for many different functions. In filter feeding, closely placed setae on the appendages function as the filter.

Gills, which are usually only absent in very small species are typically associated with the appendages, but the location, number, and form vary greatly.

Excretory organs are a pair of blind sacs in the head that open onto the bases of the second pair of antennae (antennal glands) or the second pair of maxillae (maxillary glands). A few crustaceans possess both antennal and maxillary glands.

The crustacean sense organs include two types of eyes, a pair of compound eyes and a small, median, dorsal nauplius eye, composed of three or four closely placed ocelli. Some groups lack compound eyes, and the nauplius eye, characteristic of the crustacean larva, does not persist in the adult of many groups.

Copulation is typical of most crustaceans and egg brooding is very common. The earliest hatching stage is a nauplius larva, which possesses a median nauplius eye and only the first three pairs of appendages.

Most familiar arthropods such as crabs, shrimp, lobsters, cray fish and wood lice are included in Crustacea.

In addition, there are myriad tiny crustaceans that live in the seas, lakes and ponds of the world and occupy a basic position in aquatic food chains.

Crustacea is divided into 8 classes namely Cephalocarida, Branchiopoda, Ostracoda, Copepoda, Mystacocarida, Branchiura, Cirripedia and Malacostraca.

3.4.7.1 CLASS CEPHALOCARIDA

The Class Cephalocarida is the most primitive of the existing classes of Crustacea.

It contains only seven known species. It is of special interest because of the presence of the high degree of external metamerism.

The horseshoe-shaped head is followed by an elongated trunk of 19 segments, of which only the first nine bear appendages.

All of the trunk appendages are similar to each other and to the second maxillae.

The internal anatomy and the physiology and habits of cepahalocarids are still not well known.

They are selective deposit feeders.

In other respects, these tiny crustaceans show specializations for living in the mud-water interface.

They are hermaphroditic and possess a common gonoduct that opens on the sixth segment.

Hutchinsoniella macracantha

3.4.7.2 CLASS BRANCHIOPODA

Branchiopods are distinguished by their foliaceous appendages, which in many species are adapted tor filter feeding.

The coxa is provided with a flattened epipodite that serves as a gill, hence the name Branchiopoda – "gill feet".

The first antennae and the second maxillae are vestigial.

The last abdominal, or anal segment bears a pair of large terminal processes called cercopods.

In other respects, branchiopods are diverse. Water fleas have the trunk, but not the head, enclosed within the carapace. Clam shrimp have the entire body enclosed within a bivalve carapace. Fairy shrimp and brine shrimp lack a carapace.

Branchiopods are largely inhabitants of fresh water, especially temporary pools and ditches.

The excretory organs are maxillary glands usually called shell glands when the duct can be seen coiled within the carapace wall.

In all branchiopods, the eggs are brooded for varying lengths of time.

The eggs are produced in clutches of two to several hundred, and a single female may lay several clutches.

Parthenogenesis is common in branchiopods, and in some species males are uncommon or unknown.

Leptodora, Bythotrephes, Daphnia

3.4.7.3 CLASS OSTRACODA

Ostracods, called mussel or seed shrimps are small crustaceans that are widely distributed in the sea and in all types of fresh water habitats.

Ostracods have the body enclosed in a bivalve carapace, which on a miniature scale is similar to the shell of bivalve mollusks.

Most ostracods are less than 2 mm. long. They are mostly marine benthic animals, but some species live in fresh water.

Ostracods display diverse feeding habits. They are carnivores, herbivores, scavengers and filter feeders.

Some ostracods possess antennal glands, some have maxillary glands and some possess both types of excretory organs in the adult.

A nauplius eye is present in all ostracods.

Ostracods were the first crustaceans in which luminescence was observed.

Vargula, Cypridina

3.4.7.4 CLASS COPEPODA

The Copepoda is the largest class of entomostracans, over 7,500 species having been described.

Most copepods are marine, but there are many fresh water species and a few that live in moss and soil water films. There are planktonic, epibenthic and interstitial species. There are many that are parasitic on various marine and fresh water animals, particularly fish.

Copepods possess more or less cylindrical tapered bodies. Long laterally projecting first antennae and a persistent nauplius eye are distinctive features.

The trunk appendages are markedly biramous.

The first pair of thoracic appendages has become modified to form maxillipedes for feeding.

Most copepods are less than 2 mm. long.

Filter feeding planktonic copepods are of great importance in marine food chains.

The excretory organs are maxillary glands.

In copepods, the ovary is paired or single, and the one or two glandular oviducts are provided with lateral diverticula. The copepod testis is usually single in fee living forms.

In parasitic forms, generally the female copepod is more highly modified for parasitic existence than the male, and sometimes the male is entirely free-living and displays the typical copepod appearance.

Cyclops, Calanus

3.4.7.5 CLASS MYSTACOCARIDA

The Mystacocaridia were first described in 1943. The only known genus is *Derocheilocaris.*

These little crustaceans are approximately 0.5 mm or less in length and are adapted for living between intertidal sand grains.

The body is elongated and cylindrical. The head is divided transversely by a constriction and the thoracic segment bearing the maxilliped is not completely fused with the head.

The thorax is composed of five segments, four of them bear a pair of appendages each. The thoracic appendages are reduced to a single simple lamella.

Both antennae are long and prominent, and the mouth appendages are more elongate than those in copepods and are provided with setae, probably for collecting detritus and other particulate matter.

Only the nauplius eye is present.

The sexes are separate, and a nauplius is the hatching stage.

Derocheilocaris

3.4.7.6 CLASS BRANCHIURA

This class contains 75 species of common blood-sucking ectoparasites on the skin or gill cavity of freshwater and marine fish and on some amphibians.

The most striking differences between branchiurans and copepods are the presence of a pair of sessile compound eyes and a large shield like carapace covering the head and thorax.

The abdomen is small, bilobed, and unsegmented.

Both pairs of antennae are very small and the first pair is provided with a large claw for attachment to the host.

Two large suckers modified from the bases of the first maxillae are also important in attachment. The rest of the appendages are vestigial.

The mouth parts are adapted for feeding on the mucus and blood of the host.

The second maxillae are heavy and uniramous and terminate in claws.

There are no maxillipedes..

The four thoracic appendages are large and biramous with swimming setae.

Copulation occurs while the parasites are on the host, but the eggs are deposited on the bottom.

A postnaupliar stage hatches from the egg and is parasitic like the adult.

Argulus

3.4.7.7 CLASS CIRRIPEDIA

The Cirripedia include the familiar marine animals known as barnacles.

Cirripedes are the only sessile group of crustaceans, aside from the parasitic forms. Barnacles are exclusively marine.

Louis Agassiz described a barnacle as "nothing more than a little shrimp like animal, standing on its head in a lime stone house and kicking food into its mouth".

A number of peculiarities of barnacles, such as a carapace covered with calcareous plates, feeding cirri, hermaphroditism, long tubular penis, and dwarf males, can be correlated with their sessility.

Freeliving barnacles are attached by a stalk, or peduncle, or stalk less. The peduncle represents the preoral part of the body and contains the cement glands.

Of the pedunculate barnacles, lepadids attach to floating inanimate objects, such as wood, or to pelagic animals.

In stalked barancles, sometimes called goose neck barnacles, there is a muscular, flexible stalk (peduncle) that is attached to the substratum at one end. The peduncle bears the major part of the body (capitulum) at the other end.

The scalpellids are bottom dwellers and attach to rocks and have the peduncle and capitulum covered with many small plates in addition to the five large principal ones.

The sessile barnacles which are believed to have evolved form scalpellids, are stalk less, the preoral region being represented by the basis, which contains the cement glands.

Only the paired terga and scuta are movable. The other capitular plates form a circular wall around the barnacle.

Sessile barnacles are especially adapted for intertidal life on hard substrates that are subjected to waves, surge and currents.

Commensalism, which has evolved in all three major lines of barnacles, has always resulted in reduction of the protective calcareous plates.

Commensalism has undoubtedly been the avenue to parasitism, which is characteristic of one third of the 900 species of cirripedes.

Sperm are transmitted into the cavity of the carapace by a long tubular penis of an adjacent individual or by dwarf males.

The eggs are fertilized and brooded within the carapace cavity.

Nauplius is the hatching stage.

Settling occurs at the cypris stage, which looks like an ostracod, *Cypris*.

Lepas, Balanus

3.4.7.8 CLASS MALACOSTRACA

The class Malacostraca contains the largest number of crustacean species and most of the larger forms.

The trunk is composed of a thoracic region of eight segments and an abdominal region of six segments. All trunk segments bear appendages.

Usually one or more thoracic appendages have become turned forward and function in food handling.
The other thoracic appendages (legs, or periopods) are used in prehension or crawling.
The abdominal appendages are pleopods and one or more pairs of terminal uropods.
Nebalia, Nebaliopsis

3.4.8 SUBPHYLUM UNIRAMIA

These arthropods are called uniramians because of the unbranched nature of the appendages.
Members of the Uniramia include the insects, centipedes, millipedes, symphylans and pauropods.
They are terrestrial arthropods.
They posses a single pair of antennae. They are the appendages of the second segment.
The mouthparts include a pair of mandibles. The mandible is an unsegmented limb, and primitively food is not brought forward from behind as in other arthropods but is picked up directly beneath the mouth.
The gas exchange and excretory organs are tracheae and Malpighian tubules respectively
The midgut lacks digestive diverticula.
The uniramians are believed to have evolved from terrestrial ancestors, which may have been early members of the Phylum Onychophora.

3.4.8.1 CLASS INSECTA

The Class Insecta is also known as Hexapoda.
It contains the largest number of species of any group of animals.
They rank with vertebrates as being the most successful inhabitants of the terrestrial environment.
They are distinguished from other uniramians by the presence of a body divided into head, thorax and abdomen. The head has a pair of antennae and the feeding appendages; the thorax has three pairs of legs and the abdomen with no appendages (Fig. 3-37).
They have an ability to fly. Flight has enhanced distribution, exploitation of food sources and habitats; escape form predators, and reproductive processes.
Most insects have two pairs of thoracic wings, although one pair is reduced or modified or lost in various groups.
Some like apterygotes are wingless.
The mouth parts consist of a pair of mandibles, a pair of maxillae, and a labium. The mouth parts are generally for chewing the plant material. But have become modified for a wide range of diets and feeding modes, including piercing and sucking.
Gas exchange is through tracheal system. Spiracles are located along the sides of the thorax and abdomen.
Excretion is through malpighian tubules. The nitrogenous waste of insects is uric acid.
The heart is tubular, present in the dorsal part of abdomen.
A pair of large lateral compound eyes, three ocelli and different types of sensillae over the body surface are present.
Sperm transfer is indirect in primitive forms. But in majority of insects the male deposits the spermatophores directly within the female reproductive system. The female deposits eggs, encased in protective coverings.
Cleavage is typically superficial.
In primitive insects the juvenile stages are imilar to the adult.

Development with larval stages and complete metamorphosis is a specialization of beetles, flies, bees and wasps.

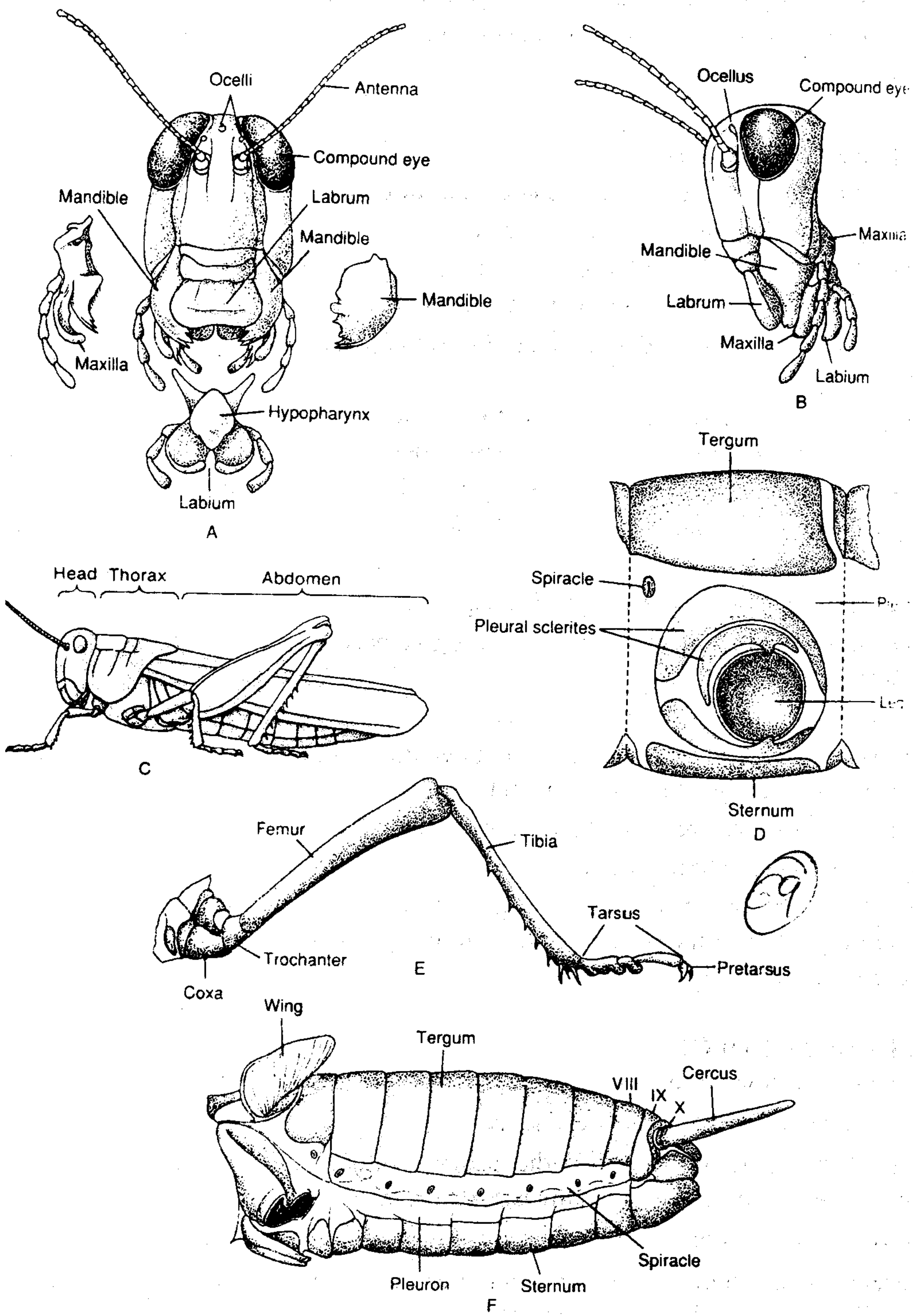

Fig. 3-37. External morphology. A, Anterior surface of the head of a grasshopper. B, Lateral view of the head of a grasshopper. C, Lateral view of the body. D, Lateral view of a wingless thoracic segment. E, Leg of a grasshopper. F, Lateral view of the abdomen of a male cricket.

In some groups only the juveniles are parasitic (blow flies). In some only the adults are parasitic (fleas). In some both juveniles and adults are parasitic (lice).

Highly developed social organization has evolved in termites, ants, bees and wasps.

Schistocerca, Apis, Termes

3.4.8.2 CLASS CHILOPODA

The members of the class Chilopoda are known as centipedes.

There are approximately 3000 species described.

Centipedes possess one pair of legs per segment. In many groups the trunk has been strengthened for a running gait by overlapping tergites of unequal size, the larger extending onto adjacent segments.

The legs of the running centipedes are long. For example, in *Scutigera* the posterior legs are twice as long as the first pair.

Centipedes are largely predaceous, and mostly feed on other small arthropods. They are caught and killed with a pair of anterior poison claws. These claws are sometimes called maxillipedes (Fig. 3-21).

There is basically one pair of spiracles per segment, but some segments may lack spiracles.

The spiracles are located mid-dorsally near the posterior margin of the tergal plates covering the leg-bearing segments.

The tracheal system of scutigeromorphs is lung like.

Centipedes possess few to many ocelli. In the scutigeromorphs, the ocelli are so clustered and organized that they form compound eyes.

Many centipedes are negatively photo tactic.

The ovary is a single tubular organ located above the gut and the oviduct opens through a median aperture on posterior, legless genital segment.

In the male 1 to 24 testes are located above the midgut.

Sperm transmission is indirect in centipedes.

Development may be epimorphic (the young have full complement of segments) or anamorphic (the young have only a part of the adult complement of segments)

Scutigera, Lithobius

3.4.8.3 CLASS DIPLOPODA

The Diplopoda are commonly known as millipedes or thousand-leggers.

More than 7500 species have been described.

A distinguishing feature of the class is the presence of doubled trunk segments, or diplo-segments, derived from the fusion of two originally separate somites.

Each diplosegment bears two pairs of legs, from which the name of the class diplopoda is derived.

The diplosegmented condition is also evident internally, as there are two pairs of ventral ganglia and two pairs of heart ostia within each segment.

The head tends to be convex dorsally and flattened ventrally, with the epistome and labrum extending anteriorly in front of the antennae.

Diplopods vary greatly in size. Species like *Polyxenus* is only 2 mm long. But most of the members are several centimeters or more in length.

Most species crawl slowly about over the ground. The gaits of diplopods, although slow are adapted for exerting a pushing force enabling the animal to push its way through humus, leaves and loose soil.

Most millipedes feed on decomposing vegetation. .

Eyes may be totally lacking, or there may be 2 to 80 ocelli.

Organs of Tomosvary are present in many millipedes and may have an olfactory function.

A pair of long, fused, tubular ovaries lie between the midgut and the ventral nerve cord.

The testes occupy positions corresponding to those of the ovary but are paired tubes.

Many millipedes produce phermones, which may initiate mating be' avior.

The dilpopod eggs are fertilized at the moment of laying. 10 to 300 eggs are produced at a time depending on the species.

Many millipedes construct a nest for the deposition of eggs.

Development is anamorphic. The eggs of most species hatch in several weeks, and the newly hatched young usually have only the first three pairs of legs and not more than seven trunk rings.

Sigmoria, Polyxenus

3.4.8.4 CLASS SYMPHYLA

Symphyla is a small class with approximately 120 known species that live in soil and mud. They range between 2 to 10 mm. long and superficially resemble centipedes (Fig. 3-38).

The trunk contains 12 leg-bearing segments, which are covered by 15 to 22 tergal plates.

The last (13th) segment has a pair of spinnerets, or cerci, and a pair of long sensory hairs. The trunk ends in a small oval telson.

Epistome and labrum are well-developed.

Most symphylans can run very rapidly and can twist, turn and loop their bodies when crawling through crevices within humus.There are no eyes. Two organs of Tomosvary are well developed. The genital organs are located on the ventral side of the fourth trunk segment.

The copulatory behavior of *Scutigerella* is known and is unusual. The male deposits 150 to 450 spermatophores, each at the end of a stalk. The female eats the spermatophore, but instead of swallowing the sperm, stores them in special buccal pouches. Then it removes the eggs with its mouth from the single gonopore, attaches them to the substratum. Lastly, it smears each egg with sperm and fertilizes it.

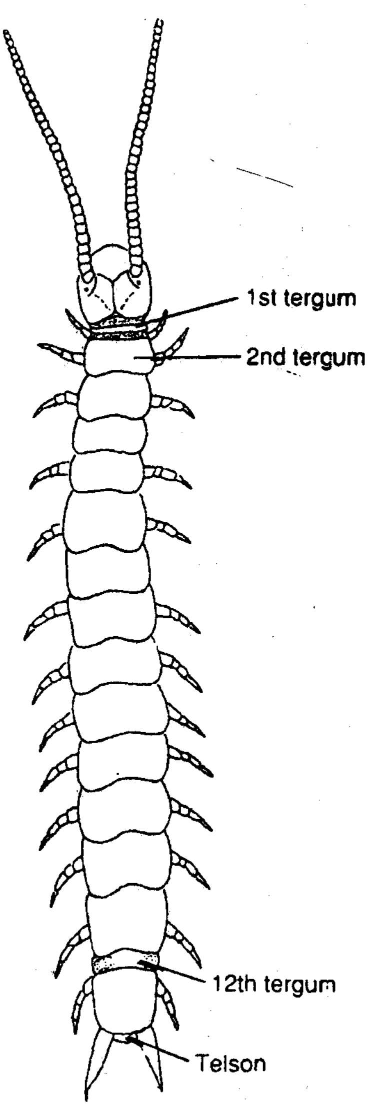

Fig. 3-38. *Scutigerella immaculata* (dorsal view).

The eggs are laid in clusters of about 8 to 12.
Parthenogenesis is common.
Development is anamorphic.
Scutigerella, Hanseniella

3.4.8.5 CLASS PAUROPODA

The pauropods constitute a small class of soft-bodied, grub-like animals. They inhabit leaf mold and soil.
All are minute, 0.5 to 2 mm. in length.
There are about 380 species that were described.
They are similar to millipedes in a number of ways.
Trunk usually has 11 segments, 9 of which bear a pair of legs each (Fig. 3-39).
Legs are absent in the first segment (collum) and the 11th segment and telson.
On each side of the head there is a peculiar disclike sensory organ, similar to Tomosvary of other myriapods.
The antennae have two branches. One branch bears a flagellum and the other bears two flagella and peculiar club shaped sensory structure.
The diet and feeding habits are poorly known.
The third trunk segment is the genital segment.
A single ovary lies below the gut and the oviduct opens into a depression between the legs.
A separate seminal receptacle also opens into the depression.
The testes are located above the gut, and the sperm ducts open between the coxae of the third legs.
The eggs are laid singly or in clusters in the humus.
Development is anamorphic.
The young hatch with only three pairs of legs.
Pauropus

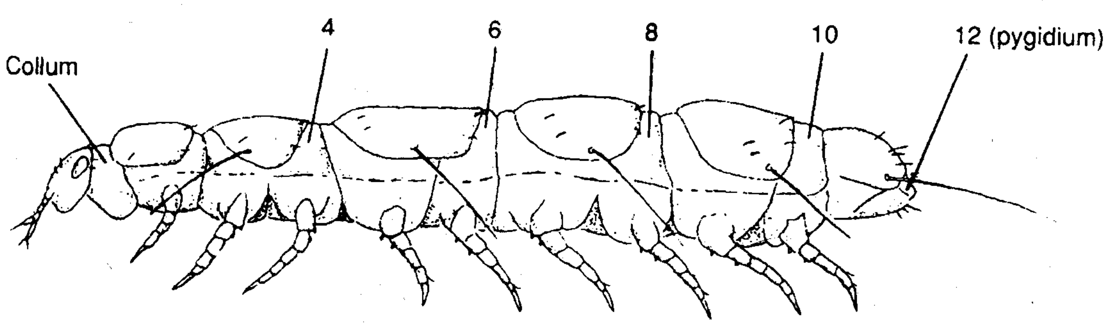

Fig. 3-39. The pauropod, *Pauropus silvaticus* (lateral view).

3.4.9. SUMMARY

Arthropods, like annelids, are metameric animals.
The subphylum Trilobitomorpha is the most primitive of all known arthropodan groups. Trilobites are an extinct group of marine arthropods.

The trilobite body was in general somewhat oval and flattened.

The trilobite body was divided into three more or less equal sections: an anterior cephalon, a middle thorax or trunk and a posterior pygidium.

Each of these body divisions was in turn divided into three lobes forming a median axial lobe and two lateral lobes. The name trilobita refers to this division of the dorsal body surface into three lobes.

Living arthropods have been divided into 3 subphyla: the subphylum Chelicerata, the subphylum Crustacea and the subphylum Uniramia.

The subphylum Chelicerata contains the only non-antennate arthropods.

The first pair of appendages is feeding structures called chelicerae.

Pedipalps are modified to perform various functions in different classes.

The subphylum Chelicerata is divided into three classes: the Merostomata, the Arachnida and the Pycnogonida.

The subphylum Crustacea consists of mostly marine forms.

Crustaceans are unique among arthropods in having two pairs of antennae.

Head appendages – one pair of mandibles and two pairs of maxillae characterize crustaceans.

The subphylum is divided into 8 classes namely Cephalocarida, Branchiopoda, Ostracoda, Copepoda, Mystacocarida, Branchiura, Cirripedia and Malacostraca.

The name Uniramia is derived because of the presence of unbranched appendages.
The subphylum Uniramia includes the insects, centipedes, millipedes, symphylans and pauropods.
Uniramians are terrestrial arthropods.
The subphylum Uniramia is divided into five classes, the Insecta, the Chilopoda, the Diplopoda, the Symphyla and the Pauropoda.

3.4.10 KEY TERMINOLOGY

Aciculum: Chitinous rod that internally supports the division of the pauropodium

Biramous: Refers to the division of annelid and some arthropod appendages into two branches.

Compound eye: An image forming eye of many arthropods composed of multiple lenses and photoreceptors called ommatidia.

Coxa: The basal article of an arthropod appendage.

Cuticle: The nonliving, extracellular layer. It is protective or supportive in function.

Cypris: A larval stage of barnacles. It follows the nauplius larva. It is a settling larval stage. It has six pairs of appendages and resembles an ostracod.

Ecdysis: Moulting or the periodic shedding of the skeleton.

Ecdysone: Hormone responsible for molting process.

Epicuticle: An outer layer of arthropod skeleton. It is composed of proteins and sometimes wax.

Epigastric furrow: A transverse groove found on the ventral side of the abdomen of arachnids. It contains the reproductive openings.

Gnathobase: Spiny medial surface of the basal articles of many crustacean limbs.

Gnathochilarium: The floor of the preoral chamber formed by a fused pair of maxillae. It is a brood flattened plate attached to the posterior ventral surface of the head of millipedes.

Hemal system: Blood vascular system.

Hemocoel: A voluminous, blood filled cavity. It may occupy the entire body.

Hepatopancreas: Large, spongy, digestive diverticula from the arthropod mid gut. It is composed of ducts and blind secretory tubules.

Malpighian tubules: Arthropod excretory organs. These are blind, tubular and contractile. These tubules arise as evaginations of the mid gut. They lie in hemocoel.

Mandibles: Third pair of oral appendages of crustaceans. Useful for chewing or grinding.

Megalopas: The post larval stage of crabs. It has a large of abdomen with fully developed appendages.

Metamerism: The division of animal's body into a linear series of similar parts or segments. Metamerism is also known as segmentation.

Metamorphosis: Transformation of a larva into an adult.

Molt: Shedding of old cuticle. A new cuticle is secreted to replace the old cuticle.

Nauplius eye: The eye of a nauplius larva of crustaceans. It is simple and lies median to the larva.

Nauplius: Earliest and basic type of crustacean larva. It has three pairs of appendages.

Organs of Tomosovary: Present in pairs at the base of the head antennae of some centipedes. Sensory in function.

Ovigerous legs: Present in male Pycnogonids. One of the third pair of appendages. Male use these legs to brood the fertilized eggs.

Oviparous: Egg laying.

Parthenogenesis: The embryonic development of unfertilized, usually diploid eggs.

Protozoea: Third larval stage of a decapod (shrimp). The preceding larval stage of protozoea is zoea. It follows the metanauplius larva.

Spermatheca: The other name for a seminal receptacle.

Spiracle: Slit like opening to the outside of the arthropod tracheal system.

Sternum: The primary ventral plate of the cuticle of each segment of an arthropod.

Subchelate: It refers to an arthropod appendage. In this the terminal piece of the appendage folds against the subterminal piece. A movable finger is absent in the subterminal piece.

Vessel: A small tubular blood channel.

Viviparous: Embryos brooded internally within the female. Supplement nutrition is supplied by the parent.

Zoea (Pl. Zoeae): The post larval stage of decapod crustaceans transforms to zoea. It is the penultimate larval stage of many decapod crustaceans.

3.4.11 SELF ASSESSMENT QUESTIONS

1. Classify the Phylum Arthropoda upto classes with suitable examples.
2. Classify the Subphylum Crustacea upto classes with atleast two examples for each class
3. Classify the Subphylum Uniramia upto classes giving examples.
4. Write short notes:
    a. Trilobitomorpha
    b. Arachnida
    c. Pycnogonida
    d. Diplopoda
    e. Chilopoda

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3.5 TROCHOPHORE LARVA AND ITS EVOLUTIONARY SIGNIFICANCE

3.5.1 OBJECTIVES

The purpose of this lesson is to:

- understand the determinate cleavage
- describe the trochophore
- study the various theories involved in the evolution of trochophore

3.5.2 INTRODUCTION

Metazoans are multicellular animals. They are motile, heterotrophic organisms, which pass through a blastula stage during the course of their early embryonic development. Although, some such as sponges and corals are cellular (multicellular), the cells are loosely aggregated without any integration into tissues. They form the lowest group among the metazoa. They have remained at a grade termed the cellular grade as opposed to the tissue grade of organization. Adult sponges and corals have become sessile; they still retain motile larvae in their life cycle. Metazoans comprise almost all forms, which are generally considered as animals.

Since the first metazoa were almost certainly radial animals (Sponges, Cnidarians), the Bilateral animals must have sprung from a radial ancestor. There must have been an alteration from radial symmetry to bilateral symmetry.

The phylum Annelida comprises bilaterally symmetrical elongate vermiform animals. The body can be divided into similar halves (right and left) through a section passing through only one plane, median longitudinal; most of the animals belong to the bilateral symmetry.

3.5.3 EGG DEPOSITION

Many polychaetes shed their eggs freely into the seawater. The eggs become planktonic. Some polychaetes, however, retain the eggs within their protective retreats. Tubes and burrows in which they live may contain the polychaete eggs. Some polychaetes lay the eggs in mucous masses. The mucous masses lodging the eggs are attached to tubes or other objects. For example, *Arenicola*, a bamboo worm produces a small ovoid egg mass. The egg mass is found attached to the chimney of the tube.

Many other tube dwelling polychaetes brood their eggs within the tubes. A few species such as *Neries limnicola* brood their eggs within the coelom.

3.5.4 DEVELOPMENT OF THE EGG

Depending on the species, the amount of yolk in the polychaete egg varies differently. Determinate or mosaic development, characteristic of most of the protostomes such as polyclad flatworms, nemertines, annelids and mollusks. The annelidan eggs undergo determinate or mosaic type of development. Determinate type of development is usually associated with spiral cleavage.

In spiral cleavage, the spindle axes are oriented obliquely with respect to the polar axis of the egg. As a result the blastomeres alternate with one another. The cells of one tier resting in the angles between the cells below them. This displacement may be clockwise (dextotropic) or counter clockwise (levotropic). Spiral cleavage is commonly holoblastic but unequal. In spiral cleavage, the fate of each blastomere can be determined, a type of study known as cell lineage. As a result of the course of developmental events, the embryo becomes an unequal coeloblastula. In *Neries, Capitullai* and others, the eggs are yolky and the embryo becomes a stereo blastula. Gastrulation takes place by invagination or epiboly or both. After gastrulation the embryo develops into a top shaped trochophore larva. The mouth forms at the site of the blastopore by way of a stomodaeal invagination. In forms with an anus, the blastopore elongates and closes medially so as to leave the anterior end as mouth and its posterior end as anus. The anal end usually closes temporarily. Later it reopens as the permanent anus. A stomodaeum is universal throughout protostomia. Growth processes elsewhere in the embryo usually shift the mouth forward. The embryo develops an apical tuft of cilia and an equator girdle of cilia and swims about as a free-swimming larva.

3.5.5 THE TROCHOPHORE

The trochophores are of two types: planktotrophic and lecithotrophic.

Planktotrophic trochophores are found in the life history of *Owenia, Polygordius,* phyllodocids and serpulid fan worms. The greatest development of larval structures is attained in these forms. They feed on plankton with long larval existence. Hence, these are called planktotrophic.

The yolky and non-feeding lecithotrophic larvae are found in the life cycle of nereids and eunicids. These larvae are bottom dwellers. Their larval existence is short.

3.5.6 STRUCTURE OF THE TROCHOPHORE

The trochophore, which is found in annelids and mollusks, is somewhat biconical creature with a protruding equator (Fig. 3-40A,B). Externally it is covered with a single layered epithelium (ectoderm), thickened at the apical pole into a sensory plate (apical), which bears a tuft of cilia.

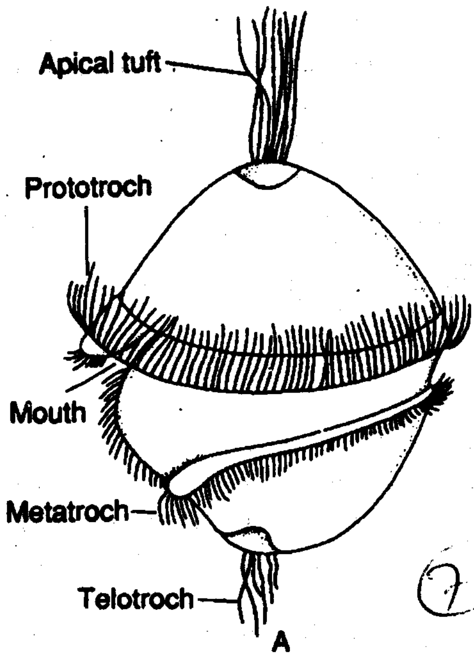

Fig. 3-40. A, External view of a trochophore larva showing characteristic cilliary bands - trochophore of the annelid *Polygordius.*

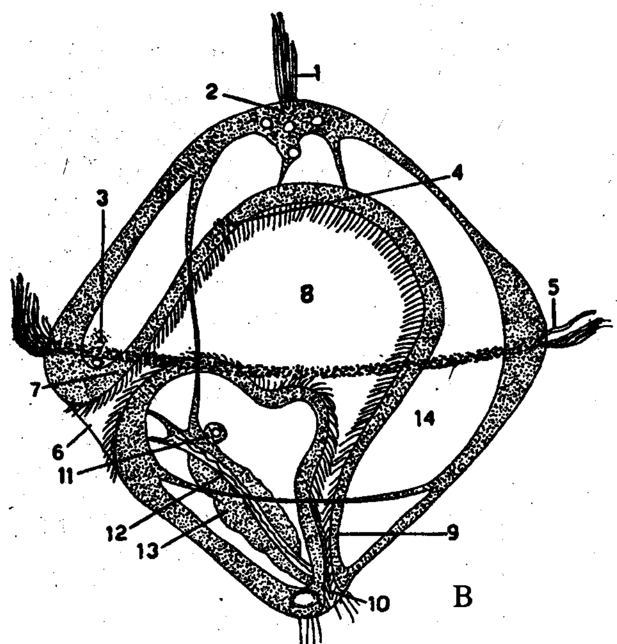

Fig. 3-40. B, An annelid trochophore - internal anatomy. 1, apical tuft of cillia; 2, apical sensory plate; 3, ectomesoderm; 4, eye; 5, prototroch; 6, mouth; 7, stomodaeum; 8. stomach; 9, proctodaeum; 10, anus; 11, statocyst; 12, archinephridium, consisting of one solenocyte; 13, mesoderm bands; 14, blastocoel.

Around the equator there is a girdle of cilia termed the prototroch, which passes above the mouth, and there may be a secondary equatorial girdle, the metatroch that passes below the mouth and sometimes also a ciliated girdle around the anus – telotroch or paratroch.

A complete digestive tract is present extending in an L- shape from the mouth at the equator to the anus at the lower pole; it consists of a ciliated stomodaeum leading into an expanded rounded stomach from which the short narrowed intestine proceeds to the anus. Between the digestive tract and the ectoderm there is a spacious cavity, which is the blastular cavity or blastocoel. Various sense organs including eyes and statocysts may be present. To either side of the intestine lies a mesoderm band derived from a teloblast and near this there is on each side a nephridium consisting of a tubule whose inner end is closed by one or more solenocytes. A solenocyte is a long tubular cell having a flagellum playing in the tube. Nephridia with solenocytes are undoubtedly different type of nephridia with flame bulbs; the later are generally present throughout the acoelomate and pseudocoelomate bilateria.

3.5.7 METAMORPHOSIS

The trochophore transforms into the juvenile body form (Fig.3-8) after metamorphosis. The most significant changes, which occur during metamorphosis are:

the gradual lengthening of the growth zone

the lengthening of the region between the mouth and the telotroch

The segments develop from anterior to posterior region. The germinal region (growth zone) remains just in front of the terminal pygidium. Thus, in adult polychaetes the oldest segments lie close to the head of the worm. In the pretrochal region the cells of the apical plate form the prostomium and the brain. The major part of the body of the adult is formed in the pretrochal region.

The metamorphosing larvae are elongated. They remain planktonic for varying lengths of time. Metamorphosing larvae (stages of spironids, sabellarids and oweniids) possess greatly enlarged, erectile, anterior setae that serve as floatation or protective devises. Metamorphosis may result in the immediate termination of a planktonic existence. In many polychaetes, the trochophore stage is passed in the egg before hatching. In such polychaetes metamorphosis is more direct. In such direct metamorphosis larval structures are poorly developed in the beginning. Still there may be a free-swimming, post trochophore larval stage. For example, in *Autolytus* (a brooding species) an elongated larva comes out by breaking the brood sac of the mother. In some other species, plank tonic stages are absent. The larval forms may assume the adult mode of existence on emerging from the jelly case.

Annual species, which live only for one or two years produce a large number of relatively small eggs. They have well developed plank tonic larvae. They are feeding larvae with a week or more of larval existence. Perennial species, which live for more than one year produce a small number of large, yolky eggs and non-feeding benthic larvae.

3.5.8 TROCHOPHORE THEORY

The name trochophore originated with Hatschek (1878); he developed the trochophore theory. According to Hatschek, trochophore is the larva of an ancestral form *Trochozoon* that was the common ancestral form of most of bilateral phyla. And of the bilateral phyla, a living rotifer *Trochosphaera* resembles to trochophore. Semper in 1959 discovered rotifers in the rice fields of Philippines, which he named *Trochosphaera* (Fig. 3-41). This rotifer shows considerable resemblances to trochophore. The resemblance between the trochophore and the *Trochosphaera* are:

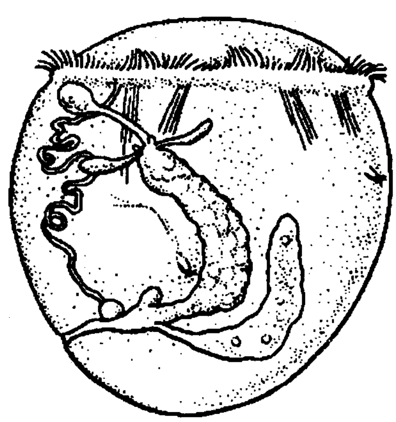

Fig. 3-41. Planktonic rotifer - the voluminous pseudocoel of *Trochosphaera solstitialis*

the general pseudocoelomate grade of structure
the ciliated girdles
the structure and location of the brain and the nature of its attached sense organs
the muscle bands
the nephridia
the form of the digestive tract and
the presence of an anus

For some time the rotifer like nature of the hypothetical trochozoon was considered. Later rotifers are regarded as specialized types by having ciliary girdles, which show alikeness to that of ciliary girdles of trochophores. Further, *Trochosphaera* has been found and restudied in various localities; it was concluded that rotifer has no evolutionary significance with regard to the trochophore theory. Nevertheless while discarding the rotifer part of the trochophore theory, one must admit that both the trochophore and the rotifer, *Trochosphaera* share a common character i.e. the pseudocoelomate grade of structure.

Nearly identical trochophore occurs in 2 phyla in which the adults are anatomically different i.e. the annelids and mollusks. This suggests that trochophore is a reminiscence of the common ancestor of eucoelomate protostomia and also of pseudocoelomate groups. However, the origin of acoelomate bilateria remains unaccounted for this theory.

3.5.9 THE CTENOPHORE – TROCHOPHORE THEORY

There was another assumption that a ctenophore resembles to a trochophore. The ctenophore-trochophore theory suggests that the trochophore may pass directly from a ctenophore like ancestor to the trochozoon so as to bridge the gap between radiate and bilateral animals. The resemblances between the ctenophore and trochophore are: apical nerve center with its attached sense organs and radiating sub epidermal nerves (often 8 in number as in spiral cleavage), occurrence of cross in cleavage pattern and origin of prototroch from 4 groups of ciliated cells.

But the course of spiral cleavage or developmental events of cleavage and the nervous system of the developed trochophore (with its longitudinal nerves connected by circular nerves) is more like that of acoel (polyclad flatworm) than is like that of a ctenophore. The ctenophore-trochophore theory is therefore rejected on these grounds.

3.5.10 EVOLUTIONARY SIGNIFICANCE

A main difficulty in the path of the trochophore theory and its variants had been to separate the acoelomate groups; it was suggested that the flatworms might have derived from the acoeloid grade of ancestor. The phylogenetic series here proposed is: planuloid ancestor-acoeloid ancestor-trochozoon (pseudocoelomate grade).

The salient features of the trochophore are the form of nervous system, the presence of anus and the occurrence of primitive nephridia. These salient features indicate that the ancestral form of trochophore would be higher than a flatworm (pseudocoelomate) and lower than an annelid (coelomate).

3.5.11 SUMMARY

Determinate development, characteristic of most of the protostomia, is usually associated with the spiral type of cleavage, found in polyclad flatworms, nemertines, annelids and mollusks.

In the annelids and mollusks, spiral cleavage often results in a characteristic larva known as the trochophore.

A trochophore larva is the basic larval stage of polychaetes.

The trochophore larva is somewhat biconical creature with a protruding equator.

It is covered externally by a one-layered epithelium (ectoderm).

An apical lobe with an apical tuft of cilia; a first equatorial girdle of cilia, the prototroch which passes above the mouth; a second equatorial girdle of cilia, metatroch, which passes below the mouth and sometimes a ciliated circlet, telotroch around anus are the characteristic features of trochophore.

A complete digestive tract (in an L shape), nervous system, excretory system, sense organs and a spacious cavity or blastocoel are present.

The trochophores are planktotrophic or lecithotrophic.

3.5.12 KEY TERMINOLOGY

Metatroch: A second girdle of cilia that develops posterior to the prototroch of a trochophore.

Prototroch: Pre oral ring of cilia of a trochophore larva.

Spiral cleavage: Type of cleavage pattern in which the cleavage spindles or cleavage planes are oblique to the polar axis of the egg.

Telotroch: A ring of cilia that encircles the anus at the posterior end of the larva.

3.5.13 SELF ASSESSMENT QUESTIONS

1. Describe the trochophore larva with a labeled diagram. Add a note on its evolutionary significance.
2. Explain the various theories involved in the path of trochophore evolution.
3. Write short notes on
   i) Trochophore
   ii) Trochophore theory

3.5.14 REFERENCE BOOKS

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UNIT - IV

4.1 GENERAL ORGANIZATION OF PHYLUM MOLLUSCA

4.1.1. OBJECTIVES :

The purpose of this lesson is to :

☆ describe the body organization of molluscs and
☆ understand the physiology of molluscs.

4.1.2. INTRODUCTION :

The phylum Mollusca forms the second largest invertebrate phylum with about 80,000 living species. In addition, about 35,000 fossil species have been described. This phylum has had a long geological history that dates back to the Cambrian. The possession of a mineral shell increases the chances of preservation that has resulted in a rich fossil record.

Molluscs are primitively bilaterally symmetrical, soft bodied and unsegmented animals. The members of this phylum show a great diversity of form. They include such familiar animals like chitons, snails, slugs, clams, oysters, squids and octopods. Inspite of some striking differences among snails, clams and squids, all the molluscs are built on the same fundamental plan. They exhibit a remarkable uniformity in the internal organization of body. All the molluscs show two important characters unique to the phylum - the presence of radula and mantle. The occurrence of radula and mantle are not found elsewhere in the animal kingdom.

4.1.3 DISTRIBUTION :

Molluscs are mostly aquatic, especially marine. Some are found in freshwater and a few like gastropods and bivalves are terrestrial. Some aquatic forms are pelagic, living along sea shores in shallow waters and also among corals. Some occur very deep upto 12,000 meters. They occur throughout the world on the coastal lines except in regions of extreme cold. They are more abundant in tropics.

Most of the molluscs are free-living. Some cling to rocks, shells and wood. Some like clams and snails burrow, wherÖas most of the cephalopods swim. A great variation is seen in their size and form. The smallest molluscs are the chitons with 3mm to 40cm long. The giant clam (*Tridacna*) of the south pacific attains a length of 1.5 meters or more and may weigh over 1100 kg. The giant squid *(Architeuthis)* is the largest known invertebrate having 6 meters long body with tentacles measuring 10.5 meters.

4.1.4. BODY ORGANIZATION IN MOLLUSCS :

To understand the basic design of molluscan body, it is necessary to examine a generalized mollusc. In the following description of a hypothetical animal, some features such as the structure and function of the degistive tract and gills are considered as important characters among primitive living species of different classes. Neverthesess, they provide a model for understanding the body organization of the major classes of molluscs.

4.1.4.1. BODY FORM :

A mollusc on which the general description is based on is an aquatic animal. It moves over and grazes on the surface of a hard substratum. Its body is bilaterally symmetrical, somewhat ovoid in shape (Fig. 4-1) and measures several centimeters in length. The body has an anterior head, a dorsal visceral hump and a ventral flattened muscular foot modified for creeping, burrowing or swimming. The dorsal surface is covered by an oval, convex, shield-like shell that protects the underlying internal organs, or visceral mass.

Shell, Mantle and Foot: The shell may be of one piece called univalve or of two, pieces, called bivalve. The underlying epidermis, called the mantle (or pallium), secretes the animal's shell, and the most active secretion occurs around the edge of the mantle and some new material is added to the

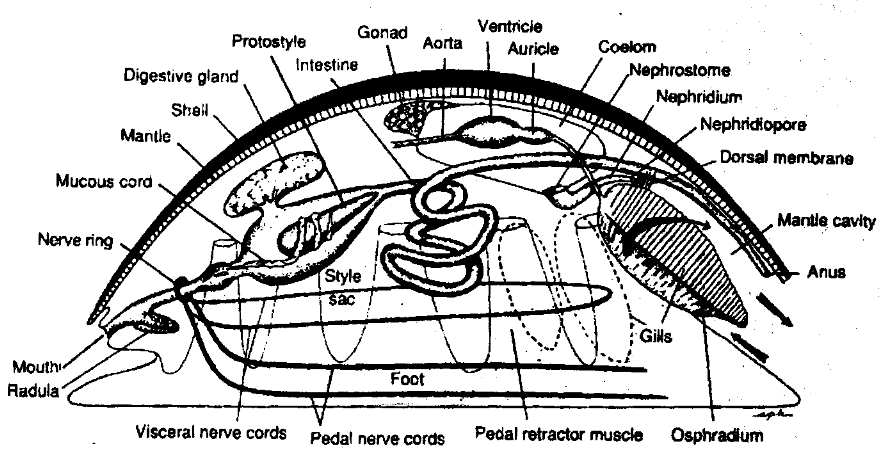

Fig. 4-1. Generalized mollusc (lateral view), Arrows indicate path of water current through mantle cavity.

older portions of the shell. Thus, the shell increases in diameter and thickness, at the same time pairs of pedal retractor muscles enable the animal to pull its shell down against the substratum on which it lives. Each retractor muscle is attached to the inner surface of the shell and is inserted into each side of the foot.

In most living molluscs, the epidermis of the exposed body parts including the foot and the mantle epidermis are covered by cilia and contain mucous gland cells. Mucus glands are more on the foot, where they lubricate the substratum to facilitate locomotion.

Between the mantle and the body is a chamber called mantle cavity. In this protective mantle cavity are pairs of gills or ctenidia and openings of pairs of nephridia (Fig. 4-1).

4.1.4.2. Gills :

Each gill (ctenidium) consists of a long, flattened axis projecting from the anterior wall of the mantle cavity and contains blood vessels, muscles and nerves (Fig. 4-2A). To each side of the broad surface of the axis are attached flattened, triangular filaments that alternate in position with those filaments on the opposite side of the axis (Fig.4-2 B and C). Such a gill is said to be bipectinate. Many living molluscs, however, have monopectinate gills in which the filaments occur on only one side of the axis, like teeth on a comb. The gills are located on opposite sides of the mantle cavity and

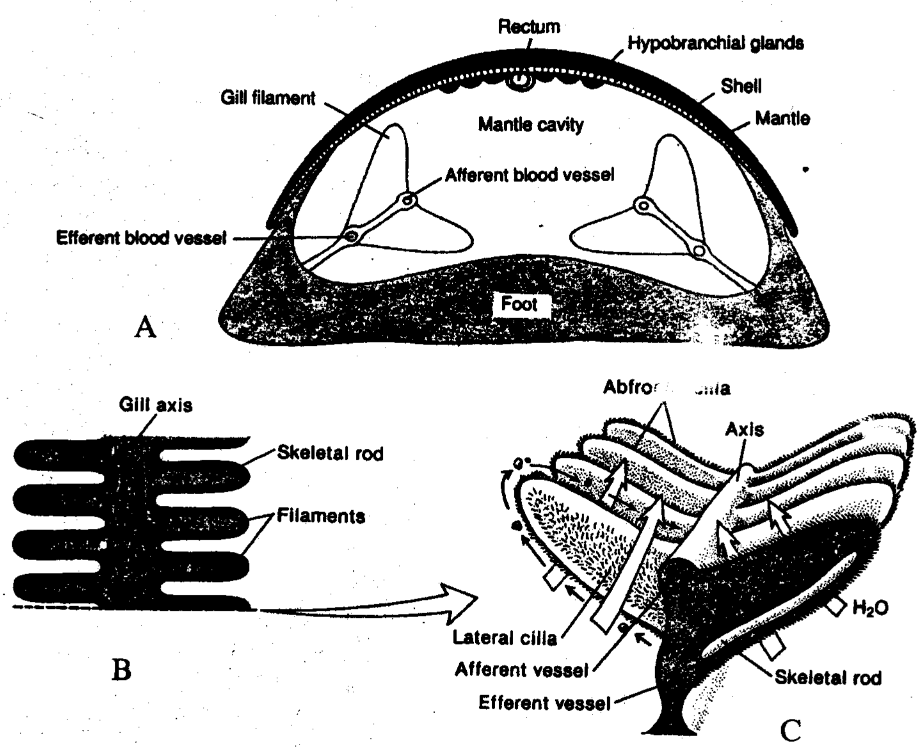

Fig. 4-2. A, Transverse section through the body of an ancestral mollusc at the level of the mantle cavity. B, Front section through the primitive gill, showing alternating filaments and supporting chitinous rods. C, Transverse section through the gill of the primitive gastropod *Haliotis*. Large outlined arrows indicate the direction of water current over gill filaments; small solid arrows indicate the direction of cleansing ciliary currents; small broken arrows indicate the direction of blood flow within gill filaments.

are held in position by a ventral and a dorsal membrane. Water enters the lower part of the mantle cavity from the posterior, passes upward between gill filaments, and then moves posteriorly back out of the cavity.

Gills are provided with surface ciliation. Propulsion of water through the mantle cavity is largely effected by the beating of a powerful band of lateral cilia located on the gills just behind the frontal margin (which has first contact with the inhalant water stream) (Fig. 4-2C). Sediment brought in by water currents is trapped by mucus on the gills. It is carried upward first by the frontal cilia and then by abfrontal cilia toward the axis. From the axis, the exhalant current sweeps the sediment out. On the mantle roof are two patches of mucus–secreting epithelium, called hypobranchial glands (Fig. 4-2A). They lie downstream to each gill and trap sediment in the existing water current.

Two blood vessels run through the gill axis. The afferent vessel, which carries blood into the gill, runs within the abfrontal margin. The efferent vessel, which drains the gills, runs along the frontal margin. Blood flows through the filaments from the afferent vessel to the efferent vessel (Fig. 4-2C). The external water stream flowing from the frontal to the abfrontal margin, constitutes a counter current flow. Such counter current flow maximizes the uptake of oxygen by the gill.

4.1.4.3. Digestive System :

Many living molluscs, graze on fine algae and other organisms growing on rocks. The anterior mouth opens into a cuticle-lined buccal cavity. The floor of the buccal cavity is thickened by an elongated, muscular, cartilaginous mass, the odontophore (Fig.4-3). A membranous belt, the radula, bears transverse rows of teeth and extends medially over the odontophore and around its anterior end. The radula arises from a deep out pocket, called the radula sac, from the posterior wall of the buccal cavity. The odontophore can be projected out of the mouth. The radula can also move to some extent over the odontophore. At rest, the lateral margins of the radula tend to roll up within the sac. As the odontophore is projected out of the mouth over the substratum, the changing tension causes the radula belt to flatten as it bends around the odontophore tip. The flattening in turn brings about the erection

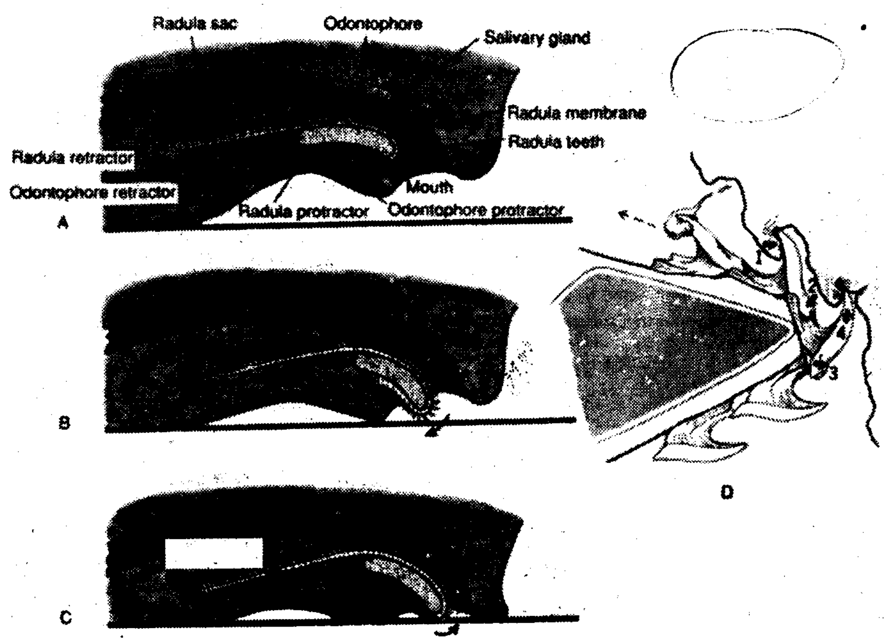

Fig. 4-3. Molluscan radula. **A,** Mouth cavity, showing radula apparatus (lateral view). **B,** Protraction of the radula against the substratum. **C,** Retracting movement, during which substratum is scraped by radula teeth. **D,** The cutting action of radula teeth when they are erected over the end of the odontophore during radula retraction.

of the teeth. In living species, the radula acts as a scraper and collector. Because the radula teeth recurve posteriorly, the effective scraping stroke is forward and upward when the odontophore is retracted (Fig. 4-3 B to D). Scraping results in a gradual loss of membrane and teeth at the anterior end of the radula. To compensate for this loss, new teeth are continuously secreted at the posterior end. The radula grows slowly at a rate of one to five rows of teeth per day.

A pair of salivary glands opens onto the anterior dorsal wall of the buccal cavity. The mucus secreted by these glands lubricates the radula and entangles the ingested food particles. Food in mucus strings passes from the buccal cavity into a tubular oesophagus and then to stomach (Fig. 4-4). In primitive living molluscs, the stomach is shaped like an ice cream cone. Its anterior end is broad and hemispherical into which the oesophagus opens. The posterior end is tapered which leads into the intenstine. The anterior region of the stomach is lined with chitin except for a ciliated, ridged sorting region and the entrance point for two ducts from a pair of lateral digestive glands (Liver), or diverticula. The posterior region of the stomach, called the style sac, is ciliated.

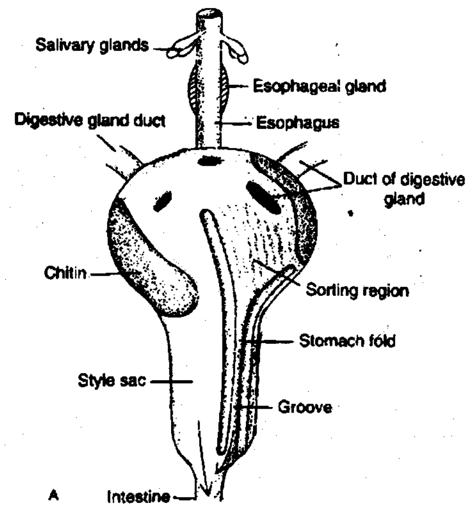

Fig. 4-4. Diagram of a primitive molluscan stomach.

Digestion : In the stomach, the ingested food is rotated by cilia of the style sac. The rotation winds up the mucus food strings, drawing them along the oesophagus and into the stomach (Fig. 4-1). The relatively stiff rotating mucus mass is called a protostyle. The size and consistency of particles within the string vary greatly. The chitinous lining of the anterior part of the stomach protects the wall from damage by sharp surfaces. The acidity of the stomach fluid (pH 5-6 in living molluscs) decreases the viscocity of the mucus and aids in freeing the food particles from mucus. Such particles are swept towards the sorting region where they are graded by size. Lighter and finer particles are driven by the cilia of the ridges to the duct openings of the digestive diverticula. Heavier and larger particles are carried in the grooves between the ridges to a large groove running along the floor of the stomach to the intestine.

Particles utilized as food pass into the ducts of the digestive glands, and digestion occurs within the cells of the distal tubules. Although digestion appears to be mostly intracellular in primitive molluscs, atleast some extracellular digestion occurs within the stomach cavity of most advanced species.

Intestine is long and coiled (Fig. 4-1). It functions largely in the formation of fecal pellets. The anus opens middorsally at the posterior margin of the mantle cavity, and wastes are swepty away by the exhalant current.

4.1.4.4. Circulatory system :

Pericardium or relatively small coelomic cavity is located in the middorsal region of the body (Fig. 4-1). It surrounds the heart dorsally and a portion of the intestine ventrally. The heart consists of a pair of posterior auricles and a single anterior ventricle. The auricles drain blood from each gill via the efferent vessels and then pass it into the muscular ventricle. Ventricle pumps the blood anteriorly through a single aorta. The aorta branches into smaller blood vessels that deliver the blood into tissue spaces and sinuses of the hemocoel. From the tissue sunises blood returns back to heart by way of the nephridia and the gills. This is an oversimplified picture of molluscan circulation. In living molluscs there is a considerable variation in the flow pattern. Like vertebrates and unlike all other invertebrates, the blood of squids and octopods is completely enclosed within vessels lined by endothelium. This is presumably because the vascular system of these animals, like that of vertebrates, is a high pressure system, important in supporting their high activity. The blood contains amoebocytes as well as the respiratory pigment called hemocyanin.

4.1.4.5. Nervous system :

The ground plan of the molluscan nervous system consists of a circumesophageal nerve ring from the underside of which two pairs of nerve cords extend posteriorly (Fig. 4-1). Because there are four nerve cords, molluscs are said to show tetraneury. The ventral pair of cords, called the pedal cords, innervates the muscles of the foot. The dorsal pair, called the visceral cords, innervates the mantle and visceral organs. Transverse connections of each pair of cords gives the appearance of a ladder.

4.1.4.6 Sense organs :

The sense organs of many living molluscs include tentacles, a pair of eyes, a pair of statocysts in the foot, and osphradia. The osphradia are patches of sensory epithelium located on the posterior margin of the ventral mesentery that supports each gill (Fig. 4-1). They function as chemoreceptors and also determine the amount of sediment in the inhalant current.

4.1.4.7. Excretory System :

The excretory organs, usually called kidneys, are organized into a metanephridial system. In living molluscs, there are commonly one or two kidneys (Fig. 4-1). A typical kidney tubule has one end connected to the pericardial cavity and the other opening to the outside through a nephridiopore. However, in most molluscs, the connection with the pericardial cavity (renopericardial canal) and the nephridiopore are at the same end of the nephridium. The nephridium is thus a blind sac. The nephridiopore opens at the back of the mantle cavity. The pericardial coelom receives blood ultrafiltrate through the auricular wall of the heart, which contains podocytes. The pericardial fluid then passes through the nephrostome into the kidney tubule. Here secretion of wastes from the blood, as well as some selective reabsorption, may occur through the tubule wall, and the final urine is discharged through a pair of renal pores into the mantle cavity.

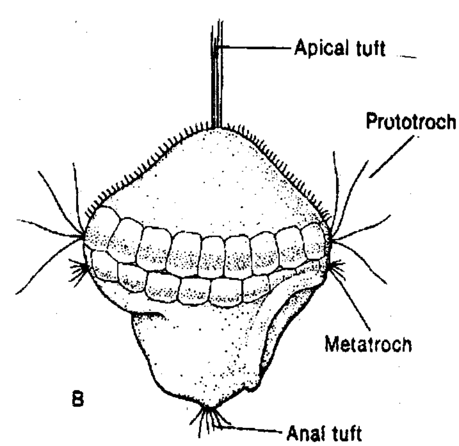

Fig. 4-5. Trochophore larva of the gastropod *Notoacmaea scutum*.

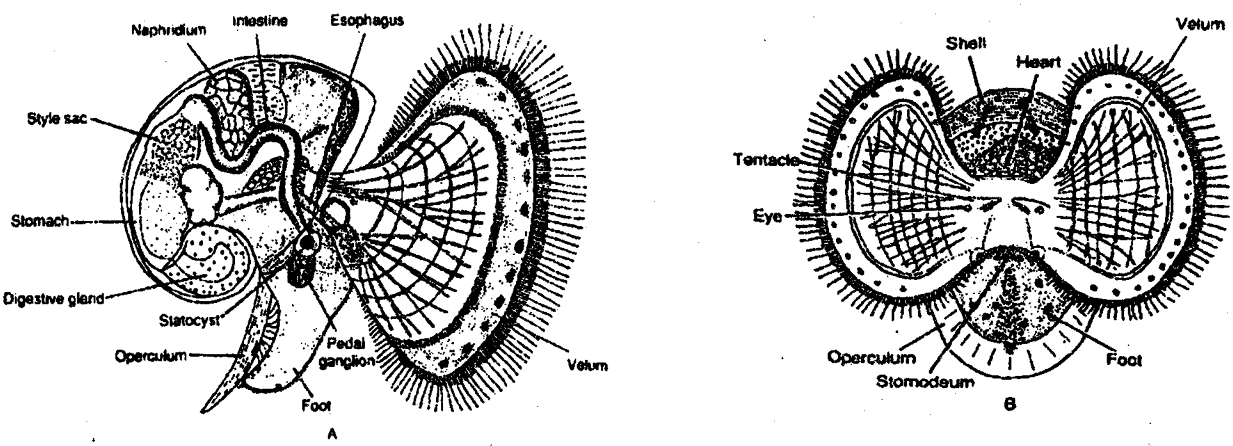

Fig. 4-6. Veliger larva of the slipper snail, *Crepidula.* A. Lateral view, B. Frontal view.

4.1.4.8. Reproduction and Development :

The generalized mollusc is dioecious and has a pair of an anterior, dorsolateral gonads (Fig. 4-1). When ripe, the eggs or sperm release into the coelomic cavity and are carried to the outside through the kidneys. Fertilization occurs externally in the seawater. Following a period of spiral cleavage, a gastrula develops into a free swimming trochophore larva (Fig. 4-5).

In most of the molluscans the trochophore passes into a more highly developed Veliger larva, in which the foot, shell and other structures make their appearance (Fig. 4-6) Characteristically, a veliger larva has to ciliated flaps, called a velum. The velum serves as a swimming and feeding organ. At the end of larval life, the larva sinks to the bottom and metamorphoses to assume the benthic habit of the adult.

4.1.5. SUMMARY :

1. Members of the Phylum Mollusca, the second largest phyla of animals, have been in existence since Cambrian.

2. They are distinguished by a muscular **foot**, a calcareous shell secreted by the underlying body wall, the mantle and a feeding organ, the **radula**.

3. They are found in the sea, in freshwater and on land. Some are pelagic and some inhabit deep waters. They may be free living or sessile.

4. A generalized mollusc is bilaterally symmetrical and possesses an anterior head, a dorsal visceral mass, covered by a shield-shaped shell and a flat creeping foot.

5. Several pairs of gills are located within a mantle cavity created by the overhanging mantle and shell. The gills (ctenidia) are composed of numerous flattened filaments that extend alternately from each side of a supporting axis. Each filament bears lateral cilia, which create the ventilating current, and frontal cilia and abfrontal cilia, which remove particulate matter.

6. The radula, a membranous belt of recurved chitinous teeth stretched over a muscular cartilage base, the odontophore. It functions as a scraper in feeding.

7. The primitive stomach is adapted for processing fine particles of food (especially algae) scraped from hard surfaces by the radula. A rotating, mucous mass in the style sac acts like a windlass, pulling in a food laden mucous string from the esophagus. Particles are separated over a sorting region and fine particles are sent up the ducts of the digestive glands, where intracellular digestion occurs. Intestine functions in the formation of fecal pellets. Wastes are swept away by the exhalent current.

8. The blood vascular system is a hemocoel. Blood flows from the gills into one (or more) pair of auricles. From each auricle blood passes into the central ventricle, which pumps it out through the aorta for distribution to the tissue sinuses.

9. The heart is surrounded by a coelomic cavity (pericardial cavity) that receives an ultrafiltrate of the blood. The metanephridial excretory tubules, called kidneys, drain the pericardial cavity, modify the ultrafiltrate, and empty into the mantle cavity.

10. The ground plan of the nervous system consists of a circumesophageal nerve ring, from which extend a pair of pedal nerve cords innervating the foot and a pair of visceral cords innervating the mantle and visceral mass.

11. Typical sense organs are tentacles, eyes, statocysts and one or two osphradia in the mantle cavity.

12. The generalized mollusc is dioecious, with a pair of gonads in the visceral mass adjacent to the pericardium. Gametes are released into the pericardial coelom, and the kidneys function as gonoducts. In such primitive molluscs fertilization is external, and development is planktonic.

13. Cleavage is spiral, a trochophore is the first larval stage, and a veliger is the second.

4.1.6. KEY TERMINOLOGY :

ıpectinate: Refers to a gill in which the filaments occur on both sides of the gill axis.

ʒlood vascular system: Circulatory system of bilaterally symmetrical animals that develops within the connective tissue.

Buccal cavity: Cavity within the mouth opening.

Calcareous: Composed of calcium carbonate.

Ctenidium (pl. ctenidia): A molluscan gill in which the filaments alternate on opposite sides of the axis.

Dioecious: Having separate sexes, i.e., some individuals contain the male reproductive system and other individuals contain the female system.

Foot: Ventral surface of a mollusc that is muscular and flattened, forming a creeping sole.

Hemocoel: A voluminous, blood-filled cavity, occupying all or most of the body.

Mantle: A body wall fold that secretes a shell.

Mantle cavity (pallial cavity): Protective chamber created by the overhanging of a mantle

Monopectinate : Refers to a gill in which the filaments occur on only one side of the axis, like teeth on a comb.

Nephridium (pl. Nephridia): An excretory tubule that usually opens to the exterior via a nephridiopore. The inner end of the tubule may be blind (protonephridium), ending in terminal cells or may open into the coelom (metanephridium) through a ciliated funnel.

Nephrostome: An open ciliated funnel at the inner coelomic end of a metanephridium.

Odontophore: An elongated, muscular, cartilaginous mass in the floor of the buccal cavity of many molluscs.

Osphradium : Sensory-area in the incurrent siphon of some molluscs.

Radula: A membranous belt, found in most molluscs. It bears transverse rows of teeth and extends medially over the odontophore and around its anterior end.

Trochophore: Type of larva in which the larval body is ringed by a girdle of cilia, the prototroch.

Veliger: Molluscan planktotrophic larva that supersedes the trochophore, and in which the shell, foot, velum and other structures make their appearance.

4.1.7. Self Assessment Questions :

1. Give an account on the general organization of phylum Mollusca.
2. Describe the body organization of a generalized mollusc.
3. Write notes on :
   a) Gills in bivalves
   b) Radula
   c) Osphradium
   d) Veliger larva
   e) Mantle

4.1.8. REFERENCE BOOKS :

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Dr. P. Padmavathi

4.2. CLASSIFICATION OF PHYLUM MOLLUSCA

4.2.1. OBJECTIVES :

The purpose of this lesson is to :

* understand the general characters of the phylum Mollusca and
* classify the phylum Mollusca upto orders.

4.2.2. INTRODUCTION :

Mollusca is the second largest phylum in the animal kingdom. The word Mollusca is derived from the latin word, *mollis* (= soft). The term "Mollusca" was coined by Aristototle. Cuvier defined Mollusca as : "Molluscs are soft bodied, bilaterally symmetrical, unsegmented coelomate animals; usually shelled having a mantle, ventral foot, anterior head and a dorsal visceral mass". Molluscs came into existence in the early Cambrian period. They have occupied different habitats of land and water and established themselves thereafter.

The beautiful symmetry, colouration and variety of molluscan shells fascinate millions of collectors. This contributed much to the knowledge of the phylum. As a result, molluscs are the best taxonomically known group next to birds and mammals. The study of Mollusca is called Malacology and the study of shells is Conchology.

4.2.3. GENERAL CHARACTERS :

1. Majority of mollusks are marine, some are freshwater and few others are terrestrial.
2. They are fundamentally bilaterally symmetrical. Some gastropods and cephalopods became secondarily asymmetrical.
3. Highly organized body showing tissue-organ grade of organization.
4. They are triploblastic, true coelomate animals.
5. The bod is soft, unsegmented and consists of head, foot, mantle and visceral mass. Jointed appendages are absent.
6. The body is covered with one layered, often ciliated epidermis
7. Body is generally protected by an exoskeletal calcareous shell of one or more pieces, secreted by the mantle. Some have internal shell and in some pulmonates like *Vaginulus,* the shell is absent.
8. The head bears a terminal mouth, eyes, tentacles and other sense organs. A distinct h ad is lacking in Pelecypoda and Scaphopoda.
9. A thick and highly muscular ventral foot forms the locomotory organ. It is abs[illegible] only in oysters.
10. The visceral mass contains the vital organs of the body.
11. The visceral mass is covered by a thick, muscular fold of the body wall called mantle or pallium.
12. The space left in between the mantle and visceral mass is called the mantle cavity containing the gills and the openings of the digestive, nephridial and reproductive systems.
13. Body cavity is a haemocoel. The true coelom is reduced and is repreented by pericardial, nephridial and reproductive cavities.
14. Alimentary canal is a simple U – shaped tube or shows coiling.
15. A rasping organ called radula is present on the floor of the buccal cavity. It is absent in bivalves (Pelecypoda).
16. A large digetive gland is present. It is involved in digestion, absorption and storage. Sometimes salivary glands are also present.
17. Respiratory organs consists of numerous gills or ctenidia usually provided with osphradium at the base. Lung is developed in terrestrial forms. Respiratory pigment is usually haemocyanin.
18. Circulatory system is open and lacunar type except in cephalopods which shows some tendency towards a closed system.
19. Heart is present on the dorsal side and enclosed in a pericardium. It consists of one to four auricles and one ventricle.
20. Nervous system consists of paired cerebral, pleural, pedal and visceral ganglia and they are connected by commissures and connectives.

21. Sense organs are eyes, tentacles, lithocysts and osphradium.
22. Excretory organs are the sac-like kidneys or metanephridia which are true coelomoducts. They communicate from pericardial cavity to the exterior by nephridiopore.
23. Sexes usually separate (dioecious) but some are hermaphroditic. Some are protandric. Gonads and gonoducts are usually single.
24. Fertilization is internal or external. Mostly oviparous and a few are viviparous.
25. Cleavage is spiral and determinate type. Development is direct or indirect with trochophore or veliger larvae in the life history.
26. Asexual reproduction and segmentation are totally absent.

4.2.4. CLASSIFICATION :

Classification of Mollusca is mainly based on the structure and shape of shell and the position of foot. Phylum Mollusca is divided into seven classes.

4.2.5. CLASS APLACOPHORA :

1. All are marine and live in burrows. Some live among corals
2. These are primitive molluscs.
3. Body worm-like, and cylindrical.
4. Shell is absent.
5. Foot absent or reduced to a ventral ridge.
6. The integument (mantle) is covered by a cuticle and contains embedded calcareous scales or spicules.
7. Radula may or may not be present.
8. Mostly hermaphroditic.
9. Life history includes trochophore larva.

4.2.5.1. SUB-CLASS CHAETODERMOMORPHA (=Caudofoveata) :

1. Burrowing aplacophorans.
2. Foot absent or reduced.
3. A pair of bipectinate gills located in the posterior mantle cavity.
   Examples : *Chaetoderma* (Fig. 4-7), *Scutopus*.

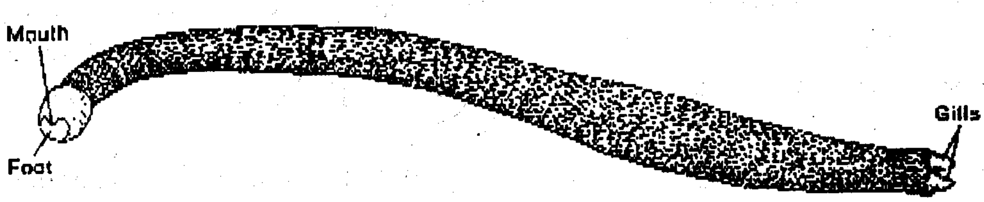


Fig. 4-7. *Chaetoderma*

4.2.5.2. SUB-CLASS NEOMENIOMORPHA (=Solenogastres)

1. Live on the surface of cnidarians
2. Foot reduced to a ventral ridge
3. Gills absent.

Examples : *Neomenia (Fig. 4-8), Lepidomenia.*

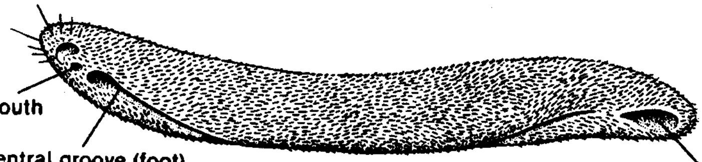


Fig. 4-8. *Neomenia*

4.2.6. CLASS POLYPLACOPHORA :

1. Commonly called chitons
2. Body is more or less oval and dorsoventrally flattened.
3. Dorsal surface is covered by eight overlapping shell plates.
4. Ventral surface is occupied by a broad creeping foot.
5. Head indistinct and devoid of eyes and tentacles.
6. Gills numerous (6 to 88 pairs), located in the pallial groove lying between the foot and the mantle edge (girdle).
7. Sexes are usually separate (dioecious) with a single gonad.
8. Trochophore larva is present in the life cycle.
9. Mostly intertidal in habitat.

4.2.6.A ORDER PALEOLORICATA :

Paleozoic and Mesozoic chitons in which the shell plates lack the middle calcareous layer (articulamentum).

4.2.6.B. ORDER NEOLORICATA :

1. Fossil and living chitons in which the shell plates possess a middle calcareous layer.
2. Valves of the shell with or without insertion plates and teeth.

Examples : *Lepidopleurus, Chiton* (Fig 4-9), *Chaetopleura* (Fig. 4-10), *Cryptochiton.*

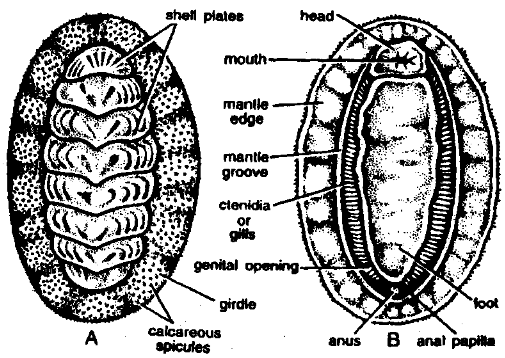


Fig 4-9. *Chiton.* A- Dorsal view; B-Ventral view

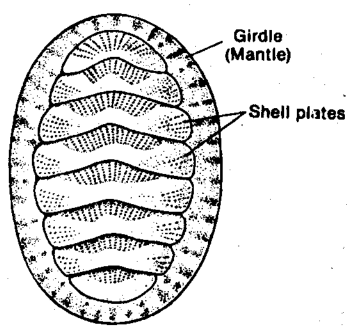


Fig 4-10. *Chaetopleura*

4.2.6. CLASS MONOPLACOPHORA :

1. Monoplacophorans inhabit deep water.
2. Body possesses a single symmetrical shell
3. Shell varies in shape from a flattened, shield–like plate to a short cone. Shell has 3 to 8 pairs of pedal retractor muscle scars (Gastropod shell has 2 scars).
4. Head indistinct, eyes are absent.
5. Foot flat and ventral.
6. Distinctive feature of monoplacophorans is the presence of many monopectinate gills (5-6 pairs), retractor muscles (8 pairs), auricles (2 pairs) and kidneys (6 pairs).
7. Sexes are separate. Two pairs of gonads are present.
8. Fertilization external and development unknown.
9. Eleven species in three genera.
   Examples : *Neopilina* (Fig. 4-11), *Vema, Monoplacophorus.*

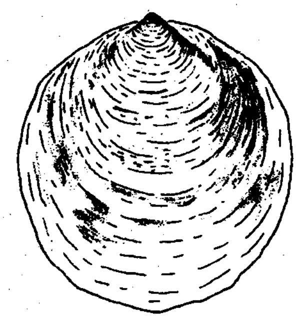


Fig. 4-11A. *Neopilina*-
Dorsal view of shell.

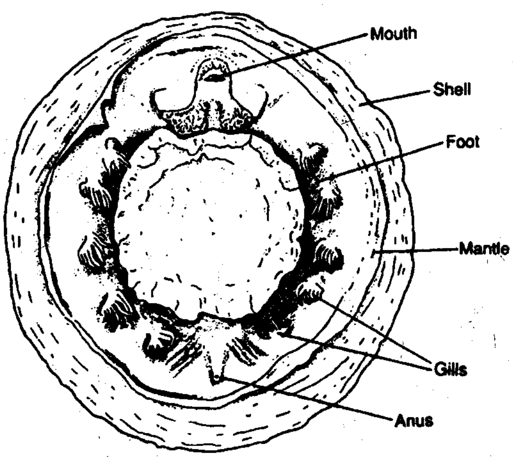


Fig. 4-11B. *Neopilina*-
ventral view.

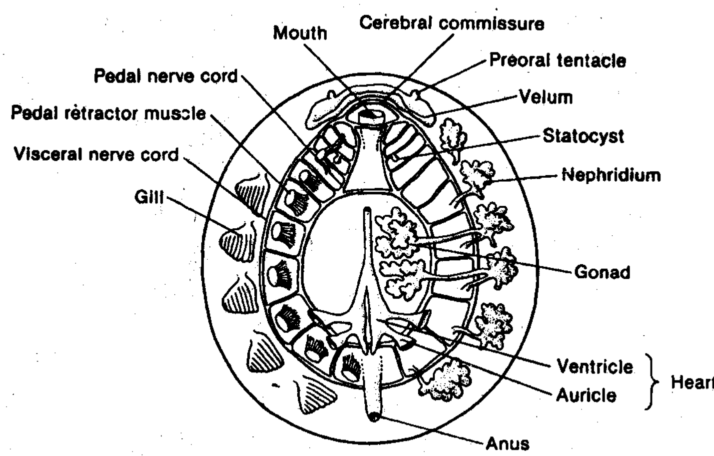


Fig. 4-11C. *Neopilina*-
Internal anatomy, ventral view.

4.2.7. CLASS GASTROPODA :

1. It is the largest class of molluscs and includes snails and slugs. These are inactive and sluggish animals.
2. Gastropods are marine, freshwater, terrestrial and few parasitic on echinoderms.
3. Body possesses a single, asymmetrically spiraled shell.
4. The visceral mass undergoes twisting. This peculiar phenomenon is called torsion. Hence, the animals become asymmetrical.
5. Head distinct with eyes and tentacles.

6. The ventral part of foot is flattened into a creeping sole and often bears dorsally a hard piece, the operculum on its posterior end.
7. Respiration is carried on mostly by ctenidia (gills) or lungs or both, and in some forms through the wall of mantle cavity.
8. Blood contains a respiratory pigment in the form of haemocyanin or hemoglobin.
9. Excretory organs comprise metanephridia (Kidneys) which are paired in primitive forms and reduced to a single nephridium in most forms.
10. Nervous system is well developed and the nerves attain a shape of "8" due to torsion. Such a nervous system is called "Streptoneury" or "Chiastoneury". In some, nervous system do not show this shape, because of detorsion. Such a nervous system is called "euthyneury".
11. Development includes trochophore and veliger larval stages.

4.2.8.1. SUB CLASS PROSOBRANCHIA :

1. Mostly marine, few freshwater or terrestrial forms.
2. Shell is generally conical and spirally coiled with an operculum.
3. Mantle cavity and other body organs are located anteriorly.
4. Aquatic species with one or two gills within the mantle cavity, anterior to heart. Hence the name Prosobranchia.
5. Head bears only a pair of tentacles.
6. Nervous system forms a figure of "8". Hence the name streptoneura.
7. Sexes are separate. Trochophore or veliger larva are seen during life history.

4.2.8.1.A. ARCHAEOGASTROPODA (DIOTOCARDIA, ASPIDOBRANCHIA)

1. **Primitive** forms in which there are usually two bipeclinate gills, two auricles and two nephridia.
2. The right gill may be reduced or absent.
3. Operculum is absent in many forms with few exceptions.
4. Osphradium is simple (ridgelike)
5. Nervous system not concentrated usually with pedal cords.

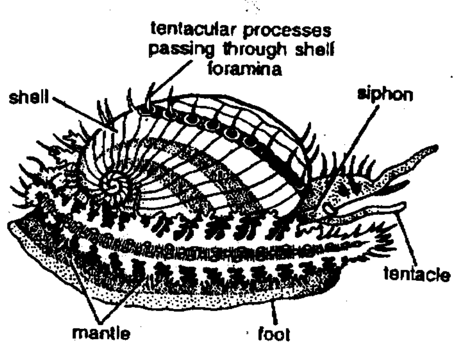


Fig. 4-12. *Haliotis.*

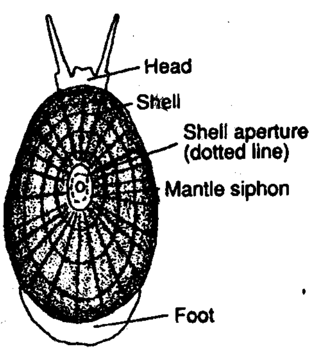


Fig. 4-13. *Diodora*

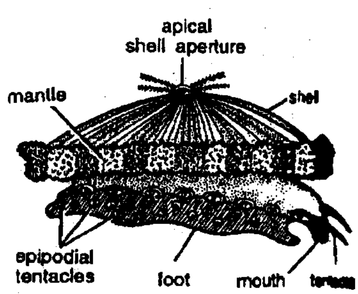


Fig. 4-14. *Fissurella*

6. Sex cells discharged directly into the sea by way of the right nephridia. Penis absent.
Examples : *Pleurotomaria, Scissurella* (Slit snails), *Haliotis (abalone)* (Fig. 4-12); *Diodora* (Fig. 4-13), *Fissurella (Keyhole limpets)* (Fig. 4-14) ; *Acmaea, Lottia, Patella* (Limpets) (Fig. 4-15); *Trochus, Callistoma; Turbo; Astraea.*

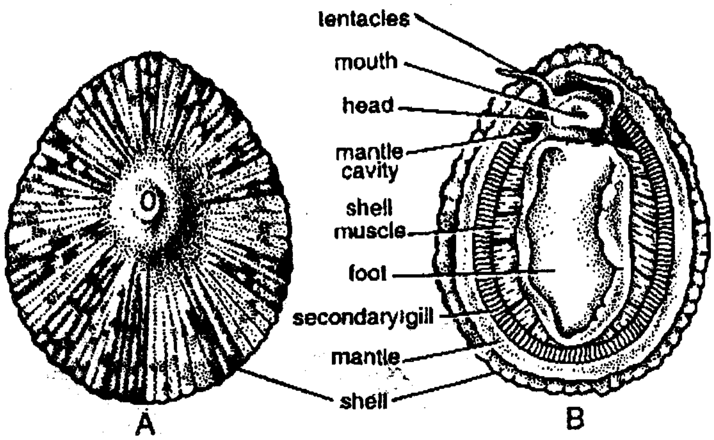


Fig. 4-15. *Patella. A*- Dorsal view; B-Ventral view

4.2.8.1. ORDER MESOGASTROPODA (TAENIOGLOSSA)

1. Forms with single monopectinate gill, one auricle and one nephridium.
2. Usually with non-calcified operculum.
3. Radula taenioglossate type, that is, seven teeth in a transverse row.
4. Osphradium is simple (ridgelike).
5. Nervous system concentrated without pedal cords.
6. Reproductive system complex, usually with a penis.
Examples: *Viviparus, Pila* (Fig. 4-16), *Littorina, Pomatias, Hydrobia, Turritella, Vermetus, Cerethium, Janthina, Entoconcha, Calyptraea, Crepidula, Strombus, Cypraea, Cymatium, Tonna.*

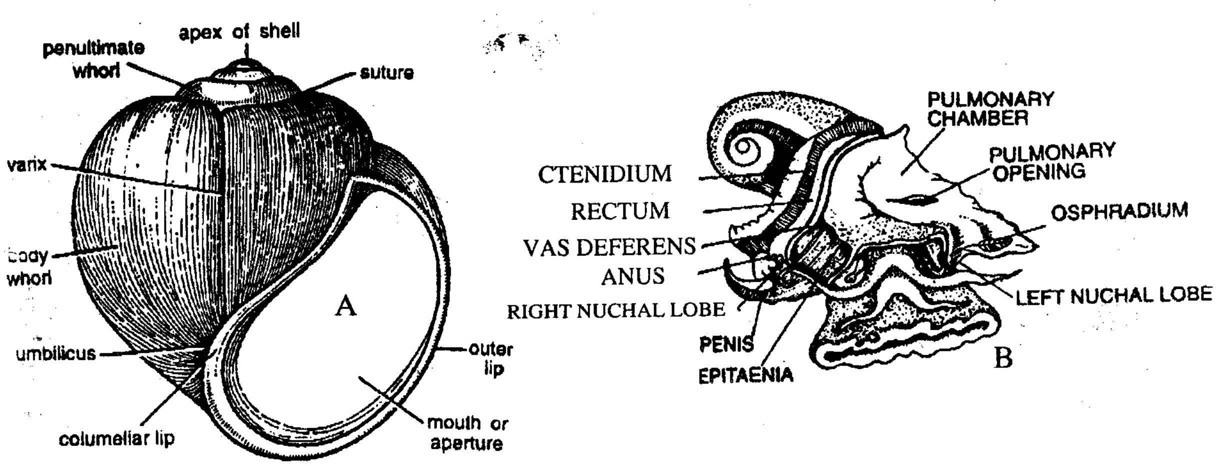


Fig. 4-16. *Pila globosa. A*- shell, ventral view; B- Pallial complex

4.2.8.1.C.ORDER NEOGASTROPODA (STENOGLOSSA) :

1. All are marine.
2. Members of this order are similar to the Mesogastropoda in having a single monopectimate gill, one auricle and one nephridium and in the complexity of their reproductive system.
3. Radula rachiglossate type, that is, three teeth in a transverse row.
4. Osphradium is complex (with bipectinate folds).

Examples : *Murex* (Fig 4-17), *Urosalpinx* (Fig 4-18), *Buccinum, Neptunea, Fasciolaria, Nassarius, Oliva, Mitra, Harpa, Voluta, Conus, Polystira, Terebra.*

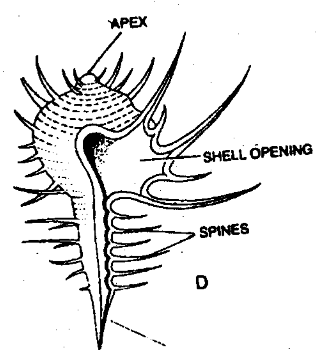


Fig. 4-17. *Murex*

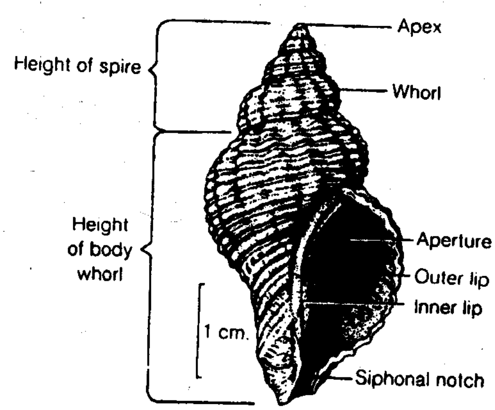


Fig. 4-18. *Urosalpinx cinerea*

4.2.8.2. SUB CLASS OPISTHOBRANCHIA :

1. Exclusively marine gastropods.
2. Reduction or loss of shell and mantle cavity. Shell if present, covered by mantle or pedal folds.
3. They have one gill, one auricle, and one nephridium. They display detorsion.
4. Operculum usually absent.
5. Head commonly bears two pairs of cephalic tentacles.
6. Buccal cavity with a pair of jaws.
7. Many opisthobranchians are secondarily bilaterally symmetrical.
8. Nervous system concentrated due to detorsion.
9. Hermaphrodites.

4.2.8.2.A. ORDER ONCHIDIACEA :

1. Slug like, naked or without shell, with pulmonary sac and anus.
2. Hermaphrodites. Female gonopore at the posterior end and male gonopore at the anterior end.

Examples : *Onchidium, Onchidella.*

4.2.8.2.B ORDER CEPHALASPIDEA :

1. Reduced and internal shell is present. Shell is absent in some forms.
2. Head with tentacular shield.
3. Parapodial lobes are present or absent.

Examples : *Acteon, Hydatina* (Fig. 4-19), *Bulla.*

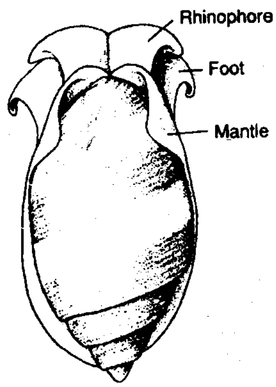


Fig. 4-19. *Hydatina*

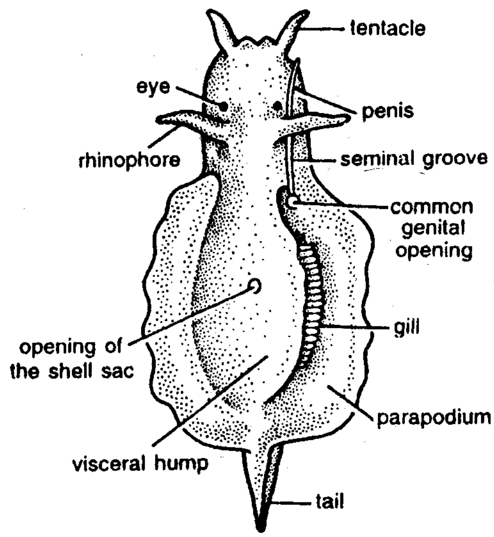


Fig. 4-20. *Aplysia*

4.2.8.2.C. ORDER ANASPIDEA OR APLYSIACEA (Sea hares) :

1. Large opisthobranchs with more or less bilaterally symmetrical external form.
2. Shell small, buried in the mantle.
3. Well developed parapodial lobes.
4. Anterior end bears a pair of tentacles, a pair of rhinophores and a pair of eyes.

Examples: *Aplysia (Fig. 4-20), Bursatella, Akera.*

4.2.8.2.D. ORDER PTEROPODA :

1. Pelagic snails with or without shell.
2. Swim by a pair of lateral pedal expansions.

Examples : *Spiratella, Cavolina* (Fig. 4-21), *Clione, Gleba.*

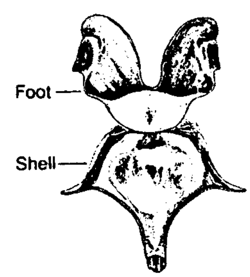


Fig. 4-21 *Cavolina*

4.2.8.2.E. ORDER ACOCHLIDIOIDEA :

1. Small naked snails with no gills.
2. The visceral mass sharply set off from the rest of the body.
3. Some members found in freshwater.

Examples: *Acochlidium, Microhedyle* (Fig. 4-22)

4.2.8.2.F. ORDER PHILINOGLOSSACEA :

1. Minute naked snails.
2. Head appendages and gills are absent.
3. Visceral mass is separated from the foot by a groove.

Example : *Philinoglossa.*

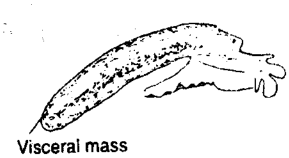


Fig. 4-22. *Microhedyle*

4.2.8.2.G. ORDER SACCOGLOSSA :

1. Body with or without shell.
2. Pharynx suctorial.

3. Sperm duct closed.
   Examples : *Oxynoe, Berthelinia* (Fig 4-23), *Elysia* (Fig. 4-24)

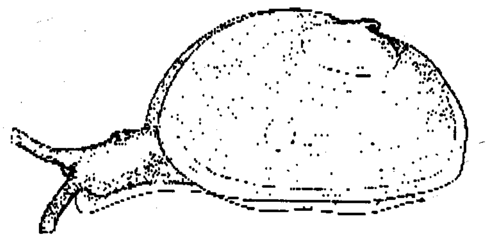


Fig. 4-23. *Berthelinia*

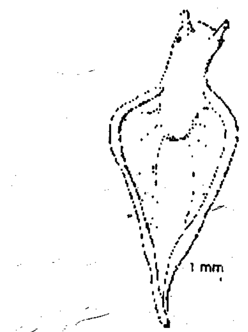


Fig. 4-24. *Elysia*

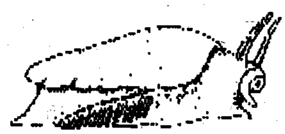


Fig. 4-25. *Pleurobranchus*

4.2.8.2.H. ORDER NOTASPIDEA :

1. Shelled or naked opisthobranchs.
2. Gills bipectinate and osphradium on the right side.
3. Parapodia absent.
4. Mantle present but devoid of mantle cavity.
   Examples : *Tylodina, Pleurobranchus*.(Fig. 4-25)

4.2.8.2.I. ORDER NUDIBRANCHIA (nudibranchs or Sea Slugs) :

1. Shell, mantle, mantle cavity, osphradium and gills are absent.
2. Doridaceans, with secondry gills around the anus.
3. Body secondarily bilaterally symmetrical.
   Examples : *Doris* (Fig. 4-26), *Glossodoris* (Fig. 4-27), *Tritonia, Armina, Aeolidia.*

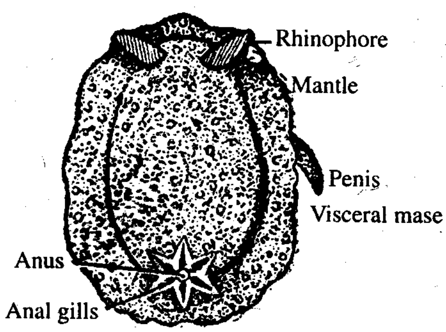


Fig. 4-26. *Doris*

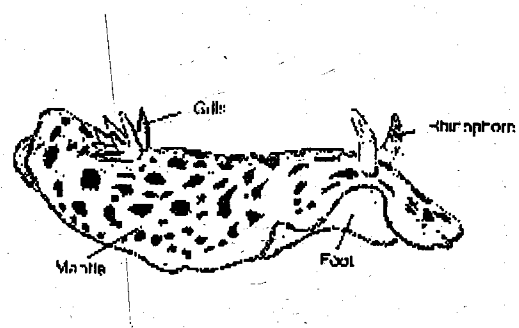


Fig. 4-27 *Glossodoris*

4.2.8.2.J. ORDER RHODOPACEA :

1. Vermiform snail.
2. No external appendages.
3. Protonephridial type nephridia are present.

Examples : *Rhodope.*

4.2.8.2.K ORDER PYRAMIDELLACEA :

1. Ectoparasites of bivalve molluscs and polychaetes.
2. Shell spirally twisted
3. Proboscis contains a stylet.
4. Radula absent.

Examples : *Pyramidella, Odostomia, Branchystomia.*

4.2.8.2.L. ORDER PARASITA :

1. Endoparasitic snails in holothurians.
2. Extremely degenerated snails.

Examples : *Entoconcha, Thyonicola.*

4.2.8.3. SUB CLASS PULMONATA :

1. Mostly freshwater or terrestrial, a few marine forms.
2. Shell typically spiral or reduced or absent.
3. Operculum is absent.
4. Gills absent. Mantle cavity transformed into a vascularized pulmonary sac for gas exchange in air or secondarily in water with a narrow pore on the right side.
5. Head with 1 or 2 pairs of tenlacles and one pair of eyes.
6. One auricle and one nephridium (Kidney)
7. Nervous system concentrated and symmetrical.
8. Hermaphrodites. A single gonad is present with a single g duct and gonopore stage in the life history.

4.2.8.3.A ORDER BASOMMATOPHORA :

1. Pulmonates with one pair of tentacles; eyes located near the tentacle base.
2. Shell delicate with a conical spire with large body whorl and aperture.
3. Primarily fresh water forms, a few marine.

Examples : Freshwater snails – *Lymnaea, Planorbis* (Fig. 4-28), *Helisoma, Bulinus, Physa.*
Freshwater limpets – *Ancylus, Ferrissia*
Marine limpets – *Siphonaria, Otina.*
Marine *Melampus, Amphibola,* the only operculate pulmonate.

4.2.8.3.B. ORDER STYLAMMATOPHORA :

1. Pulmonates with two pairs of tentacles, the upper pair bearing eyes at the tip
2. Shell with a conical spire, internal or absent

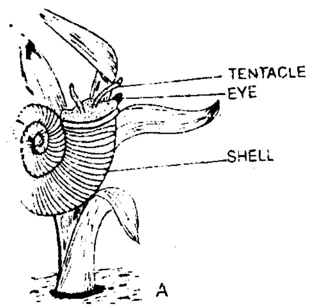


Fig. 4-28. *Planorbis on plant*

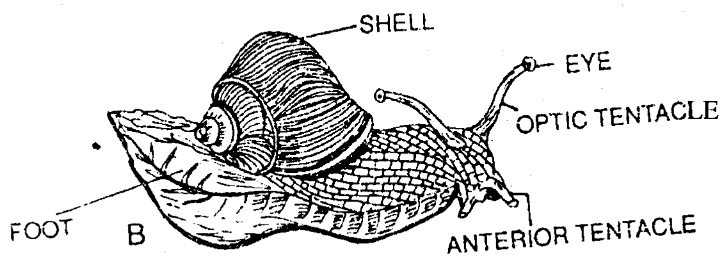


Fig. 4-29. *Helix*

3. Terrestrial pulmonates.
   Examples : *Partula, Helix* (Fig. 4-29-), *Retinella,* Land slugs – *Limax* (Fig. 4-30), *Arion, Testacella.*

4.2.8.3.C. ORDER SYSTELLOMMATOPHORA :

1. Slugs. Anus located at the posterior end of the body instead of laterally as in other pulmonates.
2. The intertidal onchidiidae, having a posterior pulmonary sac and the tropical veronicellidae, which have lost the lung.

4.2.9. CLASS BIVALVIA OR PELECYPODA :

1. The class Bivalvia, also called pelecypoda (hatchet foot) or Lamellibranchia, includes such common animals as clams, oysters and mussels).
2. Aquatic, mostly marine, some freshwater forms.

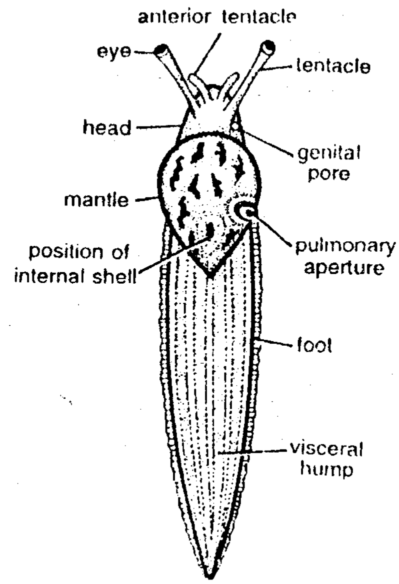


Fig. 4-30. *Limax*

3. Untorted, bilaterally symmetrical, laterally compressed molluscs in which the entire body is enclosed within two lateral shells (valves) that are hinged dorsally.
4. Head, pharynx, jaws, radula and tentacles are absent.
5. Gills, Nephridia and gonads are paired.
6. Foot is blade like in burrowing species. Foot is reduced in attached forms.
7. Mantle is bilobed, consisting of paired, right and left lobes.
8. Alimentary canal is a coiled tube with crystalline style in the stomach. The great majority of bivalves are filter feeding lamellibranchs.
9. Heart is enclosed in a pericardium and comprises one ventricle and two auricles.
10. Blood contains corpuscles, and haemocyanin is the respiratory pigment and is absent in many bivalves. The lack of respiratory pigment in most bivalves is correlated with their relatively sluggish habits and their large gill surface.
11. Excretory organs are paired nephridia or kidneys. In *Unio*, a pair of kidneys or nephridia often referred to as the Organs of Bojanus, and Keber's organ are present.

12. Cerebral and pleural ganglia of each side usually fused into a single cerebro-pleural ganglion.
13. Most bivalves are dioecious.
14. Fertilization is usually external.
15. Development planktonic, with a trochophore and veliger in marine species. Glochidium larva which is considered as a modified veliger larva leads a parasitic life on fishes. Such type of development is seen in the life history of freshwater mussels.

The relationship of the older sub classes Protobranchia, Lamellibranchia and Septibranchia to the system below is readily determined. Taxa containing the protobranchs and septibranchs are indicated; all others contain lamellibranchs.

4.2.9.1. SUB CLASS PROTOBRANCHIA :

1. Bivalves with single pair of bipectinate gills.
2. Foot not compressed but the ventral surface is flattened into a sole for creeping.
3. Byssus poorly developed.
4. Most are deposit feeders in soft bottoms and possess a pair of palpal tentacles.
5. Two adductor muscles usually isomyarian.
6. Sexes are separate.

4.2.9.1.A. ORDER NUCULOIDA :

1. Shell valves equal and toxodont (row of short teeth along hinge).
   Examples : *Nucula* (Fig. 4-31), *Yoldia*, *Molletia*.

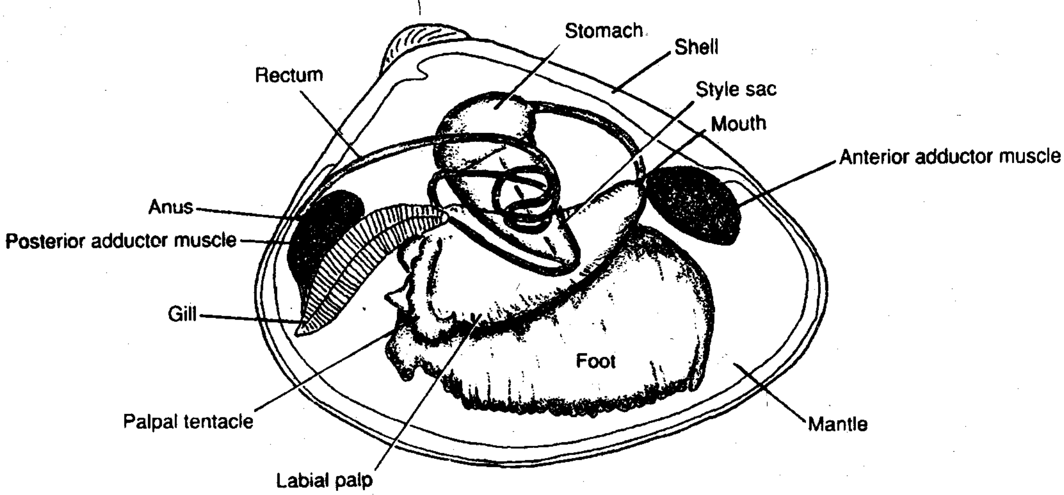


Fig. 4-31. *Nucula*

4.2.9.1.B. ORDER SOLEMYOIDA (Awning clams) :

2. Shell valves thin, equal, somewhat elongated and without hinge teeth.
3. Palpal tentacles absent.
4. Possess chemosynthetic bacteria in gills

Examples : *Solemya.*

4.2.9.2. SUB CLASS PTERIOMORPHIA :

1. Epibenthic bivalves
2. Most bivalves attached by byssus threads or cemented to the sub ratum but some secondarily free.
3. Mantle margins unfused.
4. Filibranch gills present.

4.2.9.2. A ORDER ARCOIDA (Arks) :

1. Hinge straight and usually with vertical placations.
2. Adductor muscles – iso or anisomyarian.

Examples : *Arca, Barbatia, Anadara, Noetia.*

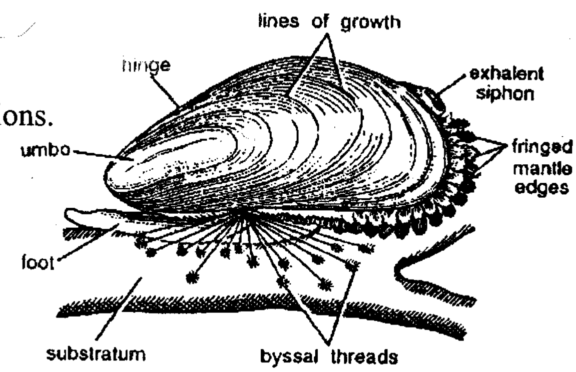


Fig. 4-32. *Mytilus*

4.2.9.2.B. ORDER MYTILOIDA (Mussels):

1. Bivalves attached by byssal threads.
2. Hinge usually without teeth.
3. Anterior adductor muscle reduced.
4. Includes only the family Mytilidae.

Examples : *Mytilus* (Fig. 4-32), *Geukensia, Lithophaga, Brachidontes.*

4.2.9.2.C ORDER PTERIOIDA (Pen Shells, Winged Oysters) :

1. Most bivalves attached by byssal threads.
2. Valves more or less equal.
3. Adductor muscles – Aniso– or monomyarian.

Examples : *Pinna, Atrina (Fig. 4-33), Pteria, Pinctada, Malleus.*

4.2.9.2.D ORDER OSRTREOIDA (Oysters, Scallops, Clams) :

1. Bivalves that lie on one side, free or attached.
2. Valves commonly unequal.
3. Aniso – or monomyarian.
4. Pseudolamellibranch type of gills present.

Examples : *Pecten* (Fig. 4-34), *Argopecten, Placopecten, Spondylus, Anomia, Ostrea, Crassostrea* (Fig. 4-35), *Placuna.*

4.2.9.2.E. ORDER LIMOIDA (File clams) :

1. Free or bysally attached bivalves.
2. Valves equal.
3. Monomyarian.
4. Mantle margin with long tentacles.

Example : *Lima.*

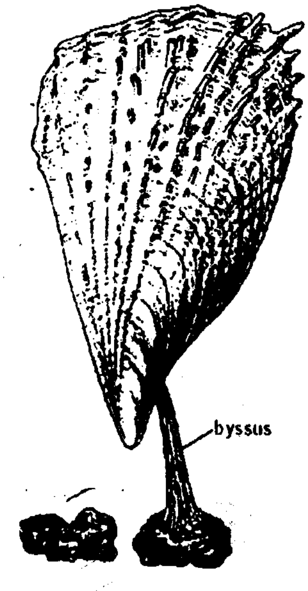
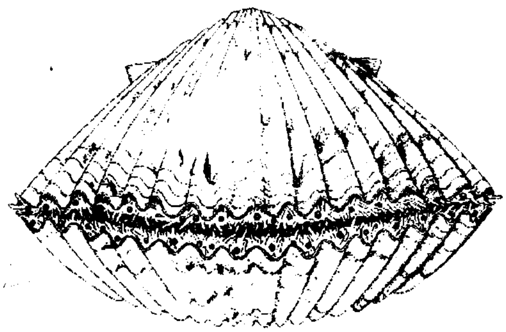


Fig. 4-33. *Atrina*



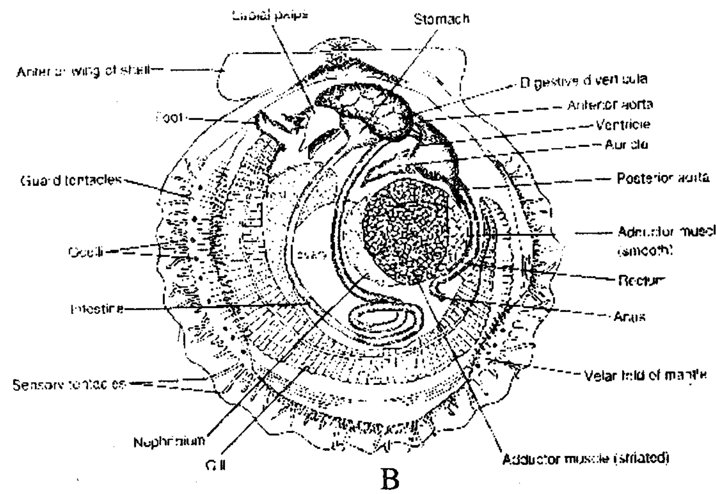


Fig. 4-34. *Pecten.* A - shell,
B - Internal anatomy

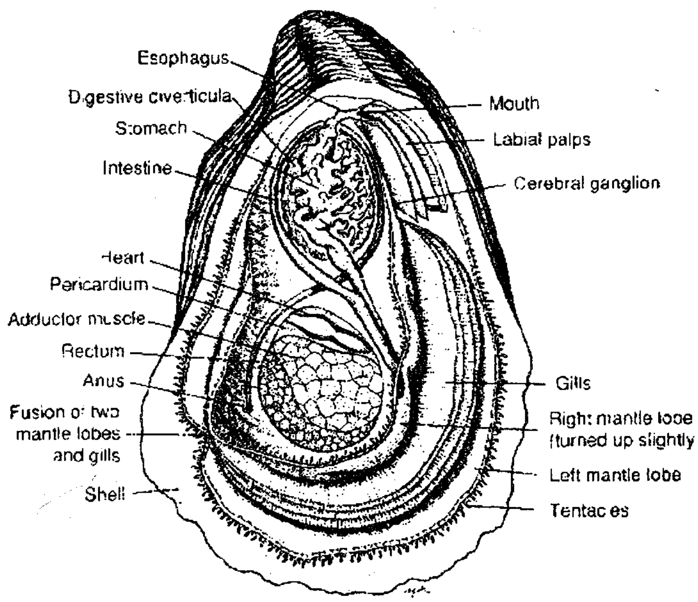


Fig. 4-35. *Crassostrea.*

4.2.9.3. SUB CLASS PALAEOHETERODONTA :

1. Shell valves equal. Few hinge teeth, with an elongated lateral teeth: Hinge teeth when present, are not separated from the large cardinal teeth.
2. An inner nacreous layer is present.
3. Eulamellibranch gills.
4. Usually without siphons.

4.2.9.3.A. ORDER UNIONOIDA :

1. Freshwater bivalves.
2. Valves round to elongated.

20) Examples: *Lamellidens* (= *Unio*) (Fig. 4-36), *Margaritifera, Anodonta, Mutela.*

4.2.9.3.B ORDER TRIGONIOIDA :

1. A single Australian genus, *Trigonia.*
2. Valves triangular.

4.2.9.4. SUB CLASS HETERODONTA :

1. Shell valves equal with a few large cardinal teeth separated by a toothless space from the elongated lateral teeth.
2. Shell without nacreous layer.
3. Eulamellibranch gills.
4. Siphons usually present.

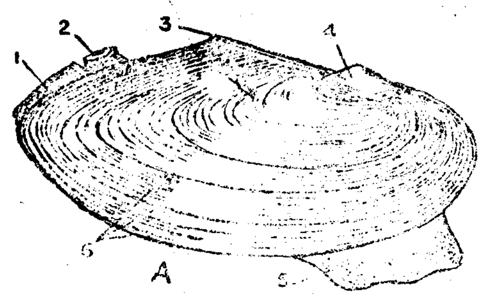


Fig. 4-36. *Unio* - Entire animal with shell
1. Inhalent siphon 2. Exhalent siphon
3. Ligaments 4. Umbo 5. Foot 6. Lines of growth.

4.2.9.4.A. ORDER VENEROIDA :

1. Usually equivalve and isomyarian.

   Examples : *Tridacna* (giant clam) (Fig. 4-37), *Cardium* (cockles), *Solen* (razor clam) (Fig. 4-38), *Dreissena* (zebra mussel), *Venus* (venus clams), *Petricola* (rock borer), *Corbicula* (Asiatic clam).

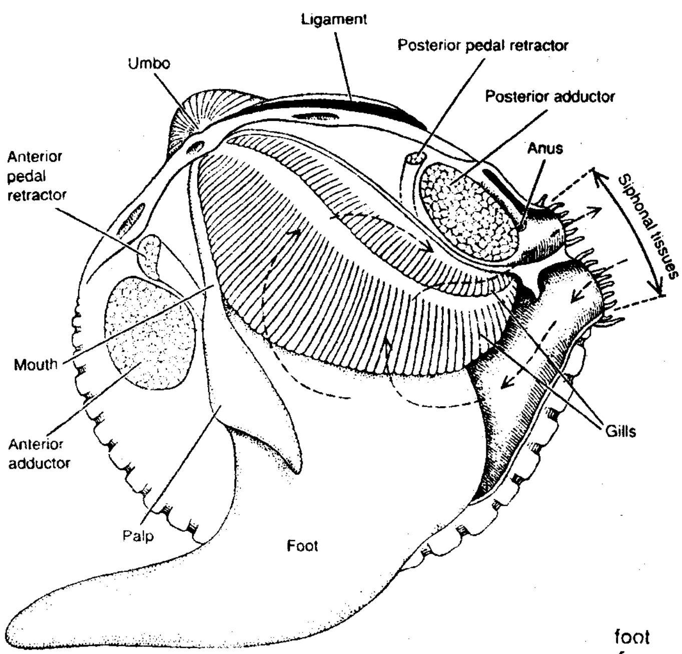


Fig. 4-37. *Tridacna*

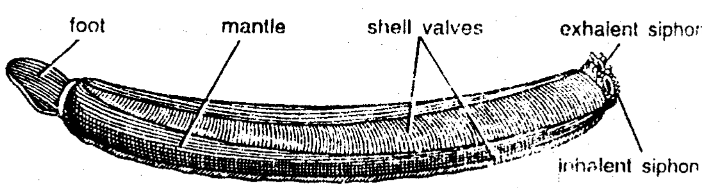


Fig. 4-38. *Solen*

4.2.9.4.B., ORDER MYOIDA :

1. Thin-shelled burrowers with well developed siphons.
2. One or no cardinal teeth.
3. Shell without nacreous layer.

Examples : *Mya* (soft-shell clam), *Martesia, Pholas* (wood borers), *Teredo (Fig. 4-39), Bankia* (wood-boring ship worms).

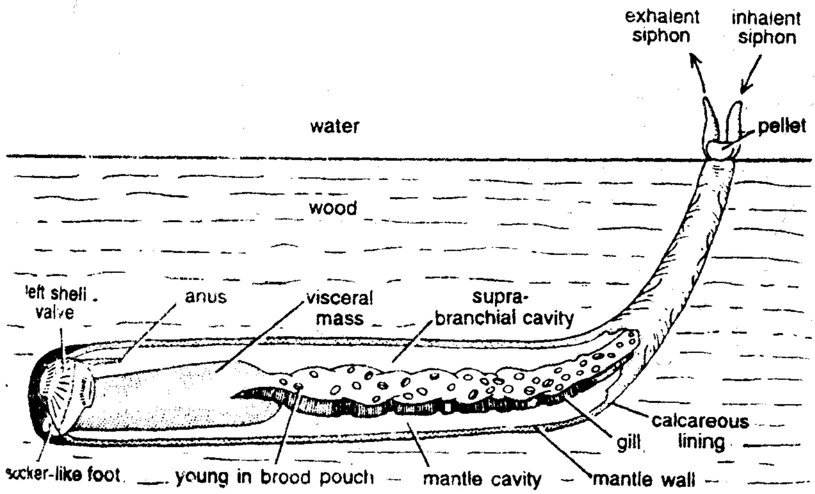


Fig. 4-39. *Teredo*

4.2.9.4.C. ORDER HIPPURITOIDA :

1. Valves unequal and one valve cemented to substratum.

Example : *Chama* (Jewel box).

4.2.9.5 SUB CLASS ANOMALODESMATA :

1. Mostly filter feeding burrowers. Also includes Septibranchians.
2. Valves equal with no hinged teeth.
3. Adductor muscles are isomyarian.
4. Mantle margins fused and siphonate.

Examples : *Lyonsia, Pandora* (watering-pot clams), *Poromya, Cuspidaria.*

4.2.10. CLASS SCAPHOPODA :

1. A small group consisting of 3 genera. *Dentalium* is the common form.
2. Burrowing marine forms, commonly called tooth or tusk shells. The shell appears like an elephant tusk. Hence the name tusk shell.
3. Body enclosed in a tubular, tusklike shell, open at both ends.
4. Large anterior opening contains the conelike foot and buccal region. Foot is boat shaped and pointed, hence the name Scaphapoda.
5. Foot is used in burrowing.
6. Anterior knobbed tentacles (captacula) surround the mouth and are used in feeding.
7. Circulating water enters and leaves through the smaller posterior opening of the shell.

8. Mantle fises at its edges forming a tubular structure.
9. Eyes, tentacles are gills are absent.
10. Heart rudimentary.
11. Excretion is by a pair of nephridia.
12. Sexes separate (dioecious).
13. Life history includes trochophore and veliger larvae. Examples : *Dentalium* (Fig. 4-40), *Caudulus.*

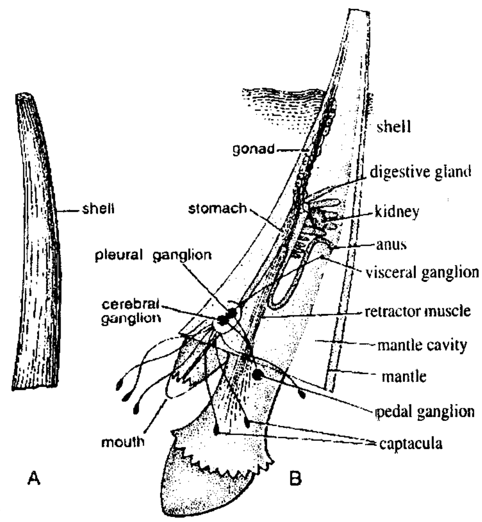


Fig. 4-40. *Dentalium A-Shell; B-Structure of specimen in burried sand.*

4.2.11. CLASS CEPHALOPODA :

1. Exclusively marine.
2. Raptorial, pelagic and actively swimming animals.
3. Body bilaterally symmetrical with a head and trunk.
4. Foot divided into muscular arms located around the buccal area. Arms bear suckers.
5. Shell spirally chambered, sometimes reduced and covered by mantle in most species or absent.
6. Where shell is complete, it is partitioned into gas-filled chambers. Shell is internal as in *Sepia,* external as in *Nautilus* or absent as in *Octopus.*
7. Head bears large eyes and mouth.
8. Trunk consists of uncoiled visceral mass and is covered by mantle on all sides.
9. Radula and a pair of jaws are present in buccal cavity. Two pairs of salivary glands and other digestive glands are also present.
10. Two or four pairs of bipectinate gills in the mantle cavity.
11. Water pumped out by a ventral funnel or siphon through mantle cavity which provides the force for swimming.
12. Blood vascular system is of closed type, heart with 2 or 4 auricles.
13. Nervous system is highly developed and the principal ganglia are concentrated around the oesophagus.
14. Excretory organs are 2 or 4 pairs of nephridia.
15. Sexes are separate with a distinct sexual dimorphism. In males one pair of arms is hectacotylized (modified to form a copulatory organ.).
16. Development is direct without any larval form.

4.2.11.1. SUB CLASS NAUTILOIDEA OR TETRABRANCHIATA :

1. Shell is external, spiral and chambered. Suture are not complex. Chambers are communicated with siphuncle.
2. Living species possess many slender, suckerless tentacles.
3. Four ctenidia or gills, four kidneys and four auricles are present.
4. Ink gland and chromatophores are absent.

5. Eyes are simple.
6. The only living genus is *Nautilus* (Fig. 4-41).

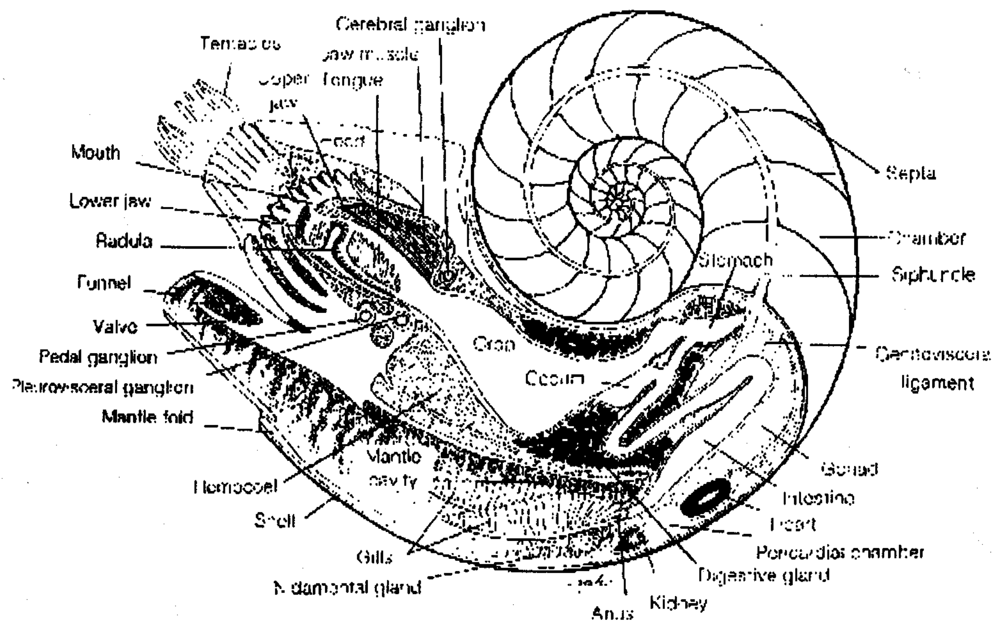


Fig. 4-41. *Nautilus*

4.2.11.2. SUB CLASS AMMONOIDEA :

1. Extinct animals. Fossil forms with coiled external shells having complex septa and sutures.
2. They had been in existence from silurian to cretaceous.
   Examples : *Ammonites, Ceratites, Scaphites, Pachydiscus.*

4.2.11.3. SUB CLASS COELEOIDEA OR DIBRANCHIATA :

1. Shell is internal, reduced or absent.
2. Foot modified into 8 or 10 sucker–bearing arms.
3. Gills, Kidneys and auricles are paired.
4. Ink gland and chromatophores are present.
5. Eyes are complex in structure.

4.2.11.3A. ORDER BELEMNOIDEA :

1. Extinct species.
2. Shell internal, chambered but with a posterior solid rostrum and a dorsal, shieldlike extension.
   Examples: *Belemnites, Belemnoteuthis.*

4.2.11.3.B. ORDER SEPIOIDEA (Cuttlefish and Sepiolas) :

1. Shell with septa, or shell greatly reduced or lost.
2. Body mostly short and broad or saclike.
3. Eight arms and two tentacles.
   Examples : *Sepia (Fig. 4-42), Spirula, Sepiola, Rossia.*

4.2.11.3.C. ORDER TEUTHOIDEA (Squids) :

1. Shell or pen a flattened blade or vane.
2. Body mostly elongated with eight arms and two long tentacles.
   Examples : *Loligo* (Fig. 4-43), *Architeuthis, Gonatus, Chiroteuthis, Cranchia.*

4.2.11.3.D. ORDER VAMPYROMORPHA (Vampire squids) :

1. Small, deep-water, octopod-like forms with eight arms united by a web, but two small filaments also present.
   Example : *Vampyroteuthis.*

4.2.11.3.E. ORDER OCTOPODA (Octopods) :

1. Possess eight arms.
2. Body globular shell is absent in *Octopus*. In *Argonauta,* the shell is absent in the male. The female has a papery shell secreted by the arms.
   Examples : *Octopus* (Fig 4-44), *Argonauta, Eledonella, Cirrothauma.*

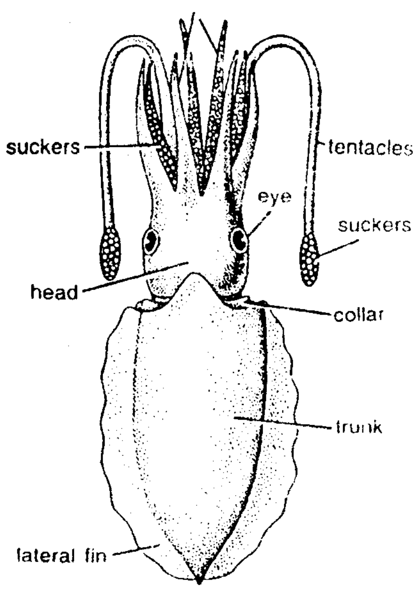


Fig. 4-42. *Sepia* (Dorsal view)

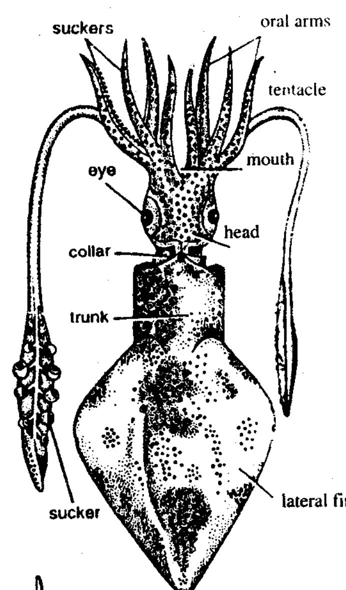


Fig. 4-43. *Loligo* (Dorsal view)

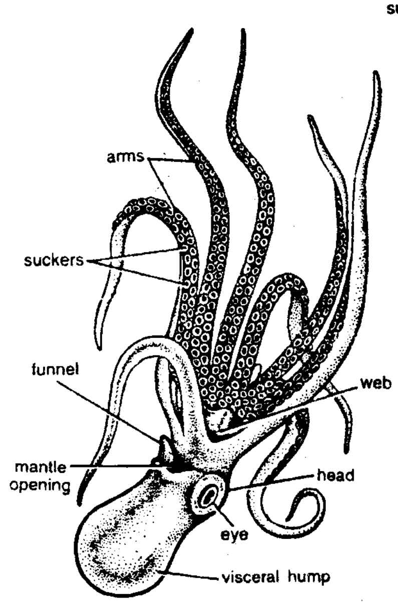


Fig. 4-44. *Octopus*

4.2.12. SUMMARY :

1. Mollusca (L, *mollis* = soft) forms the largest invertabrate phylum next to Arthropoda with some 80,000 living species.

2. Molluscs are soft bodied,bilaterally symmetrical, unsegmented, coelomate animals, usually shelled having a mantle, ventral foot, anterior head and a dorsal visceral mass. They include the conspicuous and familiar forms like snails, clams, oysters, squids and octopods.

3. Molluscs are mostly marine, some are freshwater and few live on land.

4. Body consists of head, foot, visceral mass, mantle and usually a calcareous shell.

5. Shell, if present, may be external or internal, and made up of a single valve (univalve), two valves (bivalve) or many plates (e.g. *Chiton*-8 plates).

6. Shell is secreted by the mantle, which is a thick, muscular fold of body wall covering the visceral mass.

7. The space between the mantle and visceral mass is called mantle cavity, Gills and the openings of digestive, nephridial and reproductive systems lie in the mantle cavity.

8. Body cavity is a haemocoel. The true coelom is represented by pericardial, nephridial and reproductive cavities.

9. Alimentary canal is generally a U-shaped tube. In the buccal cavity, except in bivalves, a rasping organ called radula is present. Digestive glands and sometimes salivary glands are also present.

10. Respiratory organs are gills or ctenidia in aquatic forms and lungs in terrestrial forms.

11. An olfactory organ called osphradium is present.

12. Circulatory system is open type and blood flows in lacunae. However, closed circulation is seen in cephalopods.

13. A dorsal heart consisting of one to four auricles and one ventricle is enclosed in a pericardium. Respiratory pigment is usually haemocyanin. Haemoglobin is rarely present.

14. Nervous system is well developed and the four pairs of ganglia are connected by commissures and connectives.

15. Sense organs include tentacles, eyes, osphradium and statocysts.

16. Kidneys or one to six pairs of metanephridia act as excretory organs.

17. Mostly dioecious, some are hermaphroditic.

18. Fertilization external or internal. Mostly oviparous, some viviparous. Life history includes trochophore and veliger larvae.

19. Phylum Mollusca is divided into seven classes basing on the structure and shape of shell and the position of foot.

20. Class Aplacophora includes primitive shell-less molluscs. It is divided into two subclasses, *viz.*, Chaetodermomorpha and Neomeniomorpha.

21. Class Polyplacophora includes chitons with eight shell plates. It is divided into two orders, *viz.,* Paleoloricata and Neoloricata.

22. Class Monoplacophora includes molluscs with a single symmetrical shell. Striking feature of monoplacophorans is the repetition of body parts like gills, retractor muscles, auricles and kidneys.

23. Class Gastropoda is the largest class of molluscs with a single, asymmetrically spiraled shell. Vsiceral mass undergo torsion. This class is divided into three subclasses *viz.,* Prosobranchiata with 3 orders, Opisthobranchiata with 12 orders and Pulmonata with 3 orders.

24. Class Bivalvia, also called Pelecypoda (hatchet foot) includes laterally compressed animals with two shell valves that are hinged dorsally. Head, radula, jaws and tentacles absent. It is divided into 5 subclasses, *viz,* Protobranchia with 2 orders, Pteriomorphia with 5 orders, Palaeoheterodonta with 2 orders, Heterodonta with 3 orders and Anomalodesmata.

25. Class Scaphopoda includes burrowing marine forms. Commonly called tooth or tusk shells as the shell is tubular, tusklike. Eyes and gills are absent. Knobbed tentacles called captacula surround the mouth. Foot is boat-shaped and pointed, hence the name Scaphopoda.

26. Class Cephalopoda includes raptorial, pelagic,marine molluscs. Foot divided into muscular sucker bearing arms which are located around the mouth. Shell may be external or internal (Sepia). Shell spirally chambered *(Nautilus)* or reduced or absent *(Octopus).* Blood vascular system closed type. Development direct without larval form. It is divided into 3 subclasses, *viz.,* Nautiloidea, Ammoidea and Coeleoidea with 5 orders.

4.2.13. KEY TERMINOLOGY :

Adductor: Typically, one of a pair of muscles that close the valves of a bivalved shell.

Anisomyarian: A reduction of the anterior adductor muscle in clams.

Asymmetry: Condition in which opposite sides of an animal are not alike, without symmetry.

Body whorl : The last and largest whorl of the gastropod shell that opens at one end from which the head and foot of the living animal protrudes out.

Byssus: A tough protein secretion produced by a gland in the bivalve foot and commonly in the form of threads used for attachment.

Captaculum (pl. Captacula): A thread like tentacle of scaphopod molluscs.

Chromatophore: A pigment cell in the body wall that can expand or contract to expose or conceal its pigment.

Commissure: A nerve that transversely joins two ganglia or some other part of the nervous system.

Connective: A nerve that longitudinally joins two ganglia.

Epibenthic: Bottom surface of a water body.

Eulamellibranch gill: Bivalve gill in which the filaments are joined together by continuous sheets of tissue.

Filibranch gill: Bivalve gill in which individual filaments are more or less separate and are held together only by tufts of specialized cilia.

Filter feeding: A type of suspension feeding in which particles (plankton and detritus) are removed from a water current by a filter.

Hermaphrodite: An individual possessing both male and female reproductive organs.

Hinge ligament: A noncalcified, elastic, proteinaceous band that attaches the two valves of a bivalve.

Isomyarian: Refers to more or less equal development of clam adductor muscles.

Keber's organ: Excretory organ in some bivalves like *Unio* also named as pericardial gland as it lies infront of the pericardium.

Lamella (pl. Lamellae): A sheet of tissue. In Lamellibranch bivalves, each of the four gill flaps.

Monomyarian: Absence of the anterior adductor muscle in bivalves.

Nacre: The innermost, lustrous, shell layer of molluscs.

Operculum: A lid or covering to a body whorl of the shell in gastropods.

Organs of Bojanus: Excretory organs of *Unio* which help in removing nitrogenous wastes from the pericardium.

Protandry: Production of sperm, earlier than ova.

Pseudolamellibranch gill: Bivalve gill in which the filaments are bound together with some inter filamentous tissue junctions.

Raptorial feeding: Animals that feed by capturing prey.

Rhinophore: One of the second pair of nudibranch tentacles located behind the first pair.

Septum: Partition that separates two cavities or chambers or structures.

Sexual dimorphism: Phenomenon of two sexes of a same species differing in secondary characters.

Siphon: A tubular fold of the molluscan mantle used to direct water to and from the mantle cavity.

Siphuncle : A slender outgrowth of the body wall and its thin calcareous enclosure in shelled cephalopods. It secretes gas into the chambered shell for buoyancy.

Slug: Shell-less opisthobranch or pulmonate in which the shell is absent, or reduced and burreid within the mantle.

Spire: The whorls of a gastropod shell above the body whorl.

Torsion: The 90 or 180 degree counter clockwise twist of the gastropod visceral mass with respect to the head and foot.

Viviparous: A phenomenon of giving birth to embryos. They can be brooded internally within the female where supplemental nutrition is supplied.

Whorl: A single complete turn (360 degrees) of a coiled molluscan shell.

4.2.14. SELF ASSESSMENT QUESTIONS :

1. Give the general characters of phylum Mollusca.
2. Classify the phylum Mollusca upto orders with two examples for each order.

3. Write a detailed account on the classification of class Gastropda.
4. Classify and characterize the class Bivalvia upto orders with examples.
5. Write note on:
   a) *Chiton*
   b) Aplacophora
   c) *Neopilina*
   d) Pulmonates
   e) *Dentalium.*

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Dr. P. Padmavathi

4.3 GENERAL ORGANIZATION OF PHYLUM ECHINODERMATA

4.3.1. OBJECTIVES:

The purpose of this lesson is to :

- describe the structure of echinoderms and
- understand the physiology of echinoderms with special reference to asteroids (sea stars).

4.3.2 INTRODUCTION:

Echinoderms are the most familiar and most abundant fauna of the sea-floor. The representatives of the phylum, such as the sea stars, have become virtually a symbol of sea life. Other familiar forms include sea-lilies, sea cucumbers, sea-urchins and so on. The phylum contains about 6,000 known species and a large number of fossil forms. All the living forms are marine except a single species of sea-cucumber, *Synapta similis,* which inhabits the brackish waters of the tropical regions.

Echinoderms are relatively large animals, most being atleast several centimeters in diameter. The most striking characteristic of the group is their pentamerous radial symmetry, which is secondarily acquired in their adult condition. Primarily they are bilaterally symmetrical which is expressed in their larval forms.

Characteristic of all echinoderms is the presence of an internal skeleton. The skeleton is composed of calcareous ossicles that may articulate with one another, as in sea stars and brittle stars, or may be sutured together to form a rigid skeletal test, as in sea urchins and sand dollars. In holothurians, these ossicles are in the form of microscopic bits embedded in dermis. Commonly, the skeleton bears projecting spines or tubercles that give the body surface a warty or spiny appearance, hence the name echinoderm, meaning 'spiny skin'.

The most distinctive feature of echinoderms is the presence of a unique system of coelomic canals and surface appendages composing the water-vascular system. Primitively, this system functions in collecting and transporting food, but in many echinoderms, it has assumed a locomotor function.

4.3.3. DISTRIBUTION:

Echinoderms are exclusively marine and are largely bottom dwellers. They occur in all seas, at all latitudes. Most of them are common in littoral zones. They are found in depths ranging from tidemark down to 6,000 meters. The greatest number of abyssal forms (occur more than 300 fathom deep) are found in holothurians. Feather stars live in shallow waters down to the depths of 1400 meters. Crinoids are found in depths of 4,600 meters. Echinoderms generally do not inhabit colder waters. Most of them are free living but few are pelagic. Rarely they are permanently attached (Sea-lilies). Majority show slow creeping movements on the sea-floor. They are also unique in not having any parasitic species. Few ophiothuroids are commensals.

4.3.4. BODY ORGANIZATION IN ECHINODERMS:

The crinoids (sea-lilies) are often regarded as the most primitive class of living echinoderms. Higher group of organization is observed in the familiar asteroids (sea stars). The basic structure of an echinoderm is described with an example of asteroid. The variations and more important exceptions to the other echinoderms are given as characters under different classes and orders of the next chapter i.e., Classificaion of Phylum Echinodermata.

4.3.4.1. External Structure:

Sea stars are star-shaped,free-moving ehinoderms in which the body is composed of rays, or arms, projecting from a central disc. They are typically pentamerous, with most species possessing five arms (Fig. 4-45). The sun stars, however possess 7 to 40 or more arms (Fig.4-46). Asteroids range in size from 2cm to 1m in diameter. Sea stars are commonly red, orange, blue, purple or green or exhibit combinations of colors.

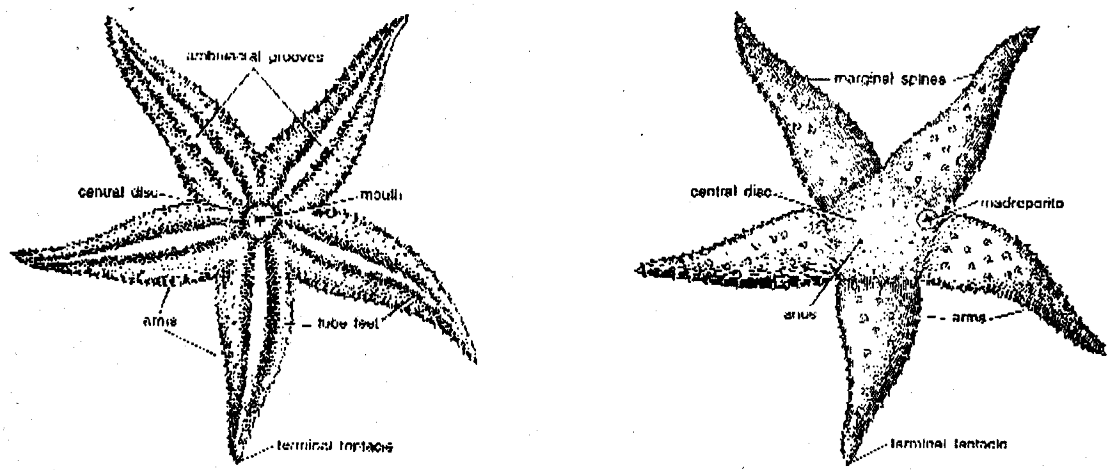


Fig. 4-45. *Asterias*. External features A- Oral view, B- Aboral view.

The arms of asteroids are not sharply set off from the central disc; that is, the arm usually grades into the disc, and some species have very short arms (e.g., *Culcita,* (Fig.4-47). The body has two surfaces. The upper convex and much darker side is called the aboral or abactinal surface. The lower surface is flat, less pigmented and is called the oral or actinal surface. The oral and aboral surfaces correspond to the left and right sides of the bilaterally symmetrical larva. The axes occupied by the arms are known as radii and the regions of the central disc between the arms are inter-radii. Head is absent.

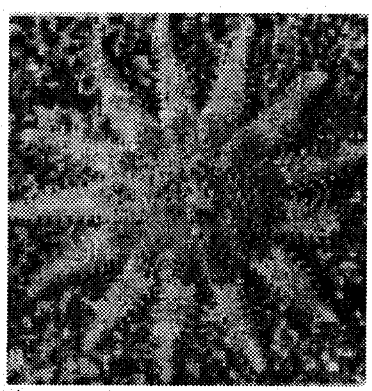


Fig. 4-46. The sun star, *Crossaster papposus.*

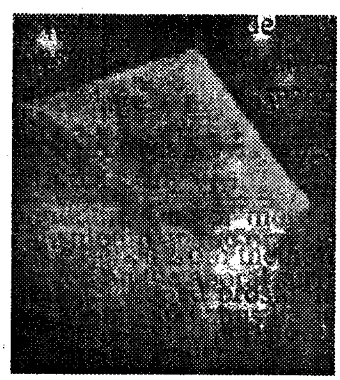


Fig. 4-47. *Culcita* - Oral view

On the oral surface, at the centre of the disc is located the mouth. From the mouth a wide furrow called ambulacral groove extends radially into each arm. Each furrow or ambulacral groove contains two or four rows of small, tubular projections, called tube feet or podia. The margins of the ambulacral grooves are guarded by movable spines that are capable of closing over the grooves. The tip of each arm bears one or more small, tentacle-like sensory tube feet and a red pigment spot.

The aboral surface (upper) bears the anus which is inconspicuous in the centre of the disc and large, button-like madreporite toward one side of the disc between two of the arms. The general body surface may appear smooth or be covered with spines, tubercles, or ridges. In some species, the arms and disc are bordered by large, conspicuous plates.

4.3.4.2. Body wall:

A. Epidermis: The outer surface of the body is covered by an epidermis composed of monociliated and non ciliated epithelial cells, mucous cells, and ciliated sensory cells (Fig. 4-48). Detritus that falls on the body is trapped in the mucus and then swept away by the epidermal cilia. Within the basal part of the epidermis is a layer of nerve cells forming an intra epidermal plexus.

B. Dermis: Below the integument, a thick layer of body wall connective tissue called the dermis houses the hard skeletal pieces (Ossicles). Although ossicles are the conspicuous part of the skeletal system, especially in sea urchins and sand dollars, the organic extracellular matrix is also an important skeletal element. Unlike any other phylum of animals, echinoderms can vary, under nervous control, the rigidity of their connective tissue. This unique phenomenon is termed mutable (or catch) connective tissue (Fig. 4-49).

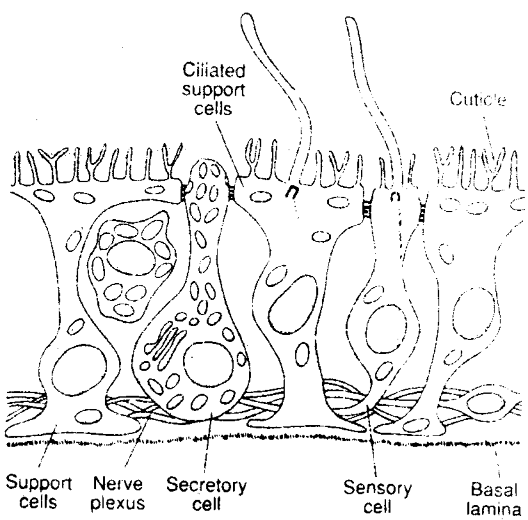
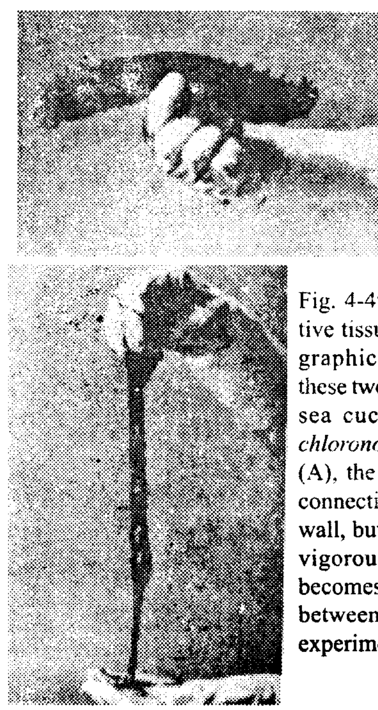


Fig. 4-48. Diagram of the echinoderm integument.



A

B

Fig. 4-49. Mutable connective tissue of echinoderm is graphically illustrated in these two photographs of the sea cucumber. *Stichopus chloronotus*. When touched (A), the animal stiffens the connective tissue in its body wall, but after being rubbed vigorously, the body wall becomes so soft that it flows between the fingers of the experimenter, (B).

Asteroid ossicles are in the shape of rods, crosses, or plates arranged in a lattice network and bound together by connective tissue (Fig. 4-50). The ossicles are irregularly perforated (fenestrated), representing an adaptation for reduction of weight and increase in strength. The most remarkable characteristic is that each ossicle of the echinoderm skeleton represents a single crystal of magnesium-rich calcite, 6 (Ca Mg) Co_3. The crystal is formed within a cell of the dermis, but as the crystal increases in size it becomes surrounded by a large number of cells, all of which are daughter cells of the original cell that initiated the formation of the crystal.

Spines and tubercles are part of the endoskeleton and as such, are also covered by the epidermis. In the paxillosid and valvatid sea stars, the aboral surface bears special ossicles, and the central portion of each is raised above the body surface and even extended out like a parasol (Fig. 51). The raised part of the ossicle is crowned with small, movable spines. Such an ossicle and its associated spines is called a paxilla ; it is an adaptation for the burrowing existence of many sea stars belonging to this group. Adjacent paxillae created a protective space above the aboral integument. Through this space respiratory and feeding currents flow. The surrounding sediment is held back by the paxillae. Paxillae account for the smooth appearance of the aboral surface of many sea stars.

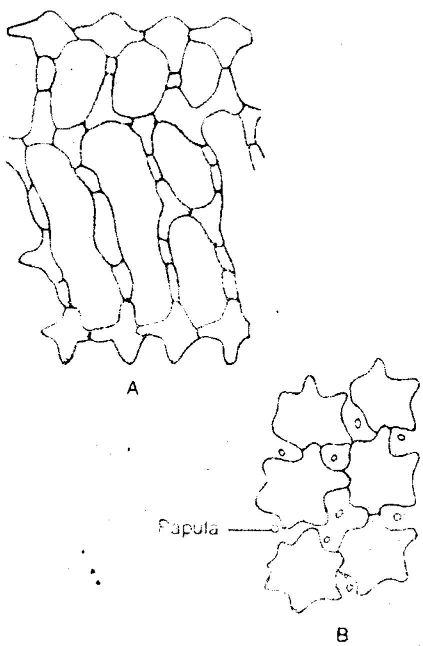


Fig. 4-50. Latice-like arrangement of skeletal ossicles in the arm of an asteriid sea star. B- Small section of endoskeletal system of a paxillosid sea star.

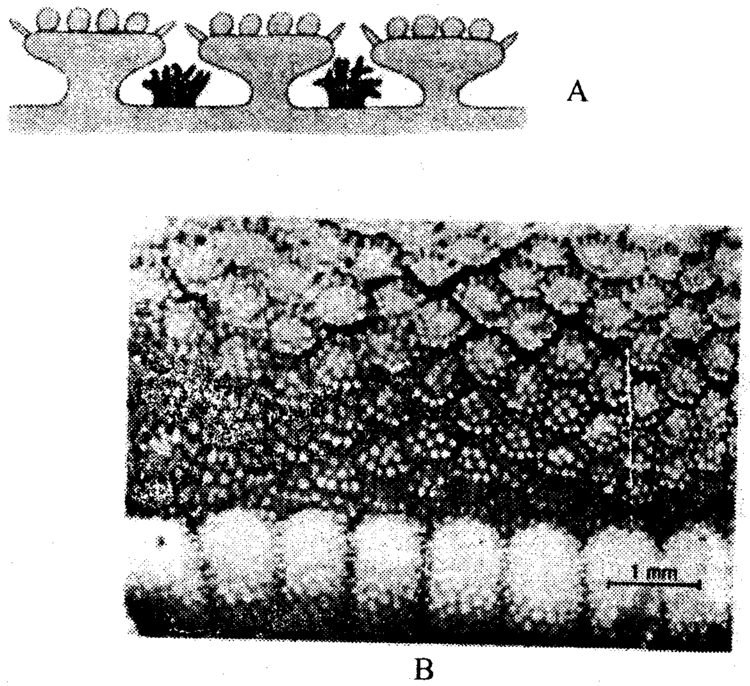


Fig. 4-51. A-Diagrammatic cross section through several paxillae of *Luidia*. The raised table shaped ossicles bear small rounded spines on the surface and flat movable spines along the edge. Dendritic papulae (black) are located in the spaces between the projecting edges of the paxillae and associated spines.
B-Surface of paxillae of *Astropecten*.

C. Muscle Layer : Beneath the dermis is a muscle layer composed of outer circular and inner longitudinal smooth fibers. They are involved in the bending of the arms. The inner surface of the muscle layer borders the coelom and is covered with an often ciliated peritoneum.

D. Pedicellariae: In two orders of sea stars, the body surface bears small, specialized jaw-like appendages (pedicellariae) that are used for protection, especially against small animals or larvae that might settle on the body surface of the sea star. The pedicellariae are of two types: Stalked and Sessile. The stalked pedicellariae are characteristic of the order Forcipulata, which includes *Asterias, Pycnopodia and Pisaster.* Each pedicellaria consists of a short, fleshy stalk surmounted by a jaw-like apparatus composed of three small, movable ossicles that are arranged to form forceps or scissors (Fig. 4-52). Stalked pedicellariae may be scattered over the body surface, situated on the spines, or commonly form a wreath around the base of the spines (Fig.4-53). Sessile pedicellariae are largely limited to the order Valvatida and are composed of two or more short, movable spines on the same or adjacent ossicles. In some species, the spines, oppose each other and articulate against each other, acting as pincers.

E. Papulae: The papulae are numerous, small evaginations of the body wall scattered over the aboral body surface. The papulae and the podia (tube feet) are discussed in connection with gas exchange and the water-vascular system.

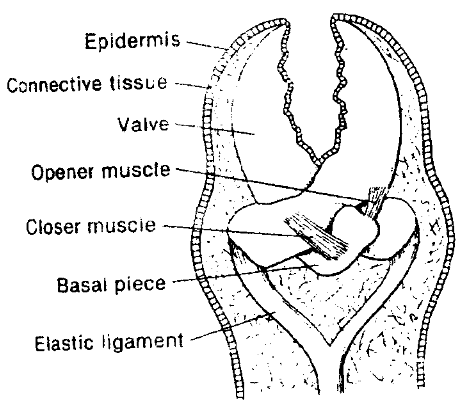


Fig. 4-52. Distal ends of a scissors type pedicellaria from *Asterias*

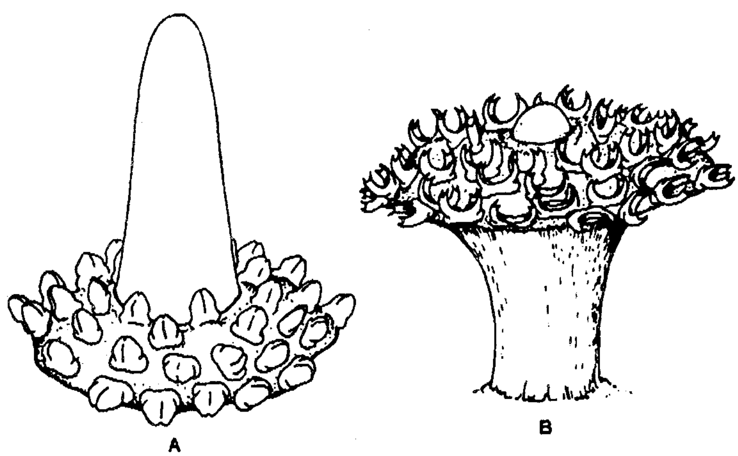


Fig. 4-53. Fish-catching pedicellariae of *Stylasterias*.
A - Wreath of pedicellariae at rest around the spine.
B-Wreath raised when stimulated by potential prey.

4.3.4.3. Coelom:

In asteroids true coelom is present and it extends into each and every part of the body. Coelom originated in enterocoelic method. Coelom is lined by outer parietal and inner visceral layers. Extending between the central disc and arms a large space called perivisceral coelom is present. Water vascular system, perihaemal canals and sinuses, and genital sinuses are coelomic compartments.

Coelomic fluid present in the coelom is just similar to the sea water in composition. It consists of some proteins, nutrients and amoebocytes. These amoebocytes help to excrete waste matter and foreign bodies from the body. Coelomic fluid also take part in exchange of gases for respiration as there are no true blood vessels.

4.3.4.4. Water-Vascular System:

The water-vascular system is unique to echinoderms. It is a system of canals and appendages of the body wall filled with a fluid resembling sea water. The entire system is derived from coelom, hence the walls of the canals are lined with ciliated epithelium. It is well developed in asteroids, and its main function is locomotion. The system includes a madreporite, a stone canal, a ring canal, five radial canals, tiedmann's bodies, lateral canals and tube feet.

Madreporite is a button-shaped hard calcareous plate on the aboral surface of the central disc. It connects the internal canals of the water vascular system to the outside (Fig. 4-54). The surface of the madreporite is traversed by numerous radiating furrows covered by the ciliated epithelium of the body surface. The bottom of each furrow contains many pores that open into pore canals passing downward through the madreporite. The pore canals eventually lead into a vertical stone canal that descends to the oral side of the disc (Fig. 4-54). The stone canal is so named because of the calcareous deposits in its walls. Its interior is lined with tall flagellated cells. The movements of the flagella draw the water currents in. On reaching the oral side of the disc, the stone canal forms a circular canal called the ring canal just to the inner side of the ossicles that ring the mouth.

The inner side of the ring canal gives rise to four or more, usually five pairs of greatly folded pouches called Tiedemann's bodies (Fig.4-54). Each pair of these pouches has an interradial position. Also attached interradially to the inner side of the ring canal in many asteroids, although not in *Asterias*, are one to five elongated, muscular sacs called polian vesicles which are suspended in ther coelom. They regulate the pressure in the system. Some believe that they produce amoeboid cells of the water-vascular system.

From the ring canal, a long, ciliated, radial canal extends into each arm (Fig.4-54). The radial canal runs on the oral side of the ossicles that form the centre of the ambulacral groove (ambulacral ossicles), and it ends in a small, external tentacle at the tip of the arm. Lateral canals arise alternately from each side of the radial canal along its entire length and pass between the ambulacral ossicles on each side of the groove (Fig. 4-54 and 4-55).

Each lateral canal is provided with a valve and terminates in a bulb and a tube foot (Fig. 4-54). The bulb, or ampulla, is a small, muscular sac that bulges into the aboral side of the perivisceral coelom. The ampulla opens directly into a canal that passes downward between the ambulacral ossicles and leads into the tube foot, or podium.

The podium is a short, tubular, external projection of the body wall located in the ambulacral groove. Commonly, the tip of the podium is flattened, forming a sucker. Like the body wall, the podium is covered on the out side with a ciliated epithelium and internally with peritoneum. Between these two layers lie connective tissue and longitudinal muscle fibers. Contraction of the muscles on one side of the podium brings about bending of the appendage. The podia are arranged

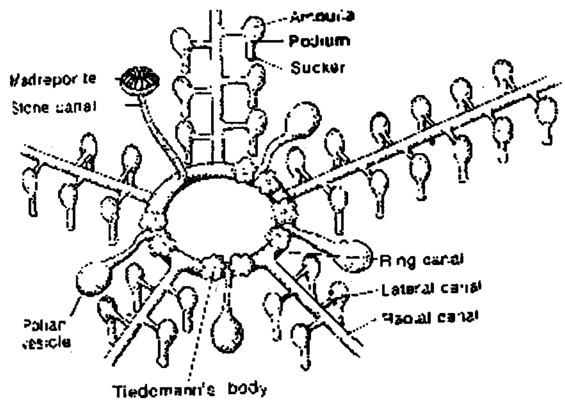


Fig. 4-54. Asteroid water-vascular system.

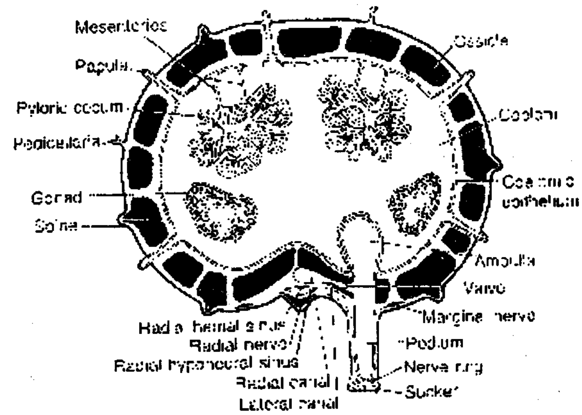


Fig. 4-55. Cross section through the arm of a sea star.

in two rows where the lateral canals are all of the same length, or four rows where they are alternately long and short.

Functioning: The entire water vascular system is filled with fluid that is similar to sea water except that it contains coelomocytes, a little protein, and a high potassium ion content. It works like a hydraulic system during locomotion.

During movement all the podia work together in coordination and extending in the same direction. One or two arms act as leading arms and are lifted in the direction wanted, during progression. The ampullae contract by the action of circular muscles. There is a valve in every lateral canal which prevent the flow of fluid from ampulla to radial canal. Consequently the water rushes into the tube feet and extend them as far as possible. At this stage, the suckers of the tube feet adhere to the substratum. When the suckers attach, the central part of the sucker is lifted and vacuum is created. As the longitudinal muscles contract, the tube feet become short and the animal is dragged forward in the direction of movement. Later the suckers detach, tube feet relax and again they extend forward. Thus the relaxation and contraction of the podia bring about a sort of slow stepping movement. On one contraction of the tube feet the animal covers a distance equal to the length of the tube feet. The powerful action of the podial suckers also enables the animal to climb vertically over the rocks.

The tube feet are also helpful in food capturing. Sometimes they act as tactile and respiratory organs. The other parts of the water-vascular system maintain the proper water pressure necessary for the operation of ampulla and podia.

Podia of many but not all sea stars that live on soft bottoms, such as *Astropecten* and *Luidia,* lack suckers. Rather, the tip is pointed to facilitate thrusting of the podium into the sand and ampullae are bilobed providing increased force for driving the podia into the substratum. Podia of this type may also be used to burrow and even to plaster the walls of the burrows with mucous.

4.3.4.5. NUTRITION:

A. Digestive System:

The digestive system is radial, extending between the oral and aboral sides of the disc (Fig. 4-56). The mouth is situated in the centre of a tough, circular, peristomial membrane, which is muscular and provided with a sphincter. It opens into a large stomach that fills most of the interior of the disc and is divided by a horizontal constriction into a large, oral chamber called the cardiac stomach, and a smaller, flattened, aboral chamber called the pyloric stomach. The walls of the cardiac stomach are pouched and connected to the ambulacral ossicles of each arm by ten pairs of triangular mesenteries called gastric ligaments. They are useful in anchoring the cardiac stomach firmly in position. The whole of the cardiac stomach can be everted out during feeding, due to the contraction of the same is brought about by five pairs of retractor muscles which arise from the lateral sides of the ambulacral ridges. The wall of the cardiac stomach is made up of tall epithelial cells which are mostly glandular and mucus secreting.

The pyloric stomach is smaller and is star-shaped or pentagonal. It is simply the reception chamber of the ducts from the pyloric ceca (Fig.4-56). There are two pyloric ceca, or digestive glands, in each arm, each of which is composed of an elongated mass of glandular cells suspended in the coelom of the arm by a dorsal mesentery (Fig.4-55).

From the pyloric stomach ascends a short, tubular intestine which gives off 2 or 3 branched diverticula called rectal ceca or intestinal ceca. The terminal part of the intestine is termed as rectum which runs straight and opens to the exterior through the anus, situated eccentrically on the aboral surface of the disc.

The entire digestive tract is lined with a ciliated epithelium, and the cilia are in the ducts of the pyloric ceca arranged to create fluid currents, both incoming and outgoing. Gland cells are particularly abundant in the cardiac stomach lining.

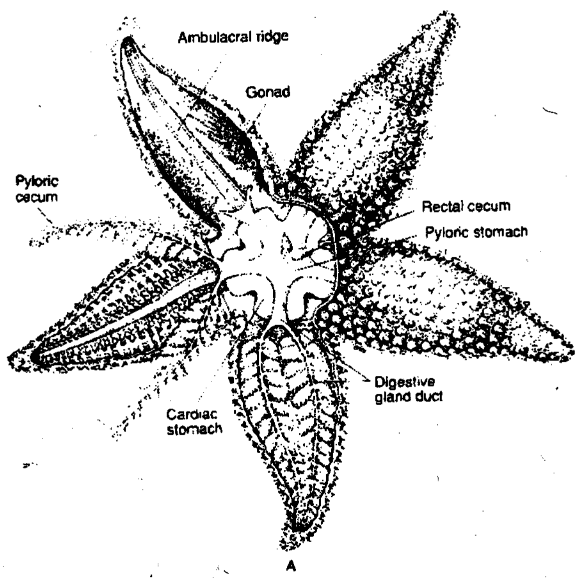


Fig. 4-56. Anatomy of *Asterias* - View from aboral side with the arms in various stages of dissection.

B. Food and Feeding:

Most asteroids are scavengers and carnivores. They feed on all sorts of invertebrates, especially snails, bivalves, crustaceans, polychaetes, other echinoderms and even fish. Oysters form their favourite food. Some have very restricted diets. Most asteroids detect and locate prey by substances the prey releases into the water. Some soft-bottom sea-stars, including species of *Luidia* and *Astropecten,* can locate buried prey and then dig down into the substratum to reach it. *Stylasterias* and *Astrometis* along the West Coast and *Leptasterias* of the East Coast of the United States catch small fish, amphipods, and crabs with the pedicellariae when the prey comes to rest against the aboral surface of the sea star. There are some asteroids (e.g., *Acanthaster*) that feed on sponges, sea anemones, and the polyps of hydroids and corals.

Some sea stars are suspension feeders. Plankton and detritus (*Poranis, Henricia)* or mud (*Ctenodiscus*) that comes in contact with the body surface is trapped in mucus and then swept toward the oral surface by the epidermal cilia. On reaching the ambulacral grooves, the food-laden mucus strands are carried by ciliary currents to the mouth. Some sera stars such as *Astropecten, and Luidia* are largely carnivorous, utilize ciliary feeding as an auxiliary method of obtaining food.

In primitive groups of sea stars, including *Astropecten* and *Luidia,* which cannot evert their stomachs, and have suckerless tube feet, the prey is swallowed whole and digested within the stomach. Shells and other indigestible material are then cast out of the mouth. Other asteroids (Valvatida, Spinulosida, Forcipulata) feed extra orally. By the contraction of the body wall muscles, the coelomic fluid exerts pressure on the cardiac stomach. Then the cardiac stomach everted out through the mouth. The everted stomach engulfs the prey. The prey then may be brought into the stomach by retraction, or digestion may begin outside the body. The soft parts of the victim are reduced to a thick broth, which is then passed into the body in ciliated gutters. When digestion is completed, the stomach muscles contract, retracting the stomach into the interior of the disc.

Many sea stars feed almost exclusively on bivalves and are notorious predators of oyster beds. Feeding on bivalves is quite peculiar. First the sea star grasps the bivalve by its arms and then arches its body over the prey like an umbrella. Then tube feet of one arm are attached to one valve and tube feet of another arm to another valve. Then it exerts pressure and pulls the valves apart with a slight gap. The cardiac stomach is everted into this gap and the digestive enzymes are poured on the soft parts of the prey, so that the digestion commences in the shell itself. Ultimately the cardiac stomach along with the food is retracted in.

C. Digestion:

Digestion is primarily extracellular. A complex of digestive enzymes is produced by the stomach wall and pyloric ceca. Products of stomach digestion are carried through the stomach wall and pyloric ducts into the pyloric ceca, where digestion (both intracellular and extracellular) and absorption occur. Products of digestion may be stored in the cells of the pyloric ceca or passed through the ceca into the coelom for distribution. The pyloric ducts also convey wastes to the rectum, where the rectal ceca act as pumps for expulsion through the anus.

4.3.4.6. Internal Transport:

Echinoderms rely primarily on coelomic circulation for internal transport of gases and some nutrients. The blood-vascular system, called the hemal system in echinoderms, is rudimentary in asteroids, although it plays a role in nutrient transport.

Asteroids have four coelomic circulatory systems: the perivisceral coelom, which occupies the disc and arms, and supplies the viscera; the water-vascular system, already described, which supplies the locomotory muscles of the tube feet; the hyponeural sinus system, which supplies the nervous system; and the genital coelom, which supplies the gonads.

Cilia on the peritoneal lining of these coeloms create a continuous circulation of the coelomic fluid. The body fluids of all asteroids as well as those of other echinoderms, are isoosmotic with sea water. Their inability to osmoregulate prevents most species from inhabiting estuarine waters. The coelomic fluid contains phagocytic coelomocytes that are produced by the coelomic peritoneum and can form a clot in response to tissue damage.

The hyponeural sinuses parallel the canals of the water-vascular system, but ampullae and tube feet are absent (Fig.4-57 and 4-58). Each sinus in the hyponeural system is double, the left being separated from the right by a mesentery. The hyponeural system has a ring sinus (hyponeural sinus) that accompanies the nerve ring, and a radial sinus (radial hyponeural sinus) along the radial nerve in each arm. A vertical sinus called the axial sinus, lies beside the stone canal and joins the hyponeural ring to the madreporite and the madreporite end of the stone canal, thus linking the water-vascular and hyponeural systems.

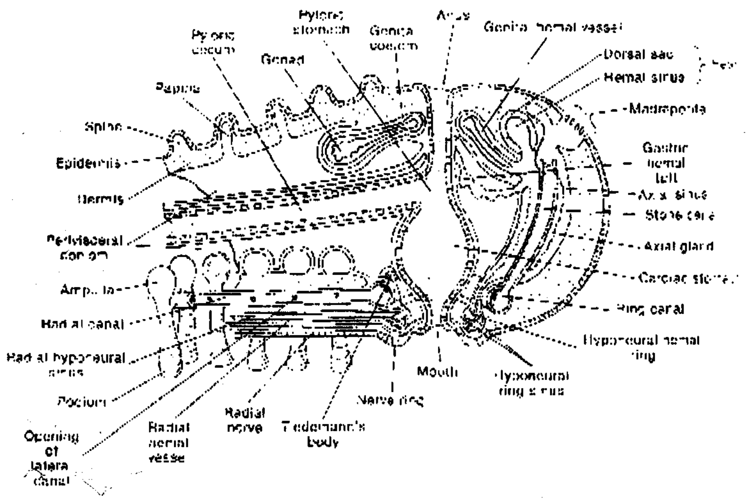


Fig. 4-57. Diagrammatic view of coelomic and blood vascular (hemal) systems of an asteroid.

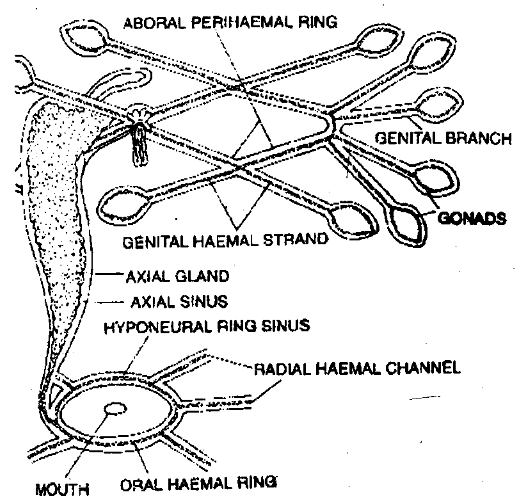


Fig. 4-58. Sea star - Perihaemal system.

Throughout the hyponeural system, a blood vessel is suspended in the mesentery between the two halves of each sinus. Other blood vessels occur in mesenteries of the perivisceral coelom, especially in association with the pyloric ceca and the genital coelom. Eventually, all blood vessels unite with the heart (dorsal sac and hemal sinus) situated just internal and to one side of the madreporite. Immediately below the heart in the axial sinus, one blood vessel becomes enlarged and folded, and is called the axial gland. Two similar vascular structures, called gastric hemal tufts, bulge into the perivisceral coelom near the junction of pyloric ceca vessels with the heart. Both the axial gland and gastric hemal tufts are covered with podocytes.

The heart beats rhythmically (approximately 6 beats per minute in *Asterias forbesi*), but the pattern of circulation of the colourless blood is unknown. There is some evidence that the blood has a role in nutrient transport, but the functional role of the glomerulus-like structures (axial gland, gastric hemal tufts) is uncertain.

4.3.4.7. Gas Exchange:

Gas exchange is carried on by the numerous fine dendral branchiae or papulae and also tube-feet. The ciliated peritoneum that forms the internal lining of the papulae and tube feet produces an internal current of coelomic fluid; the outer, ciliated epidermal investment produces a current of sea water flowing over the papulae (Fig. 4-59). The exchange of gases takes place by diffusion through the wall of the papulae and tube feet. In burrowing species, the branched papulae are produced by the paxillae, and the ventilating current flows through the channel-like spaces beneath these spines (Fig.4-51A).

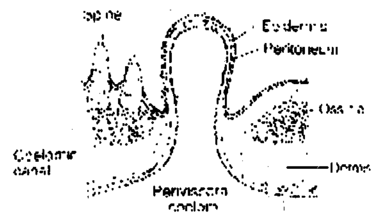


Fig. 4-59. Section through an asteroid papula.

4.3.4.8. Excretion:

There are no definite excretory organs. The excretory products are generally ammonia, urea and creatin. Removal of nitrogenous wastes (NH_3) is accomplished by general diffusion through thin areas of the body surface, such as the tube feet and the papulae. The wandering coelomocytes collect the waste material from the coelomic fluid. When they are fully laden with waste, some of them migrate to the papulae and podia, where they collect at the distal end. The tip of the papulae then constricts and pinches off, discharging the coelomocytes to the outside. Other coelomocytes may pass to the outside through the epithelium of the suckers of the podia or at other sites.

4.3.4.9. Nervous System:

It is non-ganglionated and its greater part is closely associated with the epidermis. The nervous center is a some what pentagonal, circumoral nerve ring, which lies within the base of the peristomial epidermis. From each angle of the ring a large radial nerve extends into each of the arms, forming a large, intraepidermal, V-shaped mass along the middle of the oral surface of the ambulacral groove (Fig. 4-55). The radial nerve supplies fibers to the podia and ampullae and is continuous with the general intraepidermal nerve plexus. At the margins of the ambulacral groove, the epidermal nervous layer is thickened to form a pair of marginal nerve cords that extends the length of the arm, and there are also motor centres located in the vicinity of the podia and the podia/ ampullae junctions.

The integrity of both the radial nerves and the circumoral nerve ring is essential in the coordination of the podia in the movement of sea stars. Each arm has a nerve centre, probably at the junction of the radial nerves and nerve ring. A leading arm exerts a temporary dominance over the nerve centers of the other arms. Of all the reactions to external stimuli, contact of the podia with the substratum appears to be dominant and probably accounts for the righting reaction.

4.3.4.10. Sensory Organs:

Except eye spots at the tips of the arms, there are no specialized sense organs in the asteroids. In all echinoderms, the dispersed sensory cells contained within the epidermis are the primary sensory receptors and probably function for the reception of light, contact and chemical stimuli. These epidermal sensory cells are particularly prevalent on the suckers of the tube feet, on the terminal, tentacle-like sensory tube feet, and along the margins of the ambulacral groove, where 70,000 sensory cells per square millimeter has been reported.

The eye spot at the end of each arm lies beneath the tentacle on the oral side of the arm tip and is composed of a mass of 80 to 200 pigment-cup ocelli that form an optic cushion. The importance of the optic cushions in reactions to light stimuli varies in different species, but most asteroids are positively phototactic.

4.3.4.11. Regeneration:

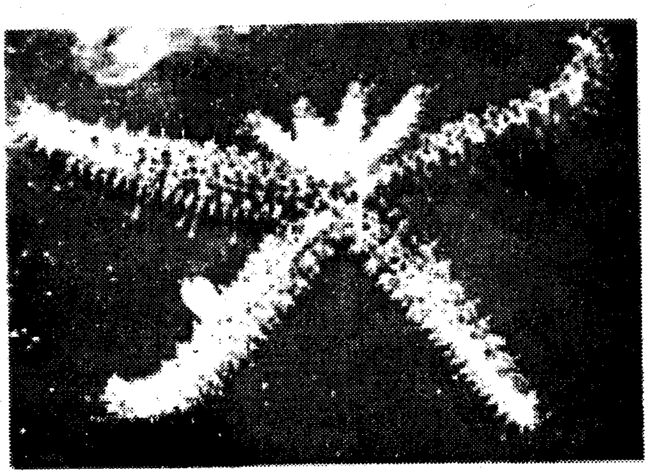
Asteroids possess a great power of regeneration. If any part of the arm is cut, it can be regenerated. The destroyed parts of the central disc can also be replaced. In *Asterias vulgaris,* if there is atleast one fifth of the central disc attached to an arm, an entire sea star will be regenerated. Regeneration is typically slow and may require as long as one year for complete reformation to take place.

4.3.4.12. Reproduction:

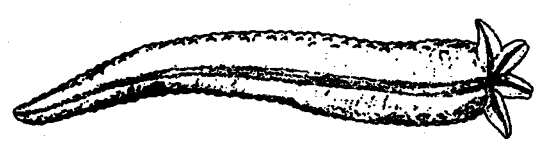
Asteroids reproduces both asexually and sexually.

A. Asexual Reproduction:

A number of asteroids normally reproduce asexually. Commonly this involves a division of the central disc so that the animal breaks into two parts. Each half then regenerates the missing portion of the disc and arms, although extra arms are commonly produced (Fig. 4-60). Species of *Linckia,* a genus of common sea stars in the Pacific and other parts of the World, are remarkable in being able to cast off their arms near the base of the disc. Unlike those of other asteroids, the severed arm regenerates a new disc and rays.



A



B

Fig. 4-60. A- Regenerating arms in *Coscinasterias,* which reproduces asexually by division of the disc. B-Comet of *Linckia.* Regeneration of body at base of detached arm.

B. Sexual Reproduction:

Asteroids are mostly dioecious. There are ten gonads, two in each arm (Fig. 4-55 and 4-56). The gonads are double-walled and tuftlike or resemble a cluster of grapes. Normally,they occupy only a small area at the base of the arm. When filled with eggs or sperm, the gonads almost completely fill each of the arms. There is a gonopore or gonopore cluster for each gonad, usually located between the bases of the arms. In a number of astropectenids and in some other groups, each arm contains many gonads. In such species the gonopores open on the oral surface.

There are a few hermaphroditic asteroid species, such as the common European sea star, *Asterina gibbosa,* which is protandric.

In the majority of asteroids the eggs and sperm are shed freely into the sea water, where fertilization takes place. There is usually only one breeding season per year, and a single female may shed as many as 2.5 million eggs.

In most asteroids, the liberated eggs and the later developmental stages are planktonic. Some sea stars, brood large, yolky eggs beneath the disc in depressions on the aboral surface of the disc, in brooding baskets formed by spines between the bases of the arms, or even in the cardiac stomach. In all the brooding species, development is direct.

Development: The fertilized egg or zygote undergo development. Development is indirect with the formation of free-swimming larval stages. The zygotes are small, homolecithal, containing little yolk. Cleavage is holoblastic. After a number of cleavages, a coeloblastula is formed. Gastrulation occurs by invagination. The new cavity in the gastrula is called archenteron. This cavity opens out by blastopore which becomes anus both in the larva and adults. Such individuals in which blastopore becomes anus are called deuterostomes. On the ventral side, mouth is formed opposite to this opening. Another opening called dorsal pore is formed on the dorsal side. Now the gastrula elongates and the cilia are arranged as bands. Thus the gastrula becomes a ciliated larva. At this stage the larva is bilaterally symmetrical. But later, the development of coelom and water vascular system changes the symmetry. Two types of larval forms are seen in the development of asteroids. They are *Bipinnaria* and *Brachiolaria.* (For description see the Chapter 4.5 Larval forms in echinoderms.).

4.3.5. SUMMARY:

1. The phylum Echinodermata is composed of marine animals that are distinguished by a pentamerous radial symmetry, an endoskeleton of calcareous ossicles, spiny ossicles on the body surface, mutable connective tissue, and a water-vascular system of coelomic cnals and body appendages, or podia, that is used in feeding or locomotion.

2. The Echinoderms are largely bottom dwellers. They occur in all seas, at all depths i.e., from intertidal zone to ocean deeps. But they are common in littoral zones.

3. The class Asteroida (sea stars) contains echinoderms in which the body is composed of a central disc and radiating arms. The arms are not sharply set off from the central disc.

4. In asteroids, the body is flattened on the oral-aboral axis. The flattened surface facing downwards is the oral surface and the convex surface directed upwards is the aboral surface. Oral surface typically has central mouth, ambulacral grooves, and tubefeet or podia. The aboral surface bears anus and madreporite and covered with stout and immovable spines in large numbers.

5. The outer surface of the body is covered by an epidermis consisting of monociliated and non-ciliated epithelial cells, mucous cells and ciliated sensory cells. Below the integument, the dermis houses the hard skeletal pieces called ossicles. Spines and tubercles are part of the endoskeleton, also covered by the epidermis. Beneath the dermis is a muscle layer made up of outer circular and inner longitudinal smooth fibers.

6. In asteroids coelom is enterocoelic. It extends into each and every part of the body. Water vascular system, perihemal canals and sinuses, and genital sinuses, are coelomic compartments.

7. Water-vascular system is unique to echinoderms and its main function is locomotion.

8. Asteroids move by means of podia, which are located within ambulacral grooves. Podia are extended by hydraulic pressure generated by the contraction of a bulb like ampulla. In many species suckers at the ends of the podia permit attachment to the substratum.

9. The arms can bend and twist, permitting the sea star to move over irregular surfaces, grasp prey and right itself. Arm movement is made possible by a flexible, lattice-like arrangement of ossicles within the dermis and by circular and longitudinal muscle layers in the body wall.

10. Sea stars inhabiting soft bottoms generally possess pointed tube feet and double ampullae; paxillae keep the papulae clear of sediment.

11. Pedicellariae, which are restricted to certain groups of sea stars, probably function to clear the body surface of settling organisms.

12. Most asteroids are scavengers and carnivores. Feeding behaviour is related not only to diet but also to arm length. Predatory species with short arms swallow the entire prey. Those with long arms evert the stomach and partially digest the prey outside the body. Those sea stars that pery on bivalves molluscs slide the stomach between the valves of the mollusc. Some species use the everted stomach like a mop to remove organic material from various surfaces.

13. The large coelom provides for internal transport. Evaginations of the body wall such as papulae, are the sites of gas exchange and excretion. The thin walls of the podia are a significant additional exchange surface.

14. Asteroids exhibit considerable powers of regeneration.

15. Asteroids reproduce both asexually and sexually. There are usually two gonads in each arm, and the gametes exit by interradial gonopores. Development leads to a bipinnaria larva, in which ciliated bands are located on long larval arms. With the formation of attachment structures, the larva is called a brachiolaria and is prepared for settling. Following settlement and attachment, the larva undergoes metamorphosis, in which the larval arms degenerate, the left side becomes the oral surface, and the adult body is derived from the posterior part of the larval body.

4.3.6. KEY TERMINOLOGY:

Aboral: Opposite the mouth.

Ampulla: A small bladder-like sac.

Bipinnaria: Larva of asteroid Echinodermata.

Diverticulum: Sac-like projection of a tubular organ.

Enterocoel: Coelomic cavity formed from an outpocketing of the embryonic archenteron.

Madreporite: Pore or sieve plate of the echinoderm water-vascular system that connects the stone canal to the exterior sea water (most echinoderms) or to the perivisceral coelomic fluid (Crinoids and Holothuroids).

Pedicellariae: A small, specialized jaw like appendage of asteroids and echinoids which is used for protection and feeding.

Radial canal: One of five fluid-filled channels of the echinoderm water-vascular system that join the ring canal to the lateral canals.

Regeneration: Replacement by growth of a part of the body that has been lost.

Ring canal: Part of the echinoderm water-vascular system that joins the stone canal to the radial canals.

Stone canal: Part of the echinoderm water-vascular system that joins the madreporite with the ring canal usually, but not always calcified.

Tiedmann's body: one of the interradial outpockets of the ring canal of many echinoderms. Removes unwanted particulates from the water-vascular system.

Tube feet: Tubular organs of locomotion found in the ambulacral grooves of sea stars and other echinoderms.

4.3.7 SELF-ASSESSMENT QUESTIONS:

1. Give an account on general organization of an echinoderm.
2. Describe the water-vascular system of asteroids and mention the role of this system.
3. Describe the digestive system and mode of feeding in sea stars.
4. Write notes on
    1. Madreporite
    2. Pedicellariae
    3. Papulae
    4. Tube feet
    5. Polian vesicles
    6. Bipinnaria.

4.3.8. REFERENCE BOOKS:

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Dr. P. Padmavathi

4.4. CLASSIFICATION OF PHYLUM ECHINODERMATA

4.4.1. OBJECTIVES :

The purpose of the lesson is to :

- understand the general characters of the phylum and
- classify the phylum Echinodermata upto orders.

4.4.2. INTRODUCTION :

The echinoderms are exclusively marine animals. They are mostly bottom dwellers. The phylum Echinodermata as remarked by Bather (1900) is "one of the best characterized and most distinct phyla of the animal kingdom". "Echinoderms are enterocoelous coelomates with pentamerous radial symmetry, without distinct head or brain, having a calcareous endoskeleton of separate plates or pieces and a peculiar water-vascular system of coelomic origin with podia or tube feet projecting out of the body".

The phylum Echinodermata contains some 6000 known species and constitutes the only major group of deuterostome invertebrates. This phylum was well differentiated even at the onset of the palaeozoic times. The fossils of echinoderms first appeared in Cambrian period. The work on echinoderms suggests that some annelids of pre-cambrian period might be the ancestors of this phylum. The name Echinodermata was first coined by Jacob Klein (1734) after observing the sea urchins.

Echinoderms have economic value. Their dried skeletons are powdered and used as fertilizer because of the presence of calcium and nitrogen in them. Among pacific Islands and in China, sea cucumbers are taken as food by man. The ovaries of sea urchin, *Echinus esculantus* and the eggs of star fishes are taken as food in South America and by the people of Meditarranian region. Some echinoderms like star fishes and sea urchings are good scavengers. Star fishes also cause great loss to oyster beds by devouring many oysters.

4.4.3. GENERAL CHARACTERS

1. Echinoderms are exclusively marine animals. They occur in all seas from the intertidal zone to the great depths.
2. Echinoderms generally live in groups. Mostly free swimming but some are sessile while some others are stalked and permanently attached (sea lilies).
3. Some animals like starfishes creep at the bottom, a few are pelagic and some like sea lilies attach permanently to rocks.
4. They are moderate to considerable size but none are microscopic.
5. Adults are pentamerous, radially symmetrical while their larvae are bilaterally symmetrical.
6. Body shape rounded to cylindrical or star-like with arms (may be five or multiples of five) radiating from the central disc.
7. Body wall triploblastic with an outer epidermis, a middle dermis and an inner peritoneum.
8. Echinoderms have distinct oral and aboral surfaces. The side on which the mouth is present is called oral surface and the opposite side is aboral surface.
9. Cephalization and segmentation is not seen.
10. The surface of the body is rarely smooth or typically marked by five symmetrically radiating grooves or areas known as ambulacra from which project the podia or tube feet.
11. Body surface of echinoderms is generally covered by calcareous oscicles and spines, hence the name (Gr. *echinus*=spiny, *derma*-skin).
12. Endoskeleton is mesodermal, hard and calcareous in nature. It may be in the form of scattered ossicles or closely fitted polygonal plates forming a shell or test or theca.
13. Body cavity is a true coelom of enterocoelous type.
14. Presence of water-vascular system or ambulacral system is the characteristic feature of echinoderms. It is derived from a part of larval coelom. It consists of tube feet, lateral canals, radial canals, ring canal, stone canal and a plate present on aboral side called 'madreporite'.
15. Contractile podia or tube feet which project from the ambulacral grooves serving the functions of locomotion, food capture and respiration.
16. Digestive system may be simple or coiled which starts with the mouth on the oral surface and ends with anus. Anus is absent in ophiuroids. The anus is located on the aboral surface either centrally or eccentrically except in hotothuroids and crinoids. Mouth and anus lie at opposite ends in hotothuroids. Mouth and anus open on the oral surface in crinoids.

17. No definite respiratory system. Respiration is carried on by different structures like papulae or dermal branchiae (star fishes), peristomial gills (sea urchins), genital bursa (brittle stars) and cloacal respiratory trees (holothurians).
18. Circulatory system is haemal and lacunar type without any heart.
19. Excretory system is absent.
20. Nervous system is primitive. It consists of a pentagonal circum-oral ring around the oesophagus and radiating ganglionated nerve cords running along the ambulacral groove.
21. Sense organs are poorly developed and are represented by tentacles, eye spots and statocysts.
22. Sexes are usually separate. No sexual dimorphism.
23. Reproduction is usually sexual, few reproduce asexually or by regeneration. Autotomy is seen in echinoderms.
24. Gonads are large and simple with a gonopore.
25. Gametes are discharged into the sea water. Fertilization is external.
26. Development indirect with a free-swimming, bilaterally symmetrical larval stage. Few are viviparous.

4.4.4. CLASSIFICATION :

The phylum Echinodermata has been divided into four sub phyla namely (1) Homalozoa (2) Crinozoa (3) Asterozoa and (4) Echinozoa.

4.4.5. SUBPHYLUM: HOMALOZOA :

1. Carpoids. Palaeozoic Echinoderms (belonging to cambrian and devonian periods) lacking radial symmetry. Some are bilaterally symmetrical and others are asymmetrical.
2. Body is dorsoventrally compressed. Dorsal plates form carapace and ventral plates form plastron.
3. Only one order, Carpoidea is included under this sub phylum.
   Example: *Enopleura.*

4.4.6. SUBPHYLUM: CRINOZOA :

1. Radially symmetrical echinoderms having a globoid or cup shaped theca and brachioles or arms, showing branching nature.
2. These animals lead a sedentary life. They attach to the substratum by aboral side and the oral surface is directed upwards.
3. This subphylum contains the fossil eocrinoids, cystoids, and the fossil and living crinoids. Only the classification of the crinoids is given here.

4.4.5.1. CLASS CRINOIDEA :

1. Includes sea lilies and feather stars.
2. Stalked (sea lilies) and free moving (feather stars) echinoderms having the oral side of the body directed upward.
3. Arms branched and provided with pinnules.
4. Mouth is provided with five triangular oral plates. In between these plates five oral or ambulacral grooves are present in the ambulacral region. Inter ambulacral region alternate with them.

5. Madreporite is absent.
6. Tube feet are in clusters and each cluster contains three tube feet without suckers.
7. Spines and pedicellariae are absent.
8. Perivisceral place is divided into compartments with the help of connective tissue strands. These compartments are lined by coelomic epithelium.
9. Respiration is carried on by general body surface.
10. Excretory organs or excretory system is absent.
11. Sexes are separate. Gonads are formed from coelomic epithelium. Gametes come out by the rupture of the wall of pinnules.
12. Fertilization is external. The larva of crinoidea is called vitellaria. After a brief swimming period, it settles down on a substratum as pentacrinoid larva.

4.4.6.1.A,B,C. SUBCLASSES: INADUNATA, FLEXIBILIA AND CAMERATA :

1. Stalked Paleozoic crinoids with or without cirri, some without pinnules.
2. Organization of calyx ossicles is important in distinguishing these fossil groups.

4.4.6.1.D. SUBCLASS: ARTICULATA :

1. Extinct forms as well as all living crinoids belong to this subclass.
2. The living crinoids are placed in five orders.

4.4.6.1.D.a. Order Millericrinida :

1. Sea lilies without cirri.
   Examples : *Hyocrinus, Calamocrinus.*

4.4.6.1.D.b. Order Cyrtocrinida

1. This order contains two living species from the Caribbean and mid-Atlantic in which the aboral end of the crown is attached directly to the substratum.
   Example: *Holopus.*

4.4.6.1.D.c. Order Bourgueticrinida :

1. Mostly small sea lilies.
2. The slender stalk lacks cirri.
   Examples: *Rhizocrinus, Bathycrinus.*

4.4.6.1.D.d. Order Isocrinida :

Sea lilies with cirri.
Examples: *Metacrinus, Cenocrinus* (Fig. 4-61)

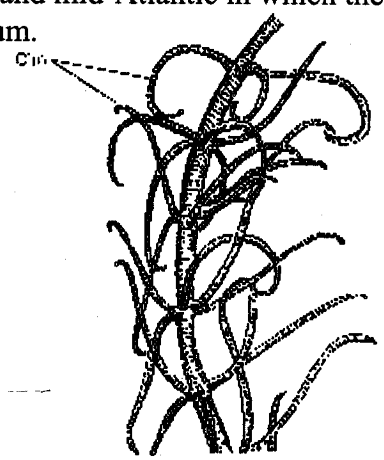


Fig. 4-61. Part of *stalk - Cenocrinus*

4.4.6.1.D.e. Order Comatulida :

Feather stars. Stalkless, unattached crinoids.
Examples: *Antedon* (Fig 4-62), *Florometra, Neometra* (Fig. 4-63)

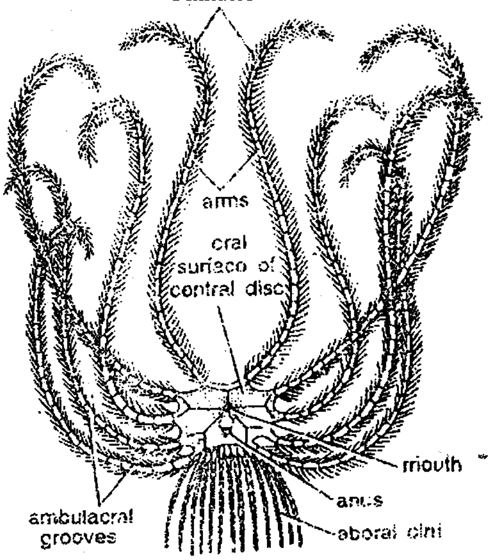


Fig. 4-62. *Antedon*

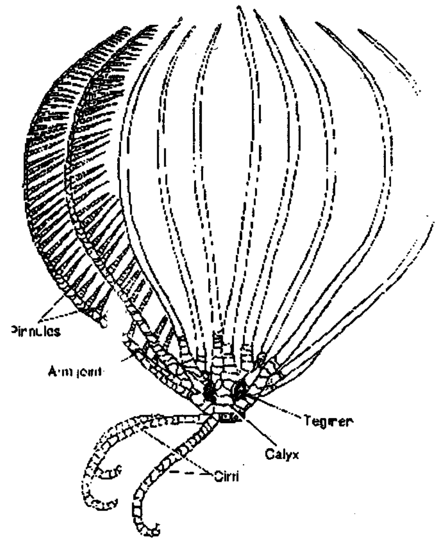


Fig. 4-63. *Neometra*

4.4.7. SUBPHYLUM ASTEROZOA :

1. Unattached, freeliving, radially symmetrical echinoderms.
2. Body composed of a flattened central disc and radially arranged arms, or rays..
3. Subphylum Asterozoa is divided into three classes : (1) Asteroidea (2) Ophiuroidea and (3) Concentricycloidea.

4.4.7.1. CLASS ASTEROIDEA :

1. Sea stars. Arms sharply set off from the central disc.
2. Ambulacral grooves are open, and a large coelomic cavity is present in the relatively wide arms.
3. Five ambulacral grooves one in each arm. From each ambulacral groove 2-4 rows of tube feet or podia arise and project into water. Tube feet are usually provided with suckers.
4. Water-vascular system is well developed. Madreporite is present on the aboral side. It leads into water vascular system through stone canal.
5. Pedicellariae and calcareous tubercles and spines are present on the body.
6. Respiration is carried on by structures called papulae.
7. At the tip of each arm there is a red eye spot which is the sense organ present in Asteroidea. Tentacle is also present. It is olfactory in function.
8. Sexes are separate. Five pairs of radially arranged gonads are present.
9. Bipinnaria and Brachiolaria larvae are seen in the life history of Asteroids.
10. Autotomy is a prominent feature in Asteroidea.
11. These are free living animals found creeping on sandy shores.

4.4.7.1.a. Order Platyasterida :

1. Feet without suckers.
2. Primitive, mostly extinct sea stars; the two living genera are *Platyasterias* and the common soft bottom *Luidia.*

4.4.7.1.b & c. Orders Paxillosida and Valvatida :

These two orders were formerly united within the order Phanerozonia.

The paxillosida lack suckers on the tube feet; the valvatida possess suckers.

Sea stars with marginal plates and usually with paxillae on the aboral surface.

Pedicellariae of the sessile type.

Examples : *Astropecten* (Fig 4-64), *Ctenodiscus, Culcita* (Fig 4-65), *Goniaster, Oreaster, Linckia, Porania.*

4.4.7.1.d. Order Spinulosida :

1. The members of this order are not always distinct from those of the two orders above, but in general conspicuous marginal plates are absent, and the tube feet are with suckers.
2. The aboral surface is covered with low spines, which give the order its name.
3. There are no pedicellariae.

Examples : *Asterina, Patiria, Echinaster, Henricia, Acanthaster* (Fig 4-66), *Crossaster, Pteraster.*

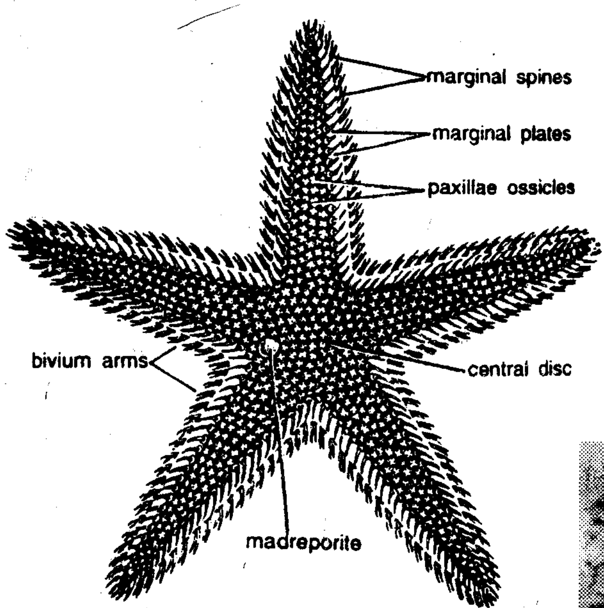


Fig. 4-64. *Astropecten*

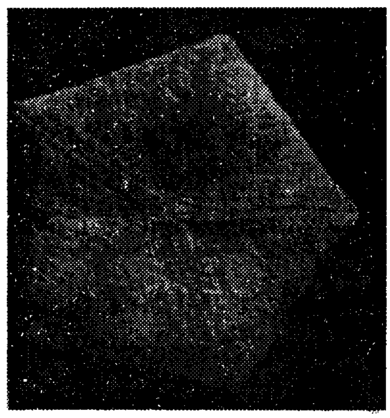


Fig. 4-65. *Culcita*

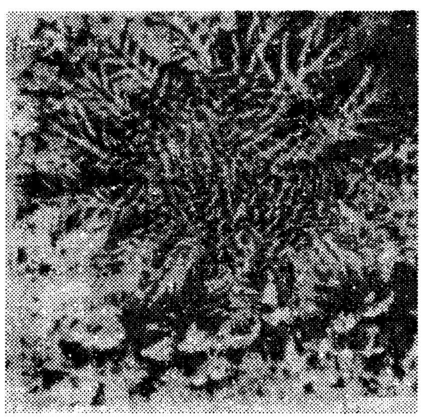


Fig. 4-66. *Acanthaster*

4.4.7.1.e. Order Forcipulata :

Sea stars with pedicellariae composed of a short stalk and three skeletal ossicles.
Tube feet with suckers.
Examples : *Heliaster, Pycnopodia, Asterias (Fig. 4-45), Leptasterias, Pisaster, Brisinga, Zoroaster.*

4.4.7.2. CLASS OPHIUROIDEA :

1. Brittle stars or serpent stars. Arms sharply set off from the central disc.
2. Ambulacral grooves are absent.
3. Arms largely filled by vertebral ossicles and with lateral spines.
4. Madreporite is present on the oral side.
5. Tube feet are present but not useful for locomotion because they have no ampullae and suckers.
6. Pedicellariae, papulae and sense organs are absent.
7. Sexes are separate. Gonoducts are absent.
8. Life history includes a free swimming larva called ophiopluteus.
9. These are free living nocturnal animals living at the bottom of the sea.

4.4.7.2.a. Order Oegophiurida :

1. A large fossil group with a single living species.
2. No dorsal and ventral arm shields or bursae.
3. Madreporites at the edge of the disc.

4.4.7.2.b. Order Phrynophiurida :

1. Ophiuroids in which dorsal arm shields are absent.
   Examples : *Ophiocanops, Asteronyx, Gorgonocephalus.*

4.4.7.2.c. Order Ophiurida :

1. This order contains most of the brittle stars, or serpent stars.
2. Mostly small ophiuroids, usually with five arms.
3. Arms capable of transverse movement only.
4. Dorsal arm shields are present.
   Examples : *Amphiura, Ophiactis, Ophiothrix* (Fig. 4-68), *Ophioderma, Ophiocoma, Ophiolepics, Ophiomaza, Ophionereis.*

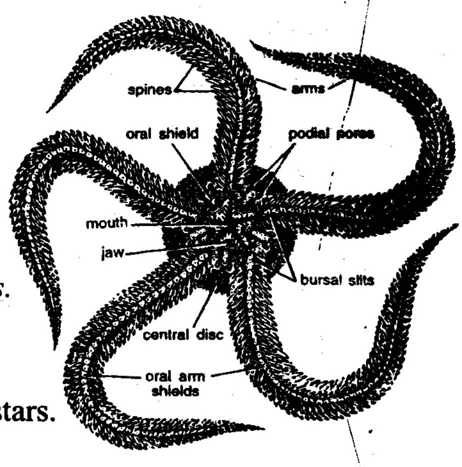


Fig. 4-68. *Ophiothrix*

4.4.7.3. CLASS CONCENTRICYCLOIDEA :

1. Minute deep water echinoderms (2-9 mm across) with disc-shaped bodies.
2. Body covered aborally with plate like ossicles.
3. Marginal spines are located around the periphery.
4. The water vascular system is peculiar in having two ring canals, with the podia arising from the outer one.

5. A pair of gonads is associated with each of five bursae.
6. The mode of feeding and other aspects of the biology are still unknown.

   Examples: *Xyloplax medusiformis (Fig. 4-69) and X. turnerae.*

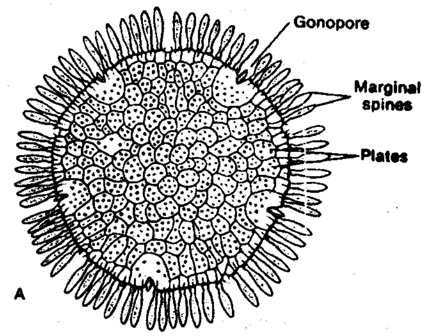


Fig. 4-69. *Xyloplax medusiformis*

4.4.8. SUBPHYLUM ECHINOZOA :

1. Radially symmetrical globoid or discoid echinoderms without arms or brachioles.
2. Mostly unattached.
3. Contains the fossil helicoplacoids and edrioasteroids as well as the echinoids (sea urchins) and holothuroids (sea cucumbers).
4. Only the last two are given here.

4.4.8.1 CLASS ECHINOIDEA :

1. This class includes sea urchins, heart urchins and sand dollars.
2. Body is oval, spherical or disc like or heart shaped. Oral and aboral ends are distinct.
3. Arms absent.
4. Ossicles fused to form an internal test on which movable spines are mounted.
5. Pedicellariae are stalked and have three jaws.
6. Outer body surface is differentiated into ambulacral and inter ambulacral areas. Each area is made of two meridional rows of plates.
7. Ambulacral grooves are absent.
8. Tube feet with suckers.
9. Madreporite lies close to anus on the aboral side.
10. Aristotle's lantern with teeth is present. It is associated with the digestive system. It is also called the masticatory apparatus.
11. Sexes are separate. Five gonads present, which are arranged interradially.
12. A free swimming Echinopluteus larva is seen during development.

4.4.8.1.A. SUB CLASS PERISCHOECHINOIDEA :

1. Largely primitive fossil urchins of the Paleozoic seas, which made their first appearance in the Ordovician period with Bothriocidaris.

4.4.8.1.A.a. ORDER CIDAROIDA :

1. Of the four orders of the subclass Perischoechinoidea, this is the only one with two rows of plates for each ambulacrum and interambulacrum.

2. It is also the only one that survived the Paleozoic era and became the ancestor of the remaining echinoids, most of which belong to the next subclass.
3. The existing members of the Cidaroida are characterized by widely separated primary spines and small secondary spines.
4. Gills are absent.

Examples : *Eucidaris* (Fig. 4-70), *Cidaris*, *Notocidaris.*

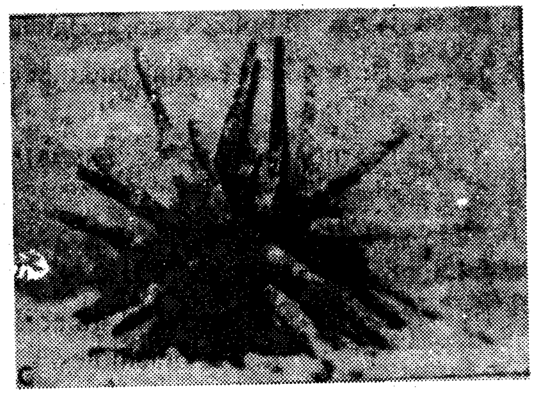


Fig. 4-70. *Eucidaris*

4.4.8.1.B. SUBCLASS EUECHINOIDEA :

This subclass contains the majority of living species of echinoids and is divided into four superorders.

4.4.8.1.B.i. SUPERORDER DIADEMATACEA :

1 Sea urchins with perforated tubercles.
2. Gills usually present.

4.4.8.1.B.i.a. ORDER : PEDINOIDA :

1. Rigid test with solid spines.
2. Ten buccal plates on peristomial membrane.

Example: *Caenopedina* is the only living genus.

4.4.8.1.B.i.b. ORDER DIADEMATOIDA :

1. Rigid or flexible test with hollow spines.
2. Ten buccal plates on peristomial membrane.

Examples: *Diadema (Fig. 4-71), Plesiodiadema.*

Fig. 4-71. *Diadema*

4.4.8.1.B.i.c. ORDER ECHINOTHUROIDA :

Flexible test with poisonous secondary spines.
Simple ambulacral plates on peristomial membrane.
Gills inconspicuous or lost.
Example: *Asthenosoma.*

4.4.8.1.B.ii. SUPERORDER ECHINACEA :

1. Sea urchins with rigid test and solid spines.
2. Gills present.
3. Peristomial membrane with ten bucal plates.

4.4.8.1.B.ii.a. ORDER ARBACIOIDA :

Periproct with four or five plates.
Example : *Arbacia (Fig. 4-72).*

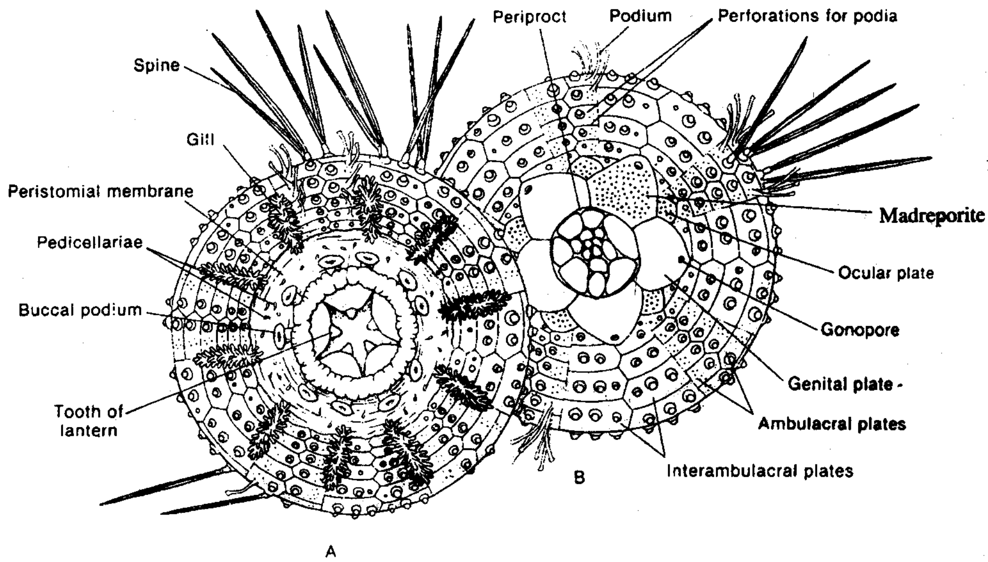


Fig. 4-72. The regular urchin, *Arbacia punctulata.* A- Oral view, B- Aboral view

4.4.8.1.B.ii.b. ORDER SALENOIDA :

Anus located eccentrically within periproct because of the presence of a large plate (Suranal plate).
Example: *Acrosalenia.*

4.4.8.1.B.ii.c. ORDER TEMNOPLEUROIDA :

1. Test sculptured in some.
2. Camarodont lantern (large epiphyses are fused acros

Example: *Tripneustes*(Fig. 4-73), *Toxopneustes, Lytechinus.*

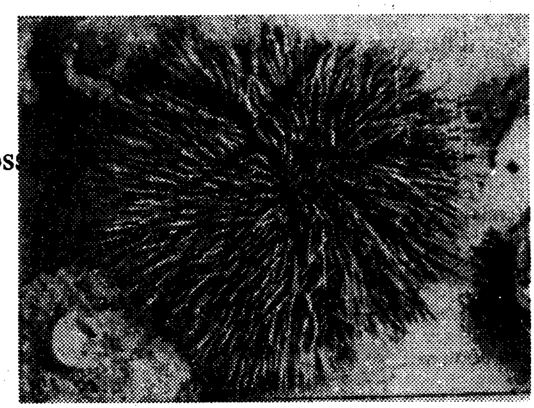


Fig. 4-73. *Tripneustes*

4.4.8.1.B.ii.d. ORDER PHYMOSOMATOIDA :

1. Phymosomatoides are similar to temnoplueroides in structure.
2. Primary tubercles are imperforate in phymosomatoides.
   Example: *Glyptocidaris.*

4.4.8.1.B.ii.e. ORDER ECHINOIDA :

Camarodont lantern and nonsculptured test with imperforate tubercles.
Examples: *Echinus* (Fig. 4-74), *Psammechinus, Paracentrotus, Echinometra, Echinostrephus, Colobocentrotus, Strongylocentrotus.*

4.4.8.1.B.iii. SUPERORDER GNATHOSTOMATA :

Irregular urchins.
Mouth is in the center of oral surface but anus has shifted out of apical center.
Lantern present.

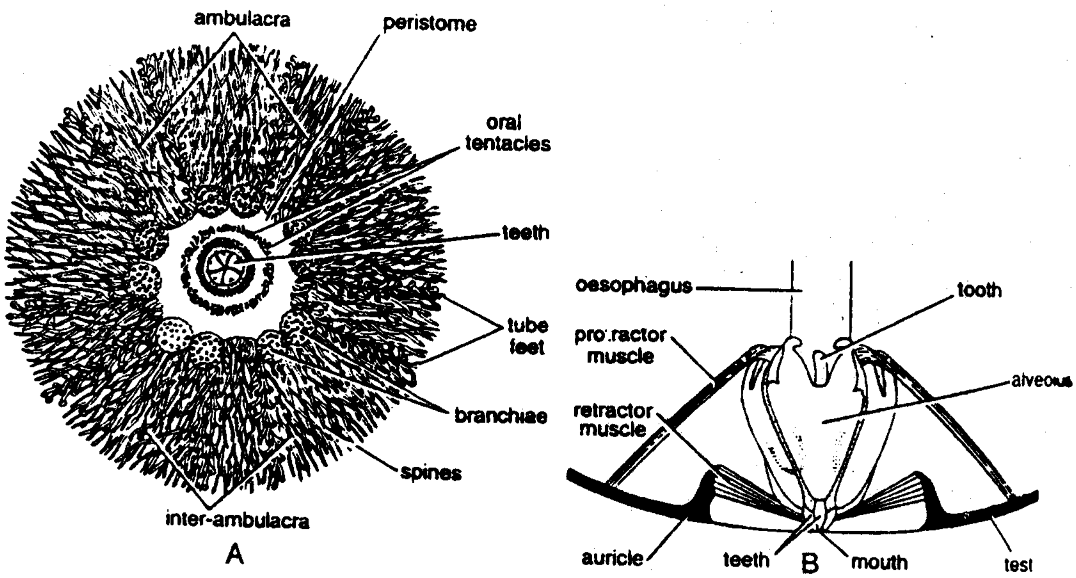


Fig. 4-74. *Echinus.* A-Oral view, B-Aristotle's lantern in situ

4.4.8.1.B.iii. a. ORDER HOLECTYPOIDA :

No petaloids. Many fossil members were essentially regular in shape. The two living genera, *Echinoneus* and *Micropetalon* are oval.

4.4.8.1.B.iii.b. ORDER CLYPEASTEROIDA :

1. True sand dollars
2. Distinct petaloids are present.
3. Test greatly flattened.
4. No phyllodes.

Examples: *Clypeaster* (Fig 4-75), *Fibularia, Mellita, Encope* (Fig. 4-76), *Rotula.*

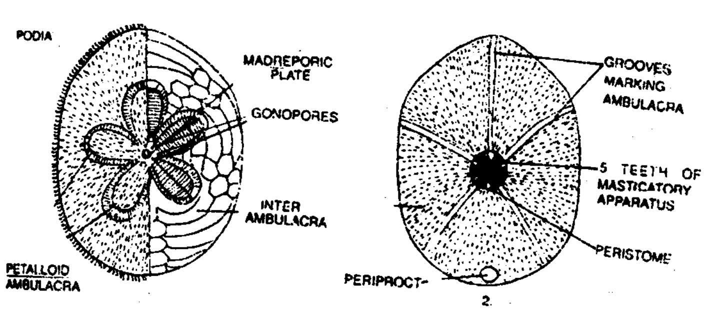


Fig. 4-75. *Clypeaster*

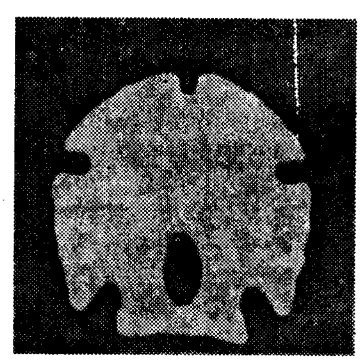


Fig. 4-76. *Encope*

4.4.8.1.B.iv. SUPERORDER ATELOSTOMATA :

1. Irregular urchins.
2. No lantern.

4.4.8.1.B.iv.a. ORDER HOLASTEROIDA :

Oval or bottle–shaped echinoids with thin, delicate test.
Petaloids and phyllodes not developed.
Deep water species.
Example: *Pourtalesia.*

4.4.8.1.B.iv.b. ORDER SPATANGOIDA :

1. Heart urchins. Oval and elongated echinoids.
2. Oral center shifted anteriorly, and anus shifted out of aboral apical center.
3. Petaloids present but may be sunk into grooves.
4. Phyllodes present.
   Examples: *Spatangus, Echinocardium (Fig. 4-77), Moira (Fig. 4-78), Meoma (Fig. 4-79), Lovenia.*

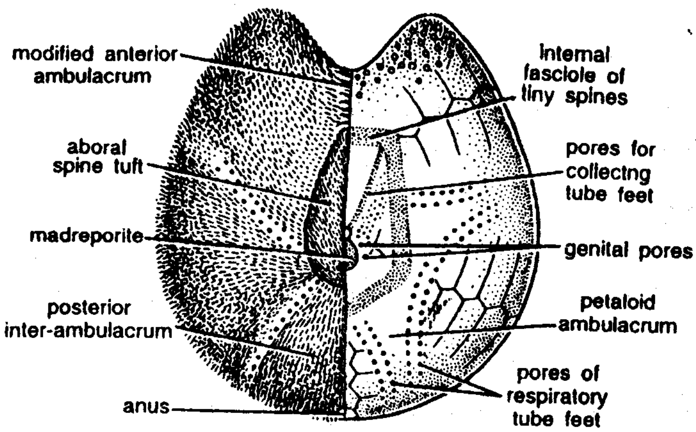
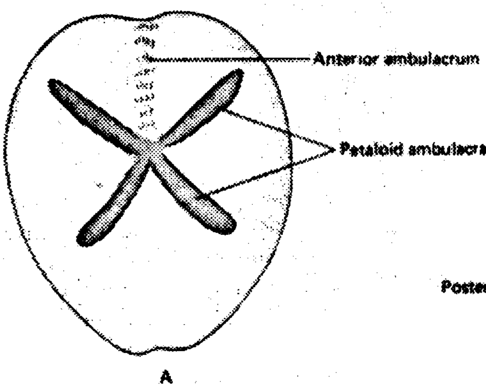


Fig. 4-77. *Echinocardium*

Fig. 4-78. Anterior end of *Moira atropos.*



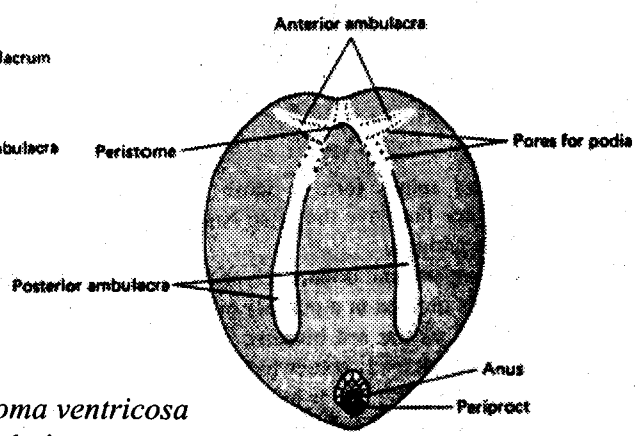


Fig. 4-79. Heart urchin - *Meoma ventricosa*
A- aboral view, B- oral view

4.4.8.1.B.iv. c. ORDER CASSIDULOIDA :

1. Mostly extinct echinoids with round to oval test and a central or slightly anterior apical center. Poorly developed petaloids.
2. Phyllodes with intervening smaller areas (bourrelets).
3. The few existing species are tropical burrowers and somewhat similar to heart urchins. Examples: *Echinolampas.*

4.4.8.2. CLASS HOLOTHUROIDEA :

1. Sea cucumbers. These are inactive and sluggish animals
2. Body elongated along the oral/aboral axis.
3. Oral podia modified as tentacles.
4. Skeleton reduced to microscopic ossicles.
5. Arms and spines are absent.
6. Five ambulacral and five inter–ambulacral areas are present on the body.
7. Tube feet with suckers.
8. Pedicellariae, ossicles and papulae are absent. Hence the skin is soft.
9. Body wall is dermo-muscular, a character common with annelids.
10. Mouth at the anterior end is surrounded by rectractile oral tentacles which are connected to water vascular system.
11. In the water vascular system the madreporite is present in the body cavity below the pharynx.
12. Alimentary canal is an elongated coiled tube with anus at the posterior end. The cloaca is surrounded usually by respiratory trees.
13. Haemal system is well developed with haemal ring and haemal sinuses. Haemal sinuses are lined by coelomic epithelium.
14. Sexes are separate. Only one branched gonad is present.
15. Development may be direct or indirect. A larva called Auricularia is seen in the indirect development.
16. Evisceration of visceral parts is a unique character of holothurians. Respiratory trees, gonad and intestine comes out through cloaca and are discarded and rebuilt.

4.4.8.2.a. ORDER DACTYLOCHIROTIDA :

1. Primitive sea cucumbers.
2. Tentacles are simple, and the body is enclosed within a flexible test.
3. Body U-shaped.
   Examples: *Sphaerothuria, Echinocucumis.*

4.4.8.2.b. ORDER DENDROCHIROTIDA :

1. Buccal podia, or tentacles are dendritic and not provided with ampullae.

2. Podia occurring on the sole, on all the ambulacra, or over the entire surface.
   Example: *Cucumaria* (Fig. 4-80), *Thyone* (Fig. 4-81), *Psolus.*

4.4.8.2.c. ORDER ASPIDOCHIROTIDA :

1. Tentacles peltate, or shield like
2. Podia are present, sometimes podia unite to form a well developed sole.
   Examples: *Holothuria* (Fig. 4-82), *Actinophyga, Stichopus.*

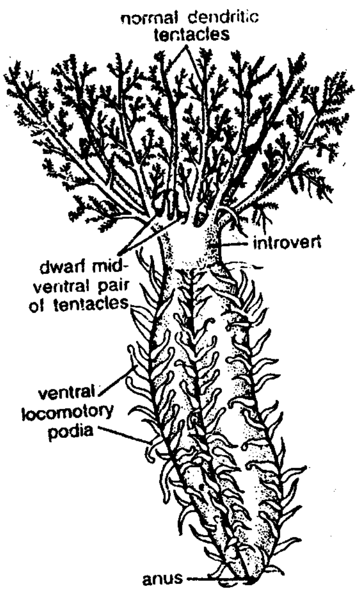


Fig. 4-80. *Cucumaria*

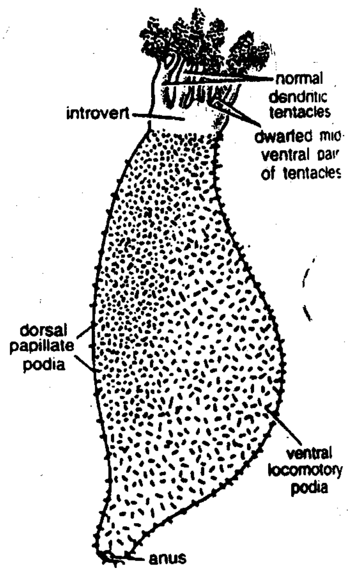


Fig. 4-81. *Thyone*

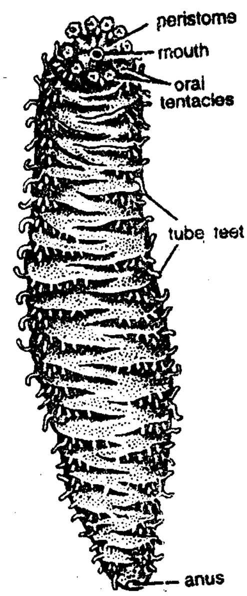


Fig. 4-82. *Holothuria.*

4.4.8.2.d. ORDER ELASIPODIDA :

1. Aberrant sea cucumbers with large, conical papillae and other appendages.
2. Tentacles peltate.
3. Almost all are deep sea species.
   Examples: *Pelagothuria, Peniagone.*

4.4.8.2.e. ORDER MOLPADIIDA :

1. Posterior end of body narrowed to a tail.
2. Fifteen digitate tentacles, but regular podia absent.
   Examples: *Molpadia, Caudina.*

4.4.8.2.f. ORDER APODIDA :

1. Wormlike sea cucumbers with only buccal podia or tentacles.
2. Tentacles digitate or pinnate.
   Examples: *Leptosynapta, Synapta, Euapta.*

4.4.9. SUMMARY :

1. The echinoderms are completely marine animals. They are living on the shore but mostly on the bottom of the seas.

2. The most striking characteristic of the group is their pentamerous radial symmetry, which is secondarily acquired in their adult condition. They have peculiar water vascular system of coelomic origin with podia or tube feet.

3. The phylum contains about 6000 known species with much of fossil record dates back to Cambrian period.

4. Echinoderms have economic values as they are used as food, fertilizer, good scavengers, etc.

5. Echinoderms are mostly free-living but some are sessile while some others are stalked and permanently attached (sea lilies).

6. They are coelomate animals with pentamerous radial symmetry, that is the body is divided into five parts arranged around a central axis, but the larva is bilaterally symmetrical.

7. These animals have distinct oral and aboral surfaces.

8. There is no head and segmentation.

9. They have an endoskeleton of calcareous ossicles made from mesoderm, there are also external spines which may be movable or fixed.

10. A large ciliated enterocoelous coelom forms a perivisceral cavity and several intricate systems. One of which is a water vascular system from which project delicate tube feet. The tube feet function in locomotion, food capture and respiration.

11. Digestive system may be simple or coiled. Anus is absent in Ophiuroidea. In Holothuroids, mouth and anus lie at the anterior and posterior end of the animal respectively. Mouth and anus open on the oral surface in crinoids.

12. Respiration is carried on by different structures like papulae, dermal branchiae, peristomial gills, genital bursa and cloacal respiratory trees in different echinoderms.

13. There is no definite blood vascular system; it is represented only by lacunar tissue. There are no definite excretory organs. Nervous system is primitive with a pentagonal circum-oral ring and radiating ganglionated nerve cords.

14. Sexes are usually separate and fertilization is external.

15. Development is indirect with a free-swimming, bilaterally symmetrical larval stage. Few are viviparous.

16. They possess great powers of regeneration and also exhibit autotomy.

17. The phylum Echinodermata has been divided into four sub-phyla namely Homalozoa, Crinozoa, Asterozoa and Echinozoa.

18. Subphylum Homalozoa includes carpoids. These are palaeozoic echinoderms lacking radial symmetry. Represented by only one order, Carpoidea.

19. Subphylum Crinozoa constitutes only one class – crinoidea which is again divided into four subclasses and five orders.

20. Subphylum Asterozoa is divided into three classes namely Asteroidea, Ophiuroidea and Concentricycloidea. Class Asteroidea is again divided into five orders and class Ophiuroidea into three orders.

21. Subphylum Echinozoa is divided into two classes namely Echinoidea and Holothuroidea. Class Echinoidea is again divided into two subclasses, four super orders and thirteen orders. Class Holothuroidea is divided into six orders.

4.4.10. KEY TERMINOLOGY :

Ambulacral groove : A grove in the arm of an echinoderm lined by tube fee.

Ambulacrum (pl. Ambulacra) : Groove, ridge or band, of tube feet, radial canal and associated body wall of echinoderms.

Aristotle's lantern: Highly developed chewing apparatus used for feeding by sea urchins.

Autotomy: Self mutilation or self amputation; the automatic "voluntary" breaking off a part of the body of an animal.

Enterocoel: Coelomic cavity formed from an out pocketing of the embryonic archenteron.

Evisceration: When the anterior or posterior end of a species ruptures and parts of the gut and associated organs are expelled.

Ossicle: An internal skeletal piece in echinoderms, commonly calcareous.

Petaloid: One of five petal-shaped areas on the aboral surface of irregular urchins that bear specialized respiratory podia.

Pinnule: A feather-like structure in the crinoid arm. It is a side branch of the crinoid arm.

Respiratory tree: One or two respiratory organs of most holothuroid echinoderms. Consists of a network of thin-walled tubules in the perivisceral coelom that originates from the cloacal wall.

Test: An encasing or shell-like skeleton, typically covered externally by cytoplasm or living tissue.

4.4.11. SELF ASSESSMENT QUESTIONS :

1. Give the general charcters of the phylum Echinodermata. Classify the phylum upto orders giving atleast two examples for each order.

2. Classify the phylum Echinodermata upto orders giving two examples for each order.

3. Write notes on :
   1) Crinoidea (2) Asteroidea (3) Echinoidea (4) Ophiuroidea (5) Holothuroidea.

4.4.12. REFERENCE BOOKS :

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Dr. P. Padmavathi

4.5. LARVAL FORMS IN ECHINODERMS

4.5.1. OBJECTIVES :

The purpose of this lesson is to

☆ understand the different types of larvae in the phylum Echinodermata and

☆ describe the structure and metamorphosis of these larval forms.

4.5.2. INTRODUCTION :

Most of the echinoderms are oviparous (egg laying). In egg-laying echinoderms, development is indirect They possess a number of larval forms in their life histories. Only few species are viviparous which brood their young in particular brood pouches. In these cases, the development is direct without the occurrence of larval stages during development.

In echinoderms, sexes are separate. External fertilization occurs in sea water. Cleavage is total, holoblastic, radial and indeterminate. The eggs are homolecithal and the early development is uniform throughout the phylum. The blastopore remains as larval anus, a characteristic feature of deuterostomes. The mouth forms as a secondary opening (deuterostome – second mouth) at the opposite end of the blastopore.

All the larval forms of echinoderms are bilaterally symmetrical. This character is in contrast to the radial symmetry of the adults. The mbryo turns into a free swimming larval stage with the appearance of locomotory ciliary bands and arms. The arms arise as projections from the body surface. The presence or absence of the arms and the nature and position of these arms are the distinguishing characters of the larvae of different echinoderms. The developing embryo takes several weeks to attain the larval stage. After a short free swimming and feeding life, the larvae undergo a remarkable metamorphosis with the suppression of the anterior part of the right side to become a radially symmetrical adult.

The structure and metamorphosis of a variety of larval forms occur in this phylum are as follows :

Class Asteroidea is characterized by the Bipinnaria larva which at the latter stage transforms into Brachiolaria larva. Class Echinoidea has Echinopluteus and the class Ophiuroidea has Ophiopluteus as larval forms in their life histories. Class Holothuroidea is characterized by the Auricularia larva. It transforms into Doliolaria larva and then metamorphoses into Pentactula larva. Class Crinoidea has characteristic Vitellaria larva which finally settles as Pentacrinoid larva. All these larval forms are considered to be derived from a common ancestoral type called Dipleurula larva.

4.5.3.A. BIPINNARIA LARVA :

Bipinnaria larva is seen in the life history of asteroids. It is a free swimming larval form which leads a planktonic life. At first the entire body surface is covered by cilia uniformly. Later the surface ciliation is confined to definite areas forming locomotory bands. They are then differentiated into one pre-oral loop and one post oral or pre ana loop. Later, the pre oral loop separates and forms an anterior ciliated ring around the body (Fig.4-83). The ciliary lining of the stomodaeum helps in feeding by driving the nutritive water currents inside. By this time, the alimentary canal of larva is fully formed

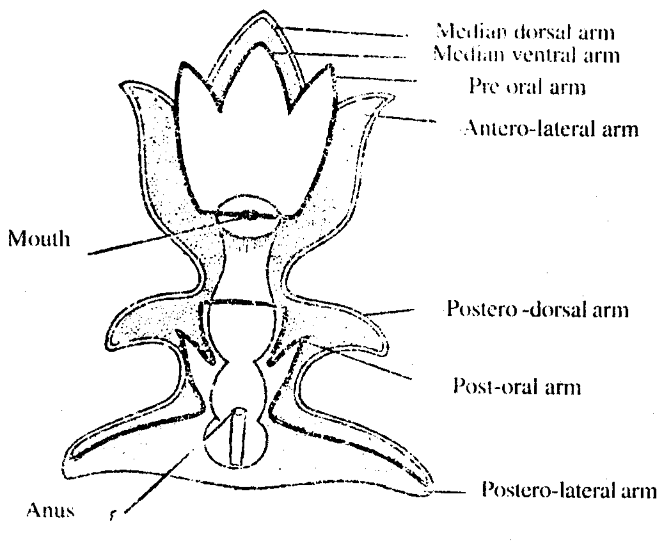

Fig. 4-83. Bipinnaria larva of sea star.

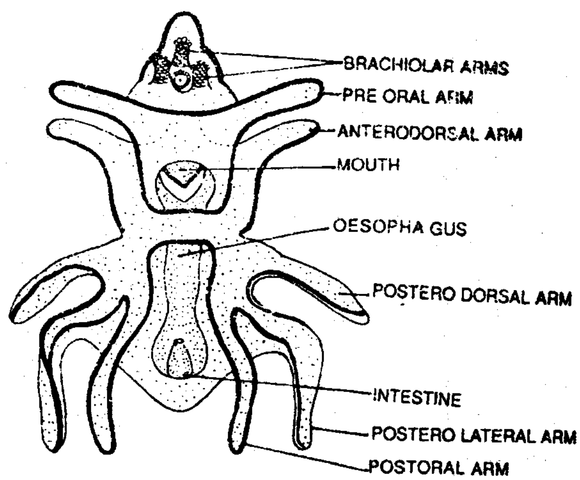

Fig. 4-84. Brachiolaria larva

and is in the form of a straight tube consisting of mouth, oesophagus, stomach, intestine and arms. Various coelomic compartments are seen inside the body. Mean while certain projections called arms develop from the body surface. They are 6 in number, 3 on each side of the body. The locomotory ciliary bands extend along the borders of the arms which become larger and slender after sometime. This larval stage then known as bipinnaria larva. Bipinnaria stage begins usually on the 4th to 6th day of development. It takes weeks to attain its complete form.

The ciliated bands function in both locomotion and feeding. The larval arms increase the surface area of the ciliated bands; thus the intensity of movement and food collection will be increased. Phytoplankton and other fine suspended particles constitute the food of the larva.

4.5.3.B. BRACHIOLARIA LARVA :

The bipinnaria larva transforms itself into a brachiolaria larva with the appearance of three additional arms, called brachiolar arms, at the anterior end. These arms are short, ventral in position, and covered with adhesive cells at the tip. These arms differ from those of bipinnaria in containing the coelomic extension in them. Between the bases of the three arms is a glandular, adhesive area that forms a sucker. The three arms and the sucker represent an attachment device. The brachiolaria then settles to the bottom and metamorphoses into an adult. There are some species, such as *Luidia* and *Astropecten* and the common European sea star *Asterina,* in which a brachiolaria stage is totally absent.

Metamorphosis takes place after settlement. The anterior end of the larva degenerates and forms only an attachment stalk. The adult body develops from the rounded, posterior end of the larva. The left side becomes the oral surface, and the right side becomes the aboral surface. The adult arms appear as extensions of the body. The larval digestive tract degenerates and is replaced by a new one which coincides with the radial symmetry. The somatocoel forms the major part of the coelom. The left axohydrocoel forms the water-vascular system. From the hydrocoel develop five pairs of projections or cavities, two in each of the developing arms. The exoskeletal ossicles develop first around the aboral pole, which contains the anus. The detached baby star fish is less than 1 mm in diameter, with very short, stubby arms.

4.5.4. CLASS ECHINOIDEA :

4.5.4.A. ECHINOPLUTEUS LARVA :

The gastrula alters into a larval type called Pluteus, which in Echinoidea termed as Echinopluteus (in Ophiuroidea as Ophiopluteus). The gastrula elongates into a cone-shaped structure, the base of which becomes flattened with a blastopore in the center. The blastopore develops into the larval anus later on. The apex becomes rounded forming the oral lobe. Just beneath this, a stomodaeal invagination starts which communicates with the archenterons and gets differentiated into mouth, oesophogus, stomach and intestine (Fig. 4-85).

Now the larva starts putting out slender projections called arms. These are supported by skeletal rods secreted by primary mesenchyme. The various arms are pre-oral, anterolateral, anterodorsal, post-oral, posterodorsal and posterolateral pairs. The first appeared pair of arms on the oral end, opposite to the oral lobe are postoral arms. Then a pair of short arms appear on the oral lobe called antero-lateral arms. This four-armed stage is reached within 4 to 6 days. It swims and feeds on

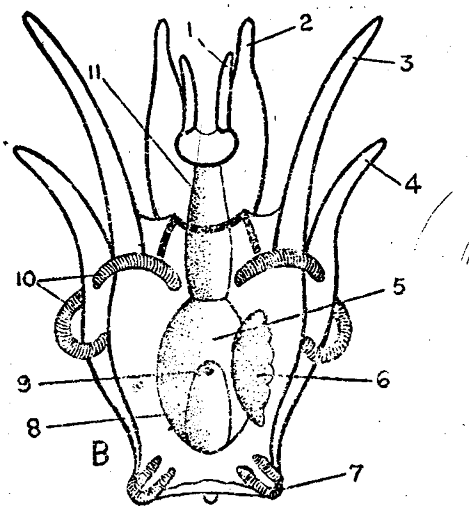

Fig. 4-85. Echinopluteus Larva
1. Preoral arm 2. Antero-lateral arm 3. Post - oral arm 4. Postero-dorsal arm 5. Stomach 6. Echinus rudiment 7. Postero lateral process 8. Intestine 9. Anus 10. Anterior epaulettes 11. Oesophagus.

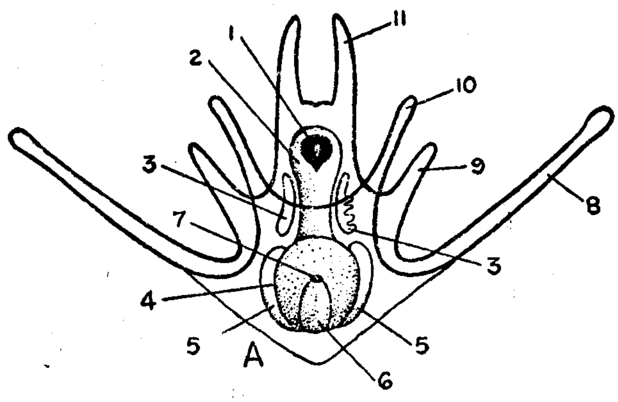

Fig. 4-86. A. Ophilopluteus Larva.
1. Mouth 2. Oesophagus 3. Hydrocoel with lobes 4. Stomach 5. Somatocoel 6. Intestine 7. anus 8. Postero lateral arm 9. Postero dorsal arm 10. Postoral arm 11. Antero lateral arm.

diatoms and other plankton. If sufficiently nourished, it grows in size and develops additional pair of arms. A postero-dorsal pair near the post oral, a preoral pair on the oral lobe and an antero-dorsal pair near the latter get developed. Sometimes an extra pair of short, backwardly directed postero-lateral pair develop on either side of the posterior end. Thus, an Echinopluteus may have either 4 pairs or 6 pairs of arms and occasionally 7 pairs. The arms also possess pigment cells of various colours. Locomotion is carried on by ciliary bands.

The pluteus is tiny and microscopic. It is planktonic, freely swimming on the surface waters. It takes several months to complete its development. The adult skeleton begins to form during the later larval life. The larva then sinks down to the bottom, there being no attachment as in asteroids. Metamorphosis is extremely rapid, which is completed within one hour. Young urchins are about 1 mm in size.

4.5.5. CLASS OPHIUROIDEA :

4.5.5.A. OPHIOPLUTEUS :

It resembles the echinopluteus closely. It has less number of arms than echinopluteus. The ciliary band is broad and encircles the various arms. The first formed arms are very long and are called the postero-laterals. On the 4th day of development appear a pair of antero-laterals. Opposite to these arise a pair of post-orals on 10th day. The last pair, postero-dorsals make their appearance on 18th day. All the arms are supported by 3 rayed skeletal rods secreted by the mesenchyme. The larva develops fully within 3 weeks. The posterior end of the larva is projected into a rounded bulb like structure into which also extend the skeletal rods (Fig. 4-86).

The larva contains the coelomic sacs and the digestive tract. It is free swimming and planktonic. Metamorphosis takes place while the larva is still free swimming and there is no attachment stage. The tiny brittle star sinks to the bottom to lead an adult life.

Ophioderma lacks a pluteus in its development, as it is viviparous. In *Ophionotus,* development is completed within the ovary and the liberated pluteus lacks the arms, but possesses a ciliated band and skeletal rods.

4.5.6. CLASS HOLOTHUROIDEA :

4.5.6.A. AURICULARIA LARVA :

It is a characteristic larval form of holothuroids. The gastrula after developing the coelomic sacs and archenteron, becomes a free swimming larva. On the 3rd day it is called auricularia. It is a transparent, pelagic, microscopic form measuring 0.5 to 1 mm in length. The auricularia is very similar to the bipinnaria of the asteroids and possesses a ciliated locomotor band (Fig. 4-87). The characteristic feature of this larva is that it has only one ciliated band. This ciliated band loops around the mouth as preoral loop and around the anus, as anal loop. The ciliary band is made up of flagellated cells even though it is described as ciliary. The digestive tract is curved and the stomach is sacciform. Coelomic sacs are three in number. An opical flagellated ectodermal thickening termed as sensory plate is also found (Fig. 4-87).

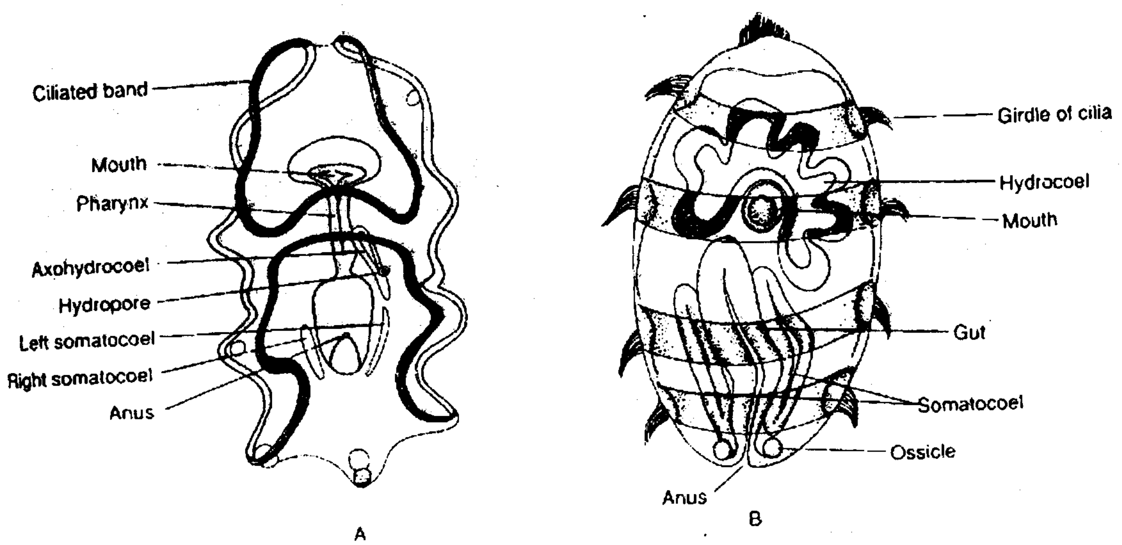

Fig. 4-87. A, An auricularial larva (oral view). B, The doliolaria larva of *Leptosynapta inhaerens;*

4.5.6.B. DOLIOLARIA :

The auricularia soon transforms into a Doliolaria. It is barrel-shaped. The original ciliated band has become broken up into 3 to 5 ciliary girdles. Gradual metamorphosis occurs during the latter part of planktonic existence. A young sea cucumber is resulted after metamorphosis. During metamorphosis, the tentacles appear first and then the podia. At this stage, the metamorphosing form is called a Pentactula larva. Eventually, the young sea cucumber settles to the bottom and assumes the adult mode of existence.

In some forms like *Cucumaria planti* and *C. quin-quesemita* the auricularia larva is absent while in some others like *C. saxicola* and *C. frondosa*, both auricularia and doliolaria are absent. In *Holothuria floridana* the embryo directly develops into adult. There are many species of holothuroids (Dendrochirotida) that possess a nonfeeding barrel-shaped Vitellaria (Fig. 4-88). This type of larva which is found in crinoids and a few ophiuroids possesses ciliated bands but no arms and is probably a specialized condition.

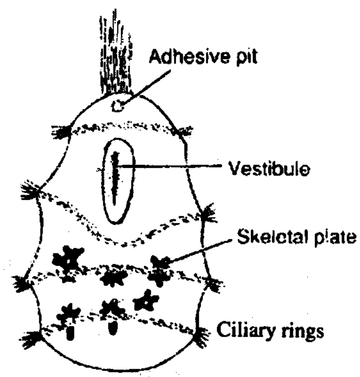

Fig. 4-88. Vitellaria larva

4.5.7. CLASS CRINOIDEA :

4.5.7.A. VITELLARIA LARVA :

It is a characteristic larval form of crinoids. Development through the early gastrula stage is essentially like that in asteroids and holothuroids. During the formation of the coelomic sacs the embryo elongates, and development proceeds toward a free-swimming larval stage. The crinoid larva, a non-feeding vitellaria, is essentially like the vitellaria of holothuroids. It is somewhat barrel-shaped with an anterior apical tuft and 4 to 5 transverse, ciliated bands around the body of the larva (Fig. 4-89 and 4-90). A glandular ecotodermal depression called the adhesive pit develops along the mid ventral line near the apical tuft. The stomodaeum appears as an elongated mid-ventral depression in between the first and second bands. The coelomic and enteric sacs are concentrated in a small area in the posterior part of the larva. The remaining larger part of the larva is filled with mesenchyme.

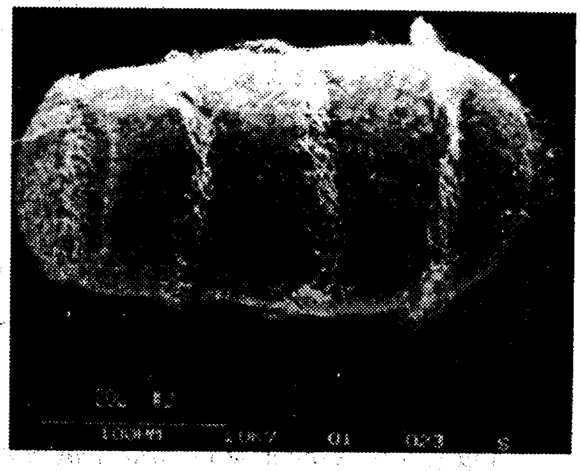

Fig. 4-89. Doliolaria larva of the feather star. *Florometra serratissima.*

4.5.7.B. PENTACRINOID LARVA :

After a free swimming existence, the vitellaria settles to the bottom and attaches by its adhesive pit. There ensues an extended metamorphosis resulting in the formation of a minute, stalked, sessile crinoid. The larva at this stage is called a cystidean or pentacrinoid which resembles a minute sea lily. The pentacrinoid of *Antedon* is about 3 mm long with developed arms. It takes 6 weeks to attain this complete form and it remains in this stage for several months. Cirri develop in the latter stages and the crown breaks away from the stalk and leads a free-swimming adult life.

4.5.8. HYPOTHETICAL DIPLEURULA – TYPE ANCESTRAL LARVA :

The above study of larval forms denotes that they resemble each other to some extent forming an evidence of their origin from a common ancestor, which might be a free-swimming, coelomate with a bilateral symmetry. (Fig.4-90)

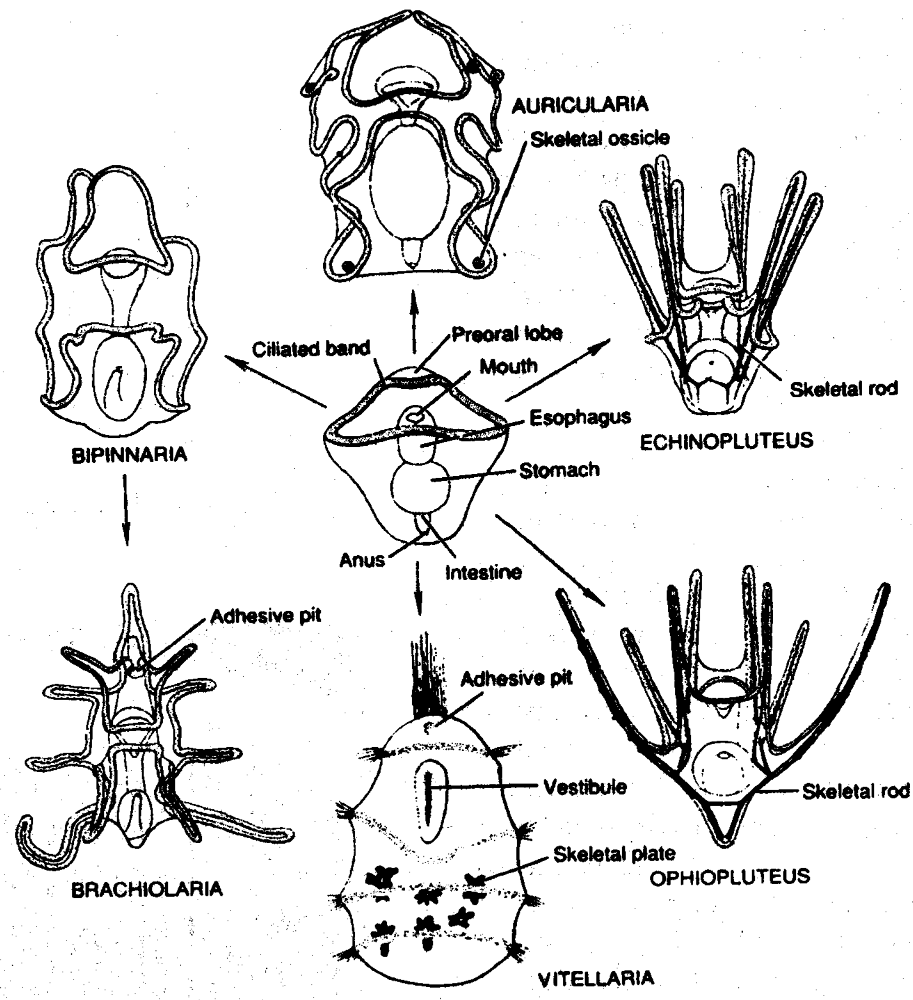

Fig. 4-90. Comparison of different types of echinoderm larvae showing relationship to a hypothetical dipleurula-type ancestral larva.

Dipleurula larva is considered as the hypothetical form because it is universally present. Various changes come across in all echinoderm larvae are due to differential position of ciliated bands and arms. The dipleurula concept was put forward by Bather in 1900.

The dipleurula larva has an oval body with a flat ventral side. The digestive system is a straight tube. Mouth is on ventral side surrounded by circum oral ciliated band.

Pentactula larva is regarded as the next stage in the evolution of dipleurula larva. This theory was adopted by Semon (1888), Barry (1895) and Hyman (1955). This larva has five tentacles around the mouth.

4.5.9. SUMMARY :

1. Most of the echinoderms include larval forms in their life histories. Sexes are separate. Mostly oviparous, in which fertilization is external.

2. Cleavage is total, holoblastic, radial and indeterminate.

3. The blastopore remains as larval anus Mouth forms as a secondary opening at the opposite end of the blastopore – a characteristic feature of deuterostomes.

4. All the larval forms are bilaterally symmetrical and free-swimming. They possess locomotory ciliary bands and arms on the body. After sometime larva undergoes metamorphosis and becomes a radially symmetrical adult.

5. A variety of larval forms occur in this phylum, characteristic of each class. The nature and position of the arms or lack of them, distinguishes the larvae of the different echinoderm class.

6. Bipinnaria larva is the characteristic larval form of the class Asteroidea. The larva possesses a pre-oral and a post-oral or pre-anal loops or ciliated bands bordering the 6 arms, three on each side of the body. The ciliated bands function in both locomotion and feeding and the arms increase the surface area of the bands.

7. Bipinnaria changes into Brachiolaria larva by developing three additional arms, called brachiolar arms, which have adhesive cells at the tip and adhesive suckers at the base. These constitute an attachment device, with which the larva attaches to the substratum and metamosphoses into adult.

8. Echinopluteus is the larval form of the class Echinoidea. The larva has 4 to 6 pairs of arms supported by skeletal rods. After a long period of swimming life, the larva settles to the bottom and metamorphoses into adult.

9. Ophiopluteus is the larval form of the class Ophiuroidea. It resembles echinopluteus but possesses only 4 pairs of arms. Metamorphosis takes place while the larva is still free-swimming. The tiny brittle star sinks to the bottom to lead an adult life.

10. Auricularia is the first larval stage of the class Holothuroidea. The characteristic feature of this larva is the presence of ciliated bands which curves around the mouth as preoral loop and around the anus as anal loop.

11. The auricularia changes into a Doliolaria larva. It is barrel-shaped and the original continuous ciliated band is broken into 3 to 5 ciliated girdles. Gradual metamorphosis occurs during the latter part of planktonic existence. The metamorphosing animal is called a pentactula larva. Eventually, the young sea cucumber settles to the bottom and leads the adult mode of life. Many species of holothuroids also possess a non-feeding barrel shaped vitellaria larva.

12. Vitellaria larva is the characteristic larval form of the class crinoidea. This larva is essentially like the vitellaria of holothuroids. It is barrel-shaped with an apical tuft and 4 to 5 transverse ciliated bands. An adhesive pit, and a stomodaeum between first and second ciliated bands are also present. After a free swimming existence, it settles to the bottom and metamorphoses into a minute, stalked, sessile crinoid called pentacrinoid larva. After several months, cirri develop and crown breaks away from the stalk and leads a free swimming adult life.

13. Dipleurula larva is considered as the hypothetical ancestral larva. Various changes come across in all echinoderm larvae are due to differential position of ciliated bands and arms. Pentacula larva is regarded as the next stage in the evolution of dipleurula larva.

4.5.10. KEY TERMINOLOGY :

Apical: At the top or apex.

Auricularia: Primary larval stage in holothuroid development.

Bipinnaria: Primary free-swimming larval stage of asteroids.

Cirri: Small, movable projections, usually tentacle-like and curved, from body surface.

Deuterostomes: Animals in which blastopore forms anus, second embryonic opening forms mouth opposite to anus.

Dipleurula: Developmental stage of echinoderms and hemichordates; hypothetical ancestor of most deuterostomes.

Direct development: Lacking a larval stage in the course of development. On hatching, the young have the adult body form.

Doliolaria: Barrel-shaped larval stage, following the auricularia, of holothuroids.

Echinopluteus: Planktonic larva of echinoid echinoderms that bears six pairs of long larval arms.

Holoblastic: Cleavage in which an entire egg cell divides. Also referred to as complete cleavage.

Homolecithal egg: Egg in which the yolk is uniformly distributed (Isolecithal).

Indeterminate cleavage: Fate of the blastomeres is fixed relatively late in development. Regulative development.

Indirect development: Having a larval stage in the course of development.

Larva: An immature, free-living stage in the life cycle of various animals, which reach the adult form by undergoing metamorphosis.

Metamorphosis : Marked structural change or transformation during development, Transformation from a larva into an adult.

Ophiopluteus: Planktotrophic larva of many species of ophiuroids.

Oviparous: Egg laying; producing eggs that hatch outside the body of the mother.

Pentactula: Metamorphosing stage of holothuroid development that bears five primary tentacles.

Pluteus: Echinoid and ophiuroid larva.

Planktotrophic larva: A larva that feeds on other planktonic organisms.

Radial cleavage: Cleavage in which successive tiers of equal-sized blastomeres lie directly above and below one another; cleavage is indeterminate.

Viviparous: Giving birth to living young that develop from egg within the body of the mother.

4.5.11. SELF ASSESSMENT QUESTIONS :

1. Give an account of larval forms of echinoderms.
2. Write notes on :
   a) Larvae of asteroids
   b) Echinopluteus larva
   c) Ophiopluteus larvae
   d) Larvae of Holothuroids

4.5.12. REFERENCE BOOKS :

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Dr. P. Padmavathi

UNIT - 5

5.1 GENERAL ORGANIZATION OF PHYLUM ROTIFERA

5.1.1 OBJECTIVES

The purpose of this lesson is to:

- describe Rotifers
- exemplify rotifers with suitable diagrams
- understand the general characters

5.1.2 INTRODUCTION

The Phylum Rotifera includes the microscopic organisms known as rotifers. Along with protozoans and small crustaceans, they dominate the freshwater zooplankton. Though some marine species exist, majority of them live in fresh water. They are the important nutrient material in aquatic systems. Most rotifers measure 0.1 to 1.0 m.m in length; they are little longer than ciliated protozoans. Most of the rotifers are solitary, free swimming (Fig. 5-1) or crawling forms. Also, there are sessile (Fig. 5-2) as well as some colonial forms. The body of the rotifer is usually transparent, although some rotifers appear green, orange, red or brown. They appear in different colors because of the coloration of the digestive tract.

5.1.3 EXTERNAL STRUCTURE

The body of the rotifer is elongated or saccular in shape. In many species, the body is divided into a short anterior region, a large trunk and a terminal foot (Fig. 5–4 A, B). The trunk composes the major part of the body. The body of rotifer is distinctly ringed, ornamented or sculptured in many ways.

The short anterior region or head is broad or narrow. The anterior region bears a ciliated organ called the crown or corona. The ciliated corona is characteristic of all the members of the phylum. The corona is used as a feeding and swimming organ. Let us know the structure of corona. The primitive corona is believed to have a large ciliated area; it is ventral in position. This ventral, ciliated area is called the buccal field (Fig. 5–5). The buccal field of cilia surrounds mouth. Some zoologists believe that rotifers evolved from a small, ciliated, creeping ancestor. It is true that the buccal field may represent a vestige of the ancestral ventral ciliation. Corona shows circum apical band of cilia, which extend from the buccal field. The circum apical band of cilia lies around the anterior margin of the head; this band of cilia forms a crown like ring. Inside this ciliated ring, there is an area in which cilia are absent. This non-ciliated area is called the apical field. It is believed that from this basic plan, different types of coronas are evolved.

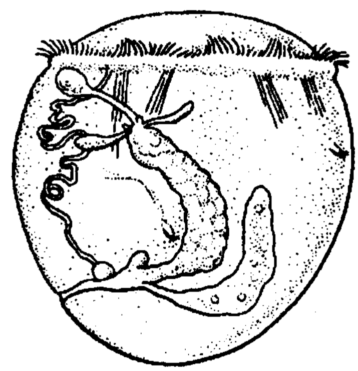

Fig. 5-1. Planktonic rotifer - the voluminous pseudocoel of *Trochosphaera solstitialis*

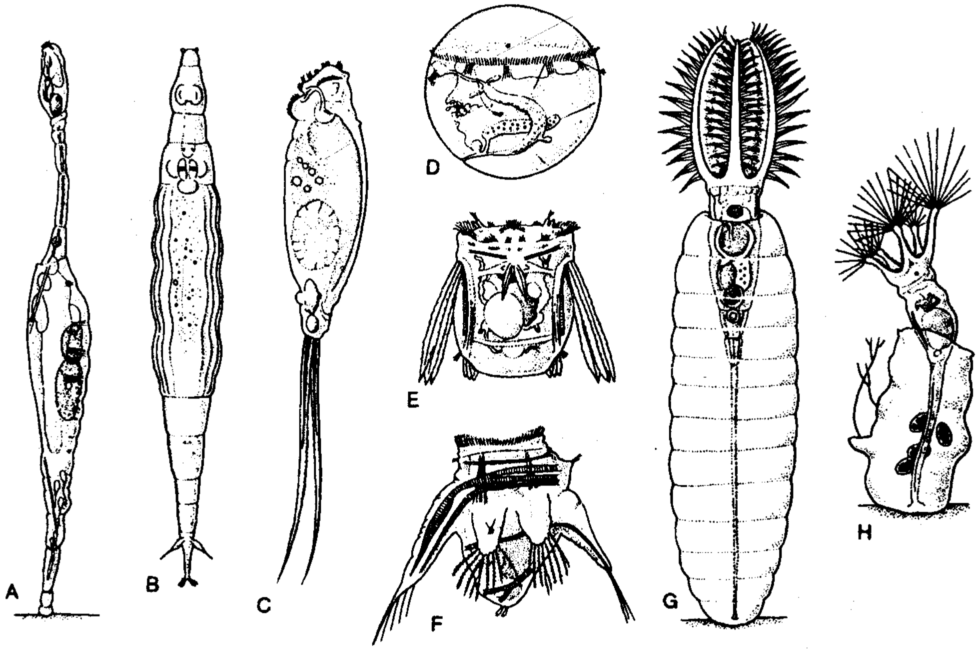

Fig. 5-2 . **A,** The seisonidean rotifer, *Seison.* **B,** The bdelloid rotifer, *Dissotrocha.* **C–H,** Monogonont rotifers: The rotifer *Monommata* **(C),** planktonic rotifers *Trochosphaera* **(D),** *Polyarthra* **(E),** *Hexarthra* **(F)**; sessile rotifers *Stephanoceros* **(G)** and *Collotheca* **(H).**

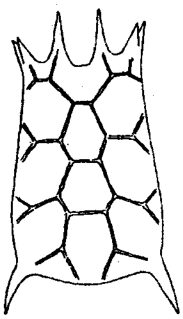

Fig. 5-3, Lorica of *Keratella quadrata.*

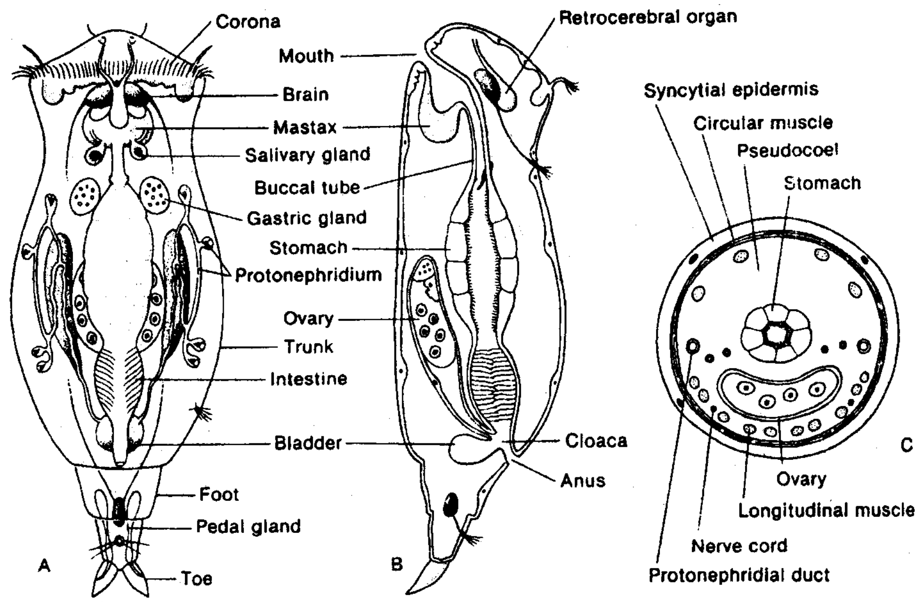

Fig. 5-4. Rotifer anatomy; **A,** Dorsal view. **B,** lateral view. **C,** Cross section.

Different types of coronas characterize different groups of rotifers. In the modified coronas, various parts of buccal field and the circum apical band have either been lost or more highly developed. In certain types of coronas, certain cilia have become modified to form cirri, membranelles or bristles.

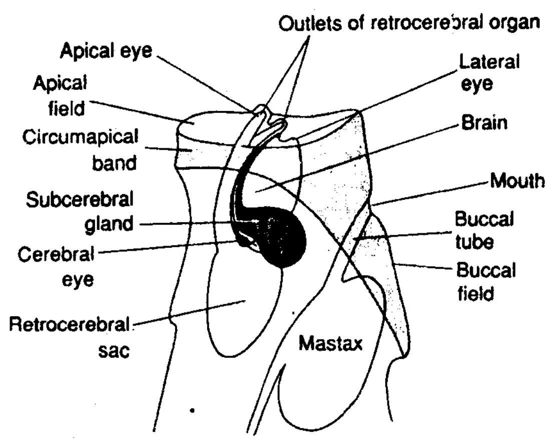

Fig. 5-5. Primitive rotifer corona (lateral view)

Let us look into the different types of coronas. For example, in *Collotheca* and related species the buccal field is modified into a funnel. Mouth lies at the bottom of the funnel. Cilia are reduced (Fig. 5– 2 H). The edges of the buccal field have become expanded to form a number of lobes. These lobes possess long bristles or setae. These long bristles or setae may be arranged in bundles or tufts. In *Polyathra* and related forms (Fig. 5– 2E) the corona is formed entirely from the circum apical band. It shows two close circlets of modified cilia – an anterior band called the trochus and a posterior band called the cingulum. The trochus passes above the mouth and the cingulum passes below the mouth.

In bdelloid rotifers, these two ciliated bands are present. But the anterior circlet of cilia, the trochus, is divided into two discs called trochal discs (Fig. 5– 6A). These trochal discs are raised on a pedestal. The posterior circlet passes below the mouth. In living forms, when the membranelles of the trochal discs beat they appear like two rotating wheels at the anterior end of the body. It is because of this type of corona, the name rotifer or wheel animalcule is derived. When the trochal discs are not in use, the trochal discs can be retracted (Fig. 5-6B). The trochal discs are used in swimming and feeding.

In bdelloid and notommatid rotifers the head carries a middorsal projetion called the rostrum. Rostrum bears cilia and sensory bristles at its tip. This little projection is adhesive in nature.

The head in rotifers carries eyes, one or two short antennae and the mucus secreting retrocerebral organ. The number and location of eyes vary in different groups of rotifers.

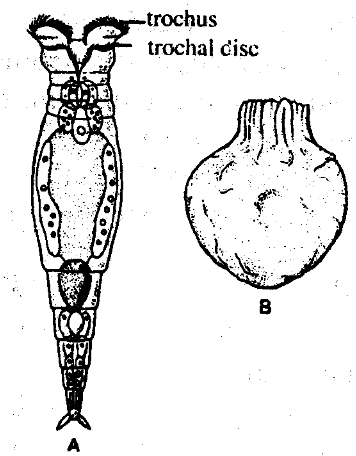

Fig. 5-6 A, *Philodina roseola* (ventral view) B, *Habrotrocha rosa.*

The trunk composes the major part of the body. The trunk is covered by a protective covering called the lorica (Fig. 5-3). The lorica may show distinct plate or ring like sections or articulation with appendages or ornamentation with ridges or spines. The spines may be long and movable in some rotifers. In *Polyarhra* (Fig. 5-2E) the appendages are modified into long, flat, skipping blades. These skipping blades are present in clusters on either side of the body.

The terminal portion of the body is foot; it is considerably narrower than the trunk (Fig. 5-4). In many bdelloids the epidermis is frequently ringed or sculptured in many ways. One to four projections called toes are present at the end of the foot. The foot contains pedal glands that open by ducts at the tips of toes or other parts of foot. The foot serves as an attachment organ in both the crawling and sessile rotifers. The pedal glands secrete an adhesive substance, which can be used for temporary attachment.

In some rotifers such as *Philodina* and *Rotatoria*, the pedal glands open onto the ends of two long and diverging conical spurs that are present at the end of the foot. The spurs function like toes.

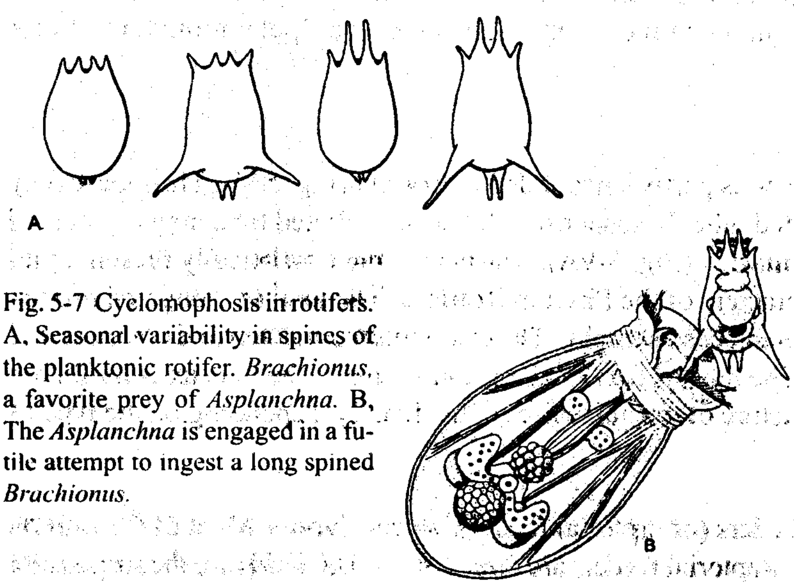

Fig. 5-7 Cyclomophosis in rotifers. A, Seasonal variability in spines of the planktonic rotifer. *Brachionus*, a favorite prey of *Asplanchna*. B, The *Asplanchna* is engaged in a futile attempt to ingest a long spined *Brachionus*.

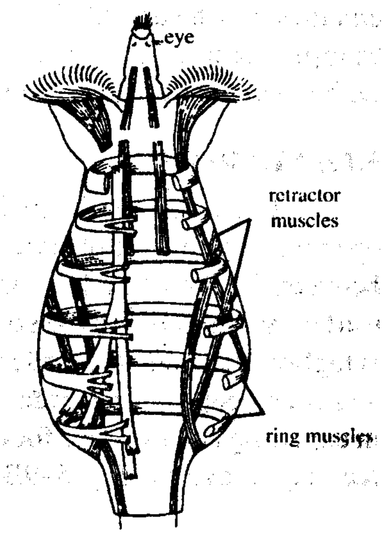

Fig. 5-8 Musculature of *Rotaria* in ventral view.

The foot is reduced or absent in planktonic rotifers. Many pelagic species exhibit seasonal changes in their body shape or proportions (Fig. 5–7A). This phenomenon is known as cyclomorphhosis. For example, some rotifers during one season of the year have spines which are longer or shorter than those developed by their descendents during another season. In *Brachionus calyciflorus*, the length of spines is induced by starvation and by some substance produced by the predatory rotifer *Asplanchna*. The elongated spines in *Brachoinus* protect the animal from the predators (Fig. 5–7B).

5.1.4 BODY WALL AND PSEUDOCOEL

Cuticle is absent in rotifers. The epidermis is supported by protein fibers. The epidermis is thin and syncytial and always possesses a specific number of nuclei . The epidermal surface also possesses scattered secretory pores. Beneath the epidermis are the striated body muscles. Some of the cross striated muscles are circular (ring muscles) and some are longitudinal (retractor muscles) (Fig. 5-8). The body wall muscles are not organized into definite circular and longitudinal sheaths (Fig. 5–4C).

The space between the body wall and gut and other internal organs is filled with a fluid known as pseudocoel.

5.1.5 LOCOMOTION

Rotifers move by creeping, swimming or skipping. Some of the benthic species never swim, but many of the benthic rotifers are able to creep and swim. In creepers, the foot serves as an adhesive organ. The secretion of pedal glands helps to adhere to the substrata. During the creeping movement, the corona is retracted and the foot adheres to the substratum. The body is extended and then it detaches the foot to move forward and again grip the substratum.

Swimmers are able to move for short distances by extending corona and retracting the foot. Few species such as *Polyarthra* and *Hexarthra* skip forward using skipping blades or appendages. Pelagic rotifers show continuous swimming movements. They may possess long spines and the foot and toes may be absent. Few colonial, pelagic rotifers such as *Conochilus*, whose members look like trumpets, spines are found radiating from a common center. The colony propels through the water with the help of combined ciliary action.

5.1.6 NUTRITION

The mouth in rotifers is ventral and is partly surrounded by corona (Fig. 5–4). The mouth may open directly into the pharynx or a ciliated tube. In suspension feeders, a ciliated tube may be situated between the mouth and the pharynx or mastax (Fig. 5-9A). Mastax is characteristically present in all rotifers and is one of the distinctive characters of the Phylum Rotifera. The oval or elongated mastax is highly muscular. It is made up of seven pieces or trophi. These are interconnected and composed of an acid mucopolysaccharide material. The mastax serves as a grinding mill. The mastax is used both in capturing and grinding food. The structure of mastax varies considerably, depending on the type of feeding behaviour (Fig. 5–9B, C).

Rotifers are either suspension feeders (or raptorial feeders) or carnivores. Most of the rotifers are either suspension or raptorial feeders. Raptorial feeders are omnivorous. Bdelloids are the suspension

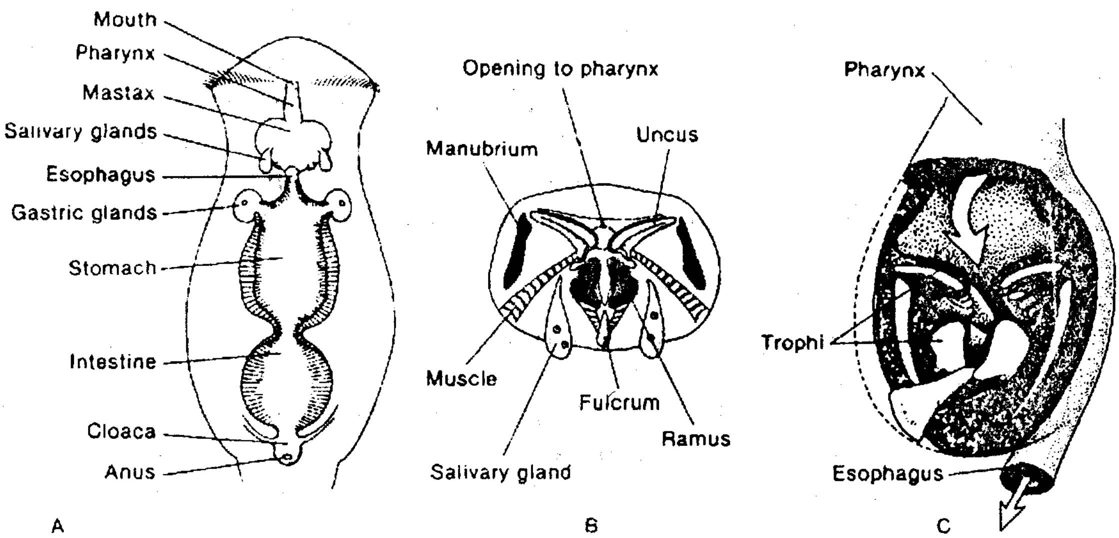

Fig. 5-9 A, Anatomy of the digestive system in dorsal view. B, Enlargement of mastax in A. C, Three - dimensional view of mastax and trophi.

feeders. They feed on minute organic particles, which are brought to the mouth in the water current by the coronal cilia. In these forms, the pre oral cilia produce the water current, which is directed backward, and function in feeding ad swimming. A food groove is present between pre oral cilia and post oral cilia. The food particles are conveyed into this food groove due to ciliary action. From the food groove food is carried to mouth.

Depending on the type of feeding, mastax is divided into 2 types as malleorammate and incadate (forcipate) type (Fig. 5-10). Suspension feeders may possess rammate type of mastax adapted for grinding the food. The mastax has 2 extremely large, plate like and ridged pieces. These two pieces oppose each other. The ridges in these plates form a surface for grinding. In suspension feeders, the mastax probably acts as a pump, sucking in particles that have collected at the mouth. In *Brachionus,* the food intake can be regulated by the ciliary beat of buccal field.

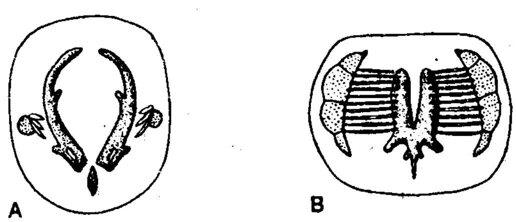

Fig. 5-10, Incudate trophi of *Asplanchna* used for seizing prey. B, Malleoramate trophi of *Filinia* used for grinding.

The carnivorous species may possess forcipate type of mastax adapted to capture the prey by trapping or by suction. Carnivorous forms feed upon protozoa, rotifers and other small metazoan animals. The forceps-like trophi are used to hold the prey. The trophi may also be used to manipulate the prey in the mastax cavity. After digestion of food, the undigested food is thrown out of the body.

In rotifers such as *Collotheca* and other forms, which possess funnel like buccal fields, the capturing and/or the trapping, mechanism of prey is similar to that of insectivorous flower, Venus' flower trap. When small protozoa accidentally fall into the funnel, they may be sucked into the foregut by mastax. In carnivorous forms the mastax is very much reduced and serves as a pump and is called a proventriculus.

In some bdelloid rotifers (notommatids) such as *Henoceros*, the trophi of mastax can be extended out of the mouth. The cell contents of filamentous algae on which they subsist can be sucked by the trophi.

The digestive system consists of mouth leading to pharynx, oesophagus, stomach, intestine and cloaca or anus. Most of the rotifers possess enzymatic glandular masses called salivary glands in the mastax walls. These salivary glands open through ducts just in front of the mastax proper. The pharynx is connected to the stomach by means of a tubular oesophagus. A pair of enzyme-secreting gastric glands is present between the oesophagus and stomach (Fig. 5-9A). Each of the gastric glands opens by a pore into each side of the digestive tract. The stomach is a large sac or tube, which passes into a short intestine. The stomach is the chief digestive and absorptive organ. The intestine is cellular and ciliated in monogonant rotifers and is syncytial with or without lumen in digonant or bdelloid rotifers.

In female rotifers, the excretory organs and the oviduct open into the terminal end of intestine; thus, it functions as a cloaca. The anus is present near the posterior end of the trunk opening on the dorsal surface.

In the large predatory species such as *Aspalancha*, the intestine and anus are absent. The anus lies anteriorly for the egestion of wastes in some sessile forms such as *Collotheca* and *Stephanoceros*.

Also, the Phylum Rotifera consists of epizoic and parasitic rotifers. The foot or mastax is modified as an attachment organ and the corona is reduced in parasitic rotifers. Small crustaceans act as hosts for parasitic rotifers.

5.1.7 EXCRETION

Protonephridia that serve as excretory organs are located in the pseudocoel. Typically two-protonephridia lie on each side of the body. Each protonephridium bears few to many terminal cells, which open into a collecting tubule. There are two protonephridial tubules that open into a bladder (Fig. 5-4A), which in turn opens into the cloaca.

The wastes from the bladder eject out through anus. The contractions of anus may be one to four for minute. The protonephridia function as both osmoregulatory and ionic regulatory organs.

Terrestrial rotifers are present in association with soil, leaf mold, mosses and lichens. When soil and other surfaces are covered with water films, the terrestrial forms swim on the water films and excreta only for short periods. In the absence of water, terrestrial rotifers can remain dormant for three to four years without undergoing cyst formation.

5.1.8 NERVOUS SYSTEM

The brain having dorsal ganglionic mass lies over the mastax. From the brain nerves are extended to anterior sense organs and to other parts of the body (Fig. 5- 11).

5.1.9 SENSE ORGANS

The sense organs consist of one or two cerebral eyes or a pair of anterior eyes or both dorsal antennae and numerous sensory bristles in various parts of the ciliated crown (Fig. 5-11). The eyes are simple pigment-cup ocelli consisting of one or two photoreceptor cells and an accessory, red-pigmented cell.

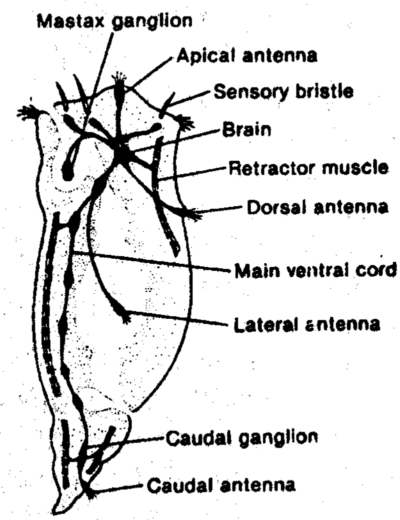

Fig. 5-11 Nervous system and sensory structures (lateral view).

5.1.10 REPRODUCTION

Rotifers are dioecious. Distinct males and females are present. Males are always smaller than females (except in Seisonidea).

In females, one or two ovaries are located anteriorly in the pseudocoel (Fig. 5-4 A, B). Each ovary is syncytial, composed of a germinal region and a yolk producing vitellarium. This type of syncytial ovary is called as germovitellarium. Oocyte nuclei are located in the germinal region. When the oocyte nucleus is surrounded by yolk, it pinches off from the syncytium as a mature egg. The mature egg passes into the cloaca or to a genital pore (if the intestine is absent) through the oviduct.

In males, a single sac like testis and a ciliated sperm duct (Fig. 5-12) are present. Males are short lived, gut is vestigial or absent and the crown is reduced. Due to the absence of gut, the sperm duct runs directly to a gonopore. The gonopore in males is homologous to the anus in female and occupies the same position. The sperm duct is associated with two or more glandular masses called accessory (prostate) glands. The terminal end of sperm duct is usually modified to form a copulatory organ. Sperms are monoflagellate.

In rotifers copulation occurs by hypodermic impregnation or through cloacal insertation.

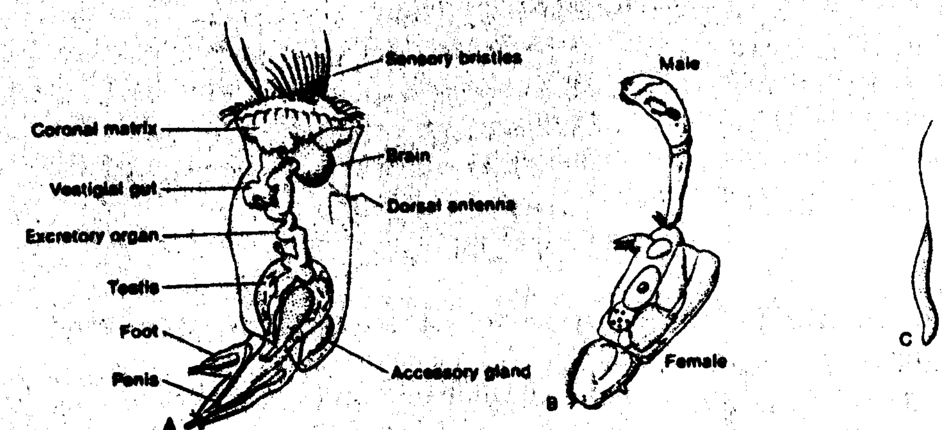

Fig. 5-12 A, Anatomy of dwarf male of *Brachionus calyciflorus* in lateral view. B, Cloacal copulation in *Cephalodella catellina*. C, Typical sperm with leading flagellum (top).

A female rotifer during its lifetime may produce 8 – 20 germinal nuclei; there may be a corresponding limit to the production of eggs. Each egg is enveloped by a number of egg membranes and a eggshell. Both the shell and egg membranes are secreted by the egg itself. The eggs are found floating in the water, attached to leaf mold, mosses etc or to the body of the female. In some rotifers such as *Asplancha* and *Rotaria*, brooding of eggs occur inside the body. Basing on the number of ovaries they possess, rotifers are divided into two types as monogonants (with single ovary) and digonants (with 2 ovaries). Monogonants lay two types of eggs. One type, called an amictic egg, is thin shelled and can not be fertilized. The unfertilized egg (amictic egg) develops by parthenogenesis into amictic female. These eggs are diploid as the typical meiosis does not occur during maturation. The second type is a mictic egg. This is also thin shelled but haploid in nature. Typical meiosis occurs during the maturation of haploid egg. If these haploid eggs are not fertilized it develops parthenogenetically into a haploid male. If the haploid, mictic eggs are fertilized, a thick heavy resistant shell is produced around each of the eggs. The fertilized mictic eggs are called dormant or resting eggs. Mictic and amictic eggs hatch in several days. Whereas dormant eggs are able to withstand the unfavorable conditions and may not hatch for several days or even years. Dormant eggs develop into females. A single female may produce amictic or mictic eggs but not produce both type of eggs. The type of egg production is determined at the developmental period of oocyte.

Majority of rotifers develop by parthenogenesis. Development by parthenogenesis is one of the characteristic features of rotifers. In parthenogenetic species, males are present in the population only at certain period. In bdelloids, there are no males. Development is by females alone through parthenogenesis and the eggs develop into females only (Fig. 5-13).

Development by the process of parthenogenesis and the production of mictic and amictic eggs are the adoptive features of fresh water rotifers, which live in ponds and streams. Rotifers exhibit a cyclic reproductive pattern. During the favorable conditions (after the rainy season) dormant eggs (which have pass Winter) develop into amictic females. These females reproduce by parthenogenesis, which includes a number of generations. Each generation of parthenogenetic female may live for one or two weeks. Some species are able to produce an increased (a double number) population in a span of two days. When such population reaches a maximum number, (in the late Spring or early Summer) haploid males appear because of the production of mictic eggs. Dormant eggs can be dispersed by birds or spread by dust when the ponds dry up. In the permanent ponds Rotifers develop and exist through a number of reproductive cycles and parthenogenetic generations throughout the whole year. The production of different types of eggs and the occurrence of parthenogenesis depend on the kind and amount of food available. The photoperiod and temperature also influence the egg production and parthenogenesis. The role of these different factors varies from species to species.

5.1.11 DEVELOPMENT

In Rotifers, cleavage is a sort of spiral cleavage. It is a modified type of typical spiral cleavage. In the early development of the egg, the nuclei undergo division. In the free moving Rotifers, development is indirect and there is no larval stage in their life cycle. When the females hatch they have all the adult characters; they require a growth period of few days to reach sexual maturity. For eg: an adult of *Philodina voseola* (a common bdelloid) is twenty eight times heavier than a newly hatched individual. A single female may lay about forty-five eggs and the development of the egg may be completed within four days. When the males hatch they do not require any growth period. The smaller males are sexually matured when they leave the egg. The sessile rotifers develop by producing free swimming "larvae". These larvae are similar in structure to free swimming adult forms. The free swimming larvae swim for short period, settle down to bottom, attach to any substrata and assume the life as parent adult.

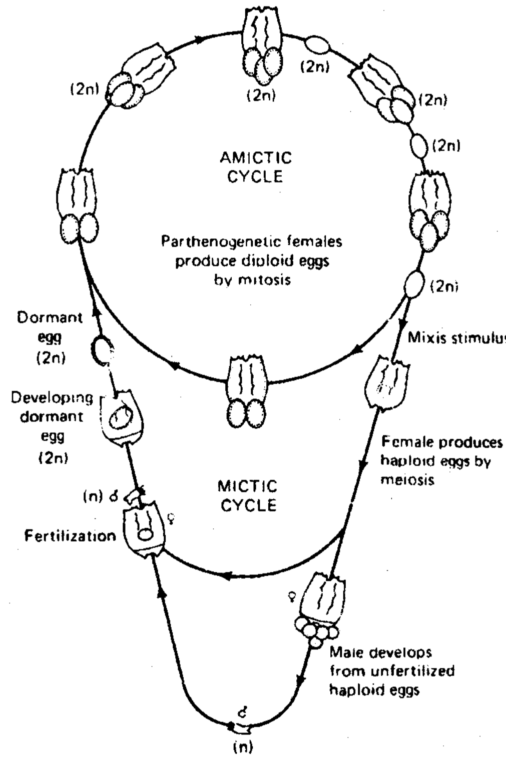

Fig. 5-13. Life cycle of a monogonont rotifer.

5.1.12 SUMMARY

Rotifers dominate the fresh water zoo-plankton and are the important nutrients for other aquaculture organisms/animals.

Rotifers are found in marine water and fresh water. They also lead their life as terrestrial forms.

These are microscopic reaching the length of 0.1 to 1.0 m.m.

Rotifers are solitary, free swimming or crawling forms. This phylum also consists of sessile as well as some colonial species.

The body of a rotifer is usually transparent.

Some rotifers exhibit green, orange, red or brown colors because of the coloration of the digestive tract.

The elongated or saccular body is somewhat cylindrical. The body is divided into a short anterior region and a large trunk, which composes the major part of the body.

A ciliated organ called crown or corona is present at the anterior end. It is the characteristic feature of the rotifer. The corona is used in swimming and food collection. The primitive corona consists of a ventral ciliated area called the buccal field.

Mouth is surrounded by the buccal field.

From the buccal field, cilia extend around the anterior margin of the head forming a crown like ring called the circum apical band. In this circum apical band of cilia, there is a region devoid of cilia called the apical field.

Different types of coronas in different groups of rotifers have evolved from this primitive form of corona.

In some coronas cilia have become modified into stiff cirri or bristles or skipping blades. For example, in *Colotheca,* the buccal field is modified into a funnel. Mouth lies at the bottom of the funnel. The cilia are reduced.

In *Polyathra* and related forms the corona is formed from circum apical band alone, which has two circlets of cilia. An anterior band called the trochus passes above the mouth, and the posterior band called the cingulum passes below the mouth.

The epidermis in the trunk is stiffened into a distinct structure called lorica.

The posterior most part of the body, the foot is comparatively narrower than the trunk.

The terminal end of the foot bears one to four projections called toes.

The foot also contains pedal glands, which open at the tip of the toes. The secretions of the pedal glands help in attachment.

Most of the pelagic rotifers vary in their body shape or proportion in various seasons of the year. This phenomenon is known as cyclomorphosis.

In rotifers, cuticle is absent. Instead, the epidermis is supported by protein fibers.

The epidermis is thin and syncytical and always possesses a constant number of nuclei. Beneath the epidermis are present the unorganized circular (ring muscles) and longitudinal (retractor muscles) muscles.

Beneath the body wall and surrounding the internal organs lies a more or less spacious fluid filled pseudocoel.

Rotifers exhibit creeping or swimming movements.

Sessile forms attach to vegetation and pelagic form swims continuously.

The ventral mouth is surrounded by some part of the corona.

In case of suspension feeders the mouth may open into ciliated buccal tube. The buccal tube opens into pharynx or mastax. In carnivorous forms, the mouth may open directly into the pharynx. The pharynx or mastax is the characteristic feature of all rotifers.

The mastax of suspension feeders is adopted for grinding.

In carnivorous forms the mastax is useful for breaking the prey on which they depend upon.

Enzymatic glandular masses called salivary glands are present in the wall of the mastax.

The pharynx is connected to the stomach by a tubular oesophagus.

A pair of enzyme secreting gastric glands lies at the junction of oesophagus and stomach.

The stomach receives the gastric gland secretions.

The large sac like stomach is digestive and absorptive in function and passes into a short intestine.

In females, the excretory organs and the oviduct open into the extreme end of the intestine, which acts as a cloaca. The anal opening lies near the posterior of the trunk.

In the large predatory species of *Asplancha*, both the intestine and anus are absent.

In the amniotelic rotifers excretion is by a pair of protonephridia lying on either side of the body, in the pseudocoel.

The protonephridial tubules open into the cloaca and the wastes will be eliminated from the anus by the anal contractions. The protonephridia in rotifers function in osmoregulation and ionic regulation.

The brain is situated over the mastax. Nerves varying in number extend from the brain to the anterior sense organs (a pair of eyes and numerous sensory bristles in the crown) and to the other parts of the body.

Rotifers are dioecious forms. Males are always smaller than females. In females, one or two syncytial ovaries called germovitellariae are present in the pseudocoel.

In the short lived males, gut is vestigial or absent. A sac like testis possesses a ciliated sperm duct. Two or more accessory glands (prostate) are associated with the sperm duct.

Sperms are monoflagellate.

Copulation is by hypodermic impregnation or by insertion into the cloaca.

In the monogonont rotifers, amicitic eggs and mictic eggs are produced. The diploid amictic eggs develop by parthenogenesis into amictic diploid females.

The haploid mictic eggs when unfertilized develop into haploid males. If they are fertilized, they secrete a thick, resistant shell. Such fertilized eggs are called resting or dormant eggs.

Resting eggs are capable of withstanding unfavorable conditions and may not hatch for several months or even years.

Dormant eggs result into diploid females.

Cleavage in rotifers is a modified form of the typical spiral cleavage.

In free moving species, larval development is absent. When the females hatch, they possess all the adult features and become sexually mature within a growth period of few days. The smaller males are sexually mature at the time of hatching.

In case of sessile rotifers, the hatched free swimming larvae are structurally similar to the free swimming forms. They swim for some time, settle down, attach and lead their life as sessile adults.

5.1.13 KEY TERMINOLOGY

Amictic egg: It is a type of egg, which is thin, shelled, cannot be fertilized and develops by parthenogenesis into amictic female

Apical field: An area, which is devoid of cilia inside the circumapical band of the corona of rotifers.

Avicularium: Jawed heterozooid found in many cheilostome bryozoans.

Bdelloid rotifers: Digonant female rotifers. In these population, males are absent.

Buccal field: In some rotifers, this is a ventral ciliated area, which lies in the crown surrounding the mouth.

Cingulum: The posterior circlet of cilia of the divided corona.

Circum apical band: A crown like ring of cilia that extends around the anterior margin of the corona or the head of rotifers.

Corona: A ciliated organ, which lies at the anterior end of rotifers. It is used in swimming and food collection.

Crown: The ciliated organ of the head end of the rotifers employed in feeding and swimming.

Cyclomorphosis: The phenomenon of changing the shape and proportions of the rotifer body.

Desiccation: Drying out

Digonant: Organism with two ovaries

Dormant egg: The fertilized egg, encircled by a thick resistant shell is able to withstand unfavorable conditions and desiccation. It may not hatch for several months or even years.

Forcipate mastax: Mastax made up of forceps like trophi (pieces) characteristic of carnivorous rotifers.

Gonopore: External opening of the male or female reproductive system.

Heterozooid: Reduced or modified zooids that have functions other than feeding.

Lorica: Skeleton which is girdle like.

Mastax: Pharynx of a rotifer

Mictic egg: A type of thin shelled, unfertilized haploid egg and develops into a haploid male.

Monogonant: Organism with a single ovary

Osmoregulation: The maintenance of internal body fluids at varied osmotic pressure in different external
aqueous environments; the salt concentration of internal body fluids is maintained usually at higher level from that of external environment.

Parthenogenesis: The development of unfertilized egg without the act of fertilization.

Pelagic: Floating or swimming forms above the water surface.

Pseudocoel: Fluid filled cavity, which occupies the connective tissue compartment.

Spiral cleavage: Type of cleavage pattern in which the cleavage spindles are oriented oblique to the polar axis of the egg.

Suspension feeders: Feeding on plankton and detritus suspended in water.
Trochus: The anterior circlet of cilia of the crown, which passes above the mouth.

Zooplankton: Microscopic organisms, which are found in water of both oceans and fresh water lakes as, free swimming or suspensors

5.1.14 SELF ASSESSMENT QUESTIONS

1. Describe the external structure of Rotifers with suitable diagrams
2. Discuss the mode of nutrition in Rotifers
3. Protonephridia act as organs of osmoregulation in rotifers. Justify the comment.
4. Discuss in detail the mode of reproduction and parthenogenesis in Rotifers.
5. Short notes on the following
    a. Crown in rotifers
    b. Mastax
    c. Cyclomorphosis
    d. Parthenogenesis in rotifers
    e. Mictic and amictic eggs

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Dr. V. Viveka Vardhani

5.2 GENERAL ORGANIZATION OF PHYLUM ECTOPROCTA

5.2.1 OBJECTIVES

The purpose of this lesson is to:

- define ectoprocts
- exemplify ectoprocts with suitable examples
- describe the general characters

5.2.2 INTRODUCTION

The phylum Bryozoa or Polyzoa or Ectoprocta consists of approximately 5,000 living species. Ectoprocts are solitary and colonial forms (Fig. 5-14). In sessile colonies, numerous zooids are present. Each zooid is approximately 0.5 mm in length. Zooids are polymorphic and small in size. Because of their small size specialized organs of gas exchange and excretion are absent. Each zooid is covered by means of a protective covering. This is also a specialized character. The peculiar characters of ectoprocts are:

Small zooids
Colonial organization

Polymorphism and rigid skeletal covering

The phylum is divided into 3 classes:

The Phylactolaemata

The Gymnolaemata

The Stenolaemata

The class Stenolaemata contain few living marine species and more than 500 fossil genera. The class Gymnolaemata contains majority of living marine animals as well as many fossil animals. The class Phylactolaemata consists of about 50 fresh water species. These are widely distributed in fresh water.

5.2.3 STRUCTURE OF THE ZOOID

The Ectoprocta zooid is box like, oval or tubular (Fig. 5 –15). Most of the description is based on gymnolaemate zooid. Each zooid is covered by means of a cuticle (zoecium). The cuticle is composed of protein chitin or calcium carbonate. This is also called as exoskeleton. In the common ***Bugula nertina*** the exoskeleton shows slight calcification. The body of the zooid consists of a trunk and a lophophore, which is covered by an eversible introvert (tentacular sheath). Sometimes the lophophore is surrounded at its base by a fold of the body wall called collar. The lophophore can be extended out of the zooid or retracted inside the body. At the anterior of the lophophore tentacles are present. During feeding the lophophore can be everted outside through the opening of the collar. This opening

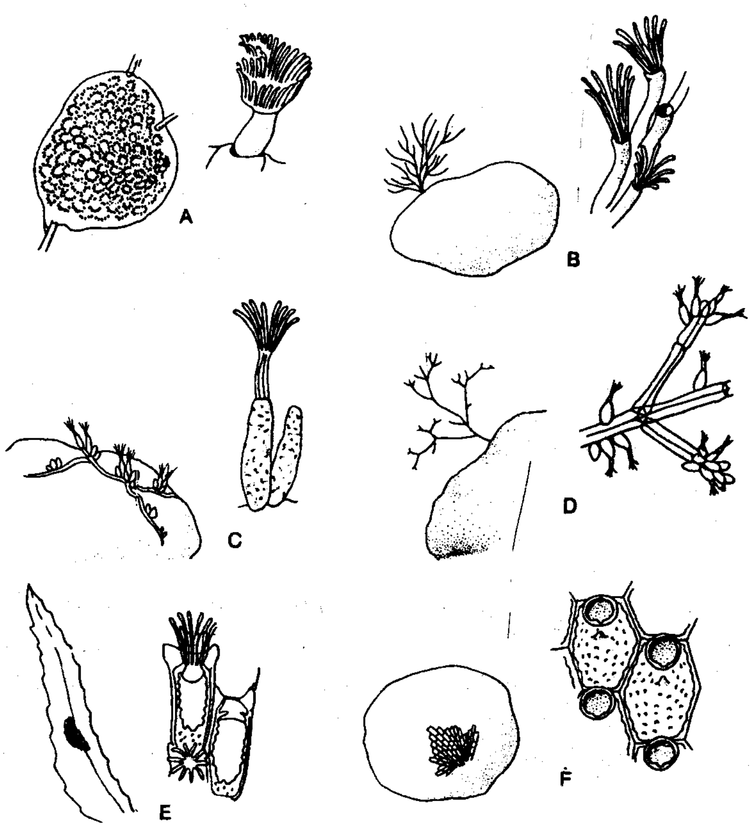

Fig. 5-14. Bryozoan diversity. A, The freshwater bryozoan, *Pectinatella magnifica* (Class Phylactolaemata). B, The marine bryozoan, *Crisia eburnea* (Class Stenolaemata). C-F, Marine bryozoans (Class Gymnolaemata). C, The stolonate ctenostome, *Bowerbankia maxima*. D, The erect ctenostome, *Zoobotryon verticillatum*, showing jointed stolon composed of tubular kenozooids. E, The anascan cheilostome, *Membranipora tuberculata*, encrusting a leaflet of Sargassum. F, The ascophoran cheilostome, *Schizoporella unicomis*, encrusting the surface of a rock.

is called the orifice (Fig 5-15). This orifice is provided with a lid (operculum), which closes when the lophophore is retracted inside the body. The space occupied by the retracted collar and the trunk is called the atrium. When the lophophore is retracted inside the tentacles bunch together to form a bundle. The bundle of tentacles can be pulled directly inside as the tentacular sheath inverts.

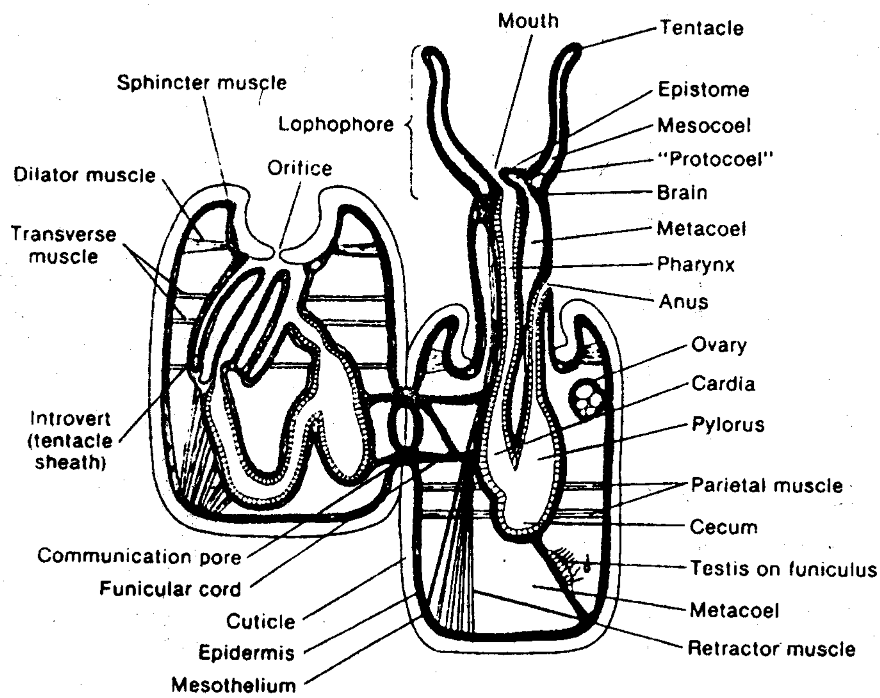

Fig. 5-15. Organization of two generalized bryozoan zooids.

5.2.4 BODY WALL

In both phylactolaematas and gymnolaemates, the body is covered by means of cuticle, which is secreted by the epidermis. Muscle layers are absent in the body wall of gymnolaemates.

5.2.5 LOPHOPHORE

In gymnolaemates the lophophore is circular. A simple lophophoral ridge is present having 8 – 30 or more tentacles. The tentacles appear like bundles during retraction and in the form of a bell shaped funnel during protrusion. Mouth lies at the base of the funnel. The tentacles are provided with cilia on the lateral surfaces and on the inner frontal surface.

5.2.6 THE INTERIOR BODY

The interior of the body is occupied by a large spacious coelom and the U-shaped digestive tract. Mouth is present in the center of the lophophore. Mouth opens into the digestive tract. The anus is situated outside the lophophore on the dorsal side of the introvert hence the name Ectoprocta (outside anus)

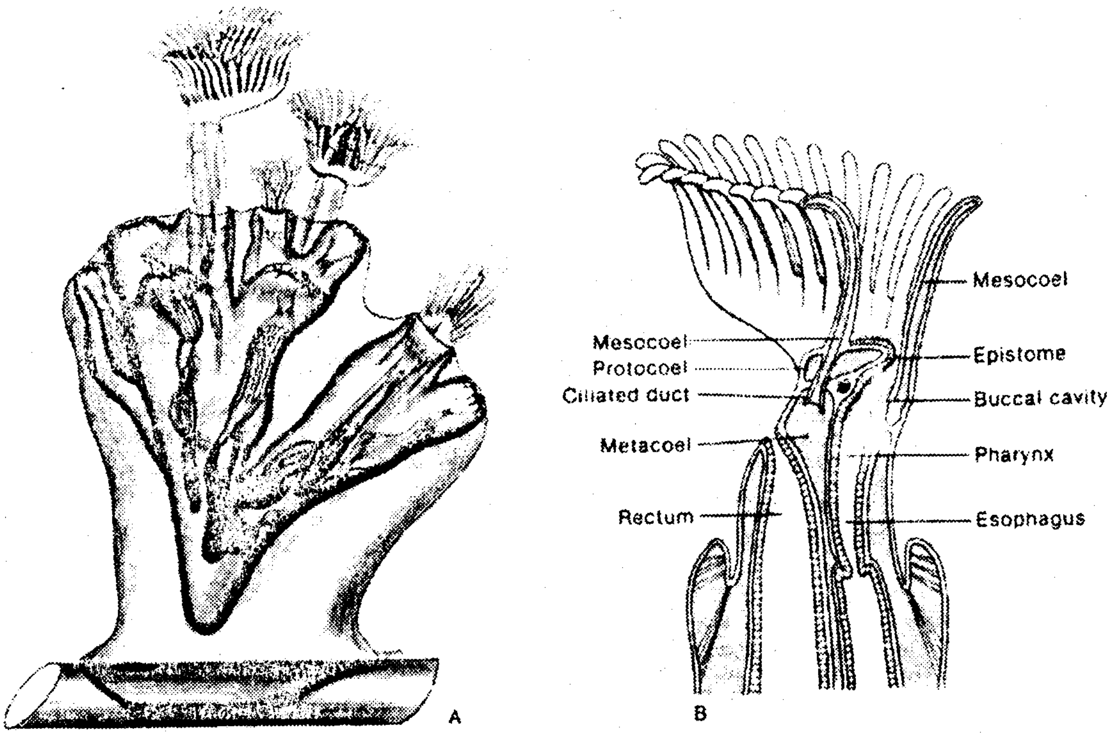

Fig. 5-16. Phylactolaemate (fresh water) bryozoans. A- Small colony of *Lophopus crystallinus* attached to a water plant. **B,** Organization of *Plumatella fungosa.*

5.2.. COELOM

The interior of the body contains a rather spacious coelom. The coelom is divided by a septum into a small anterior and a larger posterior portion. The anterior or mesocoel occupies the lophophore and tentacles (Fig. 5-18B). The larger or posterior metacoel occupies the trunk. A pore connects both the mesocoel and metacoel. The trunk coelom is crossed by muscle fibers and one or more cords of tissue. This tissue constitutes the funiculus. In gymnolaemates such as *Bowerbankia,* the funiculus extends between the pyloric stomach and the body wall (Fig. 5-15). Also, there are two sets of lophophore retractor muscles in the coelom. These retractor muscles extend on each side from the base of the lophophore to the back body wall. Internal transport of gases, some food and waste is provided with coelomic fluid. Coelomocytes are present in coelomic fluid. These cells engulf and store waste materials. However, in gymnolaemates, the metabolites are dispersed in the colony by funiculus.

5.2.8 NERVOUS SYSTEM

The nervous system is composed of pharyngeal nerve ring around the pharynx with a ganglionic mass on the dorsal side. Nerves are given out to each of the tentacles and various parts of the body from this ganglion and nerve ring.

5.2.9 SENSE ORGANS

There are no specialized sense organs in ectoprocts except the sensory cilia on the tentacles.

5.2.10 COMPARISON OF FRESH WATER AND MARINE WATER ZOOID

In fresh water zooids the body wall contains circular and longitudinal muscle layers and the epidermis is covered by a cuticle.In fresh water *Pectinatella,* the epidermis is covered by thick gelatinous layer. The lophophore of freshwater Phylactolaemates is horse-shoe shaped bearing 2 ridges with a total of 16 to 106 tentacles (with the excemption of circular lophophore in *Fredericella).* In the horse-shoe shaped lophophore one ridge passes above and the other ridge passes below the mouth at its bend. A dorsal hollow lip (epistome) over hangs the mouth. It is because of the presence of the epistome, the name Phylactolaemata is derived. It means "covered throat". Gymnolaemata means naked throat. It refers to the absence of the epistome. Stenolaemata means narrow throat.

In marine gymnolaemates, the outer covering is secreted by the epidermis of the body wall. Beneath the rigid, exoskeleton of gymnolaemates lies the body wall. The epidermis overlies a thin, delicate peritoneum. In gymnolaemates, the lophophore is circular and consists of a simple ridge bearing 8 to 30 or more tentacles. When the tentacles are retracted, they are bunched together within the sheath. When the tentacles are protruded, they fan out in the form of a funnel. Mouth lies at the centre of the lophophore.

The colonies of most gymnolaemates are polymorphic. The typical feeding zooid is autozooid. The autozooids make up the bulk of the colony. Reduced or modified zooids are heterozooids. A common type of heterozooid is the one which is modified to form stolons, attachment disks and other such vegetative parts of the colony. Other heterzooids are called avicularia and vibracula, which are defensive in function. The colonies of freshwater phylactotolaemates are non-polymorphic.

5.2.11 ORGANIZATION OF THE COLONY

In ectoprocts asexual budding of the zooids forms colonies. Marine forms or gymnolaemates and fresh water forms or phylactolaemates exhibit a wide range of colonial forms. In gymnolaemates, members of some genera like *Bowerbankia, Amathia* and *Zoobotryon* exhibit stoloniferous colonies. Some colonies are with erect or creeping stolens. The erect forms show stem like sections with modified zooids; thus appearing like a jointed stem. In these colonies unmodified feeding zooids are also present. In these stoleniferous forms calcium carbonate is absent in exoskeleton. But, in majority of marine ectoprocts (gymnolaemates), non stoloniferous colonies are present. The adjacent zooids are attached directly with the different orientation of the body to the substratum. In this orientation the dorsal surface of the zooid is attached to substratum, the free or the ventral surface is exposed to the outside. This free, exposure surface is called the frontal surface.

The common example for non stoloniferous ectoproct colony is *Bugula.* It resemble to a sea weed externally. It shows a plant like growth. The colony is in an encrusting form. The attachment of zooids in this colony appears like a seaweed. The exoskeletons of these colonies are usually rich in calcium carbonate. The other examples of the non stoloniferous colonies include – *Membranipora, Schizoporella* (Fig. 5-14 E, F), and *Microporella*

Fresh water phylactolaemates consists of 2 types of colonies as lophopodid and plumetellid types. In lophopodid colonies like *Lophopus, Cristatella* and *Pectinatella,* the zooids of the colony project from one side of the colony. The projecting zooids resemble the fingers of a glove (Fig.5-

16A). In other plumatellid colonies such as *Plumatella, Fredericella* and *Stolella,* they exhibit more or less plant like growths. They show either erect or creeping branches with zooids. They are found attached to vegetation, sub-merged wood, rocks and other objects. For example in *Cristatella,* the colony is like a ribbon creeping over the substratum. In the fresh water forms the zooids are microscopic exhibiting different colors. The organization of the colonies and the structure of the exoskeleton form a basis for the taxonomical classification of marine ectoprocts. In both marine and fresh water forms, pores located in the transverse end walls or lateral walls or both communicate the zooids of the colony.

5.2.12 POLYMORPHISM

The colonies of phylactolaemates are non polymorphic and that of most gymnolaemates are polymorphic. In such polymorphic colonies, polymorphism is contributed by the autozooids and heterozooids. The typical feeding and unmodified zooid is called an autozooid. These autozooids are found in bulk in the colony. The reduced or modified zooids are called heterozooids. Some of the heterozooids are defensive in function. A common type of reduced or modified zooid, which forms the stolen, is named as kenozooid. Other modified forms of heterozooids are attachment discs, root like structures and other vegetative parts of the colony. In these modified forms the body wall and the funicular tissue is thin.

In many cheilostomes two other types of heterozooids are present called avicularia and vibracula(Fig 5-17). In avicularia the external body and the internal structure are greatly reduced.

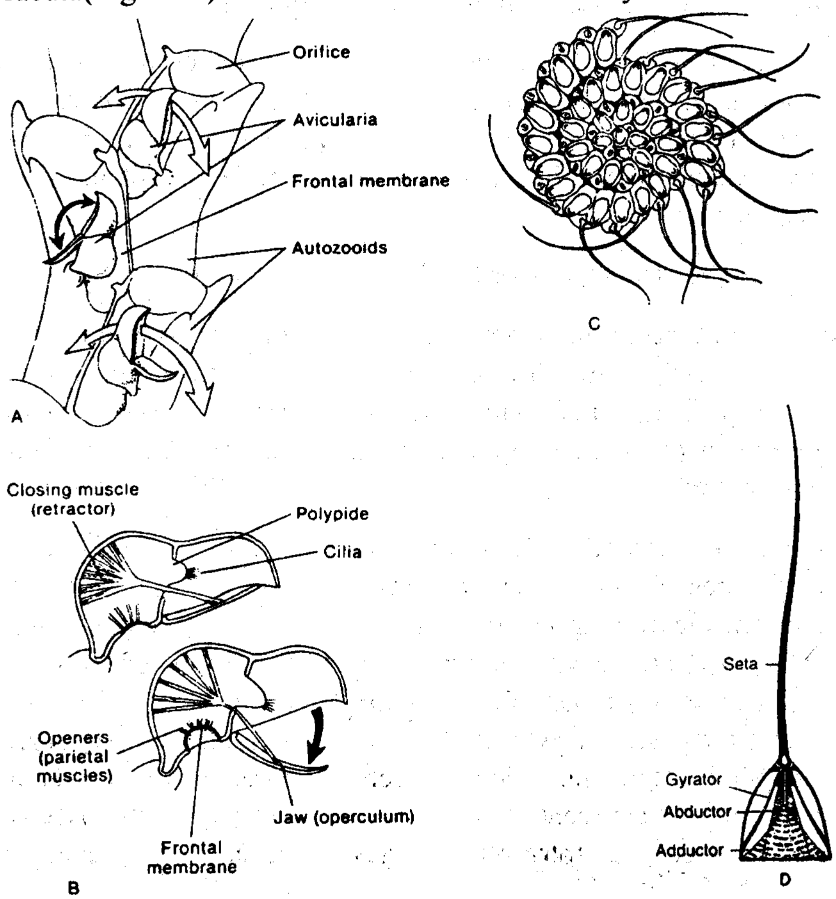

Fig. 5-17. Bryozoan heterozooids. A, Bird's head avicularia of the anascan cheilostome, *Bugula fulva.* Open arrows show avicularium movement; solid arrows, movement of jaw (operculum). B, Simplified anatomy of a bird's head avicularium. C, Part of a colony of *Heliodoma,* showing marginal vibracula. D, Anatomy of a vibraculum.

They may be sessile or stalked. The highly developed operculum is modified into a powerful movable jaw. The muscles are also highly developed. Both the sessile and stalked avicularia protect the colony from the small organisms. The stalked avicularia when attached to the colony make nodding motions. They appear like little bird heads found in the colony. The crawling, tube dwelling amphipods and polychaetes are caught by the jaws and are prevented from settling/crawling on the colony. In some forms, the sessile avicularium functions like a mouse trap to catch and immobilize the syllid polychaetes.

In the other type of modified zooid, vibraculum, the operculum is modified to form a long bristle, sometimes called a seta. The seta can move in any direction and sweeps away any material, which falls on the colony.

Some zooids are modified for reproduction. In many cheilostomes, a special external chamber called an ovicell is formed for brooding the fertilized eggs. The ovicell also contributes to polymorphism.

5.2.13 NUTRITION

Small phytoplanktonic animals are probably the principle food for ectoprocts. During feeding the lophophore is pushed outward through the atrium and orifice. With the outward pushing of lophophore, the tentacular sheath also everts outside. The tentacles of the lophophore expand forming a bell shaped funnel. The lophophore is pushed outward due to the exertion of coelomic fluid pressure. The elevation of coelomic fluid pressure occurs by the contraction of body wall musculature in phylactolaemates and by transverse parietal muscle bands in gymnolaemates.

When the lophophore is protruded, the lateral tentacular cilia create a water current, which sweeps downward into the funnel and comes outward between the tentacles (Fig. 5-18). The tentacles trap the phytoplankton and convey the food to the mouth by cilia on the inner surface of each tentacle. By what ways the food particles are filtered are not fully understood. But collection of food by ciliary action is a common method in ectoprocts.

Many ectoprocts search for particles by rotating or bending the lophophore.

In phylactolaemates, food particles accumulate beneath the epistome. In gymnolaemates, food particles accumulate within the expanded mouth. The 'U' shaped digestive tract consists of mouth (lies at the center of lophophore), pharynx, oesophagus (in suspension feeders), large stomach, intestine, rectum and anus. The anal opening lies outside the lophophoral ridge – hence the name Ectoprocta (*ecto* = outside, *procta* = anus) is derived.

When food particles accumulate to a considerable amount, the muscular sucking pharynx dilates rapidly. The pharynx together with oesophagus (when present) pushes the food into the stomach. Food particles may be rejected by tentacle flicking, closure of mouth or funnel or simply being thrown out. The gut is 'U'-shaped in both phylactolaemates and gymnolaemates. Food particles pass from the mouth to large stomach, which composes much of the U-shaped gut (Fig.5-18). The stomach is divided into an anterior cardiac and the posterior pylorus. The anterior cardiac stomach is separated from the oesophagus by a valve. Similarly the posterior stomach is separated from the rectum by a valve. A large caecum extends backward from the central stomach. Digestion occurs within the stomach. Digestion is both extracellular and intracellular. Intracellular digestion occurs mainly in the caecum.

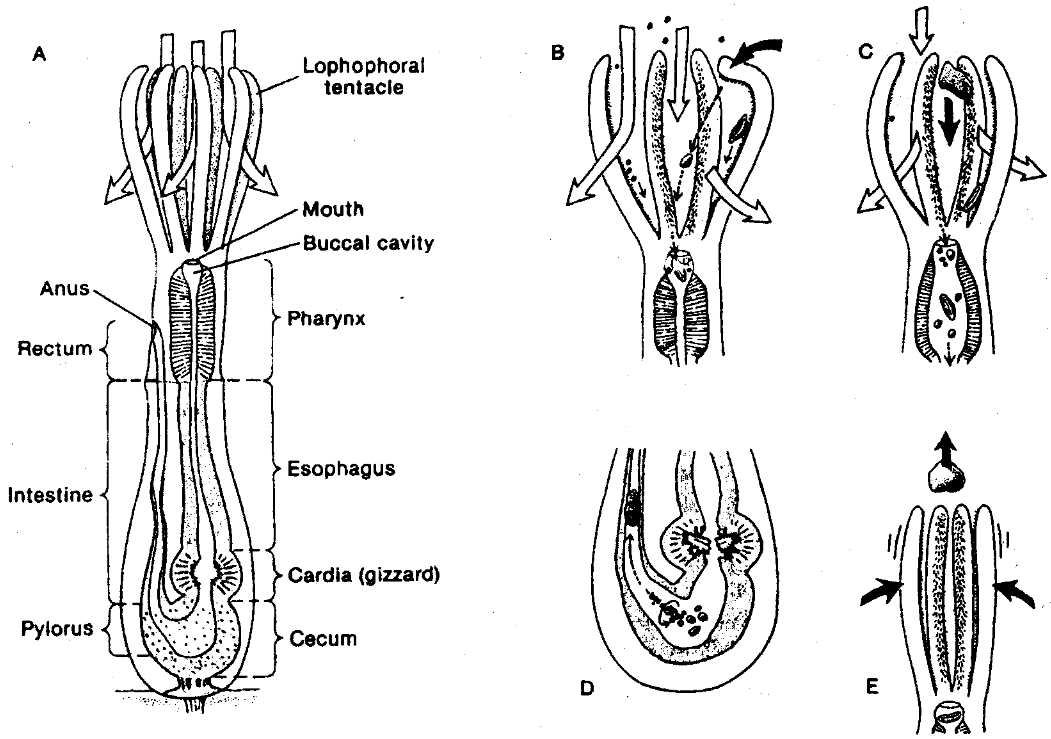

Fig. 5-18. Digestive system and feeding in gymnolaemates (based on *Zoobotryon*). A, water currents (open arrows) and digestive system. **B-D,** water currents (open arrows) bring in food particles **(B)**, which are either batted toward the mouth by a tentacular flick (large solid arrow, dashed arrow) or caught on the tentacle surface and moved toward the mouth by frontal cilia (small arrows). The collected particles accumulate in the ciliated buccal cavity **(B)** and are engulfed by a rapid dilation of the muscular pharynx **(C)**. The food particles move rapidly down the oesophagus, pass through the muscular gizzard, which crushes diatoms, before entering the cecum **(D)**. Once in the cecum, the food is rotated by cilia and digested; indigestible material is compacted into fecal pellets in the intestine **(D)**. Rejected particles may pass between tentacles and be carried away in the exhaust, but sometimes the tentacles bunch together rapidly and particles are rejected as shown in **E**.

The peristaltic contractions of the stomach help for the passage of food. The posterior stomach or pylorus function to rotate and compact waste material. The waste material passes to the rectum and thrown out by anus. In some bryozoans such as *Bowerbankia* and *Amathia*, the cardiac stomach is modified to form gizzard. In the gizzard, there is an outer lining of epithelium and a well developed circular muscle layer. The epithelial cells bear teeth.

In all bryozoans, the epithelial lining of the digestive tract is the primary site for storing reserve food.

5.2.14 GAS EXCHANGE ORGANS

There are no specialized gas exchange organs. Gas exchange occurs across the exposed body surface.

5.2.15 EXCRETION

There are no excretory organs probably because of the small size of bryozoans. Waste materials are engulfed and stored by coelomocytes.

5.2.16 REPRODUCTION

All fresh water bryozoans are hermaphroditic. Most of the marine forms also exhibit hermaphroditism. Sperms and eggs are produced simultaneously. Commonly they also show a tendency of ripening of sperms earlier than eggs. Female reproductive system shows one or two ovaries. Male reproductive system shows one to many testes. Both male and female gonads are masses of developing gametes covered by peritoneum. In a bryozoan animal, the ovaries are located in the distal end and the testes in the basal end (Fig. 5-15). In dioecious species, the entire colony may be composed of zooids of the same sex. The entire colony may consist of either male or female individuals. Genital ducts are absent. Gonads bulge into the coelom. Eggs and sperms also rupture into the coelom.

Some marine species such as *Electra* and *Membranipora* shed small eggs directly into the sea water. Majority of bryozoans brood their eggs internally ore externally. The eggs, which develop by brooding are large, yolky and few in number.

A few species brood their eggs within the coelom. In these species the digestive tract and lophophore often degenerate providing space for the egg. The invaginations of the atrial wall or the cavity of the tentacular sheath are the common sites for brooding. Some marine species including the common *Bugula,* brood their eggs in a special external chamber called an ovicell (Fig. 5-19 C). At the distal end of the zooid the body wall grows outward as a large hood; this chamber is called ovicell. A second, smaller evagination bulges into the ovicell. This smaller evagination is directly connected to the coelom. A single egg may undergo brooding in the space between the two evaginations. The developing embryo may get its nourishment from the yolk. In many species including *Bugula* some placenta like connections extend from the maternal zooid to the developing embryo. Food material is supplied from maternal zooid to the developing embryo (Fig. 5-19C)

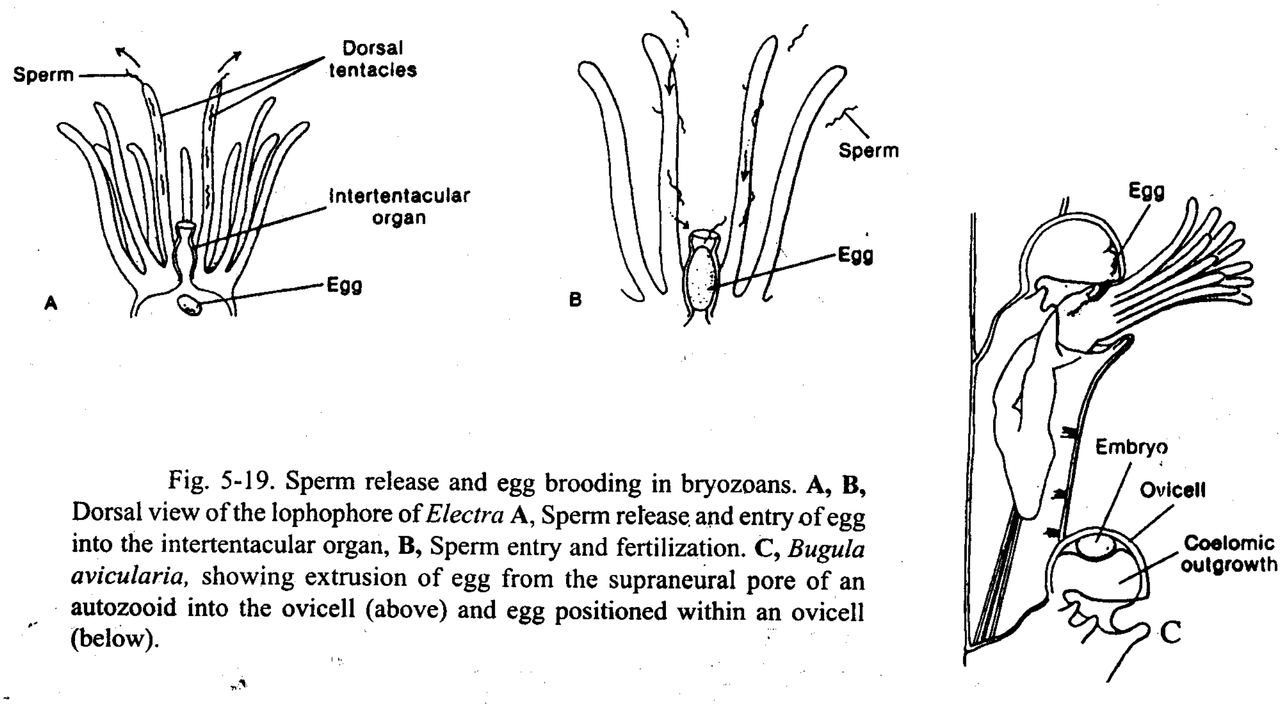

Fig. 5-19. Sperm release and egg brooding in bryozoans. **A, B,** Dorsal view of the lophophore of *Electra* **A,** Sperm release and entry of egg into the intertentacular organ, **B,** Sperm entry and fertilization. **C,** *Bugula avicularia,* showing extrusion of egg from the supraneural pore of an autozooid into the ovicell (above) and egg positioned within an ovicell (below).

An ovicell is thought to be the modified individual. Ovicell contributes to the polymorphism of the colony.

Eggs come out of the body by a special opening in the vagina of lophophore. This opening is called as coelomophore. Whether the eggs are shed in the seawater or brooded externally they come out by this opening. The coelomophore may be a simple opening or may be present at the end of a body projection. This body projection is called an intertentacular organ (Fig. 5-19A). In species, which possess ovicell, the egg is extruded through the coelomophore as a "stream" and then establishes itself within the ovicell cavity.

In some species such as *Electra, Bugula, Membranipora* and others the sperms are shed through terminal pores of the tentacles. The liberated sperms move in the water currents and attach to the tentacular surfaces of the lophophore or enter the intertentacular organ. If they adhere to the tentacular surfaces, the eggs are fertilized as they leave the intertentacular organ or if they enter the tentacular organ, fertilization of the eggs occurs there itself (Fig. 5-19 A,B). In internal brooding species, sperms enter the coelom through coelomophore.

Most commonly fertilization may occur between individuals of the same colony. But cross fertilization between two colonies may also occur.

5.2.17 DEVELOPMENT

In marine species the fertilized egg undergoes radial cleavage leading to a larva. The larva of brooding species and non-brooding species differ in both external and internal characters. Both the larvae of brooding and non-brooding species possess a locomotor ciliated girdle or corona, an anterior tuft of long cilia and a posterior adhesive sac (Fig. 5-20). The larvae of *Electra* and *Membranipora* (non-brooding species) are called cyphonautus larvae. These are triangular and laterally compressed. And a chitinous valve covers each lateral surface. In the larva of brooding species, digestive tract is absent.

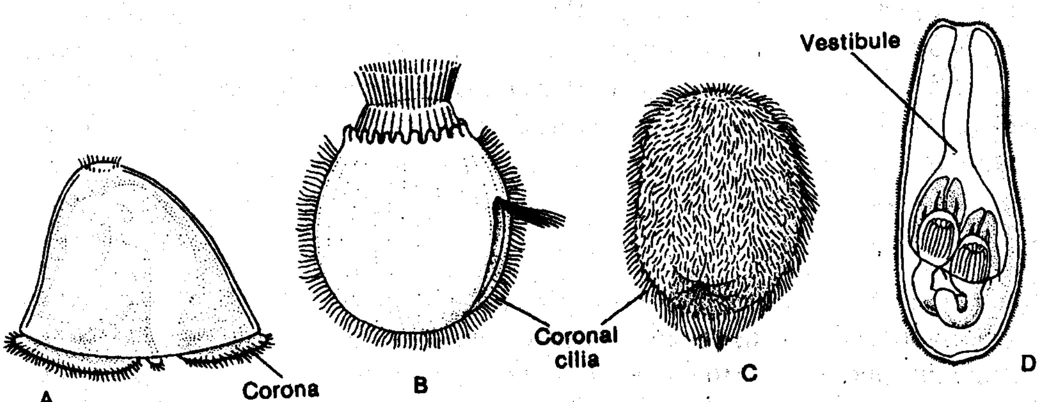

Fig. 5-20 Bryozoan larvae. **A,** A planktotrophic cyphonautes larva, as found in the genera *Membranipora* and *Electra*. The larva is laterally compressed and bears a shell **B-D,** Lecithotrophic larvae of the gymnolaemate, *Bugula neritina* **(B),** the stenolaemate, *Crisia eburnea* **(C),** and a phylactolaemate **(D),** In phylactolaemates. autozooids differentiate precociously within the larval body.

A functional digestive tract is present in the larvae of non-brooding species. During larval existence, they feed on fine particles. The non-brooding feeding larvae may have a larval life of several months. The brooding, non-feeding larvae have a brief larval existence. Larvae are at first positively photo tactic and escape from the brood chamber and disperse in the water. But as the time of settling comes near, they become negatively photo tactic and settles in shaded areas. The adhesive sac everts during settling. When the larva attaches to the substratum, the larval structures undergo retraction and histolysis and develops into adult.

The first zooid is called an ancestrula. The ancestrula gives rise to many zooids by means of budding. The newly formed buds vary in their size and shape. From these zooids, new buds are formed by budding. Thus, the colony gradually increases in size. During budding, a body wall partition forms and cuts off from the parent zooid. The new chamber evaginates by the mitotic activity of distal cells. When new material is added the skeleton of the parent stretches. New internal structures develop from the ectoderm of the body wall. New structures also form from the peritoneum. The number and location of buds in the colony determine the growth patterns of the colony. In the erect dendritic *Bugula,* buds arise from the tips of each branch. In encrusting species new buds arise from the periphery.

The life span of bryozoan colonies varies differently. Some species live only a single year. Many species live for two or more years as long as 12 years. Sexual reproduction may occur at a particular period or it may occur throughout the year.

Regardless of the life span of the colony, the lophophore and gut of a zooid degenerates after few weeks. The degenerated components may be lodged in the coelom as a conspicuous dark body called brown body. Following degeneration, a new lophophore and gut may be formed. In some species, the brown body may stay permanently in the coelom. In others it may be incorporated in the regenerating gut and expelled at the first defecation. Many marine species and others that live for many years show alternating phases of regression and regeneration.

In fresh water phylactolaemates, development takes place within the embryo sac. The embryo sac bulges into the coelom. The embryo sac transforms into a cystid sac. From this cystid sac, one to several zooids arises by budding. Thus a young ciliated colony or larva is formed in the parent body. This may be released from the parent colony and swims for short time before settling. After attachment, degeneration of cystid wall occurs outside. In the mean time, the young colony that had been developing inside may continue to give out buds or successive zooids. After producing new zooids, the parent zooid dies. Thus, living zooids are formed at the tips of branches in branching colonies and appear at the periphery of the colony.

Fresh water bryozoans reproduce asexually (by means of budding) and sexually. Additionally, they also reproduce by special resistant bodies called statoblasts (Fig.5-21). One to several statoblasts develop on the funiculus and bulge into the coelom. Peritoneal cells containing stored food material are encircled by epidermal cells to form statoblasts. When cellular organization is complete, each mass secretes an upper and lower chitinous valve. These valves serve as protective devices for the internal cells. Statoblasts are usually disc shaped. They are continuously formed during the summer and fall.

The shape and structure of statoblasts form a basis in the taxonomy of fresh water bryozoans. Some types of statoblasts may adhere to the colony or fall to the bottom. Some statoblasts contain air spaces and float in water. These floating statoblasts possess marginal hooks (Fig.5-21).

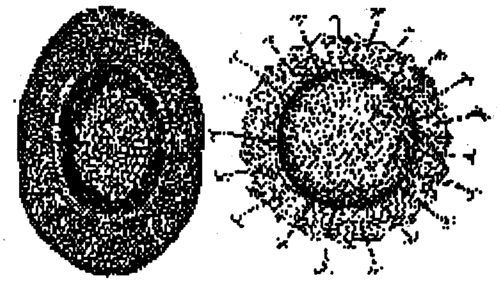

Fig. 5-21. Statoblasts of freshwater bryozoans, **A**, A floating statoblast. **B**- Statoblast with hooks.

During unfavorable conditions they may remain dormant for considerable length of period. They are able to withstand the extreme temperature, desiccation and freezing. They can be carried to long distances by animals, floating vegetationor other agents.

Statoblasts undergo germination with the onset of favorable conditions – the spring. The two germinal valves separate from each other and a zooid develops from the interior mass of cells. Fresh water bryozoans produce statoblasts in an enormous number.

5.2.18 SUMMARY

The phylum Bryozoa or Polyzoa or Ectoprocta contains approximately 4000 living species. It is the largest of the lophophorate phyla.

Bryozoans are colonial and sessile animals.

The individuals composing the colony are less than 0.5 mm in length.

Majority of the bryozoans are marine and some are fresh water species.

The peculiarities of bryozoans are their small size, colonial organization and sessile existance

Because of their small size, organs of gas exchange, circulation and excretion are absent.

The phylum is divided into three classes – the Phylactolaemata, the Gymnolaemata and the Stenolaemata. The class Stenolaemata contains some living marine species and over 500 fossil genera. The class Gymnolaemata contains majority of marine species and many fossil genera. The class Phylactolaemata contains fresh water forms and few fossil genera.

The body of marine forms is covered by a cuticle or by a skeletal covering. The outer covering provides a means for the great fossil records of bryozoans.

The protective covering contains an opening for the protrusion of the ciliated organ, lophophore.

The pressure exerted by coelomic fluid protrudes the lophophore. Usually, the coelomic pressure is produced by compression of some area of the body. It can be retracted inside the body compartment.

In Gymnolaemates, the lophophore is circular and consists of simple ridge bearing 8 to 30 or more tentacles. In Phylactolaemates with the exception of circular lophophore in *Fredericella,* the lophophore is horse-shoe shaped. The horse-shoe shaped lophophore is composed of two ridges bearing 16 to 106 tentacles. One ridge passes above the mouth and the other passes below the mouth at the bend of horse-shoe.

The lophophore serves as a feeding organ.

The interior of the bryozoan body is occupied by rather spacious coelom and the U-shaped digestive tract. A large stomach makes up the greater part of the gut.

Particles collected by the lophophore are pushed into the large stomach. Anus lies outside the lophophoral ridge. Hence, the name Ectoprocta (outside anus). Both extracellular and intracellular digestion occurs.

Some bryozoan colonies are stoloniferous and some are non-stoloniferous. Non-stoloniferous colonies have erect or encrusting growth patterns.

Most commonly marine ectoprocts exhibit polymorphism.

The zooids of the colonies communicate with each other physiologically by wall pores and a mesenchymal chord of tissue called the funiculus.

Bryozoans are hermaphroditic. Gonads break into the coelom. Sperms exist by way of tentacular pores and eggs by an elevated inter tentacular organ.

Some bryozoans are oviparous. Eggs may be produced within the coelom or outside the body (in a special chamber called ovicell).

A larva is typically present in the life cycle.

The larva of brooding species is non feeding and has a brief larval existence.

The larva of non brooding species possesses a functional digestive tract. It is a feeding larva and may have a larval life of several months.

The first zooid (adult) is called an ancestrula. Extensive colonies are formed by means of budding.

5.2.19 KEY TERMINOLOGY

Ancestrula: Zooid that develops from the egg in bryozoans.

Avicularium: A defensive zooid of marine species of ectoprocts. It is smaller than an autozooid and the internal structure is greatly reduced. Avicularia defend the colony against small organisms. May be sessile or stalked. The operculum is modified to form a movable jaw. The jaws are used to seize the prey.

Brooding larva: Larva undergoing at least early development inside or outside the body of animal.

Gonoduct: In any reproductive system, it is the principal duct employed for the passage of eggs or sperm.

Gonopore: External opening of any reproductive system

Gymnolaemate: Living marine species of ectoproct.

Hermaphroditic: Presence of both male and female reproductive systems in the same individual. When both systems appear and function at the same time, the hermaphroditism is said to be simultaneous. When the male system appears, functions first and is followed by the female system, the hermaphroditic system is said to be protandric.

Lophophore: All members of the phylum Ectoprocta at their anterior end possess a food catching organ called a lophophore; a circular or horse-shoe shaped fold of the mesosomal body wall that encircles the mouth and bears numerous hollow tentacles.

Orifice: An opening of the external covering which enables the lophophore to protrude.

Oviparous: Egg laying.

Phylactolaemate : Living fresh water form of ectoproct.

Polymorphism: The existence of two or more structurally and functionally different zooids in the colony of the same species.

Radial cleavage: Type of cleavage pattern in which the cleavage spindles are at right angles or parallel to the polar axis of the egg.

Statoblast: Fresh water ectoprocts reproduce asexually by special resistant bodies called statoblasts. One to many statoblasts develops on the funiculus. The structure and shape of the statoblasts are important in the taxonomy of fresh water bryozoans. The floating statoblasts remain dormant during unfavorable conditions for a length of time. With the advent of favorable conditions it may undergo germination and develops into a zooid.

Vibraculum: A common type of heterozooid found in many cheilostomes. It is defensive in function. In a vibraculum, the operculum is modified to form a long seta or bristle. The seta is used to sweep away the detritus.

Zoecium: The body covering of Gymnolaemates (marine species of ectoprocta). It consists of an organic cuticle composed of protein and chitin or of certain overlying calcium carbonate.

5.2.20 SELF ASSESSMENT QUESTIONS

1. Explain the general characters of ectoprocta.
2. Describe the structure of the zooid of Gymnolaemata and Phylactolaemata with diagrams
3. Discuss the differences between the zooids of Gymnolaemates and Phylactolaemates. Add a note on the peculiarities of bryozoans.
4. Write short notes on:
    a. Polymorphism in ectoprocta.
    b. Colony organization in ectoprocta.
    c. Digestive tract in ectoprocta.
    d. Lophophore in ectoprocta.
    e. Cyphonautus larva.

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5.3 GENERAL ORGANIZATION OF PHYLUM SIPUNCULA

5.3.1 OBJECTIVES

The purpose of this lesson is to:

- know about the general habit and habitat of sipunculans
- understand the general structure of sipunculan
- describe the possible phylogenetic relationship

5.3.2 INTRODUCTION

The Phylum Sipuncula is small. Sipunculans are coelomate animals. They are probably stemmed from a point along the protostome line. Three groups of Coelomates- the Sipunculans, the Echiurans and Priapulids were once kept under the phylum Gephyrea. This arrangement was found to be artificial and the three groups have been separated. Marine forms, consisting of about 300 species. They are drab-colored worms. Sometimes called peanut worms. The length of the worms range from 2 mm to more than 72 cm, although most are less than 10 cm long.

All are bottom dwellers. Majority of them occur in shallow water. The Sipunculoids are worm like animals. They are rather sedentary in habit (Fig. 5-24). Some live in sand and mud. Some worms like *Sipunculus* are active burrowers. Some live in mucus-lined excavations. Others live in coral crevices, in empty mollusk shells *(Phascolion)*. Some animals lie in empty annelidan tubes or in other protective retreats. A number of species bore the coralline rock. In coral burrows the animals are found orienting with their anterior ends directed towards the opening of its burrow. Mostly tropical reef lime stone is invaded by boring sipunculans. The chemical and mechanical processes of boring forms may help in burrowing. The exact mechanism by which these animals burrow the coralline rock is still unknown. They can not build true tubes. The burrows in which they live are lined with mucus. As many as 700 individuals per square meter have been reported from coralline rock of Hawaii.

5.3.3 EXTERNAL STRUCTURE

There is no trace of segmentation. The body of sipunculans is cylindrical. Body is divided into an anterior narrowed section, called the introvert and a larger posterior trunk (Fig.5-22). The introvert is not a proboscis. But it can be retracted into the anterior end of trunk. They are easily identified by the introvert, which is habitually run inside and outside the trunk rapidly. The introvert represents the head and anterior part of the body. Mouth is present at the anterior end of introvert. It is located below the tentacles. Or is surrounded by a scalloped fringe, lobes, tentacles or tentaculate lobes. Most of the projections of the introvert are ciliated. A deep ciliated groove is present on the inner side of each of these introvert projections. The introvert is followed by a cylindrical trunk. The surface of the introvert is found to be rough. The rough surface is typically covered with spines, tubercles and other ornamentations. In *Sipunculus* the introvert is covered with papillae. Circlets of spines are usually present on the introvert of *Phascolosoma* and *Aspidosiphon.* Spines or hooks occur on the introvert of many species of *Golfingia.* The introvert may be much shorter than the trunk in species of *Sipunculus* or range from one fourth to half to about the length of trunk in most of other species. The introvert may exceed the trunk in length in species of *Phascolion, Aspidosiphon* and *Onchnesoma*. When the introvert is fully extended the mouth is seen in the center of the anterior tip, which may be called oral disk. In *Golfingia*, the tentacles are conical or digitiform or filiform. In *Sipunculus,* the tentacles take the form of a tentacular fold. This fold completely surrounds the oral disk and has a scalloped or foliaceous margin. In *Phascolosoma,* few to numerous tentacles do not encircle the mouth but form a crescent. This crescent opens dorsally above the mouth.

The trunk is cylindrical. It may terminate bluntly or in a point. The cylindrical trunk and its surface are not strikingly ornamented except in some rock boring forms, such as species of *Aspidosiphon, Paraspidosiphon* and *Cloeosiphon.* These three are crevice-inhabiting forms. In these three forms, the surface of the trunk is thickened at the anterior end. A dorsal or collar-like shield is formed by the modification of body wall. The dorsal shield is used to block the opening of the retreat when the introvert is invaginated.

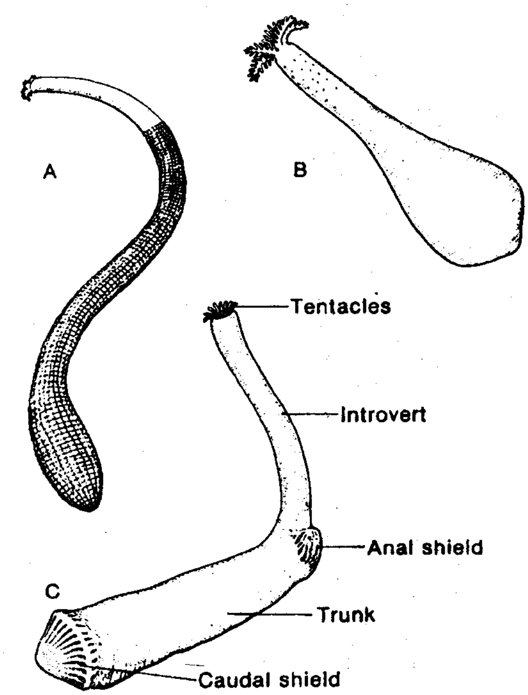
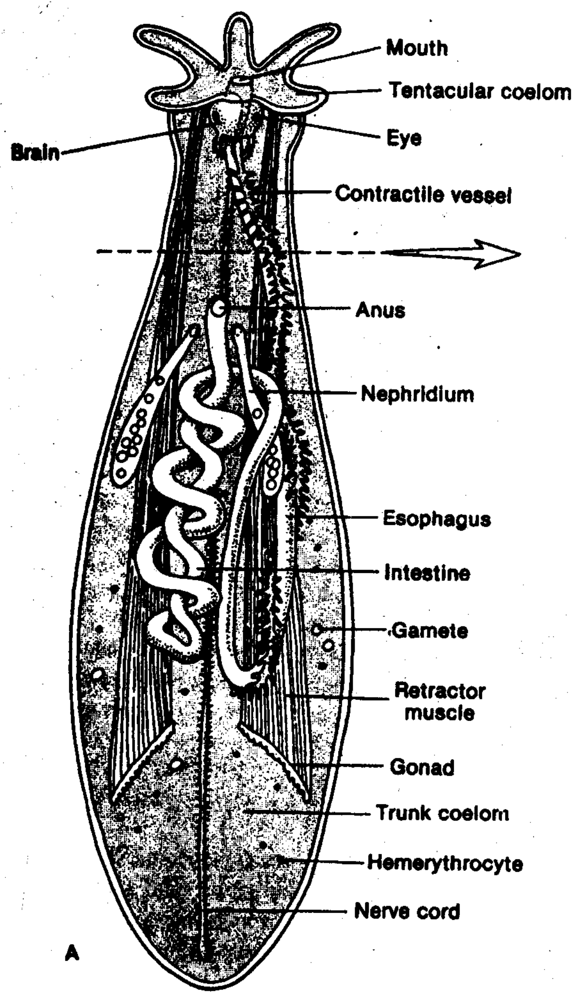


Fig. 5-22 Sipunculan body forms. **A,** The sand burrower, *Sipunculus nudus* (10 cm). **B,** The crevice dweller, *Themiste lageniformis* (1 cm). **C,** The rock borer, *Paraspidosiphon klunzingeri* (2 cm).



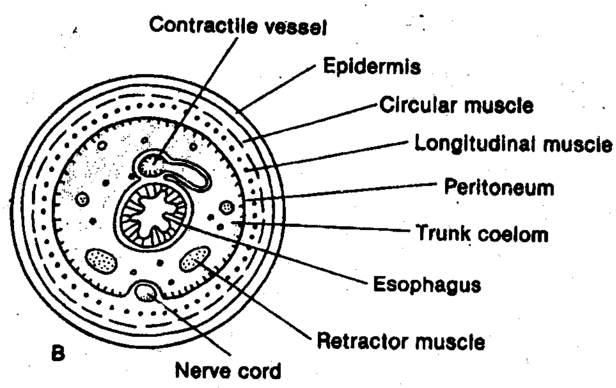


Fig. 5-23 A, Organization of a generalized sipurnculan that has a well-developed contractile vessel, B, Cross section of the body.

5.3.4 BODY WALL

Body wall is constructed like that of the annelids. The body wall is thin, soft, elastic and delicate. The body wall consists of the following layers: cuticle, epidermis, dermis and muscle layers. Cuticle is thin, non cellular and provided with openings through which epidermal gland cells may open outside. Below the cuticle lies an epidermis consisting of single layer of cells. The epidermal cells are usually sac like, but capable of being altered as a result of contraction or compression into a spindle shape. Below the epidermis is a layer of dermis in which and also to some extent in epidermis are a number of dermal bodies (Fig. 5-23B). Dermal bodies or gland cells are of three kinds – unicellular glands, bicellular glands (contained in papilla of introvert), and multicellular glands. The multicellular glands often scattered through the cuticle. Epidermis also contains an abundance of sensory organs mostly in the form of sensory buds. Sense papillae are small, rounded thickenings of the epidermis in the anterior region of the introvert. Papillae of various shapes and sizes are widely present on the surface of the sipunculoids on introvert or trunk or both. There are also numerous pigment cells. The pigment cells are responsible for the brown colors and often present locally on papillae. Glands and sensory buds may be located anteriorly in the cuticle or may project inwardly into the dermis. The dermis is a layer of connective tissue beneath the epidermis and also permeates the muscle layer. It may be thick or thin. Beneath the dermis, the body wall musculature consists of 2 layers of muscles: an outer circular and inner longitudinal layers. A thin diagonal layer exists between these two layers. The main muscles are the retractor muscles of the introvert. In many sipunculoids there are four retractors, a ventral pair and a dorsal pair. They may be of equal length or often the dorsal pair is shorter. The longitudinal layer, which is separated by spaces, forms into a series of parallel bands. All the muscles are of the smooth type. The body wall protects the animal from mechanical injury. Sensory cells or chemo receptors of the body wall detect the external environment. They also receive the external stimulus.

5.3.5 COELOM

Coelom is a continuous cavity lying between the body wall and alimentary canal. A large coelom extends along the entire length of the body. The coelom is lined with a peritoneum of flattened cells, interspersed here and there with granular cells bearing tuft of cilia. Peritoneal cells may be changed into chlorogogen cells and fixed urns. A muscular body wall encloses a spacious, undivided coelom containing the digestive tract, nephridia and gonads. The contraction of the body wall brings the elevation of coelomic fluid pressure. These will inturn brings about the protrusion of the introvert. The coelomic fluid contains an abundance of free elements that may be listed as hyaline amoebocytes, granular amoebocytes or granulocytes, free urns and bulbs of waste material. Cells having respiratory pigment, hemerythrin are also present in abundant number. The coelomic fluid functions to distribute the digested food material. Also, it helps to remove the cells having waste products.

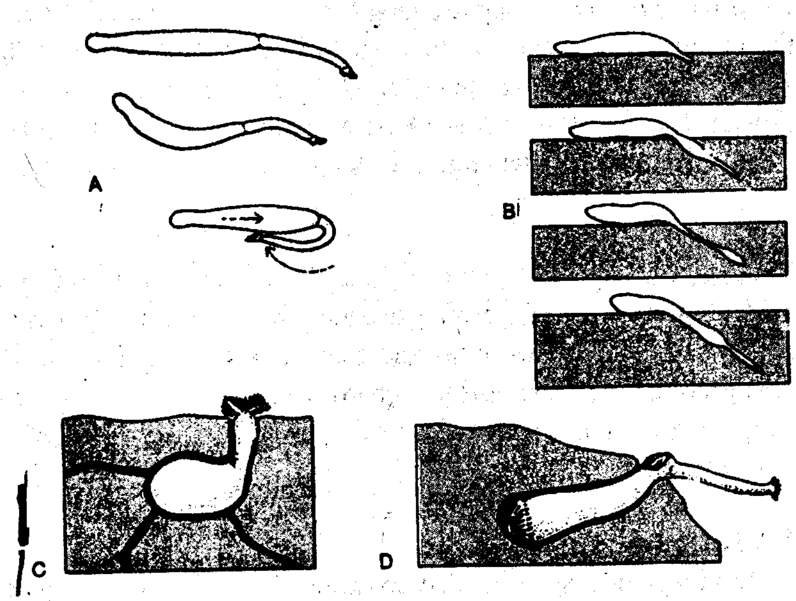


Fig. 5-24. Swimming (A) and burrowing (B) by *Sipunculus nudus*. (C) *Themiste lageniformis*, a crevice and rock dweller. D, *Lithacrosiphon*, a rock-boring sipunculan having a calcareous anal shield that caps the opening when the introvert is retracted.

5.3.6 INTROVERT

The introvert lies at the anterior end of the trunk. It is a ciliated organ. The introvert contains ciliated tentacles, tentacular lobes or a fringe of tentacles. The tentacles of introvert are hollow. The tentacles or tentacular lobes are not connected to the coelom. Each ciliated tentacle has a tentacular lumen. The lumen of all the tentacles is connected by a system of canals (Fig. 5-24C). These canals end with one or 2 blind tubular sacs that parallel the oesophagus. These blind sacs are contractile. They receive fluid from the tentacles when they are contracted. They supply fluid to the tentacles when they are expanded. When the introvert is fully evaginated, there appears at its extremity a horsshoe shaped fold of the integument, the tentacular fold which is lobed and plaited, so as to assume somewhat the appearance of circle of tentacles. The introvert with its tentacles serves as a food catching organ. In some forms, the introvert with a pair of ciliated pits or nuchal organs is useful to probe the environment in which they burrow/ live. The tentacles are probably an important site of gas exchange.

5.3.7 NUTRITION

Mostly non selective deposit feeders. They draw the sediment inside the gut by extending the introvert and tentacles. The burrowing forms such as *Sipunculus* ingest sand and silt. By ingesting sand and slit they make burrows.

Some rock boring forms such as *Phascolosoma,* extend their tentacular crown from the opening or the mouth of the burrow. And perhaps, the rock boring forms mechanically collect the food. They depend upon ciliary currents of the tentacles for obtaining the food.

The digestive tract is U-shaped and coiled (Fig. 5-23A). It is a cylindrical tube of uniform character throughout. It is twice the length of the body, running back from the mouth to the posterior end and then it bends sharply to run towards the anus. The two limbs being twisted sharply round one another. A narrow groove is present along the length of alimentary canal except the region of rectum. Connected with the rectum arise a caecum that opens into the beginning of the rectum. The anus is located mid dorsally at the anterior end of the trunk. In a single genus, *Orchnesoma,* the anus opens on the introvert. In *Sipunculus,* the descending intestine before entering the coil typically undergoes a loop. In *Phascolosoma* the typical intestinal coil is absent. Instead the intestine makes several long loops.

In all sipunculids, the digestive tract is lined throughout by a columnar ciliated epithelium generally thrown into longitudinal folds. Numerous enzymatic cells are mostly limited to the intestinal epithelium of descending intestine. An important feature of the digestive tract of sipunculids is the presence of a ciliated groove. In *Sipunculus* this groove runs from mouth to rectum and clearly visible as a reddish line along the tract. This groove always terminates in the rectal diverticulum. In *Sipunculus,* the diverticulum is of secretory in nature.

5.3.8 BLOOD VASCULAR SYSTEM

There is no blood vascular system. The absence of blood vascular system is compensated by coelom. The coelomic fluid functions as a circulating medium. The coelom contains abundant corpuscles bearing hemerythrin. The tentacles serve as organs of gas exchange.

5.3.9 EXCRETION

Excretory organs include a pair of metanephridia. These are present at the anterior trunk coelom. A single pair of large sac like metanephridia is present in almost all sipunculans (Fig. 5-23A). Metanephridia open anteriorly and ventrally by means of nephridiopores at about the same levels as anus (Fig.5-23A). Only one nephridium, usually the right one is present in the genera *Phascolion* and *Onchnesoma.* In some species of *Aspidosiphon* even one nephridium is not present. The nephridia are tubular sacs in the form of an elongated V. The greater part of the nephridium contains a single lumen. The nephrostome (Fig. 5-25B) is usually a simple opening in contact on one side with the body wall, with a crescenteric ciliated lip on the other side.

Associated with excretion in sipunculans are peculiar cell c' ıstures called fixed and free urns (Fig. 5-25A). Fixed urns are clustures of peritoneal cells. Each lusture elevated like a vase and capped by a ciliated cell. The location of fixed urns on the peritoneum varies in different species. Free urns are fixed urns, which have become detatched from the peritoneum and move about in the coelomic fluid. The free urns moving in the coelomic fluid collect waste material. The waste material may be formed as a trailing aggregate which is eventually dumped in various places within the coelom. Or the waste material may be removed by the nephridia.

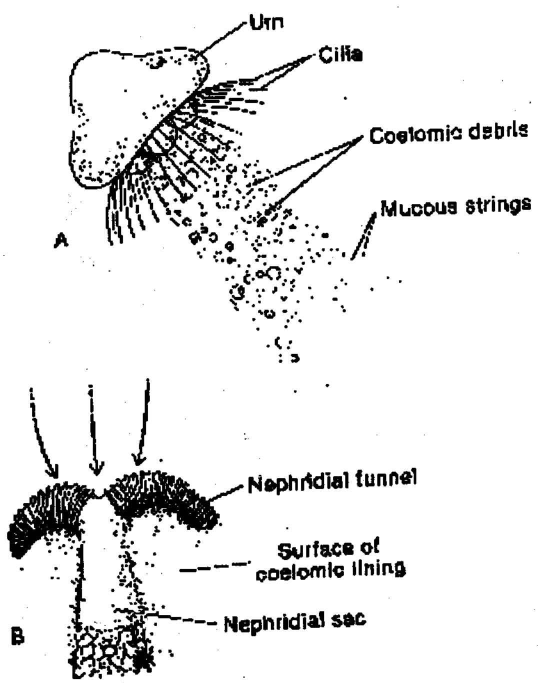


Fig. 5-25. Ciliated urn of *Sipunculus nudus*. B, Cilia on the coelomic lining of *Siphonosoma cumanense* direct fluid toward the ciliated funnel of each nephridium. The lower lip of the funell is attached to the coelomic lining, and the tree upper lip (shown) arches upward like a scoop.

5.3.10 NERVOUS SYSTEM

Nervous system is well developed. Nervous system is essentially similar to that of annelids. Nervous system consists of a brain and a single ventral nerve cord (Fig. 5-23A). The ventral nerve cord runs the length of the body mid ventrally. Metameric ganglionic swellings are absent in the ventral nerve cord. It gives off numerous lateral nerves oppositely or alternately or irregularly. Typically each lateral nerve passes into the muscle layer of the body wall. The nerve cord is covered by peritoneum.

5.3.11 SENSE ORGANS

Abundant sensory cells are particularly present on the end of the introvert that is used to probe the surrounding environment. In *Golfingia, Phascolosoma* and a few other genera, the dorsal end of the introvert bears a pair of ciliated pits, called nuchal organs, which may be chemo receptors. Also, a pair of pigment-cup ocelli are embedded in the brain of many species.

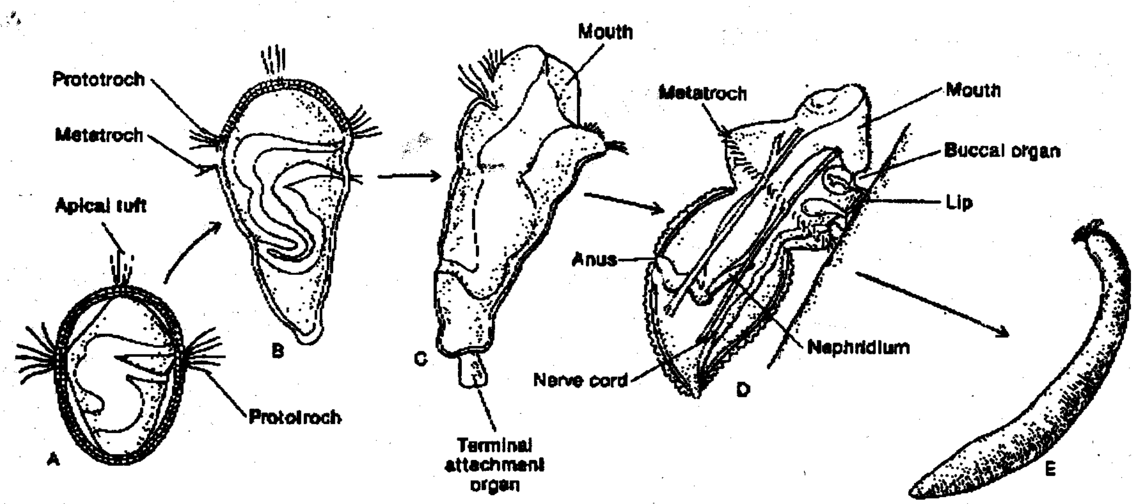


Fig. 5-26. In sipunculans, such as *Golfingia misakiana*, a feeding larva called a pelagosphera (C, D) succeeds the earlier nonfeeding trochophore (A, B). The pelagosphera eventually settles and crawls over the bottom on its lip. As it does so, the eversible buccal organ probes the substratum and may dislodge food particles to be ingested by the mouth. The head, lip, and metatrochal region (D) of the pelagosphera can be retracted into the trunk for protection. The peagosphera metamorphoses into a young sipunculan (E), Metamorphosis in this species requires approximately two weeks to complete.

5.3.12 REPRODUCTION AND DEVELOPMENT

Sipunculans are mostly dioecious. The ovaries and testes are simple masses of cells. The immature gametes, which arise from the peritoneum, are shed into the coelom. They undergo maturation in the coelom and complete their maturation in coelom. Ripe eggs and sperms leave the body by nephridial ducts which act as gonoducts. Fertilization is external. The fertilized eggs undergo spiral cleavage. Later development may be direct or lead to a trochophore larva (Fig. 5-26).

A typical trochophore appears in the life cycle of *Golfingia.* An elongated trochophore is seen in the life history of *Sipunculus.* The trochophore of *Golfingia* swims for one day and that of *Sipunculus* swims for a month. After the respective free swimming existence, metamorphosis occurs and the young worms sink to the bottom. In some species like *Phascolosoma agassizii* and *Sipunculus nudus,* the trochophore transforms to a planktonic stage called pelagosphaera. This planktonic stage is able to swim with its large ciliated metatroch. After a free swimming existence, it undergoes metamorphosis and transforms into adult.

Although sipunculans are not metameric animals, they are probably related to the annelids. The structure of body wall, the nature of the nervous system, and the embryology indicate that they are similar to annelids. Sipunculans perhaps diverged from the line of animals leading to the annelids. The point where they diverged may be the point before the development of metamerism.

5.3.13 SUMMARY

The Sipuncula is a small phylum of about 300 species.

These are unsegmented vermiform coelomates. Sometimes these are called peanut worms.

The length of the worms range form 2 mm to more than 72 cm. Most of the worms are less than 10 cm long.

All sipunculans are bottom dwellers.

Some such as *Sipunculus* burrow in sand and mud. Some live in annelidan tubes and empty molluscan shell. Some bore coralline rocks. Some live in coral crevices. Some live in mucus lined excavations. *Sipunculus* is an active burrower of sand and mud. *Phoscolion* lives in an empty molluscan shell. Species of *Aspidosiphon, Paraspidosiphon* and *Cloeosiphon* are the rock boring forms.

► In *Sipunculus,* the body is divisible into an anterior narrower section called introvert and a posterior cylindrical trunk. The introvert can be protracted outside and retracted inside the trunk.

At the anterior end of the introvert lies a number of ciliated tentacles or tentacular lobes. Tentacles are the extensions of the body wall. These are ciliated and are used in deposit feeding.

Mouth is present at the anterior end of the introvert.

Mouth lies below the tentacles or surrounded by tentacles or by tentacular outgrowths.

Body is covered by a distinct cuticle. The structure of body wall is like that of annelids.

A large spacious, non compartmented coelom is present throughout the trunk.

The hollow tentacles of the introvert are not connected to the coelom.

Most of the sipunculans are non selective deposit feeders.

Burrowing forms such as *Sipunculus* ingests sand and slit. Other species, which live in protective retreats, extend their introvert from the opening of the retreat. Detritus, which falls on the tentacles is driven to the mouth by the cilia.

The recurved, coiled digestive tract is 'U' shaped. The anus lies at the anterior end of the trunk.

Blood vascular system is absent.

Coelomic fluid serves in circulation.

Coelom contains cells bearing hemerythrin.

The tentacles serve as exchange organs.

Excretion is by a pair of large sac like one or two metanephridia. Peculiar cell clusters called fixed urns and free urns are also meant for excretion. Nephridiopores are present anteriorly. Free urns are the moving cell clusters. When the urns are loaded with nitrogenous waste material they may be dumped in the coelom or eliminated by nephridia.

Annelid type of nervous system consists of a brain and non ganglionated ventral nerve cord.

Sensory cells and nuchal organs are meant for chemoreception.

Sipunculans are dioecious. Immature gametes fall in the coelom. They undergo maturation in the coelom. External fertilization occurs. The fertilized egg undergoes spiral cleavage. A typical trochophore occurs in the life cycle of *Golfingia.* An elongated trochophore in *Sipunculus.* The trochophore undergoes metamorphosis to transform into a young worm.

The presence of trochophore larva clearly indicates a protostome relationship for the phylum *Sipuncula.* Body wall, nervous system and the embryogeny are said to be the annelidan characters found in sipunculans.

5.3.14 KEY TERMINOLOGY

Bottom dwellers: Living at the bottom.

Coelom: Body cavity lined by a mesodermally derived epithelium.

Coral crevices: Openings in corals.

Deposit feeders: Animals feeding upon detritus that settles to the bottom.

Hemerythrin: Respiratory pigment.

Metanephridium: A type of excretory organ, which opens into the coelom by a ciliated funnel or nephrostome and may open out by a nephridiopore.

Nuchal organs: Ciliated pits in the dorsal end of the introvert. They are chemo receptive in function.

Ocelli: Clusters of photoreceptors, i.e. simple eyes.

Pelagosphaera: A planktonic stage, which follows the trochophore. This larval stage is found in the life cycle of *Sipunculus nudus*.

Sedentary: Inactive, spending much time without moving.

Spiral cleavage: A type of cleavage in which the cleavage spindles are oriented obliquely with respect to the polar axis of the egg.

Trochophore larva: Type of larva found in annelids and mollusks. Characterized by sirates of cilia – prototroch, metatroch and telotroch.

5.3.15 SELF ASSESSMENT QUESTIONS

1. Describe the general organization of Sipunculans
2. Give an account of general characters of the Phylum Sipuncula.
3. Describe the coelom, digestive system and excretory system in Sipunculans.
4. Discuss the mode of cleavage and development in sipunculans.
5. Write short notes on:
    a. Introvert
    b. Nuchal organs
    c. Reproduction and development in sipunculans.

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5.4 GENERAL ORGANIZATION OF PHYLUM CHAETOGNATHA

5.4.1 OBJECTIVES

The purpose of this lesson is to:

- study the general characters of the Phylum Chaetognatha
- understand the phylogenetic relationship of chaetognaths
- know the systematic position of chaetognaths.

5.4.2 INTRODUCTION

The chaetognatha are small, bilaterally symmetrical animals. Chaetognaths are commonly found in marine plankton. The small, transparent coelomate animals darting about like arrows, which have given the popular name arrowworms. They exhibit perfect bilateral symmetry. The Phylum Chaetognatha consists of 70 species; all are reported from marine plankton except a single benthic genus, *Spadella.* All the members of the Phylum Chaetognatha are adapted to live in marine plankton. Adult chaetognaths are not similar to the deuterostome phyla. But the embryonic changes in chaetognaths would suggest that they are similar to some deuterostome phyla. The adults show characters similar to Aschelminthes in many ways.

5.4.3 EXTERNAL STRUCTURE

The shape of the arrowworms is almost like a torpedo or feathered dart. Majority of the arrow worms measure about 3 cm. Some of the worms attain a length of 10 cm (Fig.5-27). The body is elongated. It is composed of a small rounded head, trunk and postanal tail region. The head and trunk

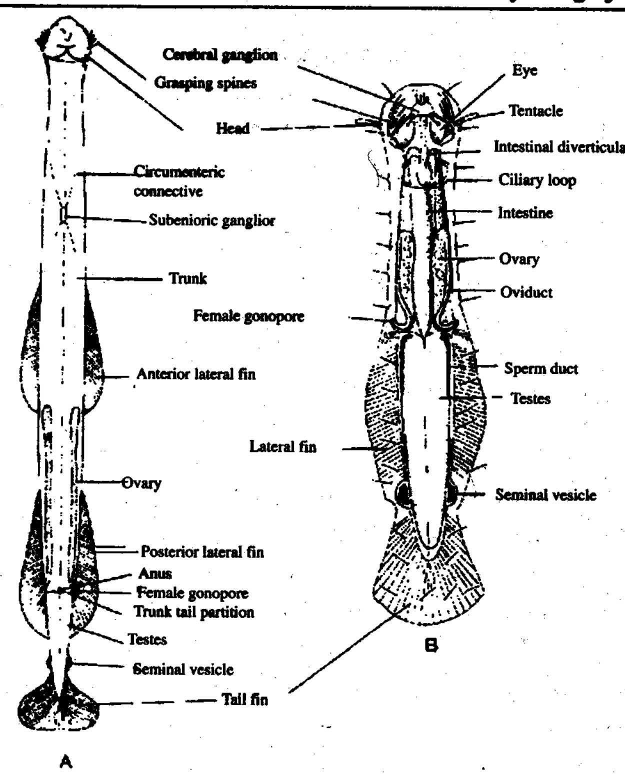

Fig. 5-27. Phylum Chaetognatha. A, *Sagitta elegans* (ventral view). B, *Spadella* (dorsal view).

are separated by a narrow neck. The mouth is a slit on the ventral side at the anterior end of the body. The ventral (underside) side of the head contains a large chamber (the vestibule), which leads into the mouth (Fig. 5-28).

On either side of the mouth is a lobe having several sickle shaped chitinous hooks or grasping spines, which are used in seizing prey. They serve as jaws. The name of the phylum has reference to the bristle-bearing jaws (Gk. *Chetae,* setae; *gnathos,* jaw). The number and arrangement of these

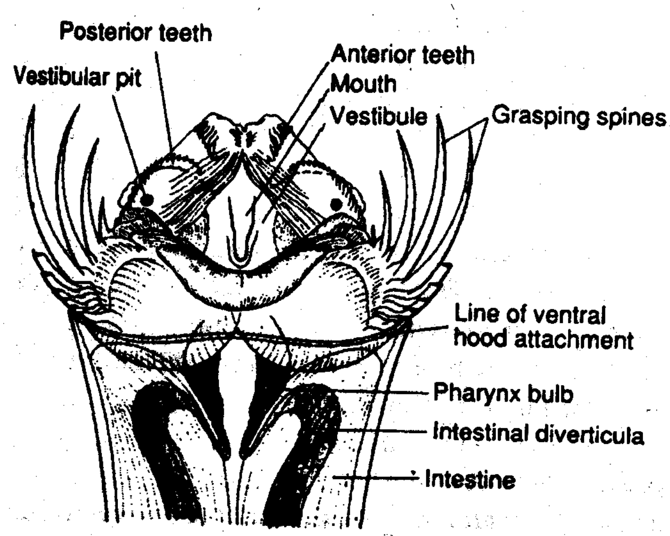

Fig. 5-28. Head of *Sagitta elegans* (ventral view).

jaws are of taxonomic importance. About 4 to 14 large, chitinous, curved spines hang from each side of the head. The curved spines are used in capturing prey. Additionally, many shorter spines are present in rows. The shorter spines are curved around the front of the head. These spines assist in capturing prey. The shorter spines are also called as teeth. The large spines and the teeth (shorter spines) are chitinous.

In the neck region a peculiar fold of body wall is present. It is called the hood. The hood can be pulled forward to cover the entire head. The hood protects both the head and spines. When the spines are not in use the hood serves as a protective device. The hood also reduces water resistance during swimming.

The neck is followed by an elongated trunk and tail. Chaetognaths are characterized by the presence of horizontal fins. The trunk and tail are bordered by fins. The fins, which border the lateral sides of the trunk, are called as lateral fins and the fin, which borders the tail, is called tail fin or caudal fin. Both the lateral and caudal fins are supported by fin rays. In some chaetognaths such as *Sagitta,* there are two pairs of lateral fins in the anterior and posterior half of the trunk and a caudal fin encircling the tail. In *Spadella,* there is one pair of lateral fins in the trunk region and a caudal fin in the tail region. In most species of arrow worms, a pair of lateral fins borders both the trunk and tail (Fig. 5-27). The fins serve for floatation and equilibrium rather than locomotion. The anus lies ventrally between the trunk and tail.

5.4.4 SENSE ORGANS

Two eyes are present posteriorly on the dorsal surface of the head. In addition to eyes, sensory hairs, a head region and the ciliary loop also serve as sense organs. Five fused pigment-cup ocelli are present in each of the two eyes at least in *Sagitta*. Sensory hairs have an internal ciliary structure. These are present in longitudinal rows along the border of the trunk on both the sides. The sensory hairs are able to detect water borne vibrations like that of the lateral line system in fish.The head organ or the ciliary loop possess 'U'-shaped tract of cilia. It extends from the head to the neck or to the anterior trunk at the back. The function of ciliary loop is till uncertain. Between the eyes is an olfactory organ composed of ciliated cells arranged in a ring.

5.4.5 BODY WALL

The body wall is composed of an outer, thin cuticle secreted by the epidermis. Below the cuticle lies a multilayered epidermis, which contains large vacuolated cells. Beneath the epidermis lies a thin basement membrane. The basement membrane is thickened to form fin rays to support caudal and horizontal fins. Inner to the basement membrane are a muscle layer and a coelomic lining. The muscles are primitive type like that of nematodes. The longitudinal muscles are arranged in the trunk in two dorsolateral and two ventrolateral bundles. Circular muscles are absent. The longer spines, the teeth, the hood and other structures of the hood are provided with special muscles for movement. The animal is able to move by the lateral movements of the body, brought about by the contractions of the muscles of the two sides. These muscles contract alternately.

5.4.6 COELOM

There is a spacious coelom in the trunk. Coelom is lined with coelomic epithelium. Coelom is divided into a right and a left half by vertical mesenteries and also into three sections by transverse septa. Coelom is compartmented. It resembles a pseudocoel because of the absence of peritoneum. The head contains a single coelomic space and the trunk bears a pair of coelomic spaces. The head coelom and the trunk coelom are separated by a head-trunk septum. Coelom also extends into the hood. The tail contains one or two coelomic spaces. But these spaces are believed to represent a secondary trunk coelom. The coelomic fluid acts as a circulatory medium. As the blood vessels are absent, the gut derived nutrients in the trunk coelom must diffuse across the trunk/tail, and trunk/head septa to supply the tail and head regions.

5.4.7 LOCOMOTION

The arrow worms are the active swimmers. They are able to swim and float with the fins. Fins act as floatation tools. When the animal starts sinking to the bottom, the longitudinal muscles of the body wall contract to push the animal forward. This forward motion is then followed by an interval of floating. The bottom dwelling *Spadella* attaches to the bottom objects. But it can swim for short distances.

5.4.8 FEEDING AND DIGESTION

All the arrow worms are carnivores. They feed on other planktonic animals such as copepods. The copepods can be detected from the vibrations of the water. *Sagitta* can consume a large fish. Other worms are able to consume large worms as large as themselves. Arrow worms are reported to be voracious feeders. For example, *Sagitta nagae* is able to consume 37 percent of its own weight on each day. During feeding, the hood is withdrawn and the large spines are spread outward. The prey is caught by the spines and its body is wounded with the teeth. The toxin, which is produced by vestibular pith, is injected into the wounds.

A simple digestive tract is present. The straight alimentary canal consists of a muscular pharynx, oesophagus, long intestine and an anus (Fig. 5-27). The mouth (oval or T-like shape) leads into a muscular tube, pharynx usually called the oesophagus. This expands posteriorly forming a bulb. The epithelial lining of the pharynx consists of secretory granular cells at its two ends. In between the granular cells are present secretory vacuolated cells.

The pharynx is bounded by head coelom laterally. Pharynx is covered by a thin layer of connective tissue. Just behind the bulb the pharynx passes through the head-trunk septum. The pharynx joins to a straight, long intestine, which opens by anus. Intestine runs through the length of the trunk. At the beginning of the intestine, a pair of lateral intestinal diverticula is present. These may extend forward to the head-trunk septum. Histologically intestinal caeca are identical with the intestine. The cuboidal or columnar epithelial lining of the intestine is composed of glandular and absorptive cells. The gland cells are present in abundant number in the anterior part of intestine. The gland cells are more or less vacuolated. The absorptive cells, more abundant in the posterior part of the intestine are granular, ciliated, columnar cells. The intestine is supported by dorsal and ventral mesenteries. These are the continuations of the basement membrane of the intestinal epithelium. The terminal part of the intestine may be called rectum. Histologically it differs from the remainder of the intestine. Anal aperture may not be governed by any special musculature. When the prey is captured with spines, it is pushed into the mouth. The pharyngeal secretions lubricate the prey in the mouth. From the pharynx food passes to the posterior of the intestine. The food is rotated, moved back and forth until it is broken down. Digestion occurs extracellularly in the posterior intestine.

5.4.9 GAS EXCHANGE ORGANS

There are no gas exchange organs.

5.4.10 EXCRETORY ORGANS

Specialized excretory organs are absent.

5.4.11 NERVOUS SYSTEM

In arrow worms, the nervous system consists of a pharyngeal nerve collar. The nerve collar appears like a nerve ring around the pharynx. The nerve ring contains a large cerebral ganglion dorsally and a number of lateral ganglia. Numerous nerves arise from these ganglia to innervate the more distal part of the body.

5.4.12 REPRODUCTION

Arrow worms are hermaphroditic. The female reproductive system consists of a pair of elongated ovaries. These are located in the trunk coelom in front of trunk tail septum (Fig. 5-27). The male reproductive system consists of a pair of testes. These are present behind the trunk tail septum. The testes are band like bodies in the anterior part of the tail coelom. They lie close to lateral walls and also extend slightly along the posterior face of the trunk – tail septum. Testes are covered by connective tissue.

The ovaries are a pair of solid elongated bodies. Ovaries are lying in the posterior part of the trunk coelom. As these are solid bodies they are found attached to the lateral body wall by a short mesentery. Eggs in various stages of ripening are found in the ovaries. Usually, ripe eggs are found in the ovaries. Usually, ripe eggs are found in the medial part of the ovaries. When medial part of the ovaries is filled with ripe eggs they press upon the intestine, forcing it into a laterally flattened shape. From each ovary a oviduct passes along the lateral side of the ovary and opens to the exterior through a female gonopore. Two female gonopores are located one on each side of the trunk just in front of the trunk tail septum.

From each testis a sperm duct runs posteriorly along the lateral side to end in a seminal vesicle of that side. The seminal vesicle lies in the lateral body wall. It is variously shaped. The shape of seminal vesicle is of taxonomic value.

When the reproductive organs mature, masses of spermatogonia are budded off from the testes into the tail coelom. Spermatogenesis or maturation of sperms is completed in the tail-coelom. The mature sperm then pass into the seminal vesicle. The sperms are formed into a single spermatophore in the seminal vesicle. Spermatophores come outside by rupturing the seminal vesicle. The sperms are filiform.

The egg begins to undergo maturation when spermatogenesis has commenced in the tail coelom. The ovaries mature after the tail coeloms are filled with sperm. A definite male gonopore is wanting.

In the benthic *Spadella*, two individuals cross each other with their heads in opposite directions. During this rapid movement, the male deposits spermatophore on the middle of the neck of female. The sperm stream comes out by breaking the spermatophore. The sperm stream runs backward along the midline of the female. The sperm stream eventually divided and the sperm enter the opening of the oviduct on each side. Thus sperm transfer is reciprocal in *Spadella.*

In some pelagic forms, spermatophore deposition has been reported. But details of sperm transfer are still not clear.

In *Sagitta,* the eggs are fertilized when they pass in the oviduct and come outside via gonopore. The eggs of *Spadella* are planktonic and are surrounded by a jelly coat. In other arrow worms, eggs may be adhered to body surface of the parent and carried about for sometime. *Spadella* deposits fertilized eggs in small clusters on algae or other subjects in water.

5.4.13 DEVELOPMENT

The *Sagitta* egg contains no evident yolk material, but the *Spadella* egg is provided with minute, uniformly distributed yolk granules. Fertilized eggs undergo radial, complete and equal cleavage. This cleavage results in a spherical coeloblastula. This coeloblastula consists of equal pyramidal cells radiating about a small central blastocoel. At the stage of about 50 blastomeres gastrulation occurs. It is a typical embolic gastrulation. The invaginating entoderm makes complete contact with the ectoderm. The blastocoel obliterates and a two walled gastrula is resulted. The blastopore marks the future posterior end of the chaetognath. Chaetognath stands as an example of early segregation of the germ cells. These germ cells become evident in the anterior wall of archenterons (opposite the blastopore), two germ cells in *Sagitta* and one cell in *Spadella.* These are the primordial germ cells. The primordial germ cells bulge from the ectoderm and soon detach, then lying free in the archenterons. The single cell of *Spadella* soon divides into two daughter cells. There now ensures the formation of coelom. Two folds appear in the anterior wall of the archenteron (Fig.5-29A). These folds progress backward, carrying with them the primordial germ cells. Eventually they meet the posterior wall of the archenteron. In the mean time the blastopore has closed completely. These folds

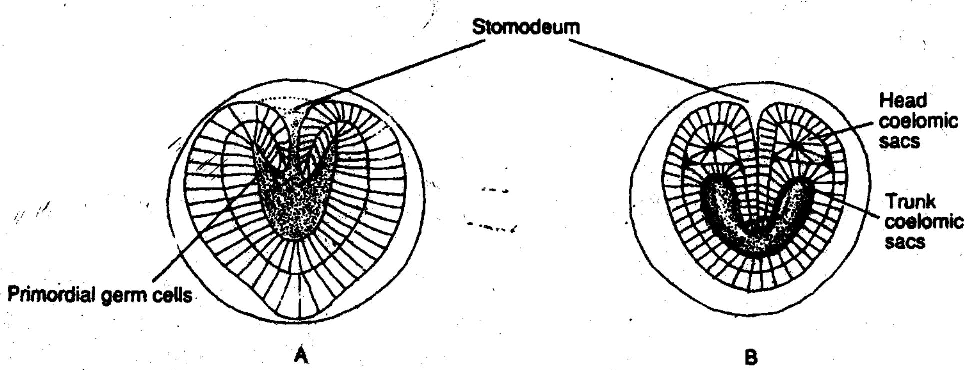

Fig. 5-29. Coelom formation in *Sagitta.* A, Initial folding of archenteron walls. B, Separation of head coelomic sacs.

mark of a central tube, the intestine. In the meantime a stomodaeal invagination has occurred at the anterior end of the embryo. The stomodaeal invagination meets and fuses with the intestine, establishing the definitive mouth and pharynx. Gastrulation occurs by invagination. As in the lower chordates, the invaginating mesentoderm fits closely against the outer ectoderm and disturbs the blastocoel. Then the anterior end wall of the archenteron invaginates folding backward on each side. During this process, 2 pairs of lateral coelomic small head spaces are separated (Fig.2-29 B). Thus the coelom is enterocoelic in origin. Later, the development of embryo is direct. When the young hatch, they are called larvae. They are similar to adult in all aspects.

Though adult chaetognaths show similarities to aschelimnthes, the embryogeny of the phylum appears to be deuterostome in nature. However, there are some peculiar characters. In chaetognaths, coelom originated enterocoelously. Coelom does not arise by a direct out pocketing of the archenteron. Only two pairs of coelomic pockets are formed instead of three. In chaetognaths there is no larval stage, which can be compared to the larvae of echinodermata and hemichordata. Thus, chaetognaths are not similar to any specific deuterostome phylum.

5.4.14 SUMMARY

The chaetognaths are small, bilaterally symmetrical enterocoelous marine animals.

The chaetognaths, called arrow worms are common marine planktonic animals.

The phylum includes about 70 known species.

A singe benthic genus *Spadella* has been described.

Adults are like aschelminthes in many respects.

The embryogeny of chaetognaths would suggest a deuterostome position.

The torpedo shaped body bears one or two pairs of horizontal lateral fins and a caudal fins. The fins are employed in swimming and floating.

The body is divided into a head, a trunk and a post anal tail region. A narrow neck separates the head and trunk.

Both larger and short spines are present on either side of the body. The spines assist in capturing the prey. Planktonic animals are seized using grasping spines located on either side of the head.

Chaetognaths are carnivorous and feed on other zooplankton.

Organs of gas exchange, excretion and internal transport are absent.

Chaetognaths are hermaphroditic with two ovaries and two testes.

Internal fertilization occurs via spermatophore.

Development of the fertilized egg is planktonic and direct.
Although the young are called larvae when they hatch, they are similar to adults.

5.4.15 KEY TERMINOLOGY

Archenteron: The embryogenic gut formed during gastrulation.

Bilateral symmetry: The upper side of the body (dorsal side) is different from the lower (ventral side) so that only one plane of symmetry divides the body into mirror-image halves.

Blastocoel: The fluid filled embryonic cavity beneath the germ layers. The embryonic connective tissue compartment.

Blastopore: Primary opening of the archenteron to the exterior of the embryo.

Coeloblastula: Blastula having an internal cavity or blastocoel.

Coelom: Body cavity lined by a mesodermally derived epithelium.

Direct development: No larval stage in the course of development.

Enterocoel: Coelomic cavity formed from an out pocketing of the embryonic archenterons.

Gonoduct: In male or female reproductive system, it is the principal duct for the passage of sperm or eggs.

Gonopore: External opening of any reproductive system.

Hermaphroditic: Having both male and female reproductive systems in the same individual.

Invagination: During development this refers to the in folding of the cells of vegetal hemispheres to form archenteron.

Pelagic: Living floating or swimming in the water column above the bottom.

Peritoneum: The innermost non-contractile layer of a stratified coelomic epithelium; separates the coelomic fluid from the musculature.

Plankton: Small plants and animals suspended in sea water (marine plankton) and in the water of streams and lakes (fresh water plankton).

Radial cleavage: Type of cleavage pattern in which the cleavage spindles or cleavage planes are at right angles or parallel to the polar axis of the egg.

Seminal vesicle: Part of the male reproductive system, which functions as storing organ of sperm.

5.4.16 SELF ASSESSMENT QUESTIONS

1. Write about the general characters of the phylum Chaetognatha.
2. Write an account of external structure and reproduction of the phylum Chaetognatha.
3. Discuss the detailed account of internal structure and physiology of phylum Chaetognatha.
4. Write short notes on:
   i) External structure of *Sagitta*
   ii) Coelom in chaetognaths
   iii) Sense organs in chaetognaths
   iv) Embryogeny in arrow worms

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Course	**Year**	**Paper No. & Title**
M.Sc.	Ist Year	Paper - II : Systematics and Anatomy of Invertebrates

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