B.Sc. ZBC-105

# NON-CHORDATES

DIRECTORATE OF DISTANCE EDUCATION

SWAMI VIVEKANAND
**SUBHARTI UNIVERSITY**
Meerut (National Capital Region Delhi)

# NON-CHORDATES

**B.Sc. ZBC-105**

**Self Learning Material**

उत्तिष्ठत जाग्रत प्राप्य वरान्निबोधत

**Directorate of Distance Education**

**SWAMI VIVEKANAND SUBHARTI UNIVERSITY**
**MEERUT–250 005**
**UTTAR PRADESH**

*SLM module developed by :*
Vandna Garg

***Reviewed by :***
Dr. R.A. Sultana

***Assessed by :***
Study Material Assessment Committee, as per the SVSU ordinance No. VI (2)



Published by : Pragati Prakashan, 240 W.K. Road, Meerut – 250 001
Tel. 2640642, 2643636, 6544643, E-mail : pragatiprakashan@gmail.com

Typeset at : Pragati Laser Type Setters Pvt. Ltd., Meerut Printed at : Arihant Electric Press, Me

**EDITION : 2021**

# Syllabus

## First Year : First Semester
## Non-Chordates
## Course Code : B.Sc. ZBC–105

**Objectives:** To acquire the basic concept of animal world, Identification classification of animal of diffeent phylum and detail account of few animals as an example of each phylum.

**Unit 1 : Protista, Parazoa**

General characteristics and outline Classification up to classes

Study of *Euglena, Paramecium,*

Life cycle and pathogenicity of Plasmodium vivax and

Locomotion and Reproductionin Protista

**Unit 2 : Porifera Cnidaria**

General characteristics and Classification up to classes, Canal System and Spicules in sponges, Metagenesis in *Obelia,* Polymorphism in *Cnidaria*, Coral and coral reefs.

**Unit 3 : Platyhelminthes Nemathelminthes**

General characteristics and Classification up to classes

Life cycle and pathogenicity of, *Fasciola hepatica, Taenia solium* and *Ascaris lumbricoides,* Parasitic adaptations in helminthes.

**Unit 4 : Annelida Arthropoda**

General Characters and classification up to classes, Excretion in Annelida, Vision in Arthropoda

**Unit 5 : Mollusca and Echinodermata**

General Characters and classification up to classes, Torsion and detorsion in Gastropods, Pear Formation in Bivalves, Evolutionary significance of Trochophore larva, Water vascular system in asteroideean, Larva forms.

# CONTENTS


| | | |
|---|---|---|
| 1. | Protista, Parazoa | 1 |
| 2. | Porifera Cnidaria | 54 |
| 3. | Platyhelminthes Nemathelminthes | 80— |
| 4. | Annelida Arthropoda | 111— |
| 5. | Mollusca and Echinodermata | 136— |

# UNIT I

# 1

# PROTISTA, PARAZOA

**STRUCTURE**

- General characteristics and outline Classification up to classes
- Study of *Euglena, Paramecium*
- *Life cycle and pathogenicity of Plasmodium vivax* and
- Locomotion and Reproduction in Protista

## • DEFINITION

Protozoa may be defined as microscopic and acellular animalcules, without tissues and organs, having one or more nuclei, but no nucleus ever in charge of a specialized part of cytoplasm. They exist either single or incolonies which differ from a metazoan in having all the individuals alike except when engaged in reproductive activities.

## • GENERAL CHARACTERS

1. Small, usually **microscopic** animalcules, ordinarily not visible without a microscope.

2. Simplest and most **primitive** of all animals, with protoplasmic grade of organization.

3. Body **unicellular**, containing one or more nuclei which are monomorphic or dimorphic.

4. **Solitary** or forming loose **colonies** in which individuals remain alike and independent.

5. Body symmetry none, bilateral, radial or spherical.

6. Body **naked** or bounded by a **pellicle** and often provided with simple to elaborate **shells** or **exoskeletons**.

7. Body form usually constant, varied in some, while changing with environment or age in many.

8. The single cell body performs all the essential and vital activities, which characterize the animal body; hence only subcellular **physiological division of labour**.

9. Locomotor organelles are finger-like **pseudopodia** or whip-like **flagella** or hairlike **cilia** or absent.

10. Nutrition **holozoic** (animal-like), **holophytic** (plant-like), **saprozoic** or **parasitic**. With or without definite oral and anal apertures. Digestion occurs intracellularly inside food vacuoles.

11. Respiration and excretion through general surface or thr contractile vacuoles, which serve mainly for **osmoregulation**.

12. Reproduction **asexual** by binary or multiple fission and bud and **sexual** by conjugation of adults (hologamy) or by fusion of gam (syngamy).

13. Life history often complicated with alternation of asexual and se phases.

14. **Encystment** commonly occurs to help in dispersal as well as to r unfavourable conditions of food, temperature and moisture.

15. **Free-living** Protozoa mostly aquatic, inhabiting fresh and waters and damp places. **Parasitic** and **commensal** Protozoa live ov inside the bodies of animals and plants. Sufficient moisture is essential in environment.

16. The single-celled individual not differentiated into somatoplasm germplasm; therefore, exempt from natural death which is the price pai the body.

17. About 50,000 known species.

## • CLASSIFICA

Phylum Protozoa is a large and varied group and poses a numbe problems in its classification. The conventional scheme followed by **Hy** (1940), **Hickman** (1961) and **Storer** (1965) etc. recognizes 2 subphyla or basis of organs of locomotion and 5 classes, briefly outlined as follows :

### Subphylum A. Plasmodroma

Locomotory organelles are flagella, pseudopodia, or none, Nuclei of one kind.

**Class 1. Mastigophora,** Move by one to many flagella. Ex. *Euglena*.

**Class 2. Sarcodina,** Move and capture food by pseudopodia. Ex. *Amoeba*.

**Class 3. Sporozoa,** No locomotory organs. All parasitic. Spore-formation common *Plasmodium*.

### Subphylum B. Ciliophora

Cilia or sucking tentacles throughout or at certain stages. Nuclei of 2 kinds.

**Class 4. Ciliata,** Move by cilia throughout life. Ex. *Paramecium*.

**Class 5. Suctoria,** Move by cilia as young and by tentacles as adult. Ex. *Podophyra*.

The following classification of Protozoa is based on the scheme given by Committee on Taxonomy and Taxonomic Problems of the Society Protozoologists, and mainly proposed by **B.M. Honigberg** and others (196 divides Protozoa first into 4 subphyla : (1) **Sarcomastigophora**, **Sporozoa**, (3) **Cnidospora**, and (4) **Ciliophora**. Only important orders been mentioned here.

### Subphylum I. Sarcomastigophora

Locomotor organelles pseudopodia or flagella or both. Nuclei of one (monomorphic).

***Superclass A. Mastigophora (=Flagellata)***

1. Simple, primitive, with firm pellicle.
2. Locomotor organelles flagella.
3. Nutrition autotrophic or heterotrophic, or both.

**CLASS 1. Phytomastigophorea (= Phytoflagellata)**

1. Chlorophyll-bearing chromatophores present.
2. Nutrition mainly holophytic by phototrophy.
3. Reserve food starch or paramylon.
4. Flagella 1 or 2, sometimes more.

**Order 1. Chrysomonadida**

1. Small, with thin pellicle, often amoeboid. Flagella 1 to 3.
2. Gullet absent. Stigma often present.
3. Chromatophores 1 or 2, yellow or brown, and discoidal.
4. Starch absent. Leucosin and fats may be present.

   Examples : *Chrysamoeba, Synura, Ochromonas, Dinobryon.*

**Order 2. Cryptomonadida**

1. Small, with a rigid pellicle. Flagella 2.
2. Anterior gullet reaches up to middle of body.
3. Chromatophores 2, yellow, brown or colourless.
4. Reserve foodstuff starch, sometimes oils. Examples : *Chilomonas, Cryptomonas.*

**Order 3. Euglenida**

1. Large, pellicle thick and firm. Flagella 1 or 2.
2. Anterior end with a gullet leading into a reservoir.
3. Chromatophores numerous, green or colourless.
4. Reserve foodstuff paramylon and oils.

   Examples : *Euglena, Peranema, Phacus, Copromonas.*

**Order 4. Volvocida (= Phytomonadida)**

1. Small, with rigid cellulose covering (theca).
2. No gullet. Flagella 2 to 4.
3. Chromatophore green, usually cup-shaped.
4. Reserve foodstuff starch and oils.

   Examples : *Chlamydomonas, Volvox.*

**Order 5. Chloromonadida**

1. Small, dorso-ventrally flat. Pellicle delicate.
2. Gullet present.
3. Chromatophores green and numerous.
4. Reserve foodstuff oils.

   Examples : *Vacularia, Coelomonas, Gonyostomum.*

**Order 6. Dinoflagellida**

1. Small, planktonic. Naked, amoeboid or with a thick cellulose theca.
2. Gullet present or absent. Flagella 2.
3. Chromatophores yellow or brown.
4. Reserve foodstuff starch or oils or both.
5. Some are bioluminescent.

   Examples : *Noctiluca, Ceratium.*

**CLASS 2. Zoomastigopohrea (= Zooflagellata)**

1. Chlorophyll or chromatophores absent. Mostly parasitic.
2. Nutrition holozoic or saprozoic.
3. Reserve food glycogen.
4. Flagella one to many.

**Order 1. Rhizomastigida**

1. Small, amoeboid, chiefly freshwater.
2. Locomotion by 1-4 flagella and pseudopodia.

   Examples : *Mastigamoeba, Dimorpha.*

**Order 2. Kinetoplastida**

1. No gullet. Kinetoplast present.
2. Flagella 1 to 4. No definite pellicle.
3. Mostly parasitic forms living in blood.

   Examples : *Bodo, Leishmania, Trypanosoma.*

**Order 3. Choanoflagellida**

1. A collar round the base of a single flagellum.
2. Free-living, solitary or colonial.

   Example : *Proterospongia.*

**Order 4. Diplomonadida**

1. Bilaterally symmetrical, binucleate, with delicate pellicle and oft with a cytostome.
2. Flagella 3 to 8. One often trailing or forming border or an undulati membrane.
3. Mostly intestinal parasites.

   Examples : *Hexamita, Giardia.*

**Order 5. Hypermastigida**

1. Highly specialized, numerous flagella.
2. Kinetosomes arranged in a circle, plate or longitudinal or spiral row
3. Mouth absent. Food ingested by pseudopodia.
4. Gut parasites of termites and cockroaches.

   Examples : *Lophomonas, Trychonympha.*

**Order 6. Trichomonadida**

1. Flagella 4 to 6. One flagellum trailing.
2. Parasites of vertebrates.

Example : *Trichomonas.*

***Superclass B. Opalinata***

1. Entire body covered by cilia-like flagella.
2. Nuclei 2 to many, monomorphic.
3. Reproduction by symmetrogenic binary fission or by syngamy of anisogametes.
4. Parasitic mainly in frogs and toads.

Examples : *Opalina, Zelleriella.*

***Superclass C. Sarcodina (=Rhizopoda)***

1. Body mostly amoeboid without definite pellicle. Some with a skeleton of some kind.
2. Locomotion by pseudopodia.
3. Nutrition holozoic or saprozoic.

**CLASS 1. Rhizopodea**

Pseudopodia as lobopodia, filopodia or reticulopodia, without axial filaments.

***Subclass (a) Lobosia***

Pseudopodia as lobopodia.

**Order 1. Amoebida**

1. Body amoeboid, naked, without skeleton.
2. Nucleus with honeycomb lattice.
3. Largely freshwater and free-living. Many parasitic.

Examples : *Amoeba, Entamoeba, Pelomyxa.*

**Order 2. Arcellinida (= Testacida)**

1. Body enclosed in one-chambered shell of pseudochitin, with a single opening through which lobopodia protrude.
2. Free-living, mostly freshwater.

Examples : *Arcella, Difflugia, Euglypha.*

***Subclass (b) Filosia***

Pseudopodia as filopodia. Naked or with a shell with single aperture.

Examples : *Allogromia, Penardia* (naked).

***Subclass (c) Granuloreticulosia***

Pseudopodia delicate granular reticulopodia.

**Order Foraminiferida**

Large sized with uni- or multichambered calcareous shell with one or more openings through which reticulopodia emerge.

Examples : *Globigerina, Elphidium (=Polystomella)*

**CLASS 2. Actinopodea**

Pseudopodia mainly axopodia with axial filaments, radiating from spherical body.

***Subclass (a) Heliozoia***

1. Spherical protozoans, called sun-animalcules.
2. Pseudopodia (axopodia) radiating.
3. Naked or skeleton of siliceous scales or spines.

   Example : *Actinophrys, Actinosphaeriuri.*

***Subclass (b) Radiolaria***

1. Body naked or with perforated chitinoid central capsule separating ectoplasm from endoplasm.
2. Reticulopodia, axopodia or filopodia.
3. Skeleton mostly of siliceous spicules or of strontium sulphate.

   Examples : *Collozoum, Thalassicola.*

***Subclass (c) Acantharia***

1. Imperforate non-chitinoid central capsule without pores.
2. Skeleton of strontium sulphate.
3. Pseudopodia are axopodia.

   Example : *Acanthometra.*

***Subclass (d) Proteomyxidia***

1. Pseudopodia are filopodia.
2. Mostly parasites on algae.

   Example : *Vampyrella, Pseudospora.*

**CLASS 3. Piroplasmea**

Small parasites in red blood cells of vertebrates.

Example : *Babesia* (formerly included with Sporozoa, but its species do not produce spores).

**Subphylum II. Sporozoa**

Locomotor organelle absent. Spores usually present. Exclusively endoparasites.

**CLASS 1. Telosporea**

Spores without polar capsules and filaments, naked or encysted.

***Subclass (a) Gregarinia***

1. Mature trophozoites large, extracellular in host's gut and body cavities.
2. Each spore produces 8 sporozoites.
3. Parasites in invertebrates.

   Examples : *Monocystis, Gregarina.*

***Subclass (b) Coccidia/Apicomplexa***

1. Mature trophozoites small and intracellular.

2. Each oocyst produces many sporozoites.
3. Blood or gut parasites of vertebrates.

Examples : *Eimeria, Isospora, Plasmodium.*

**CLASS 2. Toxoplasmea**

Spores absent. Only asexual reproduction.

Example : *Toxoplasma.*

**Class 3. Haplosporea**

Spore cases present. Only asexual reproduction.

Example : *Ichthyosporidium.*

**Subphylum III. Cnidospora**

Spores with polar filaments present.

**CLASS 1. Myxosporidea**

1. Spores large, developed from several nuclei.
2. Spores with two or three valves.
3. Parasites mostly in fishes.

Examples : *Myxidium, Myxobolus, Ceratomyxa.*

**CLASS 2. Microsporidea**

1. Spores small, developed from one nucleus.
2. Spores with a univalved membrane.
3. Intracellular parasites in arthropods and fishes.

Example : *Nosema.*

**Subphylum IV. Ciliophora**

Presence of cilia as locomotor and feeding organelles at some stage in the life cycle. Nuclei of 2 kinds (dimorphic).

**CLASS Ciliata (= Infusoria)**

1. Locomotor organelles numerous hair-like cilia, present throughout life.
2. Definite mouth (cytostome) and gullet present except in a few parasitic forms. Anal aperture (cytopyge) permanent.
3. One or more contractile vacuoles present even in marine and parasitic types.
4. Mostly two kinds of nuclei, large *macronucleus* and smaller *micronucleus*.

***Subclass (a) Holotricha***

1. Body cilia simple and uniform.
2. Buccal cilia mostly absent.

**Order 1. Gymnostomatida**

Large ciliates without oral ciliature. Cytostome opens directly. No vestibule.

Examples : *Coleps, Didinium, Prorodon, Dileptus.*

**Order 2. Trichostomatida**

With vestibular but no buccal ciliature.

Examples : *Balantidium, Colpoda.*

**Order 3. Chonotrichida**

No body ciliature. A spirally coiled apical funnel contains vestibular cilia.

Examples : *Spirochona, Lobochona.*

**Order 4. Apostomatida**

Spirally arranged body cilia. Cytostome midventral.

Example : *Hyalophysa.*

**Order 5. Astomatida**

Body ciliation uniform. Cytostome absent.

Examples : *Anoplophyrya, Maupasella.*

**Order 6. Hymenostomatida**

Body ciliation uniform. Buccal cavity ventral with ciliary membranes.

Examples : *Colpidium, Paramecium.*

***Subclass (b) Peritricha***

1. Adult without body cilia.
2. Apical end with buccal cilia.

**Order : Peritrichida**

Examples : *Vorticella, Carchesium.*

***Subclass (c) Suctoria***

1. Sessile and stalked body.
2. Young with cilia, adult with suctorial tentacles.

**Order : Suctorida**

Examples : *Acineta, Ephelota, Podophyra.*

***Subclass (d) Spirotrichia***

1. Reduced body cilia.
2. Buccal cilia well marked.

**Order 1. Heterotrichida**

Body cilia short. Uniform or absent.

Examples : *Stentor, Bursaria, Spirostomum.*

**Order 2. Oligotrichida**

Body cilia reduced or absent. Buccal membranes conspicuous.

Examples : *Strombidium, Halteria.*

**Order 3. Hypotrichida**

Dorso-ventrally flattened. Fused cilia forming ventral cirri.

Examples : *Euplotes, Stylonchia.*

## • EUGLENA VIRIDIS

There are a large number of small protozoans which move with the help of one or more whip-like structures, called **flagella**. All these unicellular organisms are included in the superclass **Mastigophora** (Gr., **mastix**, whip + **pherein**, to bear) or **Flagellata** (L., **flagrum**, a whip). The flagellates are either **plant-like** typically having chlorophyll-bearing plastids, the **chloroplasts** or **chromatophores**; or **animal-like**, with no such plastids. The former are **autotrophic** due to their capacity to synthesize organic food by photosynthesis, whereas the later are **heterotrophic** as they utilize pre-synthesized food of their environments. These two groups of flagellates belong to two separate classes : **Phytoflagellata** or **Phytomastigophorea** and **Zooflagellata** or **Zoomastigophorea**, respectively.

*Euglena* is a typical example of Mastigophora. It is a phytoflagellate as it possesses both chloroplasts as well as flagella. It is autotrophic in sunlight, but becomes heterotrophic in dark. Because of its two-fold nutritional abilities, it is usually studied as a plant as well as an animal. This plant-animal organism is important as it serves as a key organism in research on photosynthesis, chloroplast structure, photoreception and flagellar activity. The species of *Euglena* which is commonly used for classroom study is *Euglena viridis*.

As the name implies, *Euglena viridis* is a green organism with an eye-like photoreceptive structure (Gr., **eu**, true + **glene**, eyeball or eye pupil + L., **viridis**, green).

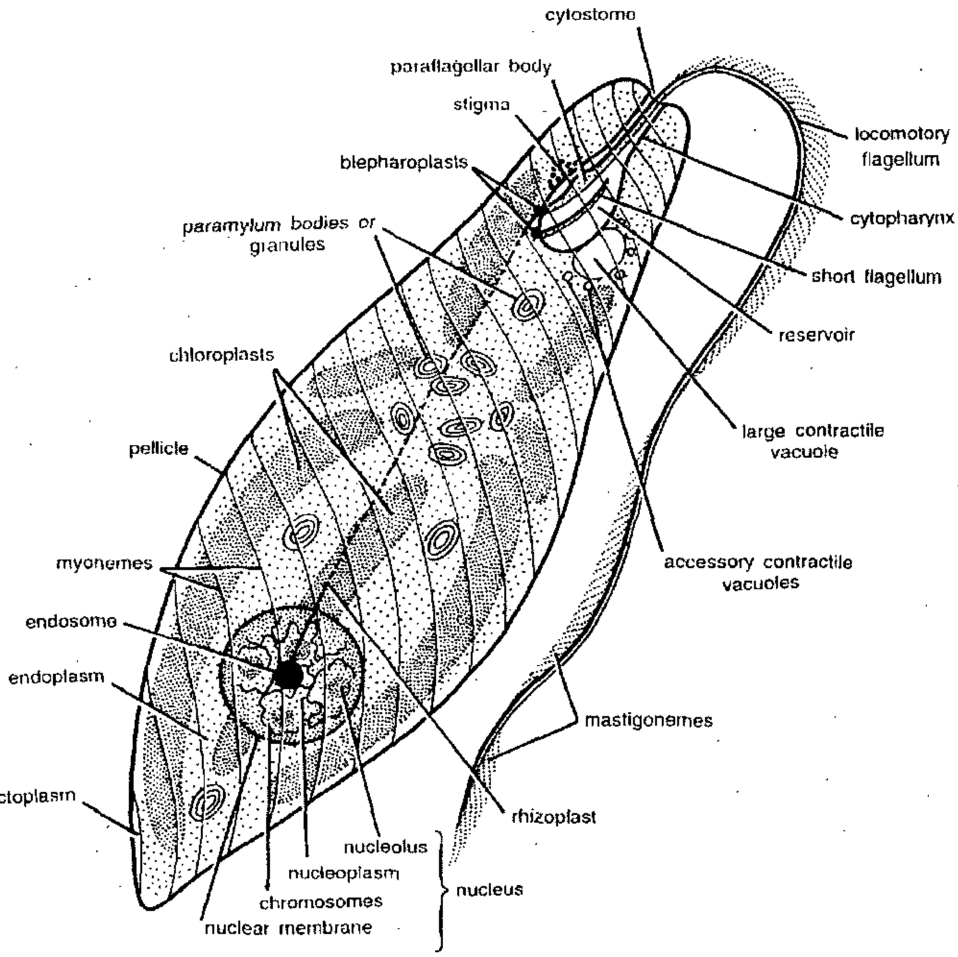



**Fig. 1.** ***Euglena viridis.***

### Systematic Position

| | |
|---|---|
| **Phylum** | Protozoa |
| **Subphylum** | Sarcomastigophora |
| **Superclass** | Mastigophora |
| **Class** | Phytomastigophorea |
| **Order** | Euglenida |
| **Genus** | *Euglena* |
| **Species** | *viridis* |

### Habits and Habitat

*Euglena viridis* is a solitary and free-living freshwater flagellate. It occurs in freshwater ponds, pools, ditches and slowly-running streams, where there is a considerable amount of vegetation. It is fairly active and often found at various depths below the surface of water. Ponds in well-maintained gardens containing decaying nitrogenous organic matter, such as faeces of animals leaves, twigs, etc., are good sources of this organism. Sometimes it is so abunda that the water appears green in colour and it seems as if a film of scum is present on the pond surface.

## • CULTURE OF EUGLENA

*Euglena* can be cultured and studied easily in the laboratory. An easy way to prepare a culture is to fill clean and wide-mouthed large bottles with boiled tap or pond water and then add 20 boiled wheat grains to each bottle. Keep these bottles in a sunny place for a week. Wheat grains may be added monthly to maintain the culture.

Another method is to prepare a culture of *Euglena* in manure solutions. Horse or cow manure is boiled in pond or distilled water. These manure solutions are allowed to stand 36 to 48 hours and then inoculated with euglenae. In the laboratory, the euglenae grow and multiply well in a jar exposed to indirect sunlight.

If kept in dark or if grown in such a media which is rich in certain organic nutrients, some photosynthetic species of *Euglena* will lose their chlorophyll and will resemble like the genus *Astasia*. Irreversible loss of chlorophyll can be induced by the treatment of Streptomycin at a higher than normal temperature. Results of such experiments shows that members of the genus *Astasia* and perheps of some other colourless genera have been derived secondarily from photosynthetic species.

## • STRUCTURE

1. **Shape and size.** E. *viridis* is a small microscopic organism measuring about 60μ (microns) in length. The body is elongated and spindle shaped. The anterior end is rounded or blunt, the middle part is somewhat wider and the posterior end is pointed. From the anterior end arises a whip-like flagellum which is seen moving when *Euglena* is progressing forward.

2. **Pellicle.** The body of *Euglena* is enveloped by a distinct, thin, elastic, tough **pellicle** which lies beneath the plasma membrane. It is flexible enough to permit movements. It is made of protein, and not cellulose, so that it is not homologous to plant cell wall. Electron microscopy has revealed that the pellicle consists of thin, firm, elastic and helically disposed **strips**. These pellicular strips fuse at both the ends of the cell body and each bears a groove along one edge and a ridge along the other. The edges of adjacent strips overlap and articulate along their entire length in such a way that the ridge of one fits into the groove of the other. Under the light microscope, these articulating

edges appear as striations, called **myonemes**. Beneath the pellicle are present a row of mucus-secreting **muciferous bodies** and bundles of **microtubules**.

3. **Cytoplasm.** The pellicle encloses the cytoplasm which is divisible into two zones :

***(a) Ectoplasm.*** It is the clear dense narrow peripheral zone containing microtubules and muciferous bodies.

***(b) Endoplasm.*** It is the more fluid-like granular central zone containing the nucleus and several types of inclusions.

4. **Reservoir.** At the blunt anterior end of the body, there is an invagination foming a permanent flask-shaped cavity. It consists of a wide **reservoir** or **flagellar sac** which leads through a short tubular canal, the **cell gullet** or **cytopharynx**, to outside. Its external opening is called the **cell mouth** or **cytostome**. The reservoir is lined by plasma membrane without pellicle beneath it. The names 'cytostome' and 'cytopharynx' are misnomer because *Euglena* does not ingest solid food.

5. **Flagellum.** At the anterior end of the body, a single thread-like flagellum arises through the cytostome. Typically it is made of an axial elastic filament or **axoneme**, covered by a protoplasmic sheath.

Electron microscopy has revealed that the flagllum is not just one but paired, the other being smaller and confind within the reservoir. The two flagella originate from two tiny granules, the **blepharoplasts** (Gr., **blepharon**, eyelid + **plastos**, formed) or **kinetosomes** which lie embedded in the cytoplasm near the base of the reservoir. The long flagellum bears a lateral swelling, the **paraflagellar body**, near its base within the reservoir. This body acts as a photoreceptor and probably contains lactoflavin as sensitizer.

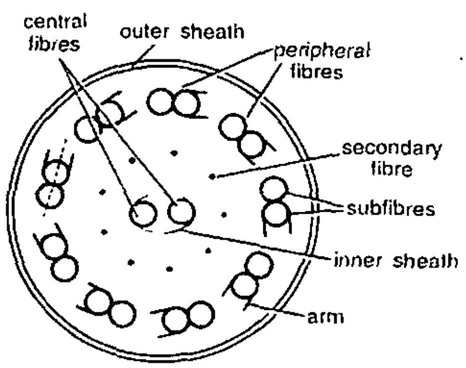



**Fig. 2. *Euglena*, T.S. flagellum (diagrammatic).**

Each flagellum consists of **2 central** and **9 peripheral fibres**. The central fibres are enclosed in an inner membranous sheath. Each central fibre is single, whereas the peripheral fibres are paired, that is, each made of two **sub-fibres**. Of each peripheral fibre, one of the two sub-fibres bears a double row of short projections, or **arms**, all pointing in the same direction. The whole flagellum is enveloped by an outer sheath which is continuous with the plasma membrane. In the space between the peripheral and central fibres lie **9 secondary fibres** which are somewhat inconspicuous. Along the side of the bundle of fibrils runs a rod-like structure. On the long axis of the flagellum is found a unilateral row of hair-like contractile processes, called **mastigonemes**. According to the investigation of **Manton** (1959), these processes arise laterally from two of the nine peripheral fibres. This type of flagellum is known as **stichonematic**.

6. **Nucleus.** A single, large, sphercial or oval, vesicular nucleus lies near the centre of endoplasm, usually towards the posterior end of the body. It contains a large solid central body or nucleolus of chromatin, called **endosome** or

**karyosome**. Its function remains controversial. The nuclear membrane is double membrane which is perforated by pores. According to electron microscope, the nucleoplasm contains several nucleoli and a large number granular and thread-like chromosomes.

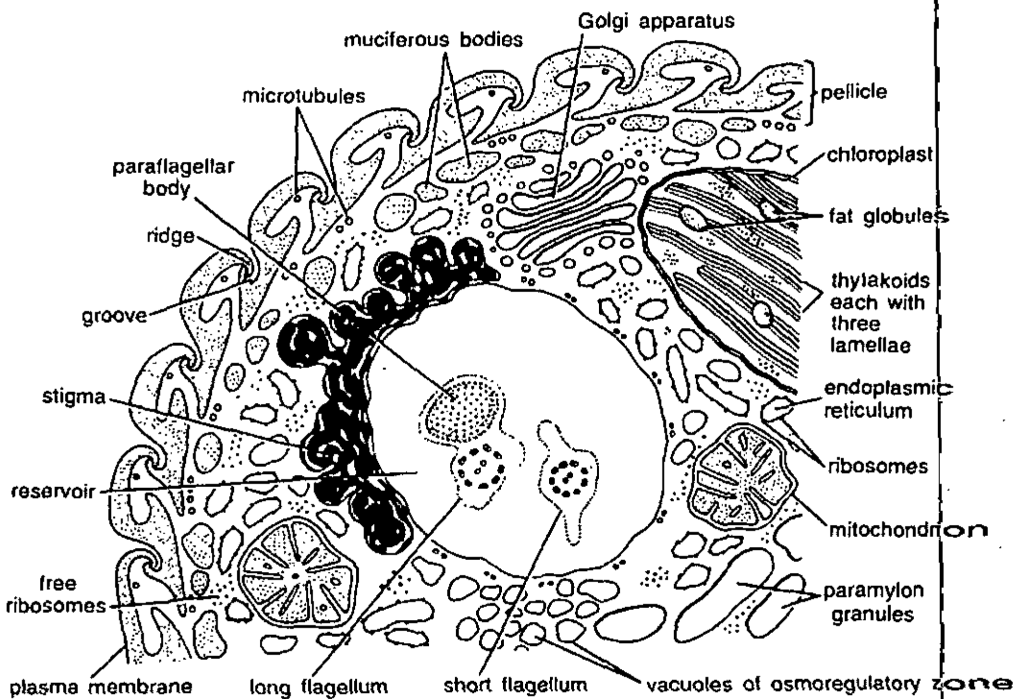



**Fig. 3.** ***Euglena*. An electron micrograph (diagrammatic) of a portion of the T.S. body, passing through the reservoir.**

7. **Contractile apparatus.** Associated with the reservoir occurs dense osmoregulatory zone. It includes a large central contractile vacuole. It is surrounded by several smaller accessory vacuoles, which probably fuse together to form the larger vacuole. These vacuoles play a role in the discharge of water along with some waste products of metabolism to outside, via the reservoir, cytopharynx and cytostome.

8. **Stigma.** Lying near the reservoir, on side opposite to that of contractile vacuole, is a discoid or shallow cup-shaped red pigment spot, the **eye-spot** or **stigma**. According to **Leedale** (1966), the stigma is composed of plate of lipid droplets, each charged with a red pigment, the **carotenoid**.

The stigma and the paraflagellar body together form a photoreceptor apparatus. When *Euglena* is moving toward light, the receptor is illuminated. The stigma evidently serves as a shield. When it changes direction, the shadow of pigment falls on the receptor. *Euglena* orients itself in such a way that the photoreceptor is continuously exposed. Thus, the animal, which depends upon sunlight for photosynthesis, can orient itself towards light.

9. **Endoplasmic inclusions.** Besides contractile apparatus and stigma, the endoplasm has other important inclusions which are as follows :

***(a) Chromatophores or chloroplasts.*** Suspended in cytoplasm are a number of green bodies, the **chromatophores** or **chloroplasts**, they give the *Euglena* its green colour because they contain the green pigments, chlorophyll a and b, along with β-carotene. Chloroplasts of *E. viridis* are slender and radiate from a central point so as to form a star-shaped grouping. In the centre of each ıloroplast is a single proteinaceous **pyrenoid**, which is probably the centre ›r the formation of a starch-like substance, called **paramylum**.

A chloroplast contains groups of chlorophyll-bearing lamellae or **ıylakoids,** each with three lamellae. These are placed in the **matrix** or **troma**, also containing ribosomes and fat globules. Each chloroplast is ·ounded by a triple membrane envelope (**Sleigh**, 1973).

***(b) Paramylon.*** The endoplasm contains several small free oval ranules of paramylon or paramylum which is a polysaccharide (β-1, 3 glucan) imilar to starch but not identical with it, as it is not coloured blue with iodine olution. It is produced by photosynthesis and represents reserve food ıaterial. These Paramylum bodies may be so numerous that they interfere /ith the observation of the chloroplasts. If *Euglena* is kept in dark for several ays, the granules for paramylum become less and the chloroplasts are more asily seen.

***(c) Other cytoplasmic structures.*** The cytoplasm contains other ubcellular organelles as well. The **Golgi bodies** are piles of large flattened acs with minute vesicles pinching off from them. The **endoplasmic eticulum** is in the form of small interconnecting tubules and vesicles. The **ıitochondria** are with tubular cristae and are more in number near the ·eservoir. The **ribosomes** occur scattered freely in the endoplasm and also on ·he endoplasmic reticulum and in the chloroplasts.

## • LOCOMOTION

*Euglena viridis* performs two different kinds of movements : (1) **flagellar**, nd (2) **euglenoid**.

### [I] Flagellar Movement

*Euglena* swims freely in water with the help of single, long locomotory ·lagellum. During swimming, the flagellum is directed obliquely backward owards the side bearing the stigma. It undergoes spiral undulations, with /aves, that are transmitted from the base to the tip, causing its beating or the ideways lashing. The flagellum beats, on an average, at the rate of 12 beats ·er second. The beating of flagellum drives water backward and induces the /hole body to move forward. Each beat not only throws the body forward but lso to one side. Thus, when the beats are repeated over and over, the *Euglena* evolves in circles or **gyrates**. As the flagellum is directed obliquely backward o the long axis of the body, the organism also **rotates** on its axis. It has been alculated that *Euglena* rotates at the rate of one turn per second.

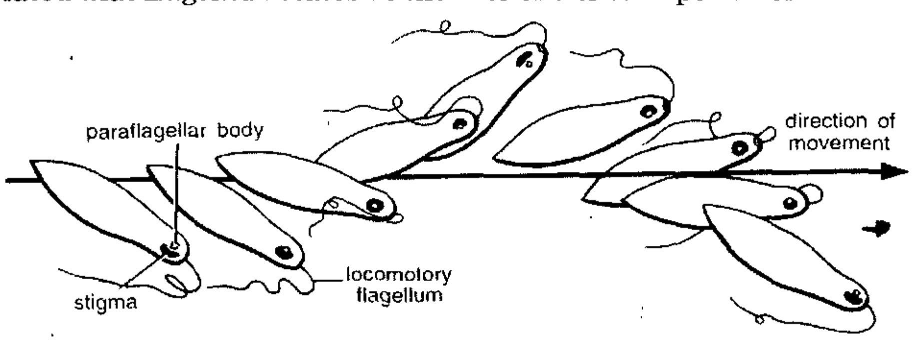



**Fig. 4. *Euglena*. Successive stages in the flagellar movement.**

Movement of a flagellum involves contraction of its nine peripheral fibres (Fig. 2). Their positi ideal for the undulating actions as they could exert bending around the flagellar axis. The energ the contractile action of fibres is supplied by ATP (adenosine triphosphate) formed in mitochondria, which are included in the blepharoplasts. The function of mastigonemes, prese the flagellum of *Euglena*, is not yet known.

### [II] Euglenoid Movement

The pellicle possesses considerable flexibility that enables *Euglen* perform peristaltic activity. This activity brings about worm-like wrigglin writhing movements while the animal creeps on the bottom. As the perist waves pass, the body becomes shorter and wider first at the anterior end, in the middle and later at the posterior end. This characteristic movem found in *Euglena* or some other Protozoa, is commonly known as the **eugle** or **metabolic movement**.

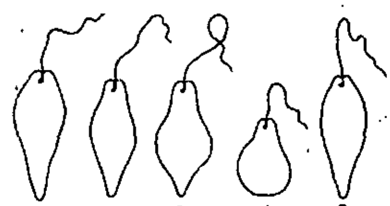



**Fig. 5.** ***Euglena*. Successive stages in euglenoid movement.**

During the euglenoid movement, the adjacent pellicular strips bend move against one another, probably the ridge of one sliding in groove of other. The sliding of the ridges in the grooves is lubricated by the secretio underlying muciferous bodies.

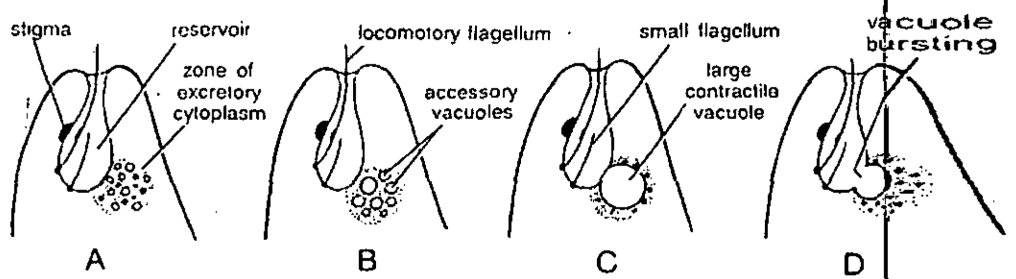



**Fig. 6.** ***Euglena*. Successive stages of diastole and systole of contractile vacuole during excretion and osmoregulation.**

## • NUTRIT

In *E. viridis*, nutrition is **autotrophic** or **holophytic** as well **saprophytic**. Such a dual mode of nutrition is frequently referred t **mixotrophic**. There is no evidence of animal-like or **holozoic** nutritio *Euglena*.

### [I] Holophytic or Autotrophic Nutrition

The chief mode of nutrition in *Euglena* is **holophytic** or **autotrophic**. T is, like green plants, it can manufacture its own food, in the presenc sunlight, by the process of **photosynthesis** with the aid of the chlorop present in the chloroplasts., The chlorophyll absorbs energy from sunli With this energy water reacts with $CO_2$ in a series of steps forming a he sugar. This is then transferred into a kind of polysaccharide, ca **paramylum** or **paramylon**. It differs from the true starch in that it does become blue with iodine solution. It is stored up for future use either scattered in the form of refractile granules in the endoplasm, or deposited around one or more proteinaceous bodies, the **pyrenoids**. Paramylon is found more abundantly in well-fed individuals.

### [II] Saprophytic or Saprozoic Nutrition

In prolonged darkness, *Euglena* loses its chlorophyll and green colour. It becomes **etiolated**, that is, becomes pale or white, yet it continues to live and perform all the life activities. In the absence of sunlight, *Euglena* lives by the **saprophytic** or **saprozoic** method, which means the products of decaying organic substances dissolved in surrounding water are absorbed through its general body surface. It seems that *Euglena* secretes digestive enzymes that are typically animal-like in nature.

Generally, the chloroplasts lost in dark are regained in the light. But in *E. gracilis*, the change is permanent; the lost chloroplasts can never be recovered.

**Pinocytosis** has also been observed to take place at the base of the reservoir for the intake of proteins and other large molecules.

## • RESPIRATION

*Euglena* respires with the help of free oxygen dissolved in water, which diffuses in through the pellicle. This oxygen brings about oxidation reactions catalysed by enzymes present in the mitochondria. The energy so liberated is entrapped in the high energy phosphate bonds of ATP, which supplies energy for metabolic activities. As a result of oxidation reactions, water and $CO_2$ are formed as by-products. In sunlight, it is likely that this $CO_2$ is utilized for photosynthesis, but in dark it is liberated to outside by diffusion through the general body surface.

## • OSMOREGULATION AND EXCRETION

The osmoregulatory function, that is, the removal of excessive water entering into the body by endosmosis, is performed by an anteriorly placed **contractile apparatus**. Outer pellicle is permeable to surrounding water, which continues to enter into euglena's body by endosmosis which is the result of differential concentration of body protoplasm and surrounding freshwater. In *E. viridis*, the contractile apparatus consists of a large contractile vacuole surrounded by numerous small accessory vacuoles. The cytoplasm secretes the excessive water into these smaller vacuoles which, in thier turn, drain into the larger vacuole. It is also likely that the accessory vacuoles are first formed which when fully extended, fuse together forming the larger vacuole. The larger vacuole finally empties into the reservoir. The process involves the **diastole** (increase in volume) and **systole** (decrease in volume) of the large contractile vacuole. In diastole, the contractile vacuole is filled with water, while in systole it is emptied to throw its watery content into the reservoir. It is believed that the postero-lateral wall of the contractile vacuole, adjacent to the reservoir, is very unstable and it bursts at the systole.

Ammonia, the nitrogenous waste product, resulting from catabolism, passes out by diffusion through the general surface of the body. Excretory substances may also be emptied by the contractile vacuole into the reservoir. It has been suggested that the dense zone of cytoplasm around the contractile apparatu both **osmoregulatory** and excretory in function. It secretes water as well excretory products into the lumen of the vacuole.

## • BEHAVIOU

*Euglena* reacts to a variety of stimuli in the same manner as other Protoz do.

### [I] Reaction to Light

It avoids strong light as well as shady areas, but reacts positively to moderately intense light such as that from a window. Like most motile a free-living uni-cellular organisms containing chlorophyll, it orients its parallel to a beam of ordinary light and swims towards the source illumination. In a dish containing culture, most of the individuals are found aggregate on the side towards the light. If the dish is placed in direct sunlig and one half of it is covered, the organisms avoid the region of direct sunlight well as the shade but gather in between the two in a small band (Fig. 7).

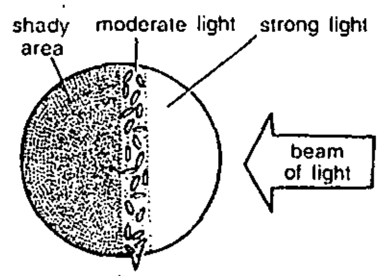



**Fig. 7. *Euglena* showing reaction to light.**

### [II] Shock Reaction

Investigations of Mast and his pupils have clearly revealed the part play by the photoreceptive stigma in the orientation of *Euglena*. Being positive phototactic, *Euglena* swims towards the source of light. It adopts a spir course, rotating and gyrating around its body axis so that the paraflagell

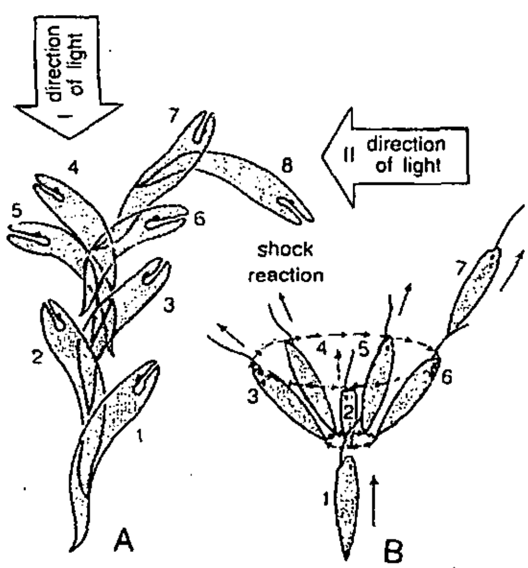



**Fig. 8. *Euglena*. A. Positions 1-4, when moving towards I direction of light. Position 5, in shock reaction. Positions 6-8, when moving towards II direction of light. B. Avoiding reaction on a trial and error pattern.**

body remains continuously exposed to light and uniformly illuminated. However, if the front source of light is screened and a new lateral beam of light is thrown, then *Euglena* produces a **shock reaction** and, by **trial** and **error**, reorients itself towards the new source of light. This shock reaction is explained as follows :

When the stigmal side of body faces a lateral beam of light, the paraflagellar body is shaded by the stigma once in each rotation. Thus, the base of flagellum is alternately darkened and illuminated in lateral light. Each darkening of the paraflagellar body excited its photoreceptor to produce a minor shock reaction. This effects flagellar action in such a way that the body bends at right angles, turning the flagellar end gradually towards the new light source. Light being essential for photosynthesis, this specialization brings the animal into light which is of sistinct advantage in its nutrition.

### [III] Avoiding Reaction

*Euglena* also responds to mechanical, thermal and chemical stimuli showing an **avoiding reaction** on a **trial** and **error** pattern (**phobotaxis**). In most cases the animal slows down, stops or even moves backwards. The posterior end of the body may act as a pivot, while the anterior end traces wider circles of gyrations and swims forward in a new spiral path.

## • REPRODUCTION

There is no evidence of sexual reproduction in *E. viridis*. It multiplies a sexually by **binary** and **multiple** fissions and undergoes **encystment**.

### [I] Binary Fission

Transverse binary fission is unknown in *Euglena*. Under favourable conditions of water, temperature and food availability, Euglena divides by a simple **longitudinal binary** fission. The longitudinal division is always **symmetrogenic**, that is, the parental *Euglena* divides into two daughter individuals, where one is the plane mirror image of the other. First the nucleus divides into two by **mitosis** which is followed by the division of cytoplasm **(cytokinesis)**. The unusual feature which is observed in nuclear division is the persistence of nuclear membrane. In **prophase stage**, all the nucleoli (endosomes) fuse together into a single **nucleolar body** and each chromosome splits longitudinally into two daughter chromosomes or **chromatids**. In **metaphase stage**, the paired chromatids come to lie in a longitudinal plane. The microtubules are present in nucleus but they do not form a spindle. In **anaphase stage**, the paired chromatids separate and move towards their respective poles. It has been suggested that the movement of chromatids is autonomous, with mutual repulsion. The nuclear membrane begins to constrict longitudinally. In the **telophase stage**, constriction in nuclear membrane deepens and finally separates the nucleus into two daughter nuclei. The nucleolar body also splits into two halves, each taking its place in the daughter nucleus of its own side. Next follows the **cytokinesis**. A longitudinal furrow appears in the cytoplasm, beginning at the anterior end, which deepens and finally divides *Euglena* into two daughter euglenae.

Organelles of the anterior end, such as the reservoir, Cytopharynx, Cytostome, flagella, stigma and contractile vacuole duplicate by the formation of a new set of these structures. However, a new set of flagella arises from basal bodies which appear in the vicinity of old basal bodies. Multiplicatio basal bodies usually precedes cell division.

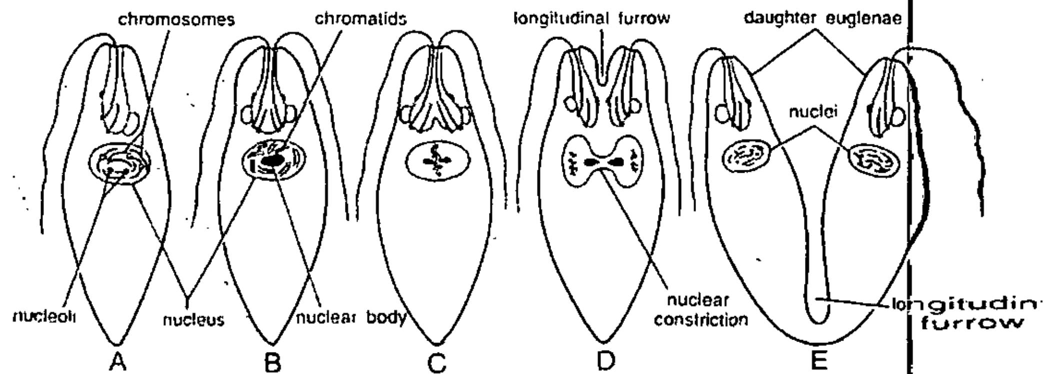



**Fig. 9.** ***Euglena*****. Stages of longitudinal binary fission. A. Interphase. B. Prophase. C. Metaphase. D. Anaphase. E. Telophase and Cytokinesis.**

### [II] Multiple Fission and Palmella Stage

Under inactive periods, *Euglena* undergoes multiple fission in an ency condition. Movement ceases altogether, flagellum is thrown off and *Eug* becomes rounded and embedded in an extensive, thick and mucilaginous or **cyst** which is secreted by the muciferous bodies. Encystment is usu followed by repeated longitudinal binary fissions with the formation of sev daughter individuals (16 or 32), embedded within a mucilaginous mass. daughter individuals within the mucilaginous mass secrete their mucilaginous coats or cysts. This resembles the palmella stage of many sl such as *Chlamydomonas*. Later these daughter individuals acquire flagella escape to grow into adult euglenae.

**• ENCYSTM**

Encystment takes place as a protective measure to tide over unfavour conditions such as the lack of food and oxygen, draught, excessive heat, et cyst-wall is secreted in the form of a thick, spherical, yellowish brown gelatinous covering, composed of a special carbohydrate. In different specie *Euglena*, cyst may be thick (2-4 layered), stalked or operculated with organism lying centrally or eccentrically in it. The encysted animal not successfully withstands the averse conditions of life, but also enjoys a far wide dispersal. When the conditions become favourable, the animal beco active and emerges from the cyst to resume its normal free-swimming life ( 10).

As already stated above, the individual may undergo a single or sev divisions, resulting in two or many new individuals (**palmella stage**).

### *Euglena* as an Animal

*Euglena* is studied as an animal as well as a plant. It is more an animal t a plant because of the following reasons :

1. Absence of a cellulose cell-wall overlying the plasma membrane.
2. Presence of centrioles forming the blepharo-plasts or kinetosomes.
3. Reserve food is paramylon which is not a true starch.

4. Presence of paraflagellar body, a sensory (photoreceptive) organelle.
5. Moves from place to place like an animal.
6. Responds to various stimuli like an animal.
7. Pinocytosis and Probably holozoic nutrition takes place.

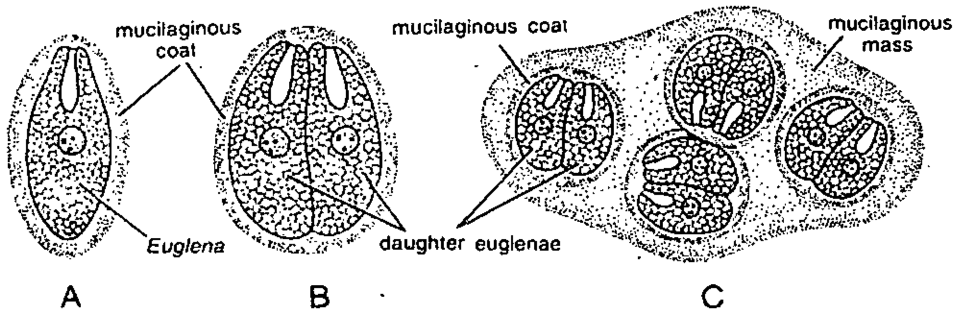



**Fig. 10. *Euglena*. Multiple fission and encystation. A. Encysted individual. B. Fission in encysted conditions. C. Palmella stage.**

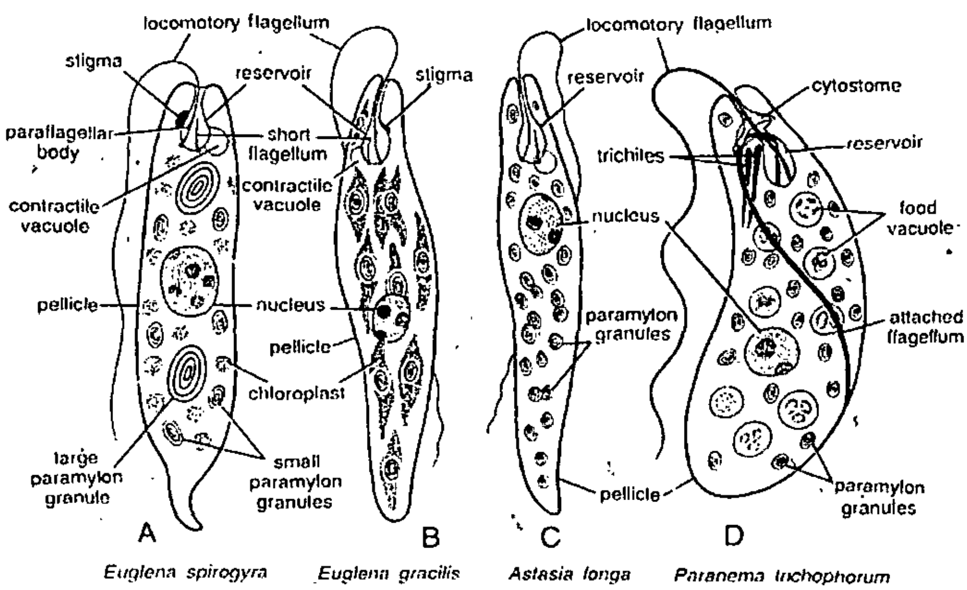



**Fig. 11. Some euglenoid flagellates.**

## OTHER EUGLENOID FLAGELLATES

**1. *Euglena spirogyra*.** It is a large *Euglena*, about 100μ long with a spindle-shaped body. Posterior end of body is somewhat tail-like. Chloroplasts are numerous, small and discoid. Pyrenoids are wanting. There are two large and many small paramylon bodies scattered in the cytoplasm.

**2. *Euglena gracilis*.** It is a small *Euglena* about 50μ long. with a spindle-shaped body. Chloroplasts are about 10 in number, large, flat and plate-like each with a proteinaceous pyrenoid. Once in darkness for a few days, the Chloroplasts are bleached off permanently and the chlorophyll does not appear again. Cytoplasm contains many paramylon bodies, each attached to a chloroplast.

**3. *Astasia longa*.** It is a euglenoid flagellate, which feeds by osmotrophy in the absence of chloroplasts. Stigma and the paraflagellar body are also wanting. Cytoplasm contains numerous small free paramylon bodies. Zoologists believe that *Astasia longa* is the bleached form of *E. gracilis*.

**4. *Paranema trichophorum*.** It is another euglenoid flagellate which is holozoic and feeds by phagotrophy upon quite large organisms. Of the two flagella, one is long and locomotory, while the other is trailing and adhered to the body surface. The stigma and paraflagellar body are absent. Cytopharynx or gullet bears an accessory rod apparatus, the **trichites**, for puncturing the body wall of a large prey. Cytoplasm contains food vacuoles and numerous small free paramylon bodies.

## • PARAMECIUM CAUDATUM : THE SLIPPER ANIMAL

Protozoa which move with the help of **cilia** are called **ciliates** an included in the subphylum *Ciliophora*. Besides the possession of locomotor organelles, all ciliates possess two types of nuclei, **macronu** and **micronucleus** (nuclear dimorphism), and a unique form of s reproduction (**conjugation**). *Pramecium* is a typical ciliate genus conta about 10 known species differing in shape, size and structure. The la species, *P. caudatum*, has a single comparatively large and co micronucleus with chromatin material scattered throughout the nucleop It occurs widely and abundantly. P. aurelia has two micronuclei wh *multimicronucleatum* has many micronuclei. *P. bursaria* is green d presence of symbiotic alga, **zoochlorella**. In the following text, the biolog *caudatum* is treated in detail.

### Systematic Position

| | |
|---|---|
| **Phylum** | Protozoa |
| **Subphylum** | Ciliophora |
| **Class** | Ciliata |
| **Subclass** | Holotricha |
| **Order** | Hymenostomatida |
| **Suborder** | Peniculina |
| **Genus** | *Paramecium* |
| **Species** | *caudatum* |

### Occurrence

*Paramecium caudatum* (Gr., **paramekes**, oblong + L. **caudata**, tail) i of the most common species of *Paramecium* having worldwide distribution found in freshwater ponds, pools, ditches, streams, rivers, lakes, reservoir It is usually abundant in those waters which contain a great deal of dec organic matter. It thrives well in ponds or slowly running streams conta aquatic plants. The paramecia often gather near the surface in scum, bu usually seen actively swimming throughout the water in which they live.

## • CULTURE OF PARAME

*Paramecium* is easily grown in wide mouthed jars with glass covers, three-quarter filled with t pond water or Chalkey's medium (NaCl 80 mg, $NACO_3$ 4mg, KCl 4mg, $CaCl_2$ 4mg, C $(PO_4)2H_2O$ 1.6 mg, dissolved in one litre of distilled water), and with 7-12 drops of skimmed added weekly. The jars are kept away from direct light to allow bacteria to flourish which ser food for the multiplying paramecia.

## • EXTERNAL STRUCT

### [I] Size

*Paramecium* is a microscopic, elongated organism which is visible t naked eye as a whitish or greyish spot. Its species vary in length from 8 350 μ. *P-caudatum*, the largest species, measures between 170 μ. and 290 μ greatest diameter of the cylindrical body is about two-third of its entire le *P. aurelia* is about 120 μ to 250 μ long. Usually the individuals of the species may exhibit minor morphological and physiological differe

Jennings was able to find in one species of *Paramecium* eight races differing in total length and size.

### [II] Shape

*Paramecium* is often described as slipper shaped, cigar-shaped or spindle-shaped. Its shape is usually constant and in general asymmetrical.

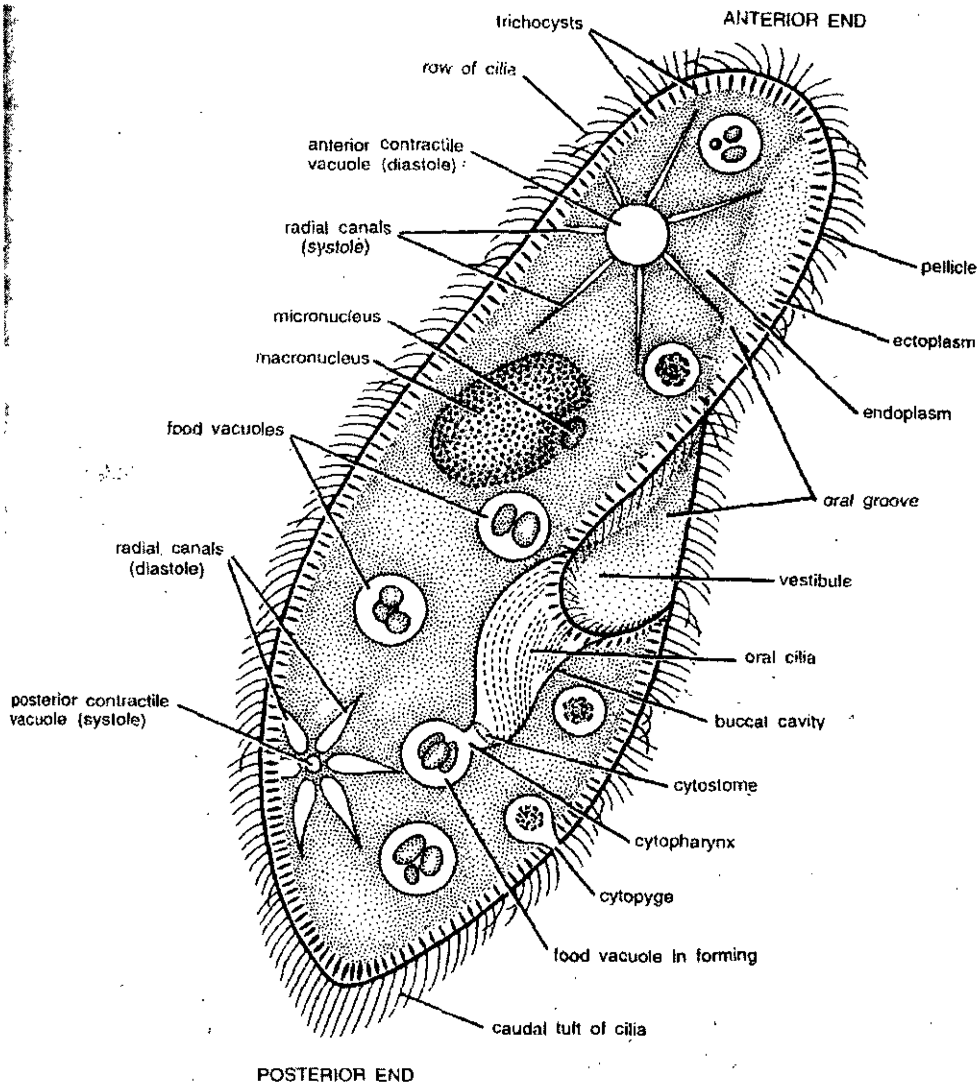



**Fig. 12. *Paramecium caudatum*.**

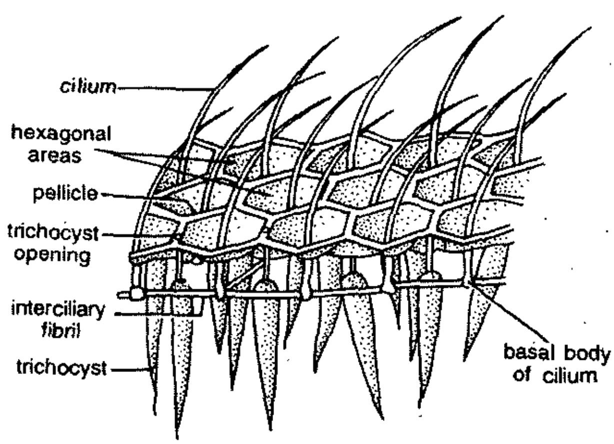



**Fig. 13. *Paramecium*. Diagrammatic surface view of a small area of pellicle.**

Because of its slipper-like shape, the *Paramecium* is sometimes called the **slipper animalcule**. Joblot assigned the name 'chausson' to *P. caudatum* which means slipper-shaped animalcule. The body is elongated, blunt and rounded at the anterior end and somewhat pointed at the posterior end. In cross section, it is circular with greatest diameter behind the centre of body. The anterior half of body is slightly twisted. The body is distinguished into an oral or ventral surface and an aboral or dorsal surface.

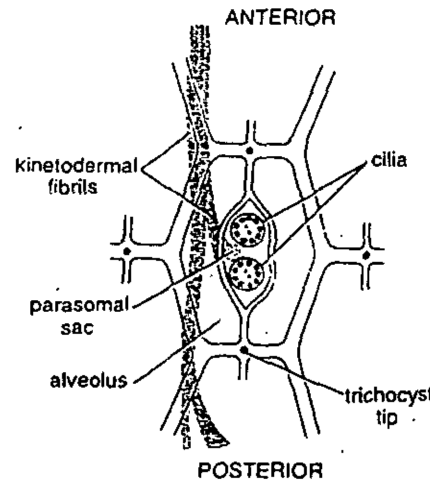



**Fig. 14.** ***Paramecium.*** **Diagram of a hexagonal area or ciliary field.**

### [III] Oral Groove

Ventral surface of body bears a prominent, oblique and shallow depression called **oral groove**. It originates from the middle of body and extends to the left side of anterior end. Posteriorly, the oral groove leads into a deeper conical **vestibule** which in turn communicates with a **buccal cavity** having a basal mouth or **cytostome**.

### [IV] Pellicle

External envelope of body is a living, clear firm and elastic cuticular membrane, the **pellicle**. When stained specimens are observed under light microscope, the pellicle appears to be a regular series of polygonal (or hexagonal) depressions with their raised rims. A single cilium emerges out from the middle of each polygon or circumciliary space. Electron microscopic studies by **Ehret** and **Powers** (1959) have revealed that the polygons are defined by a corresponding regular series of cavities, the **alveoli**. In fact, it is the pit in the centre of each **alveolus** which forms a polygon. All the alveoli collectively form a continuous alveolar layer, which is delimited by an **outer alveolar** and **inner alveolar membrane**. The outer alveolar layer lies in close contact beneath the outer cell membrane (not shown in the diagram). Thus, the pellicle of *Paramecium* includes a series of three membranes : (i) outer cell membrane, (ii) outer alveolar membrane, and (iii) inner alveolar membrane.

### [V] Cilia

The entire body surface is covered by numerous, tiny, hair-like fine projections, called **cilia.** These measure 10-12 μ in length and 0.27 μ in diameter. As already stated, one cilium (2 in *P. bursaria*) arises from the centre of each polygonal depression (circumciliary space) of pellicle. There are 10,000

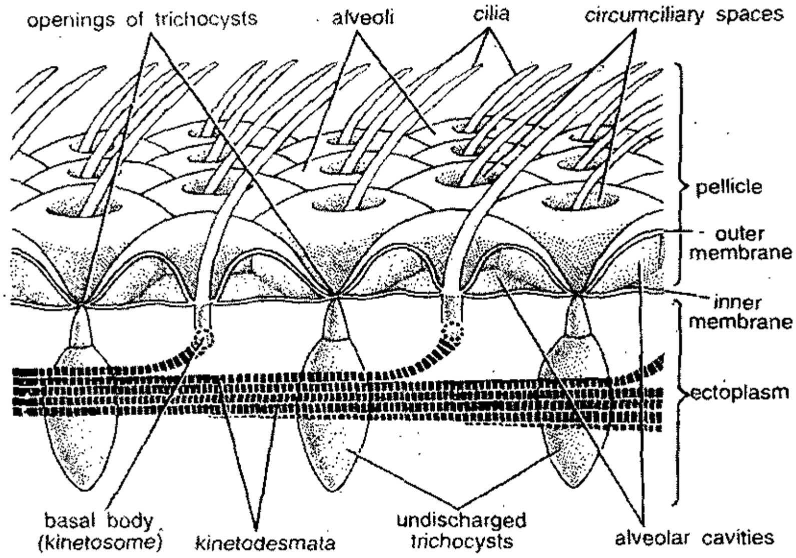



**Fig. 15. *Paramecium*. A diagrammatic three-dimensional electron microscopic representation of a portion of pellicle and infraciliary system.**

to 14,000 cilia covering the whole body surface. These motile organelles are arranged in regular longitudinal rows. Their length is uniform throughout, except for a few longer cilia at the extreme posterior end of the body, forming a **caudal tuft**, hence the species name *caudatum*.

Electron microscopy has shown that a cilium has the same fundamental structure as has been seen in case of a flagellum (Fig. 16). It consists of a fluid

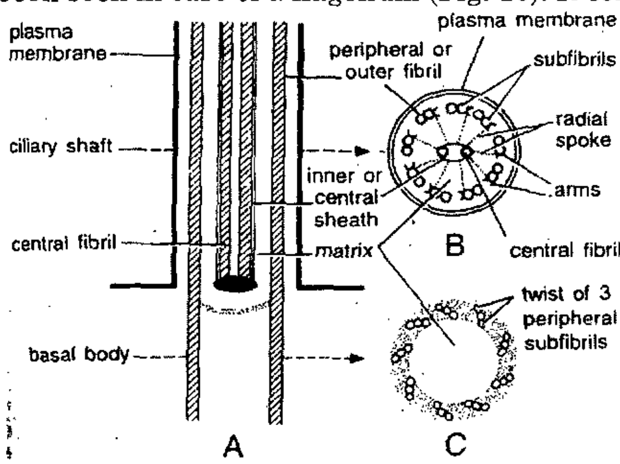



**Fig. 16. Structure of a cilium and its basal body. A. Cilium in L.S. B. Free part of cilium in T.S. C. Basal body in T.S.**

matrix, surrounded by an outer membranous sheath, which is continuous with the outer cell membrane of body. Within matrix are 9 peripheral longitudinal fibres, which run along the whole length of cilium body. Each fibre is formed of two sub-fibres, one of which carries a double row of short arms or projections, all running in the same direction (clock-wise). In the centre of matrix are two single fibres, which are enclosed within an inner membranous sheath. In between the central and peripheral fibres are nine additional accessory fibres.

## • INTERNAL STRUCTURE

### [I] Cytoplasm

Within pellicle, the cytoplasm of body is clearly differentiated into two regions.

1. **Ectoplasm.** The narrow, peripheral, clear and dense zone is cal the **ectoplasm** or **cortex**. It includes the structure of the infraciliary syst and the trichocysts.

2. **Endoplasm.** The large, central, granular and semi-fluid zone is endoplasm or **medulla**. It includes the usual cell components l **mitochondria, Golgi bodies ribosomes, crystals, reserve food granul** etc. In *P. bursaria,* the endoplasm is filled with symbiotic *Zoochlorella* unicellular chlorophyll-bearing alga. Prominent endosplasmic inclusions **nuclei, contractile vacuoles** and **food vacuoles.**

**[II] Infraciliary System**

Immediately beneath the pellicular alveoli is located the infraciliary syst constituted by the basal bodies and kinetodesmata.

1. **Basal bodies.** The base of each cilium is produced into a tube-li structure, called **basal body** or **kinetosome**. It is formed by the thicken basal ends of peripheral fibres of cilium. The central fibres do not enter into The wall of basal body consists of 9 triplets of sub-fibres. The basal bodies a self duplicating units and progenitors of new cilia. Each basal body is either centriole or its derivative.

2. **Kinetodesmata.** Associated closely with basal bodies of cilia a lying in the ectoplasm is a system of specialized striated fibrils, call **kinetodesmal fibrils**. A single fibril or **kinetodesmos** arises from t kinetosome or basal body of each cilium and runs anteriorly somewhat taperi along the course. It joins its counterparts from the posterior kinetosom forming a bundle of overlapping longitudinal fibrils, called **kinetodesm** (pleural, **kinetodesmata**). The number of fibrils in each kinetodesma constantly remains (5), because the individual fibrils do not run anterior farther than 5 basal bodies. It has been suggested that fibrils coordinate cilia beat and movement, but the evidence is very conflicting.

The kineiosomes of a longitudinal row plus their kinetodesmata constitute a structural unit calle the **kinety**. A kinety system is apparently characteristic of all ciliates. It is said that the pattern infraciliature plays an important role in the morphogenesis of Protozoa. For example, *Paramecium*, one set of kinety, is solely responsible for the development of mouth structure. A ne mouth fails to develop if this kinety is removed experimentally.

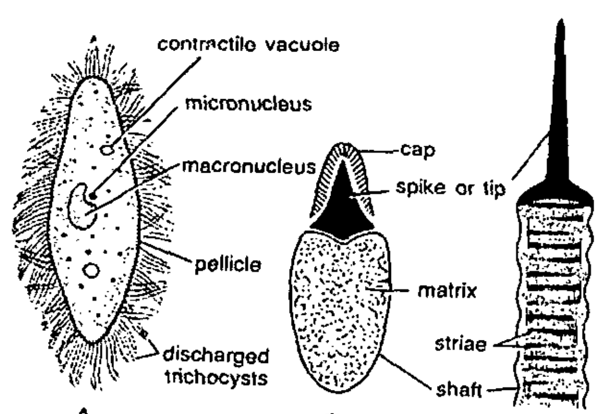



**Fig. 17. *Paramecium*. A. Animal with discharged trichocysts. B. Undischarged trichocyst. C. Apical portion of discharged trichocyst.**

### [III] Trichocysts

Trichocysts are peculiar rod-like or oval organelles present throughout the ectoplasm alternating with basal bodies and oriented at right angles to the body surface. These were first seen in *Paramecium* by Elis. These are very small in size, measuring about 4 μ in length. Each trichocyst consists of an elongated **shaft** and a terminal pointed **tip**, called the **spike** or **barb**, covered by a **cap**. The *matrix of shaft consists of a dense mass of a fibrous protein*, called **trichinin.** Its fibres remain condensed forming a cross-striated lattice work.

Function of trichocysts is not well known. It is believed that these discharge and anchor the animal to a firm substratum when it feeds upon bacteria. Others believe that these are organelles of defence.

Discharge of trichocysts is triggered by mechanical, chemical or electrical stimulation. It occurs in a span of a few milliseconds. When fully discharged the shaft becomes a long cross-striated rod and measures about 40 μ in length. It is believed *that the discharge process consists of an unfolding of the lattice of* trichinin fibres.

### [IV] Nucleus

*Paramecium* is **heterokaryotic** as it possesses two types of nuclei. In *P. caudatum*, there is a large **macronucleus** and a small **micronucleus**. Besides the macronucleus, two micronuclei are present in *P. aurelia* and many in *P. mutimicronucleatum*.

1. **Macronucleus.** The **macronucleus** is roughly kidney-shaped and with inconspicuous nuclear membrane. It is polyploid and possesses many nucleoli and much more chromatin material (DNA). Macronucleus is the somatic or vegetative nucleus and controls the day-to-day metabolic *activities of the cell. It is derived from micronucleus during reproductive* processes.

2. **Micronucleus.** The **micronucleus** is lodged in a depression on the surface of the macronucleus. It is usually spherical, with a nuclear membrane and with diploid number of chromosomes. It contains a definite nucleolus in *P. aurelia,* while in *P. caudatum* the nucleolus is absent. It controls the reproductive activities of the organism.

### [V] Contractile Apparatus

In *Paramecium*, unlike *Amoeba* and *Euglena*, there are two **contractile vacuoles**, occupying somewhat fixed positions in endoplasm. One vacuole lies near each end of body, close to the dorsal surface. Each of them is surrounded by a circlet of 6 to 10 long, narrow, spindle-shaped **radial canals** (afferent pulsating canals) extending far into cytoplasm. Each contractile vacuole opens *to outside through a permanent pore in pellicle of dorsal side of body.* The two contractile vacuoles do not lose their identity when water is expelled.

Electron microscopy has revealed that each contractile apparatus includes some of the tubules of the endoplasmic reticulum, nephridial tubules, feeder canals, accessory vacuoles (radial canals) and the main contractile vacuole. The accessory vacuoles or radial canals are, in fact, the ampullae of feeder canals.

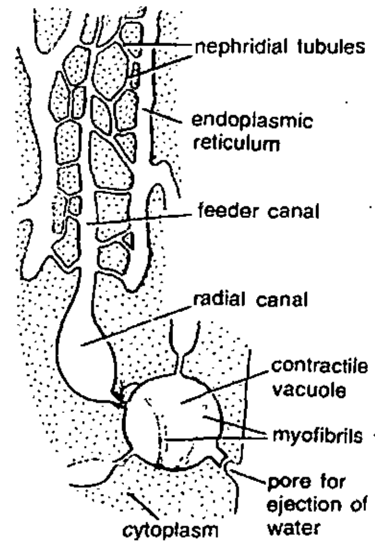



**Fig. 18.** ***Paramecium.*** **Contractile apparatus.**

### [VI] Food Vacuoles

Numerous non-contractile food vacuoles, recently termed **gastrioles** I **Vokovsky**, can be seen moving with the streaming endoplasm (cyclosis). Th differ in shape and size according to the nature of ingested food particles, b mostly they rounded in form.

### [VII] Oral Apparatus

In *Paramecium*, oral groove leads ventrally and posteriorly as a tubul structure, called **vestibule.** It leads directly into a wide tubular passage, th **buccal cavity**. In its turn it opens into a narrow gullet or **cytopharyn** through a narrow aperture, the **cytostome**. The cytopharynx, at its proxim end forms a **food vacuole**.

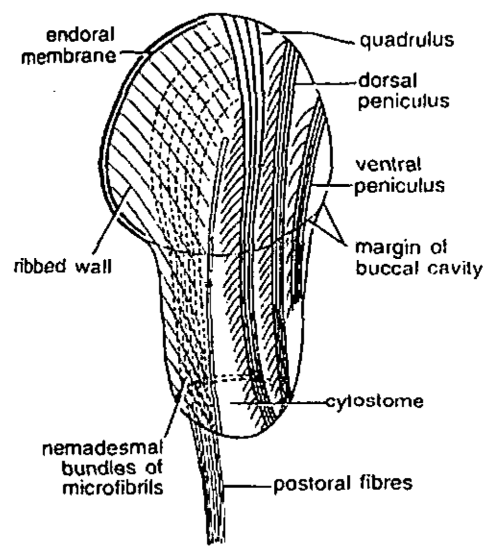



**Fig. 19.** ***Paramecium.*** **Oral apparatus showing buccal ciliature.**

Buccal cavity, at right side, is bordered by a row of cilia forming the **endora membrane**. At left side are three groups of four rows of cilia, extending from the rim of the opening to the posterior end of buccal cavity. These are **ventra peniculus, dorsal peniculus** and **quadrulus**. These ciliary rows constitut the **membranelles**. From endoral membrane a ribbed pellicle extends upt cytostome. **Nemadesmal fibres** run dorsal to the ribbed pellicle and extend as **post-oral fibres** *around* cytopharynx. Rows of normal somatic cilia line the wall of vestibule.

### [VIII] Cytopyge

Near posterior end of body, a little behind cytostome and a little to the right side, a small portion of ectoplasm and pellicle is somewhat weak. Here, at the time of **egestion**, a minute aperture called **cell anus, cytopyge** or **cytoproct**, is visible. It is, however, difficult to say whether it is a permanent opening with tightly-closed lips or a temporary opening formed at the time of egestion.

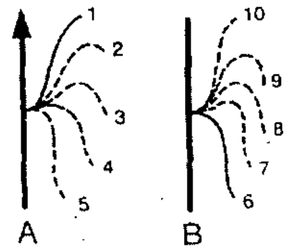



**Fig. 20. Diagram illustrating ciliary movements of a single cilium (after Gray). A. Effective stroke, B. Recovery stroke.**

## • LOCOMOTION

*Paramecium* has a streamlined body which enables it to swim about in water with a minimum amount of friction. The rapid swimming is facilitated by the beating of fine and hair-like cellular organelles, called **cilia**, that cover the animal's entire cell-body. *Paramecium* moves with a speed of 1500 μ or more per second.

### [I] *Ciliary Beats*

During movement, a cilium oscillates like a pendulum. Each oscillation comprises a fast **effective stroke** and a slow **recovery stroke**. During the **effective stroke** or the strong backward lash, the cilium becomes slightly curved and rigid and strikes the water like an oar, so that body is propelled forward in opposite direction of stroke. The **recovery stroke** which follows

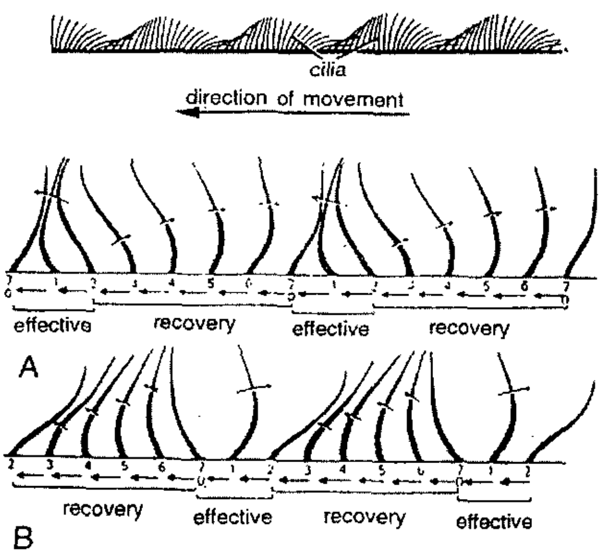



**Fig. 21. A. A single row of cilia showing metachronal rhythm. B. Cilia 1-7 indicate recovery stroke. Cilia 8-12 indicate effective stroke.**

immediately brings the cilium again into position for the next effective stroke (Fig. 21).

All the cilia of body do not move simultaneously and independently but progressively in a characteristic wave-like manner, called **metachronal rhythm**. The cilia in a longitudinal row beat in a characteristic wave beginning at the anterior end and progressing backwards. Consequently, a cilium in a longitudinal row always moves in advance of the one behind it. All the cilia of a transverse row beat simultaneously or synchronously. During forward movement of *Paramecium* the metachronal waves pass from the posterior end forwards.

### [II] Mode of Swimming

The animal does not follow a straight tract but rotates spirally like a rifle bullet along a left-handed helix. The reason for this is two fold. Firstly, the body cilia do not beat directly backwards but somewhat obliquely towards right, so that the animal rotates over to the left on its long axis. Secondly, the cilia of oral groove strike obliquely and more vigorously so as to turn the anterior end continually away from the oral side and move in circles. The combined effect causes the movement of animal along a fairly straight path, rotating about its axis in an anticlockwise direction.

In backward movement a *Paramecium* follows a straight course. In this case the metachronal wave passes from anterior end backwards. This is due to the fact that effective stroke is carried out anteriorly.

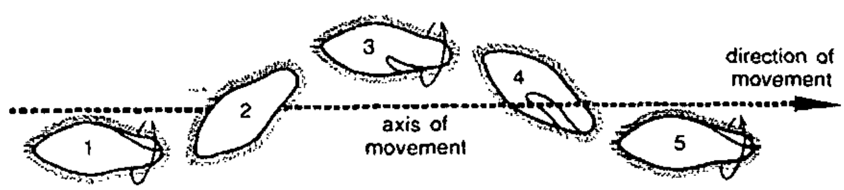



**Fig. 22. Anticlockwise spiral path followed by a swimming *Paramecium*.**

Mechanism of ciliary movement in *Paramecium* is little studied. It is now known that cilia are moved in a coordinating system. They move by the contraction of peripheral fibres located within them. The energy needed for fibrillar contraction is supplied by ATP.

## • NUTRITION

### [I] Food

*Paramecium* feeds in the **holozoic** manner, like *Amoeba*. The food consists chiefly of bacteria which float in water in which it lives. It has been estimated that 2 to 5.5 million individuals of *Bacillus coli* are devoured in 24 hours by a single *Paramecium*. In a sense, paramecia are also beneficial to bacteria, lest they might reproduce too rapidly as to endanger their own existence by overcrowding. It also feeds upon small Protozoa, unicellular plants (algae, diatoms, yeasts, etc.) and small hits of animals and vegetables. It will reject most of the non-digestible material and devour certain kinds of food. One species, *P. bursaria,* is interesting, being green in colour due to the presence of numerous unicellular alga, the symbiotic *Zoochlorella* in its endoplasm. It can thus live holophytically for long periods on food substances manufactured by

*Zoochlorella*. During scarcity of food, it can digest even its own *Zoochlorella* and can live apparently indefinitely without them.

### [II] Feeding Mechanism

*Paramecium* swims to places where it can get its food. Its food catching apparatus is much more specialized than that of *Amoeba* and *Euglena*.

Food is ingested by a definite cell mouth or **cytostome** lying at the bottom of buccal cavity. The constant lashing movements of cilia of oral groove drive a current of water with food particles towards the vestibule. Ciliary tracts of vestibule direct the food particles into buccal cavity. *Paramecium* is a selective feeder. According to **Mast** (1947), many kinds of panicles may be carried with water current into vestibule, but only selected ones are passed on inside the buccal cavity. Rest of particles are rejected, that is, discharged to outside. Passage along which ciliary action drives selected food particles, is termed the **selection path**, whereas passage along which unwanted food particles are driven outside vestibule, is the **rejection path**.

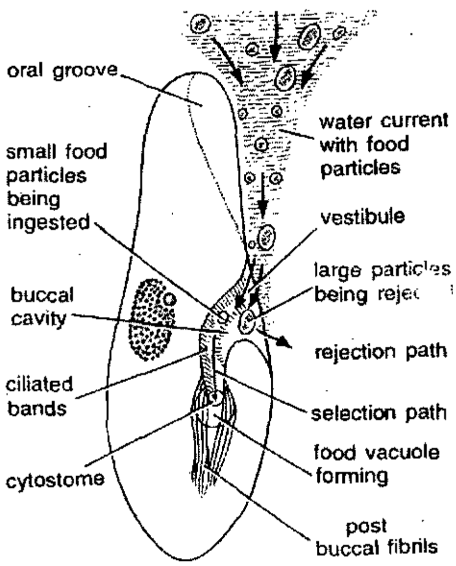



**Fig. 12. *Paramecium* receiving food particles with water current drawn into buccal cavity by ciliary action.**

Beating of cilia of membranelles of buccal cavity drives the selected food particles through cytostome into cell gullet or cytopharynx. The food now gradually collects at the bottom of cytopharynx into a membranous vesicle which is later nipped off as a **food vacuole**. Another **food vacuole** may be formed within 1 to 5 minutes depending upon the supply of food and the rate of feeding.

### [III] Digestion

Each food vacuole consists of food particles surrounded by a thin film of water. Rapid and irregular movement of endoplasm does not occur in *Paramecium*, but the food vacuole is circulated around the body along a more or less definite path by a slow streaming movement of endoplasm. known as **cyclosis**. Several vacuoles may be seen thus circulating in a definite direction in the endoplasm of a well-fed *Paramecium*. The vacuoles are carried first posteriorly, then forward and aborally and again posteriorly and orally up to cytopyge. Digestion and assimilation of food take place during this journey.

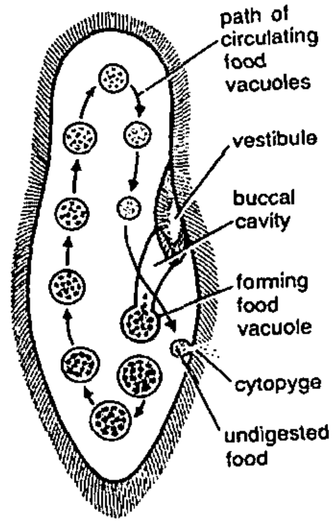



**Fig. 24. Paramecium showing cyclosis and path of food vacuoles in endoplasm.**

Digestive enzymes (proteases, carbohydrases, lipases) are secreted by lysosomes into the food vacuoles. As in *Amoeba*, the contents of a vacuole f become increasingly acidic, but later gradually become alkaline. This can demonstrated with the help of Congo Red and other indicator dyes. alkaline phase results from the secretion of enzymes within an alka medium into the vacuole. Products of digestion (glycogen and fat globules) diffused into the surrounding cytoplasm and either stored or used for v activity and growth.

### [VI] Egestion

The vacuole gradually becomes smaller as digestion and absorption proce Finally, the undigested residual matter is eliminated from body, throug definite **anal spot** or **cytopyge** on ventral surface, posterior to cytostome. cytopyge is of the nature of a potential cell anus as the undigested matte always discharged at this spot.

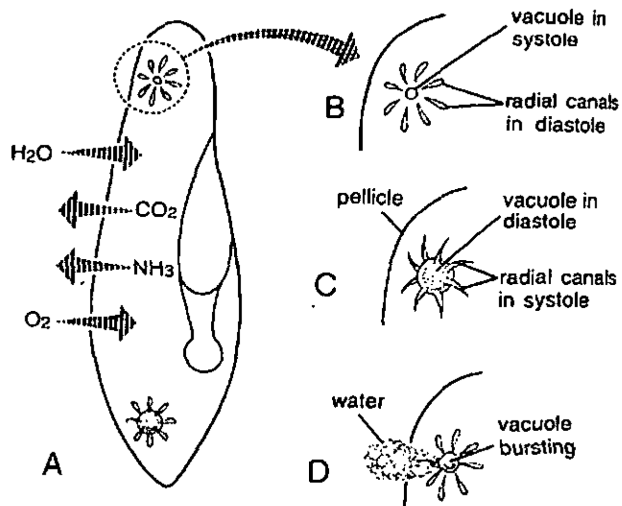



**Fig. 25. Paramecium. Diagrammatic representation of respiration, excretion and osmoregulation.**

## • RESPIRATION AND EXCRETION

*Respiration takes place, as in Amoeba and other freshwater* Protozoa, by diffusion through the semi-permeable pellicle. Oxygen dissolved in water is diffused in and used for oxidation of protoplasmic molecules. Catabolic waste products such as $CO_2$ and nitrogenous matter ($NH_3$) simply diffuse out into external water because their concentration is always higher in body. Crystals present in cytoplasm are in fact excretory products, which get dissolved and eliminated with the fluid of contractile vacuoles.

## • OSMOREGULATION

The function of the contractile vacuoles in *Paramecium* is **osmoregulation**.

An excess of water accumulates in body because of continuous endosmosis, the concentration of body cytoplasm being higher than that of external medium. Small quantities of water are also taken in along the ingested food. This excess of water is got rid off by means of contractile vacuoles which contract (**systole**) and expand .**diastole**) at regular intervals, assisted by the contractility of **myofibrils** (see Fig. 7).

Water from cytoplasm is secreted into some [of the tubules of endoplasmic reticulum from where it flows down the nephridial tubules into feeder canals to accumulate in latter's ampullae (radial canals). The ampullae converge and discharge into contractile vacuole. When vacuole has grown to its maximum size, it contracts and discharges to the exterior, through a pore in peilicle on dorsal side. Posterior contractile vacuole pulsates faster than anterior vacuole because of the large amount of water being delivered into posterior region by cytopharynx.

## • BEHAVIOUR

The way in which an organism establishes an active relationship to its environment is called **behaviour**. It is largely determined by the environmental influences or **stimuli** to which the organism is subjected. The responses of *Paramecium* to various kinds of **stimuli,** such as light intensity, temperature, concentration of $O_2$, $CO_2$ and different chemicals in water are interesting. These produce definite behavioural patterns or **reactive behaviour**. The response is **positive** if the animal moves towards a stimulus, and **negative** when it moves away.

### Avoiding Reaction

It is perhaps the most important mode of behaviour exhibited by *Paramecium*. If a fast swimming individual strikes a solid object, it moves back for a short distance, turns on its side and swims forward again but at an angle to its original path. If it again collides with an obstacle, it shows the same negative reaction which is repeated until the animal passes the obstacle or becomes exhausted.

### Trial and Error Reaction

*Paramecium* can also learn by **trial** and **error reaction**, involving a series of experiments on the part of animal. It constantly tests water just ahead by drawing it in its oral groove in the form of a cone. If water is too hot or too cold or if it contains an irritating chemical substance, the animal shows an avoiding reaction. It immediately backs up and pivots upon its posterior end, while anterior end swings in a circle. Again it swings forward but in a diffe direction. If this avoiding reaction once more brings it into the region of stimulus, it is repeated. These reactions help the animal to avoid undesir environment without actually getting into it. Moreover, these bring the an sooner or later, into the most favourable part of environment.

The responses of *Paramecium* to different stimuli may be summarise under :

1. **Temperature.** Response to temperature is **thermotaxis.** Optin temperature for *Paramecium* lies between 24°C and 28°C. An avoic reaction is given to the temperatures higher or lower than this, until animals escape or get killed.

2. **Light.** Response to light is **phototaxis**. Paramecia do not resp to ordinary changes of light, but a negative response is shown to strong li darkness and ultra-violet rays.

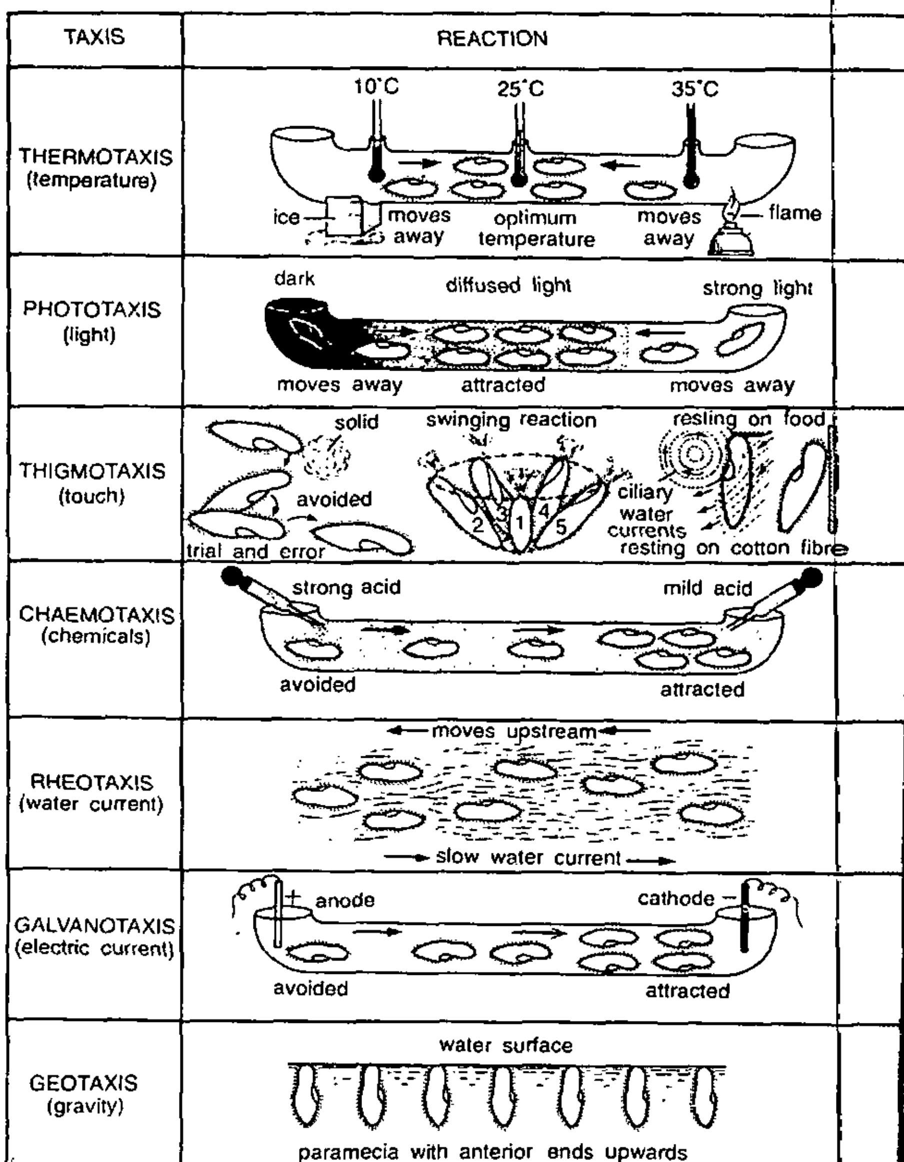



**Fig. 26. *Paramecium*. Responses to different stimuli.**

3. **Touch.** Response to contact or **thigmotaxis** is variable. If the more sensitive anterior end is strongly touched with a solid object, the avoiding reaction is given. But a slow-moving *Paramecium* frequently comes to rest in contact with an object, such as an alga or a plant stem, which can provide rich supplies of food.

4. **Chemicals.** Chemotaxis or response to chemicals is negative in most of the cases. The animals show a definite avoiding reaction and do not enter a drop of weak salt solution. However, a positive reaction occurs with a drop of weak acid solution. The animals also find and select their food in this manner.

5. **Water current.** Paramecia show a positive **rheotaxis,** orienting themselves with their anterior ends upstream and swimming against the current.

6. **Electric current.** A positive **galvanotaxis** is shown to weak electric current, the animals moving towards the negative pole (cathode). A strong current, however, causes them to move backward towards the anode, finally to disintegrate and die.

7. **Gravity.** Paramecia generally show a negative **geotaxis** or response to gravity as seen in a culture contained in a test tube, where they gather close to the surface film with their anterior ends pointed upwards. If paramecia are introduced in an inverted water-filled U-tube stoppered at both ends, they immediately move upward into the horizontal part of the tube. When, in moving across the tube, they find their path going downward, they reverse their direction of movement.

## • REPRODUCTION

*Paramecium* reproduces asexually by transverse binary fission and also undergoes several kinds of nuclear reorganisations, such as conjugation, endomixis, autogamy, etc. Under certain conditions of food and temperature, it undergoes encystment.

### Transverse Binary Fission

During favourable conditions, *Paramecium* commonly reproduces by transverse or horizontal **binary fission,** which is at right angles to the longitudinal axis of body. *Paramecium* stops feeding and its oral groove and buccal structures begin to disappear. While this is happening, the **micronucleus** starts dividing by the complicated process of mitosis, the nuclear membrane remaining intact. Micronucleus first increases slightly in size and then chromosomes, numbering from 36 to 150, depending upon the race, begin to appear. Each chromosome splits longitudinally to form two chromatids (**prophase stage**). Paired chromatids now get arranged on the nuclear spindle at its equatorial plane (**metaphase stage**). This is followed by separation apart of chromatids and elongation of micronucleus (**anaphase stage**). By the last stage (**telophase stage**), micronucleus becomes very much elongated and its two ends become organised into two daughter micronuclei. The daughter micronuclei then separate. Simultaneously, the **macronucleus** divides amitotically by simply becoming elongated and constricted in the middle. Two oral grooves now begin to form, one in the anterior half and the other in the posterior half. Two original contractile vacuoles remain, one in

each half of the dividing parent individual. Two new contractile vacuoles
later formed. Two new buccal structures also appear. In the meantim
constriction furrow appears near middle of the body. It deepens and ultima
the cytoplasm is completely divided, resulting into two daughter parameci
the two daughter paramecia, the anterior one is called **proter** and
posterior, **opisthe**. These grow to full size and divide again by fission.

*P. caudatum* divides 2-3 times in a day by binary fission. The proce
completed in about 30 minutes, though separation of daughter paramecia t
about one hour or more. The term **clone** is used to refer to all the indivic
that are produced asexually from one parent *Paramecium*. All the members
clone are genetically alike.

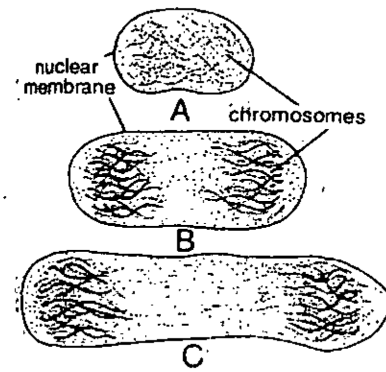



**Fig. 27.** ***Paramecium.*** **Chromosomal movement in mitosis of micronucleus.**

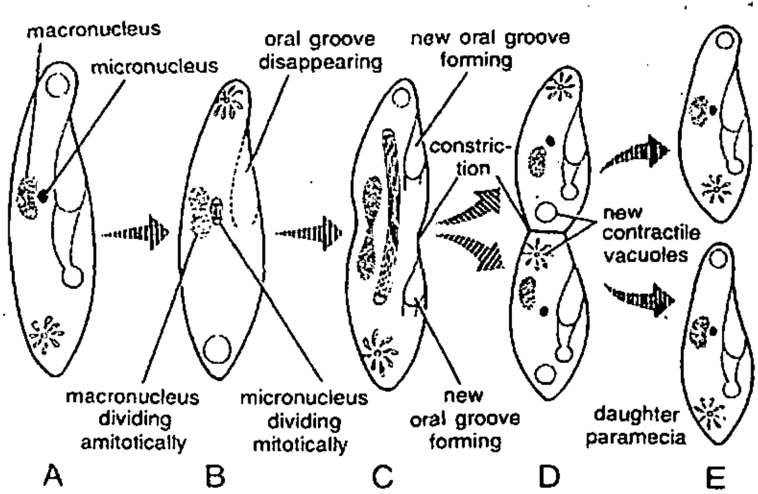



**Fig. 28.** ***Paramecium.*** **Stages showing binary fission.**

## Conjugation

*Paramecium* undergoes a sexual phenomenon, which is called conjugat
It is frequently referred to as sexual reproduction, but it is simply a tempo
union of two individuals of one and the same species for the purpos
exchanging a part of their micronuclear material. This remarkable proces
*Paramecium* occurs frequently between binary fissions and is necessary fo
continued vitality of the species.

### [I] Process of Conjugation

The details of this process differ slightly in different species of *Paramec*
The following account refers to *P. caudatum*.

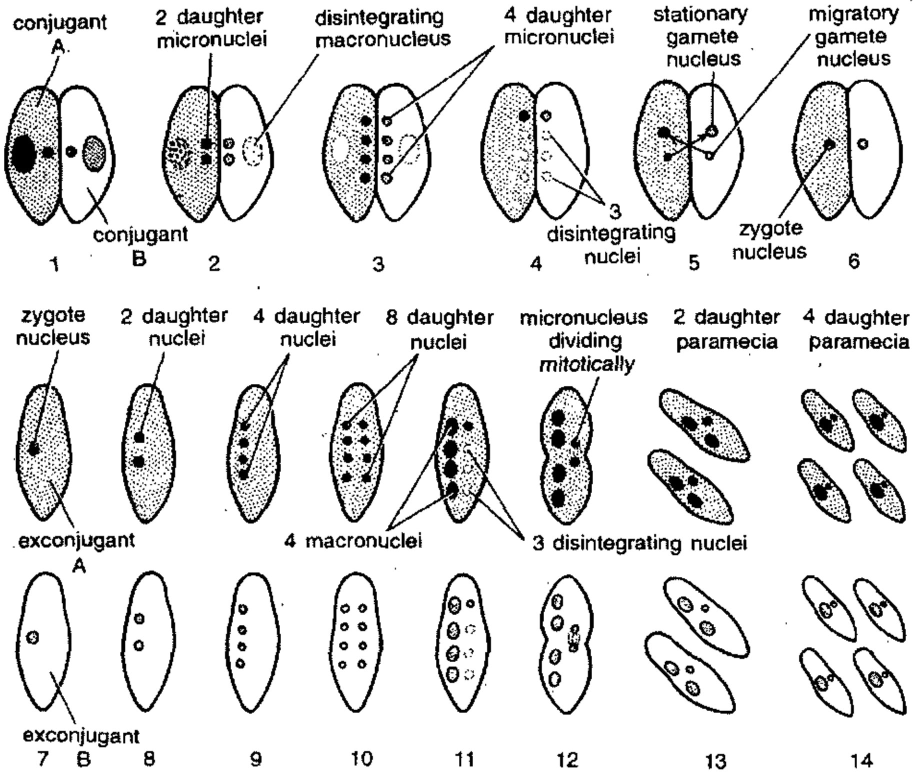



**Fig. 29.** ***Paramecium*****. Stages in conjugation.**

In conjugation, two individuals or **preconjugants**, from two different mating types, come in contact ventrally and unite by their oral grooves. They stop feeding and their buccal structures disappear. The pellicle and ectoplasm degenerate at the point of contact and a **protoplasmic bridge** is formed between the two individuals, which are now called the **conjugants.** While so united, like the 'Siamese twins', the conjugating pair continues to swim actively and a sequence of complicated nuclear changes takes place in each animal.

The vegetative **maeronucleus** simply breaks up into fragments, which are later absorbed by cytoplasm. The diploid **micronucleus** of each conjugant first grows in size and then divides by meiosis. Thus, 4 haploid daughter micronuclei are produced of which 3 degenerate or become pycnotic and disappear in each conjugant, while the remaining one divides by mitosis forming 2 unequal **pronuciei or gamete nuclei.** Smaller one is the active **migratory gamete nucleus** and the bigger one is the passive **stationary gamete nucleus.** The migratory nucleus of one conjugant then passes through the protoplasmic bridge into the other individual and fuses with its stationary nucleus, forming a single diploid **zygote nucleus** or **synkaryon**. The complete

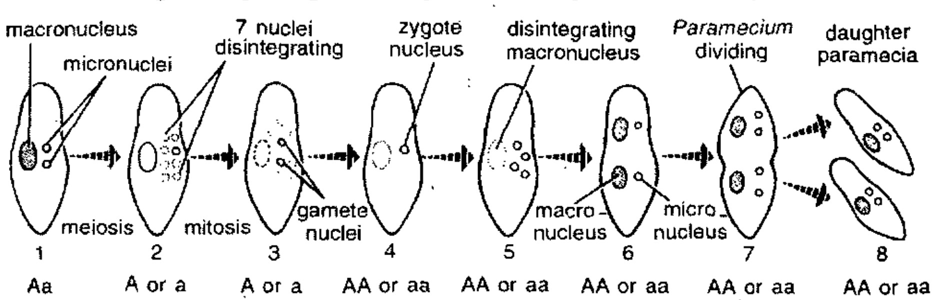



**Fig. 30.** ***Paramecium aurelia*****. Stages in autogamy.**

fusion of two nuclei from two different individuals forming a zygote nucleu termed **amphimixis**.

The two pairing paramecia, after a union of about 12 to 48 hours, sepa and are now called **exconjugants.** In each exconjugant, the zygote nuc divides by mitosis three times in rapid succession producing 8 nuclei, of whi enlarge to become **macronuclei** and other 4 become **micronuclei.** Th micronuclei disintegrate and disappear, while the remaining micronuc divides, with binary fission of exconjugant. Thus, from each exconjugant daughter paramecia are obtained, each containing 2 macronuclei and micronucleus. The micronucleus again divides with the division of daughter *Paramecium*, forming two individuals each containing macronucleus and one micronucleus. Thus, each conjugant produces daughter individuals at the end of conjugation.

**[II] Factors and Conditions of Conjugation**

Conjugation is very complex physiologically. The factors and conditi governing conjugation are several and these may also vary with the specie

(1) Conjugation does not occur under favourable living conditi Starvation or shortage of food and a particular bacterial diet or cer chemicals are said to induce conjugation in some species.

(2) A certain range of light and temperature, differing with specie said to be essential for conjugation to occur.

(3) In *P. caudatum*, conjugation usually starts early in morning is continued till afternoon.

(4) The conjugating individuals are usually smaller in size (210 μ, lo than the normal individuals (300-350 μ long).

(5) A definite state of nutrition is indispensable since starved or ove individuals generally will not conjugate.

(6) Maupas maintains that individuals must have passed throug desirable number of asexual generations (period of immaturity) before t become sexually mature and conjugate.

(7) The pairing conjugants are **isogamous** and there is morphological sexual dimorphism into male and female conjugants.

(8) Conjugation never takes place among the members of a 'pure li that is among the descendants of a single individual. It occurs only betw individuals belonging to two different **mating types.** Thus, a sort physiologically sexual differentiation exists in *Paramecium*.

(9) Agglutination favours conjugation. It is the interaction of mat type substances (proteins) which are localized in cilia.

**[III] Significance of Conjugation**

The significance of conjugation has been much discussed but it still rema uncertain. The following functions or effects are attributed to this process

1. **Rejuvenation.** If binary fission continues repeatedly for seve generations, the *Paramecium* loses its vigour and enters upon a perioc depressed physiological efficiency and senescence. The individual ceases multiply, reduces in size, degenerates in organization and eventually dies

To avoid this senile decay of race, conjugation is resorted to and the process seems to rejuvenate and revive the lost vigour for asexual reproduction.

However, **Woodruff** and **Jennings** do not support the view that conjugation helps in rejuvenescence. Woodruff succeeded in maintaining a culture of paramecia for nearly 36 years, resulting in hundreds of thousands of generations without resort to conjugation.

2. **Nuclear reorganization.** During conjugation the nuclear apparatus is reorganized and a readjustment occurs between it and the cytoplasm. Probably the macronucleus loses its potentialities in performing its manifold metabolic activities. Its replacement by a new macronucleus brings renewed vigour and vitality to accelerate the metabolic activities.

3. **Hereditary variation.** During asexual reproduction by fission, the hereditary material of the parent passes unchanged on to the progeny, so that all the descendants of one *Paramecium* have the same inheritance. The periodic occurrence of conjugation, however, ensures **inherited variation**. It brings about the blending of two lines of ancestry just as bisexual reproduction does.

### [IV] Genetic Consequences of Conjugation

If conjugation takes place between two paramecia, one homozygous for a dominant gene (AA) and the other homozygous for its recessive gene (aa), the first generation would be heterozygous (Aa). If the two conjugants are already heterozygous (Aa), then the resulting progeny would be either homozygous or heterozygous, depending upon which gene gets eliminated at the stage of disintegration of three micronuclei in each conjugation.

## Autogamy

**W.F. Diller** (1936) described a process of nuclear, reorganization in *P. aurelia*, resembling conjugation, but taking place within a single individual. He called it **autogamy** or **self-conjugation**.

### [I] Process of Autogamy

During autogamy in *P. aurelia*, the 2 diploid micronuclei divide by meiosis to form eight haploid daughter nuclei. Seven of them disintegrate, while the remaining haploid micronucleus undergoes a mitotic division forming 2 gamete nuclei. Meanwhile, the macronucleus grows into an irregular skein-like mass, which' breaks into pieces later to be absorbed in the cytoplasm. The two gamete nuclei enter a protoplasmic cone temporarily formed near cell mouth and then fuse together to form a completely' homozygous diploid zygote nucleus or **synkaryon**. This divides twice to yield 4 nuclei, 2 of which become macronuclei and 2 micronuclei. The cell body and the micronuclei then divide to form two daughter individuals, each with a new macronucleus and 2 micronuclei. Autogamy rejuvenates *Paramecium*.

### [II] Genetic Consequences of Autogamy

If autogamy takes place in a *Paramecium* heterozygous for a dominant gene (Aa), the resulting progeny will depend upon the survival of the gene A or a. If the gene A survives, it will lead to AA individuals or vice versa. Thus. autogamy always results in homozygosity.

### Cytogamy

In 1940, **R. Wichterman** reported, in *P. caudatum*, a sexual process witho nuclear exchange, termed **cytogamy**. The process resembles **conjugation** that two small paramecia (200 μ long; temporarily fuse by their oral surface The early nuclear divisions are also similar to those of conjugation; but there no nuclear exchange between the individuals (**cytogamonts**). But, two haplo **gamete nuclei** in each individual are said to fuse to form a **synkaryon**, as **autogamy**. The process is completed in about 13 hours.

### Endomixis

Endomixis (Gr., **endon** within + **mixis,** mingling) is an interesti phenomenon involving a total internal nuclear reorganization within a sing individual in a culture of a pedigreed race of *Paramecium,* taking place in t absence of conjugation. **Woodruff** and **Erdmann**, in 1914, first of all reporte endomixis in the bimicronucleate species, *P. aurelia,* occurring periodically regular intervals of about 30 days. The whole process may be summarized follows :

The vegetative **macronucleus** degenerates and disappears, while t **micronuclei** divide twice by mitosis forming 8 **daughter nuclei** of which degenerate. At this stage *Paramecium* also divides, and each daughte paramecia receive one micronucleus. This micronucleus divides twice forming nuclei, 2 of which become macronuclei and 2 micronuclei, in each individual.

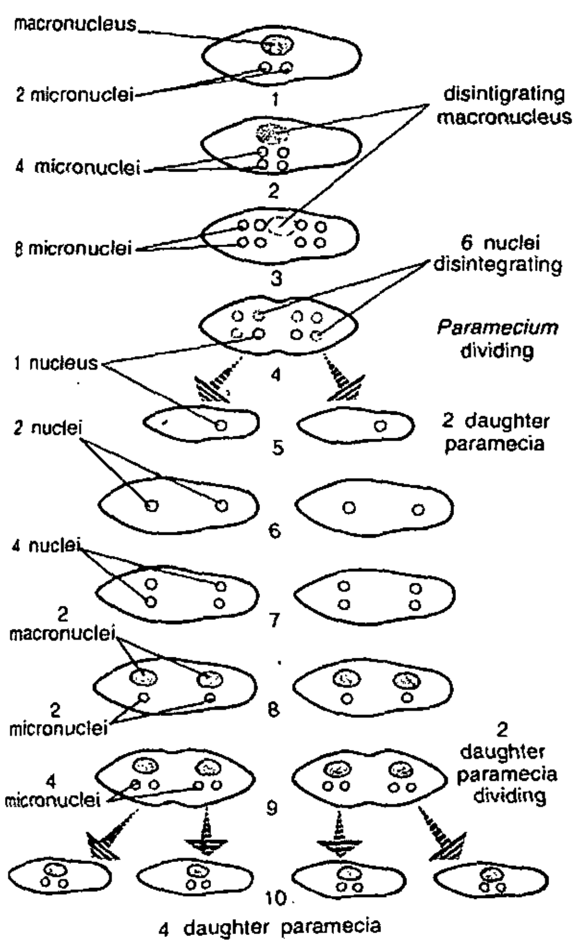



**Fig. 31. *Paramecium*. Stages in endomixis.**

The micronuclei again divide with the binary fission of *Paramecium* into two daughters, each getting one macronucleus and 2 micronuclei. Thus, four daughters are produced from a single parent bringing about an intracellular nuclear reorganization and readjustment between the cytoplasm and the nuclear apparatus in each individual.

## • CYTOPLASMIC PARTICLES IN *PARAMECIUM*

1. ***Kappa* particles.** At the time of mixing of two races of Paramecia for conjugation, **T.H. Sanneborn** found that sometimes one race survives and the other dies out. These two races have been designated as **killer** and **sensitive**, respectively. It was found out that in the individuals which survive (**killers**) occur special self-replicating cytoplasmic bodies containing DNA, called **kappa particles.** These are associated with the production of a killing substance. **paramecin.** This substance diffuses out into the surrounding water and causes the death of the sensitive (kappa free) individuals. In the course of studies about the kappa particles, it was found that a dominant gene (K) in nucleus is necessary for kappa to exist, multiply and produce paramecin. Kappa particles provide an example of cytoplasmic inheritance. They are transmitted directly by cytoplasmic genes (plasmagenes) from cytoplasm of parent cell to the daughter cells, and not by nuclear genes as in ordinary heredity.

2. ***Pi* particles.** These are mutant forms of kappa particles. They do not release any toxic substance meant for killing those which are without such particles, that is, the sensitives.

3. ***Mu* particles.** These particles are also killers and kill the mate without such particles, during conjugation.

4. ***Lambda* particles.** These particles are borne by killer paramecia and cause the sensitive paramecia to lyse or disintegrate.

## • *PLASMODIUM VIVAX* : THE MALARIAL PARASITE

Members of subphylum Sporozoa are all parasites and without organelles of locomotion as adult. These are either intra or intercellular parasites of both invertebrates and vertebrates and many of them are causative organisms of dreadful diseases like malaria, various cattle fevers, coccidiosis in chickens, epidermic deaths in cultivated honeybees and silkworms, etc. The most interesting sporozoan genus is *Plasmodium* whose 60 known species cause malaria in man and other annuals. Because of their malaria-causing abilities, the species are commonly referred to as **malarial parasites*.** All these reside in the red blood corpuscles, reproduce in them and destroy them. Mosquitoes are the transmitting agents or *vectors* of the malarial parasites.

### *Plasmodium vivax*

Four species of *Plasmodium* are known to cause different types of malaria fever in man. They are *P. vivax, P. ovale, P. malariae* and *P. falciparum.*

The following description belongs to *P. vivax* in particular, which is the most common type of malarial parasite.

*According to some, the term 'malarial parasite' is incorrect, it should be 'malaria fever parasite'.

### Systematic Position

| | |
|---|---|
| **Phylum** | Protozoa |
| **Subphylum** | Sporozoa |
| **Class** | Telosporea |
| **Subclass** | Coccidia |
| **Order** | Eucoccida |
| **Suborder** | Haemosporina |
| **Genus** | *Plasmodium* |
| **Species** | *vivax* |

### Distribution of Plasmodium

Geographical distribution of the species of *Plasmodium* is widespread in tropical and temperate countries. Where the migratory birds are hosts, the parasites are spread all over the world. Of the human infecting parasites, *P. vivax* is the most widely distributed. It prevails mainly in temperate regions of the world. *P. falciparum* is confined to the warmer parts only. *P. malariae* follows *P. vivax* in distribution. *P. ovale,* though widespread, is the rarest of the four.

## • LIFE CYCLE OF *PLASMODIUM VIVAX*

*P. vivax* is the most common of the human infecting malaria fever parasites. It is the causative organism of **benign tertian** or **vivax malaria,** which is characterized by a 48-hour cycle between the first malaria fever and subsequent recurrence of chills and fever. It is an intracellular parasite in man living in the red blood corpuscles and liver cells, while extracellular in mosquito, living in its alimentary canal and salivary glands.

### Hosts

The life cycle of *P. vivax,* is very complicated. Being **digenetic,** it is completed in two hosts, man and mosquito.

1. **Man.** Asexual cycle is passed in man in two phases. First phase in liver cells is called **liver schizogony**. It involves multiple fission forming **merozoites** at the end. Second phase is completed in red blood corpuscles. It is known as **erythrocytic schizogony** which forms **gametocytes** at the end.

2. **Mosquito.** Sexual cycle is completed in female *Anopheles* mosquito. It also involves two phases, gametogony and sporogony. **Gametogony** is concerned with the production and fusion of **gametes,** whereas **sporogony** is postzygotic multiplication resulting in the formation of infective individuals, the **sporozoites.**

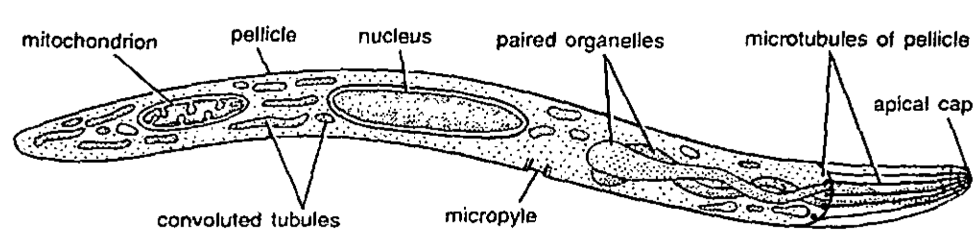



**Fig. 32.** ***Plasmodium.*** **Structure of a sporozoiie as revealed by electron microscope.**

## • ASEXUAL CYCLE OF *P. VIVAX* IN MAN

### [I] Infection

A healthy person acquires infection when a female *Anopheles* mosquito, containing infective stages of parasite (sporozoites) in its salivary glands, bites him for sucking his blood. The mosquito punctures the host's skin by its proboscis and first introduces some saliva into blood stream. Along with saliva, thousands of sporozoites contained therein are also inoculated, Purpose of pouring saliva is to check clotting of blood, as it contains an anticoagulant.

### [II] Sporozoites

Sporozoites represent the infective forms of parasite. These are small spindle-shaped, slightly curved or sickle-shaped, and uninucleate organisms, measuring 11-12 μ in length and 0.5-1 μ in width.

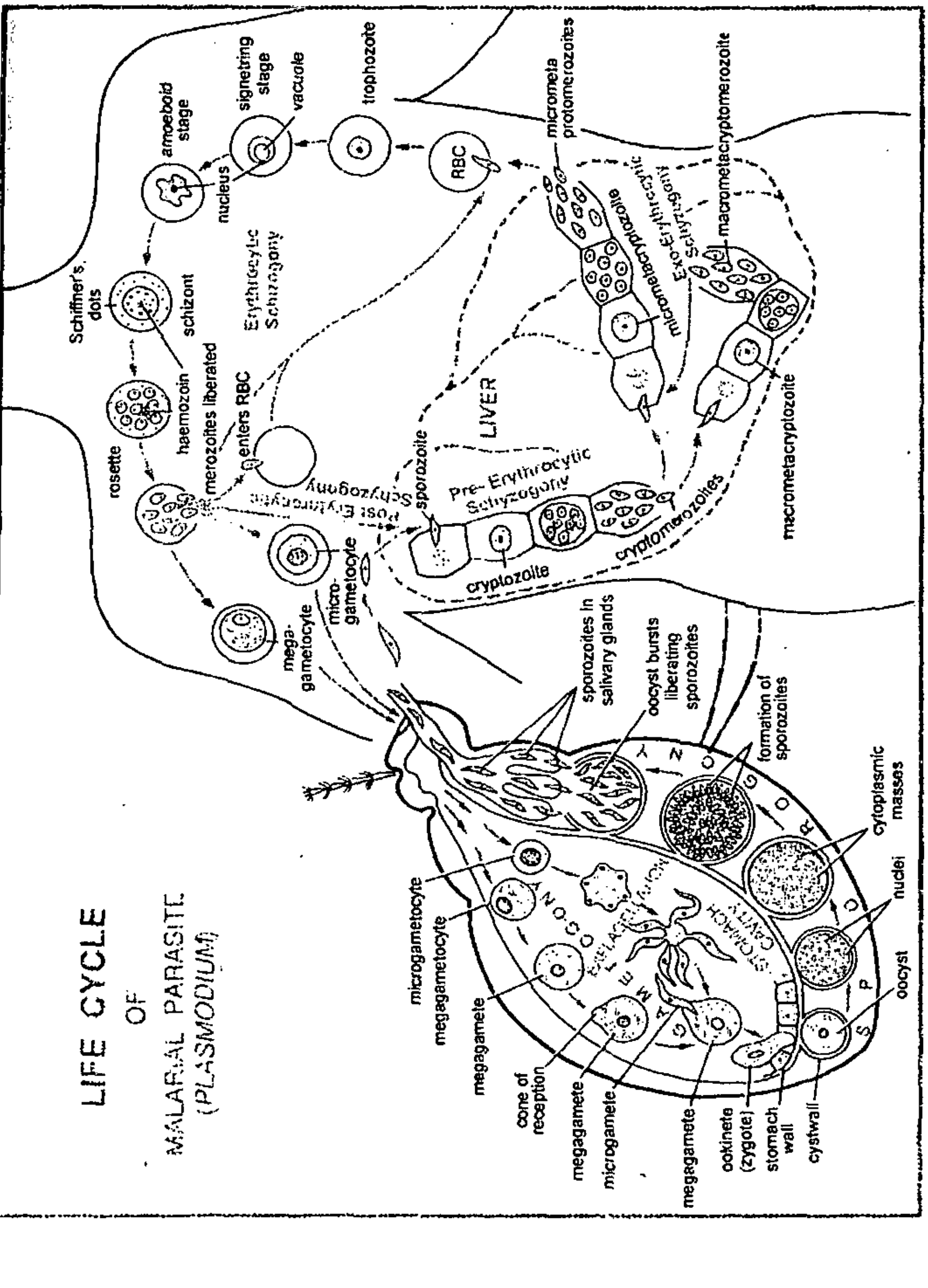



Fig. 33. Life cycle of *Plasmodium vivax*.

show sexual dimorphism, being of two types. The male or **microgametocyte** smaller and contains a large diffused nucleus. The female **megagametocyte** is larger with a small compact peripheral nucleus. Th gametocytes do not divide, but remain as intracellular parasites within the host's blood corpuscles, until they either die or are ingested by the vector, which they continue their development.

## • SEXUAL CYCLE OF *P. VIVAX* IN MOSQUITO

### [I] Ingestion by Mosquito

When a female *Anopheles* mosquito sucks blood of the infected perso containing gametocytes in R.B.C., any other phases of the parasite and R.B.C are digested. The gametocytes however survive. These are liberated an become lodged in the cavity of gut.

### [II] Gametogony

Development of gametes from gametocytes is known as **gametogony** **gametogenesis.** Like gametocytes, the gametes are also of two type **microgametes** and **macro-gametes.** In other animals and most Protozo reduction division occurs during the formation of gametes. Thus only gamet are haploid while zygote and other stages are diploid. But in *Plasmodium* according to some workers (**Bano**, 1959), meiosis or reduction division take place in the first divisions of zygote. Consequently, only zygote is diploid, whil gametes and all other stages of life cycle are haploid, as in higher plants.

1. **Microgametes.** The male or micro-gametocyte begins to undergo process, called **exflagellation,** in the midgut of mosquito. The drop i temperature, due to transfer from warm-blooded human host to cold-blooded insect, provides the stimulation for the process. In each microgametocyt nucleus divides by mitosis to produce 6-8 haploid daughter nuclei, whic assemble at the periphery. The cytoplasm outgrows into long, thin an flagella-like projections and a daughter nucleus enters each one of them. Thes projections break away as mature male or **microgametes** (sperms). Eac measures from 20-25μ in length.

2. **Megagametes.** Female megagametocyte undergoes som reorganization and becomes a female gamete, that is, **megagamete** o **macrogamete** (ovum) which is ready for fertilization.

### [III] Fertilization

The megagamete gives out a small cytoplasmic projection, the **cone** o **reception** or **fertilization cone**. Nucleus of megagamete comes to lie near it receptive cone. When a lashing microgamete comes in contact with megagamete, the former penetrates the latter through its receptive cone an **fertilization** or **syngamy** takes place. A complete fusion of nuclei an cytoplasm of two gametes occurs, resulting in the formation of **zygote** with single diploid nucleus or **synkaryon.** Syngamy is **anisogamous** as the unitin male and female gametes are dissimilar.

### [IV] Ookinete

The zygote remains rounded and motionless for some time, but soon i becomes elongated, vermiform and motile. It performs wriggling or glidin novement, and is known as the **vermicule** or **ookinete.** It measures about 5-22μ in length and 3μ in width. It moves exhibiting gregarine gliding-bending movements and peristaltic contractions and comes to lie against the peritrophic membrane of gut.

Electron microscope has revealed the presence of a central irregular **nucleus**, dense cytoplasm, brown pigment granules, many **mitochondria** and **ribosomes** in the ookinete. This suggests that a very rapid synthesis of protein takes place within this stage of the parasite. Motile nature of ookinete is due to the presence of ectoplasmic contractile fibrils, the **microtubules.**

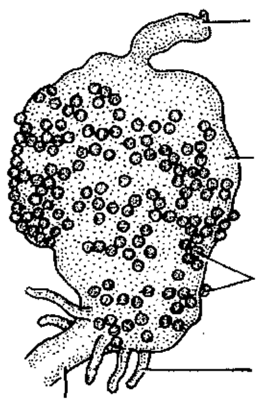



**Fig. 35. Stomach or midgut of an infected female *Anopheles* mosquito with oocysts of *Plasmodium*.**

## [V] Encystment

*Ookinete* penetrates through the wall of midgut (stomach) to settle down just under the thin membrane that separates midgut from haemocoel. Hero it becomes spherical and begins to encyst. The **cyst wall** is thin, membranous and elastic, secreted partly by ookinete and partly derived from mid-gut tissues of mosquito. The encysted zygote is called **oocyst** or **sporont**, The oocysts grow in size and they can now be seen on the outside of midgut or stomach as transparent rounded structures. These may be 50 or more in number.

## [VI] Sporogony

Each oocyst now enters a phase of asexual multiplication known as **sporogony.** Its nucleus divides first by meiosis (post-zygotic) and subsequently by mitosis (**Bano**, 1959), forming an enormous number of small haploid nuclei. At the same time, the cytoplasm develops large vacuoles and takes up a sponge-like structure, in which numerous irregular cytoplasmic masses are formed connected by protoplasmic strands. The daughter nuclei arrange themselves along the free margins of cytoplasmic masses. Later, slender and finger-like processes are given out from these cytoplasmic bodies and a daughter nucleus migrates into each of them. In this way, about 10,000 minute, slender and sickle-shaped bodies, called **sporozoites,** are formed from each oocyst*. Each sporozoite has tapering ends and a broad middle part containing a single nucleus. When mature oocysts rupture and are separated from residual cytoplasm which look like a tangled mass within the oocyst. These sporozoits are liberated into haemocoel or body cavity of mosquito. Being

* *A sporoblast stage, as found in Monocystis, is absent in Plasmodium in which the sporozoites are formed directly from the oocysts.*

motile, they move to different organs in the body of mosquito, but many of th penetrate the salivary glands. In mosquito, whole sexual cycle is comple within 10-20 days depending upon temperature.

The mosquito now becomes infective. According to one estimation, saliv glands of a single infected-mosquito may contain as many as 200. sporozoites. When it bites a healthy person, thousands of sporozoites injected in his blood along with saliva and start the cycle sain.

## • LOCOMOTOR ORGANELLES AND LOCOMOTION IN PROTOZ

### Locomotor Organelles

Locomotor organelles in Protozoa include **pseudopodia. flagella cilia a pedicular contractile structures.**

### [I] Pseudopodia

Pseudopodia or false feet are temporary structures formed by th streaming flow of cytoplasm, Sarcodina move with these structures. On basis of form and structure, pseudopodia are of the following four types :

1. **Lobopodia.** These are lobe-like pseudopodia with broad a rounded ends, as in *Amoeba*. These are composed of both ectoplasm as well endoplasm. Lobopodia move by pressure flow mechanism.

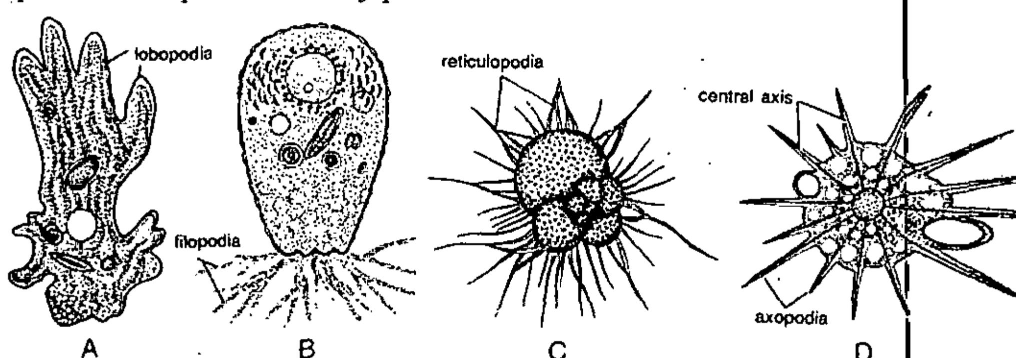



**Fig. 38. Types of locomotor organelles. A. Lobopodia of *Amoeba proteus*. B. Filopodi of *Euglypha*. C. Reticulopodia of *Globigerina*. D. Axopodia of *Actinophrys sol*.**

2. **Filopodia.** These are more or less filamentous pseudopodia, usua tapering from base to the pointed tip, as in *Euglypha*. Unlike lobopodia, t

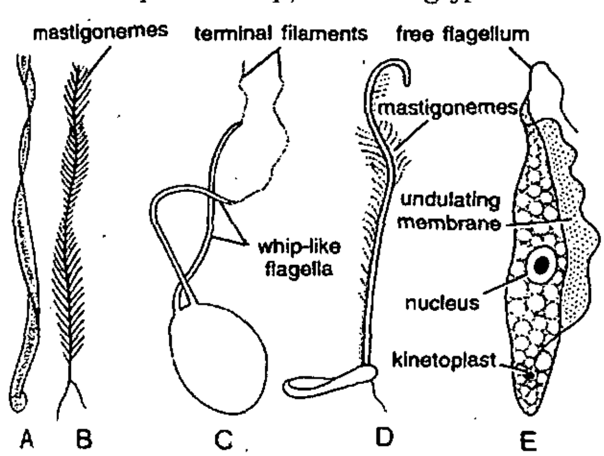



**Fig. 39. Types of flagella in Protozoa. A. Flagellum of *Trachelo monas*. B. Flagellum of *Euglena* with *mastigonemes*. C. Whip-like flagella of *Polytoma*. D. Flagellum of *Urcoelu* with mastigonemes. E. Undulating membrane of *Trypanosoma* with a flagellum.**

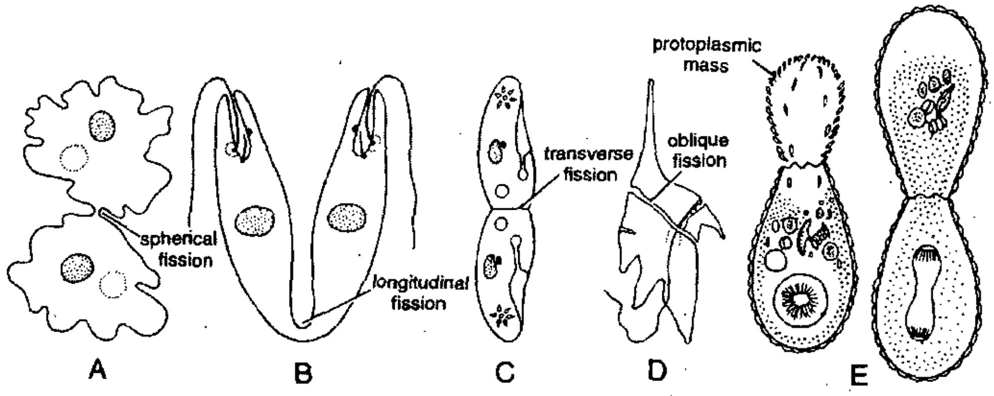
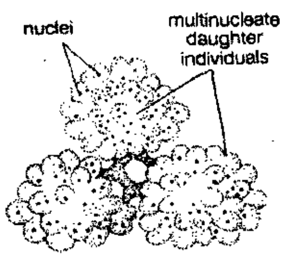
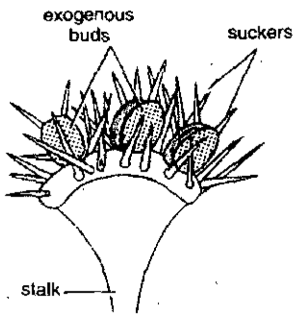



**Fig. 44. Binary fission in Protozoa. A. *Amoeba* (irregular). B. *Euglena* (longitudinal). C. *Paramecium* (transverse) D. *Ceratium* (oblique), E. *Euglypha* (Two stages in fission).**

filopodia are composed of ectoplasm only. Sometimes they may branch and form simple or complex networks.



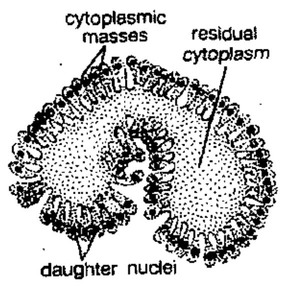




**Fig. 45. Plasmotomy. Fig. 46. Multiple budding in *Ephelota*. Fig. 47. Multiple Fission**

3. **Reticulopodia.** The reticulopodia (rhizopodia or myxopodia) are also filamentous. Filaments are branched and interconnected profusely to form a network. This type occurs in foraminiferans (*e.g., Globigerina*). Reticulopodia display two-way flow of cytoplasm.

4. **Axopodia.** These are more or less straight pseudopodia radiating from the surface of the body. Each axopodia containing a central axial rod which is covered by granular and adhesive cytoplasm. Like reticulopodia, axopodia also display two-way flow of cytoplasm. Axopodia are characteristic of heliozoans, such as *Actinosphaerium* and *Actinophrys*.

### [II] Flagella

Flagella are the locomotor organelles of flagellate Protoza, like *Euglena, Trypanosoma,* etc. These are thread-like projections on the cell surface. A typical flagellum consists of an elongate, stiff axial filament, the **axoneme**, enclosed by an **outer sheath**. In axoneme, nine longitudinal peripheral paired fibres form a cylinder, which surrounds the two central longitudinal fibres, enclosed by a membranous inner sheath. Each of the peripheral pairs bears a double row of short arms. Axoneme arises from a basal granule, the **blepharoplast** or **kinentosome**. Mostly, it is a cylindrical body formed by the bases of peripheral fibres. Blepharoplasts are derived from centrioles, as the two structures are homologous.

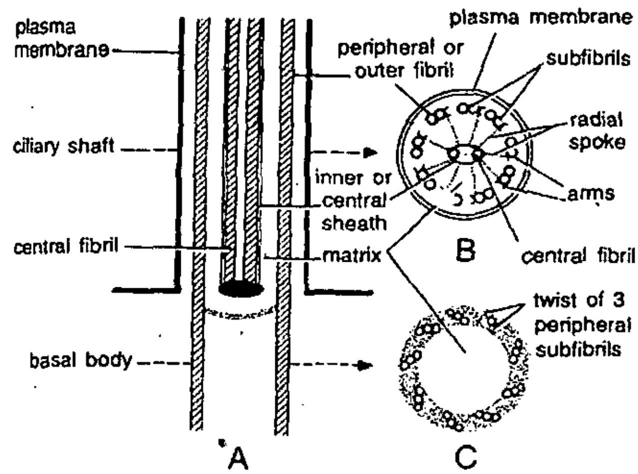



**Fig. 40. Structure of a cilium. A. In L.S. B. In T.S. C. Basal body in T.S.**

Fibres of axoneme remain embedded in a fluid matrix. In between the outer ring of peripheral fibres and inner ring of central fibres, mostly occur nine accessory fibres. In certain groups of Mastigophora are found flagellar appendages or **mastigonemes** extending laterally from the outer sheath.

Number and arrangement of flagella vary in Mastigophora from one to eight or more. Free-living species have usually one or two, while in parasitic species the number ranges from one to many.

### [III] Cilia

Cilia, characteristic of Ciliata, resemble flagella in their basic structure. These are highly vibratile small ectoplasmic processes. Electron microscopy reveals the presence of an external membranous sheath, continuous with plasma membrane of cell surface and enclosing the fluid matrix. Running along the entire length of body of cilium are nine paired peripheral fibres and two central fibres, all embedded in a structureless matrix. Central fibres are enclosed within a delicate sheath. In between the outer and inner fibre rings are present nine spoke-like **radial lamellae**. In addition to these, one **sub-fibre** or **microfibre** of each peripheral pair bears a double row of short projections, called **arms**, all pointing in the same direction.

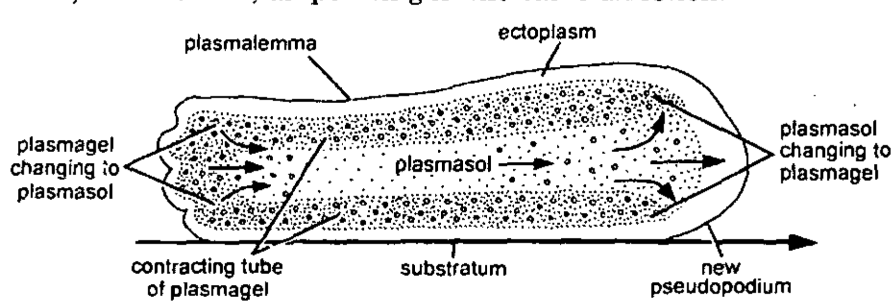



**Fig. 41. *Amoeba* showing amoeboid movement according to sol-gel theory of Mast.**

Each cilium arises from a thickened structure, the basal granule, basal body or blepharoplast. According to **Lenhssek** and **Henneguy** (1898), basal granules are centrioles or their derivatives. Basal granules show nine peripheral subfibre triplets, each disposed in a twist-like fashion. In many species, cilia become fused variously forming compound organelles, such as undulating membranes (*Pleuronema*), membranelle (*Vorticella*), and cirri (*Euplotes*).

### [IV] Pellicular Contractile Structures

In many Protozoa are found contractile structures, in pellicle or ectoplasm, called **myonemes.** These may be in the form of ridges and grooves (*e.g.*, *Euglena*), or contractile myofibrils (*e.g.*, larger ciliates), or microtubules (*e.g.*, *Trypanosoma*).

## • METHODS OF LOCOMOTION

Basically there are four known methods by which Protozoa move : (i) Amoeboid movement, (ii) Flagellar movement, (iii) Ciliary movement, and (iv) Metabolic movement. Speed of locomotion varies from 0.2 μ. to 3 μ per second in amoeboid forms, 15 μ to 300 μ in flagellates, and 400 μ to 2000 μ in ciliates.

### [I] Amoeboid Movement

It is characteristic of all Sarcodina and certain Mastigophora and Sporozoa. It consists in the formation of pseudopodia by the streaming flow of cytoplasm in the direction of movement. Locomotion by pseudopodia is possible only over a surface. We still do not know precisely about the mechanism involved in the formation of pseudopodia, but the most convincing theory at present is that it depends upon active contraction of the ectoplasmic tube (plasmagel) at the posterior end of the body. This leads the endoplasm (plasmasol) to flow forward into the expanding pseudopodium. This process involves continuous solation at the posterior end and gelation at the anterior end (Fig. 41). This is called **sol-gel** or **change of viscosity theory** by **Mast** and **Pantin** (1925). It was further developed by **Goldacre** and **Lorch** (1950) and by **Allan** and **Rosalansky** (1958). Other aspects and theories of amoeboid locomotion have been discussed at length in the chapter on *Amoeba*.

### [II] Flagellar Movement

It is characteristic of Mastigophora which bear one or more flagella. The flagella need liquid medium for movement or locomotion. Three types of flagellar movements have been recognized :

**1. Paddle stroke. Ulehla** and **Krijsman** (1925) observed that common movement of a flagellum is sideways lash, consisting of an effective **down stroke** with flagellum held out rigidly, and a relaxed **recovery stroke** in which flagellum, strongly curved, is brought forward again. As a result, the animal moves forward gyrates and is also caused to rotate on its longitudinal axis (Fig. 42A, B).

**2. Undulating motion.** Wave-like undulations in flagellum, when proceed from tip to base, pull the animal forward. Backward movement is caused when undulations pass from base to tip. When such undulations are spiral, they cause the organism to rotate in opposite direction (Fig. 42D).

**3. Simple conical gyration.** Butschli's screw theory postulates a spiral turning of flagellum like a screw. This exerts propelling action, pulling the animal forward through water with a **spiral rotation** as well as gyration (revolving in circles) around the axis of movement (Fig. 43).

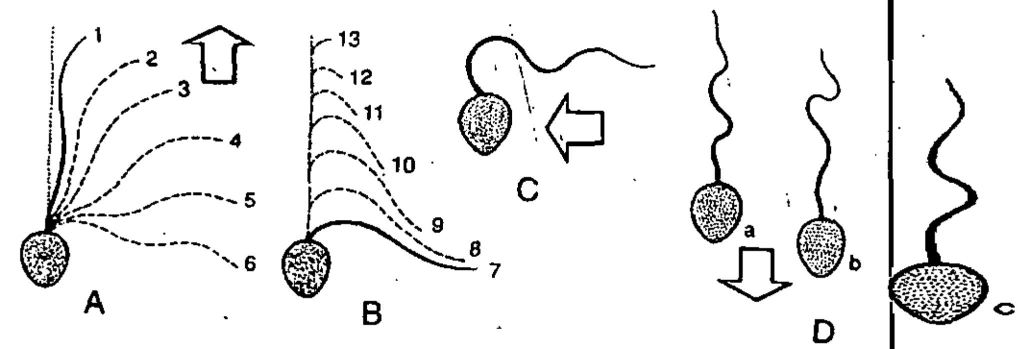



Fig. 42. Flagellar movement. A. Effective stroke. B. Recovery stroke. C. Lateral movement. D. Backward movement.

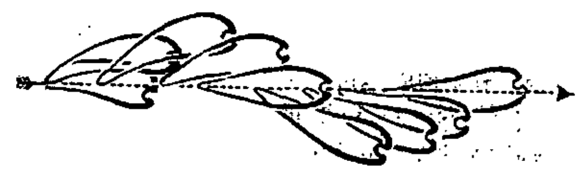


Fig. 43. Successive stages of gyrating flagellar movement.

The mechanism producing flagellar beat is not exactly known. It is beli that some or all of the axonemal fibres are involved. According to the la **sliding tubule**. Theory of flagellar (or ciliary) movement, adjacent doub slide past each other, causing the entire flagellum or cilium to bend. C bridges are formed and energy utilized for the process is supplied by adeno triphosphate (ATP).

### [III] Ciliary Movement

Most ciliates appear to move in a spiral path, rotating on their axis as go. Spiral movement is due to in opposite directions on the two sides of pseudopodial filaments oblique strokes of all body cilia working together striking in the same direction. Cordination of ciliary movement is due to that basal bodies of all cilia are linked by kinetodesmata. Cilia also need li medium for their movements. Large ciliates are the swiftest swimmers, and champion of them may be named *Paramecium caudatum*.

Ciliary action resembles the swing of a pendulum except that it is more r in one direction. Backward and forward vibrations produce a paddle st effect. Backward effective stroke is more active during which movemer brought about, while forward recovery stroke produces no signific movement. While moving, the succession of beats are coordinated in well-known pattern of metachronal rhythm, conventionally compared to passage of wind over a field of wheat (Fig. 42).

Ciliary locomotion has been discussed at length in the chapter *Paramecium*.

As regards the essential mechanism of ciliary movement, little definite be said. The evidences strongly suggest that ciliary movement is based contraction of peripheral fibres.

### [IV] Metabolic Movements

This is typical of certain flagellates (*e.g. Euglena*) and most sporozoan certain stages of their life cycles. Such organisms are seen to show glidin wriggling or peristaltic movement. Contractile myonemes or microtubu present in their pellicular walls, are responsible for this type of movement. Movements of this kind are usually also referred to as **gregarine movements** since they are characteristically exhibited by most gregarines.

## • REPRODUCTION IN PROTOZOA

### Asexual Reproduction

**1. Binary fission.** This involves the division of one individual into two approximately equal parts. The division is not a mere fragmentation but a complicated process of mitosis, during which nuclear division or **karyokinesis** is always followed by the division of cytoplasm or **cytokinesis** (Fig. 44). Division or fission may be either in a transverse plane (*e.g., Paramecium*), or in a longitudinal plane (*e.g., Euglena*), or in an oblique plane (*e.g., Ceratium*) or in any plane (*e.g., Amoeba*). The two daughter organisms produced as a result of binary fission carry all the cytoplasmic organelles of the parent individual. Some organelles like mitochondria, divide at the time of division, while others, like oral apparatus, flagella, and contractile vacuoles, are formed afresh by one of the daughters. In shelled sarcodina (*e.g., Euglypha, Arcella*) a mass of protoplasm extrudes from the opening of shell, which secretes a new shell. This double-shelled organism now divides into two. In ciliates (*e.g., Paramecium*), during fission, mega or macronucleus divides amitotically and micronucleus by usual mitotic division. Some Protozoa divide only in the encysted stage *e.g., Colpoda, Tillina*).

### [II] Plasmotomy

It is a special type of binary fission concerned with the division of multinucleate Protozoa into two or more smaller multinucleate daughter individuals. Plasmotomy takes place in *Pelomyxa*, opalinids and some other forms, etc. (Fig. 45).

### [III] Budding

In its simplest form budding implies modified fission resulting in a small daughter individual in the form of a bud. When the bud breaks off, it grows to full size. When a parental body produces only one bud it is **monotonic** (*e.g. Vorticella*), while in **multiple budding**, several buds are formed simultaneously (*e.g., Ephelota*).

### [IV] Multiple Fission

During **multiple fission** or **sporulation**. nuclear division is not followed immediately by division of cytoplasm. First, nucleus undergoes a series of divisions either by repeated binary fissions as in *Plasmodium*, or by simultaneous multiple divisions, as in *Aggregata*. The body thus becomes multinucleate. Later, the body cytoplasm divides into as many parts as there are daughter nuclei which usually arrange themselves at the periphery, each getting surrounded by a fragment of cytoplasm. Thus, the parent body simultaneously divides into as many daughter individuals as there are nuclei. Parent cell usually leaves behind some residual cytoplasm which disintegrates afterwards. Number of offspring greatly varies among different and the same species and sometimes runs into thousands.

Multiple fission is quite common in Foraminifera, Radiolaria, Sporozoa and

certain Mastigophora. The process receives different names according t
particular period in life cycle when it occurs.

**Schizogony**. In this process, a series of nuclear divisions results
numerous daughter nuclei. This is followed by the formation of cytopla
buds, each containing a nucleus. The buds are pinched off to grow directly
new organisms.

### [V] Plasmogamy

In certain Rhizopoda and Mycetozoa, two or more individuals may fus
their cytoplasm to form a plasmodium, in which the nuclei remain distinct,
they separate again unchanged afterwards. The process, which is
non-sexual and not syngamy, is called **plasmogamy** and sometimes serve
purpose of digestion of large prey.

## • SEXUAL REPRODUCT

In Protozoa, sexual reproduction takes place mainly by two processes
**syngamy** or fusion of two sex cells, and (ii) **conjugation** or temporary con
of two protozoans with nuclear exchange.

### [I] Syngamy

Syngamy is the complete fusion of two sex cells or gametes, resulting in
formation of zygote. The fusion nucleus of zygote is called synkary
Depending upon the degree of differentiation displayed, by the fusing game
syngamy is of the following types :

1. **Hologamy.** The two ordinary mature protozoan individuals do
form gametes but themselves behave as gametes and fuse together to fo
zygote. Hologamy occurs in a few Sarcodina and Mastigophora (
*Copromonas*).

2. **Isogamy.** When two fusing gametes are similar in size and shape
differ in behaviour, they are called **isogametes** and their union, isoga
Isogametes are generally produced by multiple fission. Isogamy is commo
Forminifera (*e.g., Elphidium*), Gregarinia (*e.g., Monocystis*)
Phytomonadida (*e.g., Chlamydomonas*).

3. **Anisogamy.** When two fusing gametes, differ morphologically
well as in behaviour, they are called **anisogametes**. Usually small and mo
gametes are the male or **microgametes** and large non-motile ones are
female or **macrogametes**. Fusion of such dissimilar gametes is anisoga
This mode of sexual reproduction is widely seen in Sporozoa (*e.g., Plasmodi*
and Phytomonadida (*e.g., Volvox*).

4. **Autogamy.** It is the fusion of gametes derived from the same pa
cell, as in *Actinophrys* and *Actinosphaerium*. In *Actinophrys*, during sexu
reproduction, pseudopodia are withdrawn and a cyst is formed. Now mei
division takes place and two daughter nuclei with half number of chromoso
are formed. No cell division takes place. After sometime, gametic nuclei fus
form a zygote nucleus.

### [II] Conjugation (Amphimixis)

This involves temporary union of two individuals, called **conjugants**, usually at oral or buccal regions of their body. It is characteristic of Suctoria and holotrich ciliates.

Fusion of protoplasm occurs at the place of contact. Macronuclei break up and disappear. Micronuclei undergo meiotic division now all but one micronuclei degenerate. This remaining micronucleus again divides forming two gametic micronuclei. Out of these two, one is considered **male pronucleus** and other **female pronucleus**. Male pronucleus of one conjugant moves through fused protoplasm into the other conjugant. In each conjugant, these male and female pronuclei fuse together forming a **zygote nucleus**. Now two individuals separate and are called **exconjugants.** Each exconjugant undergoes further nuclear and cytoplasmic divisions forming four daughter individuals.

Association in conjugation is not at random but indicates a high level of specialization. Sonneborn has recognized different syngens in a species of *Paramecium* and each syngen includes two mating types. Conjugation can only take place between individuals of the same syngen but belonging to opposite mating types. The unique feature of conjugation is an exchange of hereditary material so that each conjugant benefits from a renewed hereditary constitution.

Conjugation in Paramecium has been discussed at length in Chapter 11.

### Parthenogenesis

In *Actinophrys,* the gametes which fail at crossfertilization, develop parthenogenetically. It also occurs in *Chlamydomonas* and others when syngamy has been missed. Individuals of *Polytoma,* which are potential gametes, can grow and divide parthenogenetically.

### Regeneration

Most Protozoa can regenerate their lost parts, as normally displayed at fission or encystment. Parasitic Protozoa usually have slight regenerative capacity. Nucleus plays an important role in the process. Relative quantities of nuclear and cytoplasmic materials and the size of the broken piece affect the rate and result of the process of regeneration.

❑❑❑

# UNIT

# 2

# PORIFERA CNIDARIA

**STRUCTURE**

- General characteristics and Classification up to class,
- Canal System and Spicules in sponges
- Metagenesis in *Obelia*
- Polymorphism in *Cnidaria*
- Coral and coral reefs

## • GENERAL CHARACTER

1. Multicellular organisms with **cellular level** of body organization. N distinct tissues or organs.

2. Mostly marine, a few freshwater, all aquatic.

3. Solitary or colonial, all sessile.

4. Body form vase-like, cylindrical, tubular, cushion-shaped, mar branched, etc.

5. Symmetry radial or no symmetry.

6. Body wall with outer **pinacoderm** (dermal epithelium), inn **choanoderm** (gastral epithelium) and gelatinous non-cellul **mesenchyme** in between. Mesenchyme consists of skeletal elements and fr amoeboid cells.

7. Cells loosely arranged and do not form definite layers, hen regarded not truly diploblastic.

8. Body with many pores (**ostia**), canals and chambers that serve f the flow of water. One or more water exits or **oscula** present.

9. Choanocytes or flagellated collar cells usually line special chamber Sponges are the only metazoans having choanocytes,

10. Skeleton of calcareous or siliceous spicules or of protein spong fibres, or of both, or absent.

11. Digestion intracellular. No respiratory or excretory organ Contractile vacuoles in some freshwater forms.

12. Primitive nervous system of neurons arranged in a defini network of bipolar or multipolar cells in some, but is of doubtful status.

13. All sponges are hermaphrodite but cross-fertilization is the rule.

14. Asexual reproduction by **buds or gemmules.** Sexual reproduction b ova and sperms. All show regeneration power.

15. Cleavage holoblastic. Development indirect through a free-swimming ciliated larva, the **amphiblastula** or **parenchymula**.

## • CLASSIFICATION

The phylum includes about 5,000 species of sponges, grouped in 3 classes depending mainly upon the nature of skeleton they possess.

**CLASS 1. Calcarea (L., calcarius**, limy) or **Calcispongiae (L., calcis**, lime + **spongia**, sponge).

1. Small-sized calcareous sponges, below 10 cm in height. Solitary or colonial.
2. Body shape cylindrical or vase-like.
3. Skeleton of separate one or three or four-rayed calcareous spicules.
4. Body organization of asconoid, syconoid or leuconoid type.
5. Exclusively marine.

**Order 1. Homocoela ( = Asconosa)**

1. Asconoid sponges with cylindrical and radially symmetrical body.
2. Body wall unfolded. Choanocytes line the spongocoel.
3. Often colonial.

Examples : *Leucosolenia, Clathrina.*

**Order 2. Heterocoela (= Syconosa)**

1. Syconoid and leuconoid sponges with thick-walled, vase-shaped body.
2. Body wall folded. Choanocytes line the flagellated chambers (radial canals) only).
3. Solitary or colonial.

Examples : *Scypha* (= *Sycon*), *Grantia.*

**CLASS 2. Hexactinellida** (Gr, **hex**, six + **actin**, ray + **idea**, terminal suffix) or **Hyalospongiae (Gr., hyalos**, glass + **spongos**, sponge).

1. Moderate-sized glass sponges. Some reach 1 meter in length.
2. Body shape cup, urn or vase-like.
3. Skeleton of six-rayed triaxon siliceous spicules.
4. No dermal epithelium or exopinacoderm.
5. Choanocytes restricted to finger-shaped chambers.
6. Exclusively marine, many in deep sea.

**Order 1. Hexasterophora**

1. Spicules are hexasters, *i.e.*, star-like in shape with axes branching into rays at their ends.
2. Flagellated chambers regularly and radially arranged.
3. Usually attached to substratum directly.

Examples : *Euplectella* (Venus' flower basket), *Farnera, Staurocalyptus.*

**Order 2. Amphidiscophora**

1. Spicules are amphidiscs, *i.e.*, with a convex disc, bearing backward directed marginal teeth at both ends.
2. Flagellated chambers slightly different from typical shape.
3. Usually attached to substratum by root tufts.

Examples : *Hyalonema* (glassrope sponge), *Pheronema* (bo sponge).

**CLASS 3. Demospongiae**

(Gr., **demos**, frame + **spongos**, sponge).

1. Small to large-sized, solitary or colonial.
2. Body shape like a vase, cup or cushion.
3. Skeleton of siliceous spicules or spongin fibres, or both, or absent.
4. Spicules monaxon or tetraxon, never triaxon.
5. Body organization leuconoid. Choanocytes restricted to sm rounded chambers.
6. All marine except freshwater family Spongillidae.

***Subclass 1. Tetractinellida***

1. Spicules tetraxon or absent. No spongin.
2. Body flattened or rounded. Dull to brightly coloured.
3. Mostly in shallow water.

**Order 1. Myxospongida**

Structure simple. Spicules absent.

Examples : *Oscarella, Halisarca.*

**Order 2. Carnosa**

Equal-sized spicules present.

Examples : *Plankina, Chondrilla.*

**Order 3. Choristidia**

Both large and small spicules present.

Examples : *Thenea, Geodia.*

***Subclass 2. Monaxonida***

1. Spicules monaxon. Spongin present or absent.
2. Body form variable.
3. Mostly in shallow waters, some in deep sea, some in freshwater.

**Order 1. Hadromerina**

Large spicules knobbed at ends. Small spicules star-like whe present. Spongin absent.

Examples : *Cliona* (boring sponge), *Suberites.*

**Order 2. Halichondrina**

Large spicules of many kinds, usually 2-rayed. Spongin present an scanty.

Example : *Halichondria* (crumb-of-bread sponge).

**Order 3. Poecilosclerina**

Large spicules united by spongin into a regular network. Small spicules C —shaped, curved or bow-shaped.

Example : *Microciona.*

**Order 4. Haplosclerina**

Large spicules 2-rayed. Usually no small spicules. Spongin usually present.

Examples : *Chalina* (mermaid's gloves), *Haliclona* (finger sponge), *Spongilla* and *Ephydatia* (freshwater sponges).

***Subclass 3. Keratosa***

1. Horny sponges with skeleton of spongin fibres. No spicules.
2. Body form usually rounded and massive, with a leathery surface and dark colour.

Examples : *Euspongia* or *Spongia* (bath sponge), *Phyllospongia* (leaf sponge), *Hippospongia* (horse sponge).

## • COELENTERATA : CHARACTERS, CLASSIFICATION AND TYPES

### GENERAL CHARACTERS

1. All aquatic, some freshwater, mostly **marine**.
2. Solitary or colonial. Sedentary or free-swimming.
3. Symmetry **radial** or **biradial** about a longitudinal oral-aboral axis.
4. Body organization of **cell-tissue grade**. Cells mostly scattered and specialized for different functions. Some cells form tissues like **nerve net** or **nervous tissue**.
5. Exoskeleton chitinous (perisarc) or calcareous (corals).
6. Body wall **diploblastic** with two cellular layers —outer epidermis and inner gastrodermis — with a gelatinous acellular mesogloea in between. In advanced types mesogloea with cells and connective tissue, hence **triploblastic**.
7. Two types of individuals occur, attached **polyps** and free-swimming **medusae**. Some species are notable for **polymorphism** of variety o£ forms.
8. Mouth of polyps and bell margin of medusae often encircled by short and slender **tentacles**.
9. Coelom and respiratory, circulatory and excretory systems wanting.
10. Muscular system includes longitudinal and circular fibres formed by epithelio-muscle and endothelio-muscle cells.
11. A single internal cavity, lined with gastrodermis, called **gastrovascular cavity** or **coelenteron,** into which mouth opens. Anus is absent.
12. Digestion intracellular as well as extracellular.

13. One or both body layers with peculiar stinging cell organelles **nematocysts**, which serve for adhesion, food capture, offence and defense.

14. Nervous system primitive, consisting of a diffuse **nerve** ne
Central nervous system absent.

15. Sensory organs form **ocelli** and **statocysts.**

16. Asexual reproduction by budding or fission. **Sexual reproductio** by ova and sperms. Sexual forms monoecious or dioecious.

17. Development includes a free-swimming ciliated **planula larva.**

18. Life-history illustrates a regular alternation between the asexua polypoid stage and a sexual medusoid stage. True alternation of generation absent.

## CLASSIFICATION

Phylum Coelenterata includes nearly 11,000 known species half of which are extinct. These are grouped in following 3 classes :

### CLASS 1. Hydrozoa

(Gr., **hydra**, water + **zoon**, animal)

1. Freshwater or marine. Solitary or colonial.
2. Only polyps or both asexual polyps and sexual medusae present.
3. Polyps without stomodaeum and septa (mesentery).
4. Medusae with true velum (**craspedote**).
5. Mesogloea non-cellular.
6. Gonads epidermal. Sex cells shed directly on outside.

#### Order 1, Hydroida

1. Solitary or colonial.
2. Polyploid stage predominant.
3. Medusae short-lived or absent.
4. Sense organs of medusae exclusively ectodermal.

##### *Suborder I. Anthomedusae (Gymnoblastea)*

1. Polyps and blastostyles **athecate**, *i.e.*, perisarc not forming hydrothecae and gonothecae.
2. Medusa with gonads on manubrium.
3. Statocysts absent. Ocelli present in medusa.

Examples : *Hydra, Ceratella, Tubularia, Clava, Bougainvillea, Pennaria, Eudendrium, Hydractinia, Podocoryne*, etc.

##### *Suborder II. Leptomedusae (Calyptoblastea)*

1. Polyps and blastostyles **thecate**, *i.e.*, with hydrothecae and gonothecae, respectively,
2. Medusa with gonads on radial canals.
3. Both statocysts and ocelli present in medus

Examples : *Obelia, Sertularia, Campanularia, Plumularia, Aglaophenia.*

**Order 2. Trachylina**

1. Medusoid stage large, dominant, free- swimming and may develop directly from fertilized egg.
2. Polypoid stage reduced or absent.
3. Marginal sense organs or statocysts with endodermal statoliths.

***Suborder I. Trachymedusae***

1. Tentacles inserted above bell margin.
2. Gonads develop on radial canals.

Examples : *Gonionemus, Craspedacusta.*

***Suborder II. Narcomedusae***

1. Tentacles arise between bell margin and vertex of exumbrella.
2. Gonads present on manubrium or on stomach, floor.

Examples : *Cunina, Cunarcha, Polycolpa.*

**Order 3. Hydrocorallina**

1. Fixed, colonial polypoid Hydrozoa in which coenosarc secretes a massive exoskeleton of calcium carbonate.
2. Polyps **dimorphic,** with slender **dactylozooids** and short plump **gastrozooids.**

***Suborder I. Milleporina***

1. Dactylozooids hollow, with capitate tentacles.
2. Medusae free and devoid of mouth, digestive canals and tentacles.

Example : *Millepora.*

***Suborder II. Stylasterina***

1. Dactylozooids solid, without tentacles.
2. Gonophores reduced to sporosacs. Medusa not free.

Example : *Stylaster.*

**Order 4. Siphonophora**

1. Pelagic colonial Hydrozoa showing extren polymorphism of zooids.
2. Polyps without oral tentacles.
3. Medusae incomplete and rarely freed.

***Suborder I. Calycophora***

1. Pneumatophore absent.
2. Upper end of colony has one or more swimming bells (nectophores).

Examples : *Diphyes, Praya, Abyla.*

***Suborder II. Physophorida***

Upper end of colony forms a large gas-filled float (pneumatophore).

Examples : *Physalia, Halistemma, Stephalia.*

**Order 5. Chondrophora**

1. Pelagic, polymorphic polypoid colony.
2. Upper end forms a chitinous, gas-filled, oval float (pneumatophore).
3. Gonozooids produce free medusae.

Examples : *Porpita, Velella.*

**CLASS 2. Scyphozoa**

1. Exclusively marine and solitary forms.
2. Medusa stage dominant. Polyp stage reduced or absent.
3. Gastrovascular cavity with gastric pouches and endodermal gastric filaments. No stomodaeum.
4. Medusa **acraspedote,** without distinct velum.
5. Mesogloea extensive, gelatinous, with fibres, and cells.
6. Gonads gastrodermal. Sex cells released in digestive cavity.

**Order 1. Stauromedusae (Lucernariida)**

1. Bell goblet or trumpet-shaped.
2. Sessile, attached by an aboral stalk.
3. No marginal sense organs or tentaculocysts.

Examples : *Lucemaria, Halidystus.*

**Order 2. Cubomedusae (Carybdeida)**

1. Bell cubical, with 4 flattened sides.
2. Four perradial tentaculocysts present.

Examples : *Charybdea, Chiropsalmus.*

**Order 3. Coronatae**

1. Bell conical, divided by a deep circular coronary groove.
2. Tentacles long, borne on pedalia.
3. Four to sixteen tentaculocysts present.

Examples : *Periphylla, Pericolpa.*

**Order 4. Discomedusae (Semaeostomae)**

1. Flat saucer or disc-like umbrella.
2. Eight tentaculocysts present.
3. Square shaped mouth extending into 4 long oral arms.

Examples : *Aurelia, Pelagia, Cyanea, Chrysaora.*

**Order 5. Rhizostomae**

1. Bell usually hemispherical, without marginal tentacles.
2. Typically 8 or more tentaculocysts. .
3. No central mouth. Oral arms fused with several small mouths.

Examples : *Rhizostoma, Cassiopeia, Stomolophus.*

**CLASS 3. Anthozoa (Actinozoa)**

(Gr., **anthos, flower + zoios**, animal)

1. Exclusively marine. Solitary or colonial.
2. All polyps, no medusa.
3. Mouth leads into a tubular stomodaeum.
4. Gastrovascular cavity subdivided by 8 or more septa or mesenteries.
5. Mesogloea stout and cellular.
6. Mesenteries with nematocysts and gastrodermal gonads.

***Subclass I. Octocorallia (Alcyonaria)***

1. Exclusively colonial.
2. Polyps with 8 pinnate tentacles and 8 septa.
3. Gullet with one ventral siphonoglyph.

**Order 1. Stolonifera**

1. Polyps arising independently from a creeping mat or stolon.
2. Skeleton of calcareous tubes or separate calcareous spicules or absent.

Examples : *Tubipora* (organ pipe coral), *Clavularia.*

**Order 2. Telestacea**

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

Example : *Telesto.*

**Order 3. Alcyonacea**

1. Polyps proximally embedded in a fleshy mass or coenenchyme.
2. Skeleton of separate calcareous spicules.

Examples : Soft corals. *Alcyonium.*

**Order 4. Coenothecalia**

1. Polyps embedded and connected by solenial tubes.
2. Skeleton massive, calcareous and blue-green from iron salts.

Example : *Heliopora* (blue coral).

**Order 5. Gorgonacea**

1. Colony usually of plant-like branching form bearing short polyps.
2. Axial skeleton composed of horn-like **gorgonin,** separate or fused calcareous spicules, or both.

Examples : *Gorgonia* and *Corallium.*

**Order 6. Pennatulacea**

1. Colony elongated, sessile. Lower part embedded in mud. Upper part consists of a very long axial polyp with lateral branches bearing dimorphic polyps.

2. Axial skeleton of separate calcareous spicules or horny substance.

Examples : *Pennatula,* and *Pteroeides,* (Sea pens), *Renilla* pansy).

***Subclass II. Hexacorallia (Zoantharia)***

1. Solitary or colonial.
2. Tentacles usually unbranched, numerous but never 8.
3. Gullet commonly with 2 siphonoglyphs.

**Order 1. Zoanthidea**

1. Solitary or colonial. No skeleton. Mostly epizoic.
2. Polyps small and usually united by basal stolons.
3. Only single ventral siphonoglyph present.

Examples : *Zoanthus, Epizoanthus.*

**Order 2. Actiniaria**

1. Simple, often large-sized, solitary anemones.
2. Body muscular, often with an aboral pedal disc,
3. Skeleton absent.
4. Tentacles, and mesenteries are numerous.
5. Siphonoglyps usually one or two.

Examples : Sea-anemones, *Metridium, Edwardsia, Adam* *Actinia, Urticina.*

**Order 3. Ceriantharia**

1. Long, solitary, anemone-like forms, without pedal discs and skelet
2. Tentacles simple, numerous, arranged in two whorls —oral marginal.
3. Siphonoglyphs single and dorsal.

Example : *Cerianthus.*

**Order 4. Antipatharia**

1. Colonial and tree-like.
2. Tentacles and mesenteries comparatively few (6-24) in number.
3. Skeleton as branched, chitinoid axis.
4. Siphonoglyphs two.

Examples : Black corals. *Antipathes.*

**Order 5. Madreporaria**

1. Solitary or colonial.
2. Exoskeleton hard, compact, often massive, calcareous.
3. Polyps small, living in cup-like cavities on exoskeleton.
4. Siphonoglyph absent and muscles feeble,

Examples : True or stony corals. *Flabellum, Fungia* (mushroom coral), *Astrangia, Astraea* (star coral), *Favia, Oculina, Acropora* or *Madrepora* (stag horn coral), *Meandrina* or *Meandra* (brain coral).

***Subclass III. Tabulata***

Extinct colonial anthozoans with heavy calcareous skeletal tubules containing horizontal platforms or tubulae.

Examples : *Favosites, Halysites.*

## • PIORIFERA : GENERAL ACCOUNT

## CANAL SYSTEM IN SPONGES

### What is Canal System

A distinguishing feature of all sponges is the perforation of body surface by numerous apertures for the ingress and egress of water current. Inside body, t

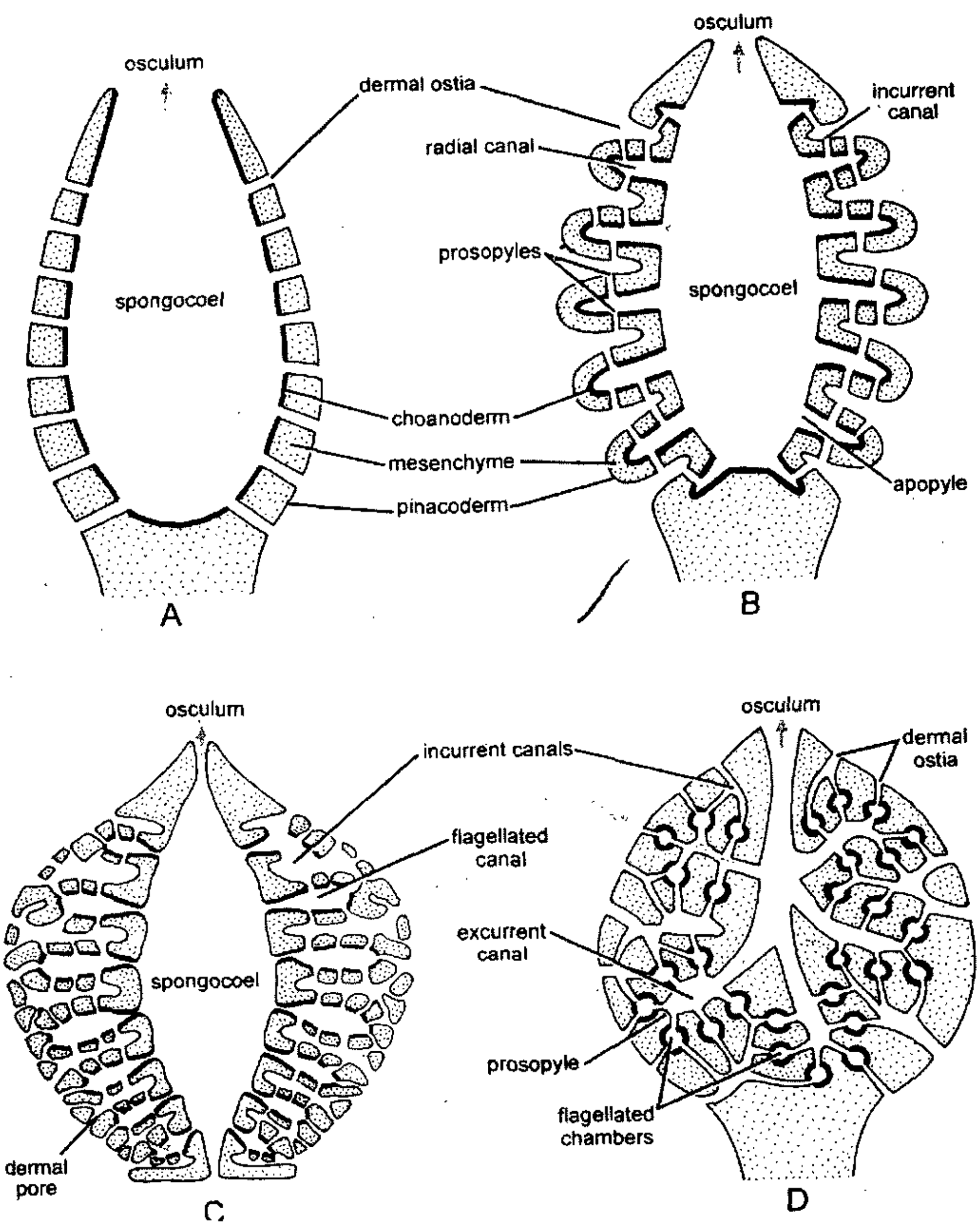



**Fig. 1. Canal system of sponges. A. Ascon type. B. Simple sycon type. C. Complex syconoid type with cortex, D. Leucon type.**

he water current flows through a certain system of spaces collectively forming the **canal system**.

### Function of Water Current

The most vital role in the physiology of sponges is played by water current on which their life depends. All exchanges between sponge body and external medium are maintained by means of this current. Food and oxygen are brought into body and excreta and reproductive bodies carried out. This current is caused by beating of flagella of collar cells.

### Types of Canal System

The arrangement and complexity of internal channels vary considerably in different sponges. Accordingly, the canal system has been divided into three types : **ascon, sycon** and **leucon**.

**1. Ascon type.** It is the simplest type of canal system which is found in asconoid sponges, like *Leucosolenia*, and in olynthus stage in the development of all syconoid sponges. Its body surface is pierced by a large number of minute openings called **incurrent pores** or **ostia**. These pores are intracellular spaces within tube-like cells, the **porocytes**, which extend radially into mesenchyme and laid open directly into **spongocoel**. The spongocoel is the single, large, spacious central cavity in the sponge body. It is lined by the flagellated collar cells or **choanocytes**. Spongocoel opens to outside through a narrow circular opening, the **osculum**, located at the distal free end, and often fringed with large monaxon spicules.

Surrounding sea water enters the canal system through ostia. Flow of water is maintained by the beating of flagella of collar cells. Rate of water flow is slow because the large spongocoel contains much water which cannot be pushed out readily through a single osculum. Course taken by water current in the body of sponge may be shown as under :

$$\text{Ingressing water} \xrightarrow[\text{Ostia}]{\text{through}} \text{Spongocoel} \xrightarrow[\text{Osculum}]{\text{through}} \text{To outside}$$

**2. Sycon type.** Sycon type of canal system is a more complex system of pores and canals and is characteristic of syconoid sponges, like *Scypha* (= *Sycon*) and Grantia. It can be theoretically derived from the asconoid type by horizontal folding of its wall. Embryonic development of *Scypha* clearly shows the asconoid pattern converting into syconoid pattern. Body wall of syconoid sponges includes two types of canals, **incurrent** and **radial**, paralleling and alternating with each other. Both types of canals end blindly in body wall but are interconnected by minute **pores**. Incurrent pores or **dermal ostia**, found on the outer surface of body, open into the incurrent canals. These canals are non-flagellated, as they are lined by pinacocytes, and lead into adjacent radial canals through minute openings, called **prosopyles.** It is not clear whether prosopyles are channels through porocytes but it is definite that, in the adults they are simple intercellular spaces. Radial canals are flagellated chambers, as only they are lined by choanocytes. These canals open into the central spongocoel by **internal ostia** or **apopyles.** Spongocoel is a narrow, non-flagellated cavity lined by pinacocytes. It opens to exterior through an excurrent pore, the **osculum**, similar to that of ascon type.

Course of water current may be represented as given below :

Ingressing water —Dermal ostia→ Incurrent canals —Prosopyles→ Radial canals —Apopyles→ Spongocoel —Osculum→ To outside

In more complex sycon type, as illustrated by *Grantia*, the incurrent canals are irregular, branching and anastomosing, forming large **sub-dermal spaces**. This is due to development of **cortex**, involving pinacoderm and mesenchyme, spreading over the entire outer surface of sponge.

**3. Leucon type.** As a result of further folding of body wall, the sycon type gives rise to a still more complex canal system, the **leucon type.** This is characteristic of leuconoid sponges, such as *Spongilla*. Here radial symmetry is lost and canal system has become very irregular. Flagellated chambers are small, spherical and lined by choanocytes. All other spaces are lined by pinacocytes. Incurrent canals open into flagellated chambers through prosopyles. Flagellated chambers, in their turn, communicate with **excurrent canals** through apopyles. Excurrent canals are developed as a result of shrinkage and division of **spongocoel** which has disappeared. Thus excurrent canals communicate with the outside through an **osculum**.

Course taken by water current is as follows:

Increasing water —Dermal ostia→ Incurrent canals —Prosopyles→ Flagellated chambers —Apopyle→ Excurrent canals —Osculum→ To outside

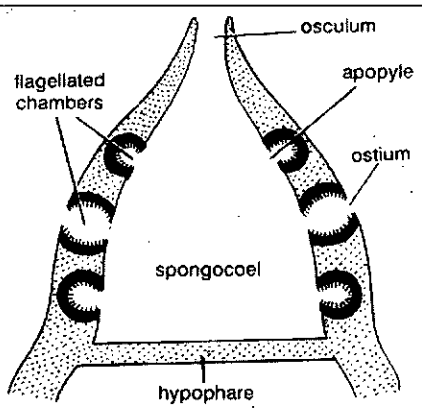



**Fig. 2. Rhagon larva in V.S.**

Though leucon type of canal system appears to be the modification of sycon type, in many calcareous sponges, leucon type is developed directly without passing through ascon and sycon types in their embryogeny. In Demospongiae, leuconoid condition is derived from a larval stage, called **rhagon**. Sponogocoel of rhagon is surrounded by flagellated chambers opening into it through very wide apopyles. A single osculum opens at the top of spongocoel. Canal system of

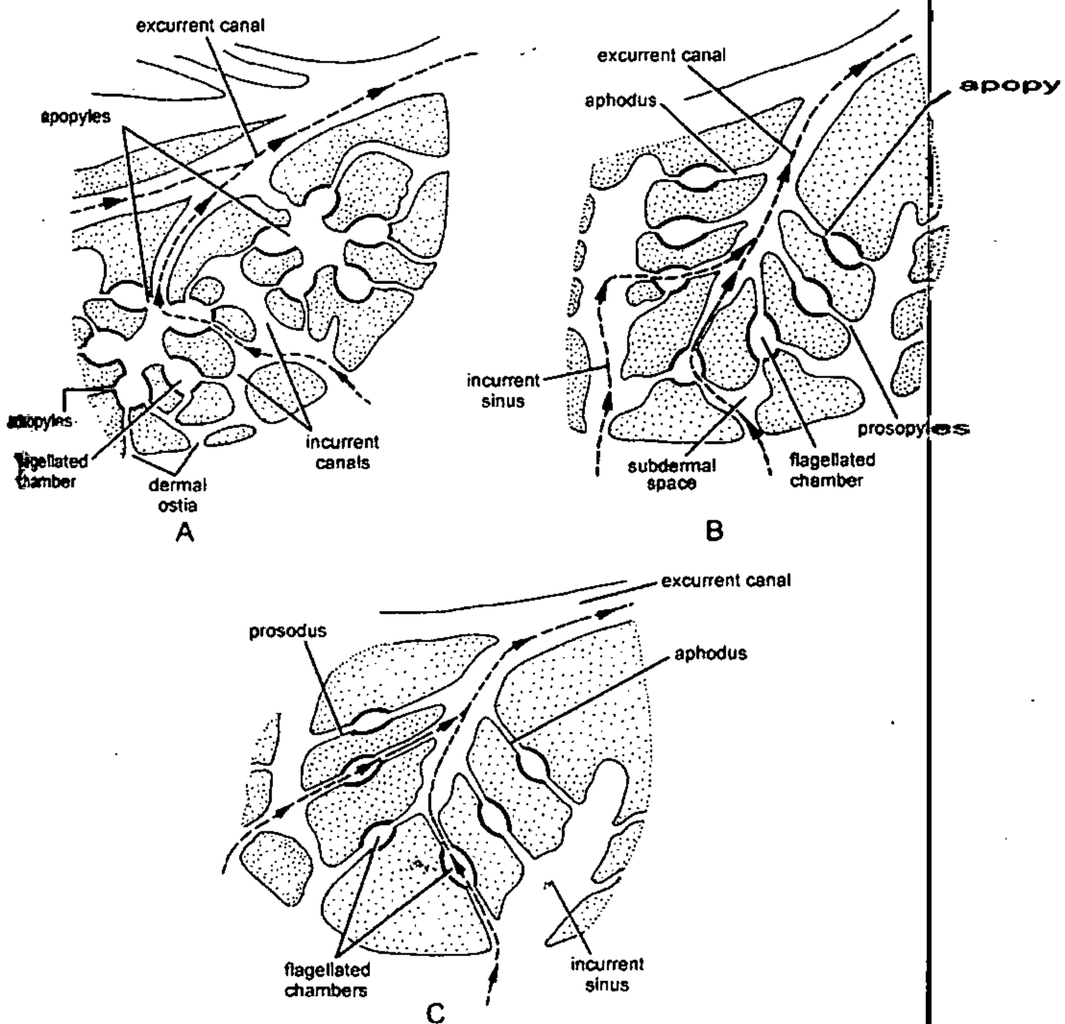



**Fig. 3. Grades in leucon type of canal system. A. Eurypylous. B. Aphodal type. C. Diplodal type.**

rhagon larva does not occur in any adult sponge. In Demospongiae, leucon t of canal system is also termed the **rhagon** type because of its derivation f rhagon stage (Fig. 2).

Leucon type of canal system presents three successive grades in evolutionary pattern :

***(a) Eurypylous type.*** It is the simplest and most primitive leucon t of canal system. In this type, the flagellated chambers communicate directly broad apertures, the **apopyles**, with excurrent canals. Ex. *Plakina.*

***(b) Aphodal type.*** In this type, the apopyle is drawn out as a nar canal, called **aphodus**. This connects the flagellated chamber with excurr canal. Ex. *Geodia.*

***(c) Diplodal type***. In some sponges, besides aphodus, another nar tube, called **prosodus**, is present between incurrent canal and flagella chamber. The pattern is called the diplodal type, Ex. *Spongilla, Oscarella.*

## SKELETON IN SPONGES

Almost all sponges are provided with a skeleton, found embedded mesenchyme. This may consist of separate **spicules**, or of interlacing spon

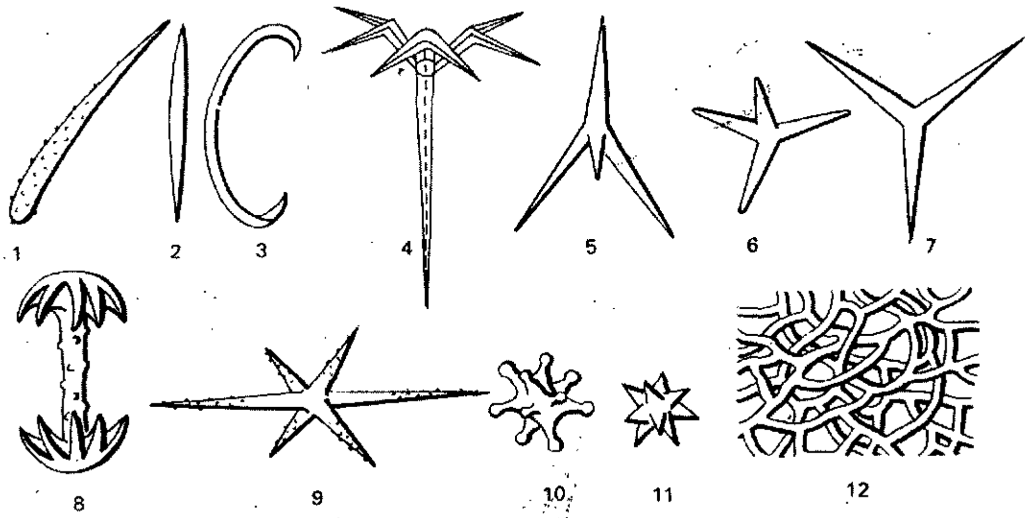



**Fig. 4. Spicules and spongin 1-9. Megascleres, 10-H. Microscleres. 1. Monactinal monaxon, 2. Diactinal monaxon. 3. Curved monaxon. 4. Triaenes. 5-6. Tetraxon calthrops. 7. Triradiate. 8. Monaxon with ends hooked (amphidisc). 9. Hexactinal triaxon. 10-11. Polyaxons. 12. Spongin fibres.**

**fibres**, or of both. Skeleton supports and protects the soft body parts and also serves as the basis of classification of sponges.

## Spicules

### 1. Structure and Types

Spicules are crystalline structures consisting of spines or rays that radiate from a point. These are secreted by special mesenchymal amoebocytes, called **scleroblasts**. All kinds of spicules have a core of organic material around which is deposited either calcium carbonate (calcite) or colloidal silica (silicon). Accordingly, the spicules are of two types : (i) calcareous, which are characteristic of the class Calcarea, and (ii) siliceous, characteristic of class Hexactinellida.

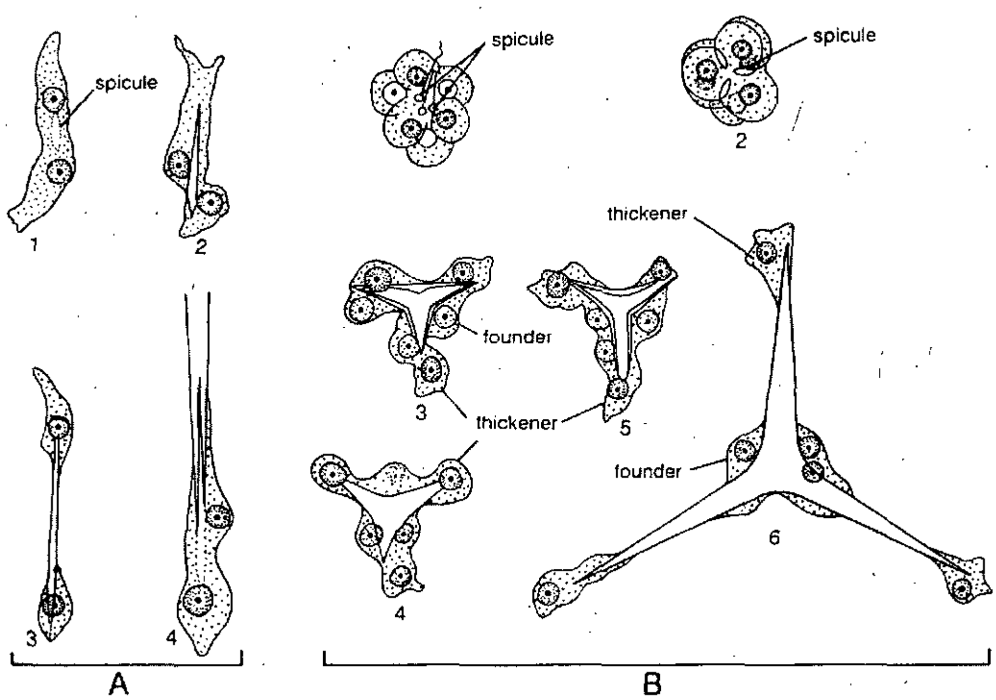



**Fig. 5. Secretion of a A. monaxon and a B. triradiate spicule.**

According to size, the larger spicules, constituting the main skeleton, called **megascleres;** and the smaller spicules, which occur interstitially, called **microscleres**. Further, spicules may occur in several forms; they may be simple rod-like or may take the form of forks, anchors, shovels, stars, plumes, etc. These forms depend upon the number of axes and rays present. Accordingly, they can be divided into the following types :

**1. Monaxon.** Monaxon spicules are formed by growth along one axis. They may be straight needle-like or rod-like or may be curved. Their ends may be pointed, knobbed or hooked. They e of two kinds : (i) **monactinal,** in which growth takes place in one direction only, and (ii) **diactinal**, in which growth occurs in both directions. Monaxons are both calcareous and siliceous types.

**2. Tetraxon.** Tetraxon spicules are with typically four rays, each pointing in a different direction. Usually one of the four rays is elongated giving the appearance of a crown of 3 rays. Such spicules are termed **triaenes**. However, when all the rays are equal, the spicule is termed the **calthrops**. When all the four rays persist, the tetraxon is also referred to **tetraradiate** or **quadriradiate**. However when one of the four rays (usually the elongated one) is lost, the spicule becomes **triradiate,** which characteristic of calcareous sponges. If the elongated ray bears a disc at ends, it is called an **amphidisc**.

**3. Triaxon.** Triaxon spicule has three axes that cross one another right angles to produce six rays. It is thus **hexactinal.** Triaxons characteristic of glass sponges (class Hexactinellida) only.

**4. Polyaxon.** These are spicules with several equal rays, radiating from a central point. They may be grouped to give bur or star-like appearance. Polyaxons are common among microscleres.

### 2. Development of Spicules

Calcareous spicules are secreted by special cells, called **sclerocytes**, derived from the mesenchymal **scleroblasts**. A monaxon spicule, or each ray triradiate spicule, is secreted by a group of two sclerocytes, one acting **thickener cell** and the other as the **founder cell**. A binucleate scleroblast believed to give rise to these cells. Formation of spicule begins as a deposition a particle of calcium carbonate between two nuclei. The particle grows drawing apart first the two nuclei and then the two sclerocytes. Thickener cell lays down additional layers of $CaCO_3$ adding to the thickness of spicule. When spicule fully formed, both the cells wander into mesenchyme.

Scleroblast secreting a calcareous spicule is called **calcoblast,** while the producing a siliceous spicule is called **silicoblast**. A siliceous monaxon believed to be secreted by a single silicoblast, while the six-rayed triaxon secreted within a multinucleate mass formed by repeated nuclear division single silicoblast.

## Spongin

### 1. Structure

Spongin is an organic, horny, elastic substance, resembling with silk chemical composition. Like nails, hair and feathers, "it is a scleroprotein containing sulphur and chemically related to collagen, a horny protein.

insoluble, chemically inert and resistant to protein digesting enzymes. Spongin contains a large amount of iodine, reaching 8 to 14% in certain tropical species of the Spongiidae and Aplysinidae. It is interesting to know that old herb-doctors for centuries used bath-sponge as a cure for croup, a throat condition of children, resulting from inflammation and partial obstruction of larynx.

Spongin occurs in various forms in class **Demospongiae**. It may occur as a cement connecting together siliceous spicules (many **Monaxonida**). More usually it is found in the form of branching or anastomosing fibres, in which siliceous spicules are embedded (**Monaxonida**). In Keratosa, spicules are completely absent and spongin alone is formed. Spongin fibres are fine threads consisting of a soft granular axial core or **medulla**, surrounded externally by concentric layers of spongin.

### 2. Development

Spongin fibres are secreted by *flask-shaped mesenchyme* cells, called **spongioblasts,** which are seen coating the fibres. Spongioblasts become

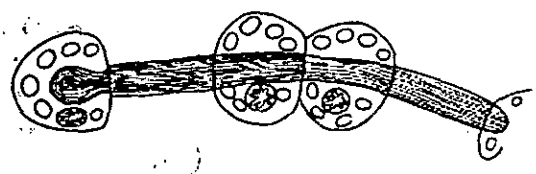


Fig. 6. Spongioblasts in series secreting a spongin fibre.

arranged in rows and the spongin rod secreted by each fuses with those of neighbouring cells to form a long fibre (Fig. 6). Spongioblasts later become vacuolated and degenerate after having secreted a certain quantity of spongin.

## • LIFE HISTORY OF OBELIA

As already described, life-history of *Obelia* includes both asexual (hydroid colony) and sexual (medusa) generations, which regularly alternate with each other to complete the life-cycle. There are separate male and female medusae producing I sperms and ova, respectively.

### [I] Fertilization

Fertilization usually occurs externally in sea-water where the gametes are set free, or sperms may be carried by water currents to female medusae, where they fertilize eggs *in situ*. Parent medusae die soon after liberating the gametes.

### [II] Development

1. **Cleavage.** Fertilized egg or **zygote** undergoes equal and complete or *holoblastic cleavage resulting* in a solid ball of cells, the **morula**. This is followed by the **blastula** stage which is a hollow ball of cells. Its cavity is termed **blastocoel** and the single layer of cells lining it, the **blastomeres**. Gastrulation occurs by two processes. First, the inner surface of **blastomeres** cut off new cells into blastocoel. This is called **delamination.** Second, cells detatch from one pole (**unipolar ingression**) migrate into blastocoel and finally fill it. Thus, the embryo becomes a **solid gastrula** or **stereogastrula**. Its outermost layer is known as **ectoderm** and the inner mass of cells as **endoderm**.

2. **Planula larva.** The gastrula elongates, the ectodermal cells acqui cilia and an elongated free-swimming ciliated **planula larva** results. Anteri end of planula is broader than its posterior end. Soon the solid endoderm spli and develops a cavity, the **enteron**. Now planula becomes a truly **two-layere** larva with an outer ciliated ectoderm and an inner endoderm. Histologicall the larva possesses columnar ectodermal, sensory, nerve and gland cell muscular processes and nematocysts.

3. **Hydrula.** After a brief and active free-swimming existence, planul larva settles down, attaches itself by its anterior end to stone, weed, wood o some other solid object in sea and undergoes metamorphosis. Its proximal er forms a basal disc for attachment, while the distal free end develops manubrium with a mouth and a circlet of tentacles. The larva now closel resembles a simple Polyp or *Hydra* and is called **hydrula.** By repeating a extensive process of asexual budding, hydrula gradually changes into a ne complex of branching *Obelia* colony similar to the parent.

Occurrence of free-swimming medusa and larva in the life-history of a fixe organism, like *Obelia*, is of distinct advantage, as it helps in dispersal an prevents overcrowding of the species.

**[III] Alternation of Generations and Metagenesis**

**Alternation of generations** may be defined as a phenomenon whereby, i the life-history of an organism, a **diploid asexual phase** and a **haploi** **sexual phase** regularly alternates with each other. This type of tru alternation of generations is common among plants, like mosses and ferns where an asexual diploid (**saprophytic**) and a sexual haploid (**gametophytic** generation alternate regularly in life-cycle. In fern, the plant (**diploi** **saprophyte**) produces **haploid spores,** which develop into flat, green, smal heart-shaped **haploid gametophytes**. These produce **haploid ova** an **sperms.** After fertilization, they give rise to a new **diploid sporophyte.** Thu completing one life-cycle.

In *Obelia*, life-cycle includes two clearly defined phases : a fixed polypoi phase (hydroid colony) and a pelagic medusoid phase. Hydroid colony has n gonads and reproduces by asexual budding to give rise to medusae. On th other hand, medusae reproduce exclusively by sexual method (ova and sperms to give rise to new hydroid colonies. This fact apparently seems to have given rise to the idea of **alternation of generations,** also called **metagenesis,** in coelenterates, in which an asexual polypoid generation appears to alternate regularly with a sexual medusoid generation.

But, in *Obelia*, medusoid phase does not represent a true haploid sexual generation, because: (i) Medusa arises from blastostyle (diploid) by a process o asexual budding. It implies that medusa too is a diploid zooid. (ii) Sex cells do not originate in medusa, but in the epidermis of blastostyle, from where they migrate into gonads of medusa. These facts show that medusa does not represent a sexual generation. It is simply a free-swimming diploid zooid specialized for dispersal of gametes of the sedentary hydroid colony. In fact, the so-called sexual generation in *Obelia* is indistinct and represented by haploid gametes only.

Thus, it is clearly impossible to differentiate between sexual and asexual generations in *Obelia*. Asexual hydroid colony and sexual medusa merely represent different phases or zooids, an example of polymorphism, and belong to a single diploid generation, so that a true alternation of generations can not be said to occur in *Obelia*.

In coelenterates (*e.g.*, *Obelia*), a regular alternation between fixed asexual hydroid and free-swimming medusoid phases, both of which are diploid, has been termed **metagenesis** by some workers. But, according to Hyman, concept of metagenesis should be discarded as there are no haploid and diploid generations in coelenterates. According to this view, medusa is regarded to be a completely evolved coelenterate while polyp is probably a persistent larval stage.

## • COELENTERATA : GENERAL ACCOUNT

### POLYMORPHISM

#### Meaning of Polymorphism

Occurrence in the same species of more than one type of individuals, which differ in form and function, is known as **polymorphism** (Gr., **polys,** many + **morphe**, form). This ensures an efficient division of labour between the several individuals.

Different individuals of a species may remain separate, as represented by various castes in termites, certain ants and cuban snail (*Polymita*). This is also known as genetic **polymorphism**. However, in coelenterates the different individuals or zooids often get united in the form of a colony. Thus, polymorphism is an important feature of hydrozoan colonies which provide some of the best examples.

#### Two Basic Forms

In Hydrozoa (or coelenterates), which may be single or colonial, there occur two main types of individuals or zooids —**polyps** and **medusae.**

1. **Polyps.** A polyp has a tubular body with a mouth surrounded by tentacles at one end. Other end is blind and usually attached by a pedal disc to the substratum.

2. **Medusa.** A medusae has a bowl or umbrella-shaped body with marginal tentacles and mouth centrally located on a projection (manubrium) of the lower concave surface.

Although, polyps are typically sessile, and medusae are generally motile, there exists a homology between the two in their basic features.

#### Importance of Polymorphism

Polymorphism is essentially a phenomenon of division of labour. Different functions are assigned to different individuals, rather than to pans or organs of one individual. Thus, polyps are concerned with feeding, protection and asexual reproduction, while medusae are concerned with sexual reproduction.

#### Patterns of Polymorphism

Degree of polymorphism varies greatly in different pups of Hydrozoa.

1. **Dimorphic.** Simplest and commonest pattern of polymorphism exhibited by many hydrozoan colonies like *Obelia, Tubularia, Campanular* etc. They have only two types of zooids (individuals). **Gastrozooids** hydranths are concerned with feeding, while **gonazooids** or **blastostyl** with asexual budding forming sexual **medusae** or **gonophores**. Such coloni bearing only two types of individuals are called **dimorphic**, and t phenomenon is termed **dimorphism**.

2. **Trimorphic.** Some forms, like *Plumularia,* are **trimorphic.** Besid gastrozooids and gonozooids, they also possess a third type of individuals, t **dactylozooids**. These are functionally non-feeding and defensive poly bearing batteries of nematocysts.

3. **Polymorphic.** Coelenterates having more than three types individuals are called **polymorphic**. A somewhat greater degree plymorphism is found in the encrusting colony of *Hydractinia* with five types polyps, each performing a specialized function. These are : (i) **gastrozooids** f feeding, (ii) **spiral dactylozooids** for protection, (iii) long senso **tentaculozooids** with sensory cells, (iv) **skeletozooids** as spiny projections chitin, and (v) **gonozooids** or reproductive individuals, bearing male or fema gonophores (sporosacs) or medusae for sexual reproduction.

Extreme examples of polymorphism are seen in the pelagic or swimmi colonies of the orders Siphonophora (*Diphyes, Halistemmia, Stephal physadia*) and chondrophora (*Porpita, Velella*). As in *Hydractinia,* bo polypoid and medusoid individuals, specialized for various vital function occur in the same colony. Polymorphism reaches its peak in siphonophora.

***(a) Modifications of polyps. Polypoid*** individuals include :

(1) **Gastrozooid** or feeding polyp with a mouth and a long tentacle.

(2) **Dactylozooid** or protective polyp without mouth and usually with long basal tentacle.

(3) **Gonozooid** or reproductive polyp which produces sexual medusa or gonophores.

***(b) Modifications of medusae.*** The **medusoid** individuals are of th following types :

(1) **Nectophore** or **nectocalyx** or swimming zooid with a muscula bell without manubrium or tentacles.

(2) **Pneumatophore** or **float** as a bladder-like medusa filled wit secreted gas.

(3) **Phyllozooid** or **bract**, usually leaf-like and studded wit nematocysts, serving for protection of other zooids.

(4) **Gonophore** bearing gonads, which may be either male, producin sperms, or female producing ova.

### Notable Polymorphic Colonies

1. **Order Siphonophora.** In calycophoran siphonophores, like *Diphyes* colonies are linear with one or more nectophores located at the apical end Polypoid and medusoid individuals are grouped as units, called **cormidia** which are repeated in a linear succession. A typical cormidium consists of a

gastrozooid with a tentacle bearing nematocysts, a phyllozooid or bract, and medusoid gonophores of one sex which are never freed. Dactylozooids are lacking.

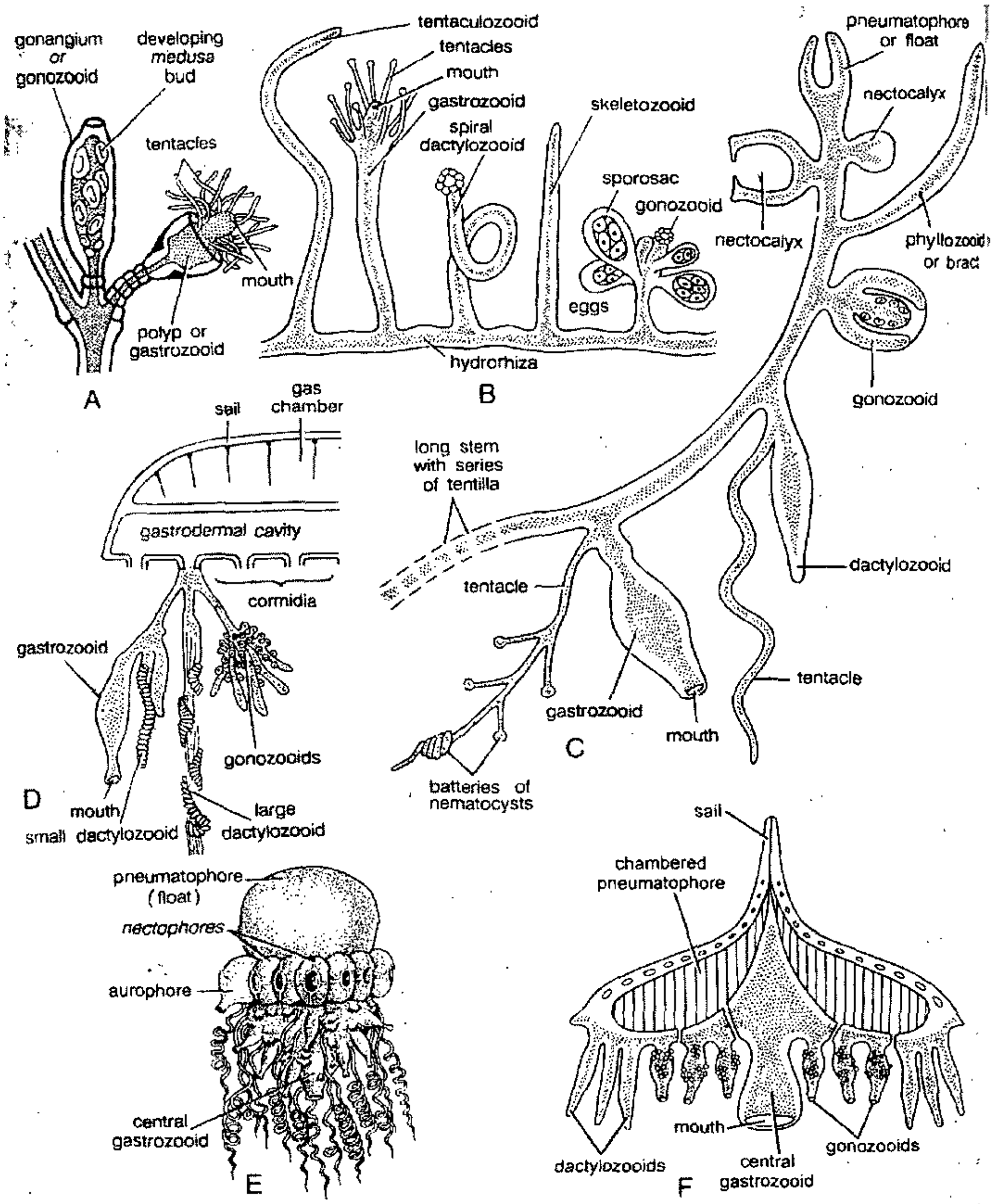



**Fig. 7. Polymorphic colonies of Hydrozoa. A. *Obelia*. B. *Hydractinia*. C. Generalized calycophoran Siphoniophora showing a single cornidiumk, D. *Physalia* showing a single cornidium. E. *Stephalia* showing swimming bells and aurophore. F. *Velella* in V.S.**

In physophoran siphonophores, there is a pneumatophore or float at the apex of colony above water level. This is filled with gas, secreted by the gas-secreting tissue, enclosed within an oval disc. In *Physalia*, underneath this disc bears groups of cormidia, each including a gastrozooid, a small and a large dactylozooid, both with long tentacles, and a branched gonozooid with both male and female gonophores. Nectocalyces or swimming bells and bracts are altogether absent.

In *Nectalia* and *Stephalia*, swimming bells are (highly developed. *Stephalia* is peculiar in that a portion of float or pneumatophore is constricted off as bell-like body, called **aurophore**. Its function and homology remain uncertain.

2. **Order Chondrophora.** In *Velella* and *Porpita*, colony seems to be highly organized. There is a single central gastrozooid with a mouth. Around it a concentric rows of gonozooids surrounded by a few rows of dactylozooids. Entire colony looks like a single individual animal.

### Origin of Polymorphism

As we have seen, colonies of Siphonophora represent the most specialized Hydrozoa, attaining the highest degree of polymorphism and presenting the greatest number of medusoid and polypoid types.

There are two views regarding which came first, polyp or medusa, during the evolution of polymorphism in Coelenterata,

According to one view, the ancestral coelenterate was a *Hydra*-like polyp (archhydra of Haeckel) which arose from gastraea. It gave rise to hydroid colony by asexual budding. In the (sessile colony some polyps became modified into 1 medusae for sexual reproduction and pelagic life. Thus, through division of labour, the hydroid colony became polymorphic.

According to second view (**Brooks,** 1886), which seems to be more acceptable, the ancestral Coelenterata was a primitive **medusa**. It arose from metagastraea by developing tentacles and : becoming free-swimming. According to **Huxley, Eschscholtz** and **Metschnikoff,** the manubrium, tentacles and umbrella of this primitive medusoid individual were multiplied and shifted from their original positions to become various zooids of the polymorphic colony. According to this view, polypoid stage is considered the persistent larval stage and medusoid the completely evolved coelenterate.

According to **Moser**, various zooids of Siphonophorae are merely organs that have not attained the grade of polymorphic individuals (**poly-organs**). Sl[illegible] regards siphonophora to be ancestral to Hydrozoa which has fully differentiated zooids (**poly-persons**). Moser believes that **poly-organs** Siphonophora by further differentiation became the **poly-persons** Hydrozoa. However, Moser's views err too much to deny the full colonial nature to Siphonophora-

## • CORAL

### Meaning of Coral

**Coral animals** or **corals** are marine, mostly colonial, polypoid coelenterates, looking like miniature sea anemones and living in a secreted skeleton of their own. Their calcareous or horny skeleton is also commonly known as **coral**. Some corals grow into massive, solid structures; others form large, branched colonies. Most of the corals belong to the class Anthozoa and few to the class Hydrozoa of phylum Coelenterata.

### Structure of Coral Polyp

**Soft structure.** A typical coral polyp from a colony is a small organism about 10 mm long and 1 to 3 mm in diameter. Solitary coral polyps are much

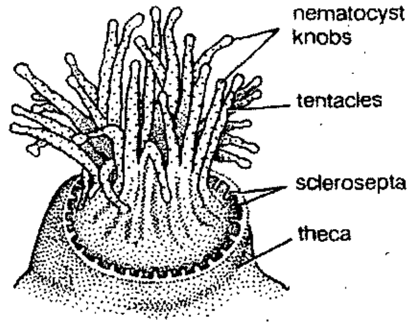



**Fig. 8. A coral polyp (Astrangia) extended from theca.**



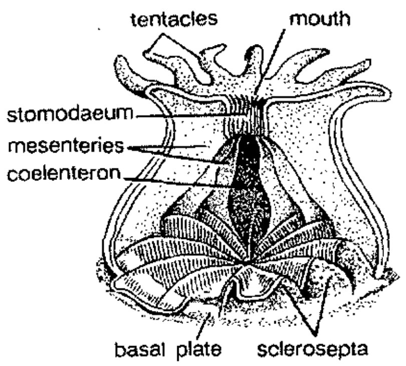



**Fig. 9. Internal structure of a coral polyp in semi-diagrammatic V.S.**

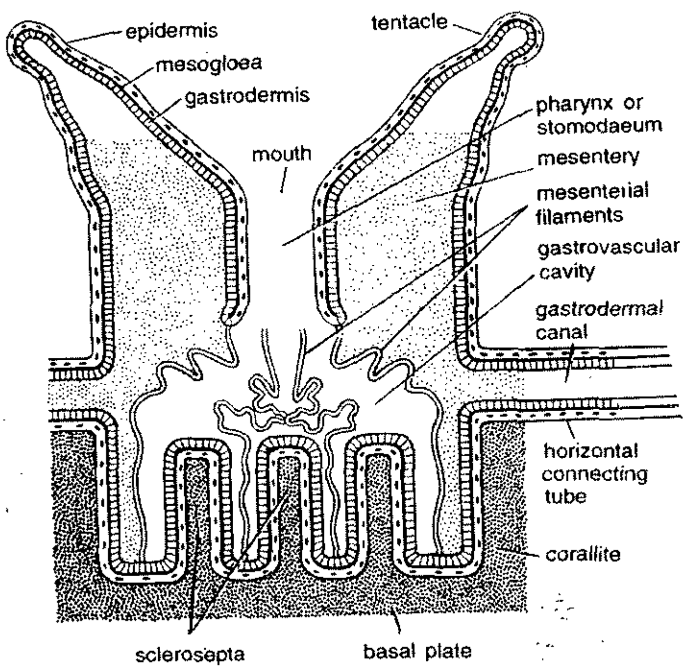



**Fig. 10. Diagrammatic V.S. of a coral polyp with its corallite.**

larger reaching up to 25 cm in diameter. A basal disc is absent because the basal region of polyp is surrounded by a calcareous exoskeleton. Oral disc bears numerous tentacles, in several rows around an elongated, oval or circular mouth. Pharynx or stomodaeum is short and without siphonoglyphs. Mesenteries are restricted to the upper part of coelenteron and mesenterial filaments contain only one glandular lobe bearing nematocysts. Bodywall is without cinclides and nematocyst bearing structures (acontia). Muscles are poorly developed while little is known about nervous system.

Living polyps are found only on surface layers of coral masses. They feed at night both by raptorial and suspension feeding. When not feeding, they withdraw into cup-like cavities of skeleton.

### Coral Skeleton

1. **Structure of coral skeleton.** Skeleton of a solitary coral is known as **corallite**. It is a calcareous exoskeleton secreted by epidermis. In a colonial coral, corallites of individual polyps fuse together to form a skeletal mass called **corallum**. Each corallite is like a stony cup with a basal part or basal **plate**, and a cup wall or **theca**, enclosing the aboral portion of polyp, Cavity of cup contains a number of vertical radiating ridges called **sclerosepta** proceeding from theca towards the centre of cup. Inner ends of sclerosepta are fused to form an irregular central skeletal mass or **columella**.

2. **Formation of coral skeleton.** In coral polyps, sexual reproduction takes place by fusion of gametes. Zygote develops into a free-swimming ciliated **planula** larva which settles down and metamorphoses into a young coral **polyp**. There is no medusa stage. By asexual budding, single polyp becomes the parent of all other members of the colony. The coral polyp begins to secrete skeletal rudiment or **prototheca** It is secreted by ectoderm, first as a basal plate. Following it, radial folds develop which secrete sclerosepta. At the same time, a rim is built up as a thecal wall around the polyp, lying at the top. Meanwhile further skeletal material is added into the gaps between sclerosepta of skeleton which usually alternates with mesenteries of the polyp.

Coral colony grows in size continuously by budding of new polyps, particularly along the margins and on surface layers of coral masses. Variety in form of compound corals results due to various patterns of budding.

### Types of Corals in Different Groups

1. **Hydrozoan corals.** Order Hydrocorallina includes few genera, like *Millepora, Stylaster* and *Distichopora*, which are colonial and secrete massive branched calcareous exoskeletons. These are found in coral reefs with other corals. Skeleton is secreted by a modified epidermis, called **calicoblastic layer**. Living within the skeleton occur two types of polyps, large feeding gastrozooids and defensive dactylozooids.

2. **Octocorallian corals**. Order Alcyonacea includes marine, colonial and soft corals. A well-known genus is *Alcyonium*, popular as dead man's fingers' because of its resemblance to a human hand. It has an endoskeleton of separate calcareous spicules embedded in a massive mesogloea or **coenenchyme**.

Order Stolonifera includes the organ pipe coral, *Tubipora musica*, widely distributed on coral reefs in warm waters. Skeleton is made of mesogloea calcareous spicules forming parallel and vertical tubes, each occupied by one polyp, and connected together by lateral platforms. Skeleton is dull red in colour due to presence of iron salts.

Order Coenothecalia includes a single genus *Heliopora*, commonly known as blue coral. Its massive calcareous, skeleton or **corallium** is secreted by polyps living in large erect, cylindrical solenial tubes on the surface of skeleton.

Order Gorgonacea includes plant-like colonies of sea fans or horny corals. In *Gorgonia*, colony branches in one plane only. Its axial skeleton is made by horny proteinaceous material intermixed with calcareous spicules arranged around the polyps. In precious red coral, *Corallium nobile,* the branching colony has canaliferous coenenchyme of coenosarc containing dimorphic polyps. Axial skeleton consists of spicules embedded in $CaCO_3$ forming precious hard red coral which is used in jewellery.

**3. Hexacorallian corals.** Order Madrepora includes stony corals or true corals, which are the principal builders of coral reefs. While some of them are solitary, most are colonial, assuming a great variety of forms.

***(a) Solitary corals.*** *Fungia, Flabellum, Caryophylla,* etc., are the solitary corals or cup corals. The corallite is disc-like, cup-like or mushroom-shaped in form and measures 5 mm to 25 cm across. It is often without a theca.

***(b) Colonial corals.*** Most of stony corals are colonial with plate-like, cup-like, spherical, or vase-shaped skeleton (**coralium**). Polyps live at the

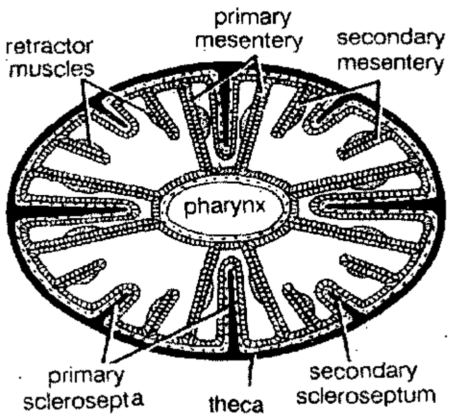



**Fig. 11, T.S. of a simple coral polyp with coralliie.**

surface of the calcareous skeleton. Typical examples of colonial madreporarian corals are *Acropora, Oculina, Favia, Madrepora, Meandrina,* etc. Some of the colonies are branched. In stag-horn coral, *Acropora*, there is always a primary polyp at the top of colony with lateral branches on either side. In some corals, like Oculina, polyps remain widely separated, each occupying a separate theca. In others, like *Favia* and *Astraea*, thecae are so close together as to have common walls. In the brain-coral, *Meandrina*, polyps as well as thecae become confluent, occupying valleys separated by ridges, on the surface of coralium.

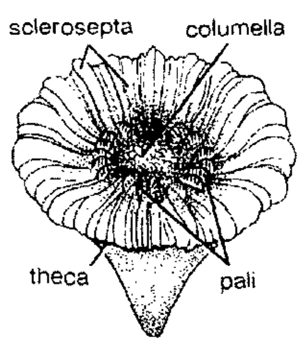



**Fig. 12, Corallite of a solitary coral (*Flabellum, Caryophyllia*).**

## Meaning of Coral Reef

Coral colonies grow continuously in size by budding of polyps and often f extensive masses, known as **coral reefs**. According to **T. Wayland Vaugh** (1917), a coral reef is a ridge or mound of limestone, the upper surface of wh is near the surface of sea and which is formed chiefly of $CaCO_3$ secreted by co polyps. Principal builders of coral reefs are stony corals (Madreporaria), other important contributors are the hydrocorallines and alcyonaria Coralline algae and Foraminiferan Protozoa also take part in the formatio coral reefs.

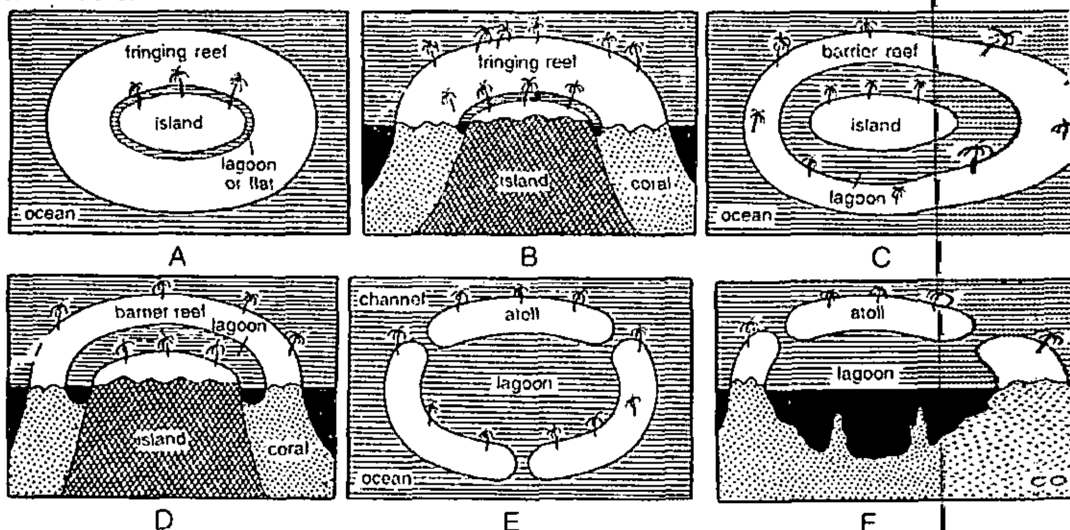



**Fig. 13, Coral reefs. A. Fringing reef. B, Fringing reef in section. C. Barrier reef. D. Barrie reef in section. E. Atoll. F. Atoll in section.**

Reef building corals require warm shallow waters (normally above 20°C They are therefore limited to the Indo-Pacific, the Central-Western Pacific, a the Caribbean regions north of Bermuda. About 50 species of corals contribu in the formation of reefs along the Florida Keys and in the West-Indies.

## Kinds of Coral Reefs

The coral reefs are of three kinds, depending on how they are formed.

1. **Fringing reefs.** Coral reefs lying close to the shores of some volcan island or part of some continent are termed **fringing reefs**. A fringing reef ma extend out to a distance of a quarter mile from the shore with the most acti zone of the coral growth facing the sea. This seaward zone is commonly calle the **edge** or **front** A shallow water channel, 50 to 100 meters broad, li between the reef-edge and shore. At low tide, water of channel recedes quickly exposing a flat bottom surface, called **reef flat** It is largely composed coral sand, mud, dead and living coral colonies and other animals.

2. **Barrier reef.** Barrier reefs are like fringing reefs but they a located some distance away from the shore. The stretch of water, separating th barrier reef from land, may be half a 16 km or more in width. It is called **lagoon**. It is 20 meters to 100 meters deep and suitable for navigation.

Most notable example of barrier reef is the Great Barrier Reef along th North-eastern coast of Australia. It is about 2,000 km long and up to 150 k from shore.

**3. Atoll.** An **atoll** is also termed a **coral island** or **lagoon island**. It is a ring-like or horse-shoe-shaped reef that encircles a lagoon but not an island. The lagoon varies from a few to about 90 km across. It may be complete or broken by a number of channels, of which only a few are navigable. Outer side of the reef slopes off rather steeply into the depth of ocean.

The atoll of Bikine, famous for atomic and hydrogen bomb tests, lies in the Pacific Ocean.

### Formation of Coral Reefs

Many theories have been advanced to explain coral-reef formation, but none are entirely satisfactory. Two theories seem to be of some convincing importance.

**1. Subsidence theory by Darwin.** According to this theory, as put forth by **Darwin** (1831), fringing reef was first formed on the sloping shore of *an island. Subsidence of sea-floor then commenced in the regions of reef* followed by upward and outward growth of coral. Thus, the fringing reef became the barrier reef. By gradual sinking the island ultimately vanished and the barrier reef became a coral atoll with a central lagoon. In time it acquired a growth of vegetation.

**2. Glacial-control theory by Daly.** Another theory, as propounded by Daly, accounts for the lowering of the ocean level by the withdrawal of water for glacial formation. This resulted in the exposing of several flat platforms cut out by the action of waves. When the glaciers melted and the temperature became favourable, corals began to grow on these platforms, building higher as the ocean level rose.

Most reefs grew at the rate of 10 to 200 mm each year. Most of the existing reefs could have formed with in a period of 15,000 to 30,000 years.

### Economic Importance of Coral Reefs

Corals of the remote geological past formed reef structures that were highly favourable sites for the accumulation of petroleum deposits. Thus coral reefs are of much importance to oil industry. Large quantities of corals are shipped every year for the curio trade. The coral reefs serve as habitats for many plants and animals like sponges, molluscs, echinoderms, fishes, etc. Some coral reefs are used as habitations by man as well. Some corals are highly priced for their decorative value. *Corallum rubrwn* is considered to be a precious stone in India and China and treated as auspicious. The red coral and organ pipe coral are used in some indigenous system of medicine in S. India. Chunks of coral skeleton belonging to species Porites are used as building material. Coral skeletons serve as raw material for the preparation of lime, mortar and cement because of their calcium carbonate and magnesium carbonate content. Coral skeletons are also helpful in making ridges that may act as natural barriers against sea erosion and cyclonic storms. Coral reefs serve as good nursery grounds for commercially important fishes. Reef fish varieties are more colourful than others.

❑❑❑

# UNIT

# 3

# PLATYHELMINTHES NEMATHELMINTHES

## STRUCTURE

- General characteristics and Classification up to class,
- Canal System and Spicules in sponges
- Metagenesis in *Obelia*
- Polymorphism in *Cnidaria*
- Coral and coral reefs

## • DEFINIT

The term **Platyhelminthes** (Gr., **platys, flat+helmins,** worm) was proposed by **Gegenbaur** (1859) for the flatworms. These may be define acoelomate, triploblastic, bilaterally symmetrical, vermiform, dorso-vent flattened organisms; devoid of a definite anus; without skeletal, respira and circulatory systems; with flame cells or protonephridia and mesenchymal cells representing mesoderm, filling up spaces between var organs.

## • MORPHOLOGICAL ADVANC

Platyhelminthes shows an advancement over the previous metazoan p (coelenterata and ctenophora) in the following respects :

1. Tissue-organ level of organization.
2. Triploblastic body. Third germ layer mesoderm instead of mesoglo
3. Symmetry definitely bilateral, at the lowest level.
4. A definite head and tail.
5. Mesodermal muscles in bundles and layers.
6. More complex and efficient gastrovascular cavity.
7. Nervous system with large, anteriorly situated ganglia and n cords running along the body.
8. Better developed sensory organs.
9. Internally situated gonads with permanent gonoducts copulatory structures.
10. Behaviour organization through learning.

## • PHYLOGENETIC SIGNIFICA

Platyhelminthes or flatworms are supposed to have evolved fro coelenterate-like ancestor, which underwent a change from radial to bilat symmetry. Coelenterate ancestor was like a **planula larva** as primitive a worms share many characteristics with planula, such as : (i) absenc epidermal basement membrane, (ii) absence of gut, (iii) absence of excretory organs, (iv) absence of gonads, (v) a centro-ventrally located mouth, and (vi) a nerve plexus under epidermis. Trematodes are thought to have evolved from some commensal or parasitic rhabdocoel turbellarians and cestodes evolved independently from trematodes.

### General Characters

1. Free-living, commensal or parasitic forms.

2. **Tissue-organ grade of organization**, *i.e.*, body cells aggregate into definite tissues and tissues make up organs.

3. **Triploblastic**, *i.e.*, body derived from three embryonic germ layers; ectoderm, mesoderm and endoderm.

4. **Bilaterally symmetrical** with definite polarity of anterior (head) and posterior (tail) ends.

5. **Dorso-ventrally flattened.** Usually with a well-defined ventral surface bearing mouth and gonopore.

6. Body **unsegmented** (except in class Cestoda).

7. **Acoelomate**, *i.e.*, without any body cavity. Spaces between various organs filled with special mesodermal tissue, the **mesenchyme** or **parenchyma**.

8. Adhesive structures like hooks, spines and suckers, and adhesive secretions common in parasitic forms.

9. **Epidermis** cellular or syncytial, frequently ciliated. Absent in some.

10. **Muscular system** of mesodermal origin. Longitudinal, circular and oblique muscle layers beneath epidermis.

11. **Digestive system** branched and incomplete without anus. Altogether absent in Acoela and Cestoda.

12. Skeletal, respiratory and circulatory systems are wanting.

13. **Excretory system** includes lateral canals and protonephridia (flame cells). Absent in some primitive forms.

14. **Nervous system** primitive, ladder-like. Comprises a pair of anterior ganglia with longitudinal nerve cords connected by transverse nerves.

15. **Sense organs** simple. Eye-spots or photo-receptors in free living forms.

16. Mostly **monoecious** (hermaphrodite) with complex reproductive system. Well-developed gonads, gonoducts and accessory organs. Eggs mostly devoid of yolk. Yolk produced separately in **yolk** or **vitellme glands**.

17. **Fertilization** internal, may be cross or self.

18. **Development** direct or indirect. Usually indirect in endoparasites with a complicated life cycle involving many larvae and hosts.

## • CLASSIFICATION

### CLASS 1. Turbellaria

(L., *turbella*, a stirring)

1. Usually non-parasitic, free-living worms are called **planarians.**

2. Terrestrial marine or freshwater.

3. Body unsegmented, flattened and covered with ciliated cellular syncytial epidermis, containing mucus secreting cells and rod-shaped bo called **rhabdites**.

4. Mouth ventral. Intestine preceded by muscular pharynx.

5. Suckers absent. Tango, chemo and photo-receptors common free-living forms.

6. Mostly hermaphroditic. Some reproduce asexually. Developm usually direct.

**Order 1. Acoela**

1. Minute, exclusively marine, less than 2 mm.
2. Ventral mouth; no muscular pharynx and without intestine.
3. Flame cells, definite gonads, gonoducts and yulk glands wanting.
4. Mostly free-living, found under stones, algae or on bottom mud. Sc dwell in intestine of sea-urchins and sea-cucumbers.

Examples : *Convoluta, Amphiscolops, Ectocotyl, Afronta.*

**Order 2. Rhabdocoela**

1. Small, usually less than 3 mm.
2. Simple pharynx and sac-like intestine.
3. Protonephridial excretory system.
4. One or two gonads. Yolk glands present or absent.
5. Marine, freshwater or terrestrial. Free-living, commensal parasitic.

Examples : *Stenostomum, Microstomum, Actinodactyletta, Catenu Macrostomum, Mesostoma.*

**Order 3. Alloecoela**

1. Moderate-sized, between 1 and 10 mm.
2. Pharynx simple, bulbous or plicate. Intestine straight or branched.
3. Protonephridia paired, usually branched.
4. Testes numerous. Penis papilla mostly present.
5. Mostly marine, common in littoral sand and mud. Some freshwater.

Examples : *Prorhynchus, Plagiostomum, Geocentrophora.*

**Order 4. Tricladida**

1. Large 2 to 60 cm in length.
2. Mouth mid-ventral, pharynx plicate and intestine with thr branches, each with many diverticula.
3. Protonephridia as lateral networks with many nephridiopores.
4. Testes numerous, ovaries two. Yolk glands present.
5. Marine, freshwater or terrestrial.

Examples : *Dugesia, Gunda, Bdelloura, Geoplana, Bipalium, Euplanaria.*

**Order 5. Polycladida**

1. Moderate-sized, 2 to 20 mm.
2. Pharynx plicate. Intestine highly branched.
3. Gonads many, scattered. Yolk glands absent.
4. Male and female gonopores separate.
5. Marine, many bottom dwellers of littoral zone.

Examples : *Leptoplana, Notoplana, Cestoplana, Planocera, Thysanozoon.*

**CLASS 2. Trematoda**

(Gr., **tremta, hole+eidos**, form)

1. Ecto-or endoparasitic flatworms, called **flukes**.
2. Body unsegmented, dorso-ventrally flattened, leaf-like. Tegument thick but without cilia and rhabdites.
3. Suckers and sometimes hooks present.
4. Alimentary canal with anterior mouth, simple pharynx and two main branches.
5. Three pairs of longitudinal nerve cords.
6. Mostly monoecious. Development direct (in ectoparasites) or indirect (in endoparasites) with alternation of hosts.

**Order 1. Monogenea**

1. Mostly ectoparasites in cold blooded aquatic vertebrates.
2. Posterior adhesive organ or opisthaptor with suckers armed with hooks or spines.
3. Excretory pores two, situated anteriorly on dorsal side.
4. Vagina one or two. Uterus small with a few shelled eggs.
5. Only a single host in life cycle.
6. Free-swimming ciliated larva called **onchomiracidium**.

Examples : *Gyrodactylus, Dactylogyrus Polystoma, Diplozoon.*

**Order 2. Digenea**

1. Mostly endoparasites in vertebrates and invertebrates.
2. Two suckers, oral and acetabulum, both devoid of hooks.
3. Single posterior excretory pore.
4. No vagina. Uterus long with numerous shelled eggs.
5. Life cycle complex with numerous larval stages in two to three intermediate hosts.
6. Larval forms reproduce asexually before metamorphosis.

Examples : *Bucephalus, Fasciola, Paramphistomum, Paragonimus, Schistosoma, Opisthorchis* (= *Clonorchis*).

4. Parasites in birds.

   Examples : *Nematoparataenia, Gastrotaenia.*

**Order 9. Nippotaeniidea**

1. No scolex but well-developed terminal sucker.
2. Proglottids few. Vitellaria few.
3. Parasites in freshwater fishes of Japan.

   Examples : *Nippotaenia, Amurotaenia,*

**Order 10. Caryophyllidea**

1. Scolex without true suckers or bothria.
2. Eggs non-embryonated when laid.
3. Parasites in fishes.

   Examples : *Caryophyllaeus, Archigetes, Glaridacris.*

**Order 11. Spathebothridea**

1. Scolex without suckers or bothria.
2. Testes are medullary. Ovary median.
3. Parasites in primitive fishes.

   Example : *Spathebothrium.*

## • PHYLUM NEMATODA : CHARACTERS, CLASSIFICATION AND TYPES

Nematodes (Gr., **nema** thread + **eidos**, form) are commonly referred to as non-segmented roundworms, threadworms or pinworms, as distinct from lower flatworms and higher segmented annelids. They constitute the largest phylum of pseudocoelomate groups combined under the super phylum Aschelminthes

### GENERAL CHARACTERS ;

Main distinguishing features of phylum Nematoda are as follows :

1. Widely distributed, aquatic or terrestrial, and parasitic or free living.
2. Body elongated, cylindrical, unsegmented, worm-like, bilaterally symmetrical, and tapering towards both ends.
3. Body triploblastic with organ-system grade of organization.
4. Body wall with, thick resistant cuticle, cellular or syncytial epidermis, and only longitudinal muscle fibres in four bands.
5. True coelom absent. Persistent blastocoel or pseudocoel present not lined by mesoderm.
6. No cilia, no circulatory and no respiratory system.
7. Digestive system complete with anus, with muscular pharynx and non-muscular intestine.
8. Excretory system of glandular organs or canals or both. Flame cells absent.
9. Nervous system with circumenteric ring and anterior and posterior nerves.

10. Sense organs poorly developed, in the form of small papillae and amphids near on two body ends.

11. Dioecious with sexual dimorphism. Male smaller than female. Gonads simple and coiled. Male genital ducts lead into cloaca. Female genital ducts with a separate opening. No asexual reproduction.

12. Fertilization internal. Development usually direct, with or without an intermediate host.

## CLASSIFICATION

Nematodes are among the most numerous of any phylum. Every fistful of soil may contain thousands of them. About 15,000 species of nematodes are known at present. Their classification is difficult due to much diversity in form and structure. **Chitwood** (1933) divided them into two classes, **Phasmidia** and **Aphasmidia**, on the basis of presence or absence of phasmids. These are grouped into 17 orders, but only some important orders have been described here.

### CLASS 1. Aphasmidia (Adenophorea)

1. Phasmids (caudal sensory organs) absent.
2. Amphids (anterior sense organs) of various types, rarely pore-like.
3. No excretory system. If present, poorly developed.
4. Mesenterial tissue well developed.
5. Caudal adhesive glands present.

#### Order 1. Enoploidea

1. Anterior end with six labial papillae and 10-12 sensory bristles.
2. Cuticle usually with bristles.
3. Amphids cyanthiform.
4. Chiefly marine, free-living.

Examples : *Enoplus, Metonchdiamus.*

#### Order 2. Dorylaimoidea

1. Anterior end with 6-10 papillae.
2. Cuticle smooth, no bristles.
3. Amphids cyanthiform.
4. Buccal cavity with protrusible spear.
5. Free-living in soil and fresh-water.

Examples : *Dorylaimus, Tylencholaimus.*

#### Order 3. Mermithoidea

1. Large-sized.
2. Anterior end with 16 labial papillae and no sensory bristles.
3. Cuticle smooth, no bristles.
4. Amphids cyanthiform or reduced.
5. Oesophagus long leading into blind intestine.
6. Larvae parasitic in invertebrates, adults free-living.

Examples : *Mermis, Agamermis, Paramermis.*

**Order 4. Chromadoroidea**

1. Small-sized.
2. Cuticle smooth or ringed; with heavy bristles.
3. Amphids spiral.
4. Buccal cavity with teeth.
5. Pharynx with posterior bulb.
6. Mostly marine; free-living.

Example : *Halichoanolaimus.*

**Order 5. Monohysteroidea**

1. Small-sized.
2. Amphids circular.
3. Cuticle smooth or slightly ringed, often with bristles.
4. Anterior end with 4, 6, 8, or many sensory bristles.
5. Free-living; mostly marine, some fresh-water, some terrestrial.

Examples : *Monohystera, Plectus.*

**Order 6. Desmoscolecoidea**

1. Small-sized.
2. Amphids cresent-shaped or pump-shaped.
3. Cuticle heavily ringed.
4. Anterior end with four sensory bristles, head armoured.
5. Marine; free-living.

Example : *Desmoscolex, Epsilonema.*

**CLASS 2. Phasmidia (Secernentea)**

1. Phasmids present.
2. Amphids pore-like.
3. Excretory system developed.
4. Mesenterial tissue weakly developed.
5. No caudal adhesive glands.

**Order 1. Trichuroidea (Trichinelloidea)**

1. Body filiform anteriorly.
2. Mouth without lips; pharynx slender.
3. Female with one ovary and male with one or none spicule.
4. Parasites of vertebrates.

Examples : *Trichuris, Trichinella.*

**Order 2. Dioctophymoidea**

1. Large worms.
2. Mouth without lips; with 6, 12 or 18 papillae.
3. Pharynx elongated and with no bulb.

4. Female with one ovary and male with one spicule and muscular bursa.

5. Parasites of mammals and birds.

Examples : *Dioctophyma, Hystrichis.*

**Order 3. Rhabditoidea**

1. Small to moderate sized.
2. Cuticle smooth or ringed.
3. Sensory bristles as papillae in two rings, an inner ring of 6 and outer ring of 4, 6 or 10.
4. Copulatory spicules in male accompanied by gubernaculum.
5. Free-living or parasitic in animals and plants.

Examples : *Rhabditis, Heterodera.*

**Order 4. Rhabdiasoidea**

1. Medium-sized.
2. Cuticle smooth
3. No pharyngeal bulb.
4. Parasite stage in vertebrates is either hermaphroditic or parthenogenetic.

Examples : *Rhabdias, Strongyloides.*

**Order 5. Oxyuroidea**

1. Pin-shaped small worms.
2. Mouth surrounded by 3-6 simple lips.
3. Pharynx with valvular posterior bulbs.
4. Female with long pointed tail.
5. Parasitic in invertebrates and vertebrates.

Examples : *Oxyuris, Enterobius.*

**Order 6. Ascaroidea**

1. Large-sized worms.
2. Mouth surrounded by 3 lips.
3. Pharynx without bulb.
4. Male with ventrally coiled tail.
5. Parasitic in vertebrates.

Examples : *Ascaris, Ascaridia.*

**Order 7. Strongyloidea**

1. Mouth without lips but with leaf crowns.
2. Buccal capsule well developed.
3. No pharyngeal bulb.
4. Male with expanded copulatory bursa; female usually with ovijector.
5. Parasites of vertebrates.

Examples : *Necator, Ancylostoma, Strongylus.*

**Order 8. Spiruroidea**

1. Mouth with two lateral lips.
2. Pharynx with bulb, muscular anteriorly and glandular posteriorly.
3. No copulatory bursa in male but with spirally coiled tail.
4. Parasites in animals.

Examples : *Thelazia, Gnathostoma, Spiroxys.*

**Order 9. Dracunculoidea**

1. No lips or buccal capsule.
2. Mouth surrounded by ring of papillae.
3. No pharyngeal bulb; pharynx muscular anteriorly and glandular posteriorly.
4. Male without copulatory bursa.
5. Parasites of vertebrates.

Examples : *Dracunculus, Philometra.*

**Order 10. Filarioidea**

1. Filiform slender worms.
2. No lips and buccal capsule.
3. Six labial papillae present.
4. No pharyngeal bulb.
5. Male small with coiled tail.
6. Microfilariae in blood or skin and develop in blood-sucking insects.
7. Parasites of vertebrates.

Examples : *Wuchereria, Microfilaria, Loa.*

## • LIFE CYCLE AND DEVELOPMENT

### [I] Digenetic Life Cycle

Life cycle of *F. hepatica* is complex and completed in two hosts. **Primary host**, in which the adult fluke lives, is sheep. While the **intermediate host**, in which numerous larval stages are passed, is a snail (*Lymnaea, Planorbis*, etc.). This type of life cycle, involving two different kinds of hosts, is termed **digenetic**.

### [II] Copulation

Self-fertilization is of rare occurrence in liver flukes though they are hermaphrodite. **Cross-fertilization** preceded by **copulation** is of normal occurrence. In *F. hepatica*, copulation takes place in bile ducts of the host.

Two flukes in copulation bring their genital pores in opposition. Cirrus of one fluke, everted through its gonopore, penetrates the Laurer's canal of the other through the latter's temporary opening, and injects spermatozoa. Secretion of prostate glands, and perhaps also of the Mehlis's glands, keep the sperm active for fertilization.

### [III] Fertilization

Fertilization is **internal**. In **cross-fertilization**, sperms received in Laurer's canal during copulation, enter the distal end of oviduct where fertilization occurs. During **self-fertilization**, sperms enter the uterus of same fluke through female genital aperture and pass down to fertilize the eggs.

### [IV] Capsule Formation

Each fertilized egg or zygote is surrounded by yolk cells, which provide yolk and shell material. Shell-globules of yolk cells contain proteins and a phenol. According to **Stephenson** (1947), phenol is oxidized to a quinone in the proximal part of uterus. Quinone then tans the protein, producing a hard, resistant and leathery **sclerotin** like that of insects. This sclerotin forms the shell around fertilized eggs. Above finding of Stephenson in liver flukes is perhaps true for all platyhelminths.

### [V] Capsules

Shelled eggs are termed **capsules** or simply **eggs.** A shell or capsule is yellow or brown, in colour and oval in shape. It is about 130 to 150μ long and 60 to 90μ wide. It is operculate, *i.e.*, provided with a lid or **operculum**. Situated immediately beneath the operculum, at the terminal end of egg is a viscous and granular cushion. About 3,000 or more such capsules may occur at a time in the uterus of a single fluke. There may be as many as 200 flukes in the liver of one sheep. If each fluke produces 500,000 eggs (in 10 years), a single infected sheep may disperse 100 million fertile eggs. This vast capacity for egg production is necessary in view of the complicated life cycle and slim chances of survival.

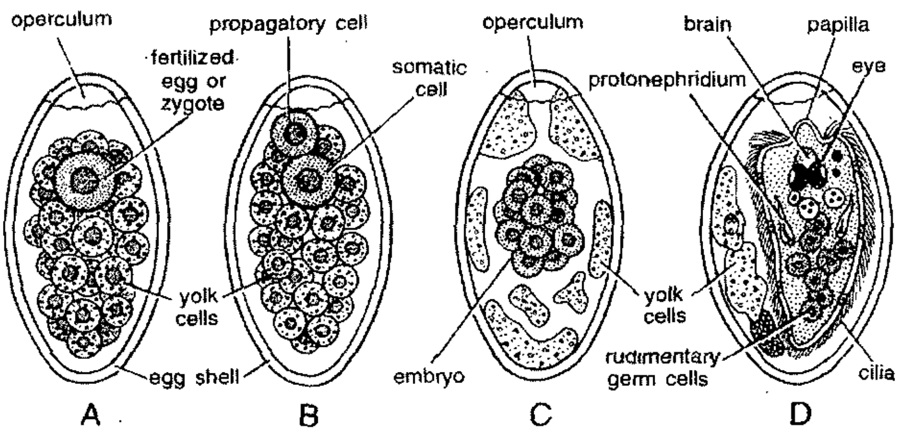



**Fig. 1. F. hepatica. Early or embryonic development. A. Zygote in capsule. B. 2-Cell stage. C. Many-cell stage. D, *Miracidium* in capsule.**

### [VI] Cleavage and Embryonic Development

Cleavage starts while eggs are still in uterus. Cleavage is **holoblastic** and **unequal**. First division of zygote results in two **unequal** cells, a larger **somatic cell** and a smaller **propagatory cell**. Subsequent divisions of somatic cell form larval ectoderm and tissues. Propagatory cell divides further into two daughter cells. One daughter cell by its divisions finally produces the larval body. Other daughter cell divides several times to form a mass of smaller **germ cells** which cluster in the posterior part of larval body.

**Encapsulated embryos** or **capsules** or simply **eggs** do not develop furt in fluke's uterus. A very large number of capsules leave fluke's body through gonopore into host's intestine, and finally ejected out with its faec Further development takes place when capsules come in contact with water damp areas with at least 60% moisture content) which slightly acidic (pH 6.5). Optimum temperature for development ranges fr 22°C to 25°C.

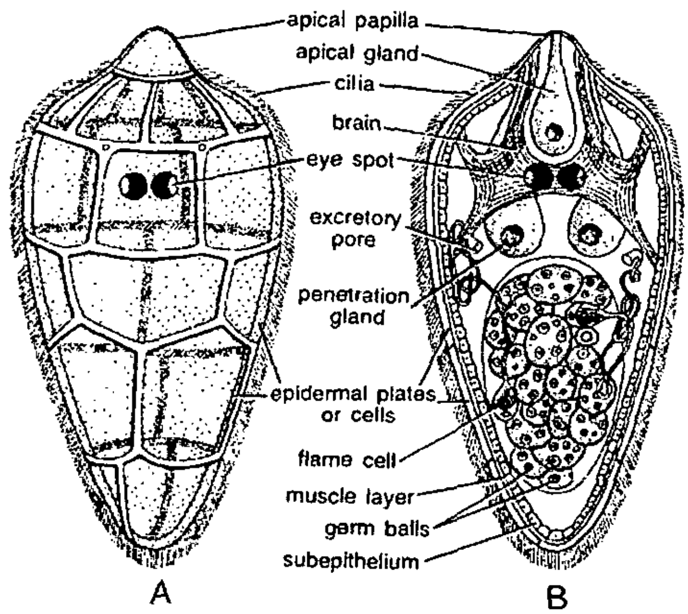



**Fig. 2.** ***F. hepatica.*** **Miracidium larva. A. External structure. B. Internal structure.**

### [VII] Miracidium Larva

It is the first larval stage involved in life cycle, When suitable conditio become available, the encapsulated embryo, in 4-15 days, differentiates into **miracidium larva**. It hatches out and swims in water. Hatching is initiated l a proteolytic **hatching enzyme**. It dissolves the cementing material by whi operculum is attached, thus releasing the operculum.

1. **External structure.** Miracidium is a minute, about 0.07 mm lon oval, elongate and richly ciliated active creature. Its broader anterior end produced into a mobile and non-ciliated **apical papilla** or **terebratoriu** Miracidium is a multicellular organism. Its body is covered with flattene ciliated **epidermal plates** or cells, 21 in number and arranged in five rows tiers.

Number and arrangement of cells in each tier is fixed. **First tier** (anterio most) has 6 plates, two dorsal, two lateral and two ventral. **Second tier** als has 6 plates, three dorsal and three ventral. **Third tier** has 3 plates one dors and two ventro-lateral. **Fourth tier** has 4 plates, two right and two left. **Fift tier** (posterior most) has 2 plates, one left and one right.

Beneath epidermal plates is a fine layer of **sub-epidermal musculatur** consisting of outer circular and inner longitudinal fibres. Below muscles is layer of cells forming the **sub-epithelium**. Epidermal plates, sub-epiderma musculature and sub-epithelium together form the body wall of miracidium.

**2. Internal structure.** Within the body of miracidium are present glands, nervous tissue, protonephridia and germ cells. A sac-like multinucleate

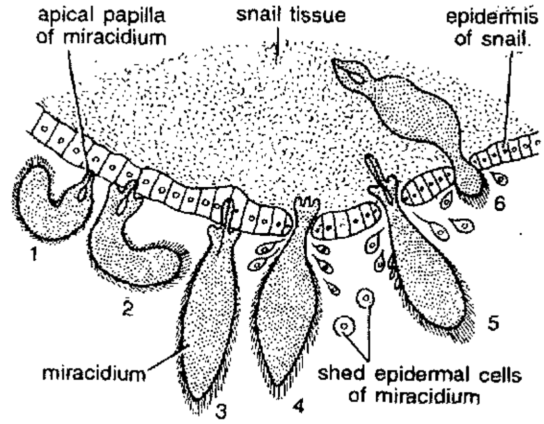



**Fig. 3. Miracidia of Fasciolopsis buski. Stage of penetration through snail epidermis.**

mass of granular protoplasm is attached to the centre of apical papilla by a stalk. This structure, earlier thought to be rudimentary gut, is now regarded an **apical gland**. A pair of large, unicellular **cephalic** or **penetration glands** open by their narrow ends near the apical papilla. A large **brain** with several associated nerve fibres lies dorsally below epidermal cells of second tier. Situated above the brain is an '*x*' shaped larval **eye**, consisting of two crescentic pigmented cells or **eye spots**, with their concavities facing away from each other. The concavities contain a clear refractile material serving as lens. (It should be noted here that a photoreceptor of any sort is absent in adult due to its or the parasitic mode of life). A pair of long tubular **protonephridia** or flame cells open to the exterior through two **nephridiopores** or **excretory pores**, situated laterally in the posterior half of body. **Germ cells** lie in groups, called **germ balls**, in the rear part of body.

**3. Physiology.** Miracidium does not feed. It swims about desperately as if **"seeking something with feverish haste" (Barlow**, 1925). Miracidia tries to penetrate any object or organism they may come across, but only those succeed that come in contact with a specific intermediate snail host (*Lymnaea, Succinea, Planorbis, Bulinus, Possaria,* or *Practicolella*). Those, which do not come across the suitable host, in about 24 hours after hatching, die invariably. For penetration, miracidium attaches its apical papilla and performs boring movements together with contractions and expansions of body. This process, aided by the action of flesh-dissolving larval secretions, results in a minute opening in the host's tissue. The larva then squeezes through this opening, casting off its ciliated epidermis while doing so. It soon makes its way into the digestive gland of snail, where it undergoes various changes and, in about 14 days, develops into the second larval stage, the **sporocyst larva**.

### [VIII] Sporocyst Larva

It looks like an elongated sac, about 0.7 mm long. Its body wall retains all the layers of body wall of miracidium except the ciliated epidermis, which is lost in the process of penetration and soon replaced by a thin **cuticle**. Glands, brain, eye spots and apical papilla of miracidium degenerate and disappear in sporocyst. **Protonephridium** of each side divides into two **flame cells** which open outside by a common excretory pore. In addition, the sporocyst contains

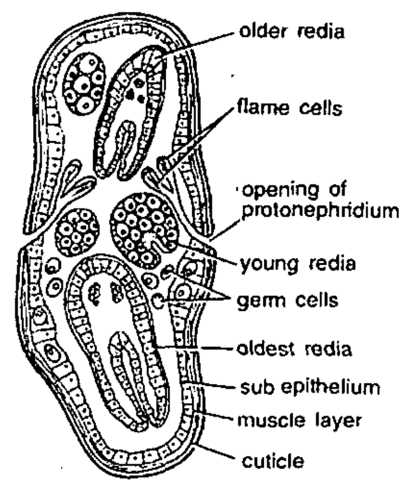



**Fig. 4.** ***E. hepatica*****. Sporocyst larva.**

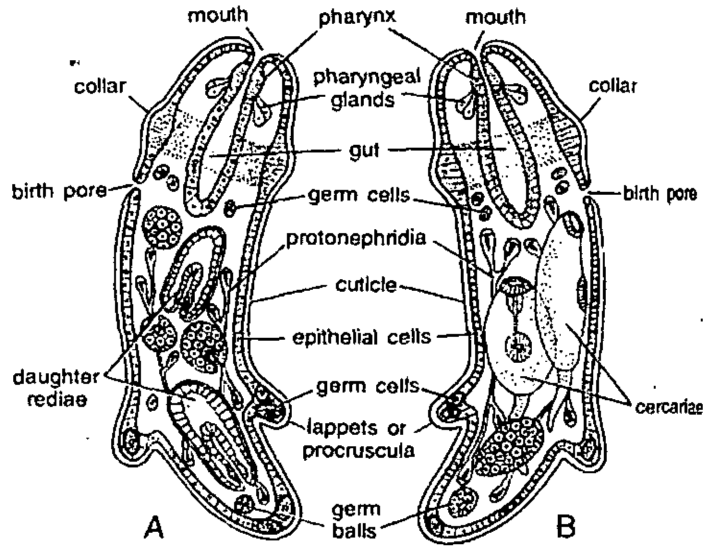



**Fig. 5,** ***F. hepatica*****. A. Redia with daughter rediae. B. Redia with cercariae.**

**germ balls**. Sporocyst moves about in the tissue of host, absorbing nutritic from it. Its germ balls develop into the next larval generation, the **rediae. Eac** sporocyst produces 5 to 8 rediae.

### [IX] Redia Larva

Rediae emerges from the sporocyst by rupture of its body wall. Each redia i an elongated and cylindrical creature, about 1.3 mm to 1.6 mm long. It bears **mouth** at the anterior end, a ring of muscular swelling or **collar** near anterio end, a permanent **birth pore** a little behind collar, and a pair of projection called **lappets** or **procruscula** ventrolaterally near the posterior end. Bod wall consists of the usual layers, viz., cuticle, musculature of outer circular an inner longitudinal fibres, and subepithelium. Mouth leads into a shor muscular *pharynx*, followed by an elongated sac-like **intestine, enteron o gut** lined by a single layer of cells. Numerous unicellular **pharyngeal gland** open into pharynx. **Protonephridia** divide further and form a much branche system. However, all the flame cells of each side open out through a commo excretory duct. Body of larva is packed with **germ balls** and mesenchyme cells.

Redia moves through the host's tissues on which it also feeds. Movement are brought about by muscular contractions of body, aided by the collar an

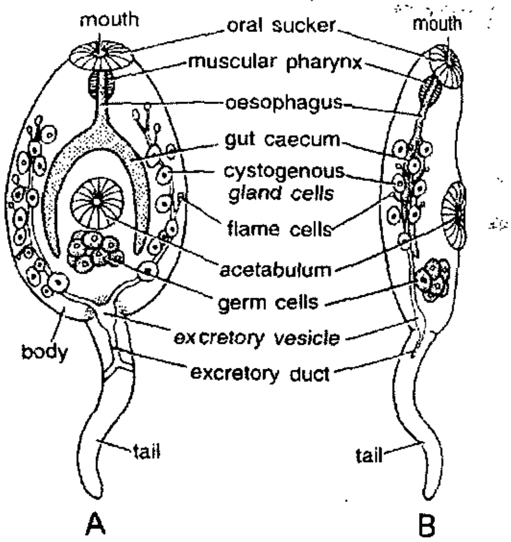



**Fig. 6.** ***F. hepatica*****, A. Cercaria in ventral view. B, Cercaria in lateral view.**

ıppets. Moving rediae enter vari. ıs organs of snail but prefer to migrate to its igestive gland. During summer months, when suffici^nt nourishment is vailable, the germ balls of rediae give rise to a **second generation of rediae**, ıorphologically identical to the parents. During winters, germ balls of rediae f second generation develop into larvae of the next stage, known as **cercaria** **-arvae.**

### ·X] Cercaria Larva

Each redia produces 14 to 20 cercaria larvae. The leave the body of redia hrough its birth pore and enters the snail's digestive gland. Morphologically, ercaria bears a close resemblance with the adult fluke. It has an oval body, ·).25 mm to 0.35 mm long, with a long simple tail for swimming. Layers of its ›ody wall are the same as of sporocyst and redia. Cuticle bears backwardly directed spines. Below body wall lie numerous **cystogenous gland cells**, vhich secrete cyst for the next larva (metacercaria). Well formed **anterior** **(oral)** and **ventral suckers** like those of adult are present. Rudiments of ıdult's digestive, excretory and genital systems can be seen in cercaria. Mouth eads into a muscular **pharynx**, followed by oesophagus and intestine, the atter forking in front of the ventral sucker to form two tubular limbs. **Flame** **ɔells** occur in large numbers along the lateral zones, opening into a pair of **ɜxcretory tubules**, which unite in front of the tail to form an **excretory vesicle** or **bladder**. An **excretory duct** arises from bladder and extends into tail, where it bifurcates .and opens out through a pair of **nephridiopores**. Lying in the body are groups of germ cells, which are direct descendants of propagatory cell of the capsule. These cells represent rudiment of adult's *genital system.*

Mature cercaria makes its way through the host's tissues, often migrates to its pulmonary sac, and from there escapes to the surrounding water. It takes 35 to 65 days, after entry of miracidium into the body of snail to the exit of cercariae from the host's body. Rate and extent of larval development in snail's body depends upon the availability of nutrients, primarily those stored in the hepatopancreas or digestive gland of snail, Temperature between 9°C and 26°C favours the emergence of cercaria from snail; pH of medium has no effect in the matter. Cercaria swims about in the surrounding water or crawls abc grass blades or some other aquatic plants. After an active life of two or days, it loses its tail and undergoes encystment on some aquatic pla become the **metacercaria larva.** The thick, hard and whitish cyst is a pr of cystogenous gland cells which degenerate soon after. Unencysted carc ingested by the primary host (sheep) are destroyed by action of its acidic g juice.

### [XI] Metacercaria Larva

As many as a thousand metacercariae may be found attached to a s grass blade. They have a rounded form with a diameter of about 0.2 Metacercaria is in fact the **juvenile fluke**, also called **marita.** It differs cercaria in that it has a rounded form, a thick hard cyst and large numb flame cells. It lacks a tail and cystogenous gland cells and its excretory bla opens out directly through a single pore. Germ cells or the genital rudim are present as such. Cyst provides protection against short perioc desiccation.

### [XII] Infection of Primary Host

Metacercaria develops into adult fluke only inside its definitive hos sheep. The latter gets infection by grazing on leaves and grass blades to w

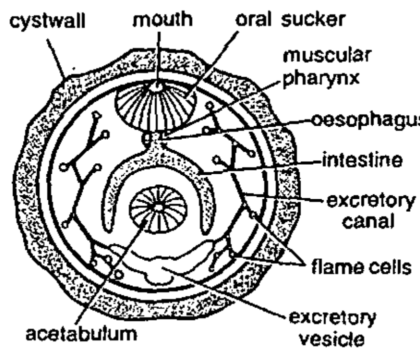



**Fig. 7.** ***F. hepatica.*** **Metacercaria.**

the cysts are attached. Metacercaria survives action of host's gastric juice a cyst is insoluble in it. Cyst wall finally dissolves in proximal part of intes and liberates the larva. It penetrates the intestinal wall and gets into coelo cavity. Now it infects the liver, feeds on its tissue, and grows in size in five tc weeks. It then takes up its position in the bile duct, where it finally atta sexual maturity. In 11 to 13 weeks, after entering the body of host, it sta laying eggs (capsules.)

## • FEATURES OF SIGNIFICANCE IN LIFE CYCLE OF *F. HEPAT*

### 1. Complex life cycle

Involvement of several larval stages complicates the life cycle of liver flu Further, liver fluke is digenetic, that is life cycle is completed in two alternat hosts. Primary or definitive host is sheep and secondary or intermediate hos a freshwater snail.

### 2. Chances of death

Due to complicated and prolonged life cycle, developmental stages have encounter several hazards. First hazard is faced by **encapsulated embryos** soon as they come out with faeces of primary host. They cannot develop furtl water (or moisture), suitable pH and temperature are not available. Second ızard is encountered by **miracidia** which emerge from the capsules. If they e unable to make contact with a suitable soft part of the specific intermediate st within 24 hours, they perish. **Cercariae** which leave the intermediate st and swim into surrounding water are the next to face an uncertain future. ingested by the vertebrate host, before they have encysted, they are stroyed by the action of host's gastric juice. Finally, **metacercariae** are stroyed if they have to face a long period of desiccation before they are gested by a suitable vertebrate host.

### High rate of reproduction

**Rate of reproduction** of an animal, as a general rule, is directly oportional to the **chances of death** it has to face at various levels. The ratio, fact, is the deciding factor for perpetuation of a species. *Fasciola hepatica*, posed to several threats to its survival, is highly prolific. Each fluke in its etime produces more than 200,000 eggs. Further, each sporocyst produces 8 rediae, each of which in turn produces 8-12 rediae in the second generation, ch of which further produces 14 to 20 cercariae. Thus, each egg is **capable** of oducing 1000 to 2000 cercariae but the actual number produced is far less e to high mortality. Out of those produced, a very small number successfully cysts and infects the final host.

### Heterogamy

**Grobben** (1882) and some others believed that germ cells in the sporocysts d rediae were eggs which developed **parthenogenetically** into subsequent rval forms. This kind of asexual parthenogenetic reproduction by larval rms is known as **heterogamy**. Reproduction in immature or larval stages is lled **paedogenesis (Gr., pais**, child; **genesis**, origin). This view, however, is w considered erroneous and has been given up in favour of the **olyembryony**, concept is described further.

### Polyembryony

Germ cells in sporocysts and rediae are direct descendants of **preparatory ells** produced by first division of zygotes. These germ cells multiply itotically and produce subsequent larval stages within sporocysts and rediae. doing so, they (germ cells or propagatory cells) behave as several embryos. hus, this process of reproduction in sporocysts and rediae has been looked on as **polyembryony** by **Ishii** (1934), **Chen** (1937), **Rees** (1940) and **Cart** 944).

### Metagenesis

Life cycle of *Fasciola* involves a period of asexual reproduction during mature stages (sporocysts and rediae) followed by a period of sexual production in the adult stage. **Steenstrup** (1942), land some others interpret is as an alternation of asexual and sexual generations in the life cycle. But **yman** is of the view that it is a continuous ontogeny (life history) involving sexual multiplication in larval stages.

### Advanced larval stages

Miracidium and cercaria, being free-living larvae, exhibit more advanced atures than the adult which has undergone degeneration in many respects to

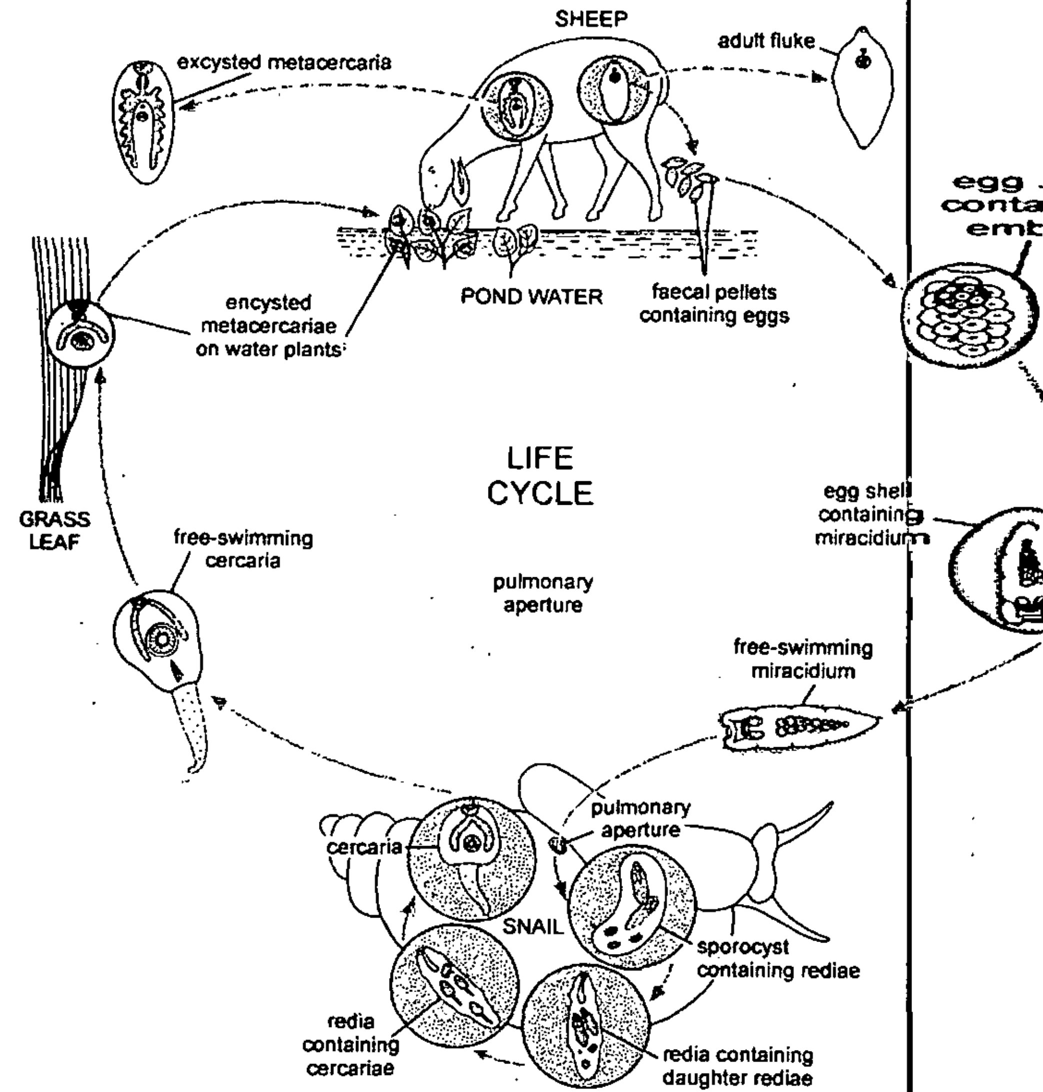



**Fig. 8.** ***F. hepatica.*** **Life cycle.**

suit its parasitic mode of life. Body cavity, locomotory organs, sense organ
a cellular epidermis are lacking in adult but are present in larvae.

## • LIVER

When sheep are infected by the liver fluke *Fasciola hepatica*, the li sheep is seriously affected in structure and function. This disease is kno 'Liver rot', or 'Fascioliasis'.

### Infection

The vertebrate host (sheep, goat, etc.) gets the infection by grazing on leaves and other vegetation to which metacercarial cysts are attached invertebrate host (snail) acquires infection when a miracidium, at ra establishes contact with a suitable part of its body,

### Pathogenesis or symptoms

Infection of invertebrate host (snail) results in a partial or con destruction of the affected site, which is preferably the digestive gland (li gonad. In case of heavy infections, snail considerably increases in size.

*Of significant economic importance is the effect of F. hepatica* on its vertebrate host, whose bile ducts as well as liver may be damaged. In bile ducts, it causes **inflammation** and **hepatitis**, resulting in loss of its epithelium and thickening of wall, followed by calcification and formation of **gall stones**. Heavy infections upset the normal metabolism of liver. This is due to **haemorrhage** caused and irritation inflicted by cuticular spines. The disease thus caused is called **liver-rot** or **fascioliasis**.

Symptoms of **liver-rot**, are more acute in lambs than in sheep, appear about a month after infection. Frequently, death may soon result due to **cerebral apoplexy**. However, if the host survives few weeks of infection, it falls a victim to acute **anaemia** and falls, even at mild contact. Its appetite declines, rumination (chewing the cud) becomes irregular and at times there is fever and increase in respiratory activity. Conjunctive becomes whitish-yellow, and dry and brittle wool falls off. After three months of infection comes the fatal period. Large **oedemas** or swellings ('watery poke') appear on jaws. Lactation and breeding are greatly reduced. Rarely does the host survive this period. In case it does, the fluke may migrate to the duodenum and finally escape to the outside world with faeces. When this happens, or when fluke somehow dies in situ, the host recovers considerably.

Infection by *F. hepatica* takes a huge toll of sheep annually. In England it caused the death of about one and a half million sheep in 1830 and about double in number in 1879-80. Ireland lost 60% of its flocks in 1882.

### Therapy or Treatment

Drug for **human fascioliasis** is **Triclabendazole** (Egaten tablets). Other drugs are **Nitazoxanide** (Nitax, Zox, Nitazox, Niazid) **Bithion Mirazid**.

**Foranimals Triclabendazole** (Fasinex liquid) is considered as the most *common drug due to its high efficacy against adult as well as juvenile flukes*. A new drug called '**Compound Alpha**' similar to triclabendazole is being tested.

**Prophylaxis** or **prevention.** *It is better to prevent infection by control of* the vector or intermediate host. Preventive measures include : (i) killing heavily infected sheep, (ii) destroying eggs and manure of infected sheep, (iii) feeding infected sheep with salt and little dry food, and (iv) killing or checking snail population. Snails are killed by adding copper sulphate solution in ponds and ditches or by draining their pastures as they are unable to survive long dry periods. Ducks feed on snails and can be usually employed in removing their population. Breeding of snails can be checked by removing vegetation from ponds and streams they inhabit. Man can avoid infection by consuming thoroughly washed and adequately cooked vegetables.

## • LIFE HISTORY AND DEVELOPMENT

### [I] Copulation and Fertilization

Life cycle of *T. solium* is **digenetic**, involving two hosts as in case of a fluke. But life cycle of tapeworm is much simpler and without a free larval stage. Presence of a single tapeworm in a host diminishes possibility of cross-fertilization. Fertilization is preceded by **copulation** which is accomplished by insertion of cirrus into vagina of the same or other proglottid to release spermatozoa. It becomes possible when the common gonopores of two mature proglottids come in contact due to folding of strobila. Anterior mature proglottids, having only male genitalia, can enter into copulation only with the posterior mature proglottids with fully developed female genital organs. Fertilization, following copulation between two different proglottids, is sometimes termed **cross-fertilization** to distinguish it from that occurring between gametes of the same proglottid (**self-fertilization**).

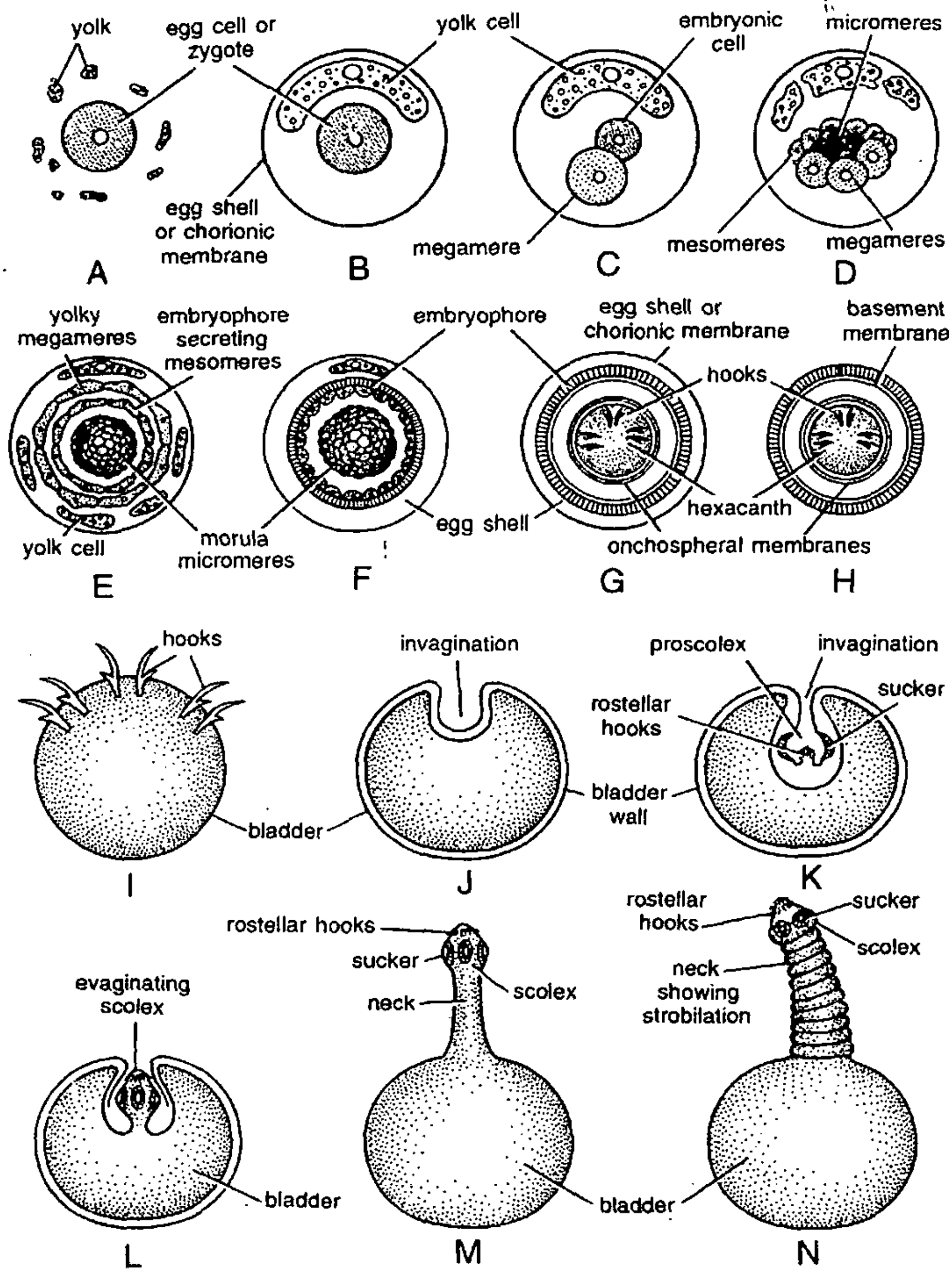



**Fig. 14.** ***Taenia solium.*** **Stage in development. A. Zygote, B. Zygote in egg shell. C. Two-cell stage. D. Early morula E. Late morula F. Formation of embryophore. G. Young onchosphere, H. Onchosphere without egg shell. I. Free hexacanth. J. Bladderworm with invagination of scolex. K. Bladderworm with proscolex. L. Evagination. M. Young cysticercus. N. Neck budding off proglottids.**

**Spermatozoa** injected into vagina, swim down to the seminal receptacle where they are stored till **ova** are released by the ovary. The two finally meet in the **fertilization duct** (part of vagina between seminal receptacle and oviduct) where fertilization takes place and **zygotes** are formed. Thus, fertilization is **internal**.

### [II] Capsule Formation

Zygotes or **egg cells** pass into the ootype, where each becomes associated with a large **yolk cell** or **vitelline** cell provided by the vitelline gland. The two become enclosed in a thin **shell** or **chorionic membrane,** formed by material exuded by the yolk cell. The **capsule** so formed passes into uterus, where further development takes place. Passage of capsules into uterus is lubricated by the secretion from Mehlis glands. As more and more capsules pass into uterus, it develops lateral branches to accommodate them.

### [III] Onchosphere Formation

**1. Cleavage.** Zygote or egg cell undergoes **cleavage** when the capsule is in uterus. Cleavage is holoblastic and **unequal**. First unequal division results in a larger **megamere** and a smaller embryonic cell.

**2. Morula.** Megamere divides further and forms several similar **megameres**, while embryonic cell divides repeatedly producing two types of embryonic cells, larger **mesomeres** and smaller **micromeres**. Thus, three types of cells result from the zygote; small micromeres, medium mesomeres and large megameres. Micromeres form a rounded mass, the **morula**, surrounded by an inner envelope of mesomeres and an outer envelope of megameres. The yolk or vitelline cell transfers its yolk to the megameres and gradually disappears. Large yolky megameres fuse to form an **outer syncytial nutritive** envelope or outer embryonic membrane, which nourishes the embryonic cells and finally disappears. Medium mesomeres form a thick, hard, cuticularized and radially striated shell, known as **embryophore** or **inner embryonic membrane** surrounding morula. Beneath embryophore is a thin **basement membrane**.

**3. Hexacanth and Onchosphere.** Morula, at its morphologically posterior end, develops three pairs of chitinous **hooks** secreted by differentiated cells, called **onchoblasts**. This six-hooked embryo, called hexacanth, possesses a pair of large penetration glands (**Reid**, 1947). It is surrounded by two hexacanth membranes. The hexacanth, together with all the membranes surrounding it, is known as **Onchosphere**. It loses the original thin shell or chorionic membrane so that embryophore forms its outermost covering.

By the time onchospheres are formed, the proglottid becomes gravid and increases in size. Its uterus forms 7-13 lateral branches on each side and contains 30,000 to 40,000 onchospheres. In *Taenia saginata*, another intestinal tapeworm of man, uterus of gravid proglottid has 16-20 lateral branches on each side. Leaving the highly-branched uterus, the remaining structures of reproductive system degenerate.

### [IV] Infection to Secondary Host (Pig)

Gravid proglottids at the posterior end of strobila detach (apolysis) in groups of 4 or 5 and pass out with the host's faeces. On ground, proglottids eventually disintegrate, setting free thousands of onchospheres. The secondary or intermediate host acquires infection by ingesting the onchospheres. Pig, which

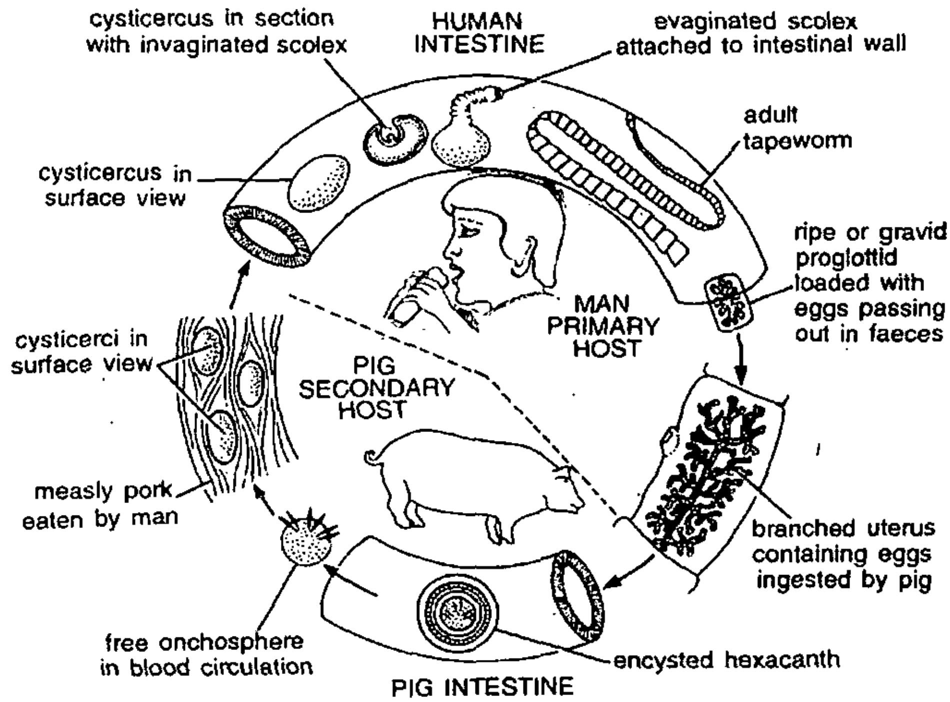



**Fig. 7.** ***Taenia solium*. Life cycle.**

regularly feeds on human excreta is the usual secondary host, but dog, monkey and sheep .are also known to get the infection. Man himself may serve as the secondary host by ingesting onchospheres with inadequately cooked or raw vegetables. Auto-infection may take place in a person already serving as a primary host. This happens when due to **reverse peristalsis** the detached proglottids are carried to the stomach, where the onchospheres are liberated.

### [V] Migration within Secondary Host

In the stomach of secondary host (pig) **Onchosphere** loses its embryophore and basement membrane by the action of acidic juices (acid pepsin). The free hexacanth embryo then passes into the small intestine, where the two persisting hexacanth membranes are also lost by the action of alkaline juices. Hexacanth, now activated by the presence of bile salts, bores its way through the intestinal epithelium to reach a submucosal or lymph vessel. This is accomplished, perhaps jointly by the six hooks and penetration glands. Hooks merely anchor the hexacanth to the intestinal wall, while secretion of penetration glands dissolves the intestinal tissues. Entire process takes about 10 minutes, after which the books, are of no further use, and are shed off. Submucosal blood vessel carries hexacanth to liver via hepatic portal vein. From liver it reaches heart land enters the arterial circulation. It finally reaches the striped (voluntary) muscles usually of the tongue, shoulder, neck, thigh, heart, etc., where it settles to develop into a **bladder-worm** or **cysticercus**. However, these may also develop in other organs such as lungs, liver, kidney or brain. Non-muscular vital organs like eyes, brain or liver may frequently become the sites of cysticercus normation.

### [VI] Cysticercus or Bladderworm Formation

Hexacanth, now devoid of hooks, absorbs nourishment from host's tissue and grows in size attaining a diameter of about 18 mm. A central cavity appears as cells in that region break down. It enlarges and becomes filled with a fluid consisting mainly of blood plasma of the host. The fluid-filled vesicle or **bladder**, as it is now called, has a thin wall consisting of an outer layer of thick syncytial protoplasmic mass (the so-called cuticle) and an inner mesenchymal or germinal layer. At a point, morphologically the anterior end (*i.e.*, opposite the side where hooks were present), the wall thickens and invaginates. The invagination, which looks like a hollow knob, differentiates into an **inverted scolex** possessing suckers, hooks and rostellum. It is called **proscolex,** the embryo at this stage is called a **bladderworm.** In *T. solium*, bladderworm is of **cysticercus** type which is characterised by a large vesicle and one scolex. That is why the bladderworm is also referred to as **cysticercus.** It appears to have a wall of cellulose and for this reason, sometimes called **cysticercus celiulosae.** Formation of cysticerci is completed in about 10 weeks in the pig.

Cysticercus develops in adult tapeworm only when ingested by the human host. In pig's body it leads quite an inactive life and remains viable for several years, after which it dies and becomes calcified. Pork (pig's flesh) containing viable cysticerci is called measly pork for its spotted appearance. One kg gm of **measly pork** may contain 500 or more cysticerci.

### [VII] Infection to Primary Host (Man)

Man gets infection by eating undercooked measly pork. Cysticercus becomes active on reaching the small intestine. Proscolex everts or evaginates and anchors to the intestinal wall. Neck begins to proliferate proglottids and the bladder, sooner or later, gets detached and digested. In 10 to 12 weeks the parasite attains adulthood and possesses gravid proglottids ready for apolysis.

## • LIFE HISTORY

The life history of Ascaris is **monogenetic** as it involves only one host, *i.e.*, **man.** However, I the life history of Ascaris can be studied as under :

1. **Copulation and fertilisation. Copulation** takes place in host's intestine. During copulation male Ascaris moves in such a way that its cloacal aperture faces the vulva of the female and then male thrusts its penial setae to open the vulva of female. Then, soon the cloacal wall of male contracts causing transfer of sperms into the vagina of the female and they come to lie in the seminal receptacle part of the uteri, wait for eggs to come through the oviduct for fertilisation. During **fertilisation** the entire sperm enters the egg. Soon, after fertilisation the glycogen globules of the egg migrate to the surface to form the **fertilisation membrane** which soon hardens into a thick, clear **inner chitinous shell**. Soon, thereafter, the fat globules of the egg form a **lipoid layer** below the chitinous shell. Now, as the fertilised egg passes down, the uterine wall secretes an outer thick, yellow or brown **albuminous** (proteinous) **coat** or **outer shell** having a characteristic wavy surface or **ripplings**. These eggs are now known as **mammiliated eggs**; such eggs are elliptical in shape measuring 60–70 $\mu$ by 40–50 $\mu$.

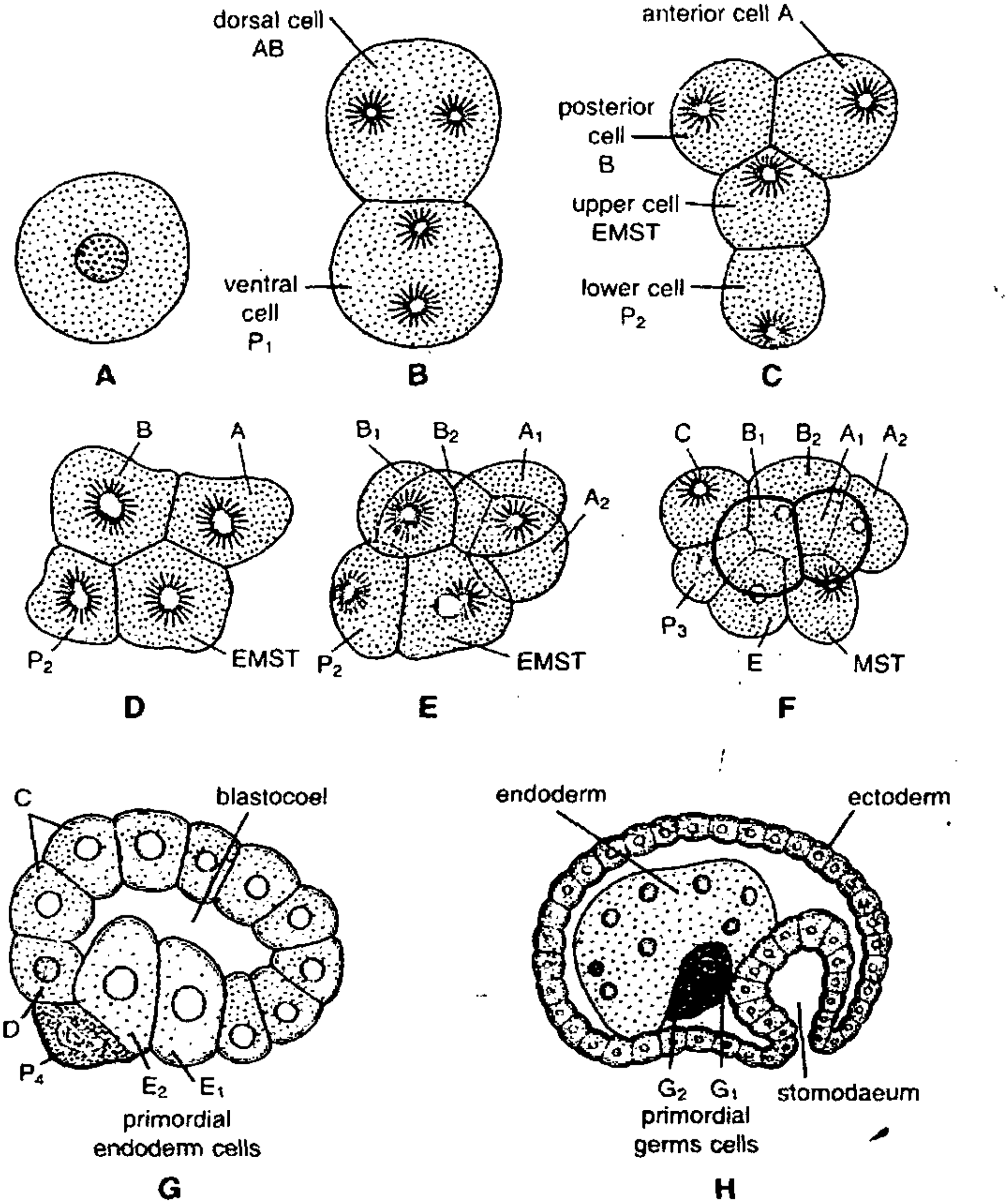



**Fig. 1. Ascaris. Early stages of development. A—Zygote; B—2-cell stage; C—4-cell stage (T-shaped); D—4-cell stage (rhomboidal); E—6-cell stage; F—8-cell stage; G—Median sagittal section through blastula; H —Median sagittal section through the embryo after invagination of stomodaeum and the primordial germ cells.**

2. **Zygote.** So, to say the zygote has a thick, clear inner shell, a lipoidal layer and an outer shell which is warty and yellow or brown in colour. The fertilised eggs (zygotes) are laid by female *Ascarix* in the small intestine of the host and they pass out with the faeces; they are unsegmented when they leave the host. One female may lay from 15,000 to 200,000 eggs in a day; the egg production of *Ascaris* is astounding, one mature female may have up to 27 million eggs. The eggs become stained yellowish or brown in the intestine. Eggs fall on the ground and can remain alive for months in the moist soil though complete drying kill's them. In order to develop they require oxygen, moisture and a temperature lower than that of the human body, the most favourable temperature is 85°F. They require a period of incubation outside the human body,

3. **Early development** (Outside the host). The stages of early embryonic development, say the cleavage or segmentation, etc,, start in the soil. The pattern of cleavage is **spiral** and **determinate**.

The fertilised egg undergoes two cleavages to form four cells or blastomeres; in fact the first cleavage results in a dorsal cell **AB** and a ventral cell $\mathbf{P_1}$, the second cleavage causes **AB** to divide into an anterior cell **A** and a posterior cell. **B,** while the ventral cell $\mathbf{P_1}$ divides into a dorsal cell **EMST** and a ventral cell $\mathbf{P_2}$. These four cells are at first arranged in the shape of a T in Ascaris, but later they become arranged in a rhomboid shape, as $\mathbf{P_2}$ comes to lie posterior to **EMST**, which is characteristic of nematodes. However, these four cells are now called A, B, $\mathbf{P_2}$ and $S_2$ or **EMST**. These cells undergo further cleavage to form smaller blastomeres.

However, in the next cleavage **A** and **B** divide into $\mathbf{A_1}$, $\mathbf{A_2}$ and $\mathbf{B_1}$, $\mathbf{B_2}$ cells respectively, $\mathbf{P_2}$ divides into $\mathbf{P_3}$ and **C**, while **EMST** into **MST** and **E**. Thereafter, $\mathbf{P_3}$ and **E** divide into $\mathbf{P_4}$ and **D** and $\mathbf{E_1}$ and $\mathbf{E_2}$ respectively. The $\mathbf{P_4}$ further divides into $\mathbf{G_1}$ and $\mathbf{G_2}$. The fate of the various cells resulted so far is fixed, *i.e.*, the descendants of **A** and **B** will give rise to the entire **ectoderm**, except that of the posterior end, **MST** form the **mesoderm** of the body wall, pseudocoel cells, and the lining of the stomodaeum, the descendants of **E** ($\mathbf{E_1}$ and $\mathbf{E_2}$) give rise to the entire endoderm of the intestine, the descendants of $\mathbf{P_4}$ ($\mathbf{G_1}$ and $\mathbf{G_2}$) will give rise the germ cells and **C** and **D** will together take part in the formation of **ectoderm** and **mesoderm**.

Thus, the cleavage of embryonic cells continues giving rise to a **blastula** at the 16-celled stage which is characterised by having a cavity, the **blastocoel**. Then **gastrufa** is formed by epiboly or overgrowth of ectodermal cells over the endodermal cells, and by invagination of stomodaeum and endodermal cells. Finally a **juvenile** is resulted in about 10–14 days from the beginning of segmentation. Structurally, a juvenile possesses an alimentary canal, a nerve ring and a lateral excretory system. This juvenile resembles very much with *Rhabditis* (a soil neraatode), hence, it is also referred to as **rhabditiform** larva or **rhabditoid**. This larva moults within the egg shell in about seven days and becomes the **second stage juvenile** or **second stage rhabditoid**; this stage of the life history of *Ascaris* is infective to the host. Data suggest that under favourable conditions of oxygen, moisture and temperature, the eggs of *Ascaris* lumbricoides with infective juveniles may remain viable for about six years in the soil.

4. **Infection to host.** As mentioned earlier, that there is no secondary host in the life history of *Ascaris,* hence, infection to host (man) occurs when he swallows the infective eggs of *Ascaris* with contaminated food or water. Thus, when the infective eggs reach in the small intestine of the host, the egg shells are dissolved by the action of host's digestive juices and the infective second stage juveniles are set free. These juveniles are about 0.2-0.3 mm long and 13-15 μ in diameter and have all the structures of the adults except the reproductive organs.

more common they dull the mental capacity and stunt growth. Their juveniles cause inflammation and haemorrhage in the lungs which results in pneumonia which may prove fatal. The disease caused by Ascaris is generally referred to as **ascariasis**.

### TREATMENT

A mixture of oil of chenopodium and tetrachloroethylene is good; but one gm of hexylresorcinol in a gelatine capsule with fasting for 12 hours before treatment and 4 hours afterwards, followed by a purgative removes about 95% of Ascaris infection. Other anti-helminth drugs like hetrazan, piperazine hydrate or citrate, tetramezole and dithiazanine are used successfully for the treatment of ascariasis these days.

### PROPHYLAXIS (PREVENTION)

Keeping good sanitary conditions is the only way to prevent the infection of Ascaris. However, pollution of soil with human faeces should be avoided, vegetables should be thoroughly washed (preferably in a mild solution of $KMnO_4$) and properly cooked before use, raw vegetables and nuts should not be used, finger nails should be regularly cut to avoid the collection of dirt and eggs below them, hands should be properly washed with some antiseptic soap before touching edibles or eating.

## • PARASITIC ADAPTATION OF FLATWORMS

**Adaptation.** Adaptation is the fitness of an organism to its environment. It is the characteristic which results in suitable and convenient morphological and functional correlation between an organism and its environment.

**Parasitic adaptations.** Parasitic flat worms (trematodes and cestodes) have undergone profound adaptations to suit their parasitic mode of life. These adaptations termed parasitic adaptations in such cases, are of morphological as well as physiological nature.

### [I] Morphological Adaptations

1. **Body covering.** Thick **tegument,** frequently provided with scales, affords suitable protection to the parasite. It is probable that this thick protoplasmic layer is continually renewed by the mesenchymal cells forming it.

2. **Organs of adhesion.** For a firm grip on or in the host's body, some special organs of adhesion are necessary. Flatworms, for this purpose, are variously armed with suckers, hooks and spines. Suckers themselves may be with or without hooks and spines.

3. **Organs of locomotion.** Locomotion is actually an effort for procuring food. But parasites habitually inhabit such places in host's body, where sufficient food is available without effort. Thus, organs of locomotion, such as cilia of free-living turbellarians, are absent in parasitic forms. It is interesting to note that locomotory organs are duly present in free-living larvae of parasitic forms. Miracidium possesses cilia and cercaria possesses a tail for locomotion.

4. **Organs of nutrition (trophic organs).** Food of parasite comprises readily available digested and semi-digested food of the host. Elaborate organs for nutrition are thus not needed. Trematodes have an incomplete gut and, in most cases, a suctorial pharynx for sucking food. An eversible pharynx present in free-living turbellarians is absent in this case, as the parasite has not to capture a large prey. In cestodes, parasite freely bathes in digested food of host which is absorbed directly. There is thus total absence of alimentation in tapeworms.

5. **Neuro-sensory system.** Need for quick and efficient 'response to stimuli' is associated with free active life and not with a quiet parasitic life in a safe environment. In parasites, therefore there is profound reduction of nervous system and total absence of sense organs. But, the free-living miracidium possesses eye spots.

6. **Reproductive system.** It is the best developed system in helminth parasites, designed and perfected to meet the need for tremendous egg production. Parasitic flatworms, with a few exceptions like *Schistosoma,* are monoecious (hermaphrodite). Hermaphroditism is of distinct advantage to the parasite, because (i) it ensures copulation even when a few individuals are present, (ii) after copulation both individuals lay eggs, thus doubling the rate of reproduction and (iii) in the absence of a companion parasite can reproduce offspring. In cestodes reproductive system is much more elaborate and each mature proglottid possesses one (*e.g., Taenia solium*) or two (*e.g., Cotugnia, Moniezia, Dipylidium*) complete sets of male and female genitalia. In a gravid proglottid all other organs of the system degenerate to make room for the uterus which becomes highly enlarged and branched to accommodate large number of eggs.

**[II] Physiological Adaptations**

1. **Protective mechanism.** Alimentary canal of parasites have to protect themselves from the action of digestive juices of host. Tapeworms accomplish this : (i) by stimulating walls of gut to secrete mucus, which then forms a protective covering around the parasite (ii) by secreting antienzymes to neutralize the digestive enzymes of host, and (iii) by probably continually renewing their protective body covering *i.e.,* tegument.

2. **Anaerobic respiration.** Environment in gut and bile ducts is devoid of free oxygen. Flatworms inhabiting these places, therefore, respire anaerobically by breaking down glycogen.

3. **Osmoregulation.** Osmotic pressure of endoparasite's body fluids, especially in case of trematodes is almost the same as that of host. This renders osmoregulation unnecessary. But in intestinal tapeworms, osmotic pressure is a little higher. This permits ready absorption of host's digested food by tapeworms.

4. **High fertility.** Eggs produced by a parasitic flatworm face a very uncertain future. While passing through the complex life cycle, these potential offsprings face several hazards as a result of which a very small percentage of

total eggs produced reaches adulthood. This threat to the very existence of species is suitably met by the parasite which in its life time may produce eggs in millions. Reproductive organs of flatworms, as already noted, are accordingly developed.

Additional multiplicative phases in life-cycle of some flatworms further increase the output of potential offspring. Several cercariae develop from a single miracidium of liver fluke and a single hexacanth of *Echinococcus* produces several scolices, each of which is a potential tapeworm.

❑❑❑

# UNIT

# 4

# ANNELIDA ARTHROPODA

**STRUCTURE**

- General Characters and classification up to classes
- Excretion in Annelida
- Vision in Arthropods

## • ANNELIDA : CHARACTERS, CLASSIFICATION AND TYPES

Name of phylum Annelida was first coined by **Lamarck** for the higher segmented worms (L., **annelus,** little ring+ Gr., **eidos,** form). In general, annelids are elongated, bilaterally symmetrical and highly organized animals, in which the organs have grouped into definite systems. Appearance of **metamerism** represents their greatest advancement, so that they are called **segmented worms** in order to distinguish them from flatworms (Platyhelminthes) and roundworms (Nematoda) which are not segmented. Their paired appendages, when present, are never jointed. Their coelom, nephridia and cephalization are better developed than those of the unsegmented worms. They are the first animals to have a closed vascular system. Nervous system is fundamentally similar to that of Arthropoda and embryology is not much different from that of Mollusca.

### GENERAL CHARACTERS

1. Mostly aquatic, some terrestrial. Burrowing or tubicolous. Some commensal and parasitic.

2. Body elongated, bilaterally symmetrical, triploblastic, truely coelomate and **metamerically segmented** into similar metameres.

3. **Epidermis** of a single layer of columnar epithelial cells, covered externally by a thin **cuticle** not made of chitin.

4. Body wall **dermo-muscular.** Outer muscle fibres circular, inner longitudinal.

5. Locomotory organs are segmentally repeated chitinous bristles, called **setae** or **chaetae**, embedded in skin. May be borne by lateral fleshy appendages or **parapodia**.

6. **Coelom**, true, schizocoelous. Mostly well-developed except in leeches. Usually divided into compartments by transverse septa. Coelomic fluid with cells or corpuscles.

7. Digestive system straight and complete. Digestion entirely extracellular.

8. Blood vascular system closed. Respiratory pigments e haemoglobin or erythrocruorin dissolved in blood plasma.

9. Respiration by moist skin or gills of parapodia and head.

10. Excretory system consisting of metamerically disposed coiled t called **nephridia**.

11. Nervous system with a pair of cerebral ganglia (brain) and a d ventral nerve cord bearing ganglia and lateral nerves in each segment.

12. Sensory organs include tactile organs, taste buds, statoc photoreceptor cells and sometimes eyes with lenses in some.

13. **Hermaphroditic** *or* sexes separate cleavage spiral determinate. Larva, when present, is a **trochophore**. Regeneration com

## Classification

About 8,700 known species of Annelida are divided into four main cla primarily on the basis of the presence or absence of parapodia, s metameres, and other morphological features.

### CLASS 1. Polychaeta

(Gr, **polys**, many + **chaite**, hair)

1. Chiefly marine, some in fresh water.
2. Segmentation internal and external.
3. Head distinct with eyes, palps and tentacles.
4. Setae numerous, on lateral parapodia.
5. Clitellum absent.
6. Sexes separate. Gonads temporary and in many segments.
7. Trochophore larva present.

Attempts to arrange families into orders has not proved satisfactory. usual, therefore, to divide polychaetes into two subclasses, *Errantia* *Sedentaria,* after **Fauvel** (1959). However according to **Dab** (1963), subdivision is artificial and not a natural one,

#### *Subclass I. Errantia*

1. Free-swimming, crawling, burrowing or tube-dwelling predatory polychaetes.
2. Segments numerous and similar, except for head and anal region.
3. Prostomium distinct with sensory structures.
4. Parapodia with acicula and compound setae.
5. Pharynx protrusible, enlarged and usually with jaws and teeth.

Examples : *Aphrodite* (sea mouse), *Polynoe, Phyllodoce, Tomopt* *Syllis, Nereis, Glycera, Eunice, Diopatra, Histriobdella.*

#### *Subclass II. Sedentaria*

1. Sedentary polychaetes living in burrows or tubes.

2. Body made of two or more regions, with dissimilar segments and parapodia.

3. Prostomium small.

4. No acicula and compound setae.

5. Pharynx without jaws and teeth.

Examples : *Chaetopterus, Arenicola, Owenia, Sabella, Sabellaria, Terebella, Amphitrite, Pomatoceros, Spirorbis, Serpula.*

**CLASS 2. Oligochaeta**

(Gr., ***oligos***, few + ***chaite***, hair)

1. Mostly terrestrial, some in fresh water.

2. Segmentation external and internal.

3. Head indistinct, without sensory organs.

4. Setae few, embedded in skin. Parapodia absent.

5. Glandular clitellum present for cocoon-formation,

6. Hermaphroditic. Testes anterior to ovaries.

7. Fertilization external (in cocoon); development direct, no larval stages.

**Order 1. Plesiopora plesiothecata**

1. Mostly aquatic.

2. Male gonopores on segment immediately following that which contains testes.

3. Spermathecae in the testes-containing segments, or nearby.

Examples : *Aelosoma, Nais, Dero, Chaetogaster, Tubifex.*

**Order 2. Plesiopora prosothecata**

Spermathecae far anteriorly to the segment containing testes.

Example : *Enchytraeus.*

**Order 3. Prosopora**

1. Mostly aquatic.

2. Male gonopores on the same segment containing testes, or on segment containing the second pair of testes.

Example : *Branchiobdella* (parasitic).

**Order 4. Opisthopora**

1. Mostly terrestrial earthworms.

2. Male gonopores some distance behind the testes-containing segments.

Examples : *Lumbricus, Eisenia, Pheretima, Megascolex, Allolobophora, Dendrobaena.*

**Chaetopoda** (Gr., **chaite**, hair + **pous**, foot). Chaetopoda is a super group which includes Polychaeta and Oligochaeta. This creation is because of the fact that both the classes are pro with setae.

### CLASS 3. Hirudinea

(L., **hirudo**, leech)

1. Freshwater, marine or terrestrial. Generally ectopara blood-sucking or carnivorous.

2. Body with fixed number of segments (33). Each segment subdi externally into annuli.

3. Segmentation external without internal septa. Parapodia and absent.

4. Both anterior and posterior ends of body with suckers.

5. Coelom much reduced due to its filling by botryoidal tissue, forms haemocoelomic sinuses.

6. Hermaphroditic with one male and one female gono Fertilization internal. Development in cocoons, direct without larval stag

#### Order 1. Acanthobdellida

1. Primitive, without anterior sucker, proboscis and jaws.
2. Setae present in 5 anterior segments.
3. Coelom with compartments.

Example : A single Russian genus and species (*Acanthobc* parasitic on salmon.

#### Order 2. Rhynchobdellida

1. Only aquatic leeches, ectoparasitic.
2. A protrusible proboscis with no jaws.
3. Coelom without compartments.
4. Blood vascular system separated from coelomic sinuses. E colourless.

Examples : *Glossiphonia, Placobdella, Helob della, Pisc Pontobdella, Branchellion, Ozobranchus.*

#### Order 3. Gnathobdellida

1. Aquatic or terrestrial. Ectoparasitic blood-sucking leeches.
2. Pharynx non-eversible with 3 pairs of jaws.

Examples : *Hirudo, Hirudinaria, Haemadipsa.*

#### Order 4. Pharyngobdellida

1. Terrestrial and aquatic. Some predaceous.
2. Pharynx non-protrusible. No teeth but one or two styles ma present.

Examples : *Erpobdella, Dina.*

**CLASS 4. Archiannellida**

(Gr., **arch**, first)

1. About one dozen genera of small, marine worms of unknown affinities.
2. Segmentation chiefly internal. No parapodia and setae.
3. Sexes usually separate.
4. Usually trochophore larva.

Examples : *Polygordius, Dinophilus, Protodrilus.*

## • ARTHROPODA : CHARACTERS, CLASSIFICATION AND TYPES

Phylum Arthropoda (Gr., **arthros**, joint + **podos,** foot) is the largest phylum of Animal Kingdom including about 1,13,40,000 species in all habitats, which constitute about 83% of all the known species of animals.

### General Characters

1. Organ-system level of body organization.
2. Body bilaterally symmetrical, triploblastic and metamerically segmented.
3. Appendages jointed, usually one pair to a somite, and with varied functions as jaws, gills, legs, etc.
4. Exoskeleton of dead chitinous cuticle that is shed at intervals, called ecdysis or moulting, for growth and development.
5. Body divisible into head, thorax and abdomen. Head and thorax often fused to form a cephalothorax.
6. True coelom reduced and largely replaced by a blood-filled haemocoel.
7. Muscles mostly striated, usually capable of rapid contraction.
8. Digestive system complete with mouth and anus. Mouth parts adapted for various modes of feeding.
9. Circulatory system open with a dorsal often many-chambered heart, arteries and blood sinuses or haemocoel.
10. Respiration by general body surface, gills, tracheae or book-lungs.
11. Excretory organs are green glands or Malpighian tubules.
12. Nervous system typically annelidan, with a dorsal brain connected with a nerve ring to a double ventral nerve cord.
13. Sensory organs comprises of eyes (simple and compound), chemo- and tactile receptors, balancing and auditory organs.
14. Sexes usually separate (dioecious). Reproductive organs and ducts paired. Fertilization usually internal. Oviparous or ovoviviparous.

15. Development direct or indirect with one to many larval sta
Parthenogenesis in some.

16. Cilia and flagella absent except in Onychophora.

17. Parental care often well-marked.

**Classification**

Arthropoda is a much heterogeneous group including a variety of ani with divergent views concerning their phylogeny. Because of this reason definitive system of classifying this phylum exists. The classification ado here is a synthesis of several views so that such a large and diverse phylum be conveniently grouped. In fact, arthropod classification is still in a sta flux, and may always remain so.

Seven subphyla are recognized in the following classification. Of these, Trilobitomorpha, Chelicerata and Mandibulata are definitely arthrop Trilobitomorpha includes a number of extinct classes only. Onychoph Tardigrada and Pentastomida show only doubtful or superficial relations with other arthropods, so that some books treat them as independent m phyla. We have also described the type *Peripatus* under a separate phy Onychophora, to accommodate this view. Pycnogonida is sometimes inclu as a class within the subphylum Chelicerata. The old class Myriapod retained here within the subphylum Mandibulata, otherwise, every orde Myriapoda is equivalent in status to other classes of Mandibulata.

### Subphylum I. Trilobitomorpha

**(Gr., tri, three + lobos, lobe + morphe, form)**

1. Fossil trilobites. Mostly marine and bottom-dwellers. Cambrian Permian.
2. Body 3-lobed, due to 2 longitudinal furrows.
3. Head distinct. Probably one pair of antennae,
4. Biramous appendages on all segments except the last one.

Examples : *Triarthrus, Dalmanites.*

### Subphylum II. Chelicerata

**(Gr., chele, claw + keros, horn + ata, group)**

1. Body divided into an anterior cephalothora (prosoma) and a poste abdomen (opisthosoma).
2. Prosomatic appendages 6 pairs. First pair of preoral chelicerae v claws, followed by postoral pedipalps and 4 pairs of walking legs.
3. Antennae and true jaws absent.

**CLASS 1. Merostomata**

(Gr., **meros**, thigh + **stoma**, mouth)

1. Marine with median simple and lateral compound eyes.
2. 5 to 6 pairs of abdominal appendages with book-gills.

3. Abdomen ending in a sharp telson or spine.

4. Excretion by coxal glands. No Malpighian tubules.

***Subclass 1. Xiphosura***

(Gr., **xiphos**, sword + **aura**, tail)

1. Cephalothorax with large extended, convex, horseshoe-shaped carapace.

2. Abdomen unsegmented with a long terminal telson.

Example : *Limulus* (horseshoe or king crab).

***Subclass 2. Eurypterida***

(Gr., **eurys**, broad + **pteryx**, wing)

1. Extinct marine, giant water scorpions.

2. Cephalothorax small. Carapace plain, not extended.

3. Abdomen 12-segmented and narrowed behind.

Examples : *Eurypterus, Pterygotus.*

**CLASS 2. Arachnida**

(Gr, **arachne,** spider)

1. Terrestrial or aquatic. Eyes simple. No compound eyes.

2. Cephalothorax (prosoma) with 2 chelicerae, 2 pedipalps and 4 pairs of walking legs.

3. Abdomen generally without appendages.

4. Respiration by tracheae, book-lungs or both.

5. Excretion by coxal glands and Malpighian tubules.

6. Dioecious. Mostly oviparous courtship before mating.

**Order 1. Scorpionida (= Scorpiones)**

1. Elongated, fair-sized true scorpions.

2. Small prosoma broadly joined to large opisthosoma, which is made of a broad anterior 7-segmented mesosoma, and a narrow posterior 5-segmented metasoma.

3. Metasoma ending in a telson and poison sting.

4. Two ventral comb-like sensory pectines on 2nd abdominal segment.

5. Respiration by 4 pairs of book lungs.

Examples : *Buthus, Palamnaeus, Androctonus, Centruroides* (= *Centruus).*

**Order 2. Pseudoscorpionida (= Chelonethida)**

1. Tiny false scorpions.

2. Abdomen 11 -segmented, without sting and telson.

3. Chelicerae 2-jointed, with comb-like serrations.

Examples : *Chelifer, Microcreagris.*

**Order 3. Araneae**

1. True spiders, prosoma and opisthosoma without visible segment and joined by a narrow pedicel.

2. Chelicerae 2-jointed, with a poison duct in terminal claw.

3. Pedipalps leg-like, used for transfer of sperms in male.

4. Opisthosoma with 3 pairs of spinnerets. No telson.

Examples : *Lycosa* (wolf spider), *Agelena* (funnel-web spider), *Latrodect* (black widow), *Achaearanea* (house spider), *Argiope* (writing spider).

**Order 4. Solifugida (= Solifuge)**

1. False spiders, sun spiders or wind spiders.

2. Prosoma divided into a large anterior and a small posterior part.

3. Opisthosoma of 10 or 11 segments. No spinnerets.

4. Chelicerae very large forming heavy pincers. No poison glands.

5. A flagellum on each chelicera of male, for sperm transfer.

Example : *Galeodes,*

**Order 5. Palpigradi**

1. Small-sized microwhip scorpions. Without eyes.

2. Prosomal carapace made of large anterior and small posteri portions.

3. Opisthosoma 11-segmented, ending in a large 15-jointed telson flagellum.

Example : *Koenenia.*

**Order 6. Pedipelpi ( = Uropygi)**

1. Elongate whip scorpions with 1 pair of eyes.

2. Prosomal carapace entire.

3. Opisthosoma 12-segmented. Last segment with a long flagellum telson.

4. Pedipalps large, heavy, with terminal pincer.

Examples : *Mastigoproctus, Thelyphonus.*

**Order 7. Amblypygi (= Phrynichida)**

1. Flattened scorpion-spiders or taillers whip scorpions.

2. Carapace undivided. Pedipalps large and rhaptorial.

3. Abdomen 12-segmented, without flagellum.

4. First pair of legs, long, whip-like, sensory.

Example : *Charinus.*

**Order 8. Ricinulei (= Podogna)**

1. Rare, small, tick-like, heavy-bodied arachnids.
2. Carapace with an anterior hood-like movable plate.
3. Opisthosoma 6-segmented. Narrow anteriorly with a posterior tubercle bearing anus.
4. Third pair of legs in male form copulatory organs.

Examples : *Ricinoides, Cryptocellus.*

**Order 9. Opioliones (= Phalangida)**

1. Spider-like Harvest-men, Harvest-spiders or daddy longlegs.
2. Body small, oval. Legs extremely long, slender.
3. Prosoma broadly joined to Opisthosoma.
4. Scent glands under carapace. Two eyes.

Examples : *Phalangium, Leiobunum.*

**Order 10. Acarina**

1. Ticks and mites. Free-living or parasitic.
2. Body small, oval, unsegmented, with no distinction between prosoma and Opisthosoma.
3. Largest arachnid order with 20,000 species.

Examples : *Sarcoptes* (*Itchomite*), *Ixodes* (Sheep tick), *Dermacentor* (Dog tick), *Argas* (Bird tick).

**Subphylum III. Mandibulata**

**(L., mandibula, mandible + ata, group)**

1. Body divisible into head, thorax and abdomen.
2. Head appendages are 1 or 2 pairs of antennae, 1 pair of jaws or mandibles and 1 or 2 pairs of maxillae.
3. Compound eyes common.

**CLASS 1. Crustacea**

(L. **crusta**. shell)

1. Head often joined with thorax to form cephalothorax.
2. Exoskeleton chitinous, hard, limy (calcareous).
3. Head 5-segmented, bearing 2 pairs of antennae, 1 pair of mandibles and 2 pairs of maxillae. Appendages typically biramous.
4. Respiration by gills or body surface.
5. Excretion by antennal glands.
6. Sexes usually separate, Development with nauplius stage.

***Subclass 1. Cephalocarida***

1. Body made of a horseshoe-shaped head and 19 trunk segments. Only

anterior 9 trunk segments bear appendages that appear triramous.

2. Antennae short. Eyes absent.

3. Hermaphrodite. Larva a metanauplius.

Example : *Hutchinsoniella.*

***Subclass 2. Branchiopoda***

1. Primitive, small-sized, mostly freshwater.

2. Trunk appendages leaf-like, serving for respiration (gills), locomotion and filter-feeding.

3. Antennules and 2nd maxillae reduced or absent.

4. Abdomen ends in a pair of jointed or unjointed caudal styles or cercopods.

**Order 1. Anostraca**

1. Fairy shrimps with 19 or more trunk segments. Only anterior 11 to 19 segments bear appendages.

2. Carapace absent. Eyes stalked. Styles unjointed.

Examples : *Artemia, Eubranchipus.*

**Order 2. Notostraca**

1. Tadpole shrimps with 25-45 trunk segments. Anterior half with 35 to 71 pairs of appendages.

2. Carapace shield-like. Eyes sessile. Styles jointed.

Examples : *Apus, Lepidurus.*

**Order 3. Diplostraca**

1. Clam shrimps and water fleas with a bivalved carapace enclosing body with or without head.

2. Eyes fused, sessile. Styles unjointed, claw-like.

Examples : *Daphnia, Cyzicus (= Estheria).*

***Subclass 3. Ostracoda***

1. Minute mussel or seed shrimps with poorly segmented body entirely enclosed in a bivalved carapace.

2. Trunk appendages 2 pairs, leg-like.

3. Antennules and antennae large, used in swimming.

**Order 1. Myodocopa**

1. Carapace with antennal notches.

2. Antennae biramous, enlarged at base.

Example : *Cypridina.*

**Order 2. Podocopa**

1. Carapace unnotched. Trunk appendages 2 pairs.

2. Antennae uniramous, clawed at tips.

Examples : *Cypris, Darwinula.*

**Order 3. Platycopa**

1. Carapace unnotched. Trunk appendages 1 pair.
2. Antennae uniramous.

Example ; *Cytherella.*

**Order 4. Cladocopa**

Carapace unnotched. Antennae biramous.

Example : *Polycope.*

***Subclass 4. Mystacocarida***

1. Primitive. Body microscopic. Antennules and Antennae prominent.
2. A single median eye. No compound eyes.
3. Abdomen limbless. A pair of caudal styles.

Example : *Derocheilocaris.*

***Subclass 5. Copepoda***

1. Body small, made of head, thorax and abdomen.
2. No carapace. No compound eyes but a median eye.
3. Antennules long. Antennae smaller.
4. Abdomen limbless. Telson with two caudal styles.

Examples : *Cyclops, Ergasilus, Caligus.*

***Subclass 6. Branchiura***

1. Fish lice. Temporarily ectoparasites of skin and gill chambers of fishes and some amphibians.
2. Body dorso-ventrally flattened.
3. Shield-like carapace covers head and thorax.
4. A pair of sessile compound eyes. Mouth suctorial.
5. Antennules and antennae reduced.
6. First maxillae modified into suckers.
7. Abdomen unsegmented, bilobed. Caudal claws minute.

Examples : *Argulus, Dolops.*

***Subclass 7. Cirripedia***

1. Barnacles. Adults sessile, attached or parasitic.
2. Carapace forms two folds of mantle surrounding body and covered externally by calcareous plates.
3. Thoracic limbs 6 pairs, biramous and cirriform.
4. Antennules become cement glands for attachment.
5. Antennae and compound eyes are lost in adult.

6. Abdomen rudimentary with caudal styles.
7. Nauplius larva passes through a cypris stage.

**Order 1. Thoracica**

1. Non-parasitic. With or without stalk, Hermaphrodite.
2. Mantle present with calcareous plates.
3. Thoracic appendages 6 pairs, cirriform.

Examples : *Lepas, Balanus.*

**Order 2. Acrothoracica**

1. Sessile. Bore into mollusc shells or corals. Unisexual.
2. Mantle reduced to a chitinous attachment disc.
3. Trunk appendges usually 4 pairs, cirriform.

Examples : *Alcippe, Cryptophialus.*

**Order 3. Ascothoracica**

1. Parasitic in echinoderms and corals.
2. Mantle bivalved or saccular.
3. Often appendages are lost but antennules remain present.

Examples : *Synagoga, Dendrogaster.*

**Order 4. Apoda**

Parasitic without mantle and appendages.

Example : *Proteolepis.*

**Order 5. Rhizocephala**

1. Adult parasitic, degenerate, sac-like.
2. Peduncle forms root-like absorptive branches ramifying throughout host's tissues.

Example : *Sacculina.*

***Subclass 8. Malacostraca***

1. Body large-sized. Typically made of 19 segments.
2. Head and one or more thoracic segments form cephalothorax.
3. Carapace well-formed or vestigial or absent.
4. Paired compound eyes stalked or sessile.
5. Abdomen ends in a telson. No caudal styles. Important orders are as follows :

**Order 1. Nebaliacea**

1. Carapace bivalved with an adductor muscle.
2. Abdominal segment 7 instead of 6.

Example : *Nebalia.*

**Order 2. Mysidacea**

1. Body elongated. Uropods form fan tail.
2. Carapace thin, covering mostly of thorax.

   Example : *Mysis* (opossum shrimp).

**Order 3. Cumacea**

1. Head and thorax greatly enlarged.
2. Carapace fused to 3-4 thoracic segments.
3. Abdomen narrows. Uropods slender.

   Examples : *Diastylis, Cumopis.*

**Order 4. Isopoda**

1. Wood lice. Body dorso-ventrally flattened.
2. Head and 1 or 2 thoracic segments form cephalothorax.
3. Carapace absent. Gills and heart abdominal.

   Examples : *Oniscus, Asellus, Limnoria.*

**Order 5. Amphipoda**

1. Sand hoppers. Body laterally compressed.
2. Carapace absent. Gills thoracic. Eyes sessile, lateral.

   Examples : *Gammarus, Caprella, Cyamus.*

**Order 6. Stomatopoda**

1. Mantis shrimps. Body flattened. Carapace small.
2. Abdomen large, broader than cephalothorax.
3. Second maxillipedes raptorial. Gills abdominal.

   Example : *Squilla.*

**Order 7. Decapoda**

1. Shrimps, crayfishes, Lobsters, prawns, crabs, etc.
2. Carapace well-developed. Usually enclosing gill chambers on sides of cephalothorax.
3. First 3 pairs of thoracic limbs form maxillipedes.
4. Gills usually in 3 series present on thorax.
5. Statocyst present. Larva typically a zoaea.

***Suborder (a) Natantia***

1. Body laterally compressed. Rostrum prominent.
2. Pleopods well-developed. Modified for swimming.

   Examples : Prawns (*Palaemon, Penaeus, Macrobrachiurri*), Shrimp (*Leucifer, Crangon*).

***Suborder (b) Reptantia***

1. Body dorso-ventrally flattened. Rostrum short, or absent.

2. Pleopods reduced. Not modified for swimming.

Examples : Lobsters (*Palinurus, Scyllarus, Homarus*), Crayfish (*Astacus, Cambarus*), True crabs (*Cancer, Carcinus*), Hermit crab (*Eupagurus*), coconut crab (*Hippo*), Spider crab (*Inachus*).

**CLASS 2. Myriapoda**

(G., myrios, ten thousand + **podos**, foot)

1. Exclusively terrestrial, air-breathing mandibulate arthropods.

2. Body worm-like, made of head and elongated trunk with many similar leg-bearing segments.

3. Antennae 1 pair, jaws 3 pairs, legs more than 11 pairs,

4. Respiration by tracheae. Spiracles arranged segmentally.

5. Excretion by 1 or 2 pairs of Malpighian tubules.

6. Sexes separate, Gonad single. Gonoducts paired.

**Note** : The following 4 orders of group Myriapodia are not related to one another and exhibit marked differences. Therefore, each one of them is nowadays treated as a separate class of mandibulate arthropods. However, the old class Myriapoda has no systematic status and is retained here just for convenience.

**Order (or class) 1. Diplopoda**

**(Gr., diplos,** double + **pous,** foot)

1. Millipedes. Body elongate, sub-cylindrical and divisible into 5-segmented head, 4-segmented thorax and 11 to 100-segmented trunk.

2. Legs 2 pairs on each trunk segment (Diplopoda).

3. Mandibles and maxillae 1 pair each (Dignatha).

Examples : *Spirobolus, Julus.*

**Order (or class) 2. Chilopoda**

(Gr., **cheilos**, lip + **pous** (foot)

1. Centipedes. Body dorso-ventrally flattened and divisible into head and 15 to 173 trunk segments.

2. Legs 1 pair on each trunk segment.

3. Mandibles 1 pair. Maxillae 2 pairs (Trignatha).

4. First pair of legs form poison claws.

Examples : *Scutigera, Lithobius, Scolopendra.*

**Order (or class) 3. Pauropoda**

(Gr., **pauros**, small + **pous**, foot)

1. Minute grub-like body divisible into head and 11-12 trunk segments with 9-10 pairs of legs.

2. No eyes.

Example : *Pauropus.*

**Order (or class) 4. Symphyla**

(Gr., **Syn**, together + **phylon**, tribe)

1. Body slender made of head and 15-22 trunk segments with 10-12 pairs of legs.

2. No eyes.

Example : *Scutigerella.*

**CLASS 3. Insecta**

(L. **insectus**, cut or divided)

1. Body made of head (6 fused segments), thorax (3 segments) and abdomen (up to 11 segments).

2. Head with compound eyes (1 pair), antennae (1 pair) mandibles (11 pair) and maxillae (2 pairs).

3. Mouth parts modified fo: 'ifferent feeding habits.

4. Thorax with 3 pairs of jointed legs and 1 or 2 pairs of wings which may be absent.

5. Respiration by tracheae. Spiracles lateral.

6. Excretion by Malpighian tubules.

7. Unisexual. Fertilization internal. Development usually with metamorphosis. 4

***Subclass 1. Apterygota (Ametabola)***

1. Primitively wingless insects.

2. Abdomen with cerci and style-like appendages.

3. Little or no metamorphosis.

**Order 1. Protura**

1, No antennae, true eyes and metamorphosis.

2. Abdomen of 11 segments plus a telson.

Example : *Acerentulus.*

**Order 2. Collembola**

1. No eyes, tracheae, Malpighian tubules and metamorphosis. Mouth parts chewing or sucking.

2. Abdomen 6-segmented with a springing organ.

Examples : *Springtails. Achorutes, Sminthurus.*

**Order 3. Thysanura**

1. Body covered by minute silvery scales.

2. Antennae long. Mouth parts chewing.

3. Abdomen 11-segmented. Cerci and telson long.

Example : *Lepisma* (silver fish).

***Subclass 2. Pterygota (Metabola)***

1. Wings present. Secondarily lost in some.
2. No abdominal appendages except cerci.
3. Metamorphosis complete or incomplete.

***Division (a). Exopterygota (Heterometabola)***

1. Wings develop externally as buds.
2. Metamorphosis gradual. Young stages are nymphs.

**Order 1. Orthoptera**

1. Wings 2 pairs. Forewings straight and leathery. Hindv membranous and folded at rest.
2. Mouth parts chewing. Prothorax large. Hindlegs jumping.

Examples : *Romalia* and *Poecilocercus* (Grasshoppers), *Schisto* (Locust), *Periplaneta* (Cockroach), *Gryllus* or *Acheta* (Cricket), *Mantis* (Pra mantis), *Phyllium* (Leaf insect), *Carausius* (Stick insect).

**Order 2. Isoptera**

1. Wings 2 pairs; Held flat on back. Or wingless.
2. Mouth parts chewing. Social insects with many castes.

Examples : Termites or white ants.

**Order 3. Dermaptera**

1. Forewings small, leathery. Hindwings large, semicircular.
2. Mouth parts chewing. Forcep-like cerci at the tip of abdomen offense and defense.

Example : *Forficula* (Earwig).

**Order 4. Ephemeroptera**

1. Wings 2 pairs, membranous. Forewings longer and triang Hindwings smaller and rounded.
2. Adult mouth parts vestigial. Mandibulate in nymphs.
3. Abdomen carries long cerci and caudal filament.

Example : *Ephemera* (Mayfly).

**Order 5. Odonata**

1. Wings 2 pairs, membranous. Eyes very large.
2. Mouth parts chewing. Predaceous.

Examples : Dragon flies, Damsel flies.

**Order 6. Plecoptera**

1. Wings 2 pairs, membranous, longer than body.
2. Antennae long. Mouth parts chewing.
3. Naiads usually with tracheal gills.

Example : *Isoperla* (Stonefly).

**Order 7. Psocoptera (= Corrodentia)**

1. Wingless or forewings larger than hindwings.
2. Antennae long. Mouthparts chewing. Cerci absent.

Examples : Book lice (wingless), Bark lice (winged).

**Order 8. Mallophaga**

1. Wings absent. Body small. Head large. Mouth parts chewing. Eyes degenerate. Legs clasping.
2. Ectoparasitic on skin, hairs and feathers of mammals and birds.

Examples : Bird lice, Biting lice (on mammals).

**Order 9. Anoplura (= Siphunculata)**

1. No wings. Body broad, flat. Head small. Mouth parts piercing and sucking.
2. Claws clinging to hairs. Ectoparasitic on mammals.

Example : *Pediculus* (Human louse).

**Order 10. Thysanoptera**

1. Wings 2 pairs, similar, fringed with long hairs.
2. Mouth parts rasping and sucking.

Example : *Thrips.*

**Order 11. Hemiptera**

1. Wings 2 pairs or wingless. Forewings thickened at base, membranous at tip (**hemelytra**).
2. Mouth parts piercing-sucking, forming jointed beak.

Examples : Bedbug (*Cimex*), Giant water bug (**Belostoma**), Water scorpion (*Ranatra*),

**Order 12. Homoptera**

1. Wingless or 2 pairs of uniform membranous wings.
2. Mouth parts form a piercing and sucking beak.

Examples : Cicadas, Aphids, Scale insects,

***Subclass 3. Endopterygota (Holometabola)***

1. Wings develop internally in pupal case.
2. Metamorphosis complete with larval and pupal stages.

**Order 1. Neuroptera**

1. Wings large, membranous, many-veined.
2. Antennae long. Mouth parts chewing. Cerci absent.
3. Larvae carnivorous. Abdominal gills in aquatic larvae.

Examples : *Crysopa* (Lacewing), *Myrmeleon* (Antlion).

**Order 2. Coleoptera**

1. Forewings leathery (elytra). Hindwings membranous, folding
2. Antennae variously modified. Mouth parts chewing.

Example : Beetles.

**Order 3. Mecoptera**

1. Wings long, similar, narrow, membranous.
2. Mouth parts chewing, on a prolonged beak.
3. In male, tip of abdomen curved sting-like.

Example : *Panorpa* (Scorpion fly).

**Order 4. Trichoptera**

1. Wings long, hairy, folded roof-like over abdomen.
2. Antennae long. Mouth parts rudimentary.
3. Larva pupates within a tube of foreign particles.

Example : Caddis flies.

**Order 5. Lepidoptera**

1. Wings membranous, covered with over-lapping scales.
2. Mouth parts sucking, coiled under head.
3. Larva a caterpillar with chewing mouth parts.

Examples : Butterflies (antennae filamentous), Moths (anten feathery).

**Order 6. Diptera**

1. Wings 1 pair. Hindwings as knob-like halteres.
2. Mouth parts piercing-sucking or sponging.
3. Larva limbless, wormlike, called maggot.

Examples : *Musca* (House fly), *Cutex* (Mosquito), *Drosophila* (F fly).

**Order 7. Hymenoptera**

1. Wings 2 pairs, similar, membranous. On each side hooked toget during flight.
2. Mouth parts sucking or chewing. Ovipositor of female usually form piercing sting.
3. Highly specialized. Some social in behaviour.

Examples : *Apis*, wasp / *Vespa* and Ants etc.

**Order 8. Siphonaptera**

1. Small. Laterally flattened. Secondarily wingless.
2. Mouth parts piercing-sucking. Legs long, leaping.
3. Ectoparasites on birds and mammals.

Examples : *Pulex* and *Xenopsylla* (Fleas).

**Minor Doubtful Arthropoda**

**Subphylum IV. Onychophora**

**(G., onychos = claw + phoros, bearing)**

1. Terrestrial, primitive, worm-like, unsegmented.
2. Single pairs of antennae, eyes and jaws.
3. Numerous stumpy, unjointed clawed legs.

Example : *Peripatus*

**Subphylum V. Tardigrada**

1. Minute, aquatic. Segmentation indistinct. No antennae.
2. Mouth retractile, with a pair of horny stylets.
3. Four pairs of stumpy, unjointed, clawed legs.
4. No respiratory, circulatory and excretory organs.

Example : *Macrobiolus* (Water bear).

**Subphylum VI.**
**Pentastomida (= Linguatulida)**

1. Vermiform, unsegmented, parasitic worms. No antennae.
2. Two pairs of ventral retractile hooks near mouth.
3. No respiratory, circulatory and excretory organs.

Example : *Linguatula* (Tongue worm).

**Subphylum VII.**
**Pycnogonida (= Pentopoda)**

1. Small, marine, spider-like. Abdomen vestigial.
2. Mouth on a long proboscis. 4 simple eyes.
3. Appendages include chelicerae, pedipalps, ovigerous legs (1 pair) and long walking legs (4 to 12 pairs).
4. No respiratory and excretory systems.

Example : *Pycnogonum, Nymphon* (Sea spiders).

## • SEGMENTAL ORGANS IN ANNELIDA (COELOMODUCTS AND NEPHRIDIA)

In annelids are found certain tubes called **segmental organs**, as they are repeated in successive segments. These tubes serve to convey the excretory and reproductive products from coelom to the exterior. Segmental organs are primarily divided into two types :

(1) **coelomoducts** derived from mesoderm, and

(2) **nephridia** derived from ectoderm.

**[I] Coelomoducts**

Coelomoducts are normally wide tubes of mesodermal origin, develope evaginations from coelom to the exterior. Typically, a coelomoduct opens, to exterior by a **genital pore** and into coelom by a relatively large ciliated fur the **coelomostome**. It is easily distinguished from the small ciliated funn **nephrostome** of the nephridium.

Coelomoducts primarily function as **gonoducts** and are confined to or few reproductive segments. In the *Oligochaeta* (earthworms), the reproduc funnels and ducts, both male and female, are coelomoducts. However, in s forms, the coelomoducts may secondarily function as excretory organs. uriniferous tubules of vertebrate kidney are coelomoducts.

**[II] Nephridia**

Nephridia are also segmentally arranged coiled tubes of ectodermal or developed as invaginations from ectoderm into coelom. They communicate the exterior through laterally placed small apertures called **nephridiopo** Internally, they may end blindly (**protonephridia**) or may open by s ciliated funnels, or **nephrostomes**, into coelom (**metanephric** Nephrostomes may open into coelom of the same segment in which nephridia lie, or of the segment just in front. Nephridia are primarily excre in function but may secondarily serve to convery the genital products to exterior. Polychaete excretory organs are either protonephridia metanephridia.

1. **Protonephridia.** The 'closed' or protonephridium seems to be r of the primitive type. It terminates in the coelom as a blind t Protonephridia, made of a tew syncytial cells with an intracellular blind en tubule, always develop in the larval polychaetes, irrespective of the kin adult nephridia. The closed end or other parts of the tube are provided peculiar specialized excretory **tube cells** or **solenocytes**. These are simila the flame cells of Platyhelminthes and Rotifera. Solenocytes may occur si or in groups. A solenocyte is a rather rounded ciliated cell connected to protonephridium by a thin tube, the lumen of which encloses a long, vibra flagellum. Excretory fluid enters through the walls of nephridial tubules w are internally ciliated. This fluid is driven into the lumen of nephridium flagellum and forced to the exterior through nephridiopore. Protonephridia found in some adult polychaetes such as *Vanadis, Phyllodoce Tomopt* *Glycera, Nephthys,* etc.

2. **Metanephridia.** The 'opened' or metanephridia are far advar and found in the majority of polychaetes (*Neanthes*), all the oligocha (*Lumbricus*) and leeches. Instead of solenocytes, the inner end metanephridium opens into coelom by a ciliated funnel or **nephrostome.** other end opens to the exterior through the **nephridiopore.** metanephridium is thus open at both ends. A typical metanephridium occur Nereis, those of other polychaetes differ only in minor details. Archianne usually possess one pair of nephridia which may be protonephr (*Dinophilus*) or metanephridia (*Polygordius, Protodrilus*). Princ

ıitrogenous waste in polychaetes is ammonia. Excretory wastes diffuse from oelomic fluid or blood into the lumen of nephridial tubule and discharged to ıutside through nephridiopore.

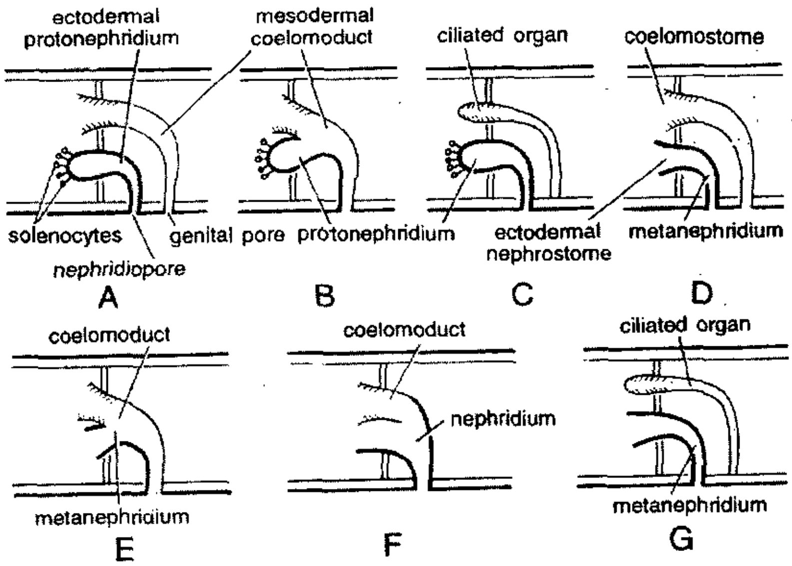



**Fig. 1. Diagrammatic representation of types of nephridia, coelomoducts and nephromixia in various adult polychaetes (After Goodrich). A. Protonephridium and coelomoduct of *Vanudis*. B. *Protonephromixium of Phyllodoce*. C. *Protonephridium and ciliated organ of Glycera* and *Nephthys*. D. Metanephridium and coelomoduct of Capiteliidae and *Notomastus*. E. Metanephromixium of Hesione. F. Mixonephridium of *Arenicola*. G . Metanephridium and ciliated organ of *Nereis*.**

***(a) Micro and Meganephridia.*** Nephridia may be micronephridia or meganephridia on the basis of their size and number. **Micronephridia** or **meronephridia** are smaller in size, sometimes microscopic, and are numerous in each segment. They are networks of fine tubes lying on the body-wall and septa in each segment. All the nephridia of *Pheretima* are micronephridia. **Meganephridia** or **holonephridia** are larger in size and generally one pair per segment. They usually extend over two segments and their nephrostomes open into the segments next in front. They are represented in Polychaeta and Hirudinea. In *Neanthes, Nereis* and *Hirudo,* they are typical metanephridia with internal ciliated funnels. But in *Hirudinaria,* a ciliated funnel or nephrostome is lacking due to its modification into **ciliated organ**. The two kinds of nephridia may exist in the same worm and even in the same segment, as in **Megascolex.** In *Serpula* and some other tubicolous worms, a division of labour exists. Nephridia in the anterior region of body are large and excretory in function, while those in the posterior region are small and serve as gonoducts.

***(b) Exo and enteronephridia.*** Nephridia are termed **exonephric** or **ectonephric** when they directly open to the exterior through **nephridiopores**, such as the meganephridia of *Nereis, Hirudinaria* and *Lumbricus,* and integumentary micronephridia of *Pheretima.* They are termed **enteronephric** when they lack nephridiopores and open into the excretory canals or alimentary canal, as septal and pharyngeal nephridia of *Pheretima.*

### [III] Nephromixia

In Oligochaeta, Hirudineà and the more primitive Polychaeta, neph and coelomoducts are separate. In some Polychaeta, coelomoducts dc remain independent but become fused, partially or wholly with the neph forming compound segmental organs or **nephromixia**. They consist bo ectoderm and mesoderm and used both as genital as well as excretory du

Nephridia and the coelomoducts show various degrees of combina Either they share only the same external opening, or their fusion may be intimate so that they share most of the same duct.

1. **Protonephromixium.** Coelomoduct is united with protonephridium. It conveys both reproductive and excretory products tc exterior. Protonephromixia occur in *Phyllodoce*,

2. **Metanephromixium.** Coelomoduct is grafted on to metanephridium. A good example is seen in *Hesione*.

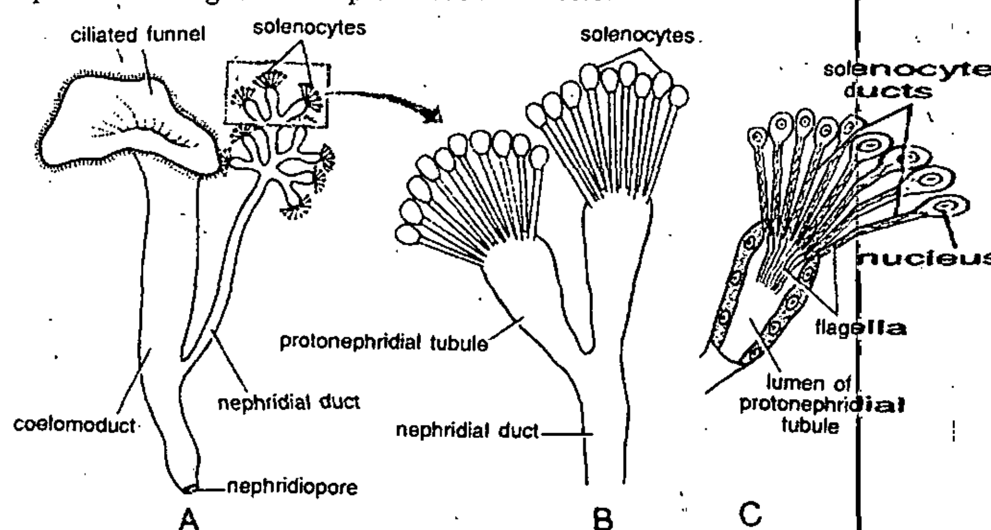



**Fig. 12. Protonephromixium of Phyllodoce paretti. A. Relation of protonephridium and Coelomoduct. B. Two branches of protonephridium. C. One branch with solenocytes in section.**

3. **Mixonephridium.** Coelomoduct and nephridium are intima fused to form a simple composite organ. Its funnel is formed by coelomoduct its duct by nephridium. Mixo-nephridia occur in *Arenicola* where they restricted to the 6 segments of the second tegma of the divided body. Each o has a frilly funnel as an internal opening, a rich supply of blood vessels, anc gonad tissue in close proximity.

4. **Ciliated organs.** In some forms, coelomoducts are reduced **ciliated organs**. In *Nereis*, they are attached to the dorso-lateral longituc muscles and are known to open externally.

---

## • VISION IN ARTHROPO

The most conspicuous sense organs are the eyes, antennules and antenn

### Compound Eyes

1. **Structure.** Prawnhas one pair of black and hemispherical e Each eye is mounted on a short, movable and two-jointed **stalk**, which is loc

in an **orbital notch** at the base of rostrum. Each eye is made of a large number of independent visual elements of units, called **ommatidia** (Gr. **ommation,** little eye). Such eyes are called the **compound eyes.** These are characteristic of **Arthropoda** and do not occur elsewhere in the animal kingdom. All the ommatidia (about 2,500) are arranged radially and are similar in structure, each consisting of many cells arranged along its central axis. Their description is as follows :

***(a) Cornea.*** The outermost convex layer of eye forming **cornea** is the transparent cuticle. In surface view, cornea exhibits a large number of squares or **facets** by clearly visible lines, thus giving the appearance of a graph paper. In insect eyes, the facets are not squares but hexagons.

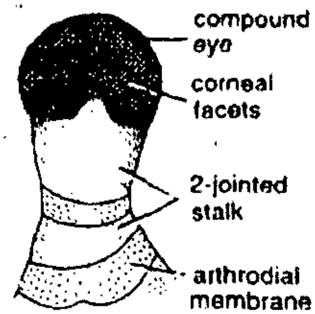



**Fig. 13.** ***Palacemon.*** **Compound eye.**

***(b) Corneagen cells.*** Each corneal facet thickens in the centre to form a **biconvex corneal lens.** Beneathu the lens lie two **corneagen** cells which are modified epidermal cells and secrete a new cornea as soon as the old one is cast off inmoulting.

***(c) Cone cells.*** Beneath the corneagen cells lie four elongated **cone cells** or **vitrellae** which constitute a transparent, homogeneous **erystalline cone.** Inner ends of cone cells are long and tappering.

The part of eye, from cornea up extreme ends of cone cells, is known as the **dioptries region,** which focusses light upon the inertia sensitive part or **receptor region** of eye.

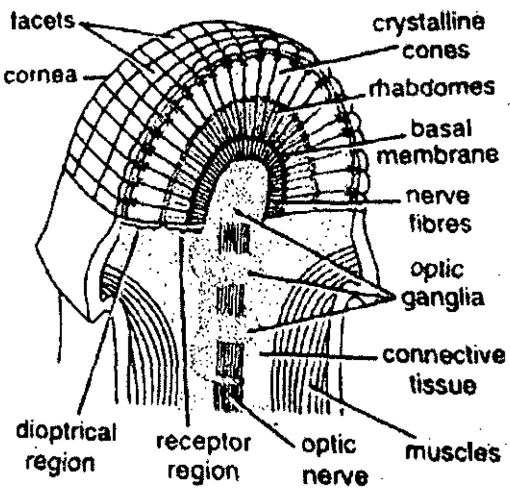



**Fig. 14.** ***Palaemon.*** **L.S. of compound eye showing *arrangement of ommatidia***

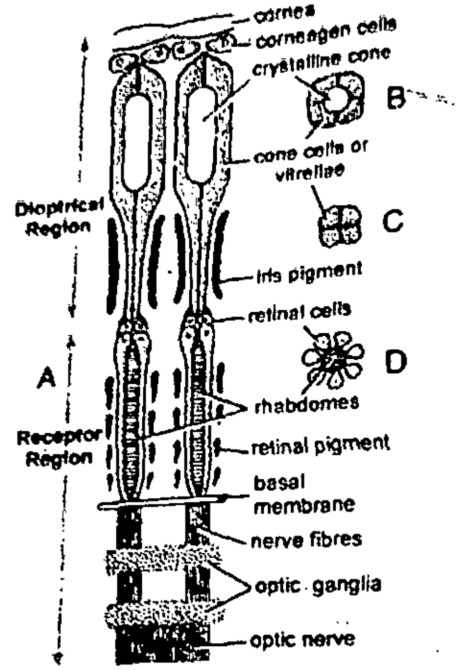



**Fig. 15.** ***Palaemon.*** **Histological structure of compound eye. A. Two ommatidia in L.S. (semi-diagrammatic). B. T.S. of an ommatidium through cone cells. C. T.S. through basal ends of cone cells. D. T.S. through retinal cells.**



***(d) Rhabdome and retinal cells.*** Inner ends of cone cells lie upon a elongated, spindle-shaped rod, the **rhabdome,** It has a transversely striate appearance. Rhabdome is secreted and surrounded by a group of seve elongated **retinal cells**. Rhabdome and retinal cells together form th **receptor region** of eye. Inner ends of retinal cells rest upon a basa **membrane** beyond which they are continuous with sensory nerve fibres c optics ganglia which are connected with brain by the optic nerve.

***(e) Chromatophores.*** Each ommatidium is cut off from its neighbours by sheath of movable which are arranged in two series. Outer series dying alon the cone cells is called iris pigmet and inner series separating the rhabdomes i called **retinal pigment.** Amoeboid pigment cells take up different position according to the variations in the intensity of light.

**2. Mosaic vision.** Working of compound eye is very complex. It is deficien in focussing ability and clarity of image. But, such an eye is efficient for pickin up motion and for peripheral vision. It functions as a very efficient organ fo photo reception. Mounted on a movable stalk, it can move on the head in muc the same manner as the antenna of radar, and gives the animal almos 360-degree vision. Each ommatidium is capable of producing a separate imag of a small part of the object seen. Therefore, in prawns and other arthropod possessing compound eyes, the image of the object viewed consists of severa dark and light tiny pieces or spots, so that the total image of an object formed i a sort of a flat mosaic. Moving objects can thus be detected, The vision effecte is said to be **mosaic vision** because of its similarity to mosaic art work.

The nature of composite image formed varies according to differen intensities of tight Thus two types of images are formed. This is made possibl by the movement of pigment cells.

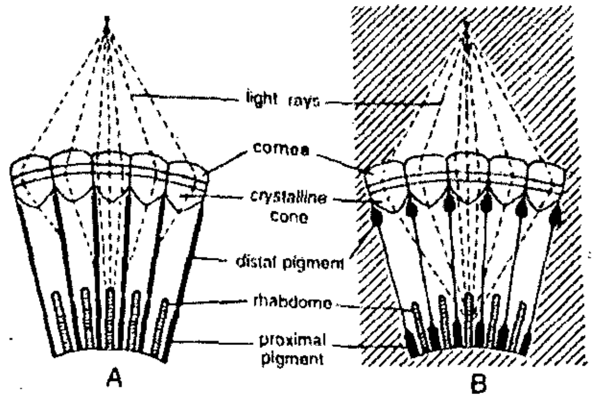



**Fig. 16. *Palaemon*. Diagrammatic representation of image formation by a compound eye. A. Apposition image in bright light (day vision). B. Superposition image in dim light (night vision).**

***(a) Apposition image.*** In **bright light** (during daytime), the pigment cells spread in such a way that they completely isolate optically the adjacent ommatidia. No light can pass through from one visual unit to the other. In this condition the rays of light, which strike the cornea obliquely, are absorbed by the pigment cells without producing a visual effect. Only those rays of light which fall perpendicularly upon the comea, can travel through the ommatidium and reach the rhabdome to form a point of image. As a result, the complete image formed is a mosaic of several components placed in juxtaposition in which the Slightest movement is readily detected. In other words, each ommatidium responds to a fragment of the total field of vision and then these fragmentary images are fitted together into a Single general picture. It is known as a mosaic or apposition image. Its sharpness depends upon the number of ommatidia involved and the degree of their isolation from one another. In butterflies, which are night-blind, the eyes are permanently Set in this condition and are suited to see only in bright light. The image formed by this type of eye is never very good. It functions best at short distances only. Thus, most arthropods are always short-sighted.

***(b) Superposition image.*** In **dim light** (during night), the pigment cells migrate and become separated into distal and proximal pigments, so that the neighbouring ommatidia no longer remain optically isolated but work in unison. In this condition even oblique rays of light are capable of forming a point of image after passing through a number of ommatidia in their way. As a result, an overlapping of the adjacent points of image occurs so that a continuous or **superposition image** is obtained. It is not sharp but the animal gets some sort of idea of the objects moving about in the surrounding. In some insects, like moths and fireflies, the eyes are permanently set like this, so that they are well adapted to see at night but are day-blind.

The prawns, like most arthropods, seem to adjust their eyes to form both types of images according to the prevailing intensity of light.

The **optic nerve** carries impulses (electro-chemical waves of energy) to the brain, where they are interpreted and registered as an upright **mental** image.

❑❑❑

# UNIT

# 5

# MOLLUSCA AND ECHINODERMATA

## STRUCTURE

- General Characters and Classification up to classes
- Torsion and detorsion in Gastropods
- Pearl Formation in Bivalves,
- Evolutionary Significance of Trochophore larva
- Water vascular system in asteroidean
- Larval forms

## • MOLLUSCA : CHARACTERS, CLASSIFICATION AND TYPE

The term 'Mollusca' is derived from Latin word **mollis** or **molluscs** whic mean soft bodied. This term was first applied by **Aristotle** to the cuttle-fish c the Aegean Sea.

### DEFINITION

Mollusca which include clams, snails, slugs, squids, octopods and nautili ar triploblastic, bilaterally symmetrical animals with anus and coelom an without segmentation. They usually have shell and a characteristic ventra muscular foot. There are 80,000 known living species in this phylum.

### DERIVATION OF NAME

In Latin, **mollusca** is the name of a soft nut with a thin shell, referring to th bivalve shell and the soft bodied animal within the shell. The term Molluscs ar among the most **abundant** of all animals. In number of species, the Mollusca i the second largest phylum after Arthopoda. It is not possible to asses accurately the total of the known species. But probably 100,000 living and good number of fossil species (35,000) exist, as compared with ten times a many insects but only half as many vertebrates. Three quarters (80,00 species) of the Mollusca are the gastropodes with about 1,700 genera. Mollusc have no uniform plan as well as no specific shape. In an evolutionary sense they are plastic material as the out lines of the body are freely altered as new habitats are acquired and new structures are needed. Most of them are slow moving and confined to rather special habitats.

### EVOLUTIONARY CHARACTERS

Molluscans exhibit few evolutionary characteristics which are :

1. Some molluscs are herbivorous while others are carnivorous. The digestive system is largely extracellular.

2. They mostly have ganglionated nervous system and the ganglia have a tendency to become concentrated at the anterior end.

3. The nephridial wall tends to become evaginated and folded to effect an increase in the surface area for tubular secretion of waste picked up from circulatory blood.

4. The gonads have lost their primitive association with the pericardial cavity and have mounted on special axis to the outside.

## GENERAL CHARACTERS

Molluscs range from limpets clinging to the rocks, to snails which crawl or dig or swim, to bivalves which anchor, burrow or bore, to cephalopods which torpedo through water or lurk watchfully on the bottom. They penetrate all habitats : the abysses of the sea, coral reefs, mudflats, deserts and forests, rivers, lakes and underground. They may be hidden as parasites in the interior of other animals. They feed on every possible food and vary in size from giant squids and clams to little snails, a millimeter long. They form one of the most definitely characterized group of animals. They have atleast two characters 'radula and mantle' not found elsewhere.

1. Tissue-system grade of body organization.

2. Triploblastic, coelomate, unsegmented (except in Monoplacophora) and bilaterally symmetrical.

3. Body divisible into head, mantle, foot and visceral mass.

4. Shell, when present, usually univalve or bivalve, constituting an exoskeleton, internal in some.

5. Coelom reduced and represented mainly by pericardial cavity, gonadial cavity and kidney.

6. Digestive system complete with a digestive gland or liver (hepatopancreas); a rasping organ, the radula, usually present.

7. Circulatory system mainly of closed type, but some emptying into sinuses: heart with one or two auricles and one ventricle; blood with amoebocytes and haemocyanin.

8. Respiration direct or by gills or lungs or both.

9. Excretion by paired metanephridia (kidneys).

10. Nervous system of paired ganglia, connectives and nerves. Ganglia usually form a circumenteric ring.

11. Sense organs include eyes, statocysts and receptors for touch, smell and taste.

12. Dioecious or monoecious; one or two gonads with gonoducts, opening into renal ducts or to exterior.

13. Fertilization external or internal; development direct or through free larval forms.

14. Terrestrial or aquatic (freshwater or marine).

## CLASSIFICATION

Molluscs are classified into six classes according to their symmetry and the characters of food, shell, mantle, gills, nervous system, muscles and radula.

**CLASS 1. Monoplacophora**

(Gr., **monos**. one + **plax**. plate + **pherein**, bearing)

1. Body bilaterally symmetrical, with a dome-shaped mantle.
2. Flattened limpet-shaped shell with spirally coiled protoconch.
3. Foot broad and flat, with 8 pairs of pedal retractor muscles.
4. Five pairs of gills in pallial grooves.
5. Six pairs of nephridia, two of which are gonoducts.
6. Radula in a raddular sac; intestine much coiled.
7. Heart of two pairs of auricles and a single ventricle.
8. Nervous system with longitudinal pallial and pedal cords.
9. Internal segmentation.
10. Marine.

Example : *Neopilina galatheae.*

**CLASS 2. Amphineura**

(Gr., **amphi,** both + **neuron**, nerve)

1. Elongated body with reduced head.
2. Radula present.
3. Shell as 8 dorsal plates or as spicules.
4. Foot ventral, large, flat and muscular.
5. Non-ganglionated nerve ring around mouth with 2 pairs interconnected nerve cord.
6. Fertilization external; larva trochophore.
7. Marine.

***Subclass I. Aplacophora***

1. Body worm-like with a mantle but no shell and foot.
2. Calcareous spicules buried in cuticle.
3. Radula simple; mantle cavity posterior, some with a pair bipectinate ctenidia.

Examples : *Neomenia, Nematomeina, Chaetoderma.*

***Subclass II. Polyplacophora***

1. Dorso-ventrally flattened body; small head (no eyes and tentacles radula, mantle, foot and external gills present.
2. Mantle cavity posterior.
3. Shell as 8 calcareous dorsal plates.

**Order 1. Lepidopleurina**

1. Valves of shell without insertion plates.

2. Ctenidia a few and posterior.

Example : *Lepidopleurus.*

**Order 2. Chitonida**

1. Valves of shell with insertion plates.
2. Gills along whole length of mantle groove.

Examples : *Chaetopleum, Chiton, Ischnochiton.*

**CLASS 3. Scaphopoda**

(Gr., **scapha**, boat+**podos**, foot)

1. Tusk-shells.
2. Body within a tubular shell, open at both ends.
3. No head; mouth with tentacles; no eyes.
4. Foot conical, radula present; no gills.
5. Kidneys paired; gonad single.
6. Dioecious; larva trochophore.
7. Marine.

Examples : *Dentalium, Cadulus, Pulsellum.*

**CLASS 4. Gastropoda**

(Gr., **gaster**, belly + **podos**, foot)

1. Snails and slugs.
2. Torsion (coiling) of body mass at sometime in development.
3. Well developed head with eyes and tentacles; radula present.
4. Foot large and flat.
5. Shell present or absent; univalve and usually coiled.
6. Mostly marine; some freshwater or terrestrial.

***Subclass I. Prosobranchia (= Streptoneura)***

1. Body mass torted.
2. Head with a single pair of tentacles.
3. Shell closed by an operculum borne on foot.
4. Two ctenidia in mantle cavity situated anterior to the heart.
5. Nervous system streptoneurous with pleuro-visceral connectives twisted in a figure of 8.
6. Sexes separate; gonad single; larvae trochophore or veliger.
7. Marine, freshwater or terrestrial.

**Order 1. Archaeogastropoda ( = Aspidobranchia)**

1. One or two bipectinate ctenidia.
2. Two kidneys and heart with two auricles.
3. Shell usually coiled.

4. Nervous system not concentrated, with pedal cord.

5. Genital products conveyed to outside through right kidne Fertilization external.

Examples : *Fissurella* (key-hole limpet), *Patella* (limpet), *Trochus* (top shel *Acmaea* (limpet).

**Order 2. Mesogastropoda (= Pectinibranchia)**

1. One auricle, one kidney and one mono-pectinate ctenidium.
2. Siphon, operculum and penis present; osphradium developed.
3. Nervous system without pedal cords.
4. Fertilization internal; larva usually a free-swimming veliger.
5. Mostly marine, some freshwater.

Examples : *Pila* (apple snail), *Littorina* (periwinkle), *Crepidu* (slipper shell), *Cypraea* (cowrie), *Natica* (star shell).

**Order 3. Neogastropoda (= Stenoglossa)**

1. Shell with a short to very long siphonal canal.
2. Nervous system concentrated.
3. Osphradium large.
4. Free-swimming veliger s ıppressed,

Examples : *Buccinum* (whelk), *Murex, Nassarius, Oliva, Magilu* *Malongena.*

***Subclass II. Opisthobranchia***

1. Shell small without operculum or no shell.
2. Body mass torted or detorted.
3. Gills posterior to heart.
4. One auricle, one kidney, and one gonad.
5. Nervous system euthyneurous, *i.e.*, without twisted pleuro-viscera loop.
6. Monoecious; larva veliger.
7. Exclusively marine.

**Order 1. Cephalaspidea**

1. Shell moderately developed.
2. Head with tentacular shield.
3. Lateral parapodial lobes prominent.

Examples : *Acteon, Bulla.*

**Order 2. Anaspidea**

1. Shell usually reduced or internal.
2. Well developed parapodial lobes.

3. Head with a pair of rhinophores.

Examples : *Aplysia* (sea-hare).

**Order 3. Pteropoda**

1. Shell present or absent.
2. Parapodial fins for swimming.
3. With or without mantle cavity.
4. Head with a pair of rhinophores.

Examples : *Cavolina, Clione, Corolla.*

**Order 4. Sacoglossa**

1. Shell present or absent.
2. Pharynx suctorial. Spermduct closed.

Examples : *Oxynoe, Elysia.*

**Order 5. Acochlidiaceae**

1. Minute to small-sized; no shell; no gill.
2. Visceral mass separated from foot and covered with spicules.
3. Inhabit coarse sand.

Examples : *Acochlidium, Unela.*

**Order 6, Notaspidea**

1. Shell external or reduced and internal.
2. Mantle, but no mantle cavity.
3. Bipectinate osphradium on the right side.

Example : *Pleurobranchus.*

**Order 7. Nudibranchia**

1. No shell, gill, mantle cavity and osphradium.
2. Various dorsal outgrowths.

Examples : *Doris, Aeolis.*

**Order 8. Pyramidellacea**

1. Shell typically spirally coiled.
2. An operculum but no gill and radula; proboscis long.
3. Semi-parasitic.

Example : *Pyramidella.*

**Order 9. Philinoglossacea**

1. Small naked snails without gill and head appendages.
2. Visceral mass separated from foot only by a groove.

Examples : *Philinoglossa, Sapha.*

**Order 10. Rhodopacea**

1. Vermiform snails, without external appendages.

2. Anus on right side of body.

   Example : *Rhodope* (Single genus).

**Order 11. Onchidiacea**

1. Slug-like without shell and with pulmonary sac.
2. Posteriorly located anus.

   Examples : *Onchidiwn, Onchidella.*

**Order 12. Parasita**

1. Endoparasitic in holothurians.
2. Shelled embryos.

   Examples : *Entoconcha, Thyonicola.*

***Subclass III. Pulmonata***

1. Detorted body mass.
2. With or without shell.
3. Mantle cavity or pulmonary sac with a pore on right side anteriorly
4. Hermaphrodites; mostly freshwater or terrestrial, a few marine.

**Order 1. Basommatophora**

1. One pair of non-invaginable tentacles.
2. Eyes at tentacular bases.
3. Male or female gonopores generally separate.

   Examples : *Siphonaria, Lymnaea, Planorhis.*

**Order 2. Stylommatophora**

1. Two pairs of invaginable tentacles.
2. Second pair of tentacles with eyes at their tips.
3. Male and female gonopores usually united.

   Examples : *Partula, Helix* (land snail), *Limax* (slug).

**CLASS 5. Pelecypoda (= Bivalvia, Lamellibranchia)**

(Gr., **pelekus**, batchet + **podos**, foot)

1. Body enclosed in a bivalve shell and laterally compressed.
2. No head, tentacles, eyes, jaws and radula.
3. Foot often hatchet-shaped and extending between mantle lobes.
4. Mostly filter-feeding.
5. Usually dioecious, veliger or glochidium larva.
6. Mostly marine, a few freshwater.

**Order 1. Protobranchia**

1. Gill filaments not folded.
2. Mouth placed at the base of muscular proboscides.
3. Stomach with style sac.

Examples : *Nucula, Nuculina, Yoldia, Malletia.*

**Order 2. Filibranchia**

1. Gill filaments reflexed but incompletely fused.
2. Chitinous gastric shield in stomach developed,
3. Style sac with crystalline style.

Examples : *Ostrea, Mytilus* (mussel), *Spondylus* (edible oyster), *ecten* (scallop),

**Order 3. Eulamellibranchia**

1. Gill filaments reflexed and fused completely to form tissue sheets.
2. Gills function for food gathering.
3. Style sac short.

Examples : *Teredo* (ship-worm), *Ensis* (razor clam), *Unio, Anodonta, amellidens.*

**Order 4. Septibranchia**

1. Gills absent.
2. Stomach lined by chitin; style sac reduced.
3. Marine.

Examples : *Poromya, Cuspidaria.*

**CLASS 6. Cephalopoda = (Siphonopoda)**

(Gr., **kephale**, head + **podos**, foot)

1. Body elongated dorsoventrally.
2. Shell external, internal or absent.
3. Head distinct and large with well-developed eyes; foot as tentacles nd siphon; radula present.
4. Dioecious; development direct.
5. Marine and free-swimming.

***Subclass I. Nautiloidea (= Tetrabranchia)***

1. Shell external, coiled or straight; without complex sutures.
2. Recent species with many suckerless tentacles.
3. Two pairs of gills; two pairs of nephridia.

Example : *Nautilus.*

***Subclass II. Smmonoidea***

1. Extinct.
2. Shell external and coiled with complex septa and sutures.

Example : *Pachydiscus.*

***Subclass III. Coeloidea (= Dibranchia)***

1. Shell internal or absent.

2. Tentacles a few with suckers.
3. One pair of gills, one pair of nephridia.

**Order 1. Decapoda**

1. Ten arms two elongated and called tentacles, and eight short arm
   Examples : *Loligo* (squid), *Sepia* (cuttle-fish), *Spirula* (spiral shell

**Order 2. Octopoda**

1. Body globular and without fins.
2. Eight equal arms.
   Examples : *Octopus, Argonauta.*

## • ECHINODERMATA : CHARACTERS, CLASSIFICATION AND T

Echinoderms are one of the most beautiful and most familiar sea creat Forms such as the sea stars have become a symbol of sea life. Other forms as brittle stars, sea urchins, sea cucumbers and sea lilies are also quite known to the visitors on the sea-shore. There are 7,000 sps know Echinodermata.

### Historical

Echinoderms are known since very ancient times. Name of this phylum introduced by **Klein** in 1734 for sea urchins. For many years echinoderms coelenterates were included as a class among Radiata, largely because o radial symmetry of the adults. **Echinodermata** were first recognized group distinct from the Radiata by **Leukart** in 1847.

### Derivation of Name

**Echinodermata** literally means 'spiny or prickly skinned' (Gr., echi hedgehog; **derma**, skin) and refers to the conspicuous spines possessed by test or skin. **Jacob Klein** (1734) first used this name for echinoids. The Gr applied the name **echinos** to the hedgehog as well as the sea urchin, having a prickly appearance. Term **echinus** has been used for a certain urchin. Possession of spines is not diagnostic of the phylum because only b known members, such as sea urchin, brittle stars and starfishes, have spi

### Definition

Echinoderms are exclusively marine and largely bottom dwe enterocoelous coelomate, triploblastic animals. They have a pentame radial symmetry derived from an original bilateral symmetry. They posses endoskeleton of calcareous plates or spicules embedded in the skin; a pec water-vascular system of coelomic origin; numerous podia or tube feet ectodermal nervous system; no definite head or brain; no nephridia; go open directly to the exterior by special ducts.

### General Characters

Phylum Echinodermata contains some 5300 known species and constit the only major group of deuterostome invertebrates. **Bather** (1900) statec phylum as "one of the best characterised and most distinct phyla of nimal kingdom". Echinoderms are distinguished from all animals by a umber of characteristics.

1. Organ-system grade of body organization.
2. Triploblastic, coelomate and radially symmetrical; often entamerous.
3. Body unsegmented with globular, star-like, spherical, discoidal or longated shape.
4. Head absent; body surface is marked by five symmetrically radiating reas (**ambulacra**) and five alternating interradii (**inter-ambulacra**).
5. Endoskeleton of dermal calcareous ossicles with spines, covered by he epidermis.
6. Water-vascular system of coelomic origin, including **podia** or **tube eet** for locomotion and usually with a **madreporite**.
7. Coelom of enterocoelous type constitute the perivisceral cavity and avity of the water-vascular system; coelomic fluid with coelomocytes.
8. Alimentary canal straight or coiled.
9. Vascular system and haemal system, enclosed in coelomic erihaemal channels.
10. Respiratory organs include dermal **branchiae, tube feet, espiratory tree** and **bursae**.
11. Nervous system without a brain and with a circumoral ring and adial nerves.
12. Poorly developed sense organs include tactile organs, hemoreceptors, terminal tentacles, photoreceptors and statocysts.
13. No excretory organs.
14. Usually dioecious, gonads large and single or multiple; fertilization xternal; development indirect through free-swimming larval forms.
15. Regeneration of lost parts, a peculiarity.
16. Exclusively marine.

## Classification

**Subphylum I. Eleutherozoa**
**(Gr., eleutheros, free + zoios = zoon, animal)**

Free-living echinoderms.

**CLASS 1. *Asteroidea***

(Gr., **aster**, star + **eidos**, form)

1. Starfishes or sea stars.
2. Arms 5 or more and not sharply marked off from the central disc.
3. Tube feet in orally placed ambulacral grooves; with suckers.
4. Anus and madreporite aboral.

5. Pedicellariae present.

6. Free-living, slow-creeping, predaceous and scavengerous.

***Subclass I : Somasteroidea***

Fossil Palaeozoic sea stars. *Platasterias latirádiata* is the only living sp

***Subclass 2. Euasteroidea***

Living sea stars.

**Order 1. Phanerozonia**

1. Body with marginal plates and usually with papulae, on a surface.

2. Pedicellariae sessile, not crossed.

3. Tube feet without suckers.

4. Mostly borrowers in soft bottom.

Examples : *Astropecten, Luidia, Goniaster, Oreasier (= Pentaceros).*

**Order 2. Spinulosa**

1. Usually without conspicuous marginal plates and with papul both surfaces.

2. Pedicellariae rare.

3. Tube feet with suckers.

4. Aboral surface with low spines.

Examples : *Asterina, Solaster, Pteraster, Echinaster.*

**Order 3. Forcipulata**

1. No conspicuous marginal plates.

2. Pedicellariae pedunculate and straight or crossed type.

3. Four rows of tube feet.

Examples : *Asterias, Heliaster.*

**CLASS 2. Ophiuroidea**

(Gr., **ophis**, snake + **oura**, tail + **eidos**, form)

1. Brittle-stars and allies.

2. Body star-like with arms sharply marked off from the central disc

3. Pedicellariae absent.

4. Stomach sac-like; no anus.

5. Ambulacral grooves absent or covered by ossicles; tube feet wi suckers.

6. Madreporite oral.

**Order 1. Ophiurae**

1. Brittle and serpent stars.

2. Small and five-armed.

3. Arms move transversely.
4. Disc and arms usually covered with plates.

Examples : *Ophiura, Ophiothrix, Ophioderma, Ophiopholis.*

**Order 2. Euryalae**

1. Arms simple or branched.
2. Arms move vertically.
3. Disc and arms covered by soft skin.

Examples : *Gorgonocephalus* (basket star), *Asteronyx.*

**CLASS 3. Echinoidea**

(Gr., **echinos**, hedgehog + **eidos**, form)

1. Sea urchins and dollars.
2. Body discoid, oval or semi-spherical and without arms.
3. Skeleton or test compact bearing movable spines and three-jawed pedicellariae.
4. Chewing apparatus or **Aristotle's lantern** with teeth.
5. Ambulacral grooves covered by ossicles; tube feet with suckers.
6. Gonads usually five or less.

***Subclass 1. Bothriocidaroida***

1. A single row of plates in each inter-ambulacral area.
2. Without typical lantern.
3. Madreporite radial.

Example : Single extinct Ordovician genus *Bothriocidaris,*

***Subclass 2. Regularia***

1. Body globular, pentamerous, with two rows of inter-ambulacral plates in existing members.
2. Mouth central.
3. Aristotle's lantern well developed.
4. Anus central on aboral surface with well-developed apical plates.
5. Madreporite oral,

**Order 1. Lepidocentroida**

1. Test flexible with overlapping plates.
2. Ambulacral plates extend up to mouth lip.
3. Inter-ambulacral plates in more than two rows in extinct forms.

Example : *Palaeodiscus.*

**Order 2. Melonechinoida**

1. Test spherical and rigid.
2. Ambulacral plates continue to mouth lip.

3. Inter-ambulacral plates in four or more rows.
4. Wholly extinct, carboniferous.

Example : *Melonechinus.*

**Order 3. Cidaroida**

1. Test globular and rigid.
2. Two rows of long narrow ambulacral plates and two row inter-ambulacral plates.
3. No peristomial gills.
4. Anus aboral and central.

Examples : *Histocidaris, Goniocidaris.*

**Order 4. Diadematoida**

1. Test globular usually with compound ambulacral plates.
2. Peristomial gills present.
3. Anus aboral and central.

Examples : *Diadema, Echinus, Arbacia.*

***Subclass 3. Irregularia***

1. Body oval or circular, flattened oral-aborally.
2. Mouth central or displaced anteriorly on oral surface.
3. Anus marginal, outside the apical system of plates.
4. Tube feet generally not locomotor.

**Order 1. Holectypoida**

1. Test regular with simple ambulacral and centrally located perist and apical system.
2. Lantern present.
3. Mostly extinct.

Examples : *Holectypus, Echinoneus.*

**Order 2. Cassiduloida**

1. Aboral ambulacral areas petaloid, forming a five-armed figure petals of a flower.
2. Lantern absent.
3. Mostly extinct.

Example : *Cassidulus.*

**Order 3. Clypeastroida**

1. Test flattened with oval or rounded shape.
2. Mouth central, anus excentric.
3. Aboral ambulacral areas petaloid.
4. Aristotle's lantern present.

5. Gills absent.
6. Bottom dwellers.

Examples : Sand dollars : *Clypeaster, Echinarachinus, Echinocyamus.*

**Order 4. Spatangoida**

1. Test oval or heart-shaped with excentric mouth and anus.
2. Four aboral ambulacral areas pataloid.
3. Lantern absent.
4. Gills absent.
5. Burrowing.

Examples : Heart urchins; *Spatangus, Echinocardium lovenia, Hemipneustes.*

**CLASS 4. Holothuroidea**

(Gr., **holothurion**, sea cucumber + **eidos**, form)

1. Sea cucumbers.
2. No arms, no spines.
3. Body elongate on oral-aboral axis; body wall leathery.
4. Mouth anterior, surrounded by tentacles.
5. Ambulacral grooves concealed; tube feet with suckers.
6. Usually with respiratory tree for respiration.

**Order 1. Dendrochirota**

1. Tentacles irregularly branched.
2. Tube feet numerous, on the sole or all ambulacral or entire surface.
3. Respiratory tree present.

Examples : *Cucumaria, Thyone.*

**Order 2. Aspidochirota**

1. Tentacles peltate or leaf-like.
2. Tube feet numerous, sometimes forming a well-developed sole.
3. Respiratory tree present.

Examples : *Holothuria, Actinopyga.*

**Order 3. Elasipoda**

1. Tentacles leaf-like.
2. No respiratory tree.
3. Tube feet webbed together to form fins.
4. Deep-sea dwellers.

Example : *Pelagothuria.*

**Order 4. Molpadonia**

1. 15 digitate tentacles.
2. No tube feet.
3. Posterior end tail-like.
4. Respiratory tree present.

Examples : *Molpadia, Caudina.*

**Order 5. Apoda**

1. Worm-like sea cucumbers.
2. No tube feet and respiratory tree.
3. Burrowing.

Examples : *Leptosynapta, Synapta.*

### Subphylum II. Pelmatozoa
### (Gr., pelmatos, stalk + zooios, animal)

Stalked, sedentary echinoderms.

**CLASS 5. Crinoidea**

(Gr., **crinon**, lily + **eidos**, form)

1. Sea lillies.
2. Body attached during part or whole of life by an aboral stalk.
3. Mouth and anus on oral surface.
4. Arms with pinnules.
5. Tube feet without suckers; no madreporite, spines and pedicellariae.
6. Ciliated ambulacral grooves on oral surface.

**Order : Articulata**

1. Living sea lillies and feather stars.
2. Feather stars non-sessile and free swimming.

Examples : *Antedon* (sea lily), *Neometra* (feather star).

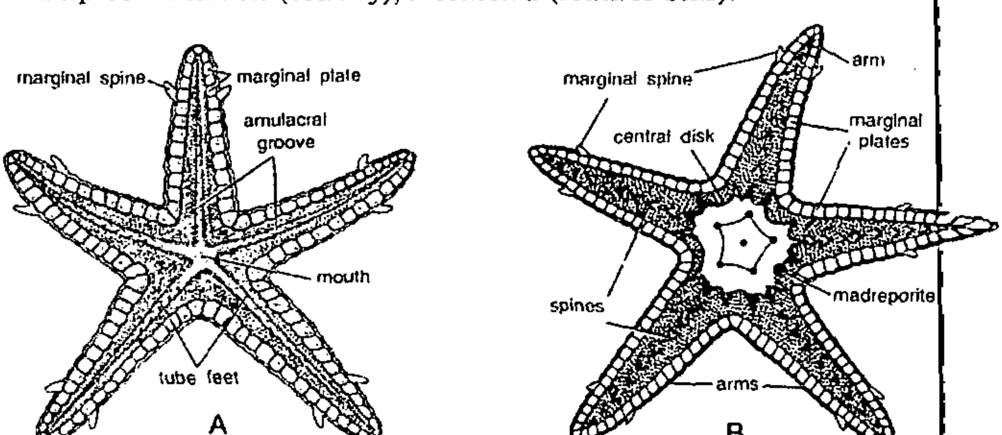



**Fig. 1.** ***Pentaceros*****. A. Oral view. B. Aboral view.**

## • TORSION IN GASTROPODA

All the living molluscs, except the Gastropoda, retain ancestral bilateral symmetry of the body, with mantle cavity lying posteriorly or laterally

Gastropods, on the other hand, possess an asymmetrical body with mantle cavity lying anteriorly, and the shell and the visceral mass coiled spirally and directed posteriorly. In spite of their asymmetry, Gastropoda are generally believed to have descended from an unsegmented and bilaterally symmetrical ancestor with a low conical shell, a straight alimentary canal ending in a posterior anus, and mantle cavity posterior, that is, lying behind the visceral dome. Anterior situation of the mantle cavity in gastropods is due to **torsion** or **twisting** of the visceral mass during development.

### What is Torsion ?

**Torsion** or **twisting** is a process, during larval development of gastropods, which rotates the viscero-pallium anti-clockwise through 180° from its initial position, so that mantle cavity, with its pallial complex, is brought in front of the body, in adult.

### Site of Torsion

In larval gastropods, only visceral mass undergoes rotation through 180°, whereas head and foot remain, fixed. Actual site of torsion is neck, behind the head-foot, through which oesophagus, rectum, aorta, visceral nerve loop and shell muscles pass. Thus, actual twisting involves the neck tissue and structures within it.

### Torsion Versus Coiling

Torsion is often confused with spiral coiling of visceral mass and shell, but the two are entirely distinct and quite independent. Torsion is not coiling of the shell which starts even much before coiling.

Coiling is achieved by a more rapid growth of one side of the visceral mass than the other. Torsion and coiling are, therefore, separate evolutionary events. Torsion was a much more drastic event than the spiralling of shell.

### How Torsion Occurs ?

Torsion is not merely an evolutionary hypothesis. Its occurrence can be seen in the embryogeny of living gastropods. Before torsion, larva is quite symmetrical, the mantle cavity faces backwards and downwards, alimentary canal is straight and anus opens posteriorly in middle line. A ventral **flexure** of the body results in looping of alimentary canal and approximation of mouth

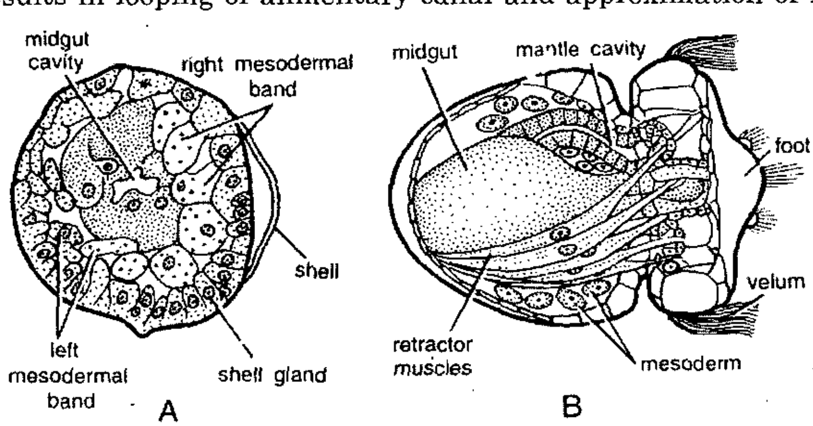



**Fig. 2. Mechanism of torsion. A. T.S. early veliger of *Haliotis* showing disprportionate growth of right mesodermal cells. B. 48 hour larva of *Patella vulgata* showing a symmetrical retractor muscle.**

and anus. Shell and visceral mass, originally saucer-shaped, become first cone-shaped and later spirally coiled. Shell lies dorsally and forms a coil on the anterior side; such a shell is called **exogastric**.

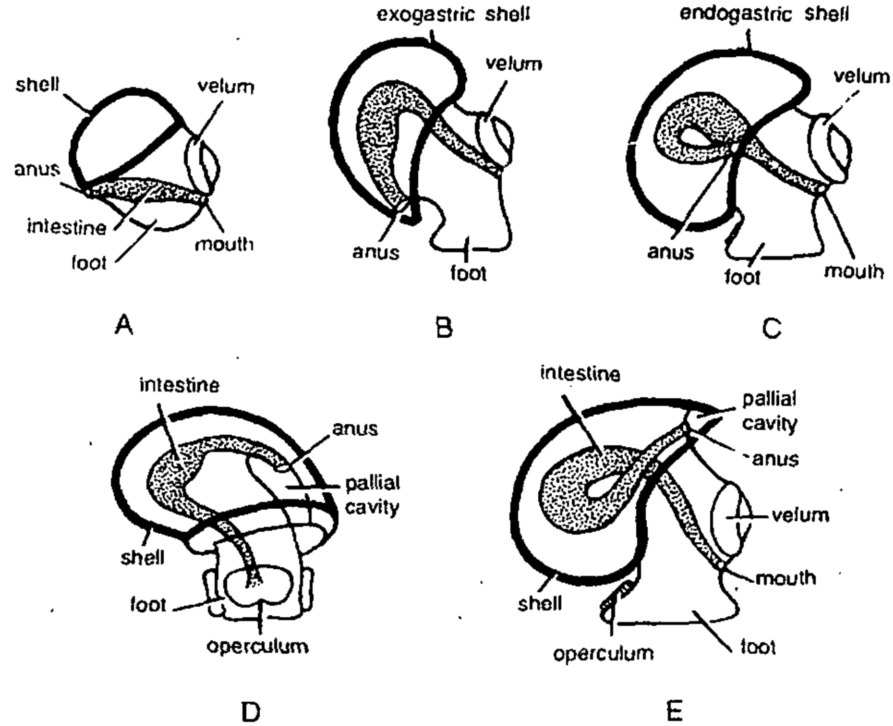



**Fig. 3. Five successive stages in the development of a gastropod to show occurrence of torsion. A. Early veliger larva or pretorsional stage in lageral view. B. Larva with ventral flexure and an exogastic shell in lateral view. C. Stage showing 90° of lateral anticlockwise torsion. Shell becomes endogastric. Mantle cavity and anus move on to right side. D. 90° torsion stage is posterior view. E. Adult stage with complete or 180° torsion in lateral view.**

Ventral flexure is followed by a lateral **torsion**, so that dorsal or exogastric shell becomes ventral or **endogastric**. Lateral torsion is probably due to arrest of growth on one side and active extension on the other. Generally, growth of the right side becomes retarded so that mantle cavity and pallial complex gradually pass round to right side, and so to the anterior side, on account of greater growth of the visceral sac towards the left. But the whole process completes in 2 or 3 minutes in *Acmaea*, so that it cannot be regarded due to differential growth. On the contrary, it is due to muscular contractions. Actual mechanism of torsion is supposed to be the asymmetrical position and pull of the larval retractor muscles running from the velar lobes to the shell. They are present only on the right side, there being no related muscles on the left side. Contraction of larval retractor muscles brings about the rotation or torsion. Only narrow neck of the larva is actually twisted. Consequently, everything between the head and anus undergoes an anticlockwise rotation or torsion through an angle of 180° around a vertical axis passing in a dorso-ventral direction.

**Thomson** (1958) after careful study recognises five ways in which torsion can be brought about :

(1) Complete or 180° rotation, achieved by muscles contraction alone is

known only for *Acmaea* (Archaeogastropoda).

(2) 180° rotation achieved in two stages, first 90° movement by contraction of larval retractor muscles and later a slower 90° rotation by differential growth. It is the commonest mechanism which is known today, *e.g.*, *Haliotes, Patella.*

(3) 180° rotation by differential growth processes alone, *e.g.*, *Vivapara.*

(4) Rotation by differential growth processes, with anus coming to a position appropriate to adult state, *e.g.*, *Aplysia.*

(5) Torsion no longer recognisable as a movement of viscero-pallium, the organs in post-torsional position from their first appearance, *e.g.*, *Adalaria.*

### Effects of Torsion

Torsion is a fundamental feature of gastropods and represents their greatest departure from the ancestral molluscan plan. Peculiarities of organization of gastropods due to torsion were first realized by **Spengel** (1881).

**1. Displacement of mantle cavity.** Mantle cavity was primitively posterior in position. Increase in length of ventral foot, which primitively was very short, tends to remove the mantle cavity and pallial complex away from the head. After torsion the mantle cavity opens just behind the head and its associated parts are shifted forwards.

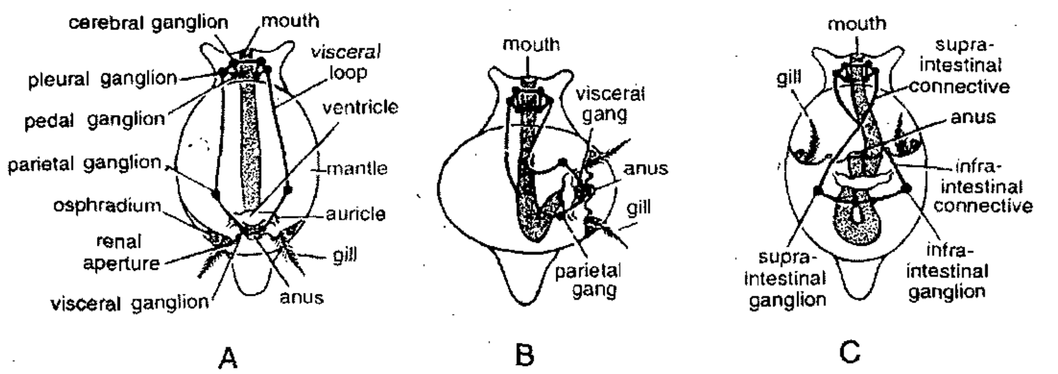



**Fig. 4. Effects of torsion upon position of gills, digestive tract and nervous system. A. Hypothetical primitive stage before torsion. B. Intermediate stage showing 90° torsion with mantle cavity and pallial complex displaced to the right side of body. C. Final stage showing 180° torsion.**

**2. Changes in relative positions.** Before torsion, anus, ctenidia and renal orifices point backwards, and the auricles lie behind ventricle. After torsion, anus, ctenidia and renal orifices project forward, and the auricles lie in front of ventricle. Original posterior face of visceral sac becomes the actual anterior face, so that visceral organs morphologically of the original right side become placed topographically on the left side, and vice versa.

**3. Looping of alimentary canal.** Digestive tract, which was originally straight from mouth to anus, is thrown into a loop.

**4. Chiastoneury.** Long, uncoiled pleuro-visceral nerve connectives become twisted into a figure of 8. Right connective with its ganglion passes over the intestine to become supra-intestinal, while left connective passing underneath the intestine to become infra-intestinal.

5. **Endogastric coil.** Coil of visceral sac and the shell, which primitively was dorsal or **exogastric**, becomes ventral or **endogastric**, after torsion.

6. **Loss of symmetry and atrophy.** Anus is displaced towards right side of the pallial cavity so that original symmetry of organisation disappears. Another characteristic feature involving asymmetry is reduction or atrophy of the paired parts of primitively left or topographically right side. In primitive

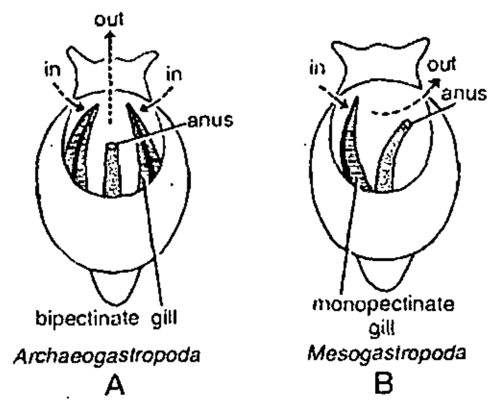



**Fig. 5. Diagrams to illustrate the loss of symmetry and atrophy due to torsion. The arrows indicate the course of respiratory water currents,**

Archaeogastropoda or Diotocardia (*Patella, Haliotis, Fissurella,* etc.) maximum symmetry is preserved by retaining two gills, two auricles and two kidneys, but the right kidney serves as a gonoduct. In more specialized Mesogastropoda or Monotocardia (*Pila, Buccinum, Littornia,* etc.), ctenidium, auricle, osphradium, hypobranchial gland and kidney of the topographically right side disappear in dextral forms, but reverse process occurs in the sinistral forms. Remaining gill may bear one row of filaments (monopectinate gill).

## Significance of Torsion

According to **Garstang** (1928), torsion first occurred as a larval mutation of advantage to the larva adapted to pelagic life but of little direct use to the adult. Before torsion, the untwisted swimming larva fell an easy victim to its predators because the posterior mantle cavity could receive the delicate head and velum only after the foot was already inside. After torsion, the mantle cavity became anterior, so that the sensitive parts *i.e.*, head and velum could withdraw first followed by the foot. Operculum sealed the aperture, the cilia of velum stopped beating, so that larva could fell to the sea bottom and avoid its enemies swimming in the water.

According to **Morton** (1958), main advantage of torsion must be to the adult. Firstly, torsion promotes stability in the adult by placing bulky mass of animal nearer the substratum. Secondly, in primitive Molluscs, the mantle cavity containing gill was situated posteriorly, so that when the animal moved upstream, the water-flow and the current due to movement of the animal opposed the respiratory current entering the mantle cavity from behind the animal. After torsion, mantle cavity is curled anteriorly above the head, so that all the three currents now flow in the same direction, thus flushing the mantle cavity continuously with fresh clean water and increasing its ventilation. Thirdly, anteriorly placed chaemoreceptive organs (osphradia) can also continuously sample the sediment and incurrent water stream and the animal orients itself properly with the help of the sense organs on the head. Once the shell is lost, gills become exposed to the external currents and their anterior position remains of no advantage, so that the mantle cavity and the pallial complex shift back to their original posterior position (**detorsion**).

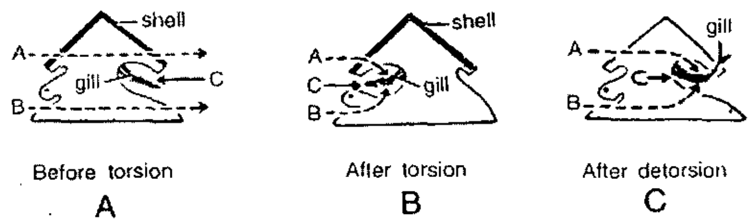



**Fig. 6. Diagrams illustrating the possible advantage of torsion. A. Current due to flow of water. B. Current due to movement of gastropod. C. Respiratory current.**

### Detorsion

Changes occurring in torsion are to a certain extent reversible. This reversion is known as **detorsion** and it is very characteristic of the whole group of the **Euthyneura**. As a result, pallial complex travels back towards the posterior end along the right side, ctenidia point backwards, auricles move behind the ventricle, and the visceral loop becomes untwisted and symmetrical. In this way, a secondary external symmetry is re-established. Torsion must be disadvantageous to adult snails, as many of them have undergone detorsion processes. Various degrees of detorsion are met within the Euthyneura. In the least specialized Opisthobranchia and Pulmonata (*Acteon, Butta,* etc.), detorsion is not complete, so that the visceral loop remains partly twisted and the anus and ctenidium are directed laterally, instead of anteriorly. Formerly, this condition was looked upon as an arrested stage in the torsion, but there is the same reduction of the paired parts of the pallial complex as in the specialized **Streptoneura.** Total detorsion, as shown by the typical **Opisthobranchia** (*Aplysia*), is accompanied by a reduction of disappearance of the shell. In extreme cases, as in *Pterotrachea*, the mantle and the visceral sac also disappear and the body elongates to become worm-like. The mantle cavity, visceral hump, external shell and even ctenidia may be lost, as in **Nudibranchia** (Eolis, Doris, etc.).

The phenomenon of detorsion can thus be elaborated as follows :

(1) In some cases the right ctenidium (originally left) and the osphradium are absent.

(2) In *Eolis,* there is veliger larva with a coiled visceral hump that undergoes torsion but adults do not show any sign and the pallial complex is posteriorly placed in adult. Naturally, the detorsion must have occurred during the course of further development.

(3) In **pulmonata,** the pallial complex is shifted but there is no chiastoneury as a result of shortening of visceral commissures. The pleurovisceral mass and so the chiastoneury is secondarily lost.

### Pearl Culture

Pearl is also called 'Mod'. It is white, highly shining globular in shape and made by the clam, a mollusc called *Oyster* within its shell. Pearls are prized as gems from ancient times. Pearls are among the most beautiful and valuable of our jewels. **Kokichi Mikimoto** of Toba (Japan) is known to be the father of Pearl Industry. He discovered a method to induce foreign particle between the mantle and the shell of the pearl Oyster and thus stimulated pearl formation.

### Pearl Formation or Pearl Fisheries

A pearl is a result of an injury to molluscs. It is secreted by the mantle as a means of protection against some foreign body. Whenever a foreign body such as a particle of sand or a small parasite (a trematode or cestode larva), a small animalcule or alga or even bit of shell, gets between the mantle and the shell it becomes enclosed in a sac of mantle epithelium which is thus irritated. Irritation stimulates the mantle epithelium to secrete nacre thin concentric layers of mother of pearl all around the foreign body. The amount of deposition is in direct proportion to the degree of irritation. At the end of several years, a pearl is formed.

### Pearl Molluscs

Pearls are often found in clams and edible oysters but these are not nacreous and therefore, they are of little value. Most precious pearls are found in pearl oysters of the genus *Pinctada*. Important species for pearls are *P. vulgaris, P. chemnitzi, P. margaritifera, P. anomioides* and *P. atropurpurea* found in Indian waters. *P. vulgaris* which is closely allied to freshwater mussel is common species distributed in gulf of Kutch, gulf of Mannar and the Palk Bay and Baroda.

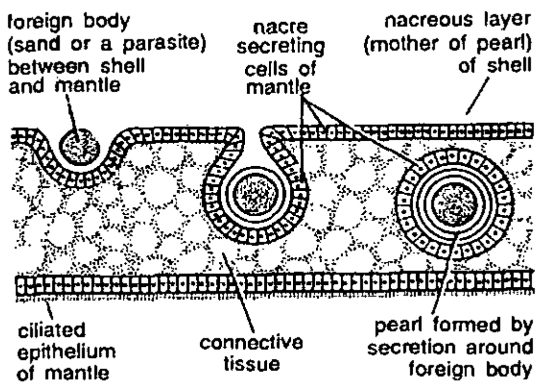



**Fig. 17, Stages in pearl formation.**

### Artificial Pearl

Japanese have developed a technique of producing pearls artificially by inserting foreign bodies, such as glass beads, into the mantle of oysters. The oysters are retained in wire cages or crates until pearls are produced, which can be later removed and sold in markets. This was Mikimoto's discovery which has ıade him a wealthy person. It takes about 3 to 4 years to produce a pearl of onsiderable size but a large one takes 7 years. Cultured pearls are genuine ıearls but are less valuable than uncultured pearls which can be identified by xperts. Imitation pearls are beads coated with an iridescent substance called ıearl essence that is obtained from scales of fishes. The best quality of pearl is :nown as 'Lingha pearl' obtained from marine oysters.

### :ulture of Oysters

The woman divers in Japan are called 'The Girls of the Sea'. From early norning till noon, they collect the oysters from the bottom of the sea with the ıelp of nets. Collection of oysters is best done in the two months of the summer ıeason when the sea is Calm and the water is nearer the shore. Oysters are :ollected, stocked and reared in rearing cages. Each cage is divided into 4-6 ımaller chambers and is covered with metal mesh provided with cotton netting. 'he oysters are cleaned before being placed in the culture cages for about 10 to :0, days for acclimatizing them to shallow water conditions. After which they ıre processed for artificial pearl formation.

## • TROCHOPHORE LARVA AND ITS SIGNIFICANCE

### ;tructure of Trochophore

Polychaetes (Annelids) have indirect development. Their life cycle includes ı free-swimming trochophore larva. This larva is a characteristic of many ırotostomous groups (*e.g.*, molluscs, sigunculus, and echiurans). Trochophore s a minute, ciliated, unsegmented, and almost gear-shaped pelagic creature, vith oral and aboral surfaces recognizable. Thus, the early presegmental rochophore (Fig. 1) is characterized by a locomotor ciliary band just anterior to

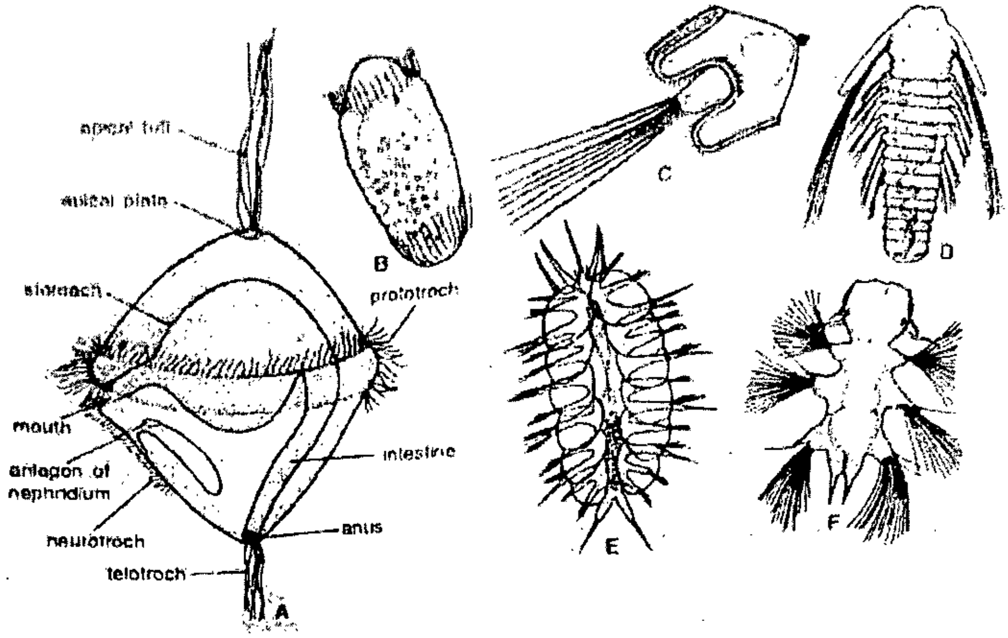



**Fig. 8. Some potychaete larvae-trochophores and beyond. A—Anatomy of a generalised early trochophore larva; B—Young trochophore of a capillid; C—Trochophore of *Owenia*; D—Late spinoid larva; E—Late larval stage of a polynoid (Scale worm F—Three-segmented nectochaeta "larva" of a nereid (after Brusca and Brusca, 2003)**

the region of the mouth. This ciliary band, the **prototroch**, arises from spe cells, called **trocboblasts,** of the first and second quartets of micromeres. M trochophore larvae also bear an **spical ciliary tuft** associated with an api **sense organ** (eye and cerebral ganglia) derived from a plate of thicke ectoderm at the anterior end. In addition, there is often a perianal ciliary b called the **telotroch**. By this stage the mesentoblast has divided to form a p of cells called **teloblasts,** which in turn proliferate a pair of mesodermal ban one on each side of the archenteron in the region of the hindgut, an area kno as the growth zone (Fig. 1B). Many trochophores bear larval sense organs s ocelli and statocyst, as well as a pair of larval protonephridia. M trochophores bear bundles of mobile chaetae, which are known to serve a defense against predators (**Pennington** and **Chia**, 1984) and to help ret sinking.

The cilia of ciliary girdles, rings or bands, when beating give the appeara of a rotating wheel, hence the name trochophore (Gr. *Trochos* = wheel; *phor* bear). Digestive tract of trochophore larva is complete, and compr **stomodaeum, stomach, intestine** and **proctodacum** (Fig. 2). A spac fluid-filled **blastocoel** surrounds the larval gut. It contains mesenchyme c larval muscle fibers and a pair of larval kidneys or protonephridia, one on e side of the gut. The nephridia open by a common passage. Trochophore la segmentation and coelom.

The fully formed trochophore may be divided into three regions **pretrochal region** comprising area about and above the mouth; 2. pygid consisting of telotroch and anal area; and 3 growth zone lying between mouth and telotroch. In polychaetes, the growth zone forms all the tr segments

Trochophore may be **planktotrophs** (*i.e.*, feeding on plankton or plankt organisms) and have long planktonic lives, or they may be **lecithotrophs** a non-feeding larva which utilises yolk as a source of nutrition) and have a s planktonic existence. The prototroch functions as the swimming organ, and feeding trochophore, it also collects the suspended food particles. The fee trochophore also has a food groove between the preoral prototroch and postoral metatroch. The larger cilia of prototroch drive water and suspe food partictes backward. The short metatroch cilia beat in opposite direc and drive the food particles into the food grove. The short cilia of the food gr carry the food particles to the mouth.

## GROWTH AND DEVELOPMENT OF TROCHOPHORE

The trochophore larva grows and elongates by proliferation of tissue ir growth zone (Fig. 3), while segments are produced by the anterior prolifera of mesoderm from the teloblast derivatives on either side of the gut. T packets of mesoderm hollow (schizocoely) and expand as paired coel spaces, which eventually obliterate the blastocoel. Thus, the productic serially arranged coelomic compartments and the formation of segments one and the same, the anterior and posterior walls of adjacent coel compartments form the intersegmental septa. Proliferation of segments by

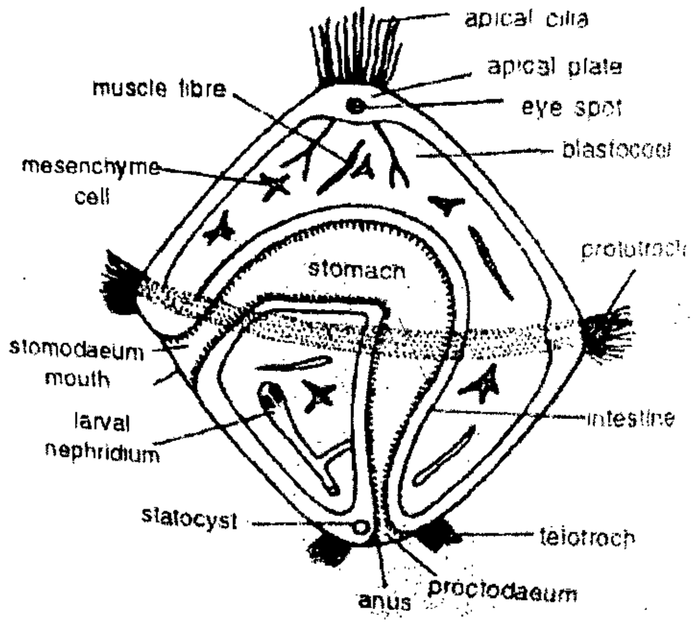



**Fig. 9. Internal structure of a trochophore larvae**

process is called **teloblastic growth**. Externally, additional ciliary bands are added at each segment, These **metatrochal bands** aid in locomotion as the animal increase in size. Such segmental larvae are some times called polytroch larvae.

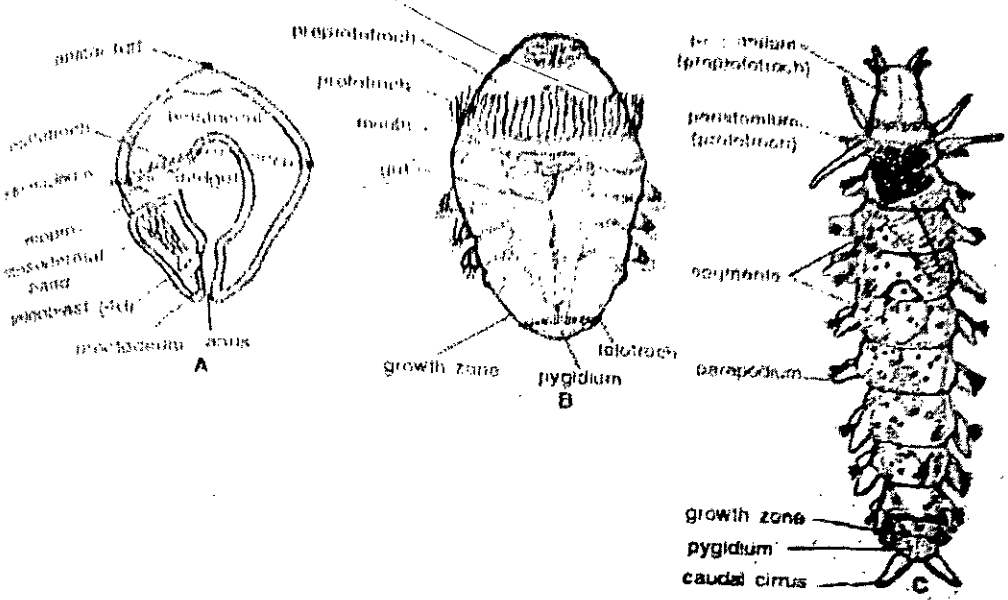



**Fig. 10. Growth of trochophore larva, A—Trochophore larva of *Arenicola*. Note the teloblastic (4d) mesodermal hands destined to form the metameric coelomic speces, B, C—Two stages in the development of *Etcone*; B—Early stage segmentation; C—Juvenile, showing the fates of the larvae regions (after Brusca and Brusca, 2003).**

The fates of the various regions of trochophore larva are now apparent (Fig. 3). The region anterior to the protrochal ring becomes the **prostomium**, while the prototrochal area firms the **peristomium**. Note that these two parts are not involved in the proliferation of segments and are thus presegmental. The segmental, metatrochal portion of the larva forms the trunk and the growth zone and post segmental pygidium remain as the corresponding adult body parts. The apical sense organ becomes the cerebral ganglion, which eventually joined with the developing ventral nerve cord by the formation circumcentric connectives. The body continues to elongate as more segme form and the juvenile worm finally drops from plankton and assumes lifestyle of a young polychaete.

## SIGNIFICANCE OF TROCHOPHORE

The trochophore larva is of great phylogenetic significance. Many anim such as polychaetes, sipunculans, echiurans, bryozoans, molluscs, brachiop and nemertines, develop a trochophore larva, of course, with cert modifications. This has led some embryologists (e.g , **Hatschek, 1878**) suggest a theory (the so-called **trochophore theory**) that these animal grou have descended from a common hypothetical ancestor called trochozo having trochophore-like features. The animal groups thought to have comm ancestry may also include other phyla (Platyhelminthes and Arthropo which may have lost the trochophore somewhere in their evolution.

There is a striking resemblance between certain rotifers and the trochoph larvae of some annelids molluscs and others. This indicates that the rotif and the animals closely related to the ancestors of the annelids, molluscs a other groups (sce chapter 34).

Trochophore larve (theory) accounts satisfactorily in many ways fo common ancestor of the coelomate prostomia but not for the acoelomate grou Mauy authorities, however, believe that the resemblances of trochoph larvae may be coincidental, the results of adaptive radiation and not evolutionary significance of actual relationship.

## • WATER-VASCULAR SYST

**Water-vascular system** is a division of the coelom and most distinct feature of echinoderms. It is a system of canals and appendages of body wal is also termed as **ambulacral system**. Since the entire system is derived fr coelom, the canals are lined with a ciliated epithelium and filled with wat fluid. Water-vascular system functions as a means of locomotion. It consist. **madreporite** or **sieve plate, stone canal, water ring** or **ring canal, rad**

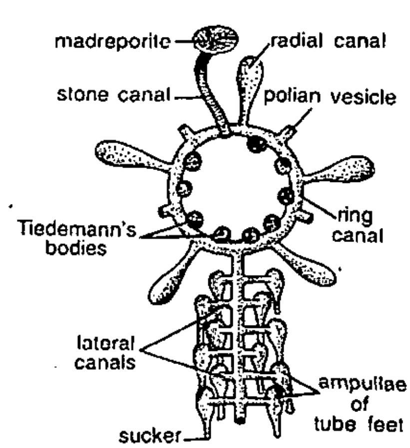



**Fig. 11. Water-vascular system of a sea star.**

canals and **podia** or **tube feet.** In different classes of Echinodermata, water-vascular system is variously modified.

### [I] Asteroidea

In asteroids, water-vascular system is based on the general echinoderm plan, with certain modifications.

1. **Madreporite.** Internal canals of the system connect with sea water outside through button-shaped **madreporite** or **seive plate** located on the aboral surface in interradial position. Seive plate is calcareous having numerous ridges and furrows. Furrow have about 200 pores, each of which leads into a **pore canal**. Pore canals join to form a common canal to open into an ampulla beneath the madreporite. Almough a great majority of asteroids have but one madreporite, multiplication of madreporites is not rare.

2. **Stone canal.** It is so named because of calcareous deposites located in its walls. A vertical S-shaped **stone canal** extends towards oral side. A longitudinal ridge divides the lumen of the stone canal into two passages. In *Henricia*, the internal ridge is very simple. In *Asterias* and *Asterina*, ridge is bifurcated into two rolled vertical lamellae. In *Asteropecten*, ridge meets the opposite wall dividing the interior into tubes provided with a pair of scrolls each. The lumen of stone canal is ciliated.

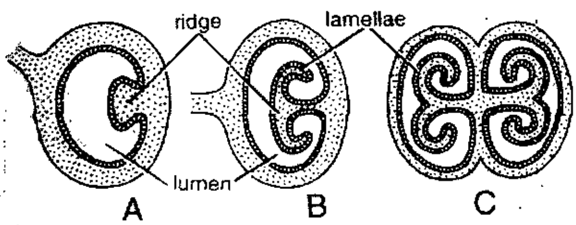



**Fig. 12. T,S. stone canals of some asteroids : A. *Henricia*. B. *Asterius*, C. *Astropecten*.**

3. **Ring canal.** Stone canal opens into a circular **ring canal** or **water ring** situated just internal to the peristomial ring of ossicles around the mouth margin. Often the walls of the ring canal are folded to divide its lumen into a more or less separate channels.

4. **Radial canals.** From the outer margin of ring canal are given out five **radial canals**. Each radial canal runs into each radial arm and terminates

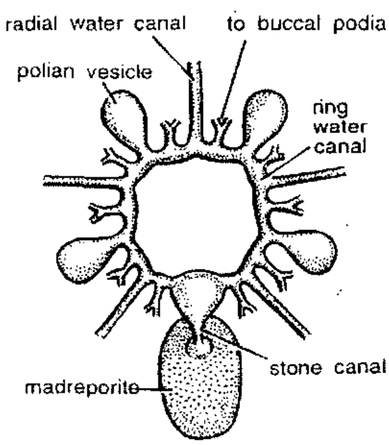



**Fig. 13. Water-vascular system of an ophiuroid (Schematic).**

into the terminal tentacle at the tip of the arm. The radial canal runs on the side of ambulacral ossicles covering the ambulacral groove.

5. **Lateral canals.** From each side of the radial canal, **lateral can** are given off alternately which pass between the ossicles on each side to e the coelom. Each lateral canal has a valve and terminates into a bulb ampulla connected to tube foot.

6. **Polian vesicles.** The ring canal, forms five polian vesicles on outerside. They store water which is to be utilized when sea star comes out the water.

7. **Tiedemann's bodies.** The ring canal on its inner side also gives interradially five pairs of small, irregularly shaped bodies, known Tiedemann's bodies. Some forms have only 9 such bodies. They proc coelomic corpuscles which are passed into ring canal as such giving the syst the name water -vascular system.

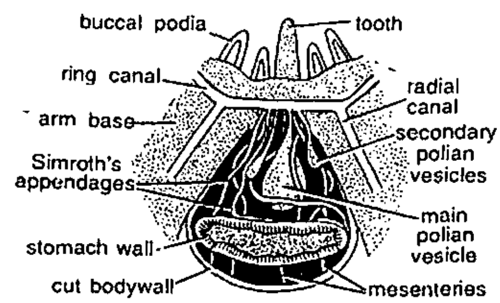



**Fig. 14. Ophiactis virens. Sector of disc showing water-vascular**

8. **Tube feet.** A **podium** or **tube foot**, is a short hollow, elastic, thin wa closed cylinder located in the ambulacral groove. Tip of the podium is flatte forming a sucker for attachment. Inner or basal end of each podium pierces ambulacral ossicle, through a tiny ambulacral pore and expands to form a l rounded bulb or bladder called **ampulla**, lying into the aboral side of coelom. The walls of ampulla contain longitudinal and circular muscle fi where as the tube foot has longitudinal fibres only, there being no circ muscles in the tube foot. Podia are arranged in four rows along the lengt ambulacral groove. As lateral canal on each side are alternately long and sh the podia look like in four rows instead of two. Species having only two row podia have lateral canals of equal length.

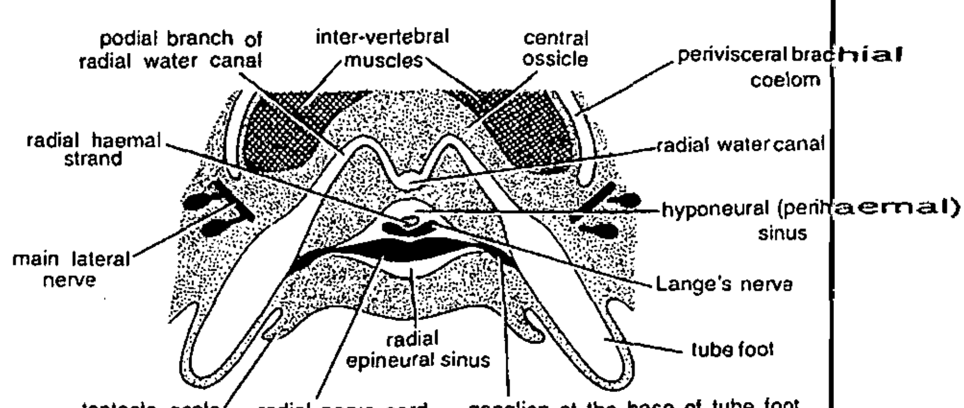
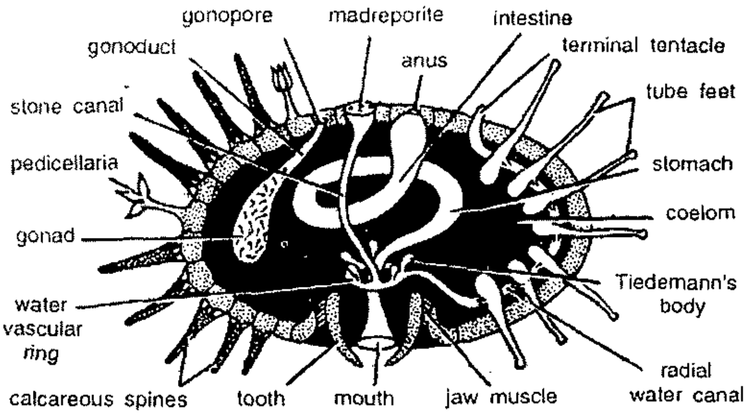



**Fig. 15. *Ophiothrix*. Partial section of arm showing podial water canals.**




**Fig, 16. *Echinoidea.* A section through a sea urchin showing water-vascular system.**

Water-vascular system helps in locomotion. Animal moves by tube feet. Water after entering the madreporite passes into stone canal, ring canal, radial canal, podial canal and finally into ampullae of podia. As ampulla contracts the water is forced into the tube foot which gets elongated. The sucker-like tip of tube foot touches the substratum and contracts again. Fluid goes back into ampulla and the body is drawn forwards bringing about the locomotion of sea star.

### [II] Ophiuroidea

**Madreporite** lies on the oral surface. It bears a single pore and a **pore canal.** Some species have more than one madreporite. **Stone canal** ascends to the **water ring**, which is located in a groove on the aboral surface of the jaws. Stone canal gives off a madreporic **ampulla** just beneath the madreporic plate. Water ring or **ring canal** gives off four **polian vesicles** in each inter radius except one which contains stone canal. Sometimes polian vesicle are accompanied by long slender, tubular appendages, known as Simroth's appendages. Ophiuroids lack **Tiedeman's bodies**. Water ring gives rise to a **radial canal** in each radius which descend, towards oral side, runs along the whole arm to terminate into terminal tentacle. Radial canals penetrate through the lower side of vertebral ossicles of the arras. In each ossicle, radial canal gives a V-shaped **podial canal** or **lateral canal** that enters into a pair of podia. **Podia** do not bear **ampulla**. There is a valve between podium and the lateral canal. Podia are reduced. Entire water-vascular system is lined with ciliated peritonium.

### [III] Echinoidea

Water-vascular system of echinoids is like that of sea stars. One of the genital plates around the periproct bear pores and **pore canal** and also serves as **madreporite. Stone canal** descends orally to a **water ring** surrounding the oesophagus aboral to the lantern. Stone canal is accompanied by axial gland. Five **radial canals** arise from the water ring and terminate into the terminal tentacle. Water ring also gives rise to five sponge like bodies called **Tiedemann's bodies**. From either side of radial canal alternately come out

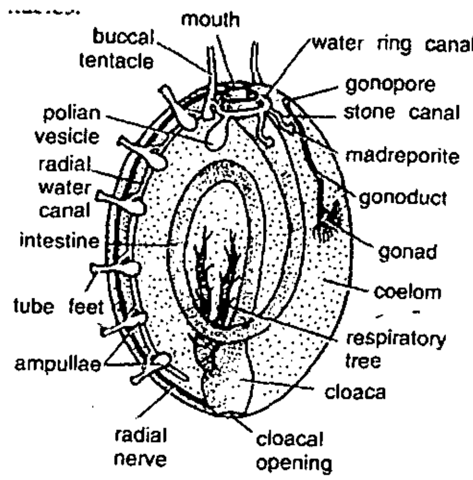



Fig. 17. L.S. of a holothurian, showing water-vascular system (diagrammatic).

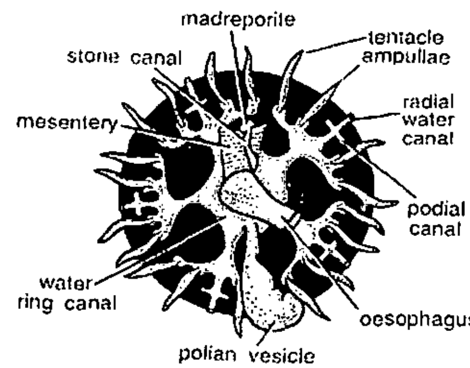



Fig. 18. *Holothuria*. Water-vascular system.

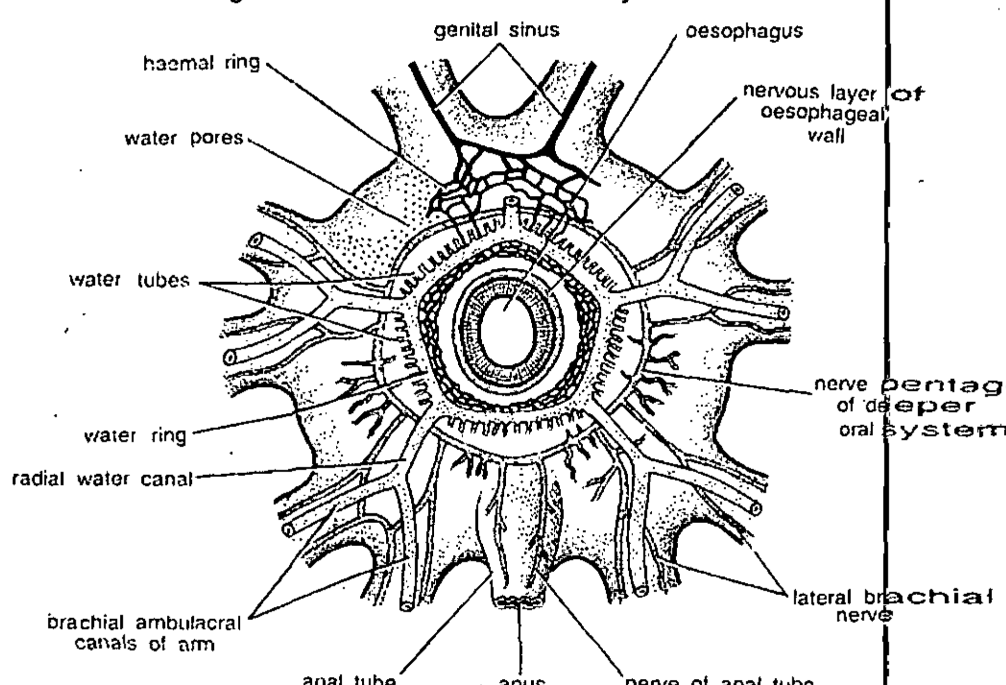



Fig. 19. *Antedon*. Water-vascular and nervous system (diagrammatic).

**lateral canals** to the bases of **ampullae**. Suckers of podia in sea urchins highly developed.

### [IV] Holothuroidea

They have water-vascular system like that of other echinoderms but **madreporite** is peculiar. Neither it is connected with the body surface nor it is attached in the coelom. It hangs just below the base of the pharynx and is connected to the **water ring** by a short **stone canal**. Pores and **pore canals** still persist in madreporite but in place of sea water, coelomic fluid circulates in it.

. Water ring encircling the base of the pharynx gives rise to elongated **polian vesicles** which hang into the coelom. Their number may be one in **cucumaria**, 3 or 4 in **thyone**, or 10 or 11 in certain Apoda. Five **radial canals** arise from water ring and pass upward to the inner side of the calcareous ring and then outward through a notch at the end of each radial plate. Before leaving the calcareous ring, each radial canal gives off smaller branches to the buccal tentacles. After leaving the ring, radial canals pass posteriorly within the body wall all along the length of ambulacral groove where they supply the **podia. Ampullae** are found on both podia and tentacles.

In Apoda, which lack podia, water-vascular system is confined to oral water ring, polian vesicles and buccal tentacles.

### [V] Crinoidea

Crinoids lack **madreporite.** Water-vascular system is restricted to a **ring canal,** 5 **radial canals** and the **podia.** Pentagonal ring canal encircles the mouth and gives off at each inter radius, a large number (30-50) of short **stone canals**, that open into coelom. Each radial canal extends into each arm, underneath the ambulacral groove and bifurcates with the arm and gives off alternate branches into pinnules and **podia. Ampullae** absent. Peculiar for crinoids is the presence of 500 to 1500 minute ciliated funnel like canals perforating the wall of tegmen to open into coelomic cavity, called as **ciliated funnels.** These perforations or openings compensate for the absence of a madreporite by permitting sea water to enter the coelom and maintain i proper fluid pressure in the body and the water-vascular system.

## • LARVAL FORMS IN ECHINODERMATA

No other group of animals has such complicated metamorphosis in the course of development. Development may be direct or indirect. In direct one, the larval stages are missing while in indirect one, various types of free-swimming larvae are formed. In each class, a few members, are viviparous, that is, they brood their young in a sort of brood pouch on the surface of their body. The development of larva takes place in a typical deuterostomous fashion. In most cases the characteristic free swimming larvae develop externally which are of great phylogenetic significance.

Echinoderm larva is strikingly bilaterally symmetrical in marked contrast to radially symmetrical adult. It swims about by means of a ciliated band, which may be complicated by a number of short or long slender projection or arms from the body wall. Based upon the nature and position of the arms or their absence, larvae of different classes of Echinodermata may be distinguished. After a free-swimming planktonic existence, the bilateral larv undergoes a metamorphosis, in which the radial symmetry of the adult i developed. In different classes of echinoderms, different types of larva complete the development.

### (1) Class I. Asteroidea

#### Bipinnaria Larva

Two types of development occurs in asteroids. The **direct** type has larg yolky eggs and no free swimming larval stage. The **indirect** type ha homolecithal eggs with little yolk and a free swimming larval stage. Afte hatching the larva develops cilia and begins a free-swimming life. The larv feeds on diatoms as an alimentary canal is formed. The presence of powerfu

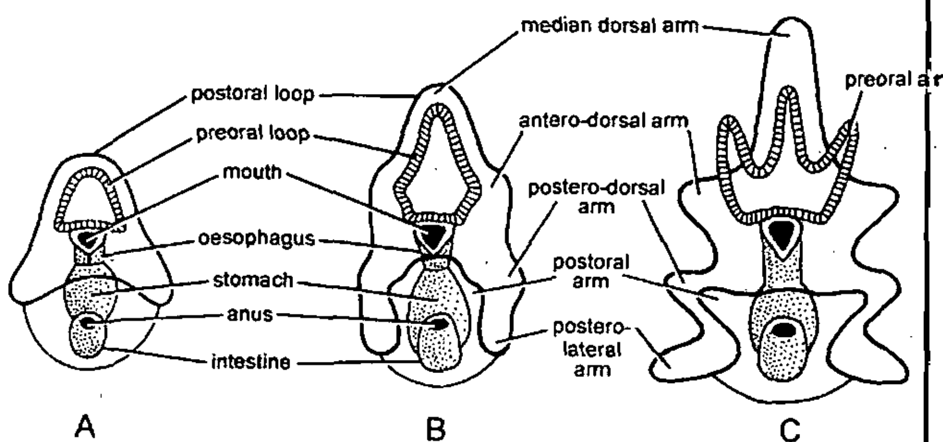



**Fig. 20. Stages in development of a bipianaria larva.**

ciliary band on the stomodaeal walls helps in feeding. Two lateral longitudin locomotory ciliated bands develop which connect infront of mouth, forming **preoral loop** and in front of the anus, to form a **preanal loop**. Preoral loc later, separates or in some cases develops independently into an anteric ciliated ring around the body. Three lateral lobes or projections are als developed on each side of the body bordered by ciliary bands. This larva known as **bipinnaria** and develops in 2 to 7 days.

**Internal development of bipinnaria.** Tip of larval archenteron forms th mesenchyme and later gives rise to two lateral pouches which conne arteriorly to form a U-shaped coelom. Posterior ends of the lateral pouche pinch off to form right and left **somateocoels**. Remaining anterior portic represents the **hydrocoel** and **axocoel**, but they never separate. Le hydrocoel connects with the dorsal surface to form the **hydropore,** withou ectodermal invagination. Ventrally an ectodermal invagination meets th archenteron and the larval gut is differentiated into mouth, oesophagu stomach and intestine. Blastopore remains as larval anus. Right somatoco and axohydrocoel get reduced in metamorphosis, while left axohydrocoel give rise to water ring and radial canals. Axocoel separates from hydrocoel ar contributes to stonecanal. Madreporite or dorsal sac originates either fro rearrangement of mesenchyme cells or from ectodermal invagination or fro

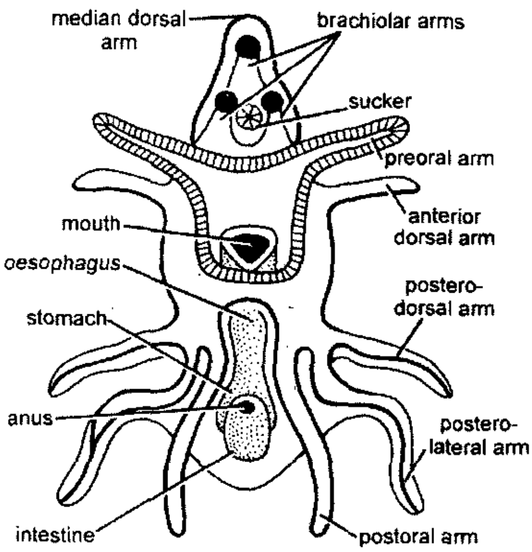



**Fig. 21. Brachiolaria larva.**

right axohydrocoel. Bipinnaria larva, after free-swimming existence for a few weeks, changes to next larval stage, called **brachiolaria larva**.

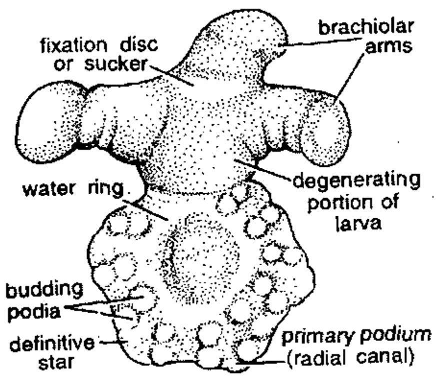



**Fig. 22. Metamorphosis of brachiolarki in sea star, Leptasterias hexactis.**

## Brachiolaria Larva

Bipinnaria transforms into brachiolaria larva which develops three short arms at preoral lobe, known as **brachiolar arms** (one median and two lateral arms). They contain coelomic extensions and adhesive cells at their tips. An adhesive glandular area at their base acts as a sucker. Appearance of the sucker marks the beginning of metamorphosis.

**Metamorphosis of brachiolaria.** With the help of adhesive structures it attaches to some object. Anterior region acts as stalk for sometime, while posterior part, having gut and coelomic chambers, converts into a young star. This star detaches itself and starts leading a free life.

Some species cut short the development as a result of deletion of some larval stages. In *Astropecten*, the brachiolaria stage is missed with the result bipinnaria directly metamorphoses into adult with in 2-3 months. In *Asterina gibbosa*, bipinnaria stage is omitted, larva develops an adhesive apparatus, as brachiolar arms and sucker, and undergoes metamorphosis. Still in *Luidia*, a giant and peculiar is formed which is called as **bipinnaria asterigeara**.

## (2) Class II. Ophiuroidea

### Ophiopluteus Larva

Piuteus is the free swimming larva in brittle stars which is known a ophiopluteus. It is similar to echinopluteus of echinoids with the only differenc that the former has fewer arms than the later. The posterolateral arms are th longest and directed forward. After gastrulation the arms develop graduall Posterolateral arms are formed first. After 4, 10 and 18 days, anterolatera

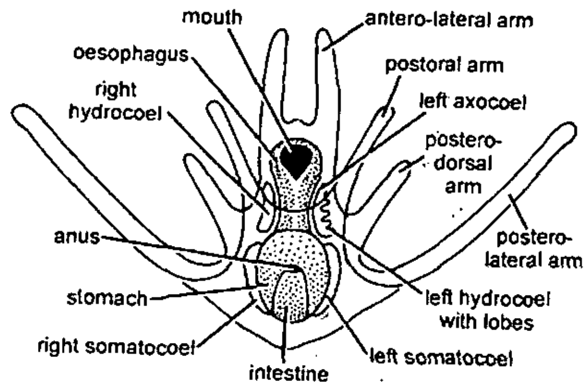



Fig. 23. Ophiopluteus larva of *Ophiocomina*.

postoral and posterodorsal arms develop, respectively. Ciliated banc accompany the arms edges. Internally the larva contains coelomic chamber and archenteron. Internal development proceeds in the same way as in oth classes. While free swimming metamorphosis of the larva starts, there being r attachment stage. Tiny serpent star sinks to the bottom to begin its adu existence.

*Amphiura vivipara,* a viviparous form, omits pluteus stage. In *Ophionotu hexactis*, development takes place in ovary and the aborted pluteus larva devoid of arms and anus.

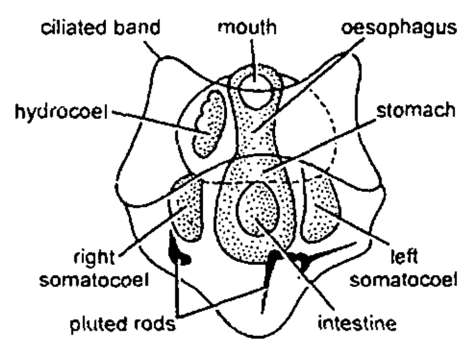



Fig. 24. Aborted pluteus of *Ophionotus hexactis*.

## (3) Class III. Echinoidea

### Echinopluteus Larva

Larva is formed after gastrulation. Gastrula becomes conical, one side which flattens to form the oral surface. Stomodaeal invagination communicate with archenteron and the gut is differentiated into mouth, oesophagu stomach and intestine. Blastopore remains as larval anus. Larva begins to for projections which develop into arms. There are six arms namely, preora

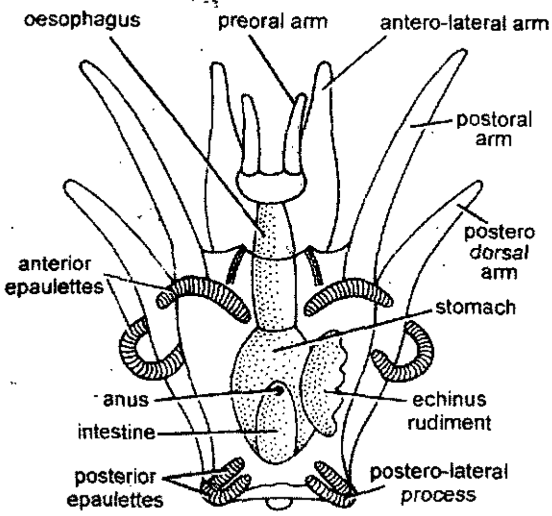



**Fig. 25. Echinopluteiis larva of *Strongylocentrotus franciscatius.***

anterolateral, anterodorsal, postoral, postero-dorsal and posterolateral. Posterolateral arms are very short and directed outwards or backwards. In some cases, anterodorsal arms may also not develop. Thus a fully developed echinopluteus may have 5 or even 4 pairs of arms instead of usual six. Tips of the arms are pigmented and are supported by calcareous skeletal rods. Locomotion is by ciliated bands, which in some case become thickened and known as **epaulettes.** In *Arbacia* and *Cidaris,* larva develops special ciliated lobes, between the arm bases known as vibratile lobes, auricular lobes or auricles.

**Internal development.** Archenteron gives off hydro-enterocoels which contribute to axocoels, hydrocoels and somatocoels. A vestibule is formed by the enlargement of an ectodermal invagination on the left side. Hydrocoel and vestibule form the oral side of the adult. Five radial arms and five primary podia are given off by the hydrocoel. Lantern is formed from left somatocoel. Echinopluteus is microscopic, free swimming in water and it develops within 7 to 30 days.

Metamorphosis is extremely rapid, taking place in about an hour. There is no attachment stage in echinoids.

### (4) Class IV. Holothuroidea

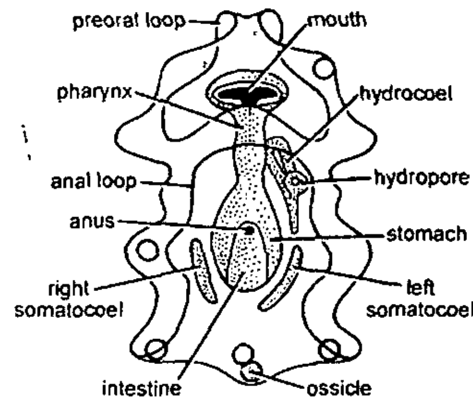
### Auricularia Larva

After gastrulation and formation of coelomic sacs and gut, the embryo becomes a free-swimming larva called **auricularia larva,** within 3 days. It is transparent, pelagic about 0.5 to 1 mm in length. It swims about by a ciliated band which forms **preoral loop** and an **anal loop**.

Internally, larva has a curved gut with sacciform stomach, hydrocoel and right and left somatocoels.

Some giant auricularians of unknown adults reported from Bermuda, Japan and Canary islands measure about 15 mm in length and possess a frilly flagellated band.

It is a transitional stage from auricularia and appears barrel-shaoed an alike doliolaria of crinoids. Continuous ciliated band breaks in 3 to 5 flagellate rings. Mouth is shifted to anterior and anus to posterior pole.




**Fig, 26. Auricularia larva.**

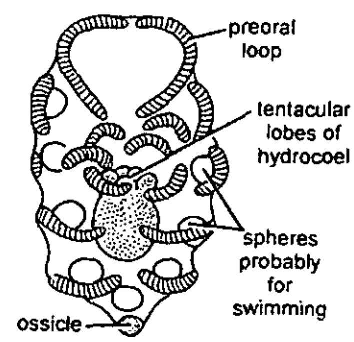



**Fig. 27. Transitional stage from auricularia to doliolaria.**

Metamorphosis is gradual during which it acquires 5 tentacles and 1 to functional podia. As such it is sometimes known as 'pentactula'. Afte appearence of more podia and tentacles, sea cucumber settles to the sea bottor and leads an adult mode of life.

Other forms of this class show marked peculiarities in larval developmen In Cucumaria planci and *C. quinquesemita,* etc., there is no auricularia stag and embryo directly develops into **doliolaria** larva. In others like *C, saxiola, C frondosa,* both of these, larval stages are omitted and the larva only swim about having an oval ciliated shape. In *Holothuria floridana,* embryo hatche directly into a young.

### (5) Class V. Crinoidea

#### Doliolaria Larva

It hatches as a free-swimming larva. Body has 4 to 5 ciliated bands with a apical sensory plate at the anterior end provided with a bunch of cilia. There : an adhesive pit over the first ciliated band, near the apical plate in the mi ventral line. Between second and third ciliated band lies the stomodaeum c vestibule. Skeleton also develops at this larval stage. After the differentiatio into prospective organs, larva attaches itself and internal organs rotate at a angle of 90 degrees from ventral to posterior position. Larva forms a stalk and :

now referred as **cystidean** or **pentacrinoid** larva which after sometime metamorphoses into adult.

### (6) Significance of Echinoderm Larvae

It is seen that different classes of echinoderras have somewhat different larvae which are differently named. Alter their study, following significant points can be drawn.

**1. Common origin of classes.** Except the larva of crinoidea which becomes sedentary, the larvae of rest of the classes have some fundamental

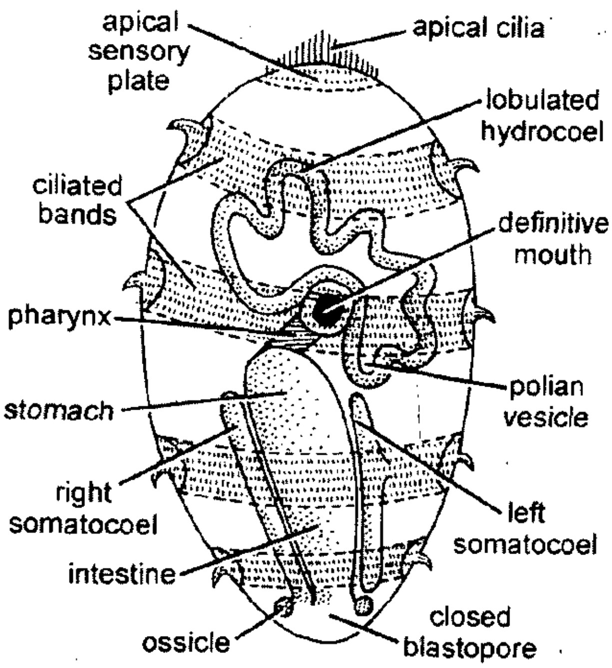



**Fig. 28. Mature doliolaria larva of *Leptosynapta inhaerens*.**

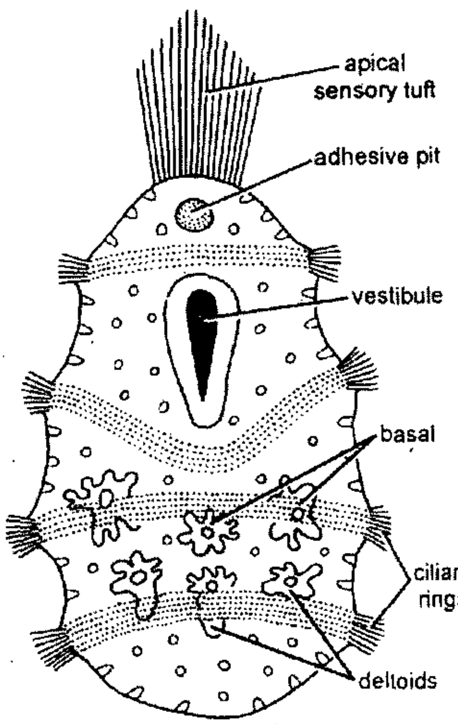



**Fig. 29. Doliolaria of *Anteihn bifida*.**

resemblances. They are constructed on the same general fundamental plan with bilateral symmetry. They have somewhat flattened body, longitudinally looped ciliated bands, gut and enterocoelic coelom. With so many common characters, one may conclude the origin of their respective classes (groups) from a common ancestor which was a coelomate, bilateral and free-swimming. Dipleurula and pentactula larva are two such hypothetical ancestors suggested by zoologists. It is believed that all modern echinoderms have originated from them.

2. **Taxonomic affinities.** Closely looking at the classification of the phylum, it is seen that the larval similarities do not indicate taxonomic affinities. Among **Eleutherozoa**, two well marked larval forms occur : (i) **Pluteus group** is common to ophiuroids and echinoids, bilaterally symmetrical with long arms, (ii) **Auricularia group**, is common to asteroids and holothurians has a winding ciliated band which may be produced into lobes. On the basis of larval similarities ophiuroids should be placed near to echinoids and asteroids near to holothurians. But this is not in agreement with the palaeontological and morphological result, according to which asteroids and ophiuroids are closely related to each other while echinoids seem to have followed an entirely independent evolution.

3. **Phylogenetic affinities.** A survey of larval types throughout echinoderms indicates several examples of close larval resemblances *e.g.*, ophiopluteus and echinopluteus. This must be due to **convergent larval evolution.** Occurrence of convergence in development is seen among unrelated groups such as Asteroidea, Holothuroidea and Crinoidea. Similarly, larva of closely related forms such as asteroids and ophiuroid, exhibit major differences which must be due to **divergent larval evolution**. Occurrence of divergent type of development is seen within related groups (ophiuroidea). Therefore, the larval structures in echinoderms, cannot serve the purpose of determining the phylogenetic affinities in the phylum.

4. **Relationship with Chordates.** Auricularia larva of Echinodermata and Tornaria larva of some enteropneusts (*e.g., Balanoglossus*) shows very close and striking similarities. Moreover, cleavage is indeterminate and mesoderm and coelom (enterocoel) have similar origin in echinoderms and lower chordates. Serology also indicates a relationship between the two groups. In view of all this and other evidences, echinoderms and chordates have been regarded as phylogenetically related groups.

5. **Aid in dispersal and feeding**. Since the adult echinoderms are somewhat sluggish, their larvae are the main dispersive phase for them. They remain in plankton for sufficient time to be swept from the place of their birth to new areas, or to restock the original areas. In addition to their dispersive function, larvae will aid the species in feeding from a different source from their adults, and thus when food is short larvae and adult will not compete.

B.Sc. ZBC-105

सर्वे भवन्तु सुखिनः सर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तु मा कश्चिद् दुःख भाग्भवेत् ।

# DIRECTORATE OF DISTANCE EDUCATION


Swami Vivekanand

**SUBHARTI UNIVERSITY**

Subhartipuram, NH-58, Delhi-Haridwar Bypass Road,
Meerut, Uttar Pradesh 250005
Phone : 0121-243 9043
Website : www.subhartidde.com, E-mail : ddesvsu@gmail.com