BIOLOGY OF INVERTEBRATE AND CELL BIOLOGY

(DSZ0011)

(BSC ZOOGOLY-I)

ACHARYA NAGARJUNA UNIVERSITY

CENTRE FOR DISTANCE EDUCATION

NAGARJUNA NAGAR,

GUNTUR

ANDHRA PRADESH

Lesson 1.1

Phylum : PROTOZOA GENERAL CHARACTERS AND CLASSIFICATION

CONTENTS

1.1.2 INTRODUCTION

Protozoa includes the simplest and most primitive animals. The name Protozoa was coined by Goldfuss (1820) who used the name simply for lower groups of Zoophyta. In 1845, Von Siebold established the unicellular nature of the protozoa. Protozoans are usually microscopic and not visible to the naked eyes. They are found in fresh-water, salt-water and damp soil, while some are parasitic, symbiotic and commensals. They are usually called acellular or non-cellular organisms i.e. the body of the individual is not subdivided into cells. The parts of the body are called organells in contrast to the organs of Metazoa. The size varies from 2 microns to 250 microns (one micron (μ)=1/1000mm). Plasmodium, Leishmania and Babesia are the smallest protozoans known so far. Protozoans like Amoeba, Paramecium, Pelomyxa can be seen with our naked eyes. Prospora gigantea, a sporozoan grows to about 16mm long. There are about 50,000 species of protozoans.

1.1.3 GENERAL CHARACTERS

1. Protozoans are believed to have been originated in Archaezoic, Precambrian period.
2. Protozoans are minute, microscopic, a cellular (non-cellular) animals inhabiting fresh, marine waters and damp places. Parasitic protozoa live over or inside bodies of animals and plants.
3. The shape is spherical, oval, elongated, irregular, bell-like, spindle shaped or slipper-like.
4. The symmetry is also variable. It may be radial, bilateral or irregular.
5. Body is covered by plasma membrane or pellicle. Some protozoans have an exoskeleton made up of $CaCO_3$ or silica.
6. The single cell performs all the life activities just like the body of an animal. There is no division of labour.
7. Protozoans are solitary or colonial. In colonial forms, the individuals are alike and independent.
8. Locomotory organells are pseudopodia, flagellae, cilia or none.
9. Nutrition is holozoic (animal-like), holophytic (plant-like) saprozoic or parasitic. Digestion takes place inside the food vacuole.
10. Respiration takes place by simple diffusion through the body surface.
11. Excretion through general body surface or through contractile vacuoles which serve mainly for osmo-regulation. But in some forms, excretion takes place through a temporary opening in the ectoplasm or through a permanent pore called cytopyge.
12. Some forms possess sensory organells in the form of pigment spot.
13. Asexual reproduction is by budding or multiple fission or binary fission and sexual reproduction is by conjugation.
14. Life history is often complicated with alternation of asexual and sexual generations (digenesis).
15. Life history may pass through various phases like amoeboid, flagellate, ciliate and encystment.
16. Generally, encystment occurs to tide-over unfavourable environmental conditions or for dispersal.

1.1.4 CLASSIFICATION

The classification followed here is based on Hyman's Vol. I i.e., "Protozoa through Ctenophora". There is much controversy regarding the classification of protozoa because of various groups of uncertain relationship.

The Phylum Protozoa is grouped into two sub-phyla — 1. Plasmodroma, and 2. Ciliophora.

Sub-phylum 1 : PLASMODROMA

These are more primitive organisms with locomotor organells like pseudopodia, flagella or none. They possess single nucleus or many nuclei of same kind. Asexual reproduction is by binary or multiple fission. Sexual reproduction takes place by syngamy i.e. fusion of gametes.

The sub-phylum Plasmodroma is divided into four classes — 1. Sarcodina, 2. Mastigophora, 3. Opalinata, and 4. Sporozoa.

Class 1 : SARCODINA

1. The organells of locomotion are lobopodia or filopodia or axopodia.
2. Body naked or with a hard internal shell or external test.
3. Cytoplasm usually marked into ectoplasm and endoplasm.
4. Most of them are free-living but some are parasitic.
5. No spore-formation, no conjugation.

The class Sarcodina is divided into two sub-classes 1. Rhizopoda and 2. Actinopoda.

Sub-class 1 : Rhizopoda

1. Locomotion by pseudopodia or filopodia but never axopodia.
2. They are generally creeping forms.

The sub-class Rhizopoda is divided into five orders.

Order 1. Lobosa

1. Body amoeboid, naked, without skeleton.
2. Presence of lobopodia
3. Generally encystment occurs.

e.g.: *Amoeba, Pelomyxa*

Order 2. Testacea

1. Body consists of a single-chambered shell made up of $CaCO_3$ or silica.
2. Mostly fresh water forms.
3. Pseudopodia are extruded through a definite aperture.

e.g.: *Arcella, Difflugia*.

Order 3. Filosa (Gromina)

1. They possess branching filopodia.
2. Fresh water or marine
3. Body naked or in a shell with definite aperture.

e.g.: *Euglypla, Gromia*

Order 4. Foraminifera

1. Pseudopodia are branched reticulopodia forming a net-work.
2. Possess a test with one to many chambers.
3. Reproduction with an alternation of sexual and asexual generations.
4. Gametes usually flagellate. e.g.: *Polystomella, Allogromia*

Order 5. Mycetozoa

1. Body large, amoeboid, forming a multinucleate plasmodium
2. Life cycle complex and has sexual reproduction.
3. Usually sporangia are formed which liberate spores.
4. Nutrition is phagocytic.

e.g.: *Plasmodiophora, Didymium*

Sub-class 2 : Actinopoda

1. Their organelles of locomotion are delicate axopodia with axial filaments radiating from a spherical body.
2. Cytoplasm with inner and outer zones.
3. Test is present or absent.
4. Gametes are usually flagellated.
5. Reproduction is both sexual and asexual.

The sub-class Actinopoda is divided into 4 orders.

Order 1. Heliozoa (helios, sun)

1. Body spherical, naked or with a test.
2. Generally called sun animalcules.
3. Mostly fresh water forms, some marine.
4. Axopodia fine, stiff, radiating unbranched with an axial filament.

e.g.: *Actinophrys, Actinosphaerium*.

Order 2. Radiolaria

1. Exclusively marine organisms.
2. Axopodia without conspicuous axial filaments.
3. Skeleton made up of siliceous spicules.

e.g.: *Actinomma, Thallassicola*

Order 3. Acantharia

1. Marine forms.
2. Skeleton with radiating spines made up of strontium sulphate.
3. Axopodia

e.g.: *Acanthometra*

Order 4. Proteomyxa

1. Largely marine and fresh water parasites of algae and higher plants.
2. Filopodia and reticulopodia in some species.
3. Often with flagellate stages in life-history.
   e.g.: *Pseudospore, Vampyrella*.

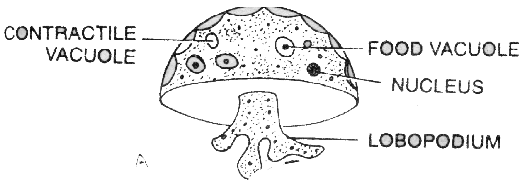
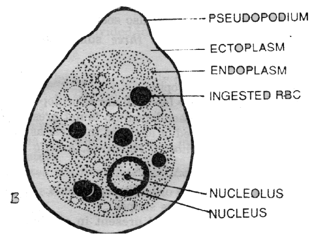
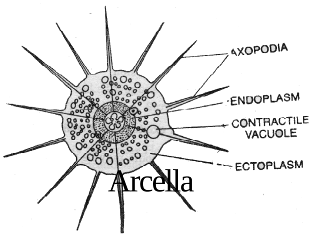


Fig. 1

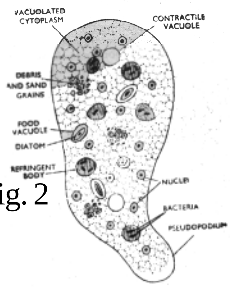


Entamoeba



Arcella

Fig. 2



Actinospherium

Polymyxa

Class 2 : MASTIGOPHORA (Flagellata)

1. Primitive and minute protozoa with much diversity in their form structure and habits.
2. Body is covered by a thin pellicle or test of cellulose, chitin or silica.
3. One or more whip-like flagella present for locomotion and food-capture.
4. Nutrition may be autotrophic, heterotrophic or mixotrophic.
5. Reproduction is asexual by longitudinal binary fission.

Fig. 3

Fig. 4

The class Mastigophora is divided into two sub-classes — 1. *Phytomastigina* 2. *Zoomastigina*.

Sub-class 1. Phytomastigina

1. These are plant-like flagellates.
2. Mostly free living; few are parasites.
3. Nutrition is holophytic or plant-like.
4. Flagella rarely more than two.

The sub-class Phytomastigina is divided into six orders.

Order 1. Chrysomonadina

1. Small flagellates with yellow or brown chromatophores.
2. Solitary or colonial, often amoeboid.
3. Flagella from one to three.
4. Nutrition is holophytic, sometimes saprophytic or holozoic.

e.g.: *Chrysamoeba, Synura*

Order 2. Cryptomonodina

1. They have green, yellow, brown or colourless chromatophores which form starch.
2. They have two flagella of unequal size.
3. They possess a gullet.

e.g.: *Cryptomonas, Chilomonas*.

Order 3. Englenoidina

1. Presence of one or two flagella arising from gullet.
2. Presence of thick pellicle.
3. Chromatophores are green or colourless.
4. Nutrition holophytic, saprophytic or holozoic.
5. Contractile vacuole and stigma are present anteriorly.

e.g.: *Euglena, Peranema*

Order 4. Phytomonadina (Volvocida)

1. Body is covered with cellulose.
2. Solitary or colonial
3. Gullet is absent.

e.g.: *Volvox, Chlamydomonas*.

Order 5. Chloromonadina

1. Presence of green chromatophores.
2. Nutrition holophytic or saprophytic.
3. Stigma is absent.

e.g.: *Goniostomum, Coelomonas*.

Order 6. Dinoflagellata

1. There are two flagella, one lying transversely and the other pointing backwards.
2. Body covered with thick pellicle or cellulose divided into plates.
3. Chromatophores numerous and variously coloured or absent.
4. Some are phosphorescent.

e.g.: *Noctiluca, Ceratium*

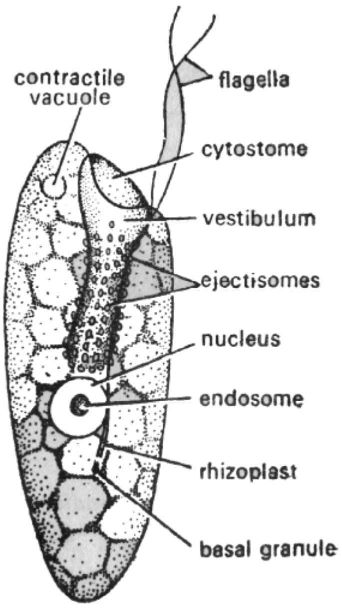


Fig. 5 Chillomonas

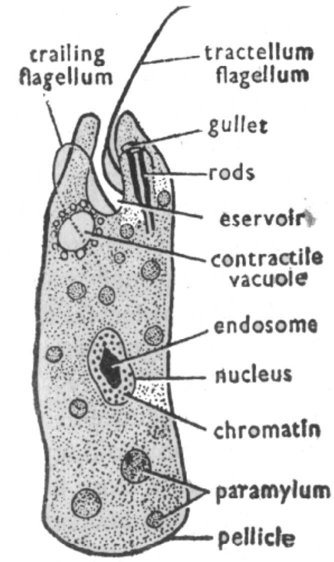


Fig. 6 Peranema

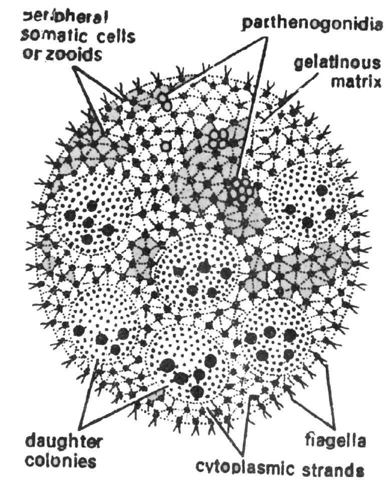


Fig. 7 Volvox

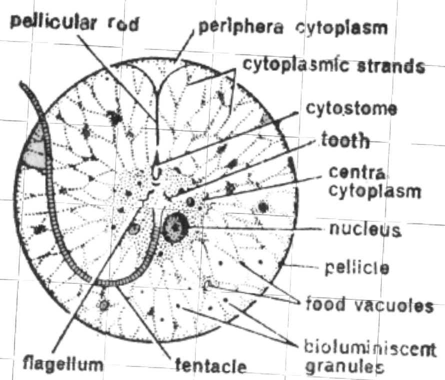


Fig. 8 Noctilluca

Sub-class 2 : ZOOMASTIGINA

1. They possess no chromatophores.
2. Presence of one to many flagella.
3. Nutrition is holozoic, saprozoic or parasitic.
4. Most of them are parasitic.

This sub-class Zoomastigina is also divided into six orders.

Order 1. Rhizomastigina

1. They have pesudopodia and one to four flagella.
2. Free living or parasitic.
3. Amoeboid forms which connect Sarcodina and Mastigophora.

e.g.: *Mastigamoeba*, *Histomonas*

Order 2. Choanoflagellina

1. Solitary or colonial flagellates.
2. Free-living in fresh or salt water.

e.g.: *Proterospongia*

Order 3. Protomonadina
1. There are one to four flagella.
2. Free living or parasitic.
3. Nutrition holozoic or saprozoic.

e.g.: *Trypanosoma, Leishmania*

Order 4. Diplomonadina
1. These are binucleate flagellates having bilateral symmetry.
2. Flagella 4 pairs.
3. Mostly parasitic.

e.g.: *Giardia, Hexamita*

Order 5. Trichomonadina
1. These are parasitic flagellates.
2. Nuclei one to many.
3. Cytostome usually present.

e.g.: *Trichomonas, Devescovina*

Order 6. Hypermastigina
1. Parasitic flagellates.
2. Highly specialized flagellates.
3. Symbionts of wood eating insects.

ı, Lophomonas

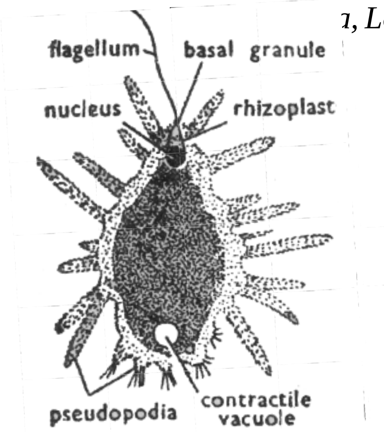


Fig. 9 Mastigamoeba

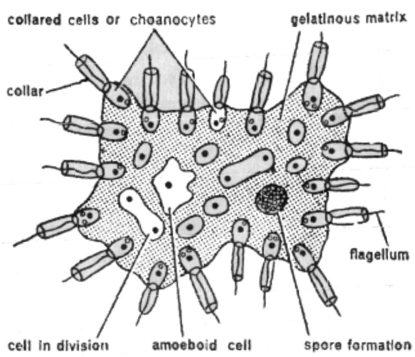


Fig. 10 Proterospongia

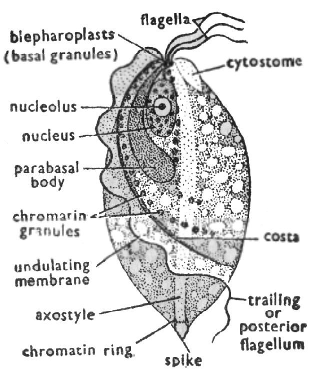


Fig. 11 Trichomonas

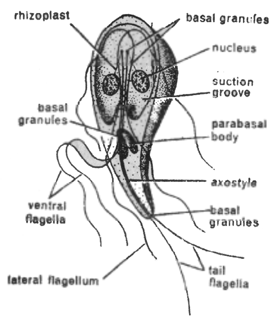


Fig. 12 Giardia

Class 3 : OPALINATA

1. The shape of the body is definite and is enclosed by a firm pellicle.
2. The organells of locomotion are cilia-like flagella which are arranged in longitudinal oblique rows.
3. Cytostome is absent and nutrition is sporozoic.
4. Contractile vacuoles absent.
5. Nuclei 2 to many, monomorphic.
6. Sexual reproduction takes place by the fusion of flagellated anisogametes.
7. Harmless parasites in the rectum of frogs and toads.

These were formerly known as primitive ciliates and were called protociliata.

The class Opalinata includes a single order Opalinida with the same characters of the class Opalinata.

Order: Opalinida – e.g.: *Opalina, Protoopalina*

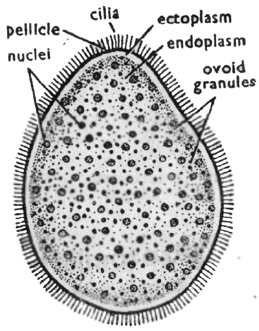


Fig. 13 Opalina

Class 4 : SPOROZOA

1. Organells for locomotion and feeding are absent.
2. Nutrition is mainly sporozoic.
3. Nucleus is of the single type.
4. Syngamy takes place after which many spores are formed.
5. Exclusively endoparasites.

The class sporozoa is divided into four sub-classess — 1. Telosporidia, 2. Piroplasmea, 3. Cnidosporidia, and 4. Acnidosporidia

Sub-class 1 : Telosporidia

1. Presence of single nucleus in adults.
2. The spores contain many sporozoites, but lack polar capsules and polar filaments.
3. Spore formation ends the life-cycle.

This sub-class consists of three orders.

Order 1. Gregarinida

1. They lead parasitic life in digestive tract and body cavity of invertebrates.
2. Mature trophozoites large, worm-like free and motile.

e.g.: *Monocystis, Gregarina*

Order 2. Coccidia

1. Mature trophozoites are small and typically intracellular.
2. Gametocytes are dimorphic.
3. Sporozoites multiply by schizogony in tissue cells.

e.g.: *Eimeria, Isospora*

Order 3. Haemosporidia

1. Mature trophozoites are small, amoeboid and intracellular.
2. Sexual reproduction (pairing of gametes) takes place in invertebrate host.
3. Schizogony takes place in a vertebrate host.

e.g.: Plasmodium

Sub-class 2 : Piroplasmea

This includes single order

Order. Piroplasmida

1. Parasites of vertebrate erythrocytes.

e.g.: *Babesia*.

Sub-class 3 : Cnidosporidia

1. The spores have polar capsules containing coiled polar filaments.
2. Spores are formed through out life.
3. Trophozoites are multinuclei forms.

This sub-class is divided into four orders.

Order 1. Myxosporidia

1. Coelozoic or histozoic in fishes, amphibians and reptiles.
2. Polar capsules 1 to 6, with a coiled polar filaments.

e.g.: *Myxidium, Myxobolus*

Order 2. Actinomyxidia

1. Polar capsules 3, enclosing a polar filament each.
2. Parasites especially in Annelida

e.g.: *Triactinomyxon, Sphaeractinomyxon*

Order 3. Helicosporidia

1. No polar capsules
2. Histozoic.

e.g.: *Helicosporidium*

Order 4. Microsporidia

1. Intracellular in Arthropoda and Fishes.
2. With or without polar capsules.

e.g.: *Nosema*

Sub-class 4 : Acnidosporidia

1. Mature sporozoites have more than one nucleus.
2. Spores simple, without capsules and filaments.

This sub-class consists of two orders.

Order 1. Sarcosporidia

1. Spore cases are absent.
2. These are muscle parasites of higher vertebrates.

e.g.: *Sarcocystis*

Order 2. Haplosporidia

1. Spore cases are absent.
2. These are parasites in fishes and chiefly in annelids.

e.g.: *Ichthyosporidium, Haplosporidium*

Sub-phylum 2. CILIOPHORA

1. All possess simple ciliary organelles for locomotion.
2. Usually two types of nuclei are present.
3. Sexual reproduction by conjugation.
4. Asexual reproduction by binary fission and budding.

This sub-phylum includes a single class called ciliata.

Class - Ciliata

1. Cilia or sucking tentacles are the locomotory organells.
2. Presence of two types of nuclei (Dimorphic).
3. Holozoic nutrition.

This class ciliata is divided into 4 sub-classes. 1. Holotricha, 2. Peritricha, 3. Suctoria, and 4. Spirotricha.

Sub-class 1 : Holotricha

The sub-class Holotricha is divided into 4 orders.

Order 1. Gymnostomatida

1. Adoral cilia are absent (no oral ciliature)
2. Cytostome opens directly to outside.

e.g.: *Didinium, Coleps,*

Order 2. Trichostomatida

1. With vestibular but no buccal ciliature., e.g.: *Balantidium*

Order 3. Chonotricha

1. Vase-shaped ciliates.
2. Body cilia are absent.
3. Chiefly marine and ectocommensal on crustaceans.

e.g.: *Spirochona, Chilodochona*

Order 4. Hymenostomatida

1. Body ciliature is typically uniform.
2. Buccal ciliature consists of an undulating membrane and an adoral zone of membranells.

e.g.: *Paramoecium, Pleuronema*

Sub-class 2 : Peritricha

1. Body bell or vase-like, mostly sessile, often colonial.
2. Without body cilia.

This sub-class consists of one order only.

Order: Peritrichida - It has all the characters of the sub-class.
e.g.: *Vorticella, Trichodina*

Sub-class 3 : Suctoria

It includes only the order Suctorida.

Order. Suctorida

1. Sessile or stalked ciliates with the distal end bearing few to many tentacles.
2. No cytostome

e.g.: *Acineta, Ephelota*

Sub-class 4 : Spirotricha

1. Generally body cilia are reduced.
2. Adoral cilia lie clockwise to cytostome

This sub-class is divided into three orders.

Order 1. Heterotrichida - Body cilia if present, short and uniform.

e.g.: *Stentor*

Order 2. Oligotricha - Small ciliates with body cilia reduced or absent. e.g.: *Halteria*

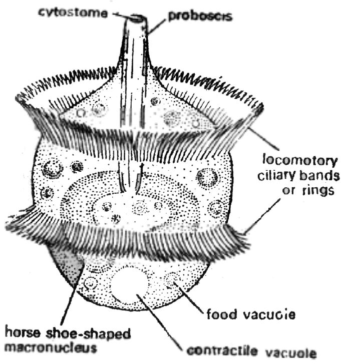


Fig. 14 Didinium

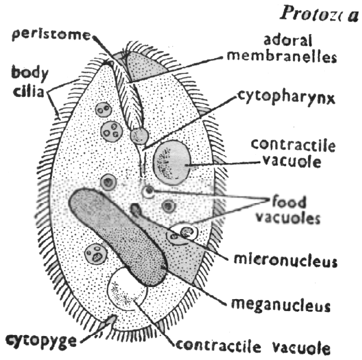


Fig. 15 Balantidium

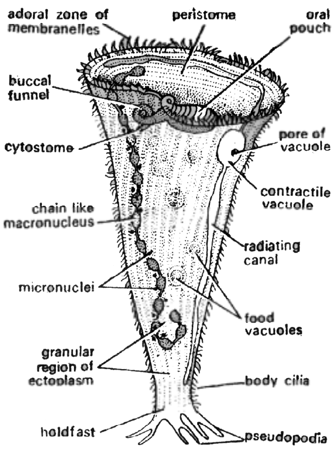


Fig. 16 Stentor

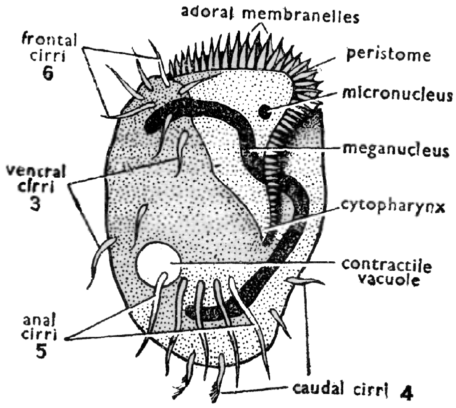


Fig. 17 Euplotes

Order 3. Hypotrichida

1. Dorso-ventrally flattened ciliates in which body cilia are fused to form cirri or tufts of cilia.
2. Adoral zone of membranells prominent.

e.g.: *Euplotes, Stylonchia*

1.1.5 SUMMARY

Protozoa are complete organisms in a single cell. The parts of the body are called organells in contrast to the organs of Metazoa. Protozoans are classified according to modes of their locomotion. Locomotion is by pseudopodia, by flagella, by cilia, by myonemes. Locomotor organells are also used for food capture. Nutrition is holophytic, holozoic, sporozoic and mixotrophic. Reproduction is asexual and sexual. Asexual reproduction is by (1) Binary fission, (2) Budding, (3) Schizogony or multiple fission, (4) Plasmotomy as in opalina etc. Sexual reproduction by conjugation, endomixis, autogamy, sporogony etc.

1.1.6 MODEL QUESTIONS

1. Give the general characters of phylum Protozoa.
2. Give the characters of class Sarcodima and classify upto orders.
3. Classify the class Mastigophora upto orders.

Write short notes on:

(a) Opalinata, (b) Telosporidia, (c) Dinoflagillate

1.1.7 KEY TERMINOLOGY

Symbiosis: It is a relationship in which there is mutual benefit between one animal called a symbiont and the other called a host. e.g. Trichonympha

Loboposia: These are broad with rounded tips and are usually composed of both ectoplasm and endoplasm.

Holozoic: Solid particles are ingested and digested as found in animals. In this method of nutrition, organisms like bacteria, algae, diatons and other protozoans are swallowed as in higher animals.

Opalina: Harmless parasite lives in the rectum of frogs and toods.

Parasite: It may be defined as an animal which "lives at the expense of another animal without giving any benefit to it".

Commensalism: It is an association in which one organism called a commensal is benefited and the other organism known as the host is neither benefitted nor harmed.

Mastigamoeba: Amoeboid forms having pseudopodia and one or two falagella. It connects Sarcodinod and Mastigophora.

Axopodia: These are stright filaments of ectoplasm and each filament is supported by a stiff central axial road.

Phytomastigina: Plant-like flagellates.

1.1.8 REFERENCE BOOKS

1. **Kotpal.**
2. **Invertebrate Zoology** by P.S. Dhani & J.K. Dhani
3. **Invertebrate Zoology** by Jordon

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1.2 POLYSTOMELLA (Elphidium)

1.2.1 OBJECTIVE

The purpose of this lesson is to know the structure and forms of Polystomella, and to understand the life cycle of it.

Classification

Phylum	- PROTOZOA
Sub-Phylum	- Plasmodroma
Class	- Sarcodina
Sub-Class	- Rhizopoda
Order	- Foraminifera
Type	- Polystomella

1.2.2 INTRODUCTION

Polystomella is the best studied foraminiferan having many-chambered shell and it also exhibits the phenomenon of dimorphism. The shell is perforated by numerous minute pores or foramina, hence the name foraminefera (pore-bearers).

1.2.3 HABIT AND HABITAT

Polystomella is a marine form found abundantly on the bottom of the ocean. It may be found in brackish waters. It is commonly found creeping about on sea weeds to a depth of 300 fathoms (one fathom = 1.8 meters).

1.2.4 STRUCTURE

The body of polystomella is covered with a hard and transluscent shall made up of Ca co_3 and small amounts of silica and magnesium sulphate. It measures 3-4 m.m in diameter. The shell is multilocular (many chambered) and perforated. The chambers of the shell originate from the initial chamber known as *Proloculum*. All the chambers communicate with one another and with the exterior by pores. The cytoplasm also becomes continuous from one chamber to another and also extends to form *reticulopodia* (pseudopodia). The anterior surface of each chamber is convex while the posterior surface is concave. The posterior concave margin of each chamber has a row of numerous minute backwardly directed, hollow, blind protoplasmic pockets called *retral processes*. The peripheral part of the shell is rigid and bears a continuous rim called *Keel* where as the central part is with a prominent rounded *umbo*. The whorls are equitant, overlapping the previous one and only the last whoral is visible from outside.

The cytoplasm is not differentiated into ectoplasm and endoplasm. However, the cytoplasm present in the chambers of the shell is called inner cytoplasm and the cytoplasm covers the shell from out side is called outer ectoplasm. The inner cytoplasm contains one or more nuclei according to the nature of the shell.

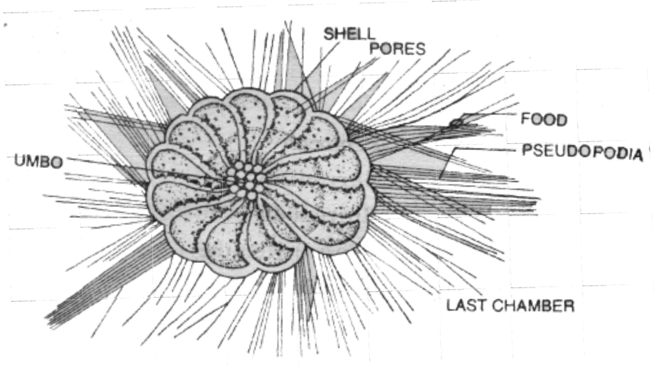

Fig. 18 Polystomella

Dimorphism: Polystomella is dimorphic and occurs in two forms i.e. microspheric and megalospheric or macrospheric.

The microspheric form has a smaller proloculum and contains several nuclei. It undergoes asexual reproduction. The macrospheric form has a larger proloculum and contains a single large nucleus. It undergoes sexual reproduction.

Differences between Microspheric and Macrospheric forms

MICROSPHERIC	MACROSPHERIC
1. Presence of small proloculum.	1. Presence of large proloculum.
2. Presence of many nuclei scattered in several chambers.	2. Single nucleus which lies in middle chamber.
3. Reproduces asexually by schizogony.	3. Sexual reproduction by isogamy.

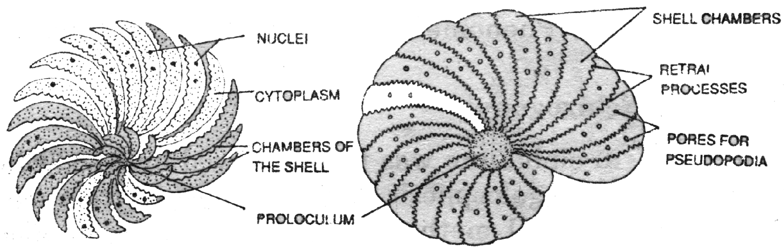

Fig.19 Dimorphic forms of Elphidium (Polystomella)

Reticulopodia: The pseudopodia of polystomella are in the form of long, slender, thread-like structures which are often branched and anastomosing. This type of pseudopodia are known as reticulopodia, rhizopodia or myxopodia. Each reticulopodium consists of the inner fibrillar axis and the outer fluid like cortex. These reticulopodia (temporary extensions of outer cytoplasm) are locomotory in function and frequently form as feeding nets.

Locomotion: Polystomella creeps slowly with the help of rhizopodia on see weeds at the bottom of the ocean. The elongated pseudopodia are fixed to the substratum by their distal ends and then contract to drag the body.

Nutrition: Nutrition is holozoic. It feeds on minute organisms like diatoms(algae), other protozoans, crustacean larvae etc. The food is trapped by the feeding nets formed by the reticulopodia. The mucous layer of the feeding nets contains proteolytic secretions which help in paralyzing the prey. The captured food enclosed in a food vacuole is drawn into the endoplasm. Digestion takes place outside the shell and the digested food passes into the inner cytoplasm.

Excretion: Nitrogenous wastes are eliminated by diffusion through the general surface of the body. The xanthosomes (pigment granules) formed during digestion will be ejected out by the retracting pseudopodia while the animal creeps.

1.2.5 REPRODUCTION AND LIFE CYCLE

Polystomella exhibits a regular alternation of generations with a remarkable sexual dimorphism. The asexual generation (schizont) is represented by microspheric form where as the sexual generation (gamont) is represented by the megalospheric form.

Asexual phase (Microspheric form): The microspheric form reproduces asexually by multiple fission to produce a number of amoebulae. During this multiple fission, the inner cytoplasmic mass containing several nuclei flows out of the shell. A small amount of cytoplasm forms around each nucleus. Thus a large number of amoebulae (agametes) are formed. The agamets now become detached from the parent shell. Each one secretes a shell around a large proloculum and becomes a young megalospheric form (young gamont).

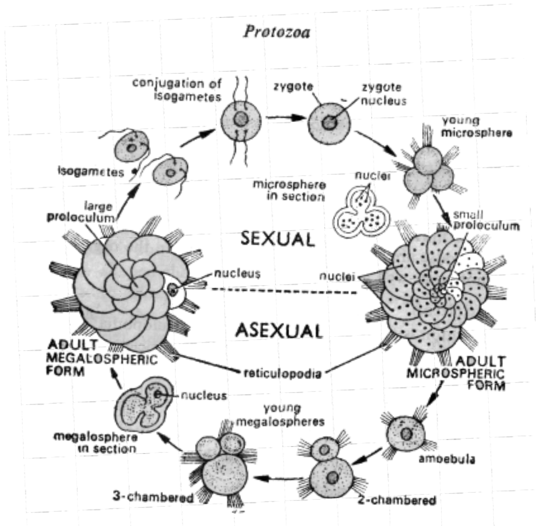

Fig.20 Life history of Elphidium

Sexual phase (Macrospheric form): The megalospheric form reproduces sexually by syngamy or conjugation. First of all, the nucleus breaks up into many daughter nuclei and each daughter nucleus becomes surrounded by a bit of cytoplasm. Thus the megalospheric forms produce large number of microscopic, biflagellate flagellulae which escape from the pores of the shell and behave as gametes. The flagellate flagellulae are haploid and known as *isogametes*. These gametes from different parents fuse (conjugate) in pairs producing zygotes. These zygotes develop into microspheric, multinucleate forms.

In brief, the microspheric form undergoes asexual reproduction to produce amoebular which develop into megalospheric forms. Then, these megalospheric forms undergo sexual reproduction to produce flagellated isogametes which fuse to develop into microspheric forms.

Thus, the life cycle of polystomella clearly exhibits the phenomenon of alternation of asexual microspheric generation with sexual megalospheric generation.

1.2.6 SUMMARY

Polystomella belongs to shell forming Protozoans i.e., Foreminifera. It lives in a multi-chambered calcareous shell with many pores. Shell is produced from ectoplasm. The chambers are spirally coiled. The pseudopodia are in the form of reticulopodia. Polystomella occurs in two forms i.e., microspheric and megalospheric. Microspheric consists of many nuclei whereas the megaspheric consists of single nucleus. Nutrition is holozoic. The life cycle shows the phenomenon of alternation of generation.

1.2.7 SELF ASSESSMENT TEST

1.Describe the structure of polystomella and bring out the differences between Microspheric and Megalospheric.
2.Give an account of alternation of generations in the life-history of Polystomella.

1.2.8 KEY TERMINOLOGY

Proloculum: In Polystomella, it is the initial chamber from which all the other chambers are originated.

Retral processes: A row of backwardly directed blind protoplasmic pockets present on the posterior concave margin of the shell of Polystomella.

Reticulopodia: There are pseudopodia with long slender, branched and freely anastomose to form a net-work composed of ectoplasm.

Keel: The peripheral part the shell forms a continuous rim-like structure.

Dimorphism: Sexual forms (Male & Female) can be easily identified from each other.

Xanthosomes: Colour granules or pigment granules.

1.2.9 REFERENCE BOOKS

1. **Protozoa** – by R.L. Kotpal.
2. **Invertebrate Zoology** – By Jordan
3. **Invertebrate Zoology** - By P.S. Dhami & J.K. Dhami.

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Lesson 1.3
TRYPANOSOMA

1.1.3 OBJECTIVE

The purpose of this lesson is to learn the life history of Trypanosoma.

Classification

Phylum - PROTOZOA
Sub-Phylum - PLASMODROMA
Class - MASTIGOPHORA
Sub-Class - ZOOMASTIGINA
Order - PROTOMONADINA
e.g.: *Trypanosoma*

1.3.2 INTRODUCTION

Different species of Trypanosoma are found in central and west Africa, Nigeria, Congo and central America. The genus Trypanosoma leads parasitic life in the blood of most of the vertebrates like fishes, amphibians, reptiles, birds and mammals. Of all the species of Trypanosoma, only three species are pathogenic in man, viz., *Trypanosoma gambiense, T. rhodesiense* and *T. cruzi*. Forde (1901) first observed this pathogenic parasite in the blood of man.

1.3.3 LIFE CYCLE

Trypanosoma gambiense causes a deadly disease known as “sleeping sickness” in Africa. T. gambiense is digenetic i.e. it completes life cycle in two hosts. The primary host (definitive host) is man and the intermediate host is the blood sucking insect called tse-tse fly (Glossina palpalis). The mammals like antelops, buffaloes, pigs etc, often act as natural reservoir hosts harbouring the parasite.

Life Cycle in man

The Trypanosomes (Metacyclic forms) are injected into the blood of man by an infected tse-tse fly while it sucks his blood. The saliva of tse-tse fly prevents the clotting of blood. The trypanosomes which start infection in man, are the metacyclic forms devoid of free flagellum. They soon become transformed into long slender forms. These parasites multiply by longitudinal binary fission in the blood and produce three forms of individuals namely (1) long and thin forms with free flagellum (2) short and stumpy forms with reduced flagellum and (3) intermediate forms.

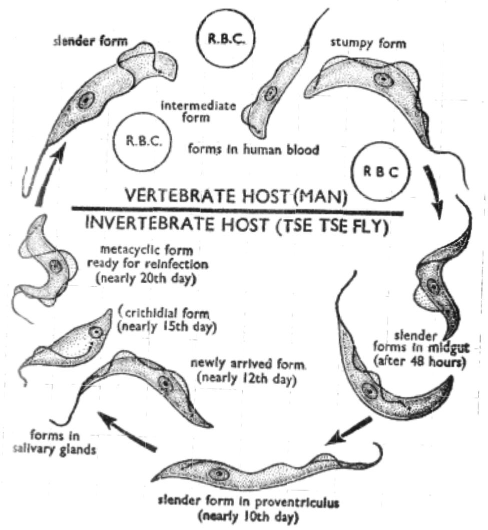

Fig.21 Trypanosoma Life History

In the process of binary fission, the parasite divides lengthwise into two parts and the division is initiated by the basal granule (blepharoplast).

While the parasites are in the blood, the infected man develops a kind of fever called “*Gambia fever*”. The victim becomes weaker and anaemic, probably because of the poisonous bye-products of the parasite. Finally, the parasites move on to the nervous system and invade cerebrospinal fluid. Then the unfortunate patient loses consciousness, enter into a lethargic condition and sleeps till death. Hence, the disease is known as “sleeping sickness” of Africa.

Life Cycle in Tse-Tse Fly (Glossina Papalis)

Transfer to tse-tse fly: When the tse-tse fly sucks the blood of infected man, a large number of Trypanosomes enter into the alimentary canal of the fly along with the blood. Only short and stumpy forms can survive in the mid-gut of the fly.

Development in mid-gut: Within the peritrophic membrane of the mid-gut (Proventriculus), the parasites multiply rapidly by binary fission for a few days and produce slender forms of diverse size. From the mid-gut, the parasites pass through the foregut into salivary glands.

Development in salivary glands: Here, the parasites rapidly multiply and develop into short and broad forms called crithidial forms. (The crithidial forms resemble the genus Crithidia in having the parabasal granules in front of the nucleus. Hence the name crithidial form).

The crithidial forms are characterized by the presence of short flagellum and small undulating membrane which do not extend in the hinder part of the body. Kinetoplast and basal granule lie above the nucleus towards the anterior end.

The short and stumpy crithidial forms multiply and produce large numbers of *metacyclic forms* which are now ready for infection. When this infected tse-tse fly bites a healthy man, the metacyclic forms enter the blood of man along with the saliva. The whole life cylce in tse-tse fly usually takes 20-30 days.

1.3.4 PATHOGENECITY (effect on the host)

The parasite causes a fatal disease called “African sleeping sickness” or “African trypanosomiasis”. When these parasites enter the cerebrospinal fluid, the victim becomes anaemic, lazy and weak. After that, the patient feels constantly sleepy and finally dies.

1.3.5 TREATMENT (Therapy)

Bayer 205 (Antrypol), Pentamidine, Lomidine, are now widely used in the early stages of infection. But aresenic and antimony compounds are used when the parasites invade the cerebro-spinal fluid. Nitrofurazone is also recommended.

1.3.6 PREVENTION (Prophylaxis)

The following measures are suggested for preventing the infection.

1. Trypanosomiasis can be prevented by eradicating the vectors.
2. The vectors can be eradicated by the destruction of their habitat.
3. Human populations from endemic areas may be isolated.

4. Preventive medicines like pentamidine injections should be given to the people to avoid the infection for about 6 months.
5. Endemic areas should be kept clean and regular spray of D.D.T. is suggested.

1.3.7 SUMMARY

Trypenosoma gambiense occurs in the blood of man of West Africa causing fatal sleeping sickness. It is polymorphic in form. It undergoes asexual reproduction by longitudinal fission in the blood of man. When the parasites are in the blood, they cause "**Gambia fever**". But when the parasites invade the cerebrospinal fluid, they cause the fatal disease called 'African Sleeping sickness". In salivary glands of tse-tse fly, the parasites multiply rapidly and develop into crithedial forms. These crithedial forms develop into metacyclic forms or inferior stages.

1.3.8 KEY TERMINOLOGY

Sleeping sickness: It is a deadly disease caused by Trypanosoma gambiense.

Metacyclic forms: These are the infective stages present in the salivary glands of tse-tse fly.

Crithidial forms: During the life-history of Trypanosoma, the parasites present in the salivary glands rapidly multiply and develop into short and stumpy crithidial forms. In these forms, Kinetoplast lies in front of the nucleus.

Gambia fever: Fever caused by Trypanosome parasites when they are in the blood of infected man.

Trypanosoma cruzi: It causes the 'Chagas' disease mostly in children of South America.

Gambia fever: It is the fever caused by the Trypamosome parasites when they are in the blood of infected man.

1.3.9 SELF ASSESSMENT TEST

1. Describe the life-cycle of Trypenosoma gambiense and add a note on various control measures.
2. Write short notes on:
   a) Sleeping sickness in Africa
   b) Life cycle in Tse-tse fly

1.3.10 REFERENCE BOOKS

1. **Protozoa** by R.L. Kotpal
2. **Invertebrate Zoology** by Jordan.

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2. PORIFERA

Lesson 2.1

PORIFERA (PORE-BEARERS) GENERAL CHARACTERS AND CLASSIFICATION

CONTENTS

2.1.1 Objective

The purpose of this lesson is to know the general characters and classification of Porifera.

2.1.2 Introduction

The morphology and physiology of sponges were first understood by R.E. Grant who created the name 'Porifera' in the year 1836. Huxley (1875) and Sollas (1884) isolated the sponges from the rest of the multicellular animals and placed them in Parazoa. So, the multicellular animals are divided into two sub-kingdoms, the Parazoa and the Metazoa. The sub-kingdom Parazoa includes all sponges under Phylum Porifera. The Phylum Porifera (L. porus = pore; ferro = to bear) or pore bearers refers to the porous body with numerous openings at the surface. The sponge body is of cellular grade of construction and is devoid of all the essential features of higher animals. The cells are loosely aggregated and they do not form into tissues. Sponges usually have an endoskeleton of separate spicules. At present nearly, 10,000 species of sponges are known.

2.1.3 General Characters

1. Sponges are the most primitive of multicellular animals.
2. All are marine except one family spongillidae which lives in fresh water.
3. Body shape is simple or vase-like or cylindrical, or highly branched.
4. They are sessile, sedentary and grow like plants.
5. Sponges are radially symmetrical or asymmetrical.
6. Body is perforated by ostia which lead internally into canals and chambers.

7. The body wall has two layers of cells, i.e., ectoderm and endoderm. Between these two layers is a gelatinous mesogloea or mesenchyme with several amoeboid cells. Therefore, sponges are said to be diploblastic. But according to some authours, sponges do not have true diploblastic nature.
8. Sponges are acoelomates without a definite body cavity.
9. The interior space of the body is known as Spongocoel which opens to the exterior by an aperture known as osculum. In the complex sponges, the body wall is much folded and the spongocoel is reduced.
10. The sponges have simple or complex type of canal systems for the passage of water currents carrying the oxygen and the food organisms.
11. Skeleton consists of spicules or spongin fibres or both.
12. There is no power of locomotion except in larval stages.
13. Mouth and digestive cavity are absent. The digestion is intracellular as in Protozoa.
14. Respiration takes place by diffusion of gases through body surface.
15. Excretion also occurs by diffusion through the body surface.
16. Sponges are the only multicellular animals without nervous system and sense organs.
17. Sponges are the only metazoans with flagellated choanocytes.
18. Asexual reproduction occurs by budding or gemmules.
19. Sexual reproduction involves the formation of ova and spermatozoa by gametogenesis.
20. Fertilization is internal.
21. Cleavage is holoblastic.
22. Two types of free swimming larvae occur among sponges for dispersal of species. They are — 1. Amphiblastula and 2. Parenchymula
23. The power of regeneration is very high and any piece of sponge is capable of growing again into a complete sponge.

2.1.4 Classification of Sponges

The classification of Porifera is based chiefly on the nature of skeleton and canal system. The Phylum is divided into three classes — 1. Calcarea 2. Hexactinellida and 3. Demospongiae.

Class 1. Calcarea

1. Skeleton composed of caleareous spicules.
2. Thy are solitary or colonial.
3. Body shape is vase-like or cylindrical.
4. They occur in shallow waters in all oceans.
5. The canal system may be Asconoid, Syconoid or Leuconoid type.
6. The choanocytes are larger in size.
7. Asexual reproduction takes place by budding.
8. Amphiblastula larva occurs in life cycle.

This class calcarea is divided into two orders.

Order 1. Homocoela (Asconosa)

1. These are the sponges with unfolded thin body wall and asconoid canal system.
2. The spongocoel is lined by flagellated cells.
3. Ectoderm consists of pinacocytes.
4. Spongocoel opens outside through osculum.
5. These are called asconoid sponges.

e.g.: Leucosolenia, *Clathrina*.

Order 2. Heterocoela (Syconosa)

1. Sponges with thick and folded body wall.
2. Flagellated cells are restricted to radial canals.
3. Spongocoel is lined by flattened endoderm cells.
4. These are called syconoid or leuconoid sponges.

e.g.: Sycon (Scypha), *Grantia*.

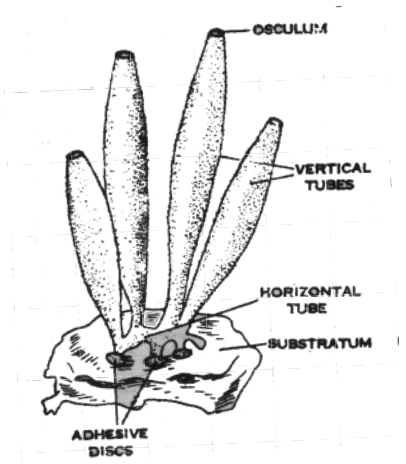

Fig.22 Leucosolenia

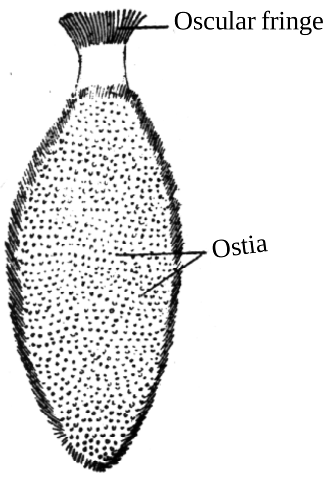

Fig.23 Grantia

Class 2. Hexactinellida (Hyalospongia) (Gr; Hyalos = glassy; sponges = sponge)

1. These are popularly known as glass sponges.
2. Skeleton is made up of siliceous spicules.
3. Spicules are triaxon with six rays (Hexactines)
4. The canal system is of eurypylous leucon type with several flagellated chambers.
5. Choanocytes are small and confined to the radial canals.
6. These sponges live in deep waters of the sea.

7. They have no power of contraction.

This class divided into two orders.

Order 1. Hexasterophora

1. Spicules are hexasters (star - like)
2. Flagellated chambers (radial canals) are simple.
3. They are not attached by root tufts but attached to a hard object.

eg. *Euplectella* (Venus Flower Basket)

Order 2. Amphidiscophora

1. Spicules are amphidiscs.
2. These sponges are attached to a substratum by root tufts.
3. Live in deep waters of Atlantic and Pacific oceans.

eg: *Hyalonema* (Glass-Rope sponge)

eg: *Pheronema*

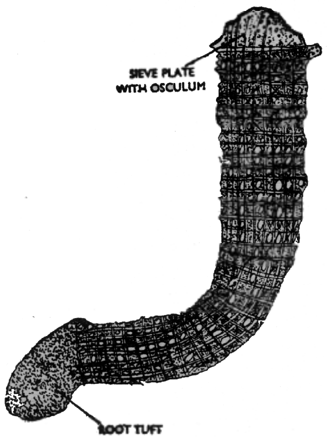

Fig.24 Euplectella

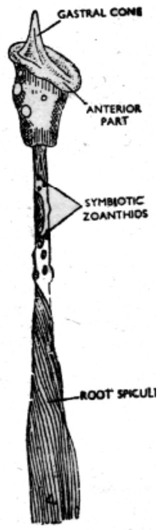

Fig.25 Hyalonema

Class 3. Demospongia

These sponges have the highest level of organisation.

Mostly marine but few are fresh water forms.

Large sized solitary or colonial sponges.

Skeleton is entirely siliceous (in siliceous sponges) or spongin fibres (in horny sponges).

Spicules are never six rayed.

Spongocoel is practically absent.

The choanocytes are small and restricted to small rounded chambers. The canal system is of leuconoid type.

They possess bright colours such as yellow, red, orange, violet, black etc.
This class is divided into three sub-classess - namely 1. Tetractinellida, 2. Monaxonida and 3. Keratosa.

Sub-class 1. Tetractinellida

1. They live shallow waters.
2. Skeleton consists of tetraxon siliceous spicules but absent in, order Myxospongia.
3. Leuconoid canal system is present.

This sub-class Tetractinellida consists of three orders.

Order 1. Myxospongia

1. These are simple sponges.
2. They grow on the bottom of the sea.
3. Skeleton is absent.
   e.g.: *Oscarella, Halisarca*.

Order 2. Carnosa

1. They have simple structure.
2. Spicules are not clearly differentiated into megascleres and microscleres.
3. Asters may be present.
   e.g.: *Plakina, Chondrilla*

Order 3. Choristida

1. Both micro and megascleres are present.
2. They possess thick cortex.

   e.g.: *Geodia, Thenea*

Sub-class 2. Monaxondia

1. Distributed throughout the world.
2. They occur in shallow and deep waters.
3. Skeleton consists of monaxon spicules.
4. Spicules are differentiated into megascleres and microscleres.
5. They occur in variety of shapes from rounded bush masses to branching types.

This sub-class Monaxonida is divided into four orders.

Order 1. Hadromerida

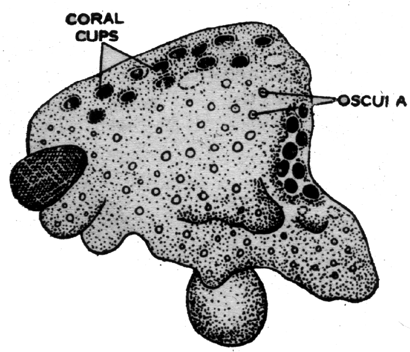

Fig.26 Cliona

1. Megascleres are present.
2. Microscleres may be present.
3. Spongin fibres are absent.
   e.g.: *Cliona, Tethya*

Order 2. Halichondrida

1. Megascleres are present.
2. Megascleres are often contain monactines or diactines.
3. Microscleres are absent.
4. Spongin fibres are present.
   e.g.: *Halichondria* (crumb of bread sponge)

Order 3. Poecilosclerida

1. Megascleric spicules are formed into net-like structures.
2. Spongin fibers give support to megascleric spicules.
3. Microscleres are typically chelas, sigmas and toxas.
   e.g.: *Cladorhiza*

Order 4. Haplosclerida

1. Diactinal monaxons are present.
2. Spongin fibres are generally present.
3. Microscleres are absent.
4. Fresh water sponges belong to this order.
   e.g.: *Chalina,* (Dead man's finger)
   e.g.: *Spongilla*

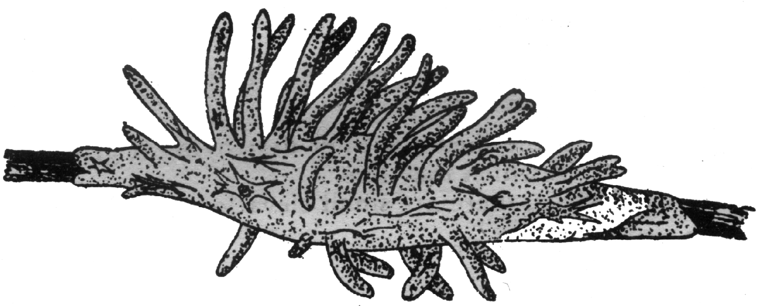
Fig.27 Spongilla

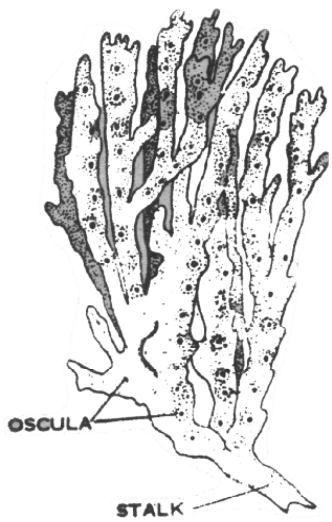

Fig.28 Chalina

Sub-class 3. Keratosa

1. These are called horny sponges.
2. They do not have spicules.
3. Skeleton consists of spongin fibres.
4. Body is rounded and massive with a number of oscula.
5. They live in shallow and worm waters.

eg: *Euspongia* (Bath sponge), *Hippospongia* (Horse sponge)

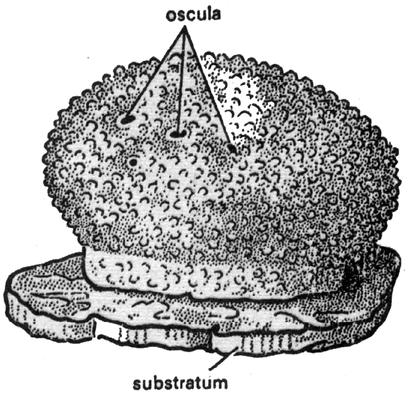

Fig.29 Euspongia

2.1.5 SUMMARY

Sponges are multicellular animals occurring in fixed forms in the sea and in fresh waters. Sponges are separate from other metazoans in having the body composed of agglomeration of cells which do not form any tissue or organ system. The classification is based on the types of spicules present in the body. The class Calcarea includes the sponges made up of calcereous spicules. The class Hexactinellida includes glass sponges and are deep forms inhabiting depths of 300 feet to over 3 miles. The class Demospongia is the largest class including the majority of existing species.

2.1.6 KEY TERMINOLOGY

Parazoa: Multicellular animals without the formation of tissues i.e. cells are loosely aggregated.

Acoelomate: Without a body cavity i.e., on animal locking a body cavity.

Diploblastic: Body wall is made up of ectoderm and endoderm.

Intercellular digestion: Digestion takes place within the cell.

Holoblastic cleavage: Cleavage in which the entire zygote divides completely.

Euplectella: Known as “Venus’s flower basket”. It belongs to class Hyalogpongia (Hexactinellida).

Keratsa: Sponges do not have spicules but possess spongin fibres. e.g. Euspongia

Amphiblastula: A larva found in the life-history of sponges.

2.1.7 SELF ASSESSMENT TEST

1. Describe the general characters of phy. porifera.
2. Classify Porifera upto the level of classes.
3. Write short notes on the following:
   (a) Demospongia (general characters)
   (b) Hyalonema and Euplectella

2.1.8 RFERENCE BOOKS

1. **Porifera** by Kotpal.
2. **Invertebrate Zoology** by Jordan.

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Lesson 2.2

CANAL SYSTEM IN SPONGES

CONTENTS

2.2.1 OBJECTIVE

The purpose of this lesson is to know the structural changes or complexity of the different types of canal systems.

2.2.2 INTRODUCTION

A system of intercommunicating cavities found in a sponge body is called canal system. The presence of canal system is an unique feature of the sponges alone because it is not found in the rest of the animal kingdom. Canal system plays an important role in the physiology of sponges. A distinguished feature of all sponges is the perforation of the body surface by numerous apertures for the ingress and egress of water current. By means of this current, most exchanges between the sponge and the external medium are effected. Mainly the canal system serves for the purposes of the Nutrition, Respiration, Excretion and Reproduction.

The canal system in sponges is of three types. 1. *Asconoid* type, 2. *Syconoid* type, and 3. *Leuconoid* type.

2.2.3 ASCONOID TYPE

This the most primitive and simplest type of canal system occurring in simple calcareous sponges such as *Olynthus* and *Leucosolenia*. In this type, the body of the sponge is radially symmetrical and vase shaped. The body wall is composed of an outer epidermis of thin flat cells or *pinacocytes* and an inner *gastral layer* of flagellated cells or *Choanocytes*. Between these two layers, there is a gelatinous mesenchyme (mesogloea) which contains several kinds of free amoeboid cells and spicules of $CaCO_3$. The body wall is perforated by numerous minute pores known as *incurrent pores* or *ostia* which extend from the external surface to the spongocoel. Each pore is intracellular, i.e., it is a canal through a tubular cell called *porocyte*. By the continuous action of flagella of choanocytes, a current of water is drawn into the spongocoel through the ostia and is passed out through the osculum. The water current in Asconoid type takes the following route:

Water from outside → ostia → spongocoel → osculum → out.

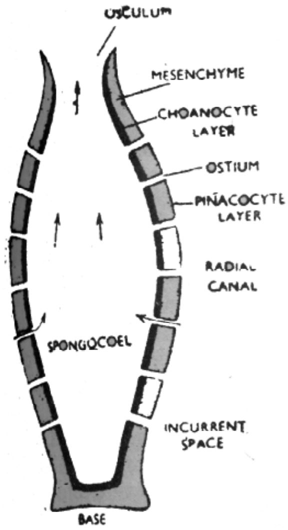

Fig.30 Asconoid type Canal System

2.2.4 SYCONOID TYPE

The syconoid type can be theoretically derived from asconoid type. This type is formed by the outpushings of the wall of an asconoid sponge at regular intervals into finger-like projections called *radial canals*. The radial canals alone are lined by choanocytes. The radial canals are free from one another without touching at any point, so that outside water surrounds their whole length. The water from outside enters into radial canals by ostia and passes into spongocoel by wide aperture, the internal ostia. So, the route followed by water current includes:

Outside water → ostia → radial canals → internal ostia → spongocoel → osculum → outside.

This type of simple Grade I syconoid canal system is seen <u>Sycetta.</u>

But in most of the sponges, the radial canals leave between them tubular spaces called incurrent canals. These incurrent canals end blindly at their inner ends. They are lined by epidermis and do not open directly into spongocoel. But they open outside by means of dermal ostia which are intercellular.

The incurrent canals open into the radial canals by numerous prosopyles. The radial canals being outpushings of the original spongocoel, are lined by choanocytes and are, therefore, better called *flagellated chambers*. The interior of the syconoid sponge is hollow and forms a large spongocoel. This spongocoel is lined by the flat epithelium derived from epidermis. The openings of the radial canals into the spongocoel are called internal ostia. So, the route of the water current in this Grade II of syconoid sponge (eg. Scypha) is :

Outside water → Dermal ostia → incurrent canals → prosopyles → radial canals → internal ostia (gastral ostia) → spongocoel → osculum → outside.

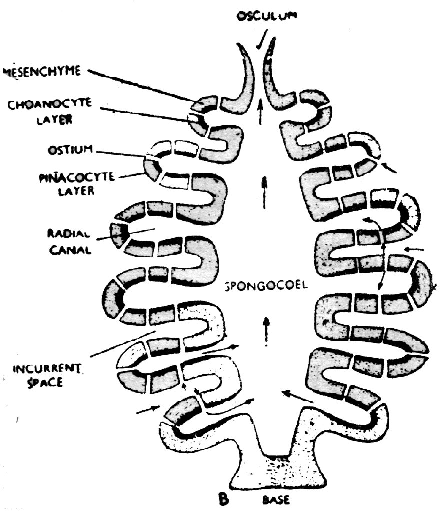

Fig.31 Grade -I Syconoid

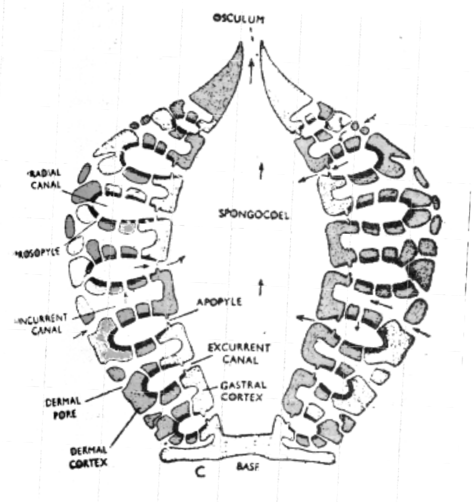

Fig.32 Grade -II Syconoid

In the Grade III of syconoid type, the dermal cortex becomes very thick. So that, the incurrent canals become narrow and long and some times branched. The radial canals open into the excurrent canals through *apopyles* present on the diaphragm. The excurrent canals open into spongocoel by means of internal ostia. This type of syconoid canal system is seen in *Grantia.*

2.2.5 LEUCONOID TYPE

This is the most complicated type of canal system found in several sponges like *Leucandra, Leucilla, Spongilla* etc.

The leuconoid type can be theoretically derived from the syconoid type by folding the radial canals into small flagellated chambers. The radial canals are folded to form clusters of small flagellated chambers. The spongocoel becomes very narrow or sometimes lacking altogether. Mesenchyme fills in the spaces around the flagellated chambers. The cortex is perforated by numerous dermal pores which open into incurrent canals. The incurrent canals are irregularly branched in mesenchyme. The excurrent canals lead into small rounded flagellated chambers by openings called *prosopyles*. The flagellated chambers open into excurrent canals by openings called *apopyles*. The excurrent canals are united to form a larger and larger tubes called *excurrent sinuses*. The course of water current in Leuconoid is:

Dermal ostia → sub-dermal spaces and incurrent canals → prosopyles or prosodus → flagellated chambers → apopyles or aphodus → excurrent canals → excurrent sinuses → ostia → outside.

There are four grades in leuconoid type. They are known as the *Eurypylous, Prosodal, Aphodal* and *Diplodal*.

Eurypylous: When apopyles open directly into the excurrent canals through wide months then it is called Eurypylous. This type of canal system is found in *Leucilla*.

The water current takes the following route:

Dermal ostia → sub-dermal spaces → incurrent canals → prosopyles → flagellated chambers → apopyles → excurrent canals → excurrent sinuses → oscula → outside.

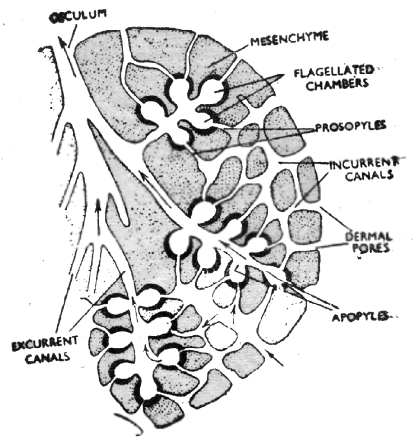

Fig.33 Eurypylous

Prosodal: If a narrow tube called prosodus is present between the flagellated chamber are incurrent canal then it is called prosodal type. In the prosodal type, the water current takes the following route:

Dermal ostia → sub-dermal spaces → incurrent canals → prosodal canals → flagellated chambers → apopyles → excurrent sinuses → oscula → outside.

Aphodal: If a narrow tube called aphodus is present between the flagellated chamber and excurrent canal then it is called aphodal. The water current takes the following route:

Dermal ostia → sub-dermal spaces → incurrent canals → prosopyles → flagellated chambers → aphodal canals → excurrent canals → excurrent sinuses → oscula → outside.

Diplodal: In this, both prosopyles and apopyles are elongated. This type of canal system is found in *Oscarella*. The route of water current is:

Ostia → sub-dermal spaces → incurrent canals → prosodus → flagellated chamber → aphodus → excurrent canals → spongocoel → oscula → outside.

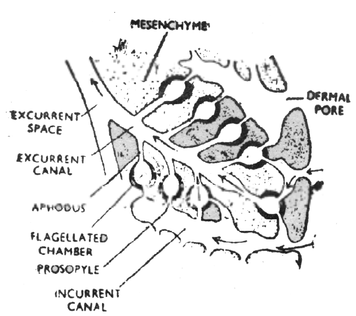

Fig.34 Aphodal

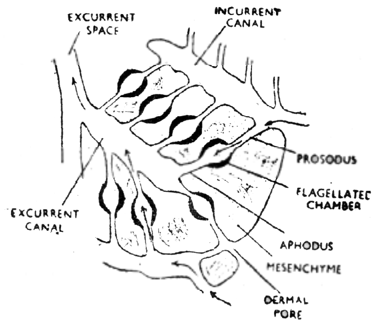

Fig.35 Diplodal

2.2.6 RHAGON TYPE

This resembles the Sycon type of canal system in having the usual dermal ostia, incurrent canals and prosopyles but is complicated by the development of numerous flagellated chambers, apopyles and excurrent canals.

The rhagon type of sponge has a conical body, tapering from the broad base to the apex. The basal wall is termed *hypophare* which has no flagellated chambers. The upper wall bearing a row of small, oval flagellated chambers is called *spongophare*.

Each flagellated chamber communicates with the exterior by a dermal pore or prosopyle and opens into the spongocoel by a wide apopyle. The route of the water current includes:

Ostia → subdermal spaces → incurrent canals → prosopyles → flagellated chambers → apopyles → excur-
r

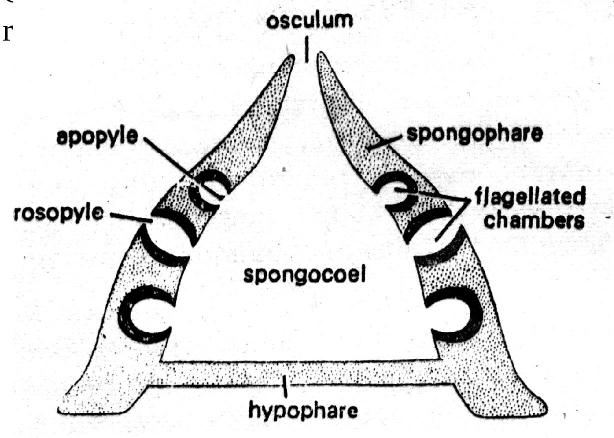

Fig.36 Rhagon type of canal system

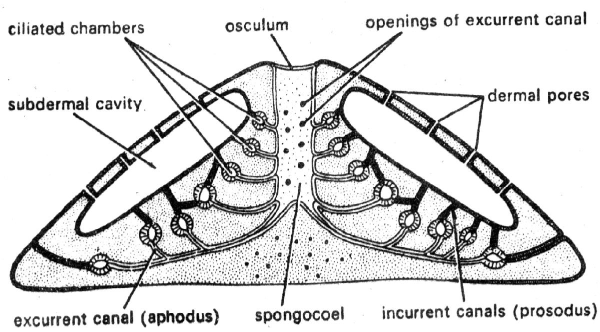

Fig.37 Diagramatic vertical section of Spongilla showing Rhagon type of Canal System

2.2.7 FUNCTIONS OF CANAL SYSTEM

The canal system helps the sponges in nutrition, respiration, excretion and reproduction. The current of water which flows through the canal system brings the food and oxygen and takes away the CO_2, nitrogen wastes and faeces. It carries sperms from one sponge to another for fertilization of ova. It increases the surface area of the sponge in contact with water.

2.2.8 SUMMARY

The ason type of canal system is simple with unfolded wall. The sycon type is more complicated with slightly folded wall. The leucon type is the most complicated with greatly folded wall. The water current runs rapidly in the ascon type, slowly in the sycon type and very slowly in the leucon type of canal system. The canal system of sponges is meant for both nutritive and respiration purposes. In the complex leuconoid type, development of mesoglea and infoldings of the wall result in formation of more cavities and decrease of the paragastric cavity. The flagellated chambers are small and spherical. The rhagon type has the body of sponge broad and conical with a single osculum at the top.

2.2.9 KEY TERMINOLOGY

Spongocoel: It is the interior space of the sponge body.

Osculum: It is single large opening at the free end of the sponge body.

Choanocytes: Confined to radial canals. Also called collar cells.

Incurrent pores: Minute pores on the body surface.

Radial canals: Exclusively lined by choanocytes. Also called flagellated chambers.

Aphodees: The apopyle of each flagellated chamber is drawn out as a narrow canal called Aphodus.

Prosodus: Narrow canal between the flagellated chamber and incurrent sinus.

2.2.10 SELF ASSESSMENT QUESTIONS

1. Describe Canal system in sponges.
2. Write notes on: (1) Ascon type, (2) Sycon type

2.2.11 REFERENCE BOOKS

1. **Porifera** by R.L. Kotpal.
2. **Invertebrate Zoology** by Dhami & Dhami
3. **Invertebrate Zoology** by Jordan.

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Lesson 2.3
HISTOLOGY OF SPONGES

CONTENTS

2.3.1 Objective

The purpose of this lesson is to understand the various types of cells and their functions in porifera.

2.3.2 Introduction

The sponge body is merely a collection of loose cells without any co-ordination of the body functions. The body wall is made up of two cellular layers, an outer dermal or pinacoderm layer and an inner gastral or choanoderm layer. Beteen these two layers, there is a gelatinous mesogloea (mesenchyme) containing several types of free amoeboid cells. These amoeboid cells are specialized for various functions.

2.3.2 Pinacoderm Layer

It consists of exopinacoderm and endopinacoderm. The exopinacoderm covers the body surface except ostia and osculum. The endopinacoderm forms the epithelial lining of the incurrent canals and spongocoel.

Pinacocytes: Pinacocytes are the large, flattened, polygonal cells which form as pinacoderm. The pinacocytes are arranged so closely that their margins form a continuous line. These cells are highly contracticle and they can greatly increase or decrease the surface area of the spongy body. The external pinacocytes are spoken as 'ectoderm' and those lining the spongocoel as 'endoderm'.

Porocytes: These are modified pinacocyctss and are called 'pore cells'. They extend between epidermis and spongocoel for the passage of water into the body. Each pore is intracellular i.e., it is a canal formed in a tubular cell (porocyte). These intracellular canals or channels are known as **prosopyles**. They connect the incurrent canals with the radial canals. Porocytes are highly contracticle cells capable of closing the pores when needed.

Myocytes: These usually surround the osculum and other openings to reduce or increase the size. These cells are elongated and contractile in nature just like the muscle cells. They form as spincters around openings to control their size. They resemble the smooth muscle cells of the other invertebrates.

2.3.3 GASTRAL EPITHELIUM OR CHOANODERM LAYER (ENDODERM)

It lines the paragastric cavity or spongocoel and radial canals. It is formed of flagellated collar cells or the choanocytes.

2.3.4 CHOANOCYTES

These were discovered by James Clark in the year 1867. These are endodermal in origin. The cells are oval or rounded and arranged in loose layer upon the mesogloes. Each cell consists of a single nucleus, one or two contractile vacuoles, food vacuoles, basal granule and blepharoplast. A long whip-like flagellum originates from the centroblepharoblast which controls the movements of the flagellum. The base of the flagellum is surrounded by a thin cytoplasmic funnel-like collar. The flagellum moves in a spiral way creating water currents from the base to the tip in the collar. The micro-food organisms of the water current are engulfed by the collar cells and the food is digested in their food vacuoles.

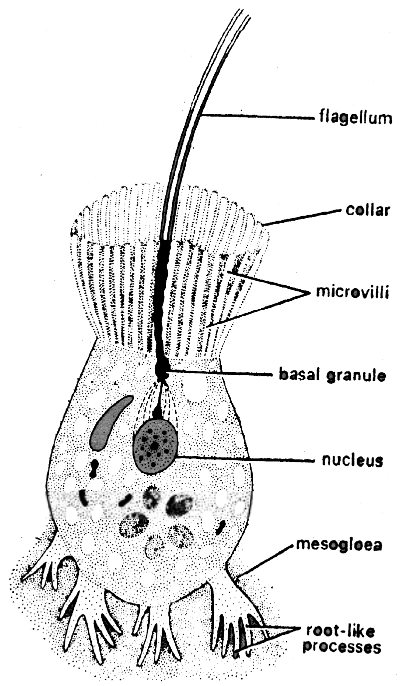

Fig.38 Choanocyte

2.3.5 MESENCHYME (MESOGLOEA): It lies between the pinacoderm and choanoderm. It is supposed to be secreted by pinacoderm. It is composed of a thin gelatinous, transparent matrix commonly called mesogloea or mesohyl. The mesogloea consists of several free amoeboid cells. The main amoeboid cells (amoebocytes) are as follows:-

(a) **Chromocytes:** These are pigmented amoebocytes having lobose preudopodia. They probably provide colouration to the body of sponge.

(b) **Thesocytes or storage cells:** These are amoebocytes having lobose pseudopodia like choanocytes but filled with reserve food materials in the form of glycogen, fat or protein masses. Thus, these cells act as storage cells.

(c) **Trophocytes or Nourishing cells:** These cells also possess lobose pseudopodia. These are found loaded partly or completely with digested food and serve to transfer it from one place to other.

(d) Phagocytes: These cells also collect food from choanocytes through their pseudopodia. They also engulf foreign particles, excrete and damaged tissues.

(e) Archaeocytes: These are large aoebocytes with blunt pseudopodia. They give rise to male and female sex cells. They play an important role in the process of regeneration. They are also concerned with the transport of food and wastes. Thus, they are called "totipotent" as they are capable of producing any kind of cells.

(f) Collencytes or Desmocytes: These are also called connective tissue cells. They have several slender, long pseudopodia which unite to form a network. These cells are commonly found in Demospongia.

(g) Scleroblasts: These amoebocytes secrete the skeleton of the spongy body. Depending upon the nature of their secretion, they are called –

1. Calcoblasts if they secrete calcareous spicules,
2. Silicoblasts if they secrete siliceous spicules, and
3. Spongioblasts if they secrete spongin fibres.

(h) Gland cells: These are amoeboid and are capable of secreting adhesive slime substance for the purpose of attachment of the spongy body to the substratum. The slime or mucus may contain toxic substances and emits unpleasant odour.

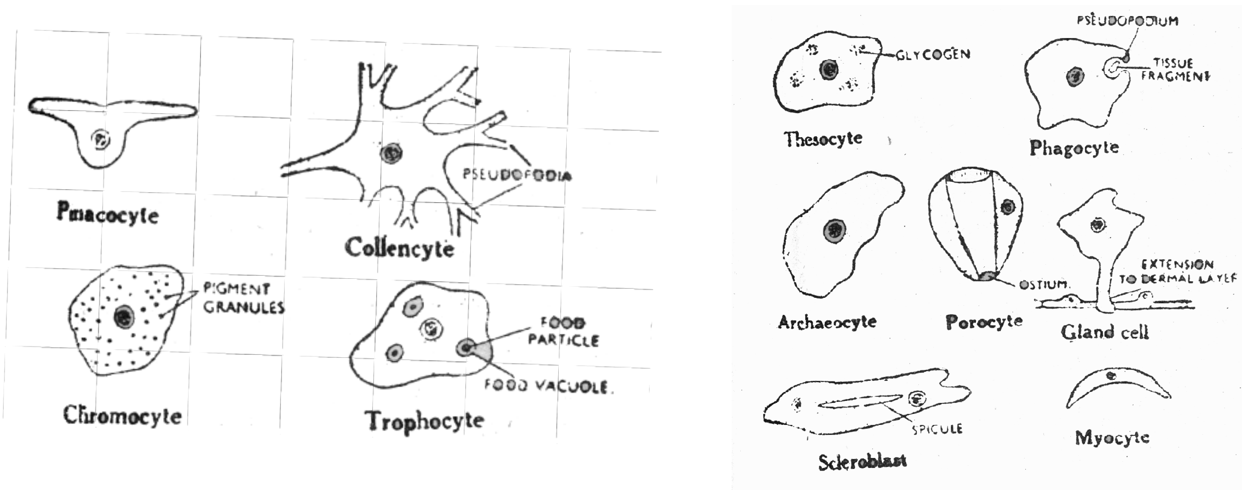

Fig.39 Types of cells found in the mesogloea in sponges

2.3.6 SUMMARY

The sponge body is merely a collection of loose cells without any coordination of the body functions.

The body is made up of two layers. Each layer consists of several kinds of cells which carry different functions. Choanocytes are for nutritive function. Thesocytes store the food materials in the form of glycogen, fat or protein masses. Archeocytes give rise to male or female sex cells. Thus the main cells are pinacocytes, amoeboid cells, collar cells, scleroblasts etc. Most of the cells are derived from amoeboid cells.

2.3.7 KEY TERMINOLOGY

Thesocytes: These are called storage cells because they are filled with reserve food materials in the form of glycogen, proteins and fats.

Chromocytes: Amoebocytes having pigments of various colours.

Prosopyle: Intracellular canal formed a tubular cell.

Myocytes: These act like muscle cells. They usually surround the opening and act as spincters.

Spongioblasts: They produce spongin fibres

Phagocytes: Any cell that insists microorganisms or other foreign particles.

Totipotent cells: Ability to produce any kind of cells.

2.3.8 MODEL QUESTIONS

1. Describe the various cells present in the body of sponges.
2. Write short notes on:
   (a) Mesenchyma in sponges
   (b) Choanocytes and Scleroblasts

2.3.9 REFERENCE BOOKS

1. **Porifera** by R.L. Kotpal.
2. **Invertebrate Zoology** by Jordan.

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Lesson 2.4
SKELETON IN SPONGES

CONTENTS

2.4.1 Objective

The purpose of this lesson is to know the different types of spicules found in Porifera.

2.4.2 Introduction

Almost all sponges are provided with a true skeleton called autoskeleton, i.e, composed of elements secreted by the sponge itself. The autoskeleton is mainly formed by spicules or spongin fibres or a combination of both. Thus, the soft body of a sponge is supported by munute spicules of various types and materials. The calcareous sponges have spicules of calcium carbonate. The spicules of Hexactinellida are made up of siliceous materials while those of Demospongia are composed of spongin fibers.

2.4.3 Spicules: Spicules are secreted by certain amoebocytes known as "scleroblast cells" present in the mesenchyme. According to the types of secretion, the scleroblasts are divided into three types -

1. Calcoblasts when they secrete spicules of $CaCo_3$
2. Silicoblasts when they secrete spicules of silica, and
3. Spongoblasts when they secrete spongin fibres

2.4.4 Classification of spicules: Spicules are of two general types – megascleres and microscleres. The megascleres are large in size forming the main supporting skeleton of the sponge. The microscleres are smaller spicules scattered in mesenchyme without any supporting function.

The spicules are further classified according to the number of their axes and rays. Megasclere spicules are of five types namely monaxons, tetraxons, triaxons, polyaxons and spheres.

Monaxons: These are rod-like spicules with a single axis. Each monaxon develops from a single scleroblast cell as an organic axis around which $CaCo_3$ is deposited. The spicule may grow in one or both the directions and may be straight or curved or rounded at one end. When growth occurs in one direction only, the spicule is called monactinal monaxon or style. Styles are generally rounded (strongylote) at one end and pointed (oxeote) at the other. Styles with knobbed end are called *Tylostyles*. Styles curved with thorny processes are known as *acanthostyles*.

Monaxons with growth in both ends are called diactinal monaxons or rhabs. Rhabs which are pointed at both ends are oxeas. Rhabs which lance headed at both ends are *tornotes*. Rhabs which rounded at both ends are strongyles and rhads with knobbed at each end are *tylotes*.

Tetraxons (Tetractines): These are the spicules having four rays starting from a central point. So, they are called *Quadriradiates*. When the four rays are equal in size, then the spicules are called *Calthrops*. When one of the four rays elongated, such spicules are termed *triaenes*. By loss of one smaller ray results into a diaene. If the elongated ray bears a disc at both ends, it is called amphidisc. Loss of elongated ray results *triradiate* or *triod*.

Triaxons (Hexactinal spicules): A triaxon spicule consists of three axes crossing at right angles, producing six rays that arise from central point. It is also called hexactinal spicule. These spicules are characteristic of the class Hexactinellida. From these spicules, so many modifications arise by reduction or loss or rays, branching and curving of the rays and the development of spines, knobs etc., upon them.

Polyaxons: These spicules in which several equal rays radiate from a central point. They are also called asters due to star-like appearance.

Spheres: These are rounded bodies in which growth occurs in rings around a central point.

Desmas: These are special megacleres of $CaCo_3$ on which, layers of silica have been deposited irregularly. Depending on the shape of the original spicule, they are named as monocrepid, tetracrepid, tricrepid etc. They are usually united to form a reticulated skeleton called *lithistid*.

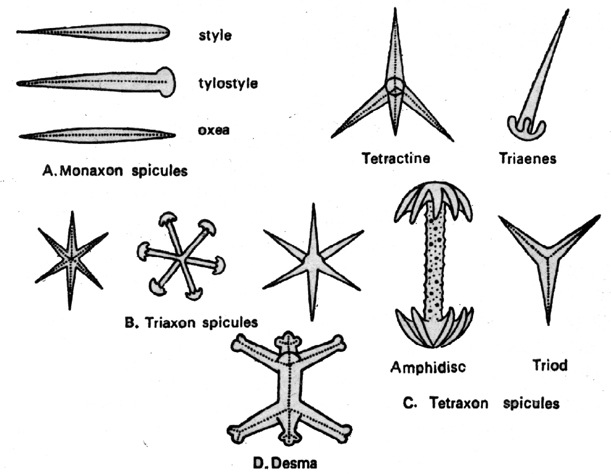


Fig.40 Types of megascleres

Microscleres: These do not form the supporting framework. These are of two types –

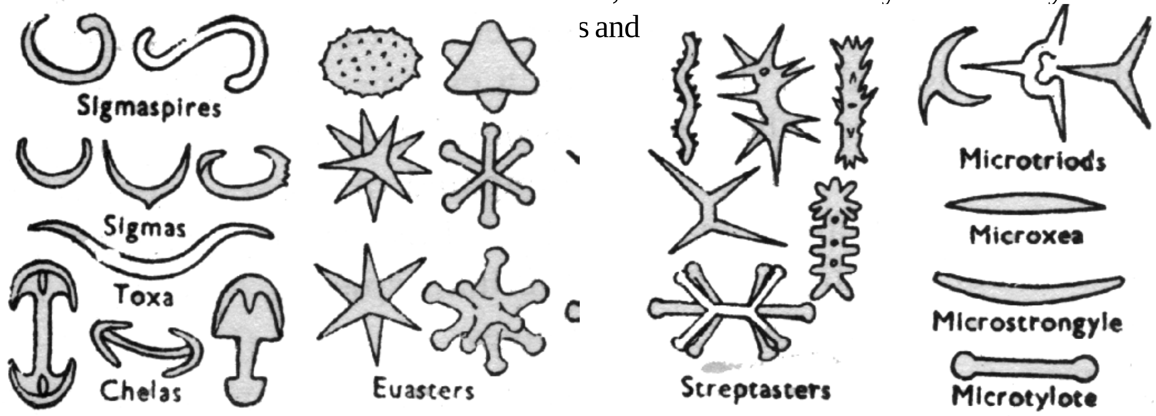
1. Spires and 2. Asters

Spires: Spires occur in many shapes. Some are curved in one plane and some are spirally twisted and so on. C-shaped forms are called **sigmas**: Spirally twisted forms are called **sigmaspires**. Bow-shaped forms are called toxas. Spicules with recurved hooks, plates or flukes at reach end are called **chelas**. When the spicules have same chelas at both ends are called **isochelas**. But, when they possess unlike chelas are called **anisochelas**.

Asters: Asters include types with small centres and long rays, and large centres and small rays. Small

ns, and with knobbed rays are called *tylasters*. Large

s and



Spires **Asters**

Fig.41 Types of Microscleres

2.4.5 Development of Spicules: The spicules are secreted by the scleroblast cells of mesenchyma. The secreting cell has two nuclei, between which, a minute organic axial thread is formed. Small amounts of $CaCo_3$ gets deposited around the axial thread. Thus, the spicule is formed between the two nuclei. As the cell prepares to divide, the two nuclei move apart and carry the two ends of spicule. Thus, the monaxon spicules increases in length. The cell situated at the inner end of the spicule is known as **founder** and the other one lying at the outer end is called **thickner**.

The founder cell establishes the shape and length of the spicule. The thickner cell supplies the additional layers of $CaCO_3$ to improve the thickness of the spicule. When the spicule is fully formed, both the cells wander into mesoglo

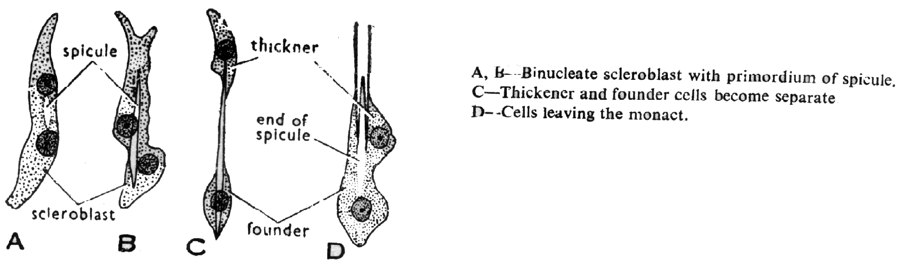


Fig.42 Development of Monaxon spicule

Spongin fibres: The spongin fibres from the skeleton of Demospongia. These fibres are secreted by a co-operative action of several spongioblasts. The spongioblasts, after secreting certain amount of spongin fibre, get degenerated. Spongin is an organic substance allied to silk.

2.4.5 SUMMARY

The skeleton consists of spicules or spongin fibres or of combination of both. The spicules are classified according to the number of axes and rays in to monoaxon, triaxon, tetraxon or spheres. The spicules according to sizes are called megascleres or microscleres. Spicules develop as a deposit within a cell called scleroblast The spicule deposit begins between the founder cell and thickener cell. Spongin fibres are secretd by spongioblasts. The spicules have a classificatory value.

2.4.6 KEY TERMINOLOGY

Cathrops: Tetraxon spicules with four equal rays.

Tylostyles: Monaxon spicules with knobbed ends.

Calico blasts: They secrete the spicules of $CaCO_3$.

Polyaxon spicules: Spicules with several axis crossing to produce many equal rays.

Founder cell: It provides shape and length of the spicule.

Thickner cell: It is concerned with the thickness of the spicule.

Spongin: Fibre secreted by several spongioblasts.

Isocheles: The spicules consist of same cheles at both ends.

2.4.7 SELF ASSESSMENT TEST

1. Give an account of various kinds of spicules present in a sponge body.
2. Classify the spicules of sponges and add a note on the development of spicules.
3. Write short notes on: (a) Monaxons, (b) Tetraxons and (c) Triaxons.

2.4.8 REFERENCE BOOKS

1. **Porifera** by R.L. Kotpal.
2. **Invertebrate Zoology** by Jordan.

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Lesson 3.1
PHYLUM: COELENTERATA - GENERAL CHARACTERS AND CLASSIFICATION

CONTENTS

3.1.1 OBJECTIVE

The purpose of this lesson is to

⇒ know the general characters
⇒ study the classification upto orders

3.1.2 INTRODUCTION

These are the first multicellular animals that they have reached the tissue grade of organisation. In 1847, Leuckart created the phylum Coelenterate and he placed the sponges and Ctenophores also in the group Coelenterate. However, Hatschek (1888) separated the coelenterata of Leuckart and created the groups Spongiaria (Porifera) Cnidaria (Coelenterate) and Ctenophora (Acnidaria). The Celenterata may be defined as "Diploblastic" Metazoa with tissue grade of construction having nematocysts and a single gastro-vascular cavity or coelenteron.

3.1.3 GENERAL CHARACTERS

1. These are the first multicellular animals with tissue grade of organisation.
2. Most of them are marine, but only few species are of fresh water forms.
3. They are sedentary or free living
4. Theya are solitary or colonial
5. They possess radial symmetry or biradial symmetry.

6. They are diploblastic animals, i.e., the body wall is made up of ectoderm and endoderm.
7. They possess a peculiar type of cells called cnidoblasts – hence phylum Cnidaria.
8. Between the ectoderm and endoderm, there is a non-cellular mesoglea.
9. The ectoderm consists of musculo-epithelial cells, interstitial or Amoeboid cells, Cnidoblast cells and nerve cells.
10. The endoderm consists of glandular cells, amoeboid cells and flagellated cells.
11. These are acoelomate animals because they do not possess body cavity or coelome.
12. Anus is absent.
13. Digestion is extra cellular as well as intracellular.
14. Respiration, circulatory and excretory systems are absent.
15. Nervous system is in the form of a diffuse network.
16. Sense organs such as ocelli and statocysts are present in medusae.
17. Muscular system consists of circular and longitudinal muscle fibres.
18. The soft body may be supported by horny or calcareous exoskeleton or endoskeleton.
19. Several coelenterates exhibit the phenomenon of polymorphism which reaches to the climax in the order Siphonophora.
20. Generally, polyps are meant for nutrition and medusae are meant for reproduction.
21. Reproduction is both by asexual and sexual,
22. Asexual reproduction takes place by budding and sexual reproduction by the formation of gametes.
23. A ciliated planula larva is often found in the life history.
24. Some of the coelenterates exhibit the phenomenon of alternation of generation or metagenesis.

3.1.4 CLASSIFICATION

According to L.H. Hyman (1940), phylum coelenterate is divided into three classes namely – 1. Hydrozoa, 2. Scyphozoa, and 3. Anthozoa.

Class: Hydrozoa:

1. They are solitary or colonial, fixed or free swimming.
2. Mostly marine, only few are fresh water forms.
3. Body wall is made up of outer ectoderm and inner endoderm separated by non-cellular mesogloea.
4. Some hydrozoans like Hydra are monomorphic, i.e., they exist in the polyp stage only. But other hydrozoa, like physalia are polymorphics, i.e., they include two or more zooids with division of labour.
5. Many hydrozoa exhibit alternation of generations.
6. In some hydrozoan corals, there is a massive stony skeleton of calcium carbonate.
7. They exhibit radial symmetry
8. The gastro-vascular cavity is without stomodeum and partions.
9. The gonads are ectodermal in origin and gametes are shed directly into the surrounding water.
10. A ciliated plamular larva is found in the life-history.

This class Hydrozoa is divided into five orders.

Order 1. Hydroida

1. Majority of Hydrozoa belong to this order.
2. Solitary or colonial forms
3. Polyploid generation is well developed
4. The medusae are usually budded of from the polyp.
5. Sense organs like ocelli and statocyst are present in a medusa.
   e.g. *Hydra, Hydractinia, Obelia*

Order 2. Milleporina

1. Massive calcereous exoskeleton is secreted by ectoderm.
2. Exoskeleton is provided with pores through which polyps protrude out.
3. The colony consists of gastrozoid and dactylozooid.
4. Gastrozooids are provided with mouth and tentacles.
5. Dactylozooids have tentacles but without mouth.
   e.g. *Millepora*

Order 3. Stylesterina

1. Calcareous exoskeleton is secreted by ectoderm.
2. Colony has two kinds of zooids.
3. Dactylozooids are small without tentacles.
4. Medusae develop in special cavities (sporosacs)
5. Planula larva is present.
   e.g. *Slylaster*

Order 4. Trachylina

1. Medusa stage is well developed
2. sometimes, medusae live as colonies
3. Polyps are reduced or absent
4. Medusae are large and proivded with statocysts and tentaculocysts
5. Gonads borne on the radial canals
   e.g. *Lirope, Polycolpa, Petasus*.

Order 5. Siphonophora

1. These are free swimming or floating colonies.
2. Perisarc is absent
3. Each colony consists of several types of zooids.

4. Polymorphism reaches to the highest degree.
5. Polyps do not possess tentacles.
   e.g. *Halistemma, Physalia, Velella, Porpita*.

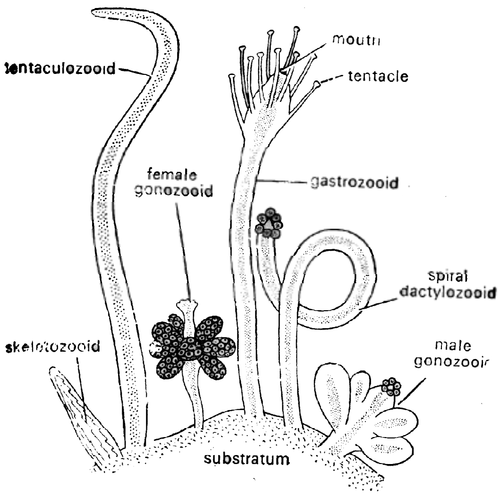

Fig. 42 Hydractinia

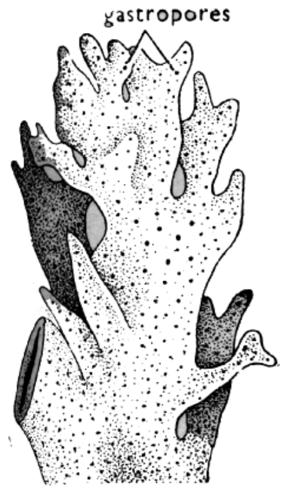

Fig. 43 Millipora

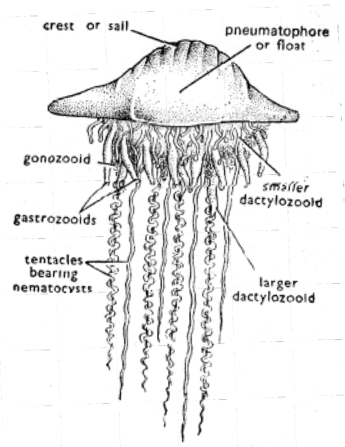

Fig.44 Physalia

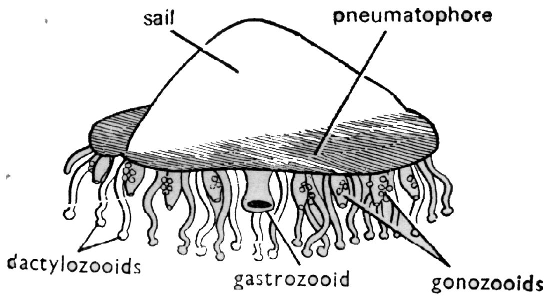

Fig.45 Velella

Class II : Scyphozoa (G.K. Skyphos = cup, zoon = animal)

1. These are called jelly fishes
2. Exclusively marine forms
3. They are in the form of cup or saucer shaped medusae
4. There is no stomodium or true velum
5. The mouth is found at the tip of the mamubrium
6. The margin of umbrella is notched, and contain special sense organs known as tentaculocysts
7. Mesogloea is thick and usually cellular
8. The gastro-vascular cavity is divided into a central stomach and four gastoric pouches.
9. The gastoric filaments and gonads are endodermal in origin.

10. The medusae arise by strobilization.
11. There is an alternation of generations.

This class is divided into five orders.

Order 1. Stauromedusae

1. Sedentary forms. Attached to the substratum by an aboral stalk.
2. Marginal sense organs are absent.
3. Eight adradial lobes are present
4. Gastric filaments are many.
   e.g. *Lucernaria, Halielystus*

Order 2. Cubomedusae:

1. They live in warm and shallow waters of tropical and subtropical regions
2. Presence of four per-radial tentacles
3. Membrium is very small
4. Gastrovascular cavity consists of many number of septa.
   e.g. *Cheryboeae*, *Chiropsalmus*

Order 3. Coronatae

1. They found inhabiting the deep waters of ocean.
2. Body conical or round-shaped or flattened.
3. Gastro-vascular cavity is divided by septa.
   e.g. *Pericolpe, Periphylla*.

Order 4. Semaeostomeae

1. They live in coastal waters of all oceans.
2. The umbrella is flat, saucer, or bowl shaped.
3. Mouth is four cornered (square)
4. The corners of the mouth are drawn into four oral a
5. The margin of the umbrella is fringed with hollow te
6. Eight tentaculocysts are present
7. Gastric pouches and filaments are absent.
   e.g. *Aurelia, Pelagia*

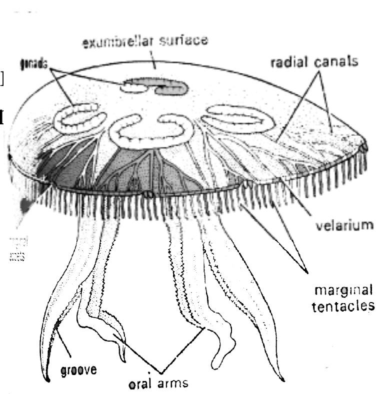

Fig.46 Aurelia

Order 5. Rhizostomae

1. They live in shallow waters of tropical and subtropical oceans.
2. The umbrella is saucer or bowl-shaped or flattened or even concave on the top.
3. The margin bears lappets in notches
4. Mouth is surrounded by eight oral arms
5. Marginal tentacles are absent, but eight tentaculocysts (rhopalia) are present.
6. Gastric septa are absent.
   e.g. *Rhizostoma, Stomalop*

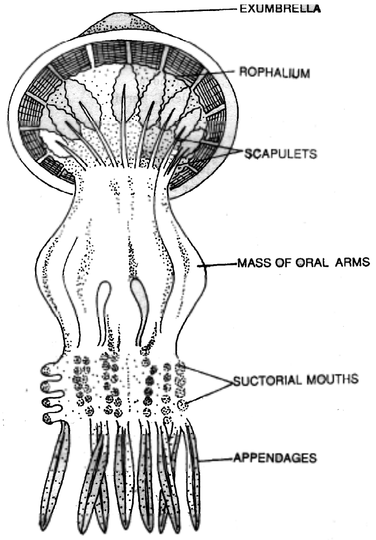

Fig.47 Rhizostoma

Class III : Anthozoa (G.K. anther = flower)

1. Solitary or colonial
2. Exclusively marine
3. These occur only in polyp form.
4. Medusoid stage is not known in any member of the class Anthozoa
5. Body is usually cylindrical
6. They exhibit biradial symmetry or radio-bilateral symmetry.
7. The mesogloea contains amoeboid cells and fibres in its gilatinous matrix.
8. The gastro-vascular cavity includes stomodium lined by epidermis and is divided into chambers by vertical septa called mesenteries.
9. Mesenteries bear hematocysts at their inner free edges.
10. The development includes planula larva.
11. The sea-anemones generally donot secrete skeletal elements. But several species of Anthozoa secrete extensive corals of calcium carbonate or chitinoid material,
12. Gonads are endodermal and they develop in mesenteries.
13. Fertilization is external

14. Ciliated planula larva occurs in life history.

The class Anthozoa is divided into two sub-classes.
Subclass 1. Alcyonaria or Octocorallia
Subclass 2. Zoantharia or Hexa-corallia

Subclass 1. Aleyonaria

1. Generally, they live in warm waters oceans.
2. The polyps exhibit dimorphism in some forms.
3. Tentacles are always eight in number
4. Only one siphonoglyph is present
5. Eight complete mesenteries are present

This sub-class includes six orders.

Order 1. Stolonifeara

1. They live in shallow waters in the tropical and temperate areas.
2. Polyps are connected by basal mats or stolons.
3. The skeleton, when present, consists of calcareous spicules which may join to form compact tubes.
   e.g. *Tubiphora* (organ pipe coral), *Clavularia*.

Order 2. Telestacea

1. These colonies consist of long polyps with lateral polyps again.
2. Skeleton consists of spicules fused by calcareous or horny secretions.
   e.g. *Telesto*.

Order 3. Alcyonacea

1. These are called soft corals
2. The basal parts of the polyps are fused to form a fleshy mass
3. The oral ends of the polyps protrude out from basal fleshy mass
4. Skeleton is in the form of calcareous spicules.
   e.g. *Alcyonium, Xenia* (Dead-Mans Finger)

Order 4. Coenothecalia

1. These are commonly called blue corals
2. They have a massive skeleton not fused of spicules but of crystalline, calcareous fibrous forming corals.
3. Skeleton contains erect cylindrical cavities for polyps.
   e.g. *Heliopora*.

Order 5. Gorgonacea

1. It includes horny corals
2. These are found in warm seas
3. These are plant-like colonial and highly branched forms
4. Axial skeleton composed of compacted calcareous spicules or horn-like gargonin.
5. Siphonoglyphs are present
6. These are commonly known as sea-fans, sea-feathers, sea-whips etc.
   e.g. *Corallium* (Red coral), Gorgonia (sea-fan)

Order 6. Pennatulacea

1. These are generally called sea-pens
2. These are elongated feather-like colonies. Each colony is made up of lower stalk part or peduncle and upper rachis part.
3. The main stem is supported by calcareous or horny skeleton.
   e.g. *Pennatula, Renilla*.

Sub-class 2. Zoantharia or Hexacorallina

1. Colonial or solitary marine polyps.
2. Tentacles are usually numerous and frequently arranged in multiples of 5 or 6.
3. Most of them have two siphonoglyphs in stomodiacum. But in some, there may be one or none.
4. Mesenteries are arranged in the multiple of five or six.
5. Polyps are usually monomorphic.

This subclass is divided into 5 orders.

Order 1. Actinaria

1. These are commonly called sea-anemones.
2. Tentacles and mesenteries are numerous and often arranged in the multiple of six.
3. There may be one or two siphonoglyphs.
4. Skeleton is absent.
   e.g. *Adamsia*

Order 2. Medreporaria

1. These are commonly celled the true or stony corals.
2. Mostly colonial, rarely solitary forms.
3. Calcareous exoskeleton is secreted by ectoderm
4. Polyps are small and enclosed in the cup-like cavity of the exoskeleton

5. Siphonoglyphs are usually lacking.
   e.g. Fungia (Mushroom-coral), Favia, Madrepora, Meandrina (Brain coral) Flabellum, Acropora (The stag-horn coral)

Order 3. Zoanthidea

1. These animals do not possess pedal disc and skeleton.
2. Only one siphonoglyph is present
3. Mesenteries are paired. The pairing of mesentries takes place with a complete one and a incomplete one.
   e.g. *Zoanthus, Epizoanthus*.

Order 4. Antipatharia

1. These are generally called black corals.
2. They possess tree-like bodies with elongated polyps.
3. Two siphonoglyphs are present
4. Mesenteries and tentacles are 6-24 in number
   e.g. *Antipathes* (Black coral)

Order 5. Ceriantharia

1. These are solitary forms.
2. Polyps are very much elongated
3. Pedal disc and skeleton are absent
4. Tentacles are numerous and arranged in two rows (oral and marginal rows)
5. Mesenteries are numerous
6. Only one siphonoglyph is present., e.g. *Cerianthus*.

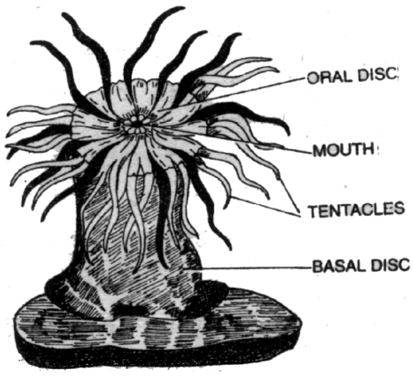

Fig.48 Seanemone

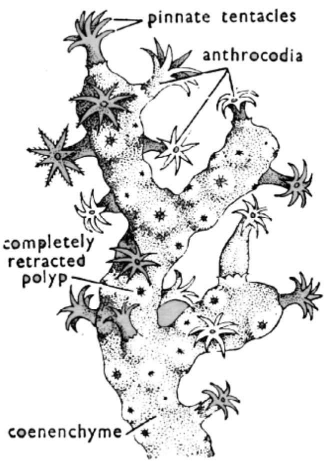

Fig.49 Corallium

Fig.50 Gorgonia

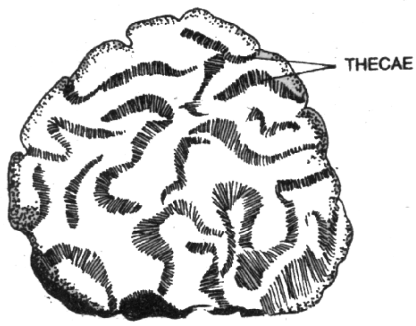

Fig.51 Meandrina

3.1.5 SUMMARY

These are diploblastic meatzoans with radial symmetry. These animals possess a peculiar type of cells called enidoblasts – hence phylum cnidaria. The ectoderm consists of musculo-epithelial cells, intestitial cells, enidoblast cells, nerve cells etc. Digestion is extra cellular as well as intracellular. Respiratory, circulatory and excretory systems are absent. Nervous system is in the form of a diffused network Reproduction is both asexual and sexual. The phylum is divided into three classes. Hydrozoan exhibit polymorphism. Scyphozoans are generally called Jelly fishes. Anthozoans occur in polyp forms. The subclass Hexacorallina includes corals.

3.1.6 KEY TERMINOLOGY

Statocysts (Otocysts): A balancing organ found in many vertebrates. It consists of fluid-filled sac lined with sensory hairs and contains granules of $CaCO_3$, sand etc.

Ocellus: A simple eye occurring in Invertebrates. It consists of light-sensitive cells.

Plonula larva: It is ciliated larva found in the life-history of Obelia.

Radial symmetry: If an organism is cut through the centre of the structure in any direction, that of produces two equal halves.

Metagenesis: Alternation of generations.

Polyp: The sedentary stage consisting of a cylindrical body fixed at one end and having a mouth surrounded by a ring of tentacles at other end. It is meant for the feeding the colony.

Medusa: It is a free-swimming stage end is meant for sexual reproduction.

Fungia: Mushroom coral.

Meandrina: Brain coral.

3.1.7 MODEL QUESTIONS

1. Give the main features of phylum Coelenterata.
2. Classify the phylum Coelenterata upto their orders.
3. Write short notes on:
   (a) Anthozoa (b) Siphonophora

3.1.8 REFERENCE BOOKS

1. **Protozoa** by R.L. Kotpal.
2. **Invertebrate Zoology** by Jordan
3. **Invertebrate Zoology** by Dhani & Dhani.

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Lesson 3.2
OBELIA GENECULATA (Sea fur)

3.2.1 OBJECTIVE

The purpose of the unit is to ….

- Know the structure of Obelia
- Describe the polyp and medusa
- Explain the alternation of generations
- Know the Homology of polyp and medusa

3.2.2 INTRODUCTION

Phylum – Coelenterata
Class – Hydrozoa
Order - Hydroidea

Obelia is a radially symmetrical, deploblastic and marine, sedentary animal. It is commonly called as Sea fur. Obelia is a colonial and have a complex life cycle. It attaches to rocks, shells and wooden piles in shallow water. Obelia is found all over the world in the shallow coastal waters upto a depth of 80 meters.

3.2.3 STRUCTURE

The colony of Obelia looks like a small fur like outgrowth. Hence, it is called as Sea fur. It is semi-transparent having whitish or light brown tinge and attains a height of 2 to 3 cm.

The colony attaches to the substratum with the help of rhizoids of hydrorhiza. From the creeping structure, many vertical branches arrives which are called as Hydrocaulus. They branch further and ends with a zooid (polyp or hydranth). The branches which are arrise from colony in an alternate manner. In the axils of the older polyps are placed cylindrical zooids are called blastostyles. Thus Obelia consists of two types of zooids i.e. dimorphic, when the blastostyles develop saucer shaped bodies called medusae, the colony then become trimorphic.

Perisarc

It is a yellowish tough transparent protective non-living layer secreted by the epidermis. The non-living layer protects the colony and serves as exoskeleton. The base of each zooid has a ringed appearance and give flexibility to the main stem. The perisarc is in close contact with coenosarc.

Coenosarc

The ectoderm and endoderm together called as coenosarc. Inside the coenosarc a tube like canal called coenosarcal canal. It is continuous with gastrovascular cavity of the zooids. In between the two layers there is a non-cellular transparent layer called mesogloea.

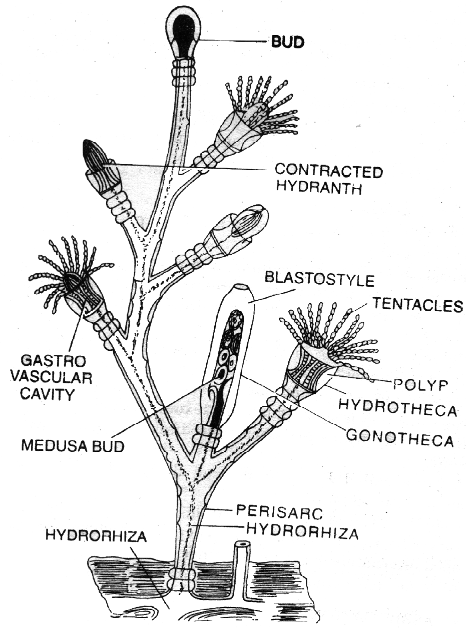


Fig.52 Obelia colony

3.2.4 ZOOIDS

The colony of Obelia has two types of zooids, namely polyp and blastostyle.

1) POLYP

It is yellowish in colour and nutritive zooid. The polyp is also known as Hydranth. The Hydranth resembles the Hydra. It has cylindrical body. Its proximal end is narrow and distal has a conical elevation, the manubrium or hypostome. At the apex of the manubrium bears a terminal aperture, the mouth. Raising from the base of the hypostome is a circlate of 30 filiform tentacles. They bear nematocysts. The tentacles are solid unlike Hydra. The perisarc covering the polyp is called Hydrotheca. When hydranth is disturbed it withdraws itself into the cup along with tentacles. The presence of tentacles, mouth and gastrovascular cavity is most suited for nutrition and hence considered as nutritive zooid.

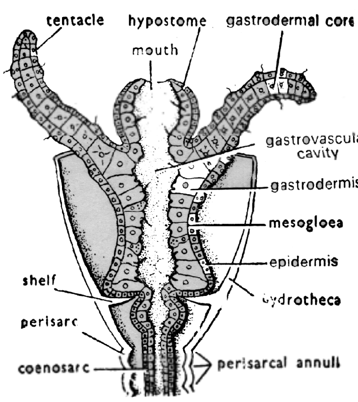


Fig.53 V.S. of polyp

2. BLASTOSTYLE

The blastostyle is the zooid that is modified for reproduction. When the hydrocaulus fully developed it produces special cylindrical bodies called blastostyles or gonozooids. It is a blind club shaped structure and less numbers than the hydranth and occur towards the lower part of the colony, in the axils of the older hydranths. The perisarc, covering the blastostyle is loose and forms a transparent sac like structure called gonotheca. Gonotheca develops an opening called gonopore at the terminal end. The blastostyle together with the medusa and gonotheca is called gonangium.

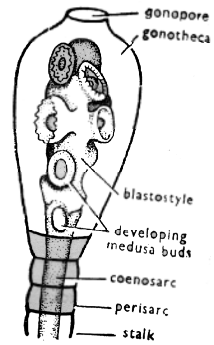


Fig.54 Blastostyle

The blastastyle by lateral asexual budding produces the sexual individuals called medusae. The medusae are of different sizes depending on their stage of development. The fully formed medusae detach from the blastostyle and escape in to the surrounding water through gonopore. Hence, the blastostyle is a reproductive zooid and totally depends on polyps for their nutrition.

3.2.5 HISTOLOGY

The body of Obelia is made up of two layers named ectoderm and endoderm. Polyp and medusa have two layers in their body. In between the two layers a transparent non-cellular mesogloea is present.

1. Ectoderm

The outer epidermis is known as ectoderm. It is a thin layer and made up of different types of cells i.e., Epithelio muscular cells, interstitial cells, nematocysts, nerve cells, sensory cells and gland cells.

a) **Epitheliomuscular cells:** The epidermis is mainly formed by these cells in between them other cells are also placed. The cells are more or less cylindrical in shape. The outer ends are broad and inner ends are narrow. Their inner narrow ends are produced into two muscle processes called muscle tails. Each muscle tail contains muscles known as myonemes. Myonemes acts as a longitudinal muscle layer and their contraction shortens the body and tentacles.

b) **Interstitial cells:** The space between the narrow inner ends of the epitheliomuscular cells is filled with small and round cells known as interstitial cells. These are undifferentiated cells which are capable of producing all other types of cells by multiplication. Thus interstitial cells are 'Totipotent' cells.

c) **Nematocysts:** In the ectoderm, the nematocysts which are also called stinging cells are present. These are the offensive and diffensive structures for the zooids. These are more numbers on the tentacles. When fully developed they migrate to the surface of the tentacles. Each enidoblast is a oval shaped sac like structure. The cytoplasm of this cell contains a nucleous lying to one side. The oval shaped bladder filled with a poisonous fluid, hypnotoxine. The bladder is known as nematocyst. The outer end of nematocyst is produce into a long hallow tubular whip-like structure called thread tube. Usually, it is coiled and lies in the stinging capsule or nematocyst. The tip of the thread tube is open and its distal part is swollen to form the butt. The inturned thread is covered with a lid-like structure called operculum. When disturbed the thread penetrates into the body of the prey and fluid hyprotoxin is injected. The nematocysts of Obelia are of basitrichous isorhiza type.

d) **Nerve cells:** These are present both on epidermis and gastrodermis. The nerve cells form a nerve net work. Each nerve cell is more or less triangular in shape. The ends of the cells produced in to filamentous nerves. The nerve filaments anastamose and form a net work. Thus nerve net is present on either side of mesoglooa.

e) **Sensory Cells:** These cells are scattered through out the epidermis in between the epithelio muscular cells. They are abundant on the tentacles. They are tall narrow thread like cells bearing the sensory bristile at the outer side. The inner end of the sensory cell is connected with the nerve cells. Sensory cells are of several kinds which are sensitive to touch, temperature and chemical stimuli.

f) **Gland cells:** These cells are abundant on the tentacles and at hypostome. These secrete mucous substance. The secretions help in the attachment of food particles to tentacles and hypostome.

II. Gastrodermis or Endoderm

Gastrodermis has Endothelio muscular cells. These are nutritive in function and columnar in shape. The free ends of the cells bear pseudopodia which help to engulf digested food particles. Some cells have long flagella which help in the movement of food in gastrovascular cavity. The muscle fibres of musculo endothelial cells of gastrodermis run transverse to the body. Gastrodermis has glandular cells and mucous secreting cells. Glandular cells secrete enzymes, to digest the food in gastrovascular cavity. Mucous cells are seen more at hypostome. They help in free movement of food in to gastrovascular cavity.

3.2.6 NUTRITION

Polyps or hydranths are the nutritive zooids of the colony. They are mostly carnivorous and prey upon small aquatic crustaceans, nematodes and other worms. With the help of tentacles armed nematocysts capture the food and convey it to the mouth. Digestive juices secrete by the gland cells of the gastrodermis bring the extracellular digestion. The gastrodermal cells with the help of pseudopodial processes engulf small pieces of the partly digested food and digest them intracellularly. Digested food is circulated through gastro-vascular cavity to all parts. Undigested food is send out through mouth itself.

3.2.7 RESPIRATION

There are no special organs of Respiration. Water regularly enters the gastrovascular cavity of the colony through the mouth of the polyps. So every cell of the gastrodermis takes in oxygen and release carbon dioxide which goes out through outgoing water. Even perisarc takes part in exchange of gases through diffusion.

3.2.8 DEVELOPMENT OF MEDUSA

Medusa arises from the blastostyle by asexual budding. Medusae are formed during spring and summer. Medusa formation begins as a projection or diverticulum, containing both ectodermis and endodermis. This out growth grows in size to become a vesicle which remains connected with the blastostyle by a narrow stalk. Its cavity is continuous with that of blastostyle. The ectoderm of vesicle at the top split into two layers. The inner layer again splits and forms a cavity called the bell rudiment which later forms subumbrellar cavity. Inner layers of the subumbrellar side projects and forms as manubrium. As the manubrium elongates the outer epidermis is at broken through, leaving a narrow marginal circular velum, which projects inwards form the margin of the umbrella. The four radial canals develop and connects with each other and form a circular canal at the velum. The young medusa fully formed is free through the mouth of the blastostyle. In few months, the medusa grows in full size.

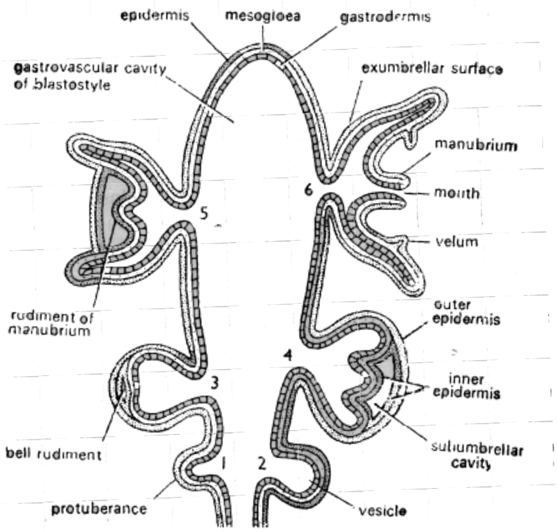


Fig.55 Stages of the development of medusa from a blastostyle

3.2.9 STRUCTURE OF MEDUSA

A fully formed medusa of obelia is umbrella shaped. When fully grown it has a diameter of 6-7 mm. The outer convex surface of the medusa is exumbrellar surface. While the inner concave surface is subumbrellar surface. From the centre of the subumbrellar surface hangs down a short hallow manubrium. As its free distal end a four sided mouth is present. The mouth leads into gastrovascular cavity. The medusae having a velum are called a craspedote.

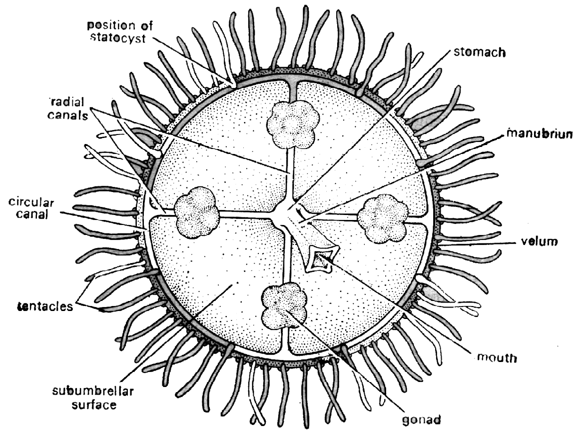


Fig.56 Medusa

Nervous system: On either side of mesogloea nerve cells belonging to the epidermis and gastrodermis forms a nerve nets. The nerve cells are concentrated along the margin of the bell, forming two circular nerve rings. The nerve ring present on the exumbrellar surface supply to tentacles and subumbrellar surface to statocysts and muscles.

Sense organs: At the base of eight adradial tentacles special sense organs called statocysts are present. Each statocystde consists of a minute, fluid filled ectodermal sac called statocyst or marginal vesicle. Its cavity contains a movable round particle of calcium carbonate called statolyth or otolith, which are secreted by a large cell named lithocyte. The base of the statocyst wall connected with nerve cells. The inner free ends of the statocyst bear a fine protoplasmic sensory processes. The statocyst helps in maintaining the equilibrium of the bell. During movement any disturbance in the body there will be change in the position of statolith. At that time, the Stataliths of that side touch the sensory processes and stimulate them. The nerve impulse, thus, created is transmitted by nerve-cells to the muscle-processes, which contrast to restore the equilibrium.

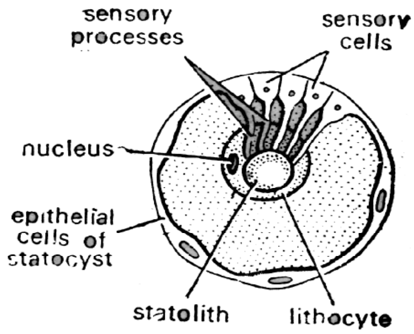


Fig.57 Statocyst

3.2.10 NUTRITION OF MEDUSA

The medusa is carnivorous. The food incudes minute worms (nematodes, insects, etc.). These are captured by nematocysts bearing tentacles and ingested by the highly contractile mouth. The prey is digested exclusively in the stomach. The digested food is distributed to the entire medusa through radial and circular canals. Undigested matter sent out through the mouth.

3.2.11 REPRODUCTION

Medusae are sexual reproductive zooids. Male and female medusae are separate or dioecious. There are four gonads (testis or ovary) on the subumbrellar surface of each radial canal. The gonads are formed as a ventral diverticular of the radial canals. The interstitial cells of both the layers migrate into the sacs and transform into germ cells. The germ cells are originate in the epidermis of the manubrium, when the medusa is still attached to the blastostyle. They migrate into the gullet and gonads. Here they undergo maturation divisions and transformed into the gametes. The outer wall (epidermis) of the mature gonads ruptures to release the gamets in water.

LIFE HISTORY OF OBELIA

Fertilization: Fertilization takes place in sea water, where the gametes are set free. Male and female medusae produce sperms and eggs respectively. They escape into the water by the rupture of the wall of the gonads. Hence, fertilization takes place externally.

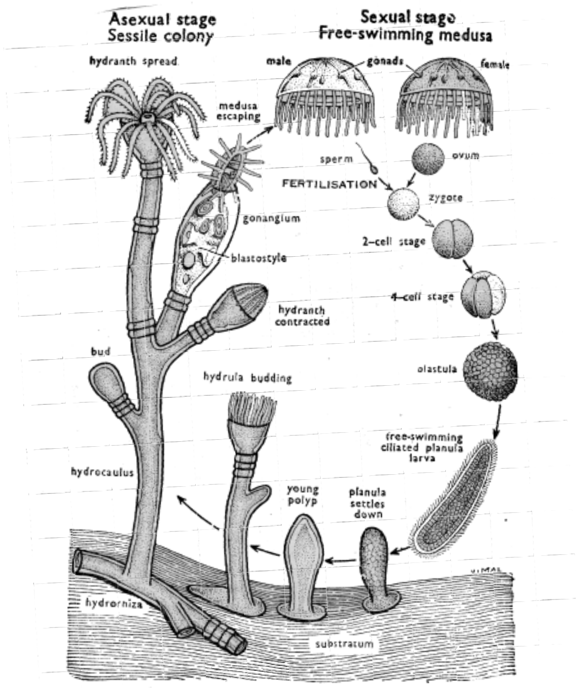


Fig.58 Life cycle of Obelia

3.2.12 DEVELOPMENT

The fertilized egg i.e., zygote undergoes equal holoblastic cleavage resulting in a mass of cells, the morula. This stage is called blastula and the cavity is blastocoel. The cells are called blastomeres. From the inner surface of the blastomeres cut off new cells which migrate into the blastocoel and fill it. The embryo is now called as Stereogastrula.

PLANULA LARVA

The stereogastula larva elongates. It has an outer most layer known as ectoderm and the inner mass of cells known as endoderm. The outer ectoderm acquires cilia and a free swimming planula larva results. The planula larva has an outer ciliated ectoderm and endoderm. After a brief active free swimming existence the larva settles down on a convenient substratum. The proximal end forms a basal disc for attachment and the distal free end develops a manubrium with a mouth and a circlet of tentacles. The larva now resembles a simple polyp called as hydrula. The hydrula gradually changes into a new branching Obelia colony.

3.2.13 METAGENESIS

Obelia exhibits alternation of generations. Medusa developed asexually by budding from the Obelia colony. Medusa reproduces by sexual process again gives rise the Obelia colony. Thus asexual and sexual generations alternate with each other. This process is known as alternation of generations. In earlier, this phenomenon referred as metagenesis.

Actually in alternation of generations a diploid stage is formed from a haploid stage. But in Obelia only sex cells are haploid and the colony and medusa are diploid. So Obelia do not exhibit alternation of generations. The sedentary Obelia colony is alternated with free swimming medusa. Both are diploid structures, where two diploid stages alternate with each other is known as metagenesis.

3.2.14 COMPARISON OF POLYP AND MEDUSA

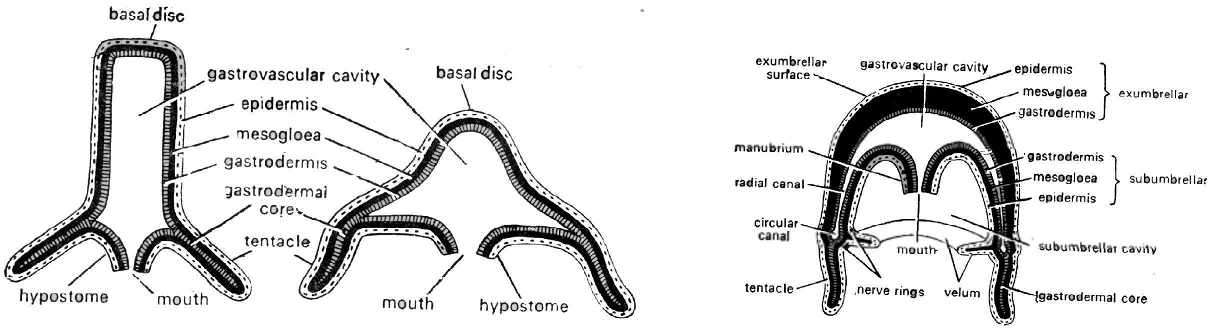
Polyp and Medusa are two different zooids. Polyp is nutritive zooid and the medusa is a reproductive zooid. Division of labour is seen in the colony.

POLYP	**MEDUSA**
1. Sessile and fixed	1. Free swimming
2. Body cylindrical and elongated	2. Body is circular and saucer shaped
3. Nutritive in function	3. Reproductive in function
4. The manubrium is directed upwards	4. The manubrium hangs downwards
5. Tentacles usually twenty four	5. 16 tentacles in young medusa numerous in adult.
6. Velum is absent	6. Velum present around the margin of the umbrella
7. Mesogloea is little and in a thin layer	7. Mesogloca is abundant
8. Gastovascular cavity simple and unbranched	8. Gastrovascular cavity includes stomach - four
radial canals and one circular canal.	
9. Mouth is circular	9. Mouth is rectangular
10. Sense organs are absent	10. At the base of eight adradial tentacles possess
marginal sense organs called statocysts.	
11. Gonads are absent	11. Four gonads are present on radial canals
12. Reproduces asexually by budding	12. Reproduces sexually by gametes

3.2.15 HOMOLOGY

Polyp and medusa show many differences externally, but they are homologous to each other. Similarity between the two is so close that one can be easily derived from the other. An inverted polyp at once assumes the medusoid form of its region of tentacles is pulled out and manubrium is pushed up. Thus the manubrium, subunibrellar surface, exumbrellar surface and tentacles of the medusa correspond to the manubrium, oral side, aboral side and tentacles of the polyps respectively. Moreover, both are radially symmetrical and diploblastic. In both cases, Gastrovascular cavity is lined by gastrodermis.

Similarly, if the exumbrellar surface of a medusa is pulled out and elongated, the cylindrical form like polyp will result.



A - Polyp in L.S B - Polyp oral-aborally compressed C - Medusa in V.S

Fig.59 Derivation of medusa from polyp

3.2.16 SUMMARY

Obelia geniculata is a colonial, sedentary coalenterate found in sea water. It consists of two types of zooids called polyps and Blastostyles. The third type of zooids, Medusae; are developed from blastostyle by budding. Polyps are cylindrical sac like zooids and nutritive in function. Blastostyles are cylindrical tubular zooids and reproductive in function. Medusae are saucer shaped or umbrella shaped zooids which are meant for sexual reproduction and dispersal. The body wall of all the zooids of obelia colony is diploblastic. Between the Ectoderm and Endoderm layers, non-cellular, jelly like mesoglea is present. Eight marginal sense organs are present in medusa called as statocysts. These are meant for muscular coordination and for maintaining equilibrium in water.

Polyp can reproduces only asexually and medusa reproduces only sexually. Fertilization takes place in sea water. Life history consists of a free swimming planula larva and hydra like hydraula stage. It exhibits metagenesis.

3.2.17 MODEL QUESTIONS

Mesoglea: Non-cellular, jally like substance present between the Ectoderm and Endoderm layers.

Hydrorhiza: Horizontal part of obelia colony.

Hydrocaulus: Vertical filaments of the obelia colony

Coelenteron: Body cavity of a obelia or a coelenterate

Otolith: A calcareous particle moves freely in the fluid of statocyst.

Planula: A free swimming larva of a Obelia.

3.2.18 MODEL QUESTIONS

1. Describe the life history of Obelia.
2. Describe the structure of Obelia
3. Write short notes on:
   (a) Planula & Hydrula
   (b) Polyp
   (c) Redusa

3.2.19 REFERENCE BOOKS

1. **A Textbook of Invertebrates.** N.C. Nair, Dr. S. Leelavathy, N. Soundra Pandian, N. Arumugam, Sara's Publications.
2. **Invertebrate Zoology.** P.S. Dhani & J.K. Dhani.
3. **Modern Textbook of Zoology - Invertebrates,** R.L. Kotpal, S.K. Agarwal and R.P. Khetarpal.

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Lesson 3.3
POLYMORPHISM IN SIPHANOPHORA

CONTENTS

3.3.1 OBJECTIVE

The purpose of this lesson is to develop an idea about the modifications of basic forms and its importance.

3.3.2 INTRODUCTION

The essential feature of polymorphism in coelenterata is the division of labour. Sometimes, a single organism or a colony may be represented by more than one kind of individuals or zooids which have different forms and perform different functions. Such an organism or a colony is said to be polymorphic and the phenomenon is called polymorphism. So, polymorphism can be defined as the representation of a single organism by more than one kind of individuals or zooids which differ in their form and function. Basically, the phenomenon is the division of labour, i.e., different zooids are assigned different functions.

The division of labour in a single individual or a colony becomes increasingly complex in the various coelenterate examples. The colonial forms like Obelia is dimorphic with two main types of zooids and Hydractinia is trimorphic with three types of special zooids for feeding, fighting and reproductive purposes.

Polymorphism in Siphanophora

The phenomenon of polymorphism attains its highest degree in the members of the order Siphonophora. The colonies of siphonophora (Physalia, Halistemma) possess more than four types of zooids which are the modified forms of either polyp or medusa.

3.3.3 MODIFICATIONS OF POLYP

The polyploid zooids are of three kinds. 1. Gastrozooid, 2. Dactylozooid, and 3. Gonozooid.

Gastrozoids (Siphons): These zooids serve to feed the colony. These are the only zooids capable of ingesting the food. Each gastrozooid is tubular with a mouth. At the base of the gastrozooid arises a single, extremely long and contractile hollow tentacle. This tentacle bears lateral contractile branches called tentilla which end with coils of nematocysts in the form of knobbed structures. In case of Velella, the gastrozooid bears no tentacle.

Dactylozooids: These are also called palpons, feelers or tasters. These are the protective zooids. They resemble the gastrozooid but they are devoid of mouth and the basal tentacle is never branched. In Physalia, the tentacles become very long filaments extending for great distances into the sea.

Gonozooids: These are the reproductive zooids. They are devoid of mouth and produce sexual medusoids by asexual budding. They may also possess a mouth as in velella and porpite. Sometimes, the gonozooids are branched and are termed the gonodendra. They bear grape-like clusters of gonophores and are associated with gonopalpons

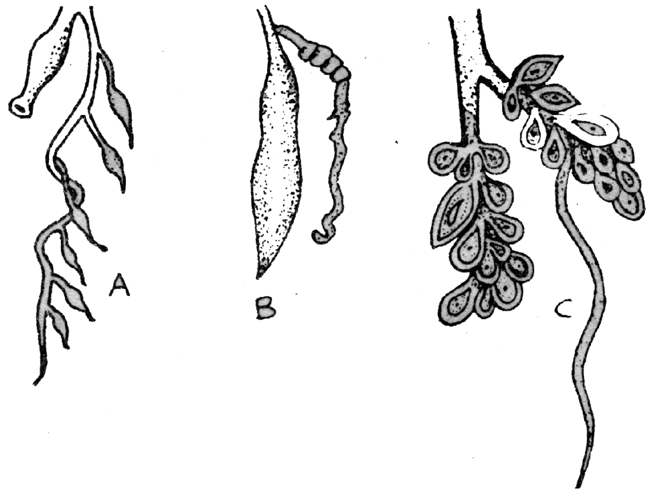

Fig.60 A) Gastrozooid; B) Dactylozooid; C) Gonozooid

3.3.4 MODIFICATIONS OF MEDUISAE

The meduzoid forms include 1. Pneumatophore, 2. Nectophores, 3. Bracts, and 4. Gonophores.

Pneumatophore (float): It functions as a float. It represents an inverted medusan bell devoid of misogloea. Pneumatophore exhibits great variation in size and structure in different siphonophoes. It is very small in Halistemma but very large and ovate in physalia. In porpita, it is disc shaped. In Velella, the float is thin and bears an erect sail.

Nectophores: These are swimming bells variously called nectozooids, nectocalyces and metaphores. They are devoid of mouth, manubrium, tentacles and sense organs. The musculature is well developed. So that, the swimming bells have excellent swimming powers and serve for the locomotion of the colony.

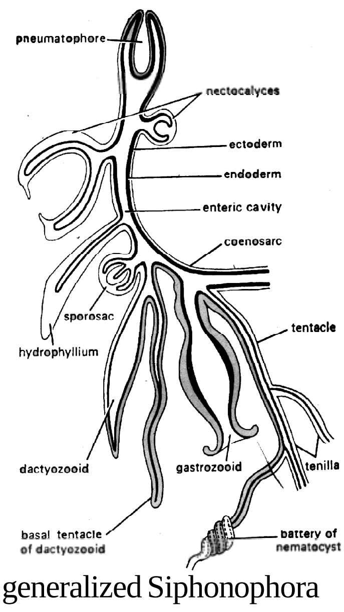

Fig.61 Diagram of a generalized Siphonophora

Bracts: These are also known as hydrophyllia or phyllozooids. They are with thick mesogloea and branched gastro-vascular cavity. They are variously shaped as leaf-like, shield-like, prism-like or helmet-shaped. Generally, the leaf-like expansion of bract protects by covering the other zooids n a colony.

Gonophores: These serve for sexual reproduction. They occur in clusters on polyploid gonozooids as in Velella or simple or branched gonodendra as in physalia. The gonophores may resemble the bell-like medusae with velum, radial canals and manubrium. But they are devoid of mouth, tentacles and sense organs. The female gonophores are medusa-like as in physalia but the male gonophores reduced to sac-like bodies. They remain attached to the colony as in male physalia or set free as in female physalia, porpita and velella.

3.3.5 TYPES OF COLONIES

The following members of Siphonophora show the highest degree of polymorphism which is not found anywhere else in the animal kingdom.

Physalia: It is commonly known as Portuguese man-of-war. It is a polymorphic colony found floating in tropical and sub-tropical oceans. It consists of four types of zooids –

1. Pneumatophore for floatation
2. Gastrozooid for nutritive function
3. Dactylozooid for protection
4. Gonozooids for reproduction

Pneumatophore is a large gas-filled structure formed by several medusoids. It contains gas glands which produce a gas having 90% nitrogen, 9% oxygen and 1% organ. Below the pneumatophore, there are several cormidia which are modified polyps. Each cormidium consists of gastrozooids, dactylozooids and gonozooids gastrozooids are tubular with a mouth but lack tentacles. They serve to feed the colony. Dactylozooids are like the gastrozooids in their shape but lack of mouth and each bears a long tentacle at the base. This long tentacle consists of strong muscles and a twisting ribbon of nematocysts. The dactylozooids protect the colony and also help in capturing the prey. The gonozooids or gonodendrae possess leaf-like gonopalpous and clusters of male and female gonophores. Thus physalia exhibits a remarkable polymorphism in Siphonophora.

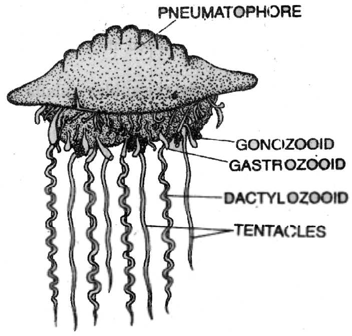

Fig.62 Physalia

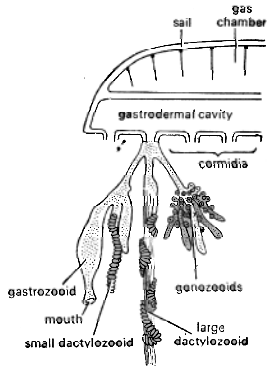

Fig.63 Physalia - single carmedium

Velella: It has four types of zooids as in physalia. Sometimes, it is referred to as "sail-by-the-wind" or the "little soil". It is a polymorphic, free-floating colony. It has a rhomboidal body and bears on its upper surface on oblique soil. The soil is divided internally ito a number of gas-filled chambers which keep the colony on the surface of water. From the middle of the body, hangs a single, large gastrozooid. It possesses mouth but lack tentacles. It feeds the colony. The margin of the body bears long, hollow and tentacle-like dactylozooids having nematocysts. These dactylozooids are called tentaculozooids. They protect the colony. The gonozooids bear clusters of medusae-like gonophores. They release gametes and soon die as they cannot feed.

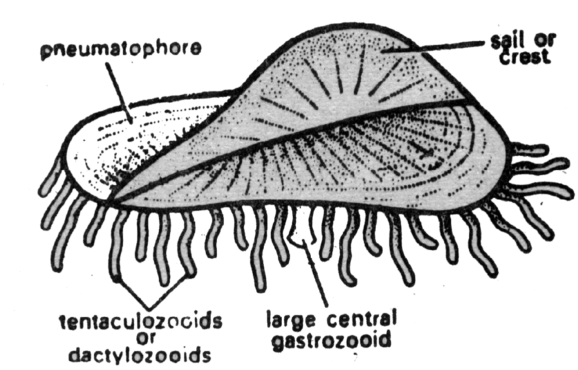

Fig.64 Velella

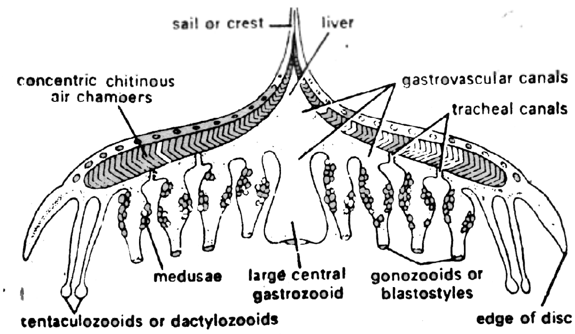

Fig.65 V.S. of velella

Porpita: It has four types of zooids as in velella. It resembles Velella in all respects except that it lacks soil. It has a large disc-like body with a chitinous, chambered pneumatophore containing air. The air chambers open to exterior by minute pores. Internally, the air chambers are connected with a tracheal system. A single gastrozooid hangs down from the centre of the body. Surrounding the single gastrozooid, there a number of tubular gonozooids. The n

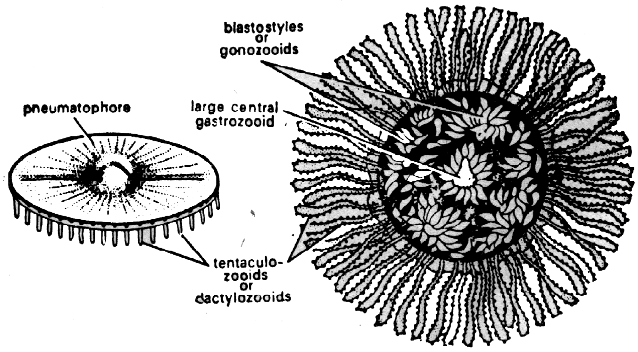

Fig.66 Porpita - Dorsal view and Ventral view

Halistemma: Polymorphism reaches its climax in Halistemma. It consists of more than six types of zooids arranged on long, slender stem with a small float on the top. It appears as a single individual floating in water. The upper end of the stem has a small gas-filled pneumatophore. Below the pneumatophore, there are several swimming bells or nectocalyces. These swimming bells arranged in pairs, are transparent and look like medusac. They possess velum, musculature and canal system but lack of manubrium. By their rhythmical muscular contractions, they propel the colony through water. Below the swimming bells, the long and slender stem gives rise to groups of zooids at regular intervals. Each group of zooids is known as a cormidium.

A carmidium has a gastrozooid, dactylozooids, hydrophyllium and gonozooids. Each gastrozooid has a cylindrical body with a mouth opening and a long branched tentacle bearing numerous nematocysts. The food collected and digested in these zooids is supplied to all the other zooids of the colony through a continuous coenosarc. Dactylozooid also has a cylindrical body but devoid of mouth. It bears a long unbranched tentacle which is sensory and contractile. It gives protection and serves to collect he prey. The hydrophyllium or bract is a leaf-like expansion which covers and protects the other zooids in a coramidium. The gonozooids are the reproductive zooids. These are unisexual and bear either male or female gonophores.

According to some zoologists, the "polymorphic" body of a siphonophore is regarded as a "colony". But according to others, it is considered as a "single individual".

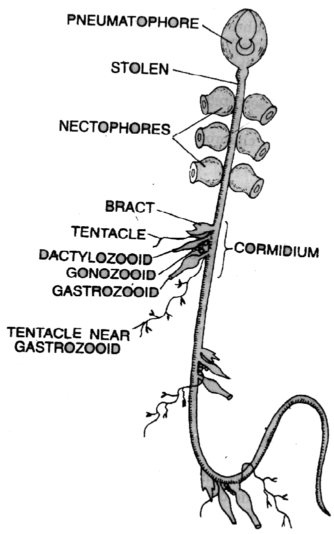

Fig.67 Halistemma

3.3.6 SUMMARY

Polymorphism is shown by certain coelenterate colonies formed by organic union of zooids. The main zooids like Polyp and Medusa have undergone various functional modifications. In Siphonophora, Polymorphism is more remarkable. The colonies drift in water and consist of pneumatophore (float), Nectocalyces (swimming bells), gastrozooids (Nutritive zooids), Dactylozooids (finger like feelers) and reproductive zooids. The colonies like Halistemma, Physalia, Velelle are the best examples of polymorphism.

3.3.7 KEY TERMINOLOGY

Dactylozooids: Also called palpons, feelers and tasters. They give protection to the colony.

Nectophores: These are swimming bells. Also called Nectozooids or Nectocalyces. They serve for the locomotion of the colony.

Cormidium: A group of zooids. Each group consists of a gastrozooid, Dactylozooid, gonozooid and hydrophyllium.

Physalia: Commonly called as Portuguese man of war. It is a polymorphic colony.

Halistemma: A polymorphic colony exhibiting the maximum polymorphism.

Pneumetophore: Acts as a float.

Gonozooids: Meant for reproduction.

3.3.8 MODEL QUESTIONS

1. Give an account of Polymorphism in Siphonophora.
2. Write short notes on:
   (a) Modifications of Polyp
   (b) Modifications of Medusa

3.3.9 REFERENCE BOOKS

1. **Coelenterata** by R.L. Kotpal.
2. **Invertebrate Zoology** by Jordan
3. **Invertebrate Zoology** by Dhami & Dhami

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Lesson 3.4

CORALS AND CORAL REEF FORMATION

CONTENTS

3.4.1 OBJECTIVE

The purpose of this lesson is to understand the coral formation, types of corals, types of coral reefs and formation of coral reefs.

3.4.2 INTRODUCTION

The corals are hard materials secreted by the living polyps of same colonial coelenterates in the sea water. Generally, the term coral is applied to the strong supporting skeleton of the coelenterate animals secreted by ectoderm. The ectoderm of the living polyps secretes calcareous substance of calcium carbonate. Most of the coral farming polyps belong to the class Anthozoa and few others to the class Hydrozoa. The red corals, blue corals, black corals and organ-pipe corals are alcyonarians but the true or stony corals belong to the order Madreporaria.

3.4.3 FORMATION OF CORALS

The coral polyp is just like a sea-anemone in structure except that it produces a skeleton of calcium carbonate. In the formation of a coral, first a calcareous basal plate is secreted between the ectoderm of the basal disc and substratum. On this calcereous basal plate, a number of vertical plates or ridges called septa are secreted. These septa grow in length and push up the base of the polyp. At the same time, a cup-like theca is formed on the basal plate by the union of the outer edges of the septa. The inner edges of the septa fuse together to form a calcareous pillar called the **Columella** in the centre of the coral. Thus, the cup-like coral consists of a basal plate, thece, central columella and number of vertical septa connecting the theca and columella. All these forms, the exoskeleton of a polyp. The exoskeleton of a single polyp is called a **Corallite** and the exoskeleton of the entire colony is known as **Corallum** (i.e. thousands of corellites are fused together).

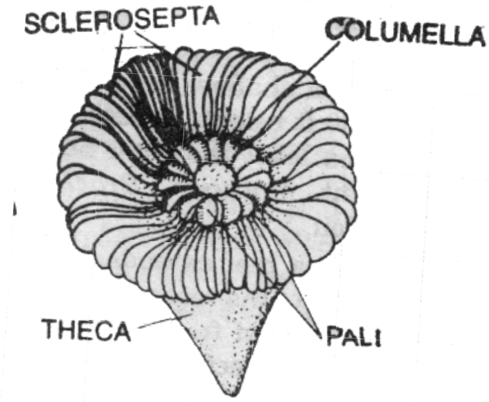

Fig.68 Corallite

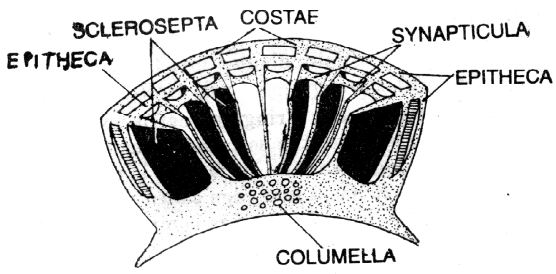

Fig.69 Section of a Coral skelton

3.4.4 TYPES OF CORALS

The corals are of two main types. (1) Hydrozoan corals, and (2) Anthozoan corals.

Hydrozoan corals: Among the hydrozoan corals, the Millipora and Stylaster form a massive calcaereous skeleton. Their epidermal cells called calicoblasts secrete an exoskeleton of calcium carbonate. The exoskeletonof all polyps in the colony fuse together and form large massive corals. the polyps of the colony contain large nutritive gastrozooids and small protective dactylozooids.

Anthozoan corals: Among the anthozoan corals the simplest form of skeleton is found in the soft corals like **Alcyonium** (Dead-Man's figner) in which mesogloea consists of numerous calcereous spicules. It is found in the warm shore waters, especially in the Indo-Pacific Ocean.

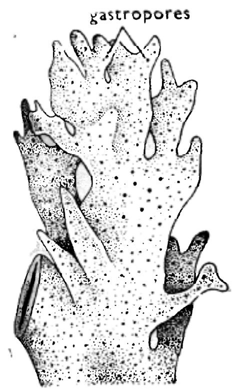

Fig.70 Millipora

In the Tubipora (Organ-pipe-coral) the skeleton is made up of fused calcareous spicules which form vertical parallel tubes connected together by plate forms. The polyps are green and reveal the dull red skeleton when they retract into the tubes.

Corallium: It (The Red Coral of Commerce) grows on the rocky bottoms in the central and western Mediterranean Sea. The skeleton of corallium is extremely hard, dense solid and branched. It is mainly formed by the accumulation of numerous red spicules in a cement like secretion.

Gorgonia (Sea fan): It is a much branched colony. The polyps secrete a horny proteinaceous material along with caleareoes spicules. The dried skeleton of sea-forms are often displayed as ornaments.

Heliopora (Blue coral): The order Coenothecalia includes a single genus Heliopore (Blue coral). In this coral, the polyps secrete caleareous spicules to form a massive skeleton called corallium. The skeleton is of blue colour which is more or less masked during life time by the brown colour of the polyps. These are generally found on the coral reefs in the Indo-Pacific ocemen.

In the order Madreporaria (true or stony corals) the skeleton is completely calcereous and is secreted by the ectoderm fro the basal region towards the oral region. The important sotny corals are: 1. Fungia (Mushroom coral), Meandrina (Brain coral), Astraea (Star-coral), Aecropone (stag-horn coral), Favia etc.

Antipathes (Black corel): It belongs to the order Antipatharia the colony looks like a true and its skeleton consists of branched chitinoid axis.

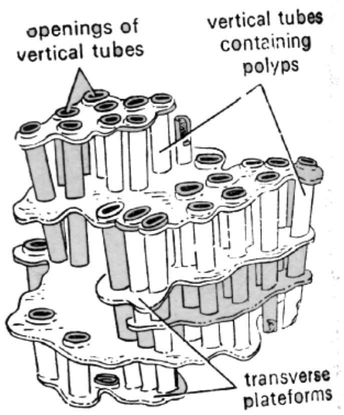

Fig.71 Tubipora

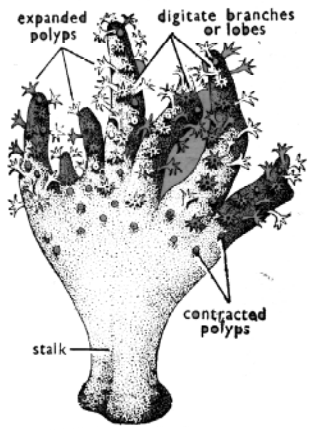

Fig.72 Alcyonium

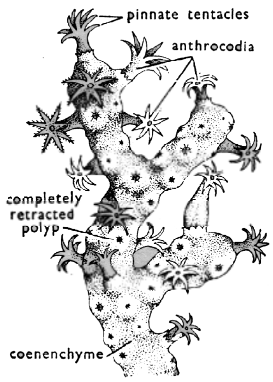

Fig.73 Corallium

3.4.5 CORAL REEFS

A coral reef is a ridge or mould of lime stone, the upper surface of which is near the surface of the sea.

Suitable conditions of reef formation:

The reef building corals require warm and shallow waters. The coral reefs grow best at the depth of about 30 metres or less. They show the maximum growth at about 22^{o}C. They fail to grow in dark shaded areas and completely die in total darkness. The corals which occur below the depth of 50 metres do not build reefs. Excessive rain and fresh water are also fatal to the corals.

Components of coral reefs:

The true or stony corals of Madreporaria play an important role in the formation of coral reefs. In addition to the stony or true corals, the other components which take part in formation of coral reefs are – Millipora, Tubipora, Heliopora, Alcyonaria, Gorgonians, Antipathes, shells of Foraminifema, sponges, star-fishes, sea-wichins, bivalves, Coralline algae etc.

3.4.6 TYPES OF CORAL REEFS

Coral reefs are of three types:

1. Fringing reef
2. Barrier reef
3. Atoll reef

1. Fringing reef: These are also called shore reefs. It forms in shallow waters extending from the shore to a distance of about 400 metres into the sea water. It consists of an elevated reef front in the sea. The shallow area between the reef front and shore is called reef flat. A greater part of the reef is exposed during low tide. So it is not navigable. A fringing reef has seaward slope on which corals grow. These reefs are quite common in East Indies.

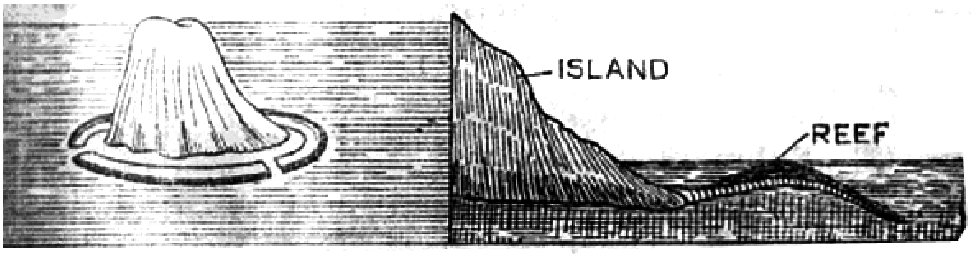

Fig.74 Fringing reef

2. Barrier reef: In this reef, the reef front is away from the sea shore more than a mile to few miles. So, the reef flat is more deeper and these forms a water lodged area known as lagoon. The area of lagoon is not usually exposed during low tide. The depth of lagoon may be 15 to 75 metres or even more. So that, it becomes navigable.

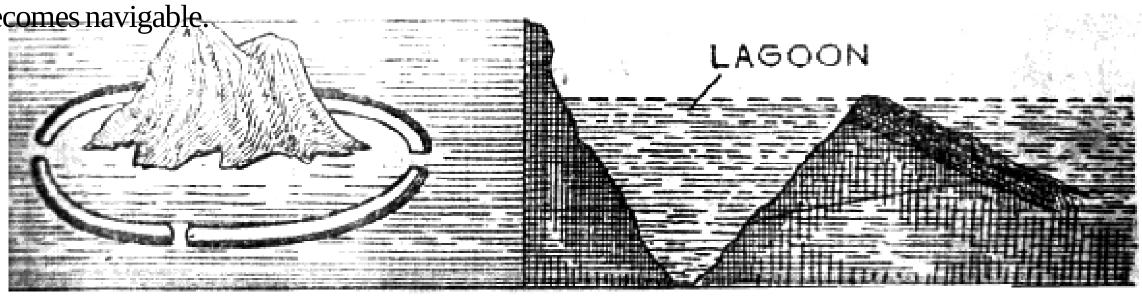

Fig.75 Barrier - reef

The Great Barrier Reef of the north-east coast of Australia is the most well known barrier reef in the world. It is over 1920 kilometres long and about 20-80 kilometres wide. The reef is situated nearly 1440 kilometres away from the shore.

3. **Atoll reef:** It is also known as coral island or a lagoon island. It is horse-shoe-shaped or circular reef enclosing a wide water lodged area (lagoon). The lagoon may be small or large upto 80 kilometres across. The rim of atoll may be complete or broken to form a number of channels. The floor of the lagoon contains dead corals, sand, mud and some living corals. Animal life on this reef may be sparce or very rich depending on the local conditions.

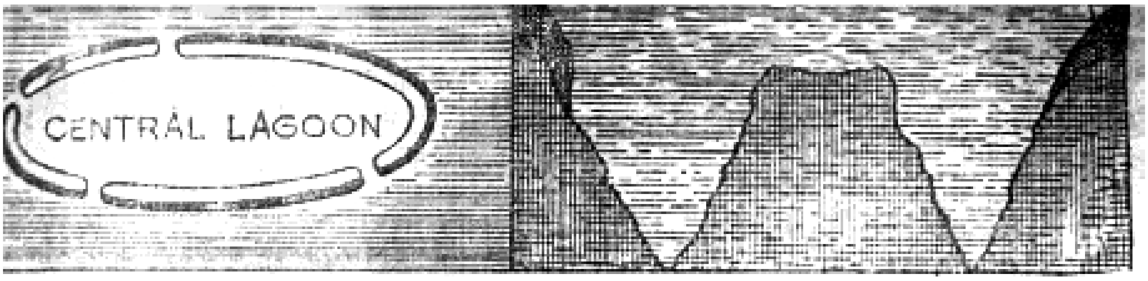

Fig.76 Atoll - reef

The best known coral islands are Maldive islands of Indian ocean, the Figi islands of pacific ocean and those located in the Bahama islands region. Bermuda is a coral island where the houses are built of coral blocks.

3.4.7 FORMATION OF CORAL REEFS

Many theories have been put forward to explain the formation of coral reefs.

1. Darwin-Dana subsidence theory

According to this theory, the coral reefs first, begin as the fring reefs with the reef front nearer to the sea shore and with a shallow reef flat. This reef becomes barrier reef by the deepening or sinking down of the reef flat. So that, a lagoon forms between the reef front and the shore. If the island sinks completely, then an atoll is formed.

2. Semper-Murray solution theory

According to this theory, the corals grow on high summits or coral platforms. These summits may be raised by the deposits of debris. But this theory is now totally discarded.

3. Sub-merged Bank theory

According to this theory, the coral reefs are formed on the pre-existing flat surfaces which are partly or greatly submerged in water.

4. Daly Glacial – Control theory

It is believed that during the last glacial period, great ice caps were formed in the oceans. Because of these huge ice caps, the level of the sea had lowered to an extent of 60-70 miles below the present surface. So that, flat surfaces, suitable for coral growth were formed. After that, with the rise in temperature, the ice melted and the sea level gradually increased again. The growth of the coral ref was in proportion to rise in water level.

3.4.8 SUMMARY

The term coral is applied to the strong supporting skeleton secreted by the ectoderm of coelenterate animals. Apart from the calcareous hydrozoan corals (Mille-porina and Stylasterina), in a majority of the Anthozoa especially in Madreporaria, there is an ectodermal skeleton formed of chitinoid material or horn-like material or calcium carbonate. The cora reefs are the enormous ridges or elevated masses of uncountable stony corals projecting into the sea water. Although the main part of a coral reef consists of the calcareous secretions of the coral polyps, the reef includes all sorts of hard materials like the sheels, hydrozoan corals, calcified alcyonarians etc., The reef-building corals can flourish only at sufficient temperatures (above 22^0C) and in shallow waters. So, the coral reefs are found only in tropical and sub-tropical shores. There are three types of coral reefs-fringing reefs, barrier reefs and atols.

3.4.9 KEY TERMINOLOGY

Coralite : A cup like coral of a single polyp.

Coral reef : It is a enoromous ridges or elevated masses of uncountable stony corals projecting into the sea water.

3.4.10 MODEL QUESTIONS

1) Write on essay on coral-reefs
2) Give an account of the corals and explain their formation
3) Write short notes on a) coral formation b) Anthozoan corals.

3.4.11 REFERENCE BOOKS

1. **Coelenterata** by R.L. Kotpal.
2. **Invertebrate Zoology** by Jordan
3. **Invertebrate Zoology** by Dhami & Dhami

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Lesson 4.1
PLATYHELMINTHES (Flat Worms)
GENERAL CHARACTERS & CLASSIFICATION

CONTENTS

GENERAL CHARACTERS AND CLASSIFICATION

4.1.1 INTRODUCTION

In cnidarians the body consists of three layers the ectoderm and endoderm separated by non-cellular mesogloea called mesoderm. The formation of a mesoderm between ectoderm and endoderm resulting complexity of the body. Animals built on this three layered plan are called triploblastic. Definite organs and organo systems are seen in these animals. A term platyhelminthes which means 'flat worms' was coined by Gaugenbaur in 1859. This group consists of lowest triploblastic animals in which coelome is absent. Hence they are called acoelomates. This phylum include free living planarians, parasitic trematodes and cestodes.

4.1.2 GENERAL CHARACTERS

1) The body of platyhelminthes is dorsoventrally compressed.
2) Body wall consists of three layers. Outer ectoderm, inner endoderm and in between mesoderm. Hence they are triploblastic animals.
3) Platyhelminthic organisms are bilaterally symmetrical. A definite coelomic cavity is absent. The space between the various organs and the body wall is filled with mesenchyme or parenchyme. Hence they are acoelomates.
4) Segmentation is absent. The anterior end has a prominent head, head like or scolex.
5) A definite mouth is present in many animals. But absent in cestoda.

6) A definite alimentary canal is in turballaria and trematoda. But absent in cestoda. Anus is absent.
7) Respiratory system is absent. Respiration is carried out by anaerobically.
8) Excretory system is consists of protonephridia with flame cells.
9) Nervous system consists of a pair of cerebral ganglia and three pairs of longitudinal nerve cords.
10) Flat worms are hermaphrodites.
11) Many vitalline glands are present which secrete yolk to the eggs in reproductive system.
12) A single genital pore is present in atrium for both male and female reproductive systems. Definite copulatory organs are present. Fertilization is internal and direct development with distinct larval stages.
13) Planaria are free living. But many are parasitic.

4.1.3 CLASSIFICATION

Phylum platyhelminthes is classified in to three classes.

a) Turbellaria b) Trematoda c) Cestoda.

Class 1 : TURBELLARIA

1) Turbellaria are mostly free living flat worms. Few are fresh water, some are land living and many are marine forms.
2) Cilia are present on ectodermis. Rhabdites are present which are rod like. Mucous glands are present on the body.
3) Body is flat and leaf like and mouth is present on ventral side.
4) A distinct head region is present.
5) In development larval stages are seen.

This class divided in to five orders.

Order 1. Acoela

1) Minute turbellarians measuring about 2m.m.
2) Ventral mouth is present, muscular pharynx and intestine are absent.
3) Flame cells, definite gonads and yolk glands are present.
4) Some are symbiotic.
   Examples: Convoluta, Ectocotyla.

Order 2. Rhabdocoela

1) Small turbellarians, measuring about less than 3m.m.
2) Simple pharynx and sac like intestine.
3) Two ventral longitudinal nerve cords are present.
4) One or two gonads; yolk glands usually present.
5) Protonephridial excretory system are present.

Examples: Microstomum, Stenostomum.

Order 3. Alloecoela

1) Measuring about 1 to 10m.m.
2) Pharynx simple, intestine straight or branched.
3) Protonephridia paired.
4) Four pairs of longitudinal nerve cords are present.
5) Testes numerous.
6) Mostly marine, some are fresh water.

Examples: Plagiostomum, Prorhynchus.

Order 4. Tricladida

1) Large turbellarians, measuring 2 to 60cm length.
2) Mouth mid-ventral, pharynx plicate and intestine with three branches.
3) Eyes are present.
4) Protonephridia with nephridiopores are present.
5) Testes numerous, ovaries two and yolk glands are present.
6) Marine, fresh-water or terrestrial.
   Examples: Dugesia, Bipalium.

Order 5. Polyclaida

1) Measuring about 2 to 20m.m.
2) Body flattened and oval shape. Pharynx plicate intestine with branched diverticula.
3) Nerve cords and eyes numerous.
4) Gonads many and scattered; yolk glands absent.
5) Male and female gonopores are separate.
6) Mar

Exa na.

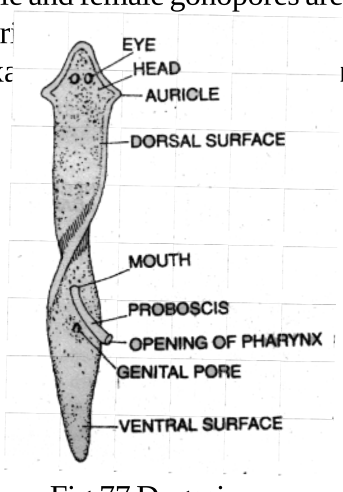

Fig.77 Dugesia

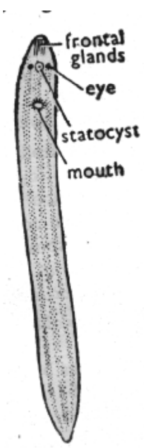

Fig.78 Convoluta

Class 2 - TREMATODA

1) This class includes all parasitic animals. All are endoparasitic.
2) Cuticle is present all over the body.
3) Body is flat, leaf like structure.
4) Body wall contains some spines or spinules.
5) One or more suckers are present for adhesion.
6) Mouth is anterior and alimentary canal with pharynx and branched intestine.
7) Mostly hermaprodites with single ovary and two testes.
8) Fertilization is internal. Life cycle complicated with larval stages.

This class divided into three orders.

Order 1. Monogenea

1) Mostly ectoparasites in cold blooded, aquatic vertebrates.
2) Life cycle complete in single host.
3) Posterior adhesive organ present with hooks or horny spines.
4) Two excretory pores situated anteriorly on the dorsal side.
5) Male and Female genital pores are separate.
6) Vagina one or two, uterus small with a few shelled eggs.
7) Free swimming ciliated larva, oncho miracidium is present.

This order divided in to two sub orders:

Sub order (i). Monopisthocotylea

Examples: Dactylogyrus, Benederia.

Sub order (ii). Polyopisthocotylea

Examples: Polystom, Doplozoon.

Order 2. Digenea

1) Mostly endoparasitic.
2) One, two are many intermediate hosts in the life cycle.
3) Two suckers, i.e., oral sucker around the mouth and the ventral sucker.
4) Single posterior excretory pore present.
5) No vagina; uterus long with numerous shelled eggs.
6) Life cycle complex with numerous larval stages in two or three intermediate hosts.
7) Larval forms reproduce asexually before metamorphasis.

This order divided in to two sub orders.

Sub order (i). Gasterostomata

Examples: Bucephalus, Rhipidocotyle.

Sub order (ii). Prostomata

Examples: Schistosoma, Paramphistomum, Opisthorchis.

Order 3. Aspidobothrea

1) Sucker covering the entire ventral surface.
2) One testis in male reproductive system.
3) Endoparasitic in the gut of fishes and reptiles.

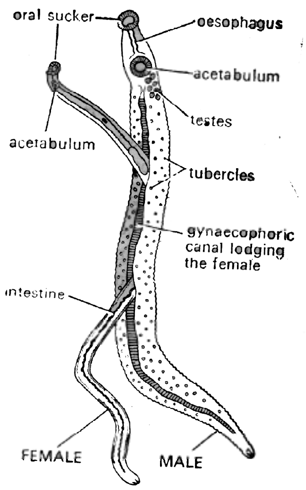

Fig.79 Schistosoma

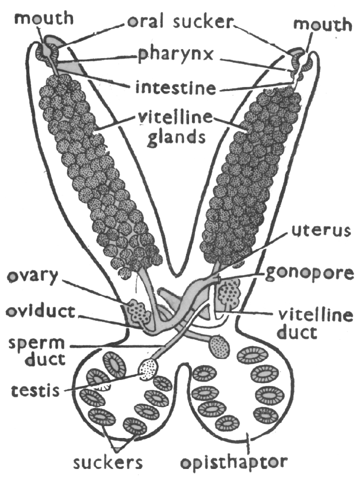

Fig.80 Diplozoon

Class 3. CESTODA

1) Endoparasitic in coelom and intestine of vertebrates.
2) Body is elongated ribbon like and divided into many segments or proglottids.
3) Cilia are absent.
4) Epidermis absent. But the wall consists of thick cuticle. At the anterior end scolex is present; which bears restellum and suckers. Hooks are present on the rostellum.
5) Mouth and digestive system are totally absent.
6) Excretory system is well developed with flame cells.
7) Cestodes are hermaprodites. Each matured proglottids contains both male and female reproductive

organs.

8) Life cycle is complicated with embryo's having hooks.

This class divided in to two sub classes.

Sub class 1. Cestodaria

1) No scolex and strobila.
2) One set of monoecious reproductive system.
3) No alimentary canal.
4) Larva with 10 hooks.
5) Endoparasites in the intestine and coelomic cavities of fishes and reptiles.

Order 1. Amphilinidea

1) No suckers, protrusible pharynx and frontal glands present.
2) Male genital pore situated posteriorly. Uterus coiled.
3) Endo parasitic in coelom of primitive fishes.

Example: Amphilina.

Order 2. Gyrocotylidea

1) Anterior sucker and posterior rosette shaped adhesive organ are present.
2) Eversible proboscis at the anterior end.
3) Uterus straight.

Example: Gyrocotylea.

Order 3. Biporophyllidea

1) Probascis present at the anterior end.
2) Male and Female genital pores in a common atrium.
3) Uterus sac-like.
4) Endoparasitic in intestine of sharks.

Example: Biporophyllaeus.

Sub class 2. Eucestoda

1) Body divided into scolex, neck and strobila.
2) Scolex with adhesive structure.
3) Mostly with several sets of monoecious reproductive organs.
4) Larvae with six hooks.

5) Endoparasites in the gut of vertebrate hosts.

Order 1. Proteocephala

1) Scolex mobile with four cup-shaped suckers.
2) Common genital atrium is marginal.
3) Ovary bilobed; uterus with many lateral diverticula.
4) Parasitic in fresh-water fishes, amphibians and reptiles.

Examples: Ophiotaenia, Protocephalus.

Order 2. Tetraphyllidea

1) Four leaf-like out growths (bothridia) on scolex.
2) Common genital atrium marginal.
3) Testes anterior to ovaries.
4) Vitelline glands scattered into lateral bands.
5) Parasitic in intestine of clasmobranch fishes.

Example: Phyllobothrium.

Order 3. Disculiceptidea

1) Scolex with large cushion-like pad at anterior end.
2) Common genital atrium on the ventral side.
3) Testes numerous; uterus lobed.
4) Endoparasites in selachii.

Example: Disculicepis.

Order 4. Pseudophyllidea

1) Scolex with dorsal and ventral bothrium.
2) Genital apertures on mid-ventral side.
3) Testis numerous, ovary bilobed.
4) Vitellaria follicular.
5) Parasitic in fishes.

Examples: Haplobothrium, Dibothriocephalus.

Order 5. Trypanorhyncha

1) Scolex with two or four bothria and four tentacles armed with hooks or spines.
2) Vitellaria in continuous layer in corticle parenchyma.

3) Genital pores lateral; uterine opening ventral.
4) Testes extend beyond ovary posteriorly.
5) Parasitic in elasmobranches.

Examples: Hepatoxylon, Grillotia.

Order 6. Cyclophyllidea

1) Scolex with four larged suckers with crown of hooks.
2) Genital pores one on both margins.
3) Ovary multi-lobed.
4) Vitellaria follicular.
5) Parasitic in amphibians, reptiles, birds and mammals.

Examples: *Echinococcus, Taenia.*

Order 7. Aporidea

1) Scolex usually without suckers.
2) No external segmentation on strobila.
3) No ootype; vitellaria present.
4) No external apertures of male and female genital systems.
5) Parasites in birds.

Examples: *Nematoparataenia, Gastrotaenia*.

Order 8. Nippotaeniidea

1) Scolex with single well developed suckers.
2) Proglottides few with one set of reproductive organs.
3) Parasites in fishes.

Examples: *Nippotaenia, Amurotaenia.*

Order 9. Caryophyllidea

1) Body unsegmented.
2) Genital and uterine apertures are present on the flat surface.
3) Eggs are non-embryonated when laid.
4) Parasites in fishes.

Examples: *Caryophyllaeus, Glaridacris*.

Order 10. Spathobothridea

1) Scolex without suckers.
2) Strobila with internal segmentation.
3) Genital pores on external surface.
4) Testes are medullary.
5) Parasites in primitive fishes.

Examples: *Bothrimonus*, *Diplocotyle*.

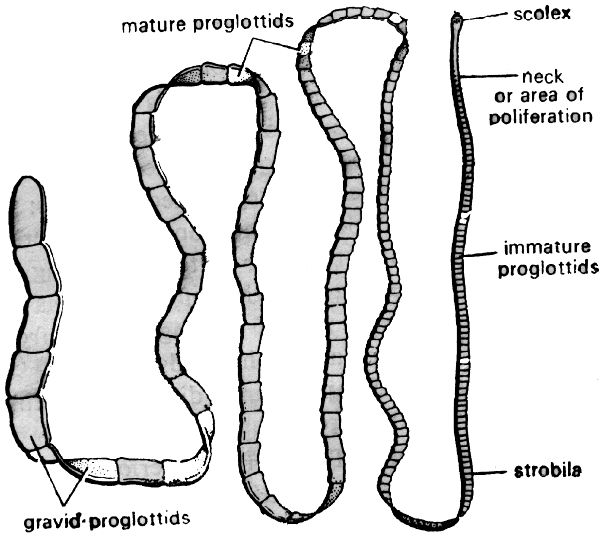

Fig.81 Taenia

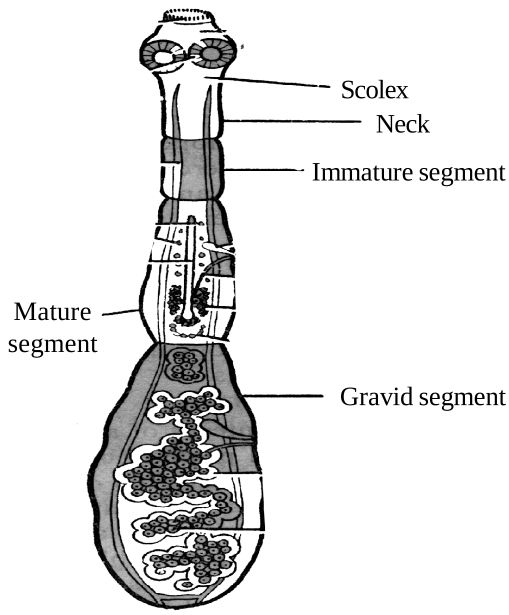

Fig.82 Echienococcus

4.1.4 SUMMARY

- The body is made of three layers – Ectoderm, endoderm and mesoderm.
- The body of platyhelminthes is dorsoventrally flattened.
- Platyhelminthes are bilaterally symmetrical.
- Segmentation is absent.
- In some flat worms coelom is absent, hence called acoelomates.
- Anarobic respiration is seen.
- Excretory system is made with flame cells.
- Flat worms are hermophrodites.
- Definite copulatory organs are present. In the development several larval stages are seen.
- Planaria are free living, but many are parasitic.

4.1.5 KEY TERMINOLOGY

Digenetic parasite: A parasite has a complex life-history with several larval forms and with one or more intermediate hosts is known as digenetic parasite.

Ectoparasite: A parasite that lives on the surface of the host's body is called Ectoparasite.

Endoparasite: A parasite that lives in the host's body is termed as Endoparasite.

Hermophrodites: Both male and female reproductive organs are present in the same animal.

Monogenetic parasite: A parasite has a simple life history and without intermediate host is known as monogenetic parasite.

4.1.6 MODEL QUESTIONS

1. Write an essay about general characters of platyhelminthes.
2. Classify the phylum platyhelminthes upto orders level.

4.1.7 REFERENCE BOOKS

1. **Modern textbook of Zoology – Invertebrates**. R.L. Kotpal, S.K. Agarwal and R.P. Khatarpal.
2. **Invertebrate Zoology**. E.L. Jordan, P.S. Verma.

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Lesson 4.2
FASCIOLA HEPATICA (Liver Fluke)

CONTENTS

Classification:
Phylum - Platyhelminthes
Class - Trematoda
Order - Digenea
Genus - Fasciola
Species - Hepatica

4.2.0 OBJECTIVE

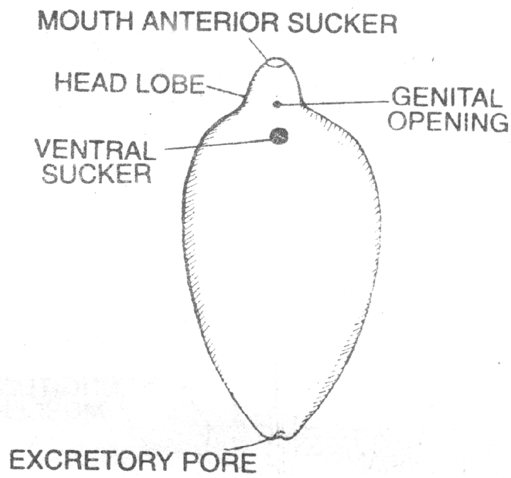
The purpose of this lesson is:

To know the structure of Fasciola.
To understand the systems of Fasciola
To have an idea about the complexity of life history of Fasciola

4.2.1 INTRODUCTION

Fasciola hepatica was first found by Jehan de Brie in 1379 in the liver of sheep in France. It is an endoparasite in the bile ducts of sheep. The disease caused by *Fasciola hepatica* is known as 'Liver rot'. It is cosmopolitan in distribution. *Fasciola indica* is another familiar species in India, liver in bile ducts of buffalos, cows, goats and pigs. The life history of *Fasciola hepatica* was completely worked out by Thomas in 1883. This a digenetic parasite, i.e., its life history is completed in two hosts, a primary vertebrates host and a secondary invertebrate host.

4.2.2 STRUCTURE



Fasciola hepatica has dorso-ventrally compressed body. It has thin, flattend leaf shaped body about 25-30 mm in length and 12 mm in breadth. The live animal is reddish brown on account of bile fixing the digestive system of the parasite in colour. The anterior end of the body is broad and the posterior part of the body is narrow. The anterior end drawn out has a conical projection called the head lobe / cephalic cone. The tip of the head lobe has an aperture on ventral side called mouth. It is surrounded by a muscular sucker known as oral or anterior sucker. A little behind the head lobe on the ventral surface, there is a cup shaped, glandular muscular organ called ventral sucker / acetabulum. Anterior to the acetabulum a common genital aperture called gonopore lying ventrally. Gonopore is a common opening for male and female reproductive systems. At the extreme posterior end of the body excretory pore is present.

Fig.83 Fasciola- Entire Animal

4.2.3 BODY WALL

The body wall consists of three layers: 1) Cuticle, 2) Muscle layers, 3) Mesenchyma cells.

1) **Cuticle:** It is a non-chitinous thick, tough outer most layer called as tegument. Cuticle consists of syncytial cytoplasmic layer from underlying parenchyma. In this layer endoplasmic reticulum. Mitochondria, vacuoles and pinocytic vesicles are present. Spines or spinules are present on the surface of the body which useful in anchoring the animal in the host. The lowest layer of the cuticle is basement membrane. Tegument provides protection, allows gaseous exchange and sent out some nitrogenous wastes.

Spinules or spines used for attachment to the bile ducts of host.

2) **Muscle layers:** Immediately beneath the basement membrane, a layer circular muscle fibres, followed by longitudinal muscle fibres and a layer of diagonal muscle fibres. All muscles are smooth. Muscles are specially developed and radially arranged in suckers. Musculature enables the worm to perform movements.

3) **Mesenchyma cells:** This layer of branched cells or dark cells are sunk into parenchyma, but their protoplasmic tubules reach the tegument. These cells secrete cuticle. So cuticle is not a product of epidermis. In between the organs, the spaces filled with a loose tissue called parenchyma which is mesodermal in origin. There is no cellular epidermis in adults but present in larval stages.

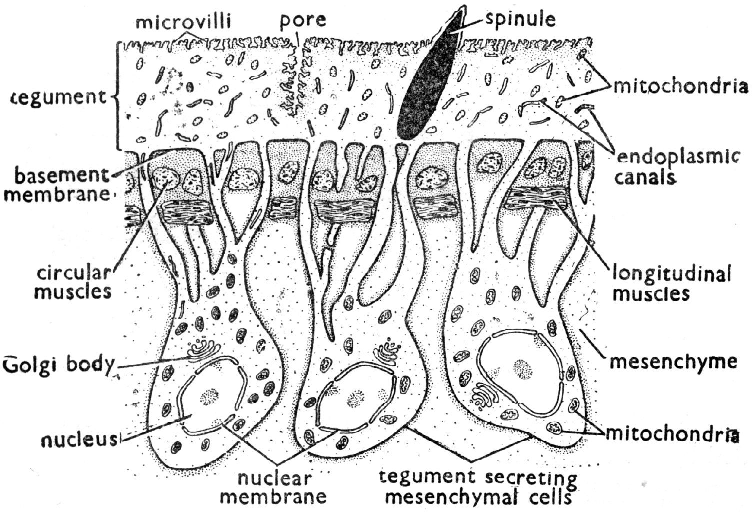


Fig.84 Fasciola T.S. Body wall

4.2.4 DIGESTIVE SYSTEM

The mouth is present at the anterior end of the head lobe. Mouth is surrounded by the oral sucker. Mouth leads into a small, thick walled, muscular oval shaped pharynx. It is surrounded by pharyngeal glands. The pharynx is opens into a short thin walled, narrow esophagus. It leads into an intestine which divides into two branches or intestinal cacca. The intestinal cacca running on either side of the posterior side ends blindly, the intestinal caeca gives out a number of branching diverticula to carry food to all parts of the body. Since there is no circulatory system.

The intestine is lined with endodermal columnar epithelial cells, the rest of the alimentary canal is lined by cuticle.

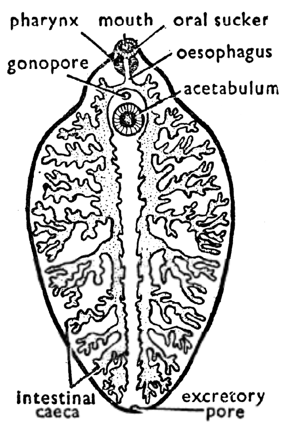


Fig. 85 Fasciola digestive system

Liver fluke feeds on bile and blood from the tissue of the host.
Liquid food is taken by sucking action of phalynx; Food reaches into the tissue, where it is digested and absorbed, finally diffused in to parenchyma. Glycogen and fats are stored as a reserve food material. Digestion is mostly extra cellular.

4.2.5 RESPIRATORY SYSTEM

There is no respiratory organs. The respiration is anaerobic. In this process, glycogen (present as reserve food) breaks up into Carbondioxide and fatty acids. This is accompanied by release of energy.

4.2.6 EXCRETORY SYSTEM

Excretory system consists of flame cells or protonephridia, secretory ducts and secretory pore. The units of excretion are the flame cells. They are scattered through out the parenchyma. Each flame cell has a microscopic capillary. These capillaries open into secretory tubules, which in turn opens into larger excretory tubes. Totally four excretory tubes are formed in this manner (two dorsal and two ventral) in the anterior part of the body. They lead into large median duct called longitudinal excretory canal or bladder. The longitudinal excretory canal starts a short distance behind the acetabulum and runs straight backwards to the excretory pore. The excretory tubules of the posterior part of the body directly open into the longitudinal excretory canal along its entire length. Except the main excretory canal, the rest of the system is lined with cilia. Excreta consists of fatty acids, CO_2 and ammonia.

Flame cells: The flame cells are characteristic of fasciola. Each flame cell has thin, elastic wall with nucleous and a cavity containing many long cilia arise from the basal granules situated in the cytoplasm. The cilia are constitently flickering like a flame hence, it is called as flame cell. Liquid nitrogenous waste material is diffused into the flame cell from the surrounding tissues and by the action of cilia, these materials moving through the tubules and are finally goes out through the excretory pore by the contractions of the body.

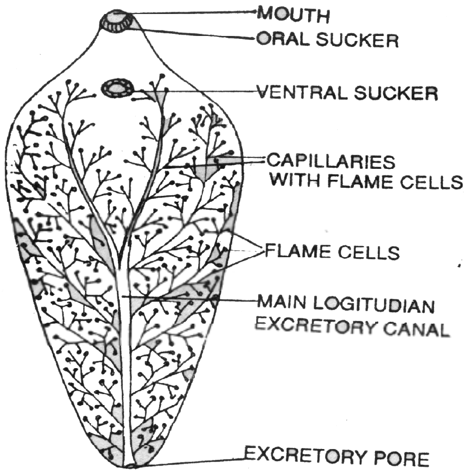


Fig. 86 Fasciola prolonephoridial system

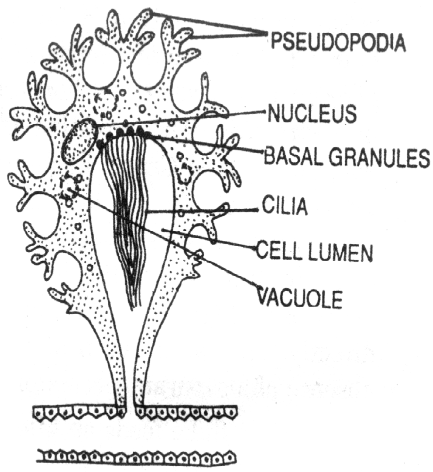


Fig.87 Fasciola flame cell

4.2.7 NERVOUS SYSTEM

Nervous system consists of a pair of cerebral ganglia on the lateral sides of esophagus and a ventral ganglion. All these ganglia are connected by a nerve ring around the esophagus. Three pairs of nerves arise from the brain and reach the head and sucker. Three pairs of longitudinal nerve cords arise from the posterior part of the brain as a dorsal pair, a ventral pair and a lateral pair. Of these lateral cords are well development and extending upto the posterior end and giving off fine nerves to various organs. The two lateral cords are connected by a transverse commissures.

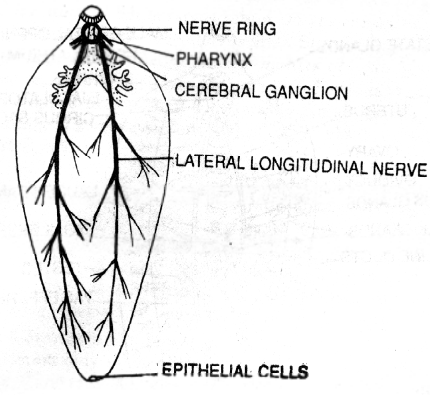


Fig. 88 Fasciola Nervous System

4.2.8 REPRODUCTIVE SYSTEM

Fasciola hepatica is a hermaphrodite (both male and female reproductive organs are present in same animal), but cross fertilization takes place. It contains complicated reproductive organs.

1) Male Reproduction system: it consists of testis, Vas deferentia,seminal vesicle prostate glands, ejaculatory ducts and cirrus or penis. A pair of highly lobed tubular testis are present on behind the other in the middle region of the body. From each testis a vas deferens arises. The two vasa deferentia run forward, side by side up to the level of the acetabulum (ventral sucker) and join to form a median pear-shaped seminal vesicle for storage of sperms. It leads in to a narrow tube, the cyaculatory duct. It opens into a muscular penis or cirrus.

This muscular organ opens in the genital atrium by male genital opening. Numerous unicellular prostate glands are surrounded and open into the ejaculatory duct. The cirrus, prostate gland and seminale vesicle are enclosed in a cirrus pouch or cirrus sac.

2. Female Reproductive System: It consists of ovary, oviduct, vitelline glands, uterus, Mehlis glands and Leurer's canal. A solitary highly branched and situated on the right side of the tests and tubular ovary is present. It is also called as germarium. All the branches of the ovary gather posteriorly to form a oviduct. Besides the ovary vitallarium are present. It consists of a large number of minute round follicles which are present on either side of the body. Numerous vitalline glands are present. These glands are produce albumineous yolk which is the food for developing embryo. From the vitelline gland anterior and posterior ducts are formed on both the sides. The anterior and posterior ducts of one side unite to form a transverse ducts. The two transverse vitalline ducts join the middle to form a median vitalline duct. The median vitalline duct joins the oviduct to form ovovitalline duct which enlarges in to a ootype. From the ootype a wide convoluted tube called uterus originates. Uterus opens into the genital atrium on the left side of the male genital opening by a female genital pore. Surrounding the ootype many unicellular mehlis glands or shell glands are present whose secretions are help in lubricating the uterus or smooth passage of eggs and in activating the sperms. From the junction of the oviduct and median vitalline duct, tube, called Laurer's canal arise and opens externally on the mid-dorsal side. During the copulation, the penis of another liver fluke is inserted into a laurer's canal for transfering spermatozoa directly into the oviduct.

Copulation: Fasciola is a hermaphrodite. But cross fertilization only takes place between the different individuals. The everted cirrus of one fluke penetrates, the Laurer's canal of the other and injects spermatozoa into the eviduct. The eggs are fertilized in the lower part of the oviduct. The eggs receives much ancient of yolk and the vitalline secretions and secrete the cells round the egg. The shell is made up of lipoproteins in two layers. It has a lid or operculum for the escape of the larva. The shell gets hardened and it reaches the uterus. Now the eggs are called capsules. They escape through female genital opening and reach the bile duct of the host. When tl and go out with the faecal matter.

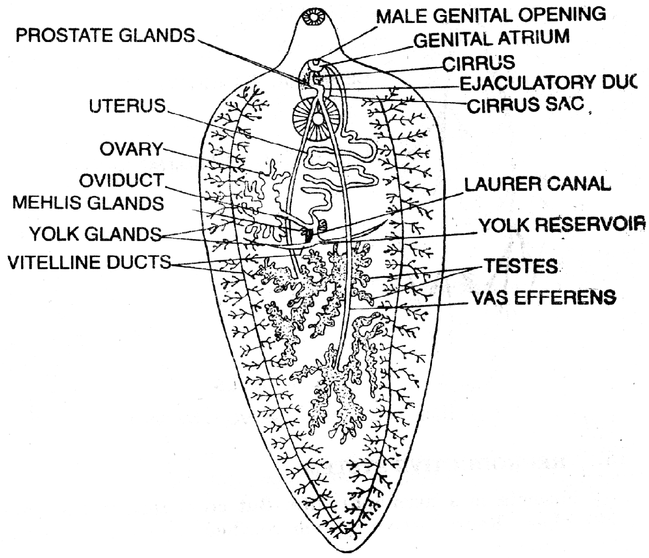


Fig. 89 Fasciola Hepatica Reproductive System

4.2.9 LIFE HISTORY

The life history of liver fluke and many hurdles are takes place. The capsules will fall in damp places will develop, at about 75°F. Development starts in the uterus and is continued on the ground. The fertilized eggs are devide into small propagatory cell and large somatic cell. the somatic cells divides and forms the ectoderm of the larva, later the propagatory cell divides into two cells. One of each forms mesoderm and endoderm of the lava and the other forms a mass of germ cells. This method of development takes place in the formation of all larval stages in the life history.

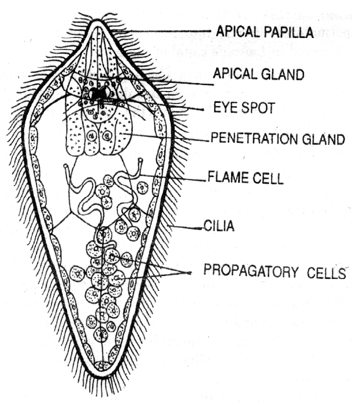


Fig 90 Miracidium Larva

Miracidium Larva: After two weeks of time free swimming ciliated miracidium larva comes out pushing the operculum of the egg. This is the first larval stage of life history of Fasciola. It is a small, oval, and active ciliated one. The larva has elongated body with broad anterior and narrow posterior end. At the anterior end a triangular, apical papilla or terebratorium is present. At the tip of the apical papilla, an apical gland and two pairs of penetration glands and a pair of pharangeal glands are also present. At the base of the papilla brain or nerve ganglion are present. A pair of eyes and flame cells are also present. The body of the larva is made of two layers. An outer]

epidermal layer made of 18-21 cells arranged in five rows. An inner layer of sub-epithelial or mesenchyme cells. These mesenchyma cells lined the central
Fig 90 Miracidium Larvacavity of the larva. Towards the posterior side a group of propagative cells are present.

The miracidium larva thus not feed, but swims freely in water. After a span of 12 to 15 hours, it reaches the intermediate host, otherwise it will die. The intermediate host is a freshwater snail, limnea, Bulinus or planorbis. When the miracidium comes in to contact it adheres to the snail by its apical papilla and enters in to the pulmonary sacs of the snail. From here it penetrates in to the tissue with the help of penetration glands. Here the miracidium looses its cilia and sense organs and become a sporocyst.

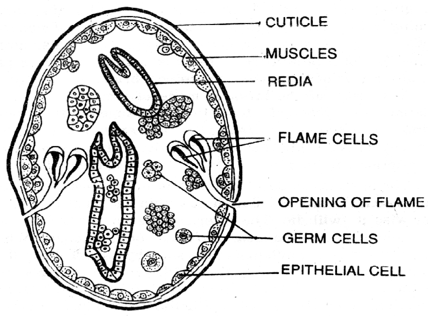


Fig 91.Sporocyst

Sporocyst: The Sporocyst is an elongated sac covered with a thin cuticle, below which or mesenchyma cells and some muscles. In side the sac, a pair of protonephridia with two flame cells are present. 6 to 12 germ balls are present. These give rise to Redia. Each sporocyst produces five to eight rediae. Redia pass out of the sporocyst in to the snail tissues with the aid of the muscular collar and ventral processes. Then the Redia migrate to the liver of the snail.

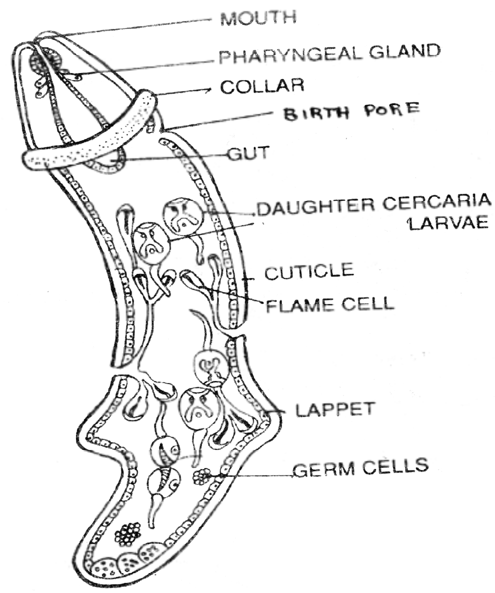


Fig.92 Redia Larva

Redia Larva: After infection of the snail in summer, the redia is formed with in 20-28 days. The body is elongated, with two ventral processes near the posterior end and a muscular circular ring called collar near the anterior end. The body wall has cuticle, mesenchye and muscles. Redia has an anterior mouth pharynx and sac like intestine and a pair of protonephridia with several flame cells. Germ cells and germ balls are present in the posterior part of the Redia. In summer, the germ cells of the Redia give rise to second generation of Redia. But in winter, they produce the next larval stage called Cercaria. These larva escape out through birth pore of Redia in to the tissues of snails. From each Redia 14-20 Cercaria are formed.

Cercaria: The Cercaria has an oval body, and simple long tail. The body is covered by thick spiny cuticle. Below the cuticle muscles, mesenchyme cells and cytogenous glands are present. There are two suckers, one on the anterior side called oral sucker, and the ventral sucker in the middle. The alimentary canal consisting of mouth, buccal cavity, pharynx, oesophagus and bifurcated intestine. There is a bladder with a pair of protorephridial canals with a number of flame cells. There are two penetration glands, they are non-functional. It also has the rudiments of reproductive organs formed from the germ cells. The mature cercaria escapes from the host to the surrounding water. The Cercaria swims in water for about 2-3 days. After that it looses its tail and get enclose, in a cyst secreted by cystogenous glands. The encysted Cercaria is called metacercaria.

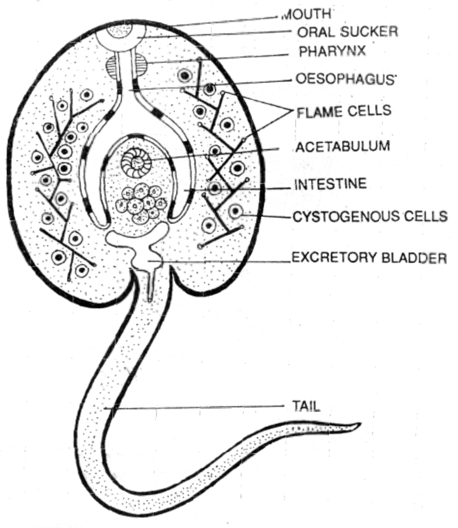


Fig 93 Cercaria

Meta Cercaria: The meta cercaria settles down on leaves of water plants. It is the infective stage of the parasite.

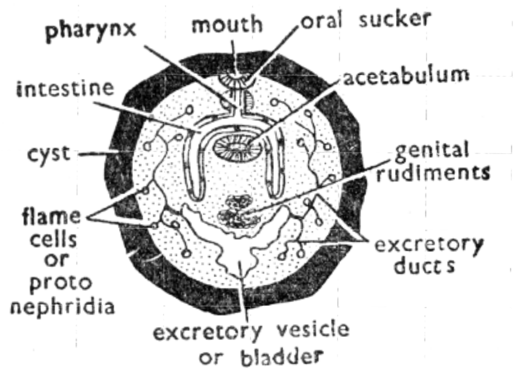


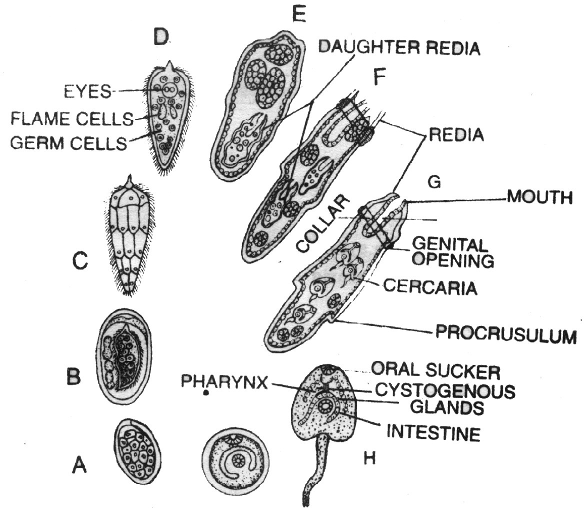
Fig 94 Meta Cercaria

4.2.10 LIFE CYCLE

Development of metacercaria takes place only if it is swallowed by the final host the sheep. In the alimentary canal of the sheep, the cyst wall is digested and a young flukes, emerges and bores through the wall of the intestine to enter the body of the host. After about 2-6 days, they enter into the liver and their movements in the liver may cause serious injuries. After several weeks they may become mature.

Liver flukes affect the liver of sheep and cause a disease 'liver rot'. The muscles of the host become week, liver will not function properly. Consequently young sheep die.

Treatment: The infected host are treated with hexa chloro ethane. Most of the flukes can be killed. If the snail population is controlled there will be a break in the life cycle of parasite. Consequently the parasite dies.



A) egg B) egg with developing miracidium C) free miracidium D) miracidium internal structure E) sporocyst. F) redia G) cercaria H) metacercaria

Fig 96 Life History of Fasciola

4.2.11 SUMMARY

- Fasciola hepatica is an endoparasite in the bile ducts of sheep.
- 'Liver rot' is the disease caused by Fasciola hepatica.
- Fasciola is leaf like and dorso ventrally flattened.
- Body of the Fasciola is covered with cuticle.
- Liver fluke feeds on bile and blood by sucking mechanism of pharynx.
- The respiration is anarobic
- Excretory system consists of protonephridial system
- Fasciola hepatica is hermaphrodite but cross fertilization takes place.
- In the life history of Fasciola many larvae are present i.e., Miracidium, Redia, Cercaria and Metacercaria.
- The life history completes in two hosts, the cattle (Vertebrate) and Snail (Invertebrate).

4.2.12 KEY TERMINOLOGY

Acetabulum: A sucker present on ventral side, behind the head lobe.

Cercaria: A free swimming oval shaped larva with tail.

Metacercaria: The encysted cercaria.

Ootype: A dilated structure formed by the junction of median vitelline duct and the oviduct.

Shell glands: A mass of unicellular glands present around the ootype.

4.2.13 MODEL QUESTIONS

1) Describe the structure and life history of Liver fluke?
2) Give an account of the reproductive system of *Fasciola hepatica*.
3) What is digenetic life cycle? Explain it with reference to the life history of *Fasciola hepatica*.

4.2.14 REFERENCE BOOKS

1. **Biology of Non-chordates** by H.C. Nigam.
2. **Invertebrate Zoology** by P.S. Dhami & J.K. Dhami

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Lesson 5.1
ANNELIDA - General characters & Classification

CONTENTS

The word Annelida has been derived from the latin word ‘Annulus’, which means rings. Early zoologists, Annelida grouped along with worms and named them as ‘vermis’. In 1978, Cuvier separated annelids from the unsegmented worms. Lamarck (1809) named the term ‘Annelida’ to these animals.

5.1.1 GENERAL CHARACTERS

1) Annelids are mostly marine and fresh-water animals. Some are ectoparasitic.
2) They live on land and in burrow or tubes.
3) Body is triploblastic and bilaterally symmetrical. These are three layers namely ectoderm, endoderm and mesoderm. During development, various organs and organo systems are formed from these layers.
4) The body is divisible matemerically into number of divisions known as segments. The segmentation is seen both externally and internally, externally they are separated from each other through grooves and internally through septa.
5) These are the true coelomic animals. Coelome is lined internally and externally with epithelial layer of cells. The coelom is filled with coelomic fluid which acts as hydraulic skeleton. In animals like leeches the cavity is filled with Botryoidal tissue.
6) Body is covered with cuticle which is secreted by epidermis and protective in function.
7) Chitinous setae are locomotory organs. But these setae are absent in leeches.
8) Alimentary canal is tube like with mouth at the anterior end and anus at the posterior end.
9) Digestive glands are present. Digestion is extracellular.
10) Blood vascular system is closed type. Blood flows in closed blood vessels. Blood is red due to the presence of haemoglobin or erythrocrurin dissolved in blood plasma.

11) Respiration is carried out by moist skin or gills.
12) Excretion is carried out by segmentally arranged 'nephridia'. Annelids are ureotelic and Ammonotelic.
13) Nervous system consists of a brain ventral nerve cord and segmental ganglia.
14) Head is provided with sense organs like eyes and tentacles.
15) Annelids are either hermaprodites or uni sexual.
16) Fertilization is external or internal.
17) The fertilized egg undergoes spiral cleavage with holoblastic divisions.
18) In earthworms and leeches the development is direct. In polychaetes, indirect development takes place. Trochophore larva is present in polychaetes.

5.1.2 CLASSIFICATION

Phylum Annelida is mainly divided in to three classes. They are:
1) Polychaeta, 2) Oligochaeta 3) Hirudinea.

Class 1. POLYCHAETA

1) Polychaetes are marine and carnivorous. Some live at the bottom of the seas and some other live as planktonic organisms.
2) The body is elongated and segmented. A distinct head at the anterior end is present. It bears tentacles, eyes and palps.
3) On either side of the body segment a pair of parapodia are present. Which are provided with numerous setae in bundles which are useful for locomotion.
4) Clitellum is absent.
5) Cirri or brancheae may be present for respiration.
6) Coelom is spacious which are divided by inter segmental sapta.
7) Alimentary canal is provided with eversible bucal cavity and protrusible pharynx.
8) Excretory organs are segmentally arranged nephridia.
9) Sexes are separate.
10) Gonads are numerous and develop during the breeding season. Gonoducts are absent. Sex cells are liberated by rupture of the body wall.
11) Fertilization is external.
12) Development is indirect and there is free-swimming larva called 'Trochophore'.

This class divided in to two sub-classes: 1) Errantia 2) Sedentaria.

Sub class 1. Errantia

1) Free swimming polychaetes.
2) Anterior part differentiated in to head and bears sense organs.
3) Para podia with acicula and many setae are present.

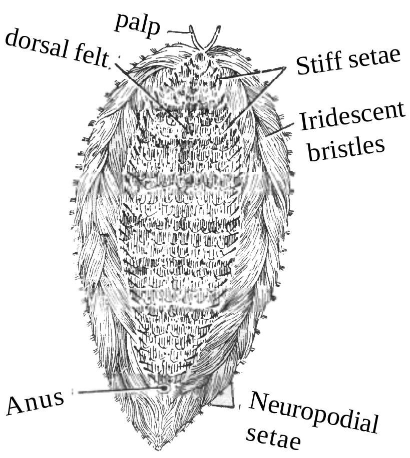
4) Exhibits sexual dimorphism.

Examples: 1) Neanthes (Nereis), 2) Aphrodite 3) Polynoe.

Sub class 2. Sedentaria

1) Sedentary polychaetes.
2) They live in tubes. The tube are made of sand grains and other foreign substances.
3) Body made of two or more regions with segments and parapodia dissimilar in the various regions.
4) Prostomium is reduced and peristomium forms a collar bearing the mouth at its base.
5) Parapodia are without setae.

Examples: 1) Arenicola 2) Chaetopterus 3) Teribella.



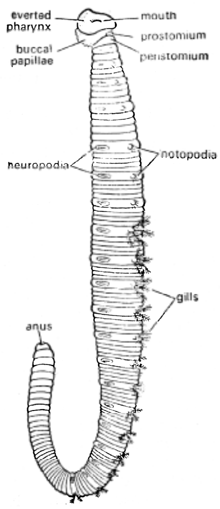


Fig 96 Life History of Fasciola

Class 2. OLIGOCHAETA

1) Mostly terrestrial. Some in fresh water.
2) Segmentation external and internal.
3) Parapodia are absent.
4) Setae are few.
5) Clitellum is usually present.
6) Metanephridia are the excretory organs.
7) Circulatory system contains one or more hearts.
8) All are hermaprodites. Tests are anterior to ovaries.
9) Fertilization is external.

10) Development is direct and takes place in cocoons-secreted by clitellum. No larval stage.
11) Annelids have good power of regeneration.

This class divided in to three orders.

Order 1. Plesiopora

1) Mostly aquatic.
2) Male gonopores on the segment following the testes.
3) Spermathecae present in the region of genital segments.

Examples: *Tubifex, Aeolosoma*.

Order 2. Prosopora

1) Majority aquatic animals.
2) Male gonopores in the same segment with the last pair of testes.

Example: *Branchiobdella.*

Order 3. Opisthopora

1) Majority are terrestrial earthworms.
2) Male gonopores some distance behind the testis containing the segments.

Examples: *Pheretima, Megascolex.*

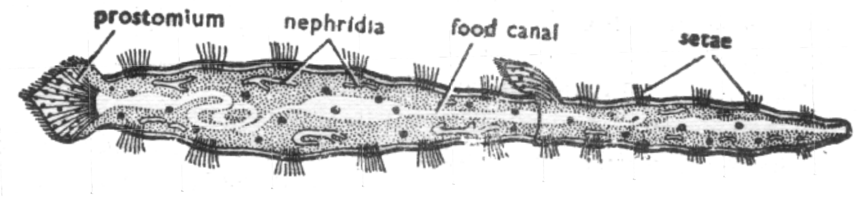


Fig 97 Aeolosoma

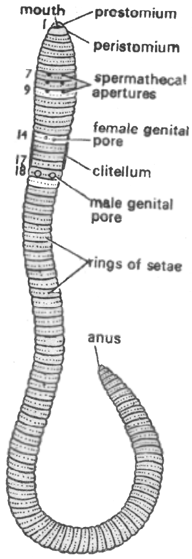


Fig 98 Megascolex

Class 3. HIRUDINEA

1) Generally ectoparasitic and blood sucking. Mostly aquatic largely freshwater and some marine water. They feed on blood of vertebrates.
2) These animals included in this class are called as leeches.
3) Body has fixed number of segments (33) which are sub-divided into annuli.
4) Both anterior and posterior ends of the body have suckers.
5) Body elongated dorso-ventrally flattened.
6) Parapodia and setae are absent.
7) Mouth opens on the ventral surface of the anterior sucker while anus opens dorsal to the posterior sucker.
8) Alimentary canal has crop divided in to number of secae which are in pairs.
9) In some leeches have proboscis, some others have jaws for making wounds on the body of the host.
10) Coelom much reduced due to its filling by botryoidal tissue.
11) Circulatory system is open type and is called haemo coelomic system.
12) Leeches are hermaprodites and develop clitellum during breeding season. Testes are many. But only pair of ovaries are present.
13) Fertilization is internal and development takes place in cocoon. No larval stage.

Examples: *Pontobdella*, *Hirudo*.

This class divided in to four orders.

Order 1. Acanthobdellida

1) Primitive leeches are present.
2) Coelom with compartments.
3) Setae present.
4) No anterior sucker.

Example: *Acanthobdella*

Order 2. Rhynchobdellida

1) Aquatic leeches and ectoparasitic.
2) Coelom without compartments.
3) Setae absent.
4) Anterior sucker may be present or absent.
5) Blood vascular system is separated from coelomic sinuses. Blood colour less.

Examples: *Pontobdella*, *Halobdella*.

Order 3. Gnathobdellida

1) Aquatic and terrestrial.
2) Ectoparasitic and blood sucking leeches.
3) No coelomic compartments and setae.
4) Three jaws are present.
5) Blood is red.

Examples: *Hirudo, Hirudinaria.*

Order 4. Pharyngobdellida

1) Terrestrial and aquatic.
2) Pharynx non-protrusible.
3) Jaws and teeth are absent.
4) Blood is red.
5) Fresh-water or amphibious and predacious leeches.

Examples: *Erpobdella, Dina*

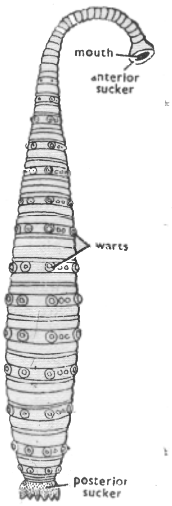


Fig 99 Pontobdella

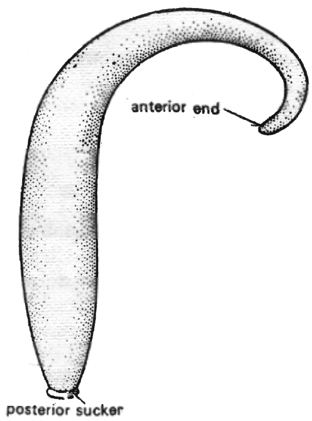


Fig 100 Acanthobdella

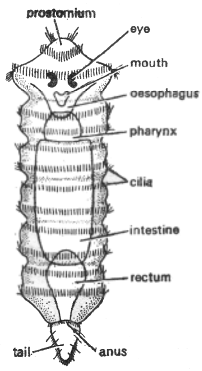


Fig 101 Dinophilus

Class 4. ARCHIANNELIDA

1) Mostly marine organisms.
2) Segmentation internal.
3) No parapodia and setae.
4) Sexes usually separate.
5) Trochophore larva present.

Examples: *Polygordins, Dinophilus, Protodrilus*.

5.1.3 SUMMARY

- Most Annelid live in marine, freshwater, land and in tubes.
- Body is triphoblastic.
- Body divide metamerically
- These annelids are true Coelomic, Coelomic fluid acts a hydraulic skeleton
- Chitinous Setae are locomotary organs in Nereis
- Digestion is extracellular
- Blood vascular system is closed type
- annelids are unisexual and hermaphrodites
- Trochophore larvae present in polychaetes.

5.1.4 KEY TERMINOLOGY

Clitellum: A prominent band encircle the particular region of the body (9-11^{th} segments - Leech)

Cuticle: Non-cellular outermost layer of the body secreted by Epidermis.

Triploblastic: Body wall is formed by three layers.

True-Coelom: Coelom is lined by Mesodermal layer or Epithelial layer.

Toso chophore: A characteristic ciliated free swimming larva of Annelida.

5.1.5 MODEL QUESTIONS

1) Give an account of general charachters of Annelida
2) Write on essay about the classification of Annelida upto classes with examples

5.1.6 REFERENCE BOOKS

1. **A text book of Invertebrates**. N.C. Nair, Dr. T. Murugan, N. Arumugam, Dr. S. Leelavathi and N. Sundara Pandian.
2. **Modern text book of Zoology, Invertebrates**. R.L. Kotpal, S.K. Agarwal, R.P. Khetarpal.

Lesson 5.2

EXTERNAL CHARACTERS
COMPARATIVE STUDY OF NEREIS AND LEECH

CONTENTS

5.2.1 OBJECTIVE

The purpose of this lesson is to develop a concept on structural changes of a free living and a ecto-parasitic animals.

5.2.2 INTRODUCTION

Nereis is a polychaete. Nereis is found on the sea shore in the shallow water, rock crevices, hidden under the stones. It is also lives in burrows. It is commonly known as sand worm or clam worm. Neanthes is a largest and most common typical marine annelid.

Leeches belongs to class Hirudinaria. Most of them lives in freshwater and land also. Very few are marine forms. Majority Leeches are ectoparasitic and feed on blood of vertebrates. Most common species is *Hirudinaria granulosa*.

5.2.3 SHAPE AND SIZE

The body of Nereis is long, slender, bilaterally, symmetrical. Some are broad anteriorly and tappering posteriorly. It is flattened dorso-ventrally. The dorsal surface being convex while the ventral surface is flat. The length of the Nereis varies from 30-40 cm.

Hirudinaria has a soft, vermiform elongated and dorso ventrally flattened body. The body measuring up to 10-15 cm, but may grow up to 35 cm. The body is broadest near the posterior end, while narrowest near the anterior end. It has a great power of contraction and expansion. Under normal conditions, the dorsal side of the leech, is convex and the ventral surface is flat.

5.2.4 COLOUR

The colour of the body varies in different species. The colour is greenish blue with tinges of orange and red or yellowish brown in different species. The colour vary in the individuals of the same species of different age and sexual maturity.

In leech, the dorsal surface is olive green and on the ventral surface is orange yellow or red. There will be a stripes of orange or yellow on either side of the body. On the dorsal side is a median longitudinal black stripe.

5.2.5 SEGMENTATION : NEREIS

The body is divided into number of segments or metameres from anterior to posterior end. The segments are arranged in a linear manner and demarcated externally by grooves. All the segments are similar, hence the name metamerism. However, the first segment is called as prostomium and the last segment called as pygidium which are differ from other segments. The number of metameres / segments varies from species to species.

Leech

The body of Leech is also divided metamerically into segments. the division is not similar to Nereis. The body is divided into 33 segments. The first two and last seven segments form suckers. Each segment is divided into small rings are called 'annuli' which are separated by furrows. From 7^{th} to 22^{nd} are known as typical segments. Each will have 5 annuli. These segments known as complete segments. The remaining segments do not have 5 annuli, hence they are called incomplete segments.

Segment	**No. of annuli in each segment**	**Total Number of annuli**
1^{st} Segment	1 annulus	1 annuli
2^{nd} Segment	1 annulus	1 annuli
3^{rd} Segment	2 annuli	2 annuli
4-6 segments	3 annuli each 3 x 3	9 annuli
7-22 segments	5 annuli each 5 x 16	80 annuli
23^{rd} segment	3 annuli 3 x 1	3 annuli
24^{th}, 26^{th} segments	2 annuli each 2 x 3	6 annuli
27-33 segments	1 annuli each 1 x 7	7 annuli
	Total	**109 annuli**

5.2.6 BODY - NEREIS

Body of Nereis is divided into 3 distinct regions-called: 1) Head, 2) Trunk, 3) Pygidium.

1) **Head:** The Head is present at the anterior end and well developed which consists of two parts prostomium and peristomium.

2) **Prostomium:** Prostomium is an anterior narrow nearly triangular fleshy outgrowth. It is situated mid-dorsal infront of the mouth. It is not the true segment of the body. It bears two pairs of pigmented eyes on the dorsal surface. A pair of short, cylindrical, sensory prostomial tentacles are present anteriorly. A pair of short fleshy and two jointed palps are present ventro laterally.

1. Peristomium: Peristomium is a large ring like structure. It is considered as the first segment of the body. The mouth is present on the ventral surface of the body. Parapodia are absent in this segment, but there are present two pairs of thread like peristominal cirri on each side. These are homologous with notopodial cirri and neuropodial cirri of the parapodia. Of these two, one pair is dorso lateral and the other ventrolateral in position.

2. Trunk: It comprises the entire body excluding the head and the last segment, the pygidium. It consists of 80-200 segments, each broader than long. Each segment is characterised by the presence of parapodium on each lateral side.

Parapodium: Each segment of the body except the peristomium and the anal segment bears on either lateral side a flat, fleshy hallow, vertical, plap like out growth, the parapodia.

Each parapodium is a biramous structure consisting of the dorsal notopodium and the ventral neuropodium. Each ramous is further divided into two lobes. Each lobe projects a bundle of long chitinous bristles called setae. These are lodged in setigerous sacs which are formed from the epidermis. Each Setae can be retracted or protruded out due to the action of parapodial muscles. In addition to hurdle of setae there is stout pointed needle like dark structure called acicula. The acicula act as internal skeleton of parapodia. The parapodium bears on its dorsal side a filamentous processes known as dorsal cirrus. Ventral cirrus is present on the neuropodium, parapodia serve the duel purpose of locomotion and respiration.

The parapodia are largest in the mid-region of the body and decrease in size towards the anterior and posterior ends of the body. The first two pairs of parapodia have no notopodial setae. At the base of each, parapodia is present an opening of nephridiophore.

3. Pygidium: The last segment of the body is called pygidium. It is also known as anal segment. It bears a terminal anus and a pair of long filamentous anal cirri. The anal cirri are sensory in function. Parapodia are absent.

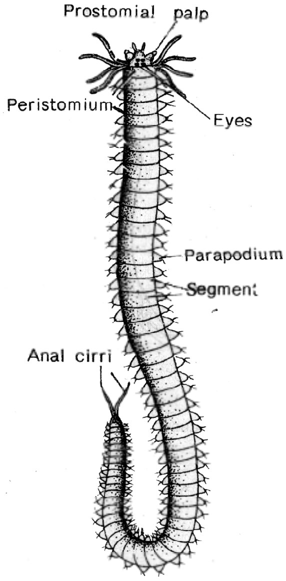


Fig 102 Nereis

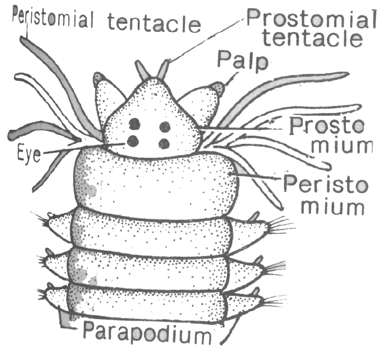


Fig 103 Head

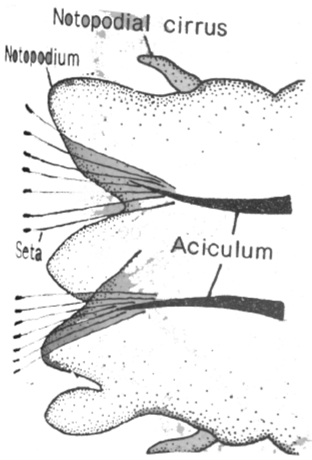


Fig 104 Parapodium

1. LEECH : Suckers

Each end of the body of leech bears a hallow muscular organ, the Sucker. The anterior sucker is cephalic sucker. Mouth is present in the cephalic Sucker. the posterior end also bears circular and highly muscular disc shaped posterior or anal sucker. Both the suckers help in adhesion or attachment. These suckers are absent in Nereis.

2. Divisions of the body: The body can be divided into 6 regions.

1) Cephalic region, 2) Pre Clitellar region, 3) Clitellar region, 4) Middle region
5) Caudal region, 6) Posterior sucker

1) **Cephalic region:** It is composed of the first five segments. These are also called ocular segments. Five pairs of eyes are present on the first five segments. Eyes are present on the prostomium in Nereis. Oral Sucker is present in the Cephalic region. The Sucker is absent in Nereis. All the five segments are further divided into annuli.

2) **Preclitellar region:** It is formed by three segments 6^{th}, 7^{th} and 8^{th}. Of these 6^{th}, has three annuli and the remaining two have 5 annuli. Nephridiophores open in these segments in leech. Nephridiopores are located in the base of parapodia in Nereis.

3) **Clitellar region:** It comprises of three segments 9^{th}, 10^{th} and 11^{th}. This region is highly glandular. A permanent clitellum does not exist. In Hirudinaria, it develops temporarily during the breeding season. On the ventral side, male genital opening is present in the groove inbetween the 2^{nd} and 3^{rd} annuli of the 10^{th} segment and female genital opening is present in the groove between the 2^{nd} and third annuli of the segment of 11^{th}. Each segment bears five annuli.

4) **Middle region:** It is largest region comprising of 11 segments (12-22). Each segment has five annuli and Nephediopores are present on all the segments.

5) **Caudal region:** Caudal region is short and consists of four segments (23-26) 23rd segment has three annuli and the rest have two annuli each. Nephrediopores are absent.

6) **Posterior Sucker:** It is composed of seven segments (27-33), arranged in concentric rings and each bears only single annulus.

Posterior Sucker helps the leech in the attachment to the hosts.
Suckers are absent in Nereis.

EXTERNAL OPENINGS

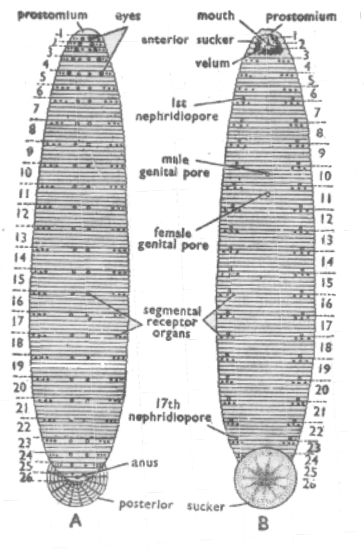
Mouth: It is a narrow, triradiate aperture situated in the centre of the anterior Sucker. In Nereis mouth is elongated transverse slit on the ventral side of the peristomium.

Anus: It is a very small aperture situated mid-dorsal at the base of the 26th segment of the posterior Sucker. In Nereis, it is located at the end of last segment called as pygidium.

Nephridiopores: There are 17 pairs of nephridiopores lying on the ventral surface of the body. In Nereis excretory openings are present. One pair in each segment at the base of the ventral cirrus of the parapodium.

Male Genital aperture: It is situated in the 2nd and 3rd annulus of 10th segment on the mid ventral side of the body. In Nereis sexes are separate. No male genital openings are present.

Female Genital aperture: It is situated mid ventrally in between the 2nd and 3rd annuli of the 11th segment. In Nereis, sexes are separate. No female genital openings are present.



A—Dorsal view. B—Ventral view.

Fig 105 Leech

Receptors: Each segment has a number of projections called receptors. In Leech two types of receptors are present.

a) **Segmental Receptors:** Seven pairs of segmental receptors are situated on the first annulus of each segment. 4 pairs are on dorsal side and 3 pairs are on ventral side.

b) **Annular receptors:** These are located in each annulus. Each annulus has 36 pairs of annular receptors, out of which, 18 pairs on the dorsal side and 18 pairs on the ventral side.

5.2.7 COMPARATIVE ACCOUNT OF NEREIS AND LEECH

NEREIS	LEECH
1) Lives in the shallow water of seas	1) Lives in freshwater, canals, ponds and ditches
2) Tubiculous animals. They lives in burrows and rock crevices.	2) Swims in water with the help of muscles. Creeps on the soil. Some time ectoparasitic.
3) Nocturnal in habit, carnivore feeds on plankton. Hence called filter feeder	3) Feeds on blood of vertebrates. They are called Sanguivore.
4) Body is long, slender narrow, slightly flattened dorsoventrally	4) Body is long, vermiform, convex on the dorsal side, flattened on the ventral side. The anterior end is narrower and the posterior end is broader.
5) Body is bluish green in colour.	5) Olive green on the dorsal side, orange-yellow on the ventral side.
6) Body divided in to number of segments maximum of 200.	6) Body is divided into 33 segments. But externally the body is made of 109 annuli, as each segment is subdivided.
7) Annuli are absent	7) Annuli are present
8) A distinct head is present which consists of palps, eyes and tentacles	8) The anterior part is distinguished and cephalic region which bears five pairs of eyes
9) Clitellum completely absent	9) During breeding season a definite clitellum is formed 9^{th}, 10^{th} and 11^{th} segments. It is temporary structure
10) The last segment is know as pygidium	10) No pygidium
11) Except the peristomium and pygidium. All the segments of the body bear a pair of parapodia. Parapodia bear number of setae on notopodium and neuropodium	11) Parapodia and setae are absent
12) Suckers are absent	12) Anterior sucker and posterior sucker are present
13) No genital apertures are present	13) Male and female genital apertures are present in 2^{nd} sub-segments of the 10^{th} and 11^{th} segments respectively.
14) Nephridial openings are present at the base of parapodia	14) Nephridiopores present in pairs from 6-22 segments
15) Anus present at the posterior end	15) Anus is present on the mid-dorsal side between the body and posterior sucker
16) Nereis and Hetero-Nereis stages are present	16) Different stages are not seen.
17) Receptors are not seen	17) Annular and segmental receptors are seen. They are sensory in function
18) Botryoidal tissue is absent	18) Special and characteristic Botryaidal tissue

5.2.8 SUMMARY

- Nereis is a largest and most common typical animal.
- Leeches are ectoparasitic and feed on blood of Vertebrates.
- The colour of Nereis is greenish blue with tinges of orange and red or yellow.
- The colour of leech is olive green on the dorsal orange yellow on the ventral.
- The segmentation in Nereis is linear manner and demarcated externally by grooves. All the segments are similar.
- The segmentation in leech is not similar. The body segments limited to 33 and subdivided into annuli.
- Each segment of the Nereis has parapodium on either side, except prostomium and pygidium.
- Parepodium completely absent in leech. But anterior sucker and posterior sucker are present.
- External openings are present in leech such as mouth, anus, Nephridiopores, male and female genital openings.

5.2.9 KEY TERMINOLOGY

Neuropodium: Ventral part of the distal region of parapodium.

Notopodium: Dorsal part of the distal region of parapodium.

Parapodium: Hollow lateral outgrowth of the body.

Prostomium: A triangular lobe lies in front of the mouth.

Pygidium: Last segment of the body

Receptors: Small projections of the body wall. These are sensory in function.

5.2.10 MODEL QUESTIONS

1. Give an account of external characters of Nereis and leech.
2. Give an account of body divisions of Nereis and leech.
3. Write an essay about the external apertures of leech.
4. Give comparative account of external characters of Leech and Nereis.

5.2.11 REFERENCE BOOKS

1. **Invertebrate Zoology**. P.S.Dhami, J.K. Dhami.
2. **Invertebrate Zoology.** E.L. Jordan, P.S. Verma.

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Lesson 5.3
COMPARATIVE STUDY OF LEECH & NEREIS DIGESTIVE SYSTEM

CONTENTS

5.3.1 OBJECTIVE

The purpose of this lesson is to know:

- the structure and physiology of Digestive system of Nereis & Leech
- the feed and feeding habits of Nereis & Leech.

5.3.2 INTRODUCTION

Digestive system includes the alimentary canal and digestive glands. Alimentary canal is a straight tube, extending through out the length of the body. Structure of the alimentary canal shows variation in Nereis and Leech according to their food and feeding habits. Nereis is a carnivorous animal, where as leech is a Sanguivorous animal.

5.3.3 ALIMENTARY CANAL OF NEREIS

The Alimentary Canal is straight tube extending from anterior to posterior end of the body. The mouth is opens at the anterior end and the anus present on the Pygidium. The entire system is suspended in the body cavity by the inter segmental septa and the mesentaries.

The Alimentary Canal is differentiated in to stomodaeum or foregut, mesenteron or mid gut and proctodaeum or hind gut.

Stomodaeum

It is the anterior region of the alimentary canal lined internally by ectoderm and cuticle and comprises the buccal cavity and pharynx.

The mouth is a transverse slit lies ventrally to the prostomium. The mouth opens in to a wide chamber, the buccal cavity. The buccal cavity leads in to muscular protrusible pharynx, extending up to 4th segment. Buccal cavity has several small dark brown denticles.

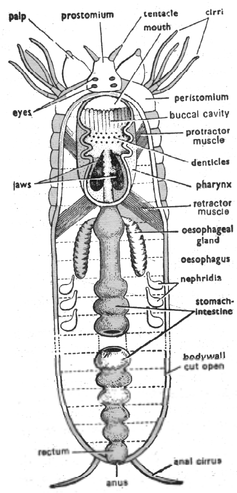

Fig 106 Nereis - Digestive system

Mesenteron

It is the middle region of the Alimentary Canal. The pharynx opens in to a narrow oesophagus which runs up to the 9th segment. A pair of sacculated glandular oesophageal caecae opens in to oesophagus. The oesophagus opens posteriorly in to stomach and intestine which is a wide tube extending through remaining length of the body. The intestine is a straight and long tube which divided externally in to segments by septa.

Proctodaeum

It is the Posterior - most part of the Alimentary Canal lined internally by ectoderm and cuticle and comprising only rectum. The rectum is a short tube - like structure which opens posteriorly through the anus.

5.3.4 ALIMENTARY CANAL OF LEECH

The Alimentary Canal of Leech is also a straight tube as in Nereis. In both the animals the diameter of the alimentary canal varies in different regions. Leech feed on vertebrate blood. In leech it is not easy to get the food as and when it requires. So the system is built in such a way the alimentary canal acts like a store house.

The alimentary canal of leech is differentiated in to buccal cavity, Pharynx, Oesophagus, Crop, Stomach, intestine and rectum.

Buccal Cavity

The mouth leads in to the buccal cavity. Three chitinous jaws are present in the buccal cavity. One is on the mid-dorsal side, and remaining two are in ventro-lateral position. Each Jaw is laterally compressed muscular cushion covered with fine cuticle which is thickened at

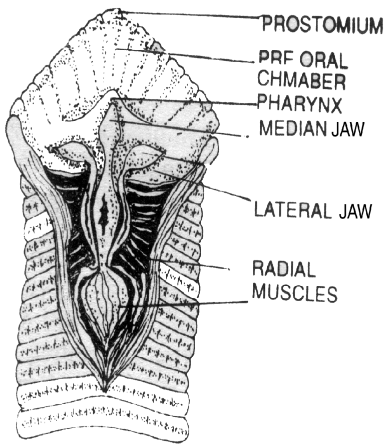

Fig 107 Alimentary Canal- Anterior End

the free edge bearing minute teeth in a single row. Such Jaws are termed as monostichodont. On each side of the Jaw are small button shaped salivary papilla. Each bearing a number of openings of salivary glands. They produce the characteristic triradiate bite i.e. 'Y' shaped wound in the skin of the host.

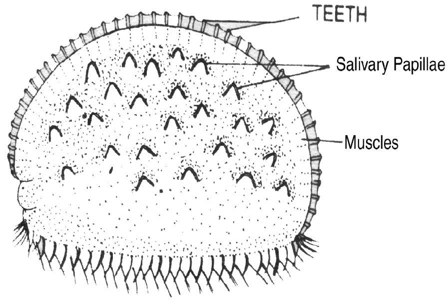

Fig 108 Lateral View of Jaws

Pharynx

The buccal cavity leads in to a highly muscular pharynx which is an oval sec extending from 5^{th} to 8^{th} segment. Pharynx is surrounded by unicellular salivary glands which open on salivary papilla of Jaws. The secretion of salivary glands contains hirudin which is an anti coagulin which prevents the clotting of blood while feeding on a vertebrate. No such glands are seen in Nereis. Numerous radial muscles connect the wall of the Pharynx with the body wall.

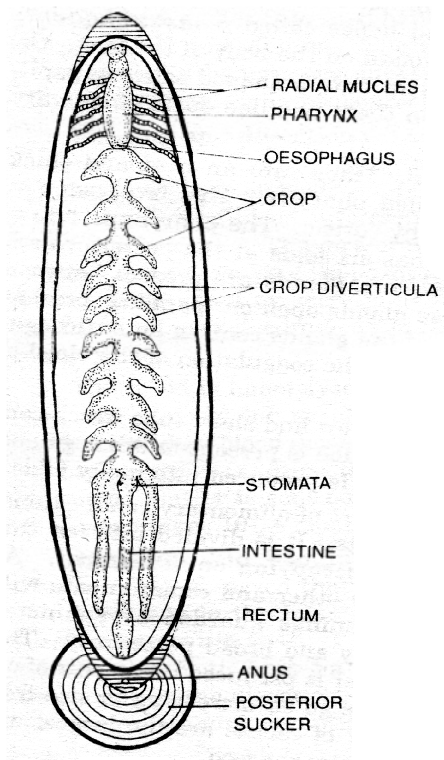

Fig 109 Alimentary Canal

Oesophagus

It is a short narrow tube through which the pharynx leads in to the crop. The lumen of oesophagus is very narrow and its epithelial lining is produced in to narrow folds.

Crop

The Crop is the largest region of the alimentary canal extending from the 9^{th} to 18^{th} segments. It has 10 thin walled chambers. One in each segment. Each chamber consists of small anterior and broad posterior part which is produced in to a pair of lateral backwardly directed blind out growths the caeca. The growth chambers and caeca gradually increase in size towards posterior side. The 10^{th} pair is long, extending as two greatly elongated blind sacs along the intestine up to the 22^{nd} segment. The crop is used for storing blood. One cropful of blood lasts several months. This type of food storage phenomenon is not seen in nereis.

Stomach

Crop leads in to the stomach present in the 19^{th} segment. The opening of the crop in to the stomach is narrow having sphincter muscles which regulate the flow of blood. The stomach has secretory and absorbed epithelial cells and its inner lining is produced in to numerous folds which anastomose with one another.

Intestine

Stomach leads in to the intestine a thin walled, straight narrow tube running from 20-22 segments. Its inner lining is thrown in to numerous spiral folds and villi like processes which increase the area of absorption. These process are not seen in Nereis.

Rectum

Intestine opens in to short, thin walled rectum running from 22-26 segments. The rectum opens out by anus situated on the dorsal side of the 26^{th} segment. In Nereis the anus is terminal.

5.3.5 FOOD AND FEEDING

Nereis is carnivorous which feeds on small organisms present in the water by everting the pharynx to capture the prey. While capturing the prey the entire part of the buccal cavity and pharynx become inside out through the mouth. The two jaws of the pharynx grasp the prey by coming closer to each other. Then the pharynx withdrawn to its original position. All this mechanism comes in to force by the contraction of protractor and retractor muscles and the pressure caused by the coelomic fluid. The food is transfer from one part of the gut to the other by the contraction of the muscles. The digestion and absorption of food occur mainly in the stomach-intestine. the digestion is extra-cellular.

Leech is aquatic and terrestrial animal. Leech feeds on blood of vertebrates. Hence it is called as sanguivore. When a vertebrate or cattle or man enters in to pond the leech attaches it self by its posterior sucker with the help of anterior sucker it painlessly puncture the skin and make ‘Y’ shaped wound with the help of three jaws. It secrete the saliva which contains Hirudin which is an anti coagulent. So the blood from the wound flows continueously. Then the leech starts sucking the blood with the contraction of the radial muscles expand the pharangeal cavity and the blood flows in to the caece of the crop. After filling completely the leeches detaches from the host. The food is sufficient for several months. The blood is passed drop by drop into the stomach and digested by the peptolytic enzymes.

5.3.6 COMPARATIVE ACCOUNT OF DIGESTIVE SYSTEM

NEREIS	LEECH
1).Carnivorous and food consists of crustaceans and small organisms. Its alimentary canal is modified according to its food and feeding habits.	1).Food consists of vertebrate blood. Its alimentary canal is modified in accordance with its ectoparasitic life.
2).The alimentary canal is suspended in the coelom by the dorsal mesentery and septa.	2).The alimentary canal is held in position by the Botryoidal tissue and septa.
3).Alimentary canal is a straight tube extending from one end of the body to the other. It is differentiated in to mouth, Buccal Cavity, Pharynx, Stomach, intestine, rectum and anus.	3).The alimentary canal is a straight tube extending up to 26^{th} segment. It is differentiated in to the following parts. Pre oral cavity, Mouth, Buccal Cavity, Pharynx, Oesophagus, Crop, Stomach, Intestine Rectum and Anus.
4).Mouth is a transverse slit present on the ventral side at the anterior end near peristomium.	4).Mouth is present ventrally at the bottom of oral sucker.
5).Buccal Cavity is short; but wide muscular chamber.	5).It is a very short and contains three Jaws, one on the mid dorsal and two are ventro - lateral in position. The jaws are provided with teeth.
6).Pharynx is a wide muscular chamber with small denticles, internally and a pair of stout, movable, chitinous jaws. It extends upto the end of 6^{th} segment.	6).Pharynx is an oval, muscular chamber connected by radial muscles with the body wall. It extends from the 5^{th} to 8^{th} segment.

7).Buccal Cavity and pharynx are protrusible as a proboscis.	7) No protrusible proboscis.
8).Oesophagus is a long and narrow tube extending up to 7th to 11th segments. At the anterior end a pair of long oesophageal glands or caeca are present.	8).Oesophagus is a short and narrow. Its inner lying is much folded.
9).Oesophagus opens into stomach-intestine.	9).Oesophagus opens in to crop which is a characteristic feature of leech.
10).There is no crop.	10) Crop has ten thin-walled chambers with caeca, extended from 9th to 18th segments.
11).Stomach and intestine are combined in to a single structure, the stomach-intestine, which is a segmentally, constructed tube extending from oesophagus to the last but one segment.	11).Stomach is a narrow tube much folded internally. It is situated in the 19th segment followed by intestine extending up to 22nd segment.
12).Rectum is short tube in the last segment.	12).Rectum extends from 22nd to 26th segments.
13).Anus is terminal at the end of pygidium.	13).Anus lies on the mid-dorsal surface at the junction of body and posterior sucker.
14).Oesophageal caecal glands, mid gut glands from the epithelium are the digestive glands.	14).Numerous unicellular salivary glands, mucous glands, which are surrounding the pharynx. Mucous gland cells also present in the lining of the Crop, Stomach and intestine.
15).Nereis is a carnivorous animal. When it lives in burrows, it feeds on minute particles by filter mechanism.	15).It is a sanguivorous. It sucks blood of vertebrates.

5.3.7 SUMMARY

Nereis is carnivorous and feeds on small organisms like Crustaceans, worms, molluscs and larvae. The digestive system of Nereis consists of alimentary canal and digestive glands called oesophageal glands. The alimentary canal is differentiated into three regions, namely: 1) stomodaeum or foregut, comprising the buccal cavity and pharynx, 2) mesenteron or midgut, comprising the oesophagous and stomach-Intestine, 3) Proctodaem or hindgut, comprising the rectum.

Leech feeds on blood of Vertebrates. So it is a Sanguivorous. The digestive system consists of a long alimentary canal and pharyngeal glands. The alimentary canal consists of pre-oral chamber, buccal cavity, pharynx, oesophagus, crop, stomach, Intestine and rectum.

5.3.8 KEY TERMINOLOGY

Denticles: Dark brown cuticular thickenings of the pharynx region of the Nereis.

Hirudin: A anticoagulin, present in a saliva of Leech.

Peristatsis: The rhythemic contractions of the muscles.

Salivary Papillae: Button like structures present on the jaws of leech.

5.3.9 MODEL QUESTIONS

1. Describe the digestive system of leech with neat lablled diagrames
2. Descirbe the digestive system of nereis with neat lablled diagrames
3. Write an essay about the comparative account of digestive system of Leech and Neries

5.3.10 REFERENCE BOOKS

1. Inverbrate Zoology by Jordan
2. Annelida - R.L. Kotpal

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Lesson 5.4

COMPARATIVE STUDY OF REPRODUCTIVE SYSTEM OF LEECH AND NEREIS

Contents:

5.4.1Objective : The purpose of this lesson is to have an idea about the reproductive organs and development of Nereis and Leech.

5.4.2 Introduction

Leech is *hermophrodite* animal, both male and female reproductive organs are seen in same animal. But self fertilisation is prevented due to the early maturity of testis than the ovary (*Protandry*). Fertilization takes place in the vagina, and further development takes place in the cocoon; there is no larval stage in the life history.

Nereis is unisexual animal, ova and sperms are discharged into the sea, fertilization is external. Development is indirect with a ciliated larva 'Nectochetes' which metamorphosises into adult.

5.4.3 Reproductive system in Leech

Leech is bisexual (hermophrodite) animal, each individual possesses male and female reproductive organs. Cross fertilization occurs by the process of copulation of two individuals.

Male reproductive organs

Male reproductive system consists of testissacs, vasa efferentia, vasa deferentia, epididyms, ejaculatory ducts, atrium and male genital pore.

Testis sacs: They are 11 pairs in number. They are spherical sac-like structures present in segments 12 to 22, 1 pair in each segment on either side of the ventral nerve cord. The testis sacs are filled with colourless coelomic fluid with some amoeboid corpuscles. Sperm mother cells (Spermatogonia) are produced from the walls of the testis sacs which transform into spermatozoa.

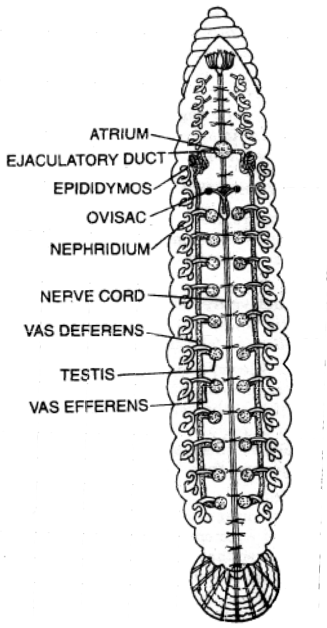


Fig 110 Reproductive system

Vasa efferentia: From each testis sac, a small duct vas efferens starts. The vasa efferentia which are produced from the eleven testis sacs of one side join the common vas deferens of that side.

Vas deferens: It is a longitudinal duct which is present parallel to the nerve cord extending from 11th segment to 22nd segment. There are two vasa deferentia on either side of the ventral nerve cord.

Epididymes: In 10th segment, each vas deferens form a convoluted structure called *epididymes*.

Ejaculatory duct: From the anterior part of the epididymes, a short duct arises, which is called ejaculatory duct.

Atrium: The ejaculatory ducts of both sides join a sac like structure called atrium which is present in 10th segment / 9th and 10th segments. It opens outside by male genital pore, present on a papilla in the groove between the 2nd and 3rd annuli of 10th segment.

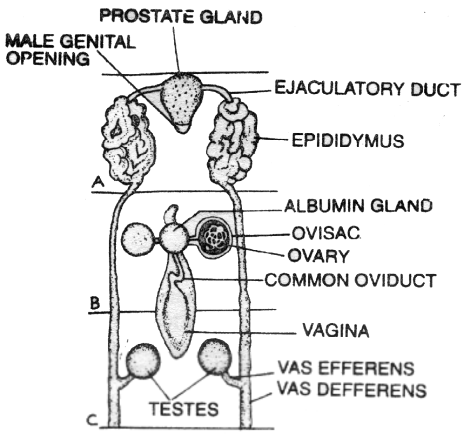


Fig 111 Reproductive organs of 10th, 11th and 12th segments

The atrium consists of two parts, anterior **Prostrate chamber** and posterior neck like **penis sac**. The prostrate chamber is muscular with numerous unicellular prostrate glands. The penis sac is a muscular tube containing a tubular penis which protrudes out through Male genital pore. Prostrate secretions help to bind the spermatozoa into bundles called **spermatophores**, which are transferred into the vagina of other leech by the penis during copulation.

Female reproductive system: Female reproductive system consists of ovisacs, oviducts, common oviduct and vagina.

Ovisacs: One pair of hollow sac like structures called ovisacs are present on either side of ventral nerve cord in segment 11. Ovisacs consists of coiled thread like ovaries floating in (Coelomic) fluid. The terminal positions of the ovaries are enlarged.

Oviducts: From the basal portion of the orisac, narrow tube like oviduct starts and proceeds backwards.

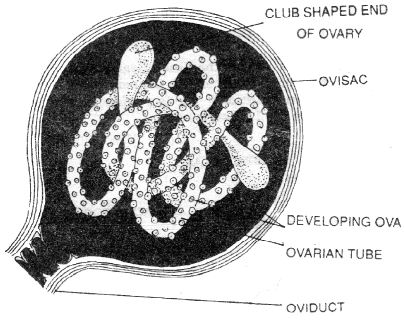


Fig 112 Ovisac with overy

Common oviduct: The two oviducts which emerge from the base of the ovisacs of both sides join to form common oviduct in segment 11. The point of the formation of common oviduct is covered by unicellular **albumen glands**. The remaining part of the common oviduct is curved like 'S' and open into the **vagina**.

Vagina: It is a large pear shaped muscular bag in the posterior part of 11th segment. Anteriorly, it narrows into a short duct, which opens out through female genital pore located in the groove between 2nd and 3rd annuli of 11th segment. The ova produced by the ovaries pass into ovisacs, then pass through the oviduct into the vagina, where fertilisation occurs.

5.4.4 Copulation and fertilization: Copulation occurs between two leeches; two individuals come into contact by their ventral surface in head-to-tail position so that male genital pore of one animal lies against the female genital pore of the other. The spermatophores of one leech are transferred into the vagina of other leech and vice-versa. Fertilization occurs in the vagina and the zygotes are discharged into the cocoon where further development takes place.

5.4.5 Cocoon: Cocoon is a girdle shaped structure secreted by the clitellar glands around 10th and 11th segments. The clitellar glands also produce thick albuminous fluid into the cocoon. After the cocoon is filled with fertilized ova, it passes over the head of the individual. The pre-clitellar region is with drawn by rythmic movements and the cocoon is laid in a moist place and becomes hardened on exposure to air. Fully developed cocoon is light-yellow coloured barrel shaped structure of about 25 to 30 mm long and 10 to 15 mm wide. It is made up of an inner thin and tough membrane and outer thick and spongy layer. At one end, it consists of a polar plug and from this point, young ones emerge out.

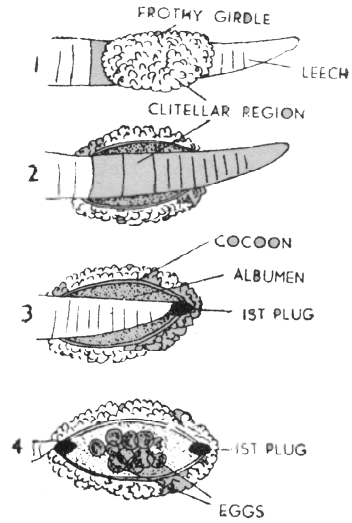


Fig 113 Cocoon formation

5.4.6 Development: Development of fertilized ova takes place in the cocoon (1 to 24 embryos), the albumen present in the cocoon will nourish the developing embryos. Development is direct without any larval stage.

Complete development takes place within 15 days and young ones are released from the cocoons when the **polar plug** of the cocoon is dropped off.

5.4.7 Reproductive System in Nereis

Nereis is unisexual animal. The reproductive organs are very simple which are represented in form of **masses** of **cells** which are produced from the coelomic epithelial cells, present surrounding the main blood vessels. Thus well defined **testes** and **ovaries** are absent. The reproductive elements are formed in each segment, except from the anterior few. Such cells liberated from the coelomic epithelium remain in the coelom till they mature. Sepermatogenesis occurs resulting in the formation of spermazoa with a minute head and long tail. Similarly oogenesis results in the formation of large round ova, pilled with yolk globules.

In Nereis there are no specialised gonoducts also. Mature ova and sperms are released out through nephridia or by the rupture of the body wall.

A pair of **ciliated organs** occur on the dorsal side of each segment, which are provided with funnel shaped structure which opens into the body cavity. They have no external openings. They resemble the coelomoducts, during reproductive season these funnels open out through temporary pores in the body wall. This is an assumption and there is no clear evidence of the functioning of these ciliated funnels.

Reproduction occurs during summer months the mature worms come out of the burrows, swim to the surface in large numbers. Such **swarming** occurs at night and depends on the season, lunar cycle, calmness of the sea water. The eggs and sperms are released into the sea water and it is supposed that a specific substance released by the ova stimulates the male worms to release the sperms. After releasing the gametes, the mature worms die. Fertilization occurs in water.

The cleavage is unequal and spiral. The fate of the bastomeres is fixed after 4 cell stage (**Determinate**) A, B, C and D. Cells A and C will form the **lateral** quadrants, B forms the **ventral** quadrant and C, the dorsal quadrant. The blastomeres formed are unequal, they are not placed directly above or below one another but slightly displaced to the right or left due to the **spiral cleavage**. Typical *Trochophore* larva is present.

5.4.8 Trochophore: It is characteristic larva of annelids but the trochophore of **Nereis** is slightly different, without definite coelom. Typical Trochophore is unsegmented ciliated free swimming larva, with broad anterior end.

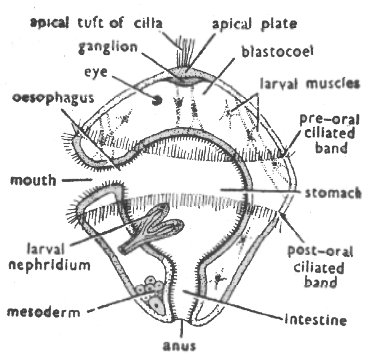
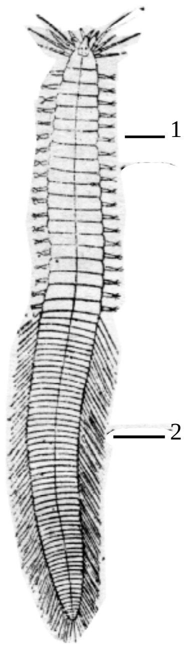


Fig 114 Trochophore larva

The anterior and consists of thickened epidermal region called **apical plate** with a tuft of sensory **apical cilia**, a pair of larval eyes and a cerebral ganglion. In the middle region, there is a **mouth** (ventral) which leads into a short **oesophagus** (Stomodaeum). This opens into wide **midgut** (stomach), which is continued into **hindgut** (proctodaeum), opens out through **anus**, present at the posterior end of the body.

This digestive tract is ciliated. The larva has a large space which is *blastocoel* but not true coelomic space. A pair of larval excretory organs *protonephridia* are present, consisting of a **flame** cell, an excretory duct which opens out near anus. Balancing organ **Otocyst** is present. The larval body is surrounded by **two circlets of cilia**, one in front of mouth (pre-oral proto troch) and the other behind mouth (post-oral Metatroch). These circlets of celia help the larva in swimming and food collection.

The trochophore metamorphosises into adult, the pre-oral part becomes **prostomium**. The post oral part gets elongatedand segmented; the segments develop **parapodia**. Gradually the ciliary bands disappear, larva grows in size and metamorphosises into adult worm, which sinks to the bottom and becomes burrowing adult worm.



1- Atoke 2-Apitoke

Fig 115 Heteronereis

5.4.9 Heteronereis: In some species, such as *Nereis (Neanthes) dumerilii*, the sexually mature forms aquire certain modifications externally and those forms are referred to as *Heteronereis*. In the posterior part of the body, the reproductive cells will be more abundant. The species exhibit two phases in their life, **non-sexual nereis phase** and **sexual heteronereis phase**.

Nereis forms are burrowing while heteronereis swims actively in surface water. The body of heteronereis is divisible into two distinct regions – anterior asexual region **atoke** and posterior sexual region – **epitoke**. The **Parapodia** of posterior region become large expanded vascularised outgrowths which assist in **rapid respiration**. The normal **setae** are replaced by **oar** shaped structures which help in active **swimming**.

The eyes become large and conspicuous, the sense of sight is well developed. The intestine gets compressed due to the development of gonads. The anal segment develops special sensory papillae. These heteronereis forms come to the surface waters by the undulating movements of the body and paddling movement of the parapodia. The sexual elements are released into water and sexual individuals die.

5.4.10 Comparative account

Nereis	Leech
1) Sexes are separate	1) Hermophrodaite
2) Gonads are located only in the posterior segments	2) Both the gonads are located in the anterior segments
3) Gonads appear only during breeding season	3) Gonads are permanent
4) Single pair of testes and numerious ovanies are present	4) 11 pairs of testes in segments 12 to 22 and single pair of ovaries in 11th segment

5) No gonoducts	5) Gonoducts are present. Male gonoducts have 11 pairs of vas efferentia (12-22) a pair of vas deferentia, apair of epididymes in segment 10, a pair of ejaculatory ducts and atrium (9&10) Female gonoducts have a pair of ovidu cts common oviduct and vagina.
6) Gonoducts are discharged to outside mostly through metanephridia or in some others through the temporary pores formed by the break down of body wall.	6) Parmanent genital pores are present. Male genital pore is situated on ventral side of 10^{th} segment. Femal genital pore is situated on the ventral side of the 11^{th} segment.
7) Prostate and albumin glands are absent.	7) Present
8) Male and female swim together but not copulate	8) Two leeches copulate in head-to-tail position.
9) Copuletory organ or peris is absent	9) Present in atrium
10) Fertilization occurs in sea water	10) Fertilizztion occurs in vagina
11) Development includes a trochophore larva.	11) Direct development no larval stage

5.4.11 Summary:

Nereis is a dioecious animal. Gonads are appear only in the breeding season Fertilization occurs in seawater development is indirect. It indludes a larva called trochophore. Sexually mature nereis of certain species show variations. Such species exhibt two distinct phases in the life cycle. i.e. anterior non-sexual or atoke part and posterior sexual part or epitoke.

Leech is a hermaphrodite. Male reproductive system consists of testes, Vas efferentia vas deferntia, epididymes, ejaculatory duct and atrium. Female reproductive system consists of the ovaries oviducts common oviduct and vegina. Cross fertilization takes place by copulation copulation. Occurs in water between two leeches in head-to tail position for one hour during March and April Fertilization occurs in vagina i.e internal development takes place inside the cocoon.

5.4.12 Key terminology

1) Atoke : asexual part of nereis
2) Cocoon : a barrel shaped proteerive covering around the eggs is called cocoon.
3) Ejaculatory duct : a convoluted structure formed by vas differentia of leech.
4) Epitoke: posterior sexual part of nereis

5.4.13 Model questions

1) Describe the reproductive system of leech.
2) Give an account of the reproduction and development of Nereis
3) Write short notes on i) Trochophore ii) Heteronereis iii) Cocoon

5.4.14. Reference books.

1 Invertebrate Zoology – E.L. Jordon
2. Text book of Zoology - invertebrates® R.L. Kotpal, S.K Agrawal, R.P Khetarpal

* * * *

Lesson 5.5
COELOM AND COELOMODUCTS

Contents:

5.5.1 Objective:

The purpose of this lesson is to understand the types & functions of coelom and coelomoducts.

5.5.2 Introduction:

coelom or body cavity is the wide space between the body wall and the alimentary canal. In annelids, in general, there is a spacious coelom around the alimentarycanal and it is qreatly reduced in Leeches. The Coelom is lined with a mesodermal epithelium called the peritoneum. The Peritoneum which lines the body wall is known as the perietal peritoneum or somatic mesoderm, and that which covered the internal organs called visceral peritoneumj or splanhnic mesoderm. coelom contains free mesenchyme cells or coelomic corpuceles floating in coelomic fluid.

Coelomoducts are segmentally arranged tubes, which originates from mesoderm as outpushings from the coelom to the outside. The primary function of coelomoducts is conveying the genital products, secondarily it also takes up the excretory funetion and some times becomes exclusively excretory in function.

5.5.3 Coelom:

Coelom in Polychaeta : The coelom is spacious and is devided into compartments by septa. The coelomic cavity of each segment is divided into longitudinal compartments by vertical mesenteries. They are usually perforated by apertures to allow flow of coelom fluid from one segment to another. In burrowing and tubicolous worms, the septa are in completely developed or may even be absent.

Coelom in oligochaeta: There is on specious coelom divided into compartments by septa and filled with a colourles coelomic fluid. The alimentary canal, blood vessels, Nephidia, Nerves and reproductive organs are all lodged in it.

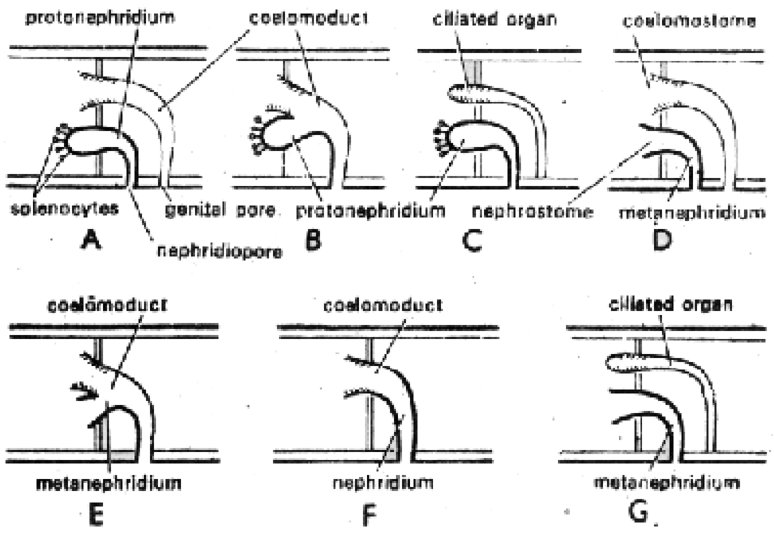
Coelom in Hirudinea: In Hirudinea the periviceral coelom divided into compartments by septa seen only in a single primitive leech acanthobdella, the sole representative of acanthobdelidae. In all other froms there is no distinct coelom. The coelom is filled with a kind of connective tissue known as botryoidal tissue. Thus the coelom is greatly reduced in the adult condition and the remnants of coelom are represented as sinuses and channels. The sinuses and channels are filled with coelomic fluid which resembles blood in having free amoeboid cells and disssolved haemoglobin. Thus the coelomic fluid is described as haemoglobin fluid. Coelom and coelomoducts in Anuelida

5.5.4 Coelomoducts:

In annelids, there are certain tubular structures which arranged segmentally; they are seen repeated by in many segments and their main function is to deliver the excretory and reproductive elements from the body to the exterior. These segmental organs are mainly two types, coelomoducts and nephridia. coelomoducts are derived from mesoderm and nephridia are ectodermal in origin. They were supposed to be homologous organs but goodrich has confirmed that they are morphologically different structures.

Coelomoducts develop as evaginations from coelom, which communicate the coelomic space to the exterior. towards the coelomic space they bear a ciliated funnel coelomostome and on the other hand they bear an opening genital pore through which they open to the exterior. Their main function is to deliver the gaments, which bear gonads, the spemaducal funnels and oviducal funnels of oliogocheates are the modified coelomoducts.

Nephormixia : In many polychaetes, the coelomoducts and nephridia are not independent but become combined. Their external pores and even the canals become combined. such compound structures are called rephromixia.



A - Protonephridium and coelomoduct of Vanadis
B - Protonephromixium of Pollyodoce
C - Protonephridium and citiated organ of Glycera and Nephthys
D - Metanephridium and coelomoduct fo Capitellidae and Notomastus
E - Metanephromixium of Hesione
F - Mixonephridium of Arenicola
G - Metanephridium and Ciliated organ of Nereis

Fig.116 Types of Nephridia, Coelomoducts and Nephromixia in various polychaetes

1) Protonephromyxium : It is formed by the union of coelomoduct and protenephridium. It serves to remove both the genital and excretotry products. It occurs in Phyllodoce.
2) Metanephromyxium: It is formed by the association of coelomoduct with a metanephridium, removing the excreta and sex cells Eg. Hesione
3) Mixonephridium: The coelomoduct and nephridium are very intimately joined to form an organ similar to a funnel. This type is found in arenicola.
4) Ciliated organs : In some forms, the coelomoducts are reduced to ciliated organs. In neanthes they are joined to dorso laterel longitudinal muscles and do not open externally.genital ducts of oligochaeta and Hirudinea are coelomoducts and restricted to some segments.

5.5.5 Summary :

Coelom or body cavity is the wide space between the body wall and the alimentary canal. It is lined by a coelomic epethebium. It is filled with coelomic fluid. Coelomic fluid contains coelomic corpuscles.

Coelomoducts are segmentally arranged tubes, which originates from mesodenm as outpushings from the coelom to the outside. the coelomoducts primarily function as gonoducts for coveying to the exterior the genital products which develop on the wall of the coelom. However in some forms, the coelomoducts may secondarily function as excretory organs.

5.5.6 Key terminology:

1) Monocoel :The coelomic space restricted to reproductive organs is called gonocoel.
2) Nephrocoel: The coelomic space is restricted to excretory organs called Nephrocoel
3) Nephromixia: The coelomoducts and Nephridia are fused partially or wholly, forming compound segmental organs called nephromixia.
4) Protonephromyxium: It is formed by the union of coelomoduct and protonephridium

5.5.7 Model Questions:

1) Write an essay about the coelom and coelomoducts in annelida
2) Write short notes an coelomoducts.

5.5.8 Reference books

1) Annelida - Phylum series - R.L. Kotpal
2) Invertebrate Zoology - E.L Jordan

Lesson 5.6
METAMERISM

CONTENTS

5.6.1 OBJECTIVE

The purpose of this unit is to understand the origin, types and significance of metamerism.

5.6.2 INTRODUCTION

Metamerism is the most important distinguishing characteristic feature of phylum annelida. The elongated body is divided into a number of rings or segments along the antero-posterior axis called metamerism. Each segment is almost similar to all other segments and contains a set of representatives of all the body systems (muscles, nerves, excretory organs, gonads, etc.). The segmental organs are interdependent and act as a single functional unit. Metameric segmentation is an evolutionary advance character of coelomates. It is originates in the mesoderm and extends outward upto the cuticle. As a result, the body becomes divided transversely into a number of similar parts or segments. The subdivisions may be indicated externally by constrictions of the body surface. Internally the segmenets are separate from each other by septa extending across the coelom. Only the alimentary canal, nerve cord and the main blood vessels are unaffected, but they extend through each segment.

Metamerism is usually more complete or uniform through out the body of the embryo than of the adult. Due to the developmental modifications i.e., formation of head, limbs etc., the dissimilarity of the metamerism is seen in adults.

5.6.3 TYPES OF METAMERISM

Metamerism in animals has been studied under six categories. They are as follows:

a) **True metamerism or mesodermal metamerism:** True metamerism is found in Annelids, Arthropods and chordates. In true metamerism, the segmentation begins from inside in the mesoderm and extends to outside upto body wall. Hence, the external constrictions correspond to the internal segmentation. New segments are formed at the posterior end in front of the last or anal segment, so the older segments appears at the anterior end. All segments work in co-ordination, none is a self-contained unit.

b) **Pseudometamerism or superficial metamerism:** Pseudometamerism is seen in tape-worms. In this, the segmentation begins from outside with the cuticle and extends inwards upto some extent. The internal body parts are not segmented. New segments are formed at the anterior end. Hence, the older segments occur at the posterior end. All are self-contained units.

c) **Complete metamerism:** If the ssegementation is found in all the organs, the metamerism is called complete metamerism.
e.g. Annelids.

d) **Incomplete metamerism:** If the segmentation is not found in all organs, the metamerism is called incomplete metamerism.
e.g. Arthropoda and Chordates.

e) Homonomous segmentation: All the body segments of an animal are identical and also having a set of representatives of all the body parts. This type of segmentation is called homonomous segementation. No such animal exists since one or more segments are fused to form head or anal segments, and these segments differ from typical body segments. Some of the polychaetes are nearest to this ideal condition. In these animals, all the segments between the head and the anal segment are identical. Homonomous segmentation is a primitive condition.

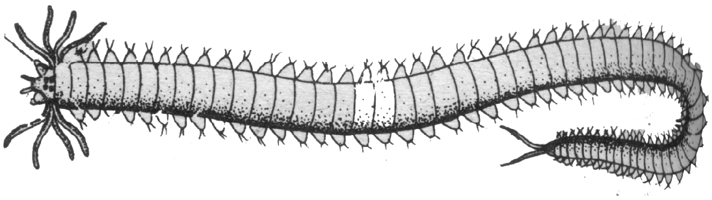


Fig.117 Homonomous segmentation

Heteronomous segmentation: In most of the animals, the segmentation has undergone local alternations through loss or fusion of segments and the concentration of certain organs in certain segments and the loss of certain organs in some segments to perform different functions. This type of dissimilarity in the segmentation is called Heteronomous segmentation.
e.g. Arthropods and Chordates.

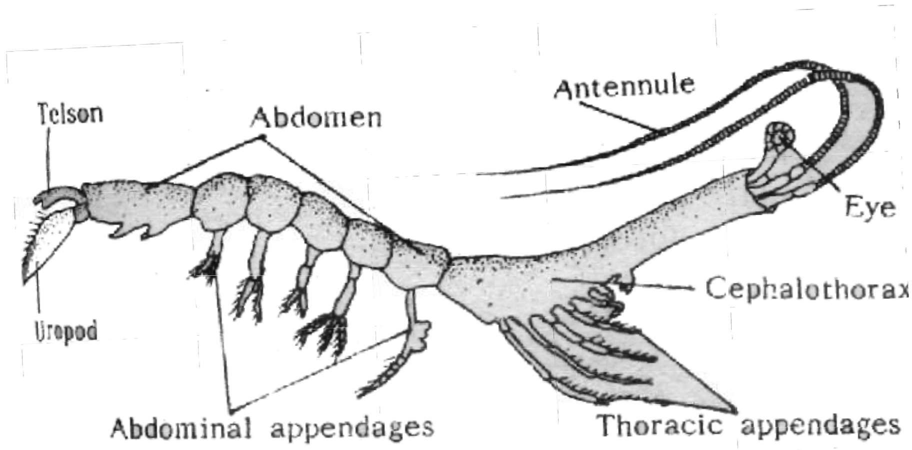


Fig 118 Heteronomous Metamerism

5.6.4 ORIGIN OF METAMERISM

How metamerism has been brought about is still doubtful. No satisfactory reason can be given for the origin of metamerism. Many theories are put forward regarding the origin of segmentation.

They are as follows:

(a) **Pseudo-metamerism theory:** According to this theory, metamerism developed as a result of repetition of body parts, such as muscles, nerves, nephridia, blood vessels etc., in a single individual. Later, a segmented condition was obtained by the formation of cross-partitions in between them, so that each segment received a repeated part of each system. This theory was supported by Hyman (1951) and goodrich.

In flatworms when gonads mature they occupy maximum space and create pressure on the adjacent systems and also do not permit the bending of the body. Consequently the body started bending only at the region between gonads. In due course of time, constrictions are formed at these place and segmentation resulted.

(b) **Fisson (or) corn theory:** According to this theory, the non-segmented body of an animal undergoes transverse fission repeatedly, producing a chain of individuals. These are fail to detach themselves and are united end to end and give the appearance of segments. In this way, segmented animals might have formed.

(c) **Locomotory theory:** According to this theory, metamerism is formed by the breaking up of the body as a result of serpentine swimming movements. Soft bodied animals during their locomotion make undulating movements. This results in bends of the body at certain places. In course of time, the musculature at the point of bends may break up to facilitate free movement of the body. It was followed by other organs. In this way, the whole body may be broken into segments.

(d) **Embryological theory:** It suggests that mechanical stresses in the mesoderm of the elongating embryo or larva resulted in its fragmentation leading to segmental repetition of mesodermal derivatives in the adult.

5.6.5 SUMMARY

The division of body into a number of compartments or segments along the anterio-posterior direction is called metamerism. The oldest segment will be at the anterior end and youngest at the posterior end. Each segment contains the organs of all the body systems. Metamerism is also seen in phyla like Arthropoda and chordata. A true metameric segmented animal must show the segmentation of mesoderm because many internal systems like excretory, circulatory, muscular systems are derived from mesoderm. Metamerism facilitates the locomotion.

5.6.6 KEY TERMINOLOGY

Heteronomous segmentation: Dissimilarity in the segmentation (due to loss or fusion of the segments) of the body is called Heteronomous segmentation.

Metamerism: Division of Body into a number of similar rings or segments along the antero. Posterior axis is called Metamerism.

Superficial metamerism or Pseudometamerism: Segmentation limited to externally. Internal body parts are not segmented. Ex. Tapeworm.

5.6.7 MODEL QUESTIONS

1. Write an essay on Metamerism.
2. Define the metamerism? Explain the types and origin of Metamerism.

5.6.8 REFERENCE BOOKS

1. Invertebrate Zoology. E.L. Jordan & AP.S. Verma
2. Annelida - Phylum series. Kotpal.

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Lesson 6.1
GENERAL CHARACTERS AND CLASSIFICATION OF PHYLUM ARTHROPODA

6.1.1 **OBJECTIVE:**

The purpose of this lesson is to understand different arthopods, their general characters and an outline classification with common examples.

6.1.1 INTRODUCTION

Arthropoda is the largest phylum in the Animal Kingdom. It includes a vast assemblage of animals such as ***prawns, crabs, lobsters, centipedes, millipedes, insects, spiders, scorpions, ticks, mites*** etc., representing about 80% of the animal species. It is the most successful group with its representatives distributed in ***freshwater, marine and terrestrial habitats*** along with some ***parasitic*** forms. The term '***Arthropoda***' was coined by Von Siebold (Arthros = jointed, podos = foot), which includes animals with jointed appendages.

6.1.2 GENERAL CHARACTERS

Arthropods are bilaterally symmetrical, Triploblastic, metamerically segmented animals. Anterior few segments are fused to form head (***cephalisation***). Formation of head provides the concentration of nervous control and sensory perception in the brain.

Body is divided into head, thorax and abdomen (insects); in some forms head and thorax fuses forming ***Cephalothorax*** (prawn); in some others body is divided into prosoma, mesosoma and metasoma (scorpion).

Body is covered by thick chitinous exoskeleton. The skeleton is in form of plates, called ***Sclerites***. The exoskeleton is cast off periodically to permit the growth of the individual, this process is called ***Ecdysis*** or ***moulting***. The exoskeleton helps to prevent the loss of water from the body (**desiccation**). Body segments bear **jointed appendages**, which are adapted for crawling, walking and swimming. **Striped muscles** appear for the first time in Arthropods. Digestive system includes a long coiled Alimentary canal and digestive glands are **Salivary glands, hepatic caecae, hepatopancreas**. Mouth parts are variously modified to suit with the mode of feeding. True coelom is present (***Schizocoelic***) but completely filled with blood (***haemocoel***). Blood vascular system is ***open type*** and blood is devoid of pigmentation (***haemolymph***); blood flows in spaces – ***lacunae*** or ***sinuses***. Haemolymph contains respiratory pigment – ***Haemocyanin***, copper containing compound. Dorsal tubular heart is present which is divided into compartments; Blood flows into these compartments through openings called ***ostia***. Respiratory organs are **gills, trachea, book lungs** and **book gills**. Excretion is carried out by **green glands, coxal glands** and **Malpighian tubules**. Nervous system consists of a nerve ring and double ventral nerve cord, which is of **annelidan type**. Sense organs are better developed than in Annelids, which include simple eyes (***Ocelli***), **compound eyes**, **antennae, statocyst**. Sexes are separate, **sexual dimorphism** is exhibited in some forms. Fertilisation is internal. Development direct without any larval stage in some forms (Ametaboly). Majority show indirect development with **nymph** or **larval stages** in their life history. Larva metamorphosises into adult. Eggs are mostly **centrolecithal** with centrally located yolk and cleavage is **superficial**. **Parental care** is exhibited by some forms.

6.1.3 CLASSIFICATION

Phylum Arthropoda is divided into 4 sub-phyla,
TRILOBITOMORPHA (TRILOBITA)
CHELICERATA
MANDIBULATA and PYCNOGONIDA

Trilobitomorpha includes extinct primitive arthropods.

Chelicerata includes animals with body divided into ***Prosoma*** and ***Opisthosoma***, first pair of appendages ***Chelicerae***.

Mandibulata includes animals with body divided into head, thorax, abdomen (cephalothorax and abdomen in some forms). Mandibles and antennae are present.

Pycnogonida includes a small group of marine sea spiders. Body is very small as compared with the legs.

S. PHY: TRILOBITOMORPHA

The representatives of this phylum are extinct, survived during ***Palaeozoic era***. Body is divided into **anterior head** (***Cephalon***) with 4 or 5 fused segments, middle ***trunk*** region and posterior ***pygidium*** (**Abdomen**). Body is divided into a median and two lateral longitudinal lobes, and hence the name ***trilobita***. Head bears antennae and eyes. Trunk bears paired appendages, without any special modifications. Animals are adapted to lead **burrowing, planktonic** and **swimming** modes of life.

Eg : ***Triarthrus, Megalaspis, Radiaspis***.

SUB-PHYLUM 2: CHELICERATA

Body is divided into anterior ***Prosoma*** (cephalothorax) and posterior ***opisthosoma*** (Abdomen). Prosoma is generally six segmented and opisthosoma thirteen segmented. First pair of appendages ***Chelicerae,*** which help in masticating the food. Second pair of appendages ***Pedipalpi***. Generally 4 pairs of walking legs are present. ***Antennae*** are exclusively absent.

Opisthosoma bears no appendages.

Sub-phylum chelicerata includes 2 classes, namely: ***Merostomata*** and ***Arachnida.***

CLASS : 1. MEROSTOMATA

Horse shoe crabs and some extinct aquatic arthropods are included in this class. Marine forms, inhabit shallow waters and soft bottoms. Body is divided into ***prosoma, mesosoma*** and ***metasoma***. Prosoma is covered by horse shoe shaped exoskeleton-***Carapace***. Prosoma bears ***chelicerae*** and **five pairs of legs**. Mesosoma bears 5 pairs of ***book-gills***, which are respiratory in function. Metasoma is extended posteriorly into long pointed spine like ***telson***.

Class : Merostomata includes two sub-classes,

Subclass: ***Xiphosura*** and
Subclass: ***Eurypterida***

SUB-CLASS 1 : Xiphosura

Horse shoe crabs are included in this sub-class.

Cephalothorax is large with horse-shoe shaped Carapace.
Posterior pointed telson is present.

Eg. ***Limulus*** (king-crab)

This remained unchanged over millions of years and hence re

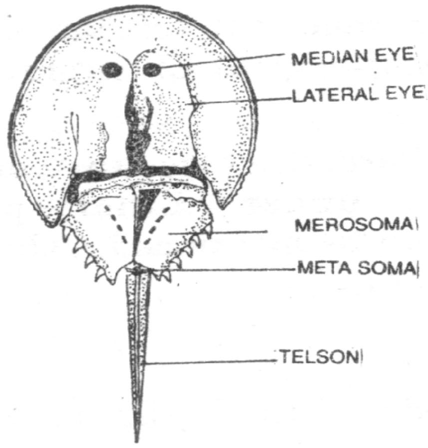

Fig 119 Limulus

SUB-CLASS 2 : Eurypterida

Extinct giant aquatic arthropods are included in this sub-class

Cephalothorax is small. Abdomen is pointed posteriorly.

Eg: ***Eurypterus***

CLASS 2 : ARACHNIDA

Spiders, scorpions, ticks and ***mites*** are included in this class. Animals are terrestrials, few forms are aquatic. Body is divided into ***prosoma*** and ***opisthosoma***. Prosoma bears a pair of ***chelicerae***, a pair of

pedipalpi and ***4 pairs of walking legs***. Mesosoma and Metasoma bears no appendages. In scorpions, the metasoma appears as elongated tail, ending with pointed ***sting***. In scorpions and spiders ***book lungs*** serve the function of respiration and ***trachea*** are seen in some spiders and pseudoscorpions. Excretory organs are ***coxal glands*** and malpighian tubules. Development is direct. Scorpions are viviparous.

This class includes 10 orders:
Scorpionida
Araneae
Palpigradi
Pedipalpi
Amblypygi
Solifugae
Pseudoscorpionida
Phalangida
Podogona, and
Acarina

Order 1: Scorpionida

Scorpions are included in this order. Elongated, nocturnal animals. Prosoma short and unsegmented. Opisthosoma is divided into mesosoma and metasoma. Mesosoma is 7 segmented. Metasoma is 5 segmented with poisonous sting at its end. Chelicerae small and 3 segmented. Pedipalps large. Respiration by book lungs. Animals exhibit mating dance. Species are viviparous.

Eg. ***Palamnaeus, Buthus, Centrurus***.

Order 2: Araneae

This order includes **spiders**. Animals are chiefly terrestrial. Body is divided into prosoma and opisthosoma which are unsegmented. Head is marked. Opisthosoma without telson. 2 to 4 pairs of spinneretes are seen which spin thread. Chelicerae 2 jointed. Pedipalps simple, leg like. Respiration by book-lungs or trachea.

Eg: ***Aranea*** (web-spider)
Salticus (Jumping spider)
Lycosa (Wolf-spider)

Order 3 : Palpigradi

Small sized arachnids. Body divided into prosoma and opisthosoma. Tail like telson is present. Chelicerae 3 jointed. Pedipalps 6 jointed. Respiration by book lungs

Eg: ***Koenenia*** (Micro-whip Scorpion)

Order 4 : Pedipalpi

This is also called Uropygi. Small nocturnal animals. Prosoma unsegmented. Opisthosoma 9-12 segmented. Many jointed telson is present. Chelicerae 2 jointed. Pedipalps large, six jointed. Respiration by book-lungs.

Eg: ***Thelyphonus***

Order 5 : Amblypygi

Flattened, crab like nocturnal animals. Prosoma unsegmented. Opisthosoma 12 segmented.
Chelicerae 2 segmented, hook like.
Pedipalps large. First pair of legs long.

Eg. ***Charinus.***

Order 6 : Solifugae

Nocturnal animals. Opisthosoma 10-11 jointed, without telson. Chelicerae 2 jointed. Pedipalps 6 jointed. Respiration by Trachea.

Eg: ***Galeodes*** (Sun-spider)

Order 7 : Pseudoscorpionida

Small, scorpion-like animals. Prosoma unsegmented. Opisthosoma 12 segmented. Chelicerae small, 2 jointed. Pedipalps large, 6 jointed. Respiration by Trachea.

Eg. ***Chelifer*** (Pseudoscoprion)

Order 8 : Phalangida

Small, oval, spider like animals. Prosoma unsegmented. Opisthosoma 10 jointed. Chelicerae 3 jointed. Pedipalps 6 jointed, small. Legs long and slender. Respiration by Trachea.

Eg. ***Phalangium***

Order 9 : Podogona

Small, tick-like animals. Carapace bears hood-like plate. Opisthosoma six jointed. Chelicerae 2 jointed and small. Pedipalps – 6 jointed. Respiration by Trachea.

Eg: ***Cryptocellus***

Order 10 : Acarina

Parasitic arachnids live as parasites on animals and pests of plants. Body small, oval, compact and unsegmented. Prosoma and opisthosoma not distinct. Chelicerae and pedipalps small and chelate. Biting, piercing and sucking mouth parts are seen. Respiration by Trachea.

Eg: Mites and Ticks,
Sarcoptes (Itch-mite), Ixodes (Sheeep-tick), Argas (Bird-tick).

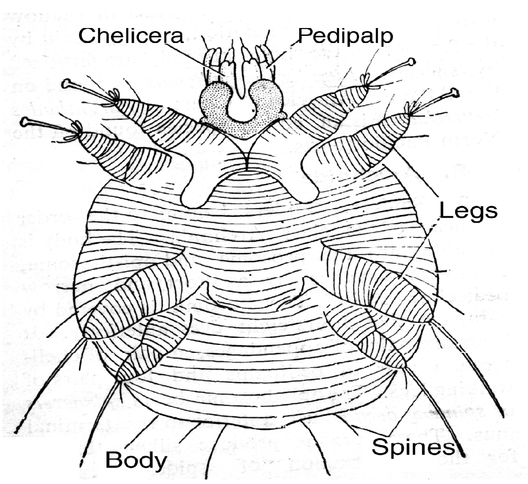

Fig 120 Sarcoptes

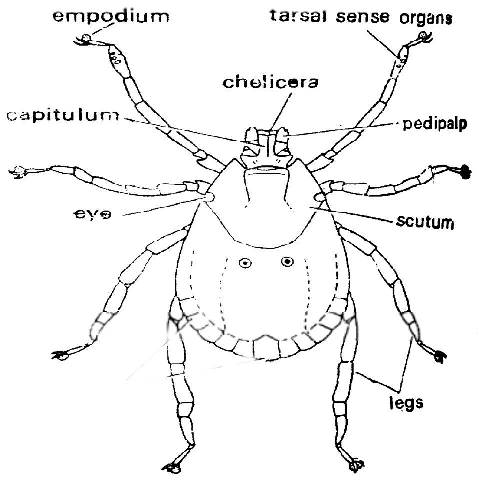

Fig 121 Tick

SUB-PHYLUM 3 : MANDIBULATA

Crustaceans, Millipedes Centipedes and Insects are included in this subphylum. Mandibles are characteristic appendages of this group, which are the first pair of mouth parts, help in biting and cutting the food.

The sub phylum includes 4 classes,

Crustacea
Chilopoda
Diplopoda, and
Insecta

CLASS I : CRUSTACEA

This class includes ***prawns, crabs, lobsters, barnacles*** and ***cray fish***. Animals are primarily aquatic, inhabiting seas, lakes and ponds. Few are parasitic. Body is divided into head, thorax and abdomen, in most forms head and thorax unite to form cephalothorax which is covered by a protective shield called ***Carapace***. Head bears antennae, mandibles and maxillae. Appendages are biramous with basal ***Protopodite***, an outer ***exopodite*** and an inner ***endopodite***. Alimentary canal is divided into foregut (stomodaeum), midgut (mesenteron) and hindgut (proctodaeum). Digestive glands include ***hepatopancreas*** which serves the function of liver and pancreas of higher animals. Body cavity is filled with blood (haemocoel); true coelom is confined to gonads and kidneys. Chief Respiratory organs are gills (branchiae). Blood vascular system is open type or lacunar type. Dorsal contractile heart is present. Excretion is carried out by **antennary glands** or **green glands**. Nervous system consists of brain and ventral nerve cord. Compound eyes and simple eyes ocelli are present. Mostly unisexual. Development indirect. Typical larva is Nauplius.

Class Crustacea is divided into 8 sub classes.

Cephalocarida
Branchiopoda
Ostracoda
Mystacocarida
Copepoda
Branchiura
Cirripedia, and
Malacostraca

Subclass 1: Cephalocarida

Most primitive animals. Marine, bottom dwellers. Body small and slender, divided into head and trunk. Eyes absent. Antennules, Antennae short. Maxillae well developed. Larva – Metanauplius.

Eg: ***Hutchinsoniella***.

Subclass 2 : Branchiopoda

Small primitive animals. Mostly freshwater forms.Carapace shield like. Trunk appendages leaf like. Abdomen has no appendages. Larva is nauplius.

This subclass includes 4 orders.

Order 1 : Anostraca

Includes fairy shrimps. Stalked eyes present. Trunk elongated.

Eg: ***Streptocephalus, Eubranchipus***

Order 2 : Notostraca

Includes ***tadpole shrimps***. Antennae reduced. Trunk bears many appendages. Caudal styles present.

Eg. ***Triops***

Order 3 : Conchostraca

Includes ***clam shrimps***. Carapace bivalved. Body is compressed. Antennae large. Caudal styles claw-like.

Eg: ***Estheria***.

Order 4 : Cladocera

Water fleas are included in this order. They form important components of zooplankton. Antennae biramous. Eyes fused together. Caudal styles claw-like.

Eg: ***Daphnia***

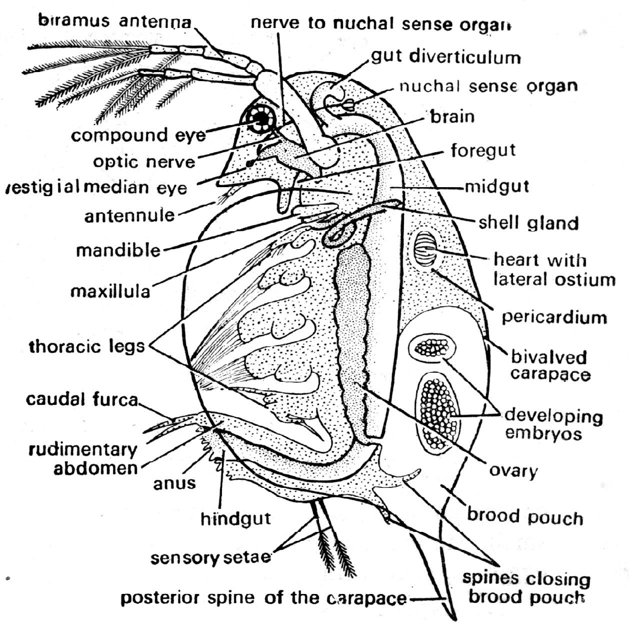

Fig 122 Daphnia

Sub-class 3 : Ostracoda

Small freeliving animals. Body laterally compressed. Body enclosed in bivalve shell. Abdomen rudimentary. Larva is Nauplius.

This subclass includes 4 orders,

Order 1 : Myodocopa

Marine animals
Antennae biramous

Eg. ***Cypridina***

Order 2 : Cladocopa

Marine animals.
Antennae biramous.

Eg. ***Polycope***

Order 3 : Podocopa

Marine, freshwater forms.
Antennae uniramous.
Trunk appendages 2 pairs. eg. ***Cypris***

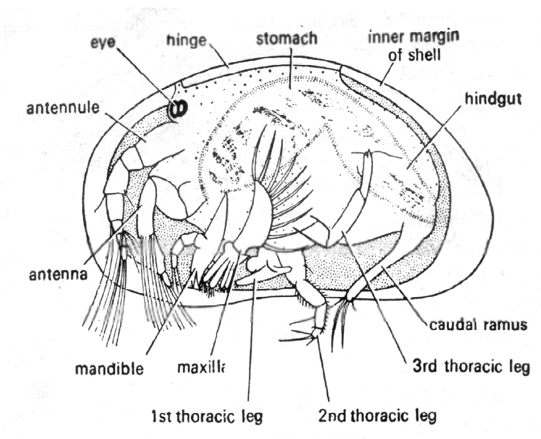

Fig 123 Cypris

Order 4 : Platycopa

Marine animals
Single pair of trunk appendages
e.g. ***Cytherella***

Subclass 4 : Mystacocarida

Primitive marine animals. Body elongated. Compound eye absent; Nauplius eye present. Abdomen limb-less. Larva metanauplius.

Eg. ***Derocheilocarus***

Subclass 5 : Copepoda

Free swimming freshwater and marine forms. Form bulk of zooplankton. Body small, elongated with head, thorax and abdomen. Single median eye present. Antennules and Antennae help in swimming. Abdomen without appendages. Larva Nauplius.

Eg. ***Cyclops*** and ***Calanus***.

Subclass-6 : Branchiura

Species live as ectoparasites on fishes and amphibians; commonly called ***Fish-lice***. Body-flat with head, thorax and abdomen. Carapace large and shield like. One pair of compound eyes present. Abdomen small and limb-less.

Eg. ***Argulus***

Sub-class 7 : Cirripedia

Barnacles are included. Marine, parasitic and sedentary forms attached to rocks, boats etc. Body large, enclosed in a carapace. Abdomen limb-less. Larva Nauplius.

This subclass includes 5 orders.

Order 1. Thoracica

Animals live as commensals. Body covered with calcareous plates.

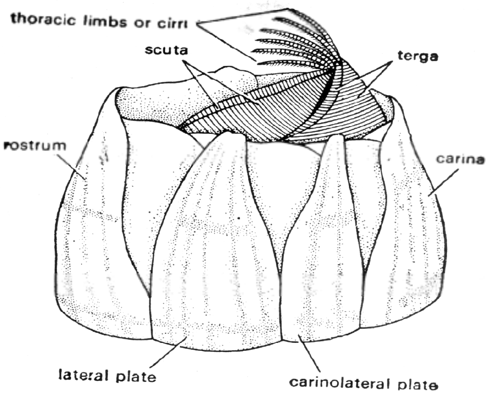

Fig 124 Balanus

Eg. ***Lepas*** (Goose barnacle) and ***Balanus*** (Acorn barnacle)

Order 2. Acrothoracica

Minute, sessile forms live on molluscan shells and corals. Thoracic appendages 4 pairs.
Eg. ***Trypetesa***.

Order 3. Ascothoracica

Parasitic forms on Echinoderms. Thoracic appendages 6 pairs. Mouth parts piercing and sucking type.

Eg. ***Synagoga***

Order 4. Apoda

Parasitic forms. Body is made up of rings. Mouth suctorial.

Eg. ***Proteolepas***

Order 5. Rhizocephala

Parasitic forms on crabs. Adult body degenerate, sac-like. No segmentation is seen. Appendages are absent. Parasite sends absorptive roots into the body parts of the host. Life history includes Nauplius larva. Shows retrogresive metamorphosis, cause damage to the host, parasitic castration.

Eg. ***Sacculina***

Subclass 8. Malacostraca

Large sized animals. Marine and freshwater forms. Body is divided into head, thorax and abdomen. Compound eyes are present. Appendages 19 pairs. Typical larva – Nauplius.

In this subclass, 10 orders are present.

Order 1. ***Nebaliacea***.
Includes large bivalved animals.
Eg. ***Nebalia***

Order 2. ***Anaspidacea***.
Freshwater forms of Australia. Stalked eyes are present.
Eg. ***Anaspides***

Order 3. ***Bathynellacea***
Small, aquatic forms of Europe. Eyes absent. Pleopods absent.
Eg. ***Bathynella***

Order 4. ***Mysidacea***

Opposum shrimps are included. Marine and freshwater forms. Body elongated, uropods and tail fin present.

Eg. ***Mysis***

Order 5. *Cumacea*

Small, marine animals. Head and thorax enlarged. Abdomen slender

Eg. ***Diastyles***

Order 6. *Tanaidacea*

Minute marine forms. Carapace small.

Eg. ***Tanais***

Order 7. *Isopoda*

Marine, freshwater and terrestrial forms. Body flat. Carapace absent.

Eg. ***Ligia***

Order 8. *Amphipoda*

Mostly marine, some freshwater forms. Body elongated. Carapace absent.

Eg. ***Gammarus***

Order 9. ***Stomatopoda***

Mantis shrimps are included. Marine forms. Abdomen larger than cephalothorax. Abdominal gills present.

Eg. ***Squilla***

Order 10. ***Decapoda***.

Prawns and **crabs** are included in this order.

Marine and freshwater forms. Carapace well developed. Statocyst is present. Characteristic larvae are zoea, mysis and megalopa.

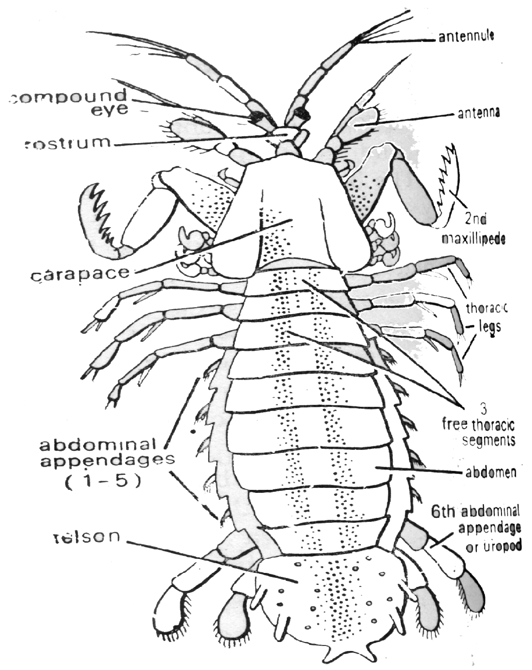

Fig 125 Squilla

Eg. ***Penaeus, Macrobrachium, Panulirus, Eupagurus, Cancer***.

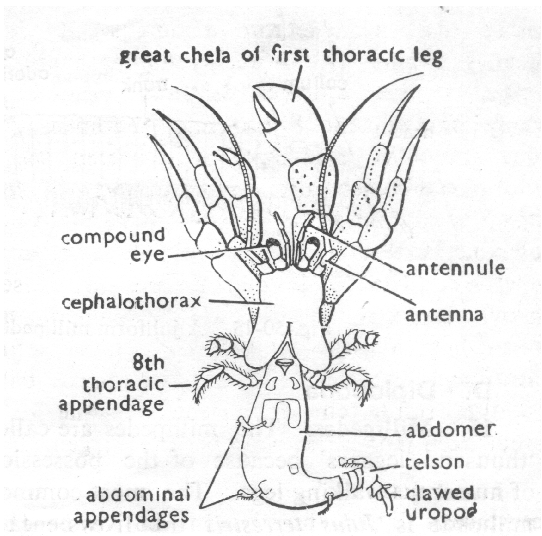

Fig 126 Eupagurus

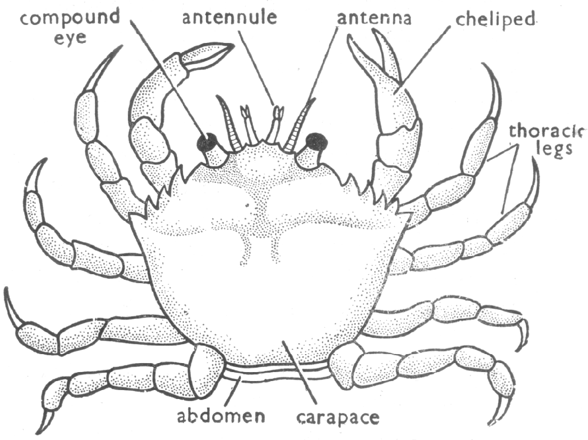

Fig 127 Cancer

CLASS : CHILOPODA

Members are called ***centipedes***. Terrestrial air-breathing forms. Body is elongated, segmented, divided into **head** and **trunk**. Each segment bears one pair of legs. Body is dorso- ventrally flattened, extend upto 30 cms long. Head bears 1 pair of antennae, 1 pair of mandibles and 2 pairs of maxillae. First pair of legs are transformed into poison claws. Respiration is carried out by trachea. Excretory organs are malpighian tubules. Sexes are separate. Genital opening is seen in the posterior part of the trunk (Penultimate segment) and hence are called *Opisthogoneates*.

Eg. ***Scolopendra*** and ***Scutigera***.

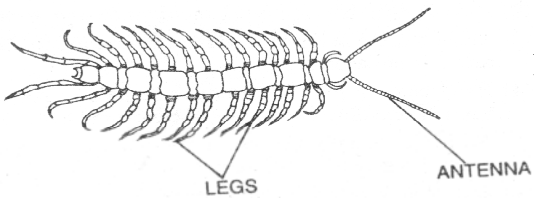

Fig 128 Scolopendra

4 orders are included in this class,

Order 1. ***Scutigeromorpha***. eg. ***Scutigera***

2. ***Lithobiomorphoa***. eg. ***Lithobius***

3. ***Geophilomorpha***. eg. ***Geophilus***, and

4. ***Scolopendromorpha.*** eg. ***Scolopendra***

CLASS 3. DIPLOPODA

The representatives of this class are called millipedes. Terrestrial air breathing forms. Body is elongated, sub-cylindrical, extend upto 20 cms in length. Body is divided into head, short thorax and abdomen. Head bears 1 pair of antennae, 1 pair of mandibles and 1 pair of maxillae. Legs are short and one pair each in thoracic segments and 2 pairs each on abdominal segments. Animals feed on decaying plant material. Respiration is by trachea. Simple eyes ocelli are present. Excretory organs are malpighian tubules. Genital opening is seen in the anterior part of the trunk and hence they are called ***Progoneates***.

There are 6 orders in this class,

Order 1. ***Pentazonia***. Eg. ***Glomeries***

Order 2. ***Limacorpha***. Eg. ***Glomeridesmus***

Order 3. ***Colobognatha***. Eg. ***Siphonophora***

Order 4. ***Nematophora***. Eg. ***Polymicrodon***

Order 5. ***Polydesmida***. Eg. ***Polydesmus***

Order 6. ***Juliformia***. Eg. ***Julus, Spirobolus***

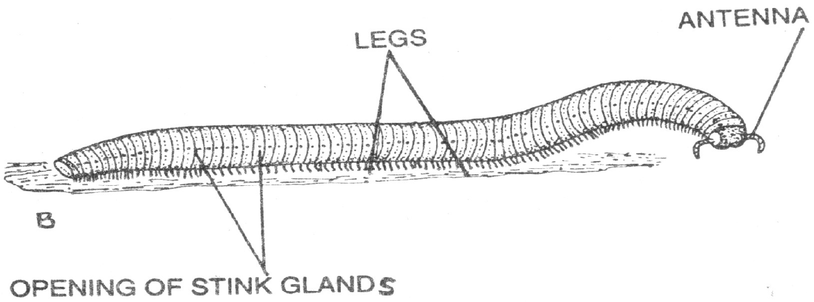

Fig 129 Julus

CLASS : INSECTA

Insects are most successful animals. They are cosmopolitan in distribution, adapted to live in every type of environment (exceptionally absent in marine habitat). **Mosquitoes, house flies, bees, bugs, ants, wasps, silkworms** etc., are included in this class. Body is divided into head, thorax and abdomen. Head bears antennae, mandibles, maxillae. Compound eyes and simple eyes (ocelli) are present. Mouth parts are variously modified depending on their mode of feeding such as biting and chewing (cockroach), piercing and sucking (mosquito), sponging and sucking (house fly), siphoning (butterfly), lapping chewing (honey bees) type.

Thorax bears one or two pairs of wings and three pairs of legs (***hexapods***). Abdomen bears no appendages in adult stage. Salivary glands are present. Respiratory organs are Trachea. Excretory organs are malpighian tubules. Nervous system is annelidan type with brain, nerve ring and double ventral nerve cord. Sense organs include compound eyes and Sensillae. Sexes separate, sexual dimorphism is marked in some insects. Fertilisation internal. Development direct (***Ametaboly***) in some insects such as ***Lepisma***; majority of insects show metamorphosis with a ***nymph*** in the life cycle (**Heterometaboly**) such as **cock-roach, dragon fly**; larva and pupa (**Holometaboly**) as seen in **house fly, mosquito, butterfly** etc.

Eg. ***Lepisma* (Silver fish)**
***Periplanata* (Cockroach)**
***Poeciloceros* (Grass hopper)**
***Termites* (White ants)**
***Pediculus* (Louse)**
Dragon fly
***Cimex* (bed bug)**
***Drosophila* (Fruit fly)**

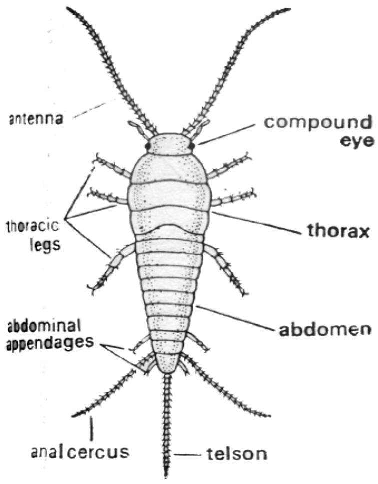

Fig 130 Lepisma

Class Insecta is divided into 2 sub-classes

Apterygota, and ***Pterygota***.

Apterygota include primitive wingless insects. Metamorphosis is absent (Larval stages are not seen in life history).

Order 1. Protrura

Animals are soft bodied. Eyes and antennae absent. Mouth parts suctorial. ***Telson tails*** are included in this order.

Eg. ***Acerentomon***

Order 2. Collembola

Small insects. Antennae moderately long. Mouth parts chewing type. Metamorphosis absent.

Eg. ***Isotoma*** (Spring tails)

Order 3. Thysanura

Small insects. Body covered by silvery scales. Tip of the abdomen bears caudal filament. Mouth parts chewing type. No metamorphosis.

Eg. ***Lepisma*** (Silver fish)

Subclass ***Pterygota*** includes winged insects.

Metamorphosis complete or incomplete.

This subclass is divided into 2 divisions:
Exopterygota and ***Endopterygota***.

Division Exopterygota includes insects with wings which develop externally as buds. Metamorphosis includes *Nymph* stage.

Eg. Cockroaches, Grass hoppers, Locusts, Crickets, Stick-insects, Leaf-insects and Praying mantis, Termites, Human Lice, Bird-Lice, Thrips, May flies, Dragon flies, water bugs and bed bugs.

Division Endopterygota includes insects with wings which develop internally.

Metamorphosis is complete with larva and pupa stages.

Eg. Mosquitoes, House flies, Moths, Butter flies, Beetles and Fleas.

In **Subclass Apterygota**, there are 3 orders.

Division Exopterygota includes 12 orders

Order 1. Orthoptera

Large insects. Prothorax is large. Forewi
bears anal cerci.

Eg. ***Periplanata*** (Cockroach),
Poeciloceros (grass hopper)
Gryllus (cricket)
Mantis (Praying mantis)

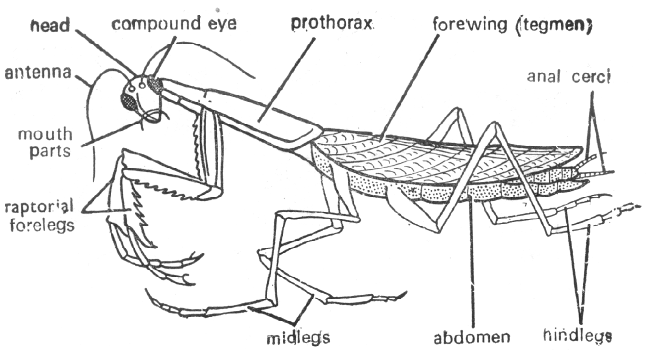

Fig 131 Mantis

Order 2. Dermaptera

Slender insects. Body flat. Forewings short and leathery (Hemielytra). Hindwings broad, fan shaped.

Eg. ***Forficula***.

Order 3. Isoptera

Small soft bodied social insects, live in colonies. Wings 2 pairs. Colony contains winged and wingless forms.

Eg. ***Termites***

Order 4. Plecoptera

Soft-bodied, flat insects. Antennae long hair like. 2 pairs of wings, longer than the body. Nymphs aquatic.

Eg. **Stone flies**

Order 5. Embioptera

Small slender insects. Head and eyes large. Females wingless. Silk spinning glands are present.

Eg. ***Oligotoma*** (Web-spinners).

Order 6. Psocoptera

Small soft insects
Antennae long.

Eg. **Book-lice**

Order 7. Siphunculata

Wingless insects. Parasitic, blood sucking forms. Head narrow. Mouth parts piercing and sucking type. Metamorphosis absent.

Eg. ***Pediculus*** (Human body louse).

Order 8. Mallophaga

Small wingless insects. Ectoparasitic on birds. Head large.
Mouth parts biting type.

Eg. ***Menopon*** (Bird-louse)

Order 9. Thysanoptera

Minute slender insects. Mouth parts rasping and sucking type. Wings long and narrow.

Eg. ***Heliothrips***

Order 10. Ephemeroptera

May flies are included in this order:

Soft elongated insects. Abdomen with a pair of long cerci and median-filament. Nymphs are aquatic.

Eg. ***Ephemera***

Order 11. Odonata

Dragon flies and **Damsel flies** are included in this order. Large insects, powerful fliers. Head large and mobile. 2 pairs of wings. Nymphs (Naids) are aquatic.

Eg. ***Dragon fly***

Order 12. Hemiptera

Body broad and flattened. Parasitic forms and blood suckers. Some are aquatic.

Eg. ***Cimex*** (Bed bug), ***Belostoma*** (Giant water bug), ***Water scorpions***, and ***Aphids***.

In Division ENDOPTERYGOTA, there are 9 orders.

Order 1. Neuroptera

Soft bodied insects. Large eyes are present. Wings 2 pairs, large, membranous. Mouth parts chewing type. Larvae aquatic. Metamorphosis complete.

Eg. **Lace wings – *Chrysopa Ant lions***.

Order 2. Mecoptera

Mouth parts are specific with beak-like structure. Eyes large. Wings 2 pairs. Tip of the abdomen curved like the sting of a scorpion. Metamorphosis complete.

Eg. ***Panorpa*** (**Scorpion Fly)**

Order 3. Trichoptera

These are called **Caddis-flies**, Moth-like insects. Head free, eyes large. Larvae aquatic.

Eg. ***Platycentropus***

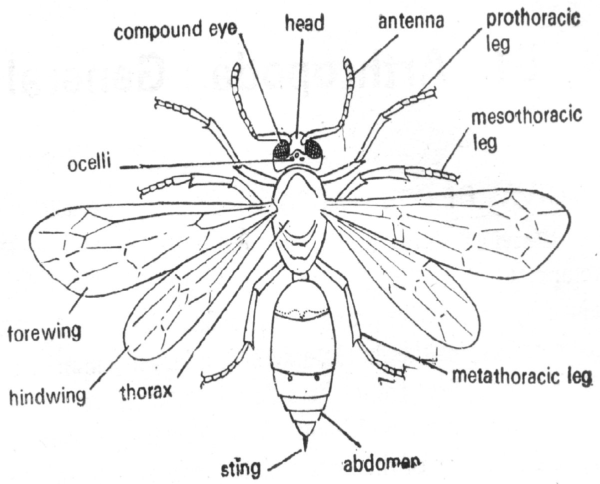

Fig 132 Wasp

Order 4. Hymenoptera

Highly specialised insects. Social insects. Sometimes parasitic.

Eg. **Ants, Bees, Wasps** and **Saw-flies.**

Order 5. Diptera

Small, soft bodied insects. Wings only one pair. Hind wings are reduced, called as **Halters**. Metamorphosis complete. Larvae are called **Maggots**.

Eg. **Mosquitoes, House flies, Fruit flies**.

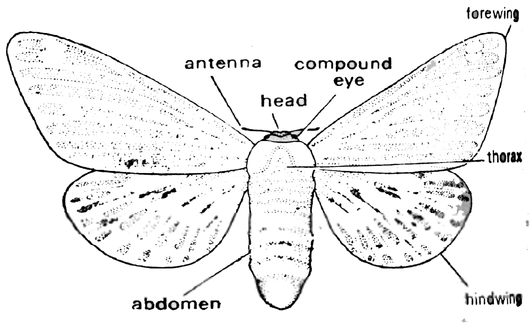

Fig 133 Moth

Order 6. Lepidoptera

Large sized insects. Large compound eyes are present. Wings 2 pairs, large. Mouth parts sucking (Siphoning) type. Larvae – caterpillars.

Eg. ***Butterflies, Moths***.

Order 7. Coleoptera

Stout insects. Forewings thick, called **Elytra**. Hindwings thin, membranous. Metamorphosis complete.

Eg. **Beetles**

Order 8. Strepsiptera

Small endoparasitic insects. Sexual dimorphism distinct. Males free living, females parasitic. Males have 2 pairs of wings, 1 pair reduced as *Pseudohalters*. Females have no eyes, no wings and no legs.

Eg. ***Stylopids***

Order 9. Siphonoptera

Small wingless insects. Ectoparasitic on birds and mammals. Body compressed. eyes simple. Legs long.

Eg. Fleas – *Xenopsylla* *Pulex*.

SUB-PHYLUM 4. PYCNOGONIDA

This is a small group consisting of marine sea-spiders. Body narrow with anterior proboscis and 4 to 6 pairs of legs. Carnivorous or detritus feeders. Commonly seen on Hydroids and Bryozoans.

Eg. ***Nymphon*** (Sea-Spider)

6.1.4. SUMMARY

Arthropoda is the largest phylum in the animal kingdom including prawns, crabs, lobsters, cantipedes, millipedes, insects, spiders, scorpions, ticks and mites. Representatives are distributed in almost all habitats such as freshwater, marine, terrestrial habitats. Few forms are parasitic. Animals have jointed appendages. Bilaterally symmetrical, triploblastic, metamerically segmented true coelomates. Body is covered by chitinous exoskeleton. Striped muscles are present. Digestive system includes long coiled alimentary canal and digestive glands. Blood vascular system is open (lacunar) type Coelom is filled with blood (haemocoel). Common respiratory pigment is haemocyanin. Respiratory organs are trachea, gills, book-lungs and book-gills. Excretion is carried out by green glands (Antennary glands), coxal glands and malpighian tubules. Nervous system annelidan type with nerve ring and double ventral nerve cord. Sense organs include ocelli, compound eyes and statocyst. Sexes separate, sexual dimorphism is seen. Development direct without larval stage or indirect with nymph or larval stages in the life history. Larva metamorphosises into adult. Parental care is exhibited by some forms.

CLASSIFICATION

Phylum Arthropoda is divided into 4 sub-phyla ***Trilobita, Chelicerata, Mandibulata*** and ***Pycnogonida***. ***Trilobita*** includes extinct forms with body divided into 3 longitudinal lobes. ***Chelicerata*** includes animals with body divided into prosoma and opisthosoma. First pair of appendages are chelicerae. This sub-phylum includes 2 classes, ***Merostomata*** and ***Arachnida***. Merostomata includes horse shoe crabs Arachnda includes spiders, scorpions, ticks and mites. Merostomata includes 2 sub-classes ***Xiphosura*** and ***Eurypterida***. Arachnida includes 10 orders namely, Scorpionida, Araneae, Palpigradi, Pedipalpi, Amblypygi, Solifugae, Pseudo scorpionida, Phalangida, Podogona and Acarina.

Sub-phylum ***Mandibulata*** is divided into 4 classes, ***Crustacea, Chilopoda, Diplopoda*** and ***Insecta***. Crustacea includes prawns, crabs, lobsters, barnacles and cray fish.

Class ***Crustacea*** is divided into 8 sub-classes, Cephalocarida, Branchiopoda, Ostracoda, Mystacocarida, Copepoda, Branchiura, Cirripedia and Malacostraca.

Sub-class ***Branchiopoda*** includes 4 orders, Anostraca, Notostraca, Conchostraca and Cladocera.

Sub-class ***Ostracoda*** includes 4 orders, Myodocopa, Cladocopa, Podocopa and Platycopa.

Sub-class ***Cirripedia*** includes 5 orders, Thoracica, Acrothoracica, Ascothoracica, Apoda and Rhizocephala.

Sub-class ***Malacostraca*** includes 10 orders, Nebaliacea, Anaspidacea, Bathynellacea, Mysidacea, Cumacea, Tanaidacea, Isopoda, Amphipoda, Stomatopoda and Decapoda.

Class ***Chilopoda*** includes ***Centipedes***. This class includes 4 orders, Scutigeromorpha, Lithobiomorpha, Geophilomorpha and Scolopendromorpha.

Class ***Diplopoda*** includes ***millipedes***, there are 6 orders in this class, namely Pentazonia, Limacorpha, Colobognatha, Nematophora, Polydesmida and Juliformia.

Class **insecta** includes wide variety of animals such as mosquitoes, house-flies, bees, bugs, ants, wasps, silkworms etc. This class includes 2 sub-classes ***Apterygota*** and ***Pterygota***. Apterygota includes primitive wingless forms, there are 3 orders in this sub-class, namely Protrura, Collembola and Thysanura.

Subclass ***Pterygota*** includes 2 divisions, ***Exopterygota*** and ***Endopterygota***. In ***Exopterygota***, there are **12 orders**, Orthopera, Dermaptera, Isoptera, Plecoptera, Embioptera, Psocoptera, Siphunculata, Mallophaga, Thysanoptera, Ephemeroptera, Odonata and Hemiptera.

Endopterygota includes 9 orders, Neuroptera, Mecoptera, Trichoptera, Hymenoptera, Diptera, Lepidoptera, Coleoptera, Strepsiptera and Siphonoptera.

Subphylum ***Pycnogonida*** includes marine sea spiders.

6.1.5 KEY TERMINOLOGY

Ametaboly: Development without any larval stage in the life history.

Biramous appendage: Two branched appendages with basal protopodite, outer exopodite and inner endopodite.

Cuticle: Protective outermost layer of body wall.

Ecdysis: Also known as moulting, periodic shedding of outermost body layer (skeleton).

Hepatopancreas: Digestive gland which serves the function of liver and pancreas of higher animals.

Malpighian tubules: Excretory organs seen in arthropods, which prevent loss of water and maintain homoiostasis

Megalopa: Characteristic larva of crabs.

Metamorphosis: Transformation of larva into adult.

Mysis: Characteristic larva of prawns.

Nauplius: Larval stage of Crustaceans.

Opisthogeneates: Genital opening is present in the posterior part of the body as seen in chilopods.

Progoneates: Genital opening present in the anterior part of the body as seen in diplopods.

Statocyst: Sense organs seen in prawns, which maintain equilibrium.

Zoea: Typical larva seen in decapod crustaceans.

6.1.6 MODEL QUESTIONS

1. List out the general characters of phylum Arthropoda and classify upto classes giving examples.
2. Write short notes on:
   a) Crustacea
   b) Arachnida
   c) Chilopoda
   d) Diplopoda
   e) Limulus
   f) Metamorphosis

6.1.7 REFERENCE BOOKS

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3. Parker, T.J. and Haswell, W.A. 1972. **A Text Book of Zoology**, Marshall A & Williams, W.D. McMillan.

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Lesson 6.2
COMPARATIVE ACCOUNT OF EXTERNAL CHARACTERS OF PRAWN & SCORPION

6.2.1 OBJECTIVE

The purpose of this lesson is to understand the External characters of Prawn & Scorpion i.e., a freshwater form and a terrestrial form.

6.2.2 INTRODUCTION

PRAWN

The common Indian Freshwater Prawn is *Macrobrachium* (Palaemon) *malcolmsoni*, belongs to class Crustacea. It is found in freshwater streams, ponds, lakes and rivers. It is a nocturnal, bottom dweller (benthic) crawling on the bottom and comes to the surface at night for food. It feeds on algae, moss, small insects. It can swim actively with the help of abdominal appendages (Pleopods).

Systematic position

Phylum	:	Arthropoda
Sub-phylum	:	Mandibulata
Class	:	Crustacea
Subclass	:	Malacostraca
Order	:	Decapoda
Family	:	Palaemonidae

SCORPION

Scorpions belong to class Arachnida, the common genera are Palaennaeus, Buthus, Scorpio, Androctonus.

Scorpions are terrestrial forms which live in Crevisces, holes, under stones, logs and other debris. They are nocturnal and predaceous animals feeding on spiders, insects and other small animals. Cannibolism is also seen.

Systematic position:

Phylum	:	Arthropoda
Sub-phylum	:	Chelicerata
Class	:	Arachnida
Order	:	Scorpionida

6.2.3 EXTERNAL CHARACTERS

Prawn: The body of prawn is elongated, more or less spindle shaped, size varies from 25 to 90 cms in length. Body colour is dull, pale or greenish with brown patches.

Body is divided into Cephalothorax and abdomen.

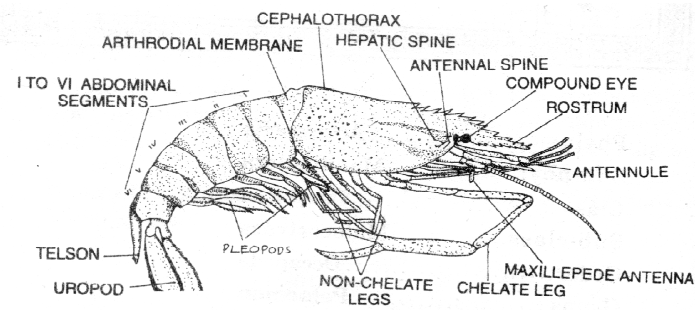

Fig 134 Prawn External Characters

CEPHALOTHORAX: Cephalothorax is formed by the fusion of head and thorax which is rigid unjointed structure. It is made up of 13 segments (five cephalic segments 8 thoracic segments).

ABDOMEN: It is made up of six segments with a terminal conical piece called Telson or Tail plate.

Scorpion: The body of scorpion is long, narrow and dorso ventrally flattened, size varies from 2.5 cms to 15 cms in length.

Body colour is variable, pale yellow to shining black. Dorsal surface is darker than the ventral surface.

Body is divided into *Prosoma* and *Opisthosoma*. The *Prosoma* or Cephalothorax is short, rectangular unsegmented part. It is formed by the fusion of six segments.

The *Opisthosoma* is long, narrow and segmented region which is divided into *Mesosoma* and *Metasoma*.

The *Mesosoma* is broad anteriorly and narrow posteriorly. It is made up of 7 segments (8 in the embryonic condition).

Metasoma appears as tail. It is made up of 5 segments, the last segment bears terminal Telson or stinging apparatus.

6.2.4 EXOSKELETON

The body of prawn is covered by a hard chitinous exoskeleton, formed by the deposition of *lime salts* and *sclerotin*. It is secreted by epidermis; it is made up of several plates called *Sclerites*. These plates are attached to underlying thin membrane called *Arthroidal membrane*.

The sclerites of Cephalothorax unite forming a single large continuous structure called *Dorsal shield*; anteriorly it is formed as compressed pointed structure called *rostrum* with serrated margin. The posterior part of the rostrum is called *Carapace*. At the base of the rostrum, stalked compound eyes are present one on either side. The lateral sides of the Carapace forms gill cover or *Branchiostegites*, which enclose the gills.

The abdominal sclerites form a dorsal *tergum*, ventral narrow *Sternum* and two lateral plates *Pleura*. The appendages are connected with these *pleura*. The pleura of the last abdominal segment are reduced. The adjacent abdominal segments articulate with each other by ninge-joints.

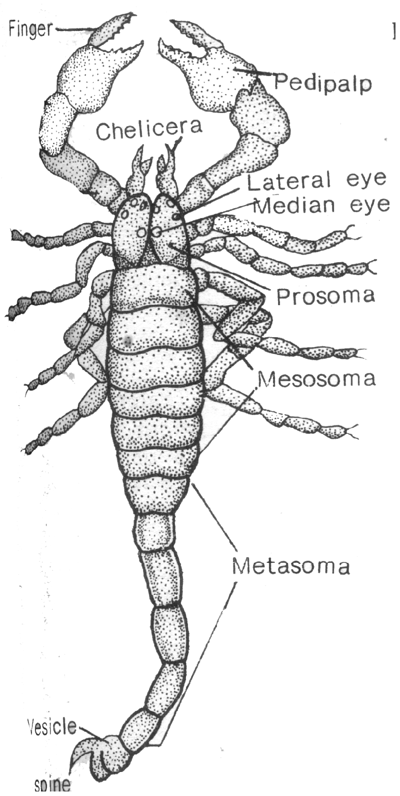

Fig 135 Dorsal View

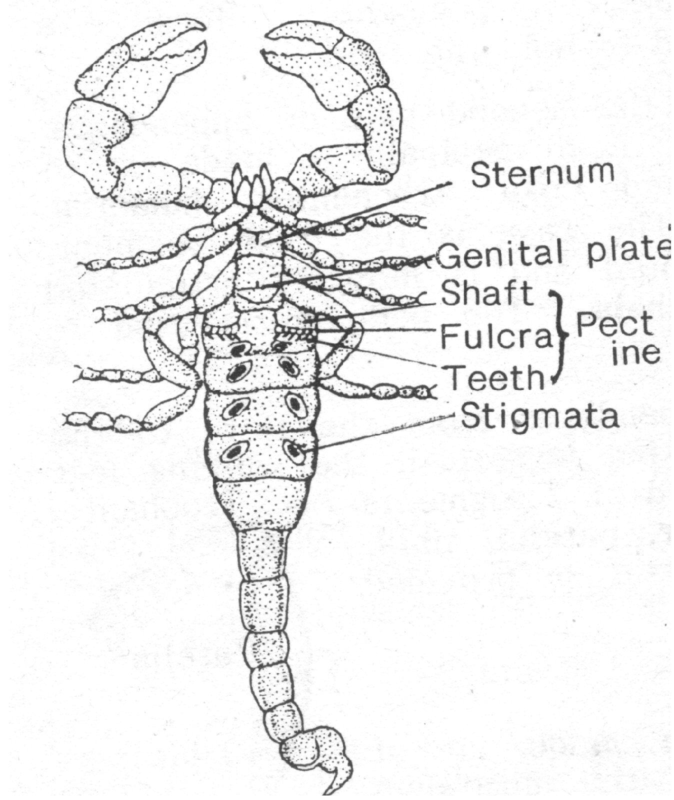

Fig 136 Ventral View

In Scorpion, the prosoma is covered by a single large Cephalothoracic shield called *Carapace* which is almost squarish with anterior median notch. The carapace bears 1 pair of median eyes and 2 to 5 pairs of small lateral eyes on the antero-lateral margins. In Scorpion, compound eyes are absent. The ventral surface of prosoma consists of a single triangular plate Sternum.

The mesosomal segments are covered by dorsal plates called *Terga* and ventral plates called Sterna, they are joined laterally by flexible arthroidal membrane. The Sternum of the first segment consists of a median plate called *genital operculum*, below which genital pore is present.

The sternum of second segment bears a pair of comb-like *pectines*, which consists of sensory cells which are tactile in function.

The sterna of 3^{rd}, 4^{th}, 5^{th} and 6^{th} mesosomal segments bear slit like apertures called *Stigmata* which allow the passage of air into book-lungs. The Sternum of 7^{th} segment bears no appendages.

Stinging apparatus: The terminal part of Metasoma in scorpion consists of a stinging apparatus or Telson. It consists of a swollen base-vesicle or *ampulla* and a sharp curved *spine*. In the vesicle, a pair of poison glands are present, the ducts of these glands open at the tip of the spine by a pair of openings.

6.2.5 EXTERNAL APERTURES

Prawn

Mouth: It is a slit like opening at the anterior end of the cephalothorax. It is bounded by anterior labrum, posterior labium and lateral mandibles. Anus is a longitudinal opening at the base of telson. Renal apertures are seen on the inner surface of the coxa of antennae, one pair in number.

Female genital pores: 1 pair in number, on the inner surface of coxae of 3^{rd} pair of walking legs, in female.

Male genital pores: 1 pair, on the inner surface of the coxae of 5^{th} pair of walking legs.

Scorpion: Mouth is present at the anterior end of the body under the labrum. A small median aperture anus is present on the last metasomal segment.

Genital aperture is present on the first mesosomal segment stigmata are 4 pairs, seen on 3^{rd}, 4^{th}, 5^{th} and 6^{th} mesosomal segments.

1 pair of small openings of poison glands are seen at the tip of the sting.

Two small openings of the coxal glands are seen at the coxal segments of 5^{th} pair of appendages.

6.2.6 SUMMARY

The body of Palaemon is elongated and more or less spindle shaped, slightly tapering at the posterior end. It is a bilaterally symmetrical and a true Coelom. Young ones are pale yellow in colour, where as older ones are bluish in colour. Prawn has a truly segmented body divisible into a head, thorax and abdomen but head and thorax are fused early and formed, a structure known as cephalothorax which is unjointed. Abdomen is jointed, laterally compressed, movable and is formed by six segments. At the end of the abdomen there is a conical post-segmental tail piece or telson. Each segment has a paired segmental appendages at the junction of sternum and tergum of a segment.

Scorpions are confined to tropical countries of the world, always terrestrial, air-breathing, fluid-feeding nocturnal animals. Body colour varies from black to grey and brown. Body is divisible into an anterior unsegmented part, the prosoma or trunk, and a segmented part, the episthosoma or abdomen. There is no distinct head. Opisthosoma is differentiated into a anterior mesosoma or preabdomen and a posterior metasoma or post-abdomen.

Prawn has two stalked compound eyes. They are located beneath the rostrum. Scorpion has a pair of conspicuous median eyes dorsally and three pairs of smaller lateral eyes on the anterio lateral margins of the Carapace.

6.2.7 KEY TERMINOLOGY

Cephalothorax: Cephalic and thoracic segments are fused to form cephalothroax.

Opisthosoma: Posterior part of the body of arachnids

Prosoma: Anterior part of the body of arachnids

Sternum: Ventral skeletal plate of arthropods

Telson: A conical, spine like structure present at the end of the Abdomen of Prawn.

Tergum: Dorsal skeletal plate of arthropods.

6.2.8 MODEL QUESTIONS

1. Describe the external features of Prawn
2. Describe the external features of scorpion

6.2.9 REFERENCE BOOKS

1. Bernes, R.D. 1980, **Invertebrate Zoology.**
2. Kotpal, R.L. **Arthropoda.**
3. Parker, T.J. and Maswell, W.A. 1972**, A Textbook of Zoology**

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COMPARATIVE ACCOUNT OF APPENDAGES OF PRAWN & SCORPION

6.3.1 OBJECTIVE

The purpose of this lesson is to develop an idea about the structure and functions of Appendages of a Crustacean and a Arachnide.

6.3.2 INTRODUCTION

In Prawn, the appendages appear very different from one another, for they are meant for different purposes. The appendages do various functions like the sensory function, feeding, locomotion, respiration, copulation etc. Although they are different in shape and size, yet they all have the same typical structure and develop in the same way i.e, these are homologous organs. There are 19 pairs of appendages in the prawn. Each segment bears a pair of appendages in the ventral side. Scorpion has 6 pairs of segmental appendages in cephalothorax or prosoma. Each prosomal segment bears a pair of appendages. They are one pair of Chelicerae, one pair of Pedipalpi and four pairs of walking legs.

6.3.3 APPENDAGES

Prawn: In Prawn, the appendages are said to be BIRAMOUS type, which consists of a basal part called *protopodite,* an outer part called *exopodite* and an inner part *endopodite*. The protopodite consists of two segments *coxa* and *basis*. From the basis, exopodite and endopodite start and they are variously modified depending on their function. Thus the appendages are *Homologous*.

In Prawn, there are 19 pairs of appendages, 13 pairs in Cephalothorax (5 pairs cephalic and 8 pairs thoracic appendages)and 6 pairs in abdomen.

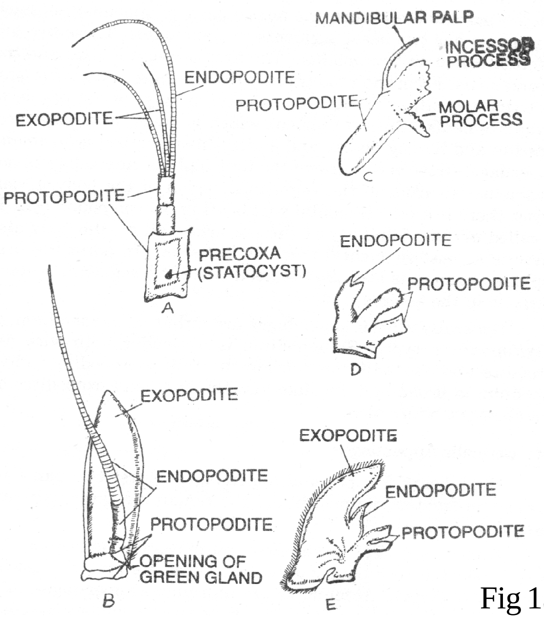
Cephalic appendages: There are 5 pairs of cephalic (head) appendages, namely Antennules, Antennae, mandibles, maxillules and maxillae. First two pairs are pre-oral and 3 pairs are post-oral.
Antennules: These are first pair of appendages present below the eye stalks. The protopodite consists of pre coxa, coxa and basis. The pre-coxa bears a depression containing the opening of Statocyst. The coxa is short and cyllindrical. The basis is elongated. It carries, two feelers, which are long whip like and many jointed. The outer feeler is forked. The antennules bear sensory setae and are tactile in function.

Antennae: They are present just below the antennules. The protopodite is swollen and bears excretory organ, which opens out by a renal aperture on the inner margin of coxa. The Endopodite is in form of a long multijointed feeler; the exopodite is in form of a broad leaf like structure called *Squama*, which acts as a balancer while swimming. As a whole, the antennae serves sensory, excretory and balancing functions.

Mandibles: They are strong, calcified structures on either side of the mouth. Each mendible bears a head with a stout **molar process** and a plate like **incisor process** bearing teeth. The exopodite is absent. On the outer side of the coxa, there is a mandibular palp which represents the endopodite.

Maxillules: Just behind the labium (lower-lip), there are two small leaf like appendages called maxillules. The coxa and basis are represented as *Jaws* or *Gnathobases* with pointed stiff spines. The exopodite is absent, the endopodite is represented as hook-like curved process. The Maxillules help in the manipulation of food.

Maxillae: They are thin leaf like appendages behind mexillules. The coxa is small, the basis is large and bifurcated. The exopodite forms a large expanded fan shaped structure called *Scaphognathite* which acts as baling organ (creates current of water over the gills). The endopodite is small and conical structure. The Maxillae



A. Antennule
B. Antennaw
C. Mandible
D. Maxilla I
E. Maxilla II

Fig 137 Prawn Cephalic Appendages

THORACIC APPENDAGES

They are 8 pairs in number, the first three pairs are called *Maxillipedes* and the remaining 5 pairs are called walking legs or *Paraeopods*.

First Maxillipedes: They are thin leaf like structures, the coxa and basis form gnathobases towards inner side; the coxa bears a bilobed respiratory organ *epipodite*. The exopodite and endopodite bear setae on their margins.

Second Maxillipedes: The coxa bears an *epipodite* on its outer margin and the basis bears an unjointed exopodite and five jointed endopodite. These five joints are called *Podomeres*, which are named as *Ischium, merus, carpus, propodus* and *dactylus*.

Third maxillipedes: They appear as legs with a coxa bearing an *epipodite*; the exopodite is long, slender and unjointed; the endopodite has 5 segments. The propodus and dactylus are joined together.

Walking legs: They are 5 pairs in number; Exopodite and endopodite are absent. A typical walking up consists of two jointed protopodite and 5 jointed endopodite. All these segments, namely, the coxa, basis, ischium, merus, carpus, propodus and dactylus are arranged in linear fashion and are movably articulated. In the first and second pair of walking legs, the propodus and dactylus are closely held together and act as blades of a pincer. They are called *Chelate legs*. They help in grasping the food, and pass it on to the mouth. They also act as organs of offence and defence.

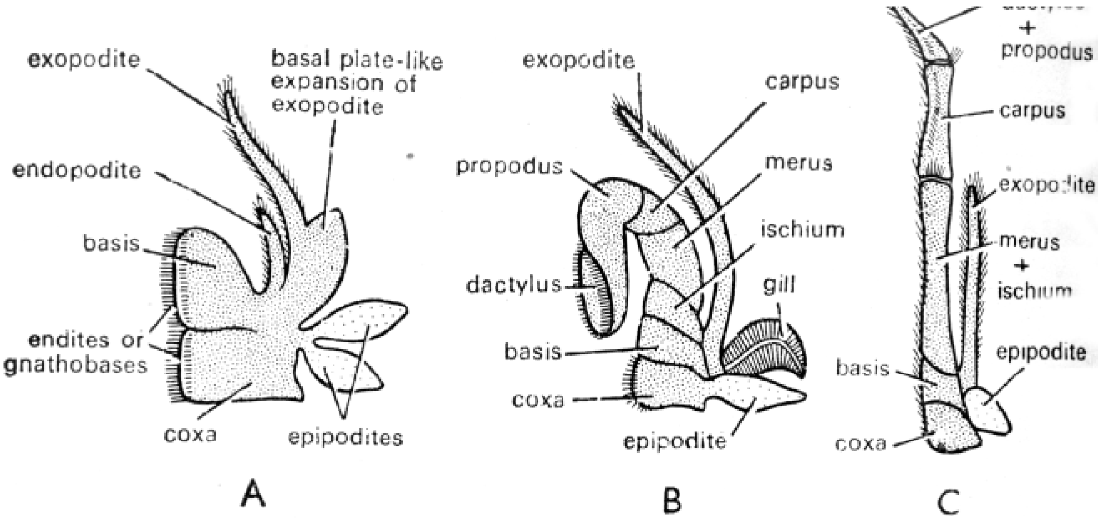


Fig 138 *Palaemon*. Maxillipedes. A—First maxillipede. B—Second maxillipede. C—Third maxillipede.

The third, fourth and fifth pair of walking legs are *non-chelate*, where the propodus and dactylus will not form a pincer-like structure.

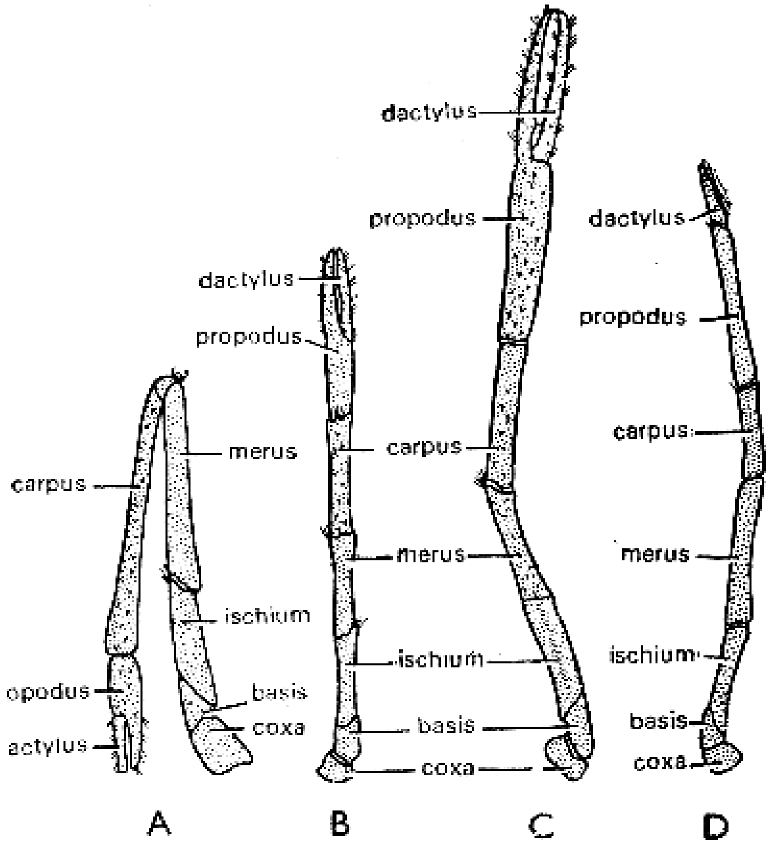


Fig 139 *Palaemon*. Thoracic legs. A—First chelate leg. B—Second chelate leg of female. C—Second chelate leg of male. D—Typical

Abdominal appendages:

They are six pairs in numbers and are called *Pleopods* or *Swimmerets*. They help in swimming and also serve to carry eggs.

Typical abdominal appendage:

The protopodite consists of a ring like coxa and elongated basis. From the basis arises inner small endopodite and large exopodite from the inner side of the endopodite arises small rod-like *appendix interna*. In females, the appendix internae of both side form bridge like structure to carry the eggs. Other abdominal appendages slightly differ from the typical ones. In the first abdominal appendages, appendix interna is absent. In males, the second abdominal appendages bear rod like structure called *appendix masculina* as additional structure.

The sixth pair of abdominal appendages form *Uropod* (tail-feet) on either side of telson. The Uropod and telson form a broad fan like *Tail-fin* which acts as balancing organ. The coxa and basis fuse to form *Sympod*. It bears the exopodite and endopodite which are provided with setae.

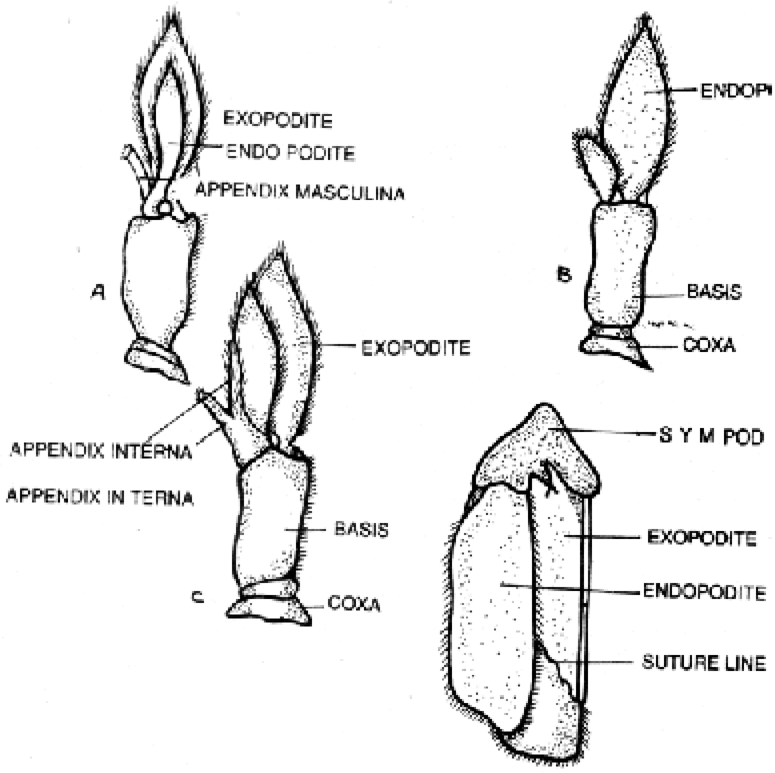


Fig 140 : Abdominal Appendages
(A) Tipical Appendage, (B) First Abdominal Appendage (C) Seconc Abdominal Appendage

6.3.4 APPENDAGES OF SCORPION

In Scorpion, there are six pairs of appendages in Cephalothorax region (Prosoma). They are:
1 pair of Chelicerae,
1 pair of Pedipalpi, and
4 pairs of Walking legs

Chelicerae: They are seen on either side of the mouth. Each chelicera is 3 segmented chelate appendage with a ring like basal segment and two distal segments which form *Chela* or Pincer. The inner piece is immovable finger and the outer curved piece is movable finger of the chela. The chelicerae help to hold and tear the prey.

Pedipalps: They are second pair of appendages present behind the mouth (post-oral). Each pedipalp is 6 segmented, with coxa, trochanter, humerus, brachium, manus and a movable finger. The coxa bears a blade like structure – *gnathobase* which works as jaw. The gnathobases of opposite sides help to squeeze the body of the prey. The last two segments form *Chela* which help to seize the prey. They also act as tactile organs.

Walking legs: In Scorpion, there are 4 pairs of walking legs, each consists of 7 segments, the coxa, trochanter, femur, patella, fibia, protarsus and tarsus. The tarsus consists of 3 curved, pointed horny claws.

The coxae of first and second pair of legs bear *gnathobases*. The coxae of 3rd, 4th pairs of legs are immovable. Legs help scorpions in feeding besides walking.

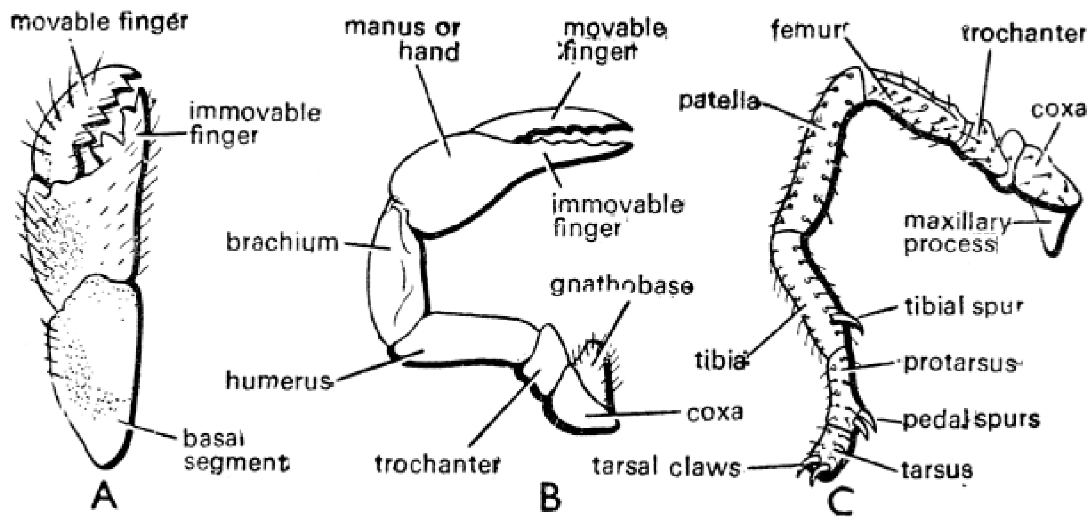


Fig 141: Scorpion. Appendages. A—Chelicera. B—Pedipalp. C—First walking leg.

6.3.5 SUMMARY

The appendages of Prawn are biramous structures i.e., each limb consists of two rami or branches, which appear from the basal part articulating with the body. The basal part is consists of coxa and basis. Coxa is a proximal part and is attached to the body and basis is the distat part and bears two rami, namely the Exopodite and Endopodite.

There are 19 pairs of appendages in Prawn, one pair of appendages in each segment. Head bears 5 pairs, thorax bears 8 pairs and abdomen has six pairs of appendages. Cephalic (head) appendages can be grouped into two types: (a) Pre-oral cephalic appendages, which include: (1) antennules, (2) antennae; (b) Post-oral cephalic appendages which include (1) mandibles, (2) maxillulae, and (3) maxillae. Thoracic appendages consist of anterior three pairs which form maxillipedes and the posterior five pairs, the paraeopods or walking legs. First two pairs of walking legs are called as chaelate legs. The remaining three pairs of legs are termed as non-chaelate legs. Ist to 5th abdominal appendages are called pleopods and the sixth appendage is called Uropod.

The cephalothorax of scorpion bears six pairs of appendages. Cephalic appendages include a pair each of Chelicerae and Pedipalpi. Thoracic appendages include 4 pairs of legs.

6.3.6 KEY TERMINOLOGY

Coxa: Proximal part of the protopodite or basal part of the appendage, which is attached to the body.

Chelicerae: First pair of appendages of scorpion.

Endopedite: Inner ramous of the appendage.

Exopodite: Outer ramous of the appendage

Paraeopods: Last five pairs of thoracic appendages of prawn.

Pleopods: First five pairs of abdominal appendages of prawn.

Pedipalpi: Second Pair of appendages of scorpion.

Podomeres: Segments of the appendage

Uropod: Broad and flat appendage of the sixth abdominal segment.

6.3.7 MODEL QUESTIONS

1. Give an account of cephalic appendages of Prawn.
2. Describe the appendages of Scorpion.
3. Give an account of the structure and functional modifications of the thoracic appendages of Prawn.
4. Write short notes on:
   Uropod, Pleopod, Paracopod, Mandible, antinnule, Chelicerae, Pedipalp.

6.3.8 REFERENCE BOOKS

1. **Modern textbook of Zoology - Invertebrates:** R.L. Kotpal, S..K. Agarwal, R.P. Khaetarpal.
2. **A Text book of Zoology**. Parker, T.J., and Haswell, W.A.

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Lesson 6.4
COMPARATIVE ACCOUNT OF RESPIRATORY SYSTEM IN PRAWN AND SCORPION

CONTENTS

6.4.1 OBJECTIVE

The purpose of this lesson is to develop an idea about the structure of Respiratory organs and mechanism of Respiration.

6.4.2 INTRODUCTION

Prawn is an aquatic animal and the respiratory organs are gills or branchiae, Epipodites and the living of branchiostegites.

Scorpion is a terrestrial animal and the respiratory organs are book-lungs or pulmonary sacs.

6.4.3 RESPIRATORY SYSTEM IN PRAWN

The chief respiratory organs are gills. In addition, the lining of branchiostegites and epipodites also assist in respiration.

Gills: A total number of 8 pairs of gills are present, they are located in gill chambers on either side of cephalothorax (8 in right chamber and 8 in left chamber). Of eight gills, only seven are exposed on removing the gill cover because the third gill lies beneath the second gill. Depending on the attachment, the gills are classified into 3 types, the *Podobranch*, *Arthrobranch* and *Pleurobranch; Podobranch,* also called *foot-gill* is attached to the coxa of the appendage. In palaemon one podobranch is present attached to the coxa of the second maxillipede. Arthrobranch, also called the joint-gill is attached to the arthroidal membrane between the body and the appendage. In palaemon, two arthrobranchs are present attached near the third maxillipede. Pleurobranch or side gill is attached to the lateral wall of the body. In Palaemon, 5 pairs of pleurobranchs are seen close to the five walking legs.

Structure of gill

Gills are crescentic in shape, the size of the gill increases from anterior end to posterior end in the gill chamber. The third gill is covered by the second gill. The gill is attached to the body by a small connection called *gill-root* through which blood vessels and nerves pass through. Each gill consists of a *gill-axis*. On either side of this axis, leaf like gill plates are attached like the leaves of a book. The gill plates at the ends of the gill are smaller and those in the middle are larger. The gill plates consists of pigmented and transparent cells and the gill base consists of connective tissue.

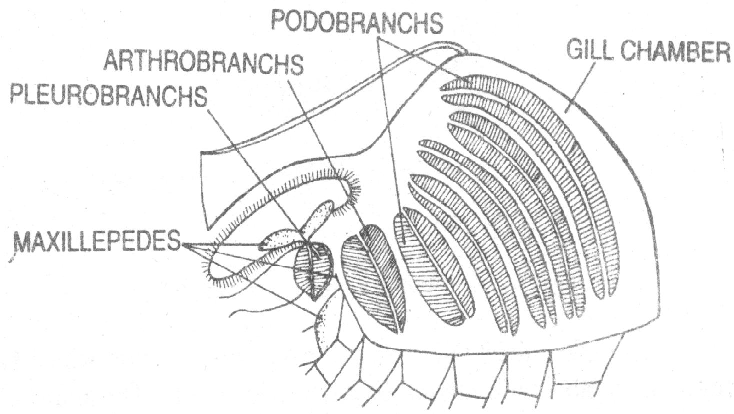

Fig 142 : Palaemon-gill chamber with gills.

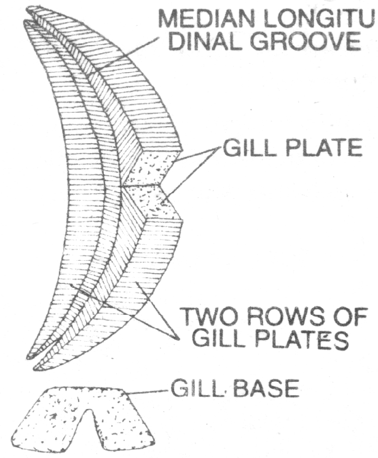

Fig 143 : Phyllobranch of Palaemon

6.4.4 BLOOD CIRCULATION IN GILL

The gills are richly supplied with blood, there are 3 longitudinal blood channels pass through the gill base; **one median channel and two lateral channels**. The median longitudinal channel passes through the apex of the gill base and the lateral channels run along the lateral margins, one on ether side. The two lateral channels are connected with each other by *transverse channels* giving a ladder-like appearance. From the lateral channels small branches are given off which are called *marginal channels* which run along the margin of the gill plate and join with the median channel.

Lateral longitudinal channel $\rightarrow$ Marginal channel $\rightarrow$ Median longitudinal channel

Blood Flow

Deoxygenated blood from the body is sent into the **Afferent branchial channel** which enters the gill root and open into a transverse connective, through which blood passes into the lateral longitudinal channels and from there blood passes through the marginal channels which are present in the gill plates; the marginal channels open into the median longitudinal channel. In course of this circulation, blood gets oxygenated and from median longitudinal channel blood flows into the pericardial sinus through efferent branchial channel.

Deoxygenated blood → Afferent branchial channel → Transverse connective → Lateral longitudinal channel

6.4.5 FLOW OF WATER IN GILL CHAMBER

Fresh water enters the gill chamber from behind and the current of after flows over the lining of the gill covers (Branchiostegites), the epipodites and the gills. These are richly supplied with blood vessels and exchange of gases takes place while water is flowing over thrown. The oxygen dissolved in water is taken into the blood and carbon-di-oxide diffuses into water.

The scaphognathite of the maxilla bales out the water by its constant vibrating movements and continuous flow of water is maintained over the gills.

6.4.6 RESPIRATORY SYSTEM IN SCORPION

In Scorpion, respiratory function is carried out by book-lungs. They re 4 pair in number; one pair in each segment, in third, fourth, fifth and sixth segments of *Mesosoma*.

Structure of Book-lung

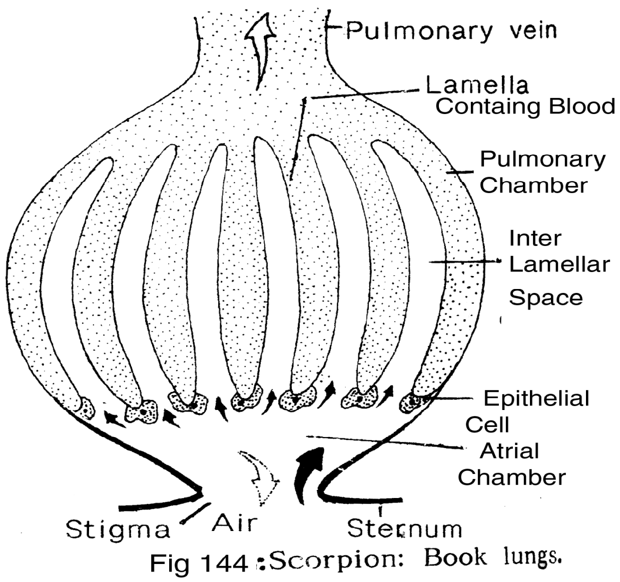

Fig 144 :Scorpion: Book lungs.

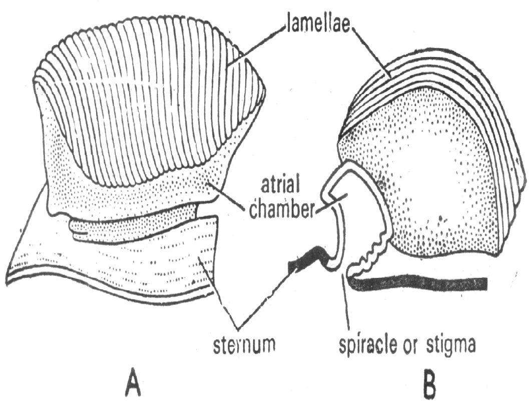

Fig 145 Scorpion. A—A book-lung.
B–The book-lung in V.S.

Each book-lung is a sac like structure, into which air enters through a slit like opening called *Stigma*. This is present on the ventrolateral side of the sternum. Each book lung consists of two parts, a ventral small, sac like **atrial chamber** and a dorsal chamber called **pulmonary chamber**. In the pulmonary chamber, there are about 150 vertical plate like (folds) structures called **lamellae** which are arranged like the pages of a book (hence it is named as book-lung). These lamellae are hollow structures and are filled with bloods, the space inbetween the adjacent lamellae is called inter-lamellar air space. The atrial chamber communicates with this air space through small openings. When air passes through these spaces, blood present in the lamellae takes in oxygen and gives out carbon-di-oxide.

Blood Supply

The venous blood from the ventral sinus in sent into the book lung by a small diverticulum; blood is circulated into the lamellae of the book lung which receives oxygen and the oxygenated blood is collected by the pulmonary vein which opens into the pericardium.

Ventral sinus $\rightarrow$ diverticulum $\rightarrow$ Book lung $\rightarrow$ Lamallae $\rightarrow$ Pulmonary vein $\rightarrow$ Pericardium

6.4.7 MECHANISM OF RESPIRATION

The dorso-ventral muscles and atrial muscles control the inflow and outflow of air through the book lungs. When these muscles contract, the book lungs are compressed air is forced out of the inter lamellar spaces, then to atrial chamber and then to the exterior through *Stigmata*. When these muscles relax, fresh air enters into the atrial chamber through stigmata and then to interlamellar space. Blood present in the lamellae gets oxygen by the process of diffusion from the air present in the interlamellar space and carbon-di-oxide from the blood diffuses into the interlamellar space.

6.4.8 SUMMARY

In prawn, chief organs of respiration are the gills or branchiae. Epipodites of the maxillipeds, and thin lining of the gill cover (branchiostegite) provide additional surfaces for respiration. The inner lining of the branchiostegite is richly supplied with blood. It is constantly bathed by the water-current. Hence, exchange of gases occurs between the water and the blood. Epipodites are the membranous outgrowths of the integument arising from the coxa of the thoracic appendages.

The gills are delicate feather like outgrowths of the thoracic appendages, located inside the gill chamber. The gills are crescent shaped. Eight gills are present on each side between gill cover and the wall of cephalothorax. Depending on the place of origin and attachment gills are of three types: (1) Podobranch (gill attached to the coxa of an appendage), (2) Arthrobranch (attached to arthroidal membrane), (3) Pleuro branch (attached to the lateral wall of segment). Exchange of gases takes place on the surface of gills and epipodites which are highly supplied with blood vessels.

Scorpion is a terrestrial animal taking oxygen from air through four pairs of respiratory structures known as book lungs. The book-lungs are found in the 3rd, 4th, 5th and 6th segments of the mesosoma, one pair in each segment. Each book lung has two parts. The lower small atrial chamber and the upper large pulmonary chamber. The atrial chamber contains air and communicates with the exterior by an oblique slit, the stigmata or spiracle. The pulmonary chamber contains thin vertical lamellae that hang from its roof.

Each book-lung receives deoxygenated blood that enters the lamellae at their bases. The aerated blood from the lamellae is returned by a pulmonary vein to the pericardium.

6.4.9 KEY TERMINOLOGY

Arthrobranch: When the gill is attached to the arthroidal membrane present between the appendage and thorax, it is called Arthrobranch or joint gill.

Book-lung: Respiratory structure of a scorpion.

Foot gill: When the gill is attached to the coxa of an appendage, it is called as foot gill or podobranch.

Pleuro branch: When the gill is attached to the lateral wall of the segment, it is called pleuro branch.

Stigmata: Oblique slit like opening of the book-lung.

6.4.10 MODEL QUESTIONS

1. Write an essay about respiratory organs and the process of respiration in prawn
2. Explain the respiratory organs and process of respiration in scorpion.

<u>Write short notes on</u>:
1. Book lung
2. Gills of Prawn

6.4.11 REFERENCE BOOKS

1. **Invertebrate Zoology** by T.C. Majupuria.
2. **Biology of Non-chordates** by H.C. Nigam.
3. **Modern Text book of Zoology – Invertebrates**. R.L. Kotpal, S.K. Agarwal, R.P. Khetarpal.

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Lesson 6.5
COMPARATIVE STUDY OF EXCRETORY SYSTEM IN PALAEMON AND SCORPION

CONTENTS

6.5.1 OBJECTIVE

The purpose of this lesson is to develop an idea about the structure and physiology of Excretory systems of Palaemon and scorpion.

6.5.2 INTRODUCTION

Excretion is the process of elimination of nitrogenous waste materials from the body. Excretory system of adult palaemon consists of a pair of antennay or green glands, a median sac termed the nephro-peritoneal or renal sac and integument. The excretory system of scorpion comprises a malphighian tubules, coxal glands and hepatopancreas.

In most of the Crustaceans antennary glands function as kidneys in larva, while in adults maxillary glands are the excretory organs. But in prawn, maxillary glands function as kidneys in the larvae, while in adults antennary glands act as excretory organs. Generally, both the glands do not function simultaneously because one type succeeds the other.

6.5.3 EXCRETORY SYSTEM OF PALAEMON

1) Antennary glands or green glands: A pair of antennary or green glands are located in the coxal segments of antenna. They are the characteristic excretory organs of palaemon. They are opaque and green in colour. They also called as renal glands. Each gland consists of: a) end sac, b) labyrinth, and c) bladder.

a) End sac: End sac is small, bean shaped structure, situated in the anterior part of the gland. It has two layers, the outer thick layer consists of connective tissue with numerous small blood Lacunae while the inner layer is thin and is made up of epithelial cells which project into the cavity of end sac lies inner to labyrinth and communicates with it by an aperture.

b) Glandular plexus or labyrinth: Labyrinth is larger than end sac and has a spongy wall. It is made up of a mass of coiled tubules, joined on one end with the end sac by a single aperture and on the other with the bladder by many openings. These tubules are lined by glandular epithelium. The space between the tubules are filled with connective tissue.

c) Bladder: Bladder is a thin walled sac, situated on the inner side of the end sac. It gives off from its inner side a short narrow tube, the excretory duct or ureter. Ureter opens to the outside by a small renal or excretory aperture located on a papilla on the innerside of the coxopodite of the antenna and in front of the labrum.

From the bladder on each side a lateral duct arise and runs posteriorly. These two lateral ducts are connected by a transverse connective. Finally, the lateral ducts open into an elongated renal sac.

2) Renal Sac or Nephro-Peritoneal sac

A ... ted above the cardiac stomach and below the Carapace. ... s by lateral ducts. It extends posteriorly upto the gonads w... le layer of flattened epithelial cells.

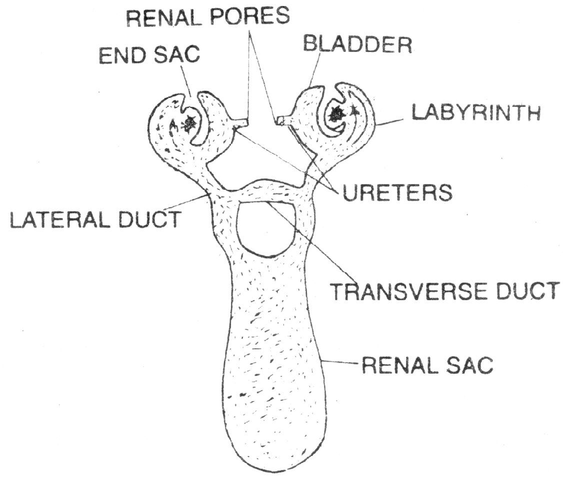

Fig.146 Palaemon-excretory organs

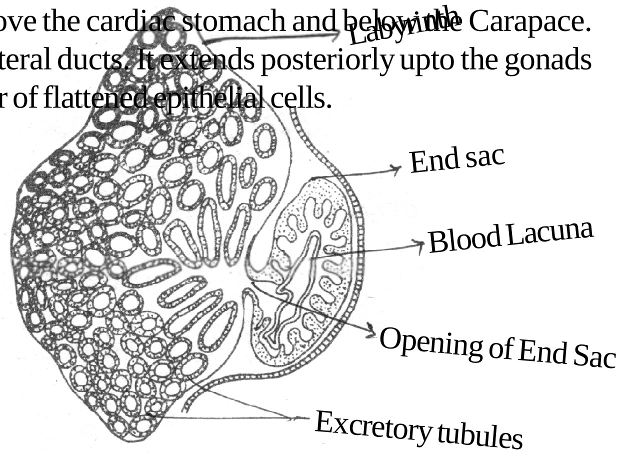

Fig.147 T.S. of Antennary gland

Antennary glands extract nitrogenous waste materials and excess of water from blood same as vertebrate kidney. Hence, they have dual function excretion and osmoregulation. End sac removes ammonia while other nitrogenous compounds removed by other parts. The excretory fluid from the end sacs passes into the labyrinths. Here selective reabsorption takes place by which useful materials sent back to the blood. The remaining fluid passes into bladders and is finally expelled out through the renal apertures.

Brown's blood is hypertonic to the surrounding water. Hence, large quantity of water constantly enters into the body through the gill surfaces. This excess of water is eliminated by the green glands thus performing osmo-regulatory function also.

Integument: Integument is also considered as an organ of excretion. The non-living nitrogenous waste material which is deposited over integument is cast off during ecdysis or moulting.

6.5.4 EXCRETORY SYSTEM OF SCORPION

a) Malpighian tubules: In scorpion, two pairs of malpighian tubules are present. They are endodermal in origin and one end attached to the junction of mesenteron and hind gut the other end freely floats in the blood. They extract the nitrogenous waste material from the blood and damage it into the gut from where they are passed out with faeces.

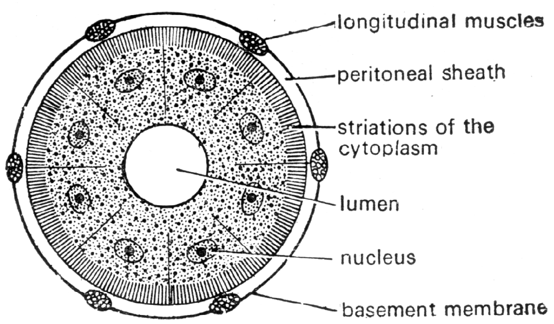

Fig.No.148 Malphigion tubule T.s

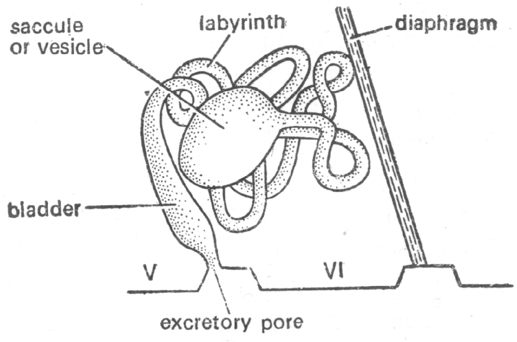

Fig.No.149 Coxal glands

b) Coxal glands: Scorpion has a pair of coxal glands. These are shiny white in colour and lie at the base of the third walking leg in the fifth segment of the prosoma. Each coxal gland is a modified coelmoduct. It consists of a large saccule or end sac, a long coiled duct or labyrinth and a small terminal reservoir or bladder. The bladder opens out by a small excretory pore situated in the groove between the coxa of the third leg and the sternum of prosoma. The end sac and labyrinth filter the nitrogenous waste material from the blood and collected in the bladder and are sent out through the excretory pore.

c) Hepatopancreas: It is located around the midgut. It opens into the gut by five pairs of ducts. Pavlovsky felt that the hepatopancreas of the scorpion serves also the function excretion. According to him, the ammonia Caramine injected in the body cavity of scorpion is collected in the form of small, bright red granules by the cells of hepatopancreas.

6.5.5 Comparative account of Excretory system

	Palemon	Scorpion
1	Excretory system consists of antennary or green or renal glands, renal sac and integument.	Excretory system includes malpighian tubules, coxal gland and hepatopancreas.
2	A pair of excretory pores present on the coxae of the antennae.	A pair of excretory pores occur at the coxae of 3rd legs.
3	Antennary glands are paired structures present in the coxal segments of antennae.	A pair of coxal glands are present at the base of third walking leg in the fifth segment of prosoma.
4	Antennary gland consists of end sac labyrinth and bladder	Coxal gland comprises of end sac, labyrinth and a terminal reservoir or bladder.
5	Integument is also serves as an excretory organ.	Hepatopancreas is also serves as an excretory organ.

6.5.6 SUMMARY

A pair of green glands or antennary glands or Renal glands are the excretory organs of palaemon. They are situated in coxal segment of each antenna. It consists of three parts namely end sac, labyrinth and bladder. The green glands extract nitrogenous waste materials and excess of water from blood. Integument also serves as a excretory organ. Malpighian tubules, coxal glands and hepatopancreas are the excretory organs of scorpion. Malpighian tubules are the chief organs of excretion discharging into the hindgut. Coxal glands are derived from Coelomoducts. These are homologous to the green glands of palaemon. Coxal glands and hepatopancreas also do the excretory function.

6.5.7 KEY TERMINOLOGY

Antennary gland: Characteristic excretory organ of Palaemon, situated in croxal segment of each antenna.

Coxal gland: Excretory organ of scorpion, situated at the base of the each third walking leg.

Excretion: Removal of Nitrogenous waste materials from the body.

Malpighian tubules: Two pairs of malpighian tubules are present in scorpion as excretory organs, one end attached to the midgut and the other end freely floats in the blood.

6.5.8 MODEL QUESTIONS

1. Describe the excretory system of Palaemon.
2. Describe the excretory system of scorpion.
3. Give a comparative account of excretory system of Palaemon and Scorpion.

4. Write short notes on:
   1. Antennary gland
   2. Coxal gland

6.5.9 REFERENCE BOOKS

1. **Invertebrate Zoology**. P.S. Dhami, J.K. Dhami.
2. **Biology of Non-chordates**. H.C. Nigam.
3. **Text book of Zoology – Invertebrate, Vol. I**. Parker & Maswell.

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Lesson 6.6
COMPARATIVE STUDY OF CIRCULATORY SYSTEM OF PALAEMON AND SCORPION

CONTENTS

6.6.1 OBJECTIVE

The study of this unit makes an idea about the similarities and differences of the structural characteristics of circulatory system and path of circulation of a fresh water Crustacean (Palaemon) and a terrestrial air-breathing arachinid (Scorpion).

6.6.2 INTRODUCTION

The purpose of a circulatory system is to provide rapid mass flow of material from one part of the body to another over distances where diffusion would be too slow. The blood vascular system of palaemon consists of heart and pericardium, arteries, blood lacunae or sinuses and blood channels. The blood vascular system of scorpion includes the heart and pericardium, arteries, blood Lacunae and Veins. The blood vascular system is of the open type in Palaemon and scorpion. In this type, blood is pumped by the heart into an aorta which branches into a number of arteries. These open into a series of blood spaces without their own epithelial walls called blood lacunae or sinuses. These blood sinuses collectively called the **haemocoel**. The coelome is greatly reduced in these animals and its place taken by the haemocoel.

6.6.3 BLOOD

In Palaemon and scorpion, the blood is a thin, watery, colourless fluid containing suspended **amoebocytes** or **leucocytes**. The colour of the blood is changed to blue when expose to air as it has **haemocyanin**, the respiratory pigment dissolved in the plasma. The function of haemocyanin is the same as that of haemoglobin expects that it contains copper instead of iron.

Blood carries oxygen from the gills to the various tissues and carbondioxide to the gills. It transports food material from one part of the body to another. It also serves as vehicle for the transport of internal secretions.

6.6.4 HEART AND PERICARDIUM

1) **Palaemon:** Heart is a triangular structure situated in the posterior part of the cephalothorax, just above the hepatopancreas and below the carapace. Its apex directed forwards and broader base backwards. It is lodged in the **pericardium** or **pericardial sinus**. Pericardial sinus is a wide space found just below the dorsal thoracic wall and above the hepatopancreas and reproductive organs. It is separated from the reproductive organs by a horizontal pericardial septum, which is attached in front and behind to the dorsal body wall, on the two sides to the lateral walls of the thorax. The heart is suspended in the pericardium by three fibrous cords, the alae cordis, one of these, the **cardio-pyloric strand** is median and extend between the apex of heart and the dorsal wall of the pyloric stomach, the other two, the **lateral strands**, connect the heart with the lateral body wall. The thick and muscular wall of the heart has five pairs of slit like apertures or ostia. These are a **dorsal pair** lying on the dorsal surface little behind the middle, an anterio lateral pair situated just behind the apex, a posterio lateral pair at lateral angels, a **ventral pair** present on the ventral surface opposite to the dorsal ostia, and a **posterior pair** lies in the hind border. The side walls or lips of the ostia act as valves allowing the blood only to enter the heart and not *vice versa*. The lumen of the heart is spongy and is traversed by a mesh of muscle fibres.

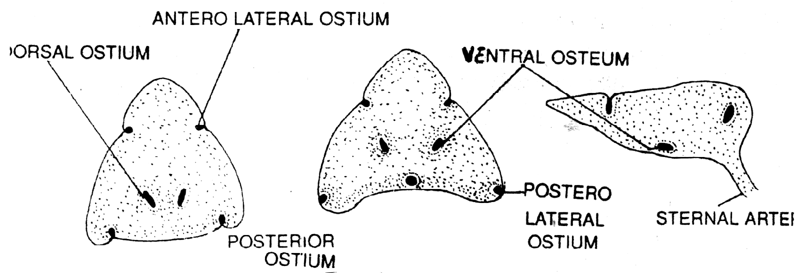

Fig.No.150 Heart showing osteia

2) **Scorpion:** Heart is a long, muscular tube situated beneath the terga along the mid dorsal line from 7th to 13th segment. It is surrounded by a thin walled sac known as pericardium. The heart is suspended into the pericardium by a pair of connective tissue bands or ligaments in each segment. The heart is divided internally by folds into seven chambers, one in each preabdominal segment. Each chamber has a pair of ostia to receive the blood from the pericardial sinus. The wall of each ostium is slightly drawn into the form of a valve which allow the flow of blood for the pericardial sinus into heart and not *vice-versa*.

6.6.5 ARTERIES

1) **Palaemon:** The heart receives the blood from the pericardial sinus and pumps it by the contraction into thick, muscular, narrow tubes known as arteries which convey it to various parts of the body. From the apex of the heart arises a median ophthalmic artery and paired anternnary and hepatic arteries. From the posterior end or broad base of the heart arises a single median posterior or sterno-intestinal artery.

a) **Median ophthalmic artery:** It is a single, slender artery which arise from the apex of the heart. It runs anteriorly in the mid-dorsal region below the Carapace upto the root of the oesophagus along the renal sac. Above the oesophagus, it joins two antennary arteries.

b) **Antennary arteries:** A pair of antennary arteries arise from the apex of the heart, one on each side of the median ophthalmic. Each antennary artery passes obliquely and gives out three branches; (a) pericardial branch to the pericardium, (b) gastric branch to the cardiac stomach and (c) mandibular branch to mandibular muscles. At the anterior end of the head, each antennary artery divides into a dorsal and ventral branch. The dorsal branch divides into an optic artery to the eye and then meets its fellow of the opposite side and median ophthalmic artery forming *Circulus cephalicus*, which gives off a pair of rostral arteries supplying the rostrum. The ventral branch also divides into two, one of which goes to the antennule and the outer redivides into two, supplying the renal organ and antenna.

c) **Hepatic arteries:** Hepatic arteries arise from the heart on the ventro-lateral sides of the roots of antennary arteries. They divide repeatedly in the hepatopancreas.

d) **Median posterior artery:** This is a short, stout, median artery arises from the middle of the posterio-ventral surface of the heart. It immediately divides into a slender supra-intestinal and a stout sternal artery. The supra-intestinal artery passes straight backwards along the dorsal surface of the intestine upto hindgut, while it bifurcates into two branches. It supplies blood to the intestine and the dorsal abdominal muscles.

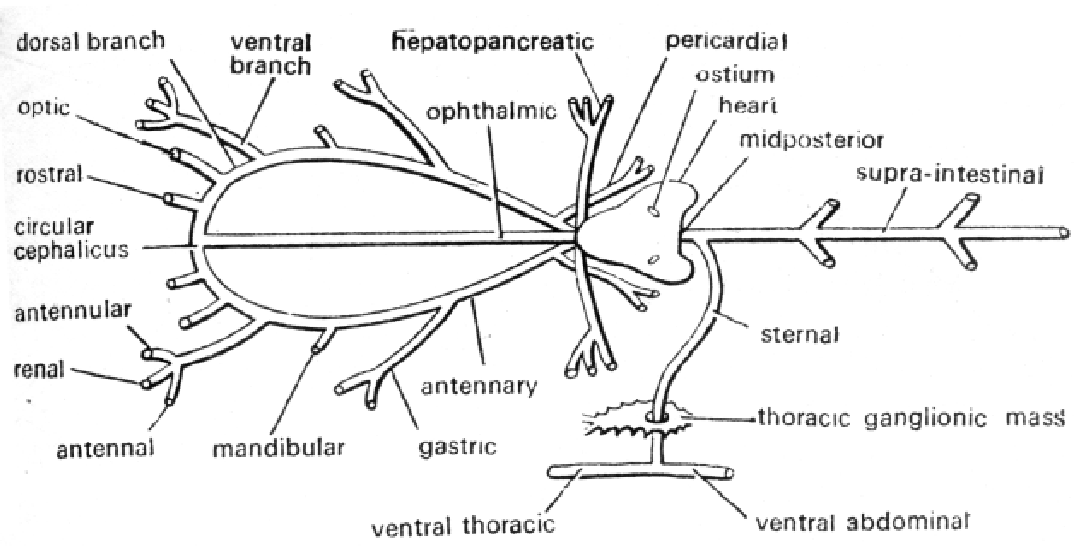

Fig.No.151 Heart in principle arteries

The sternal artery is the stoutest of all others. It runs downwards obliquely either to the left or to the right side of midgut. It pierces through the thoracic ganglionic mass and splits into two branches: the larger ventral thoracic artery and the smaller ventral abdominal artery. Ventral thoracic artery supplies blood to the sternal region, maxillae, maxillulae and first three pairs of walking legs. Ventral abdominal branch supplies blood to the ventral region of the abdomen, last two pairs of legs, pleopods and to midgut.

2) **Scorpion:** The first chamber of the heart is continued anteriorly along the alimentary canal as anterior aorta and the last chamber is continued behind the post abdomen as posterior aorta. A pair of lateral systemic arteries also arise from the each chamber of the heart.

a) **Anterior aorta:** It is a short and wide vessel, runs forwards, passes into the prosoma and divides into two arteries, which after embracing the oesophagus join below to form the ventral aorta or supraneural aorta. Ventral aorta runs backwards medially above the ventral nerve cord and ends in the telson. The anterior aorta supplies blood to the stomach and the hepatopancreas by a pair of visceral arteries and to the brain and cephalic appendages by 6 pairs of appendicular arteries.

b) **Posterior aorta:** It runs backwards over the intestine in the metasoma ending in the telson. It supplies blood to the intestine and dorsal segmental muscles of post-abdomen.

c) **Systematic Arteries:** These arteries run laterally and distribute blood to the dorsal and lateral segmental muscles and to the viscera in the prosoma.

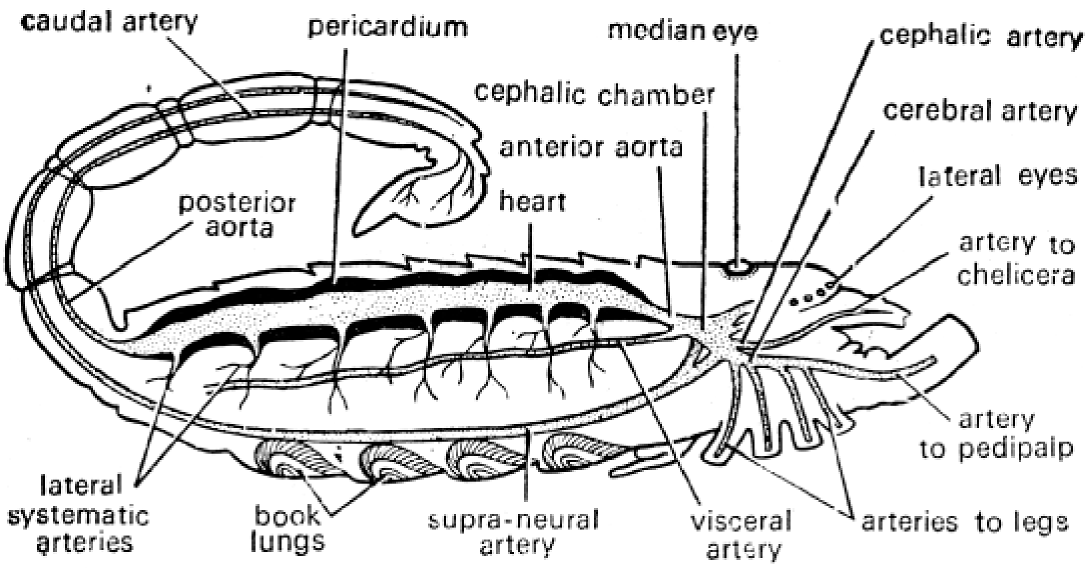

Fig.No.152 Scorpion - circulator system in lateral view

6.6.6 BLOOD LACUNAE OR SINUSES

1) **Palaemon:** Arteries divide and redivide into numerous branches in the organs of the body and communicate openly with the small blood (lacunae) sinuses. The smaller sinuses join to form larger sinuses which, in turn, unite to form a pair of large ventral or sternal sinuses. These are lie side by side beneath the flower muscles of the thorax and the hepatopancreas. The two ventral sinuses are interconnected by a number of small connecting sinuses.

2) **Scorpion:** The branches of the arteries open into small spaces or lacunae. From these small lacunae, situated among viscera, blood is collected by large sinuses. Large sinuses are five in number. The pericardial sinus is situated around the heart. The dorsal sinus is located just above the pericardial sinus. The two lateral sinuses are situated one on either side of the body. A large ventral sinus is found on the ventral side of the body. The ventral sinus sends blood to the book lungs by the diverticula for oxygenation.

6.6.7 BLOOD CHANNELS

1) Palaemon: From the ventral sinus of each side the blood passes into 6 afferent branchial channels first of which carries blood to the two arthrobranches and podobranch while the rest supply each of the five pleurobranches. In the gills, blood is circulated through minute longitudinal channels. Aeration takes place during the course of blood through the gill plates. Aerated blood returns into the pericardial sinu

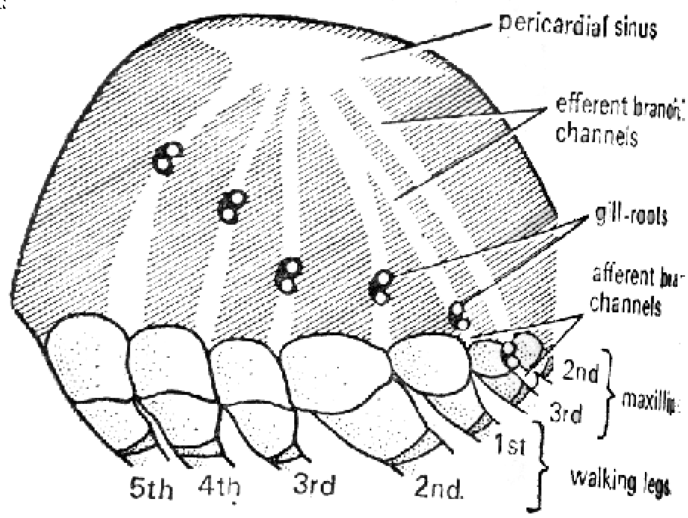

Fig.No.153 Palaemon - Blood channels in cephalothorax

Palaemon-lateral view of the thoracic wall showing the pericardial sinus and branchial channels

Scorpion: There is no blood channels in Scorpion

6.6.8 VEINS

There is no veins in palaemon.

Scorpion: Four pairs of thin walled pulmonary veins carry oxygenated blood from the book lungs to the pericardial sinus.

6.6.9 COURSE OF BLOOD CIRCULATION

Palaemon: The blood from the different parts of the body is emptied into the ventral sinuses through various small sinuses. From the ventral sinuses the blood passes into the gills by afferent branchial channels. Blood is oxygenated in the gills and is returned to pericardial sinus through the six pairs of efferent branchial channels. Blood is oxygenated in the gills and is returned to pericardial sinus through the six pairs of efferent branchial channels. From the pericardial sinus the blood enters the heart through ostia. From the heart, the blood pumped to the different parts of the body through arteries by its rhythemic contractions.

HEART

↓	↑
ARTERIES	PERICARDIAL SINUS
↓	↑
BRANCHES OF ARTERIES TO VISCERA	EFFERENT BRANCHIAL CHANNEL
↑	
	GILLS (Through minute longitudinal channels)
	↑
BLOOD LACUNAE	AFFERENT BRANCHIAL CHANNELS

VENTRAL SINUSES

SCORPION: The cavity of the heart enlarges by the contraction of the ligaments and the blood from the pericardium flows through the ostia into the heart. When the heart contracts, the blood passes into the various organs of the body through the different arteries. The deoxygenated blood from the viscera is collected in the ventral sinus. From the ventral sinus, the blood passes to the book lungs for oxygenation.

ARTERIES	HEART		(ostia)
↓			↑
BLOOD LACUNA IN VISCERA			PERICARDIAL SINUS
↓			
DORSAL, LATERAL and PERIVISCERAL SINUSES	VENTRAL SINUS	BOOK LUNGS	(Pulmonary veins)

6.6.10 SUMMARY

Blood vascular system is an 'open type' in palaemon and scorpion. In these animals, the blood is blue in colour, when expose to air, due to presence of haemocyanin in plasma. Circulatory system of palaemon consists of triangular heart, pericardium, arteries, blood sinuses and blood channels. The principle arteries are median ophthalmic artery, paired antennary, a pair of hepatic and a median posterior or sterno-intestinal artery. Capillaries and veins are absent. Oxygenation of blood occurs in gills.

Circulatory system of Scorpion comprises mid-dorsal tubular heart, pericardium or pericardial sinus, arteries, sinuses and veins. Principle arteries are anterior aorta, posterior aorta and systemic arteries. Oxygenation of blood takes place in book lungs.

6.6.11 COMPARATIVE ACCOUNT OF CIRCULATORY SYSTEM OF PALAEMON & SCORPION

S.No.	Palaemon	Scorpion
1	Circulatory system is of open type	Open type
2	Circulatory system consists of heart, pericardium, arteries, blood sinuses and channels	Circulatory system includes heart, pericaridum, arteries, sinuses and veins
3	Blood is blue in colour, when expose to air, dueto haemocyanin	same
4	Blood has plasma and amoeboytes or Leucocytes	same
5	Heart is triangular, situated in the posterior part of the cephalothorax, just above the hepatopancreas and below the carapace	Heart is tubular, located beneath the terga along the mid-dorsal line from 7^{th} to 13^{th} segment
6	Heart is suspended in the pericardial sinus by three fibrous cords, i.e., cardio pyloric strand, lateral strands	Heart is suspended into the pericardial sinus by a pair of connective tissue bands or ligaments in each segment
7	Heart is not divided into chambers	Heart is in completely divided internally by folds into seven chambers
8	Heart has five pairs of slit like apertures or ostia with valves	Each chamber has a pair of ostia on its dorso-lateral side with valves
9	Heart gives off from the anterior end a median ophthalmic artery, paired antennary and hepatic arteries. From the posterior end arises a single median posterior or sterno-intestinal artery.	Heart is extended anteriorly as anterior aorta, posteriorly as posterio aorta
10	Systemic arteries absent	Heart gives off a pair of lateral systemic arteries from each chamber

11	Median ophthalmic artery supplies blood to oesophagus, cardiac stomach and the head	Anterior aorta supplies blood to the brain and cephalic appendages by 6 pairs of appendicular arteries
12	Each antennary artery gives off three branches, pericardial, gastric and mandibular, supplies blood to pericardium, cardiac stomach and mandibular muscles respectively. Antennary artery again divides into dorsal and ventral branches in the anterior end and supplies blood to the eye, rostrum, antennule, antennae and renal organ	Systemic arteries distribute blood to the dorsal and lateral segmented muscles and to viscera in the prosoma
13	Hepatic arteries supply blood to hepatopancreas	Visceral arteries of anterior aorta supply blood to hepatopancreas and stomach
14	Median posterior artery divides into supra-intestinal artery, supplies blood to Intestine dorsal muscles of abdomen, sternal region of thorax, abdomen and appendages	Posterior aorta supplies blood to the Intestine and dorsal segmented muscles of post-abdomen
15	Circulus cephalicus present	Absent
16	Two large ventral sinuses are present	Five large sinuses are present, i.e., pericardial sinus, dorsal sinus, two lateral sinuses and a large ventral sinus
17	Capillaries and veins absent	Four pairs of pulmonary veins present
18	Blood is carried from the ventral sinuses to the gills by six afferent branchial channels	Blood is carried from the ventral sinus to the book lungs by diverticula of ventral sinus
19	Oxygenation takes place in gills	Oxygenation takes place in book lungs
20	Oxygenated blood is sent back to the pericardial sinus by six efferent branchial channels	Oxygenated blood is sent back to the pericardial sinus by four pairs of pulmonary veins

6.6.12 KEY TERMINOLOGY

Blood Sinus/Lacunae: A thin walled cavity filled with blood.

Haemocoel: The coelom filled with blood

Haemocyanin: A respiratory pigment having copper as a metallic ion.

Open type: Blood flows in blood sinuses or Lacunae.

Pericardium: A thin layer enclosing the heart

6.6.13 MODEL QUESTIONS

1. Compare the circulatory systems of palaemon and scorpion.
2. Describe the circulatory system and the course of circualtion in Palaemon.
3. Describe the circulatory system and blood stream of scorpion.
4. Describe the circulatory system of prawn and compare it with that of scorpion.

6.6.14 REFERENCE BOOKS

1. **Biology of Non-Chordates –** H.C. Nigam.
2. **Invertebrate Zoology** – T.C. Majupuria.
3. **Modern Textbook of Zoology –** R.L. Kotpal, S.K. Agarwal, R.P. Khetarpal.
4. **Invertebrate Structure & Function –** E.J.W. Barrington.

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Lesson 6.7
STRUCTURE AND AFFINITIES OF PERIPATUS

CONTENTS

6.7.1 OBJECTIVE

The purpose of this lesson is to understand the structure and physiology of Excretory systems of Palaemon and scorpion.

6.7.2 INTRODUCTION

Peripatus belongs to phylum **Onychophora**. Earlier onychophora was included as a class of the phylum arthropoda. Depending on the several unique characters at present it is given a status of a separate phylum. Onychophora has about a dozen genera and nearly seventy species of which peripatus is the best known. The largest species is *Peripatopsis torquatus* measuring about 15 cm.

6.7.3 STRUCTURE

Peripatus is a small, cataerpillar-like, slow moving bilaterally symmetrical animal. It is commonly called as "**walking worm**". It is a terrestrial, nocturnal animal which lives in moist and shady places under stones, logs of trees in forests. It has a soft, velvety, cylindrical body. It is covered by a thin flexible cuticle. The body is not divided into segments distinctly. The segmentation can be noted only by observing the paired appendages arising from the body. Numerous superficial annuli are appeared on the skin which give wrinkled nature tot he body. The integument bears all over minute papillae, each bearing a little spine.

Body of peripatus is divided into head and trunk and there is no indication of thorax and abdomen.

A) Head: The anterior part of the head is termed as **Prostomium** or **Acron**. The head bears a pair of long, mobile antennae, a pair of jaws, a pair of short oral papillae and a pair of simple eyes. Antennae are anterior in position and are provided with numerous spiny rings. They are chief sense organs and tactile in function. The toothed jaws are placed on either side of the mouth for tearing the food. Each jaw has two curved and pointed chitinous plates, one of which is toothed on its inner edge. Salivary glands open behind the mandibles through salivary openings. The oral papillae are shorter than antennae and are blunt outgrowths on the sides of the mouth. Each oral papilla bear large tubercles distally and an opening of a slime gland. A jet of slime is thrown through this opening in defence and for capturing the prey. Behind the oral papillae mouth is present on ventral side. Oral papillae are sensory in function. The eyes lie dorsally and are simple.

B) Trunk: Skin of the trunk behind the head is thrown into the fine wrinkles or annuli bearing numerous conical tubercles with chitinous spines. The appendages or walking legs of the trunk vary in number, 14-43; in different species. It has two parts-leg and foot. Each leg is a hollow and conical structure. Its distal end has some spiny pads to provide grip to the animal in movement. The foot is attached to the distal end of the leg and bears a pair of claws.

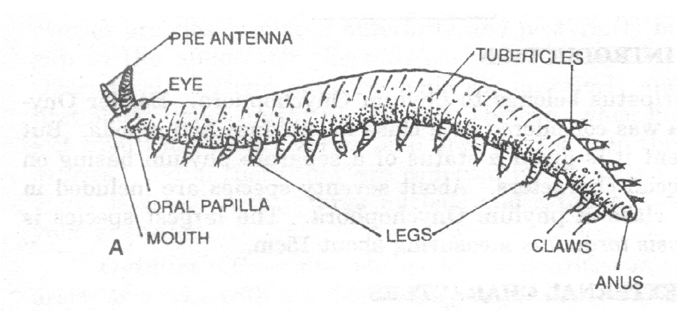

Fig.No.154 A) Peripatus entire

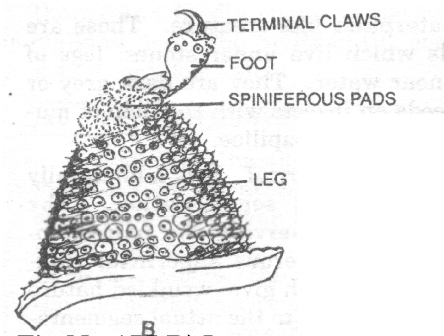

Fig.No.155 B) Leg

Excretory pores are present on the ventral side of walking legs. Coxal glands are open at the base of the legs. Genital opening is situated between the last pair of legs and anus in the last segment.

6.7.4 INTERNAL STRUCTURE

Body wall is dermo-muscular. It consists of a thin flexible chitinous cuticle, single layered epidermis, dermis, circular and longitudinal muscles. Body cavity is a haemocoel. True coelom is restricted to cavities of gonads and excretory organs. Alimentary canal is a straight tube and is divided into fore, mid and hind guts. It is associated with a pair of salivary glands. Heart is tubular and is located dorsally to alimentary canal. It is extending from the head to the posterior end of the body. Respiration is carried on by the tracheal system. Excretion is performed by segmentally arranged nephridia. The nephridium of a peripatus is a modified coelomoduct. Nervous system consists of nerve ring and ventral nerve cords. In peripatus sexes are separate. Males are smaller than females. Fertilization is internal. Most of the species are viviparous.

Peripatus is found in Australia, New Zealand, Tasmania, New Britain, Malay Archipelago, South America, Mexico, West Indies and Africa.

6.7.5 AFFINITIES

Peripatus was first discovered by guilding in 1825. He included it in the phylum Mollusca due its soft body and sluggish movement. But H.N. Mosely in 1874 observed the tracheal system in these animals and considered them as Arthropods. Peripatus has both Annelidan and Arthropodan characters besides some unique characters. Hence, orychophora has been described as the 'missing link'; between the two phyla. Now it is treated as a separate phylum due to unique characters.

A) Resemblances with Annelids

1. Segmentation of the body is similar both in peripatus and Annelids.
2. Body wall is dermo-muscular in both the phyla.
3. The legs of peripatus resemble that of parapodia of annelids in their structure.
4. Eyes are simple like those of polychaetes.
5. Body is worm like pointed at either end.
6. Presence of segmentally arranged paired nephridia.
7. Alimentary canal is straight and simple.
8. Reproductive tracts are ciliated.
9. Slime glands and coxal glands correspond to similar type of glands of chaetopoda.

b) Differences with Annelids

Peripatus differs from Annelids in the respiratory, vascular, nervous and reproductive systems. The external segmentation does not correspond with the internal segmentation as in annelids.

C) Resemblances with Arthropods

1. Presence of one pair of antennae and mandibles.
2. Cuticle is chitinous.
3. Body cavity is haemocoel.
4. Presence of dorsal tubular heart
5. Respiration is by tracheal tubes as in insects.
6. Presence of salivary and coxal glands.
7. Brain and development is similar to that of Arthropods.

d) Differences with Arthopods

1. Tracheae are not arranged like that of Arthropods. In onychophores each segment has many permanently opened spiracles.
2. Body wall is not like that of Arthropods.
3. The two ventral nerve cords are separated from each other and are connected by transverse commisures. Ganglia are absent. But it is different in Arthropods.

e) Special characters

1. Skin is velvety and is provided with a number of tubercles.
2. Irregularly scattered stigmata.

3. Body is thrown into wrinkles but not externally segmented.
4. Cephalization is not clear, but anterior part is differentiated as head due to presence of antennae, oral papillae and eyes.
5. In peripatus, the testes open into vas efferentia. They open into seminal vesicle which lead to vas deferentia which is a unique feature. (In other animals, the testes open into vas efferentia and vas differentia which enlarge at the base to form seminal vesicle).

Onychophora has of both Annelidan and Arthropodan characters. It indicates that, the arthropods may have been derived from an annelidan like ancestor. Onychrophores also exhibit some unique characters. Hence, they can neither be included in Annelida nor in Arthropoda and has a separated phylum status along with annelids and Arthropods.

6.7 SUMMARY

Peripatus was first discovered by Guilding in 1825. It belongs to phylum onychopohora. It is a caterpillar like, bilaterally symmetrical, terrestrial and nocturnal animal. It exhibits discontinuous distribution. Body is divided into head and trunk. Head bears a pair of antennae, mandibles or jaws, oral papillae and simple eyes. Surface cuticle is thin. Body wall is dermo-muscular. Body cavity is haemocoel. Alimentary canal is straight, heart is tubular. Excretory organs are segmentally arranged modified coelmoducts or nephridia. Organs of respiration are a system of Trachea and spiracles. Ventral nerve cords are widely separated and without ganglia. Reproductive organs are ciliated. Development is direct.

Peripatus has both annelidan and arthropodan characters. With annelids they resemble in having paired excretory nephridia and the flexible cuticle covering the body. The chief characters that resemble the arthropodans are the embryonic development particularly the cleavage, the haemocoel, the tracheal system and clawed paired legs. Hence, onychophora has been described as a 'missing link' between the two phyla. Earlier onychophora was considered as a class in phylum Arthropoda. But now it is treated as a separate phylum due to some peculiar characters.

6.7.7 KEY TERMINOLOGY

Appendage: A movable projecting part of the body.

Haemocoel: A portion of body cavity filled with haemolymph.

Nocturnal: Active at night. Opposite to diurnal.

Onychophora: A phylum with small caterpillar like animals, structurally intermediate between the annelids and Arthropods (missing-link/living-link).

Papilla: Small nipple-shaped elevation.

Tactile: Pertaining to sense of touch.

Viviparous: An organism that gives birth to living young are that develops from egg within the body of mother.

6.7.8 MODEL QUESTIONS

1) Describe the salient features of peripatus and justify its inclusion in a separate phyl.
2) Enumerate the structure and affinities of onychophora.

6.7.9 REFERENCE BOOKS

1. **Invertebrate Zoology.** P.S. Dhami & J.R. Dhami.
2. **Manual of Zoology – Part-I**. M. Ekambaranath Ayyar.
3. **Invertebrate Zoology –** S.N. Prasad.

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Lesson 7.1
PHYLUM MOLLUSCA

7.1.1 Objective : The purpos of this lesson is to understand the characters and classification of Molluscans Introductiokns

7.1.2 Introduction

The term mollusca [Mollis = soft] means soft bodied. The word mollusca was coined by Aristotle. It was established as a separate phylum by Lankaster. The phylum mollusca includes, clams, oysters, snails, squids, octopods etc., Mollusca is the second largest phylum in the animal kingdom. Architeuthis (giants squid) is the largest inverterbrate animal belongs to the phylum mollusca. The science dealing with the study of molluscs is called Malacology. The study of molluscan shells is called conchology.

7.1.3 General Characters :

1. Majority of the molluscs are marine, some are fresh water forms and others are Terrestrial.
2. The body is soft, unsegmented and bilaterally symmetrical
3. These are triploblastic, schicoelomate animals without appendages
4. Generally the body is divided into 4 regions : head, foot, visceral mass and mantle.
5. The head is distinct bearing the mouth, tentacles, eyes and other sense organs except in scapopoda and pelecypoda

6. The ventral part of the body is modified into a muscular foot. It is useful in creeping, burrowing and swimming
7. The visceral mass or visceral hump contains the vital visceral organs of the body.
8. A thin fleshy fold of skin called mantle or pallium is present. It encloses the visceral mass and various body parts. The space between the mantle and the body is called mantle cavity or pallial cavity.
9. Unstriped muscles are found in the body of molluscs
10. Important Character of molluscs is the presence of shell which is either internal or external. It may be made up of single valve or two valves or many plates. Shell is absent in vaginulus and Doris. The shell is secreted by the mantle.
11. Coelom (schizocoel) is reduced and represented mainly by pericardial cavity, gonadial cavity and renal cavity.
12. The body cavity is a haemocoel. It is derived from the embryonic blastocoel.
13. The alimentary canal is straight or coiled. In most of the molluscs a rasping organ called radula is present in the buccal cavity. It bears transverse rows of teeth. The anus opens into the mantle cavity. [Radula is absent in pelecypoda]
14. A large digestive gland called (liver) hepatorpaneras is present. It helps in digestion, absorption and storage of food.
15. Crystaline style is present in the alimentary canal of pelecypods and some other molluscs. It is useful in the digestion of carbohydrates.
16. Respiratory organs are gills (ctenidia), lung (pulmonary sac) and mantle. Ctenidia vary in number from one to many pairs.
17. Blood vascular system is open type (lacunar) i.e. blood flows in body spaces (lacunae). But in cephalopods the blood vascular system is of closed type.
18. The heart consists of one to four auricles and one ventricle.
19. Blood is called haemolymph.
20. Respiratory pigmant is a copper based haemocyanin. It imports greenish blue colour to the oxygenated blood.
21. Excretion is carried out by meta nephridia (Kidneys) organ of Bojanus and Keber's organ. The metanephridia are the true coelmoducts and comminicate from pericaridial cavity to the exterioir by nephridiopore].
22. Nervous system is well developed. It is made up of paired cerebral, pedal, pleural and visceral ganglia. These ganglia are interconnected by connectives and commissures.
23. Sense organs are in the form of eyesa, tentacles, statocysts and ospharadium. Osphradium is a leaf like sense organ. It is a chemo and alfactory receptor detecting the purity of water.

24. Molluscs are mostly unisexual (dioecious) but some of them are bisexual (monoecious) one or two gonads present with gonoducts. Some have copulatory organs.
25. Fertilization is internal or external.
26. Clevage is holoblastic, spiral and determinate type (In cephalopods clevage is meroblastic)
27. Development is direct (as in cephalopods) or indirect with trochophore or veliger in the life history.

7.1.4 Classification :

Classification of Mollusca is mainly based on the structure of shell and foot. Phylum Mollusca is divided into 7 classes

Class : Aplacophora:

1. Aplacophorans are commonly called as solenogasters (tube stomach)
2. These are primitive molluscs with worm-like body.
3. All are marine and live in burrows.
4. Shell is absent, hence the name Aplacophora
5. Mantle contains calcarious spicules
6. Foot is reduced or absent
7. Alimentary canal is tubular, with mouth and anus at opposite ends. Radula is absent
8. Respiration is either by gills or mantle.
9. Heart consists of one auricle and one ventricle.
10. These are bisexual (hermaphrodite). Life history includes trochophore larva
    Ex: Chaetoderma.

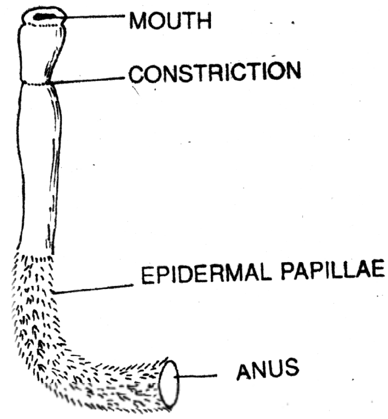

Fig.155 Chaetodarma

Class 2 Monoplacophora : [One plate bearers]

1. Mostly extinct belonging to Cambrian to Devonian periods. In 1952 Ten species of (living fossil) were colleted from the deep sea of the central American coast Neopilina galathea.
2. These are marine, and the body is oral and bilaterally symmetrical.

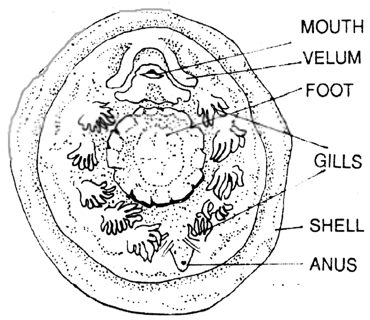

Fig.156 Neopillina

3. Body is metamerically segmented [Internal segmentation]
4. Shell is dorsal and consisting of a single piece.
5. Head is not distinct. Eyes are absent
6. They have a spacious coelom. These animals differ from other molluscs in this respect.
7. Heart is unique in having two auricles and two ventricles
8. Stomach contains crystalline style.
9. Nervous system is primitive and lacks ganglia.
10. Sexes are separate (dioecious) and development is indirect with a trochophore larva

Ex: Neopilina galatheae

Neopilina is considered as a connecting link between annelida and mollusca.

Class 3 Polyplacophora (Many plate bearers)

1. These are marine and bilaterally sytmmetrical.
2. Body is elliptical, convex dorsally and flattened ventrally.
3. Shell is dorsal and formed of 8 plates.
4. Head is distinct without eyes and tentacles.
5. Mantle extends in the form of a gridle around the margin of the body.
6. Foot is ventral broad, flat and useful for creping.
7. Radula is present in the baccal cavity
8. It has a unique sensory device called the sub-radula sac.
9. Many pairs of gills (ctenidia) are arranged on the margin of the foot.
10. Sexes are separate. Trochophare larva is present in the life history.

Ex: Chiton, Chaetopleura

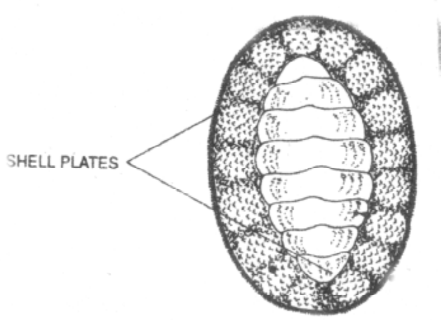

Fig.157 Chiton

Class : 4 Scaphopoda [G.Scapha = boat, Poda = foot]

1. These are commonly called tusk-shells or tooth shells as the shell resembles the tusk of an elephant.
2. These are marine and burrowing.

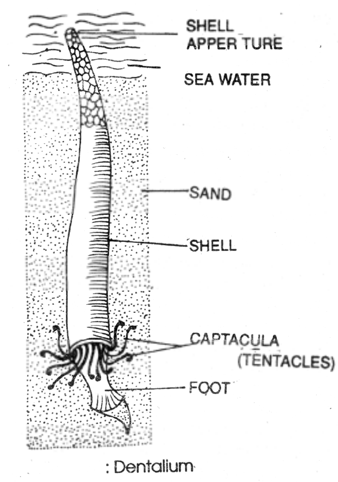

Fig.158 Dentalium

3. Body is elongated, worm-like enclosed in a tusk-like shell which opens at both ends.
4. Head is not distinct, eyes and tentacles are absent.
5. Foot is boat shaped and pointed, It helps in burrowing
6. Gills are absent. Exchange of gases takes place through the mantle surface.
7. Mouth is surrounds by elongated, tubular, contractile filaments called capatacula. They help in feeding.
8. Sexes are separate (dioecious)
9. Development, indirect with trochophore and veliger stages.

   Ex: Dentalium, Pulsellum

Class : 6 Pelecypoda or Bivalvia (Pelekys = hatchet, pods = foot)

1. Pelecypoda is also called as Bivalvia because the shell is made of two valves
2. They are marine or fresh water.
3. Body is laterally compressed
4. Head, eyes, tentacles and radula are absent
5. Foot is blade-like (axe-shaped) and adapted for burrowing. Some animals have byssus apparatus for attachment to substratum

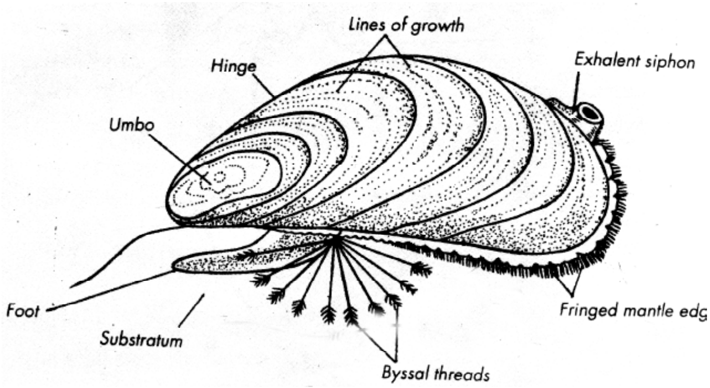

Fig.159 Mytilus

6. Mantle is bilobed and covers the dorsal and lateral sides at the posterior end the mantle forms two siphons called inhalent siphon and exhalent siphon
7. Alimentary canal is a coiled tube with crytaline style in the intestine. They are ciliary, filter feeders.
8. Respiration is cariied by one pair of lamerllar ctenidia (gills) projecting ventrally into the mantile cavity.
9. Heart is made of two auticles and one centricle
10. Excretory organs are a pair of kidneys.
11. They are unisexual or bisexual
12. Development is indirect which includes tyrochophore and veliger larval stages. In fresh water species glochidium larva is produced which is parasitic on fishes.

Ex Unio (Fresh water Mussel) Mytilus (marine muscle) Pinctada (Pear oyster). Teredo (Ship worm), Pholas (Rock borar)

Class 7:Cephalopoda or Siphonopoda

1. These are exclusively marine.
2. Body is bilaterally symmetrical with a distinct head and trunk.
3. Shell is external or internal or absent.
4. Head bears mouth and a pair of large eyes.
5. Foot is modified into 8 ro 10 sucker bearing arms (tentacles) and a siphon (funnel)
6. Two or four pairs of bipectinate gills present.
7. Blood vascular system is closed type with three hearts – one systemic heart and two branchial herts.
8. Cephadopods move by jet propulsion, the muscular mantle forces water, out of the mantle cavity through a siphon or funnel.
9. In most cephalopods an ink gland is present which is difensive in function.
10. Nervous system is well developed
11. Sexes are separate. In male one pair of the arms (tentacles) is modified for transferring sperms into the mantle cavity of the female. That modified arm is called heterocotylized arm
12. Clevage is meroblastic
13. Development is direct without larval stages

    Ex. Sepia (cuttle fish) Loligo (squid) Octopus (devil fish) Nautilus. Architeuthis (giant squid)

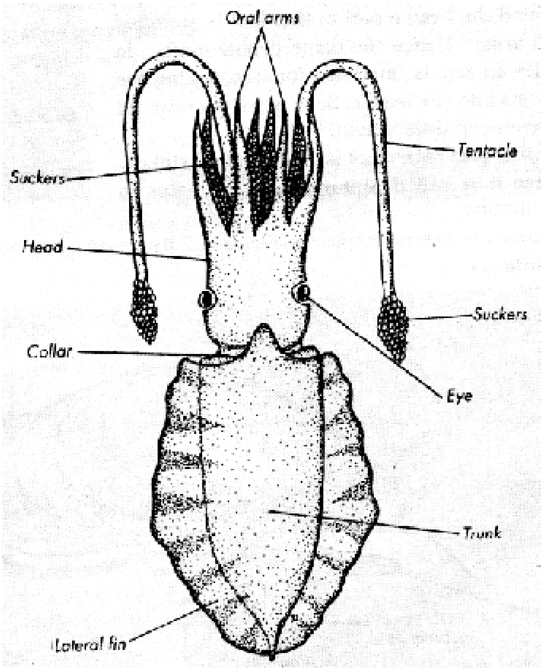

Fig.160 Sepia

7.1.5 Summary

Molluscans are soft bodied, triploblastic, Coelomate animals without visible segmentation. Body consists of head, a ventral muscular foot for locomotion, and a dorsol mass, surrounded by a thin fleshy layer called the mantle. Commonly body is enclosed by a callcareous shell for protection. Shell is secreated by a mantle. A pair of ctnidia or gills are located in the mantle cavity for aquatic respiration. Development includes veliger or trochophore larva.

There are about 10,000 living species which are divided into 7 classes depending on the characters of foot, mantle and shell.

7.1.6 Key Terminology:

1. Malacology : The science dealing with the study of Molluscs
2. Conchology: Study Molluscan Shells.
3. Monoplacophora : A class which includes molluscans with single piece of shell
4. Aplacophora: A class which includes molluscans without shell
5. Polyplacophora : A class which includes molluscans with many plates of shell

7.1.7 Model Questions:

1. Give the salient features of mollusca and classify it with suitable examples
2. Write a short notes on following

   1) Gastropoda 2) Pelecypoda 3) Scaphopoda 4) Polyplacophora

7.1.8 Reference Books :

Mollusca - Kotpal (Phylum Series)

Invertebrate Zoology P.S Dhami J.K. Dhami

Lesson 7.2
COMPARATIVE STUDY OF EXTERNAL CHARACTERS OF PILA AND FRESH WATER MUSSEL

7.2.1 Objective :

The purpose of this lesson is to understand ‘Structural differences between the PILA & UNIO

7.2.2 Introduction :

Pila belongs to class gastropoda or univalvia. The genus pila is confined to the oriental and the Ethiopian regions. The common species occurring in northern India is the Apple snail, pila globosa formerly known as Ampullaria globosa. It is a one of the largest and common India fresh water apple snail. It is herbivorous. It is describes as the “apple snail” probably because of its delicious taste and is regularly used as food by poor people.

Fresh water mussels are very common examples of calss. Pelecypods or lamellibranchiates. They found at the bottom of Fresh water ponds and rivers. They are partly burrowed in the moist sand in which they move slowly with their wedge shaped foot.

7.2.3 External structure of Pila : Pila is commonly known as “apple snail” or pond snail. It is the largest known fresh water snail. They live mostly in water but they can live on land also. Therefore they lead an amphibious life generally they inhabit ponds, tanks canals and paddy fields. They usually occur in areas where there is a large amount of vegetation. Presence of shell is an important characters of molluscs. Shell is secreted by the mantle.

The body of pila is enclosed in a calcarious shell. The shell is made of a single valve and hence is called univalve shell. The shell is somewhat conical and is coiled around a central axis called columella. A single coil of the

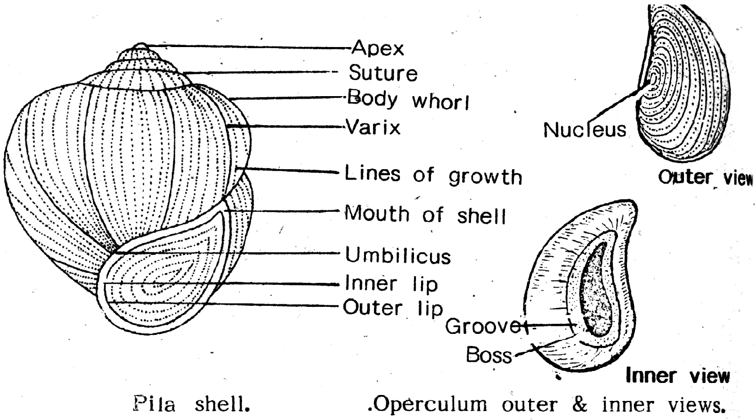

Fig.161 External structure of pila

shell is called whorl. There are usually

3 to 4 whorls in all that gradually from the top to the base of the shell. The top of the shell is called apex. It is the oldest and first formed part of the shell. This is also known as protochonch. The lower most whorl is the largest and is known as the body whorl. The whorl next to the body whorl is the penultimate whorl. The body whorl and penultimate whorl contain most of the snail's body. Externally the whorls are separated by deep lines called sutures. All the whorls, excepting the body whorl are together called as a spire. The surface of the whorls is marked by faint vertical ridges called the lines of growth A few of there lines are more prominent and an known as varices (singular varix). These repreent seasonal cessation (stoppage) of shell secretion.

The body whorl opens out by a large operature known as mouth of the shell.

Margin of the mouth is called peristome. It has a convex outer-lip and a concave inner-lip or columellar lip. Near the inner lip is a small opening called umbilicus. The mouth of the shell is covered by a calcarious plate called Operculum. The outer surface of the operculum bears ring-like of growth, concentric lines of growth round a centre circle known as nucleus. The inner surface of the operculum has a cream coloured, elliptic area called bass. It is surrounded by a shallow groove. The boss serves for the attachment of opercular muscles. The operculum is borne by the foot. After the withdrawal of the head and foot into the body whorl the operculum closes.

Types of shells : on the basis of coiling the shells are of two types

1) Dextral Shell : The shell with right side coiling is called dextral shell i.e, if the shell is held with the apex facing upwards and opening facing the observer, the mouth is towards the right.

2) Sinistral Shell: The shell with left sid coiling is called sinistral shelli.e, If the shell i held with the apex facing upwards and open ing facing the observer, the mouth is toward the left.

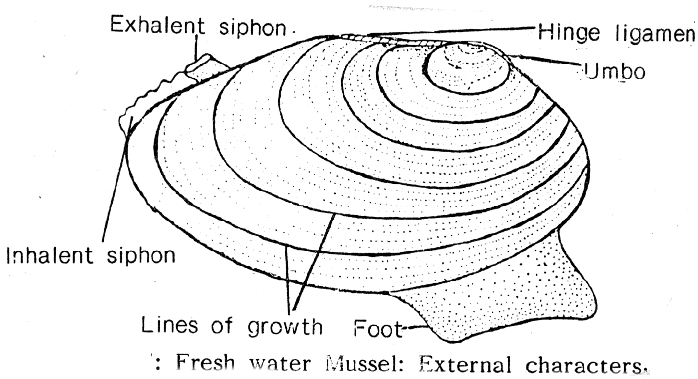

Fig.162 External structure Unio

7.2.4 External structure of Unio

Unio is commonly known as freshwater mussel. It lives in fresh water ponds. It leads burrowing mode of life. The body of unio (fresh water mussel) is enclosed in a hard shell. The shell is laterally compressed and roughly oval in shape. The anterior end is broader than the posterior end. The shell contains two similar halves called the valves. The two valves are

attached and articulated dorsally with each other by tough, elastic hinge ligaments. Each valve bears a dorsal protuberance towards the anterior end called umbo. It is the oldest and first formed part of the shell. The outer surface of each valve is marked by concentric lines of growth. The dorsal inner surface of each valve possesses, small sharp ridges called hinge teeth. The teeth of one valve fit into the corresponding sockets of the other to prevent lateral slipping.

Inner surface of each valve bears characteristic muscle impressionsor scars. Parallel to the free lower edge and a little away from it is a pallial line. At the anterior end of the pallial line is a large oval mark called anterior auductor impression. The small marks lie behind the anterior auductor impression. They are 1) anterior retractor impression and 2) anterior protractor impression. At the posterior end of the pallial line is a large oval mark called posterior auductor muscle impression. A small mark, the Posterior retractor impression lies close above the postuior auductor impressions.

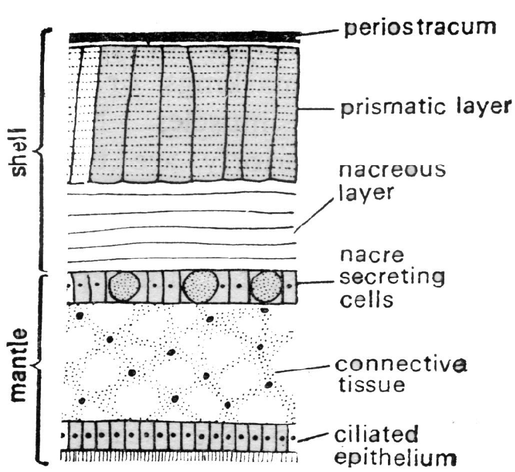

Fig.163 Structure of shell

7.2.5 Chenical compositin of the shell :

The shell is made up of Calcium carbonate (89-99%) and chitin like organic base called conchiolin.

Microscopic structure of the shell: The shell is composed of three layers 1) Periastracum 2) Ostracum or Prismastic layer and 3) Hypostracum or nacre.

1) Periastracum : It is the outer layer of shell. It is thin,

homogenous and pigmented. It is formed of conchiolin. It is protective in function. It is secreted from the edge of the mantle.

2) Ostracum or Prismatic layer: It is the middle layer of the shell. It is the thickest layer. It is composed of alternating layers of calcium carbonate and conchiolin. These two types of layers are arranged perpendicular (right angles) to the surface of the shell. It is secreted from the edge of the mantle.

3) Hypostracum or Nacreous or Mother of pearl: It is inner most layer of the shell. It is smooth, iridescent or lustrous. It is composed of alternating layers of calcium carbonate and conchiolin. These two types of layers are arranged parallel to athe surface of the shell. It is secreated by the whole outer surface of mantle.

7.2

	PILA		UNIO
1	It is univalved, consists of a single valve	1	It is bivalved, consists of two valves.
2	It is conical in shape	2	It is laterally compressed and oval shaped
3	The shell is spirally coiled around a central axis called columella	3	The shell is not coiled. The two shell valves are held together on the dorsal side by hinge teeth and hinge-ligaments
4	Each coil of the shell is called whorl. These are 3-4 in number	4	Whorls are absent.
5	The first formed region of the shell is called protoconch . It lies at the apex of the shell	5	The first formed region of the shell is umbo. It lies at the anterodorsal part of the shell
6	Shell mouth is present	6	Shell mouth is absent
7	Operculum is present covering the shell mouth	7	Opercullum is absent
8	Varices are present	8	Varices are absent

7.2.7 Mantle (or) Pallium

Definition : The visceral mass is covered by a thin, delicate glandular membrane called Mantle or pallium . It is a characteristic molluscan organ. Shell is secreted by the mantele. Periostracum and ostracum of the shell is secreted by the thick,free edge of the mantle.The hypostracum is secreted by the entire dorsal surface of the mantle.

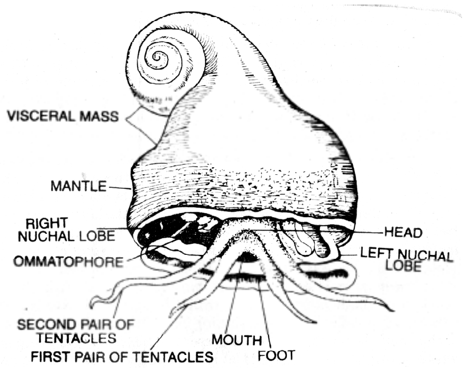

Fig.164 Pila soft parts

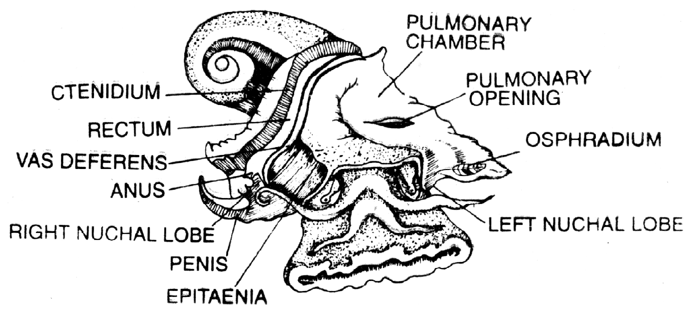

Fig.165 Pila Pallial complex

Histology of mantle: The mantle is a thin sheet of fibro- muscular tissue covered on either side by a single –layered epithelium. The outer epithelium contains numerous unicellular glands. The inner epithelium is ciliated.

Functions of mantle: 1) It protects the delicate internal organs. 2) It secretes the shell 3)It acts as an additional respiratory organ 4) It aids in setting up a water current through the mantle.

Mantle in Pila: The mantle covers the visceral mass a hood on the dorsal side. Anteriorly the mantle forms a thickned, pigmented cloak. The head is withdrawn under the mantle for protection. On either side of the head the mantle is produced into a highly Contractial and felshy processes called nuchal lobes or pseudepipoda. The pseudepipoda is longer and rolls into a tubular respiratory shipoon for air breathing.

Pallial complex: The space between the visceral mass and the mantle is called mantle cavity or Pallial cavity. This cavity is covered dorsally and laterally by the mantle fold ventally by the dorsal body wall. Many important organs lie in the mautle complex. Thesde are collevtively known as organs of pallial comoplex.. There organs include.

1) Epitaenia : The Epitaenia is a prominent ridge on the floor extending from the base of the right nuchal lobe to the posterior end of the mantle cavity. It divides the mantle cavity into two un-equal chanbers. The small, right one is called branchial chamber. The large, left chamber is called pulmonary chamber.

2) Pulmonary sac or lung : It is large bag like structure hanging from the floor of the pulmonary chamber. It opens into the pulmonary chamber by a large pulmonary aperture or pneumostome. The pulmonary sac helps in aerial respiration.

3) Osphradium: It is a small, oval, leaf like structue attached to the roof of the pulmonary chamber, just behind the base of the of the left nuchal lobe. It helps in testing the purity of water.

4) Ctenidium or gill : It is a long, lamellar organ hanging from the mantle at the extreme right side of the branchial chamber. It contains a series of thin plates or lamella. It is involved in aquatic respiration.

5) Rectum : It is a long tubular structure situated just on the left of the ctenidium (gill) in the branchial chamber. It opens into the mantle cavity through anus near the right nuchal lobe.

6) Genital duct : Vas deference or vagina lies on the left of the rectum. It opens close to the anus. In males a copulatory organ called penis is present near the male genilal aperature. It is a derivative of the edge of the mantle. At the base of the penis is present a glandular structure called hypo-branchial gland.

7) Kidney : It is a reddish coloured structure present at the posterior end of the epitaenia

Mantle in unio : Below the shell is present a thin, semi-transparent fold of skin called pallium or mantle. It consists of two lateral halves or mantle lobes. The mantle lobes are attached dorsally to the body and ventrally to the shell valves along the pallial line. At the posterior end the edges of the mantle lobes are fused in the middle to form two short tubes. The dorsal narrow tube is called exhalant siphon and wide lobe and has a fimbriated edge and it is known as inhalent siphon. Water enters into the mantle cavity throught the inhalant siphon.

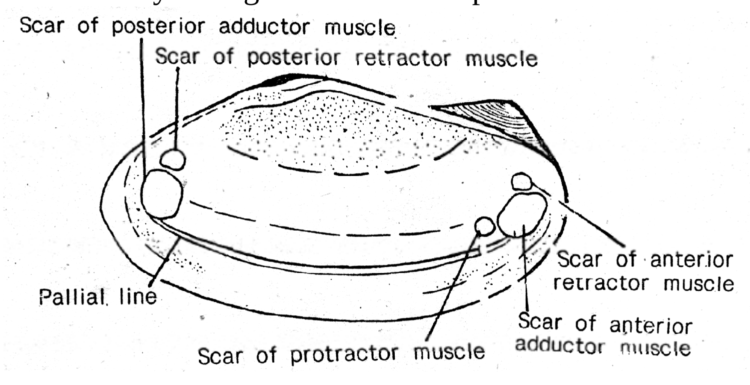

Fig.166 Unio inner view of shell valve

Mantle cavity : The space between the two mantle lobes is called mantle cavity or pallial cavity.

Pallial complex: The mantle cavity contains the visceral mass, gills and foot. These are collecftively called pallial compelx.

1) Visceral mass : It occupies the dorsal part of the mantle cavity. The visceral mass contains most of the organ systems – digestive system, circulatory system, excretory system and reproductive system

2) Etenidia (gills) : There are two ctenidia (gills) hanging in the mantle cavity, one on either side of the body. Each gill consists two rectangular plates – the inner and outer laminae

7.2.8 The foot :

The foot of the gestrepods is characteristically found along the whole length of the belly ventrally. There is no noundary between the head and the foot both of which lie outside the shell during movement.

The Pila has a large, highly extensile triangular foot with its pointed apex directed backwards. It's flat smooth ventral surface known as creeping sole and is provided with longitudival muscle fibres whose movements are coordinated by a nervous network. Foot is used for creeping. UNIO has a wedge shaped foot. Internally the foot contains the intstine. The digestive glands and the gonads. The foot is used for burrowing.

7.2.9 Summary :

Pila is commonly called apple snail. It has a soft unsegmented body covered by a mantle and shell. It is an asymmetrical animal with a spirally coiled shell. The body is divisable into three parts, namely head, foot and visceral mass. The head has two pairs tenterles and a pair of eyes. The visceral mass forms the main part of the body and is spirally coiled like the shell. It is covered by a fold of skin known as mantle or pallium. The foot is ventral and highly muscular and used for creeping.

UNIO commonly called as fresh water muswel. It has a bilaterally symmetrical soft body covered by the mantle and shell. The shell is formed of two pices and the foot is wedge shaped. Head is absent. Mantle is a fold of skin covering the soft body below the shell. It is formed of two halves called mantle lobes. Fresh water mussel is omnivorous and feeds by the fildter feeding method.

7.2.10 Key Terminology

Bysus : A group of thread-like structures present in some pelecypods and glochidium larva. They help in attachment.

Ctendium or gill : Ctenidia or gills are one of the respiratory organs of molluscs. Each ctenidum has a central axis from which arises one (monopectinate) or two (bipectinate) rows of filaments or lamellae

Crystaline style : It is a structure found in the lumen of intestine of fresh water mussel. It helps in the digestion of carbohydrates

Epitaenia : The ridge present on the floor of the mantle cavity of pila is called epitaenia. It separates the mantle cavity into branchial chamber and pulmonary chamber.

Keber's organ or Pericardial gland : It is an excretory organ found in fresh water mussel (pelecypods). It is present in front of the pericardium

Glochidum larva : It is the larval form of fresh water mussel. It lives as an ectoparasite on the gills of fresh water fishes.

Haemocyanin : It is a respiratory pigment present in the blood of molluscs and crustaceans. It contains copper.

Hetero cotylysed arm : In Cephalopods one of the arms (tentacles) is modified into a copulatory organ called heterocolysed arm. It helps in transferring the spermatophores into the female.

Mantle or Pallium : The thin fold of skin covering the body of the molluscs is called mantle. It secrutes the shell. It also takes part in respiration.

Nuchal lobe or Pseudopipodium : This is a tube-like structure is formed by the folding of the mantle. It is found in gartropods. It helps in drawing in water and air for respiration.

Odontophore : It is a ridge present in the floor of the buccal cavity, over which the ribbon – shaped radula moves to and fro

Organ of Bojanus : It is an excretory organ found in fresh water mussel (pelecypoda). It helps in draining the nitrogenous wastes from the pericardium to the exterior.

Ommatophores : These are the small stalk-like structures found in pila, one on each side of the head. Each ommatphore bears an eye at its tip.

Operculum : In gastropods the shell mouth is covered by a lid-like operculum. It is formed by the foot. The outer surface of operculum bears concentric lines of growth around a nucleus. The inner surface has a prominent elipitical area called boss. It is surrounded by shallow groove.

Ink gland : It is found in cephalopods. The ink squirted out forms a dark serene behind the animal and the animal escapes from the enemies.

Foot : It is a highly muscular organ present in moluscans. It lies on the central surface of the body. It is formed by the striated muscles. The shape of the foot is variable. In cephalopods, it is formed by the striated muscles. The shape of the foot is variable. In cephalopods it is modified into 8-10 arms and a simphon . the foot helps in creeping, sorrowing and swimming.

Torsion : In the early development of gastropods a peculiar phenomenon called torsion occurs. In this process the visceval mass grows unequally in such a way that the body rotates through 180^0. Due to torsion the shell becomes spirally coiled. As a result of torsion the bilateral symmetrical larva transforms into asymmetrical form.

Varices : The shells of molluss like Pila, Unio etc., bear growth lines on their outer surface. The thick lines are called Varices. These represent the period of inactivity during which the animal growth is stopped.

Veliger larva : It is the larval form of certain molluscs. It is a modified trochophore larva. It is a ciliated free swimming larva. It undergoes metamorphosis into an adult.

7.2.11 Model Questions:

1) Write an essay about eomparative study of external character of pila and unio
2) Write shosrt notes on i) Shell ii) Mantle iii) Compare the Shell of Pila and unio

7.2.11 Reference Books.

1) Mollusca – Kotpal (Phylum series)
2) Inverbrate Zoology – Jordan

Lesson 7.3
PEARL FORMATION

7.3.1 Objective : The purpose of this lesson to understand the pearl structure and formation , types and culture of pearls .

7.3.2 Introduction : The oldest record of suing pearls go back to the Chinese people. They are said to have used pearls as far as 3500 B.C. Royal families and Nobles of every country in ages have adorned the persons with pearls. Mollusca economically more important to man. They have been used for various purposes. Pearls are obtained from pearl oysters. They are most beautiful and valuable jewels. Though pearls are formed naturally in bivalved molluscs (oysters) now-a-days man is producing them in large numbers by artificial methods.

7.3.3 What is a Pearl : A Pearl is produced by mulluscs like oysters and clams. It consists of nacre or mother of pearl which is the inner layer of the molluscan shell. It is secreted by the mantle as means of protection against foreign body. A Pearl is formed by the deposition of nacreous substansce in concentric layers around a foreign body by the mantle.

7.3.4 Pearl formation : The pearl formation is an adaptation to protect against foreign materials. It occurs when a foreign material such as sand grain or parasite happens to enter in between the shell and mantle. The mantle epithelium immediately grows over the foreign material. The mantle epithelium starts secreting a layer of pearl material (nacre) to prevent irritation. More layers of nacre are gradually laid around this, and this produces a pearl. It takes about 3-7 years to form a pearl of commercial value.

Chemical Compostition of Pearl : The Pearl material (nacre) is formed of two substances- Calcium carbonate and Conchiolin ($C_{30}H_{42}N_{2O}O_{11}$). Calcium Carbonate is in the form of argonite or calcite. The chemical composition of the pearl is :

Calcium Carbonate	-	88 – 90%
Conchiolin (organic matter)	-	3.8 – 5%
Water	-	2 – 3%
Residue	-	0.1 – 0.8%

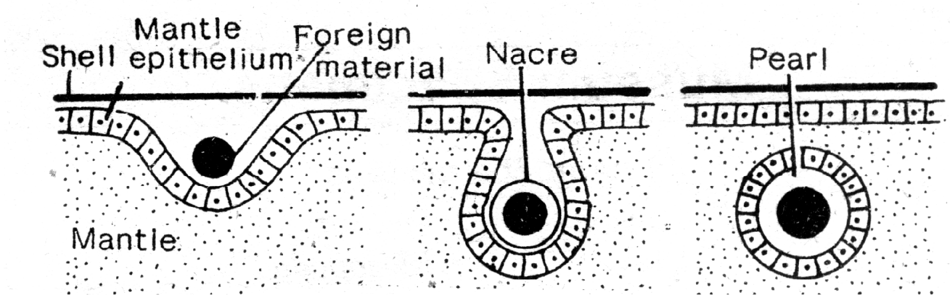

Fig.167 Culture fo pearls

7.3.5 Types of Pearls :

There are four main types of pearls.

1) Blister Pearls : When some foreign material (sand – grain, parasites) becomes lodged between the mantle and the shell, blister pearls are formed. Such pearls are attached to the shell. They are not spherical. Succeeding layers of nacre not formed on all sides.

2) Boroque pearls : These pearls are spherical in shape. They are formed inside the mantle epithelium succeeding layers of nacre are added on all sides.

3) Hemi pearls : These are formed near the margin of the mantle (mantle edge does not secrete nacre, it produces periostracum and prismatic layers of he shell). These pearls are brown or black in clour.

1) Seed Pearls : The small pearls are called seed pearls. Pearl producing animals : Pearls are produced by bivalved molluscs, Pinctada vulgaris and P.margaritifera produce superior quality of pearls. These are marine forms. These are commonly called pearl oysters. Unio margaritifera and Lamellidens marginalis are fresh water mussels. These produce inferior quality pearls. Pearl oysters are marine and live attached to rocks by byssal threads. The shell valves are unequal in size. The hinge-line is straight .

7.3.6 Culture of Pearls : Mr. Mikimoto of japan has discovered a method of stimulating the pearl oysters to form pearls by artificially introducing foreign particles between the mantle and the shell. The culture of pearls is a complex but sensitive process. It involves the following steps.

1) Collection of Oysters :The larvae of Pearl oysters are called spats. They are free swimming and found in shallow waters of the sea. Spats are collected from their natural resources by different methods. They are

   a) Semi cylindrical tiles

   b) bamboo poles with barnacles

   c) Shells of various molluscs

   d) Plastic nests

1. ii) The young oysters are collected from the bottom of the sea

   iii) In the laboratories the eggs of pearl oysters are fertilized and young ones (spats) are obtained. The spats are maintained in nursuries upto certain time,

2) Preparation of graft tissue: The piece of tissue which is inserted into the oyster for artificial pearl culture is called graft issue. The tissue is usually a piece of mantle that is cut off from another oyster. It should in the form of a square with 2x2mm size.

3) Preperation of nucleus: The nucleus is a foreign material which is insert in to the oyster. It should be in the form of a bead with a diameter of 2mm. Any small particle may function as nucleus to initiate pearl formation. Calcarious nucleus is the best (because the deposition of nacre was found to be more satisfactory on calcarious nucleus as compared to any other particle).

4) Implantation: The Pearl-Oyster's foot is exposed and a small incision is made on the foot. On this incision the graft tissue is placed. The nucleus is placed on the graft tissue. Then the oyster is released in the cage.

5) Rearing of pearl oysters: The operated Pearl oysters are placed in cages and are sus-pended in the sea from rafts. Rafts are rectangular wooden frames floating at water surface. They are made to float by empty oil drums or tins. The rafts are kept in place by anchors. Besides rafts other methods include – long lines rack culture, pole culture and bottom culture.

6) Harvesting : Pearls attain maximum size in 3 years After that period the oysters are removed from cages and the pearl is taken out.

7) Cleaning Pearls : After taking out the pearls from the oyster they are washed properly, cleaned with soap solution. It should be advised that pearls should not be rubbed much.

7.3.7 Problems of Pearl industry : 1) Boring sponges, star fishes, eels and Octopuses destroy the pearl oysters. 2) Temperature fluctuations, low salinity, turbidity hammer the pearl industry by affecting the proper rearing of the pearl oysters. In India we have units for artificial pearl production in Mandapam of Tamil Nadu.

7.3.8 Model Questions

a) Write note on pearl formation

b) Describe the types of pearls

7.3.9 Reference Books

A text book of invertebrate – N.C. Nair Dr.S. Leelavathy

Invertibrate Zoology – P.S. Dhani, J.K Dhani

Lesson 7.4
TORSION IN GASTROPODS

7.4.1 Objective :

The purpose of this lesson is to understand the process, effect of torsion in gastropods and advantages of Torsion.

7.4.2 Introduction :

In most of the gastropods, the larval stages are bilaterally symmetrical but, the adult stages are asymmetrical. Asymmetry in adult gastropods is due to a peculiar phenomenon called torsion.

7.4.3 Definition :

Rotation of the visceral organs to an angle of 180^0 in an anti-clock wise direction is called torsion. It occurs in the larval stages of gastropods.

7.4.4 Process of Torsion :

Asymmetrical character of adult gastropods is produced by a change in the original position of the organs above and behind the neck. In the larva the mantle cavity and the associated parts [anus, ctenidia and exeretory pore] are posterior, the ctenidia are behind the heart, the alimentary canal is strainght and the nervous system is symmetrical. During development, the mentle cavity with its organs shift forwards to a new position near the head.

Torsion occurs in two stages 1) ventral flexure 2) lateral torsion

1) Ventral flexure : Flexure of the ventral part of the body takes place about the transverse axis at right angle to the main anterio-posterior axis of the body. As a consequence of ventral fluxure, the visceral mass, and shell which were originally saucer shaped becomes a pointed cone. During this process the visceral mass assumes spiral coiling.

2) Lateral torsion : The ventral flexure is soon followed by lateral torsion. This is brought about by un-equal growth on two sides. The organs present on the left side grow normally and of the right side growth is retarded. Therefore the organs from left side shifts towards right. The mantle cavity and pallial complex are shifted towards the right side and becomes anterior in position. Thus the parts above the neck un-dergo an anti-clock wise rotation through about 180^0 around a vertical axis passing in a dorso-ventral direction.

Torsion may be rapid or gradual process or both. It is rapid and completed in just 3 minutes in acmaea (marine limpet) and takes 10 days in Pomatias. In Patella and Haliotis torsion occurs in two phases. The first phase is rapid and the second phase is gradual. Rapid torsion is brought about by the contraction of the larval retractor muscles. They originate from the right side of the larval shell and pass over the body to get inserted in the left side of the head foot complex. Gradual torsion occurs by differential growth process.

7.4.5 Effects of torsion :

1. Before torsion the mantle cavity is posterior in position, but after torsion the mantle cavity comes to face forwards and opens above the head.
2. Before torsion the auricles lie behind the ventricle, but after torsion the ventricles lie anterior to the ventricle
3. The alimentary canal which was straight from mouth to anus is thrown into a loop.
4. Before torsion the organs forming pallial complex lie at the posterior end, but after torsion they come to lie in front of the heart.
5. The organs which are originally on the right side come to lie on the left side and vice-versa.
6. Nervous system becomes twisted into a figure of 'S' and most of the ganglia come to lie in the anterior part of the body. Such a type of nervous system (twisted 'S' shaped) is called Strueptorecury or Chiastoneury.

7.4.6 Theories of torsion :

There are several theories to explain the cause of torsion. They are

1) Banton (1919) proposed that torsion occurs in the embryo due to antagonism between the growth of foot and that of shell. In gastropods the shell is univalved, which opens on one side. The shell encloses all the visceral organs of the body. The head and the gills have to protrude out of the opening of the shell. This requirement shifted the ctenidia and mantle cavity to come towards head end. The extensive development of the poor results in shifting the mantle cavity and anus towards the anterior end of the body.

2) Yarstang (1928) Proposed that torsion first occurred as a result of mutation. It is advantageous to the pelagic larva but of little direct use to the adult. Before torsion, the free swimming larva fall an

easy victium to its predator, because the posterior mantle cavity could receive the delicate head and velum only after the foot was already inside. After torsion the mantle cavity becomes anterior in position, so that the head and velum could withdraw first followed by the foot. There are several objections to this theory.

3) Anderson (1925) Suggested that the twisting of visceral mass and the anterior shifting of the mantle cavity is due to twisting of shell and visceral mass. In molluscs the digestive gland (lever) is very in size, it play an important role in digestion and absorption of food. The growth of this gland caused a projection in visceral hump. As a result one side of the visceral hump grows faster than the other side. This upsets the equilibrium of animal due to the unequal growth of organs. For keeping the balance the organs are therefore, twisted in such away that the balance does not lost due to differential growth of visceral mass.

7.4.7 Advantages of torsion.: Torsion provides the following advantages to the animal

1) Respiration : Before torsion the ctenidia (gills) and anus are situated posteriorly due to release of faecalmatter from anus, the water becomes turbid and impure. This impure water is inhaled into the mantle cavity for respiration. After torsion, the gills are brought forward, hence by torsion, the animal gets pure water for respiration.
2) Locomotion : Before torsion, the respiratory current and water current oppose each other. This creates difficulty in locomotion after torsion gills are placed forwards and the respiratory water is taken from a head. So the respiratory current coincides with water current. This does not produce any hinderance to locomotion.
3) Protection. : Before torsion the foot is withdrawn into the shell first followed by the head and ctinidia. But after torsion the head and ctenidia are withdrawn into the shell first, followed by the foot. This gives potection from enemies.

7.4.8 Disadvantages of torsion :

1) Sanitation :Torsion brings the anus close to the mouth. The faecal matter released from the anus makes the water impure. The impure water is drawn into the mantle cavity for respiration. Therefore torsion caused sanitary problems.

Detorsion : Changes ocuring in torsion are reversible and these changes are known as detorsion. The anus and organs of pallial complex are carried back to its original position. (i.e to the posterior end) due to detorsion. The nervous system is not twisted into the figure of ‘S’ because of detorsion. Such a nervous system is called.

Cuthynery Thus the lost symmetry reappears. Therefore adults bilateral symmetry. E.g Aplysia

7.4.10 Model Questions

Explain the torsion in gastropoda

7.4.11 Reference books

Mollusca – Kotpal

Inverbrate Zoology – Jordan.

Lesson 8.1
ECHINODERMATA GENERAL CHARACTERS AND CLASSIFICATION

CONTENTS

8.1.0 OBJECTIVES

To present diagnostic characters, an outline classification of Phylum Echinodermata upto the level of orders with important characters and examples of each order. Pentamerous radial symmetry, water vascular system and enterocoelomate nature of coelome of this exclusively marine group of invertebrates can be readily understood after going through this unit.

8.1.1 INTRODUCTION

Echinoderms (Gk Echinos = spiny, derma = skin) are **spiny skinned** animals mostly commonly **pentagonal** with five arms. They are exclusively marine and bottom dwellers and very few are found in brackish waters. The endoskeleton is in the form of spicules and ossicles embedded in the skin and is made up of calcium carbonate. They are **triploblastic** animals with enterocoelus coelom. This group has unique **water-vascular** system. Distinct head, brain and excretory organs are absent. They are very ancient animals, having thrived in the **cambrian** period. About 5000 living and over 13000 extinct species are recorded. The term echinodermata was coined by **Jacob Klein** in 1734. It was established as a distinct group of metazoa by Leuckart in 1847.

8.1.2 GENERAL CHARACTERS

Echinodermata possess many unusual characters which are not met with in any other phylum.

1) They are found in deep sea water in almost all seas of the world. They are sometime found in brackish waters (*Synapta similis*).

2) They have an unsegmented body with various shapes. **Star** like, **disc** like, **cylindrical** (or) flower like.

3) The symmetry is **radial** in the adults and **bilateral** in the larva. The radial symmetry of the adult is usually pentamerous.

4) Body develops from three germ layers. The echinoderms are therefore, triploblastic.

5) Body lacks head and anterior end. Body has two distinct surfaces, an **oral surface** with mouth and an **aboral surface** with five radial areas, the ambulacral areas, with tube feet and five inter radial areas, the inter **ambulacral areas**.

6) Epidermis is single layered and ciliated. Endo skeleton is mesodermal, thick and, consists of numerous fixed or movable calcareous plates or ossicles which usually occur in a definite pattern and often have spines, hence Echinodermata. Muscles are smooth and lie subjacent to the dermis.

7) Organs of the body are arranged in definite system, so that the echinoderms are metazoa with organ system level of organisation.

8) Coelome is well developed, spacious, enterocoelus lined by ciliated peritoneum and containing celomic fluid with free amoebocytes. A part of the larval coelome is modified into a unique water filled ambulacral system with tube feet. This system helps in locomotion.

9) Alimentary canal is complete and simple running from mouth to anus. In some forms it is incomplete. Food is captured by tube feet.

10) Respiration takes place by minute gills called dermal branchiae (or) papillae that protrude from the coelome and also by tube feet. Some forms have cloacal respiratory trees.

11) Circulatory system is greatly reduced and is open type. It is known as haemal system. Heart is absent.

12) There are no definite excretory organs. Nitrogenous wastes diffuses out via papillae.

13) Nervous system is simple with out brain. It consists of cirum oral nerve ring surrounding mouth and radial nerve cords.

14) Special sense organs are inadequately developed. They comprise simple tactile tentacles, pigmented eye spots and statocysts.

15) Sexes are separate. Males and females are alike externally. Fertilization is external in the sea water. Development is indirect which includes microscopic, ciliated, bilaterally symmetrical, transparent larva that under goes metamorphosis to change into an adult.

16) Some forms reproduce asexually by self division (autotomy) and regeneration.

They are mostly free living but slow moving. Some are pelageic and a few sedentary Parasitic and colonial forms are absent.

UNIQUE FEATURES

The unique features of echinoderms are:-

1) Bilateral symmetry in the larvae and radial symmetry in the adults.
2) Demarcation of the body surface into ambulacral and inter ambulacral areas.
3) Presence of an endoskeleton of calcareous plates usually with spines.
4) Modifications of part of coclome into water filled ambulacral system for locomotion.
5) Greatly reduced open circulatory system.

CLASSIFICATION OF PHYLUM ECHINODERMATA

Phylum Echinodermata is divided into two sub phyla:

1) **ELEUTHEROZOA**, and 2) **PELMATOZOA**

Sub Phylum : 1) Eleutherozoa

The Eleutherozoa are free living echinoderms devoid of stalk. The mouth lies on the oral surface and anus lies on the aboral surface. The ambulacral system have the form of grooves radiating from the mouth and contains two rows of tube feet. Tube feet usually possess terminal suckers and are used for locomotion.

Sub Phylum Eleutherozoa is divided into four classes:

a) ASTEROIDEA
b) OPHIUROIDEA
c) ECHINOIDEA, and
d) HOLOTHUROIDEA

CLASS 1 : ASTEROIDEA

a) The body is flattened, star shaped and is differentiated into a central disc and arms.
b) The arms are usually five in number but many vary upto 50.
c) Endoskeleton consists of separate ossicles spines are short.
d) There are distinct oral and aboral surfaces.
e) Oral surface bears mouth and five narrow open ambulacral grooves. Aboral surface carries the anus and madreporite.
f) Tube feet occur in two or four rows in each ambulaccral grooves and used as locomotory, respiratory, tactile and adhesive organs.
g) Pedicillaria are small and contain two jaws.
h) Viscera extends into the arms. Stomach is eversible.
i) Larva is Bipinnaria (or) Brachiolaria.

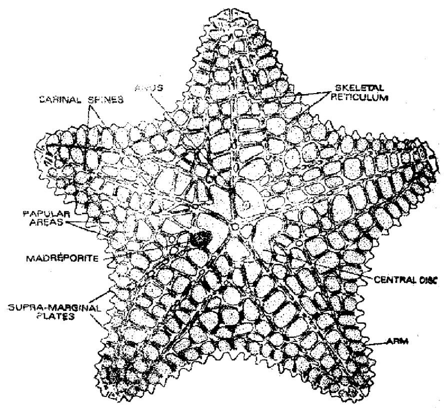

Fig.169 Oreaster

The class Asterozoa is divided into 3 orders:

a) Phanerogonia
b) Spinulosa
c) Forcipulata.

Order a) : Phanerogonia

a) Arms have two rows of large prominent marginal plates.
b) Pedicellaria are sessile.

E.g.: ***Oreaster, Astropecten***

Order b) : Spinulosa

a) Arms have small, inconspicuous marginal plates.
b) Oral and aboral surfaces often merge.
c) Pedicellaria are usually absent.
d) Aboral surface is beset with low spines.

E.g.: ***Asterina, Echinaster*** and ***Solaster***.

Order c) : Forcipulata

a) Arms have small, in conspicuous marginal plates.
b) Oral and aboral surfaces often merge.
c) Pedicellaria are stalked and have 2 calcareous plates.
E.g.: ***Asterias***.

Class 2 : OPHIUROIDEA

a) Body is flattened and star shaped. It is differentiated into a central disc and arms.
b) Arms are usually 5 in number. They are long slender, cylindrical, pointed and highly flexible. In some they are branched.
c) Endo skeleton consists of separate ossicles. Spines are short.
d) Oral and aboral surfaces are distinct. Oral surface has mouth and madreporite. Anus is absent. Egestion takes place through mouth.
e) There are no ambulalacral grooves. Tube feet occur in two rows, lack ampullae and suckers, and function as tactile and respiratory organs. They also serve to pass the food to the mouth.
f) Locomotion is effected by flexions and extensions of the arms.
g) Pedicellariae are absent.
h) Viscera do not extend into the arms. Stomach is not eversible.
i) At the base of each arm on the oral surface, genital bursae are present which function as organs of respiration and contain genital apertures.
j) The larva is ophiopluteus.

The class Ophiuroidea is divided into 2 orders.

1) **Ophiurae** 2) **Eurylae**

Order 1 : Ophiurae

a) Arms are unbranched and cannot twist or turn to mouth.
b) Disc and arms are usually covered with plates.

E.g.: ***Ophiothrix, Ophioderma***.

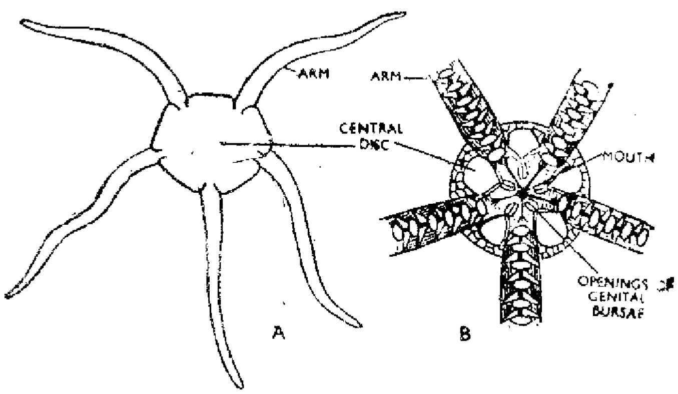

Fig.170 Ophiothrix

Order 2 : Eurylae

a) Arms are usually branched and can twist and turn to grip objects.
b) Disc and arms are covered with thick skin.
E.g.: ***Gorganocephalus, Astrophyton***.

Class 3 : ECHINOIDEA

a) Body is globular, or heart shaped or disc like.
b) Arms are absent.
c) Endoskeleton forms a shell (or) carona of immovable calcareous ossicles. Spines are long and movable and are used in locomotion.
d) Oral and aboral surfaces are distinct. Mouth is centrally placed on the oral surface, while anus is found at the aboral surface.
e) There are no ambulacral grooves but surface is differentiated into ambulacral and inter ambulacral zones.
f) Tube feet have ampullae and suckers and are used as locomotory, respiratory and tactile organs.
g) Pedicillaria are stalked and 3 - jawed.
h) Mouth has 5 - jawed masticatory structure called 'Aristotle's Lantern'.
i) Larva is echinopluteus

Class Echinoidea includes two sub classes : 1) **Regularia** 2) **Irregularia**

Sub-class : Regularia

Corona is globular. Mouth and anus are polar i.e., in the centre of oral and aboral surfaces. Aristotle's lantern is present. It includes order camarodonta.

Order : Camarodonta Corona is rigid.

E.g. Echinus.

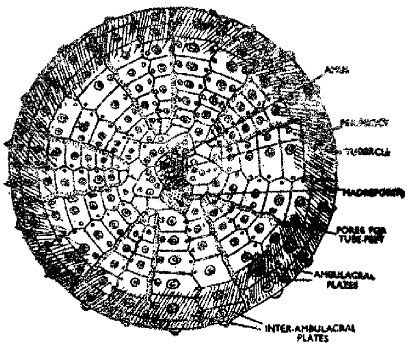

Fig.171 Echinus

Sub-class : Irregularia

Corona is flat. Mouth is central or excentric. Anus is marginal on oral (or) aboral surface Aristotle's lantern may be present or absent. It includes 2 orders :

1) **Clypeasteroidea** 2) **Spatangoida**

Order 1 : Clypeasteroidea

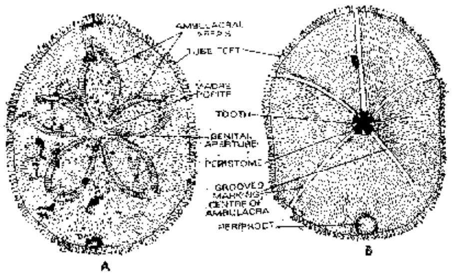

Fig.172 Clypeaster

Corona is circular (or) oval. Mouth is central.
Anus is excentric.
Aristotle's lantern is present.
E.g.: ***Clypeaster*** and ***Echinonarochinus***.

Order 2 : Spatangoida

Corona is oval (or) heart-shaped. Mouth is sometimes excentric. Anus is always excentric Aristotle's lantern is absent.

Eg: ***Echinocardium***.

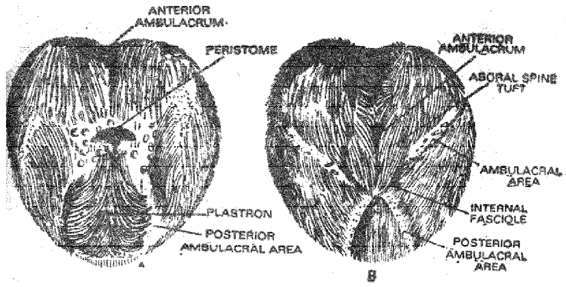

Fig.173 Echinocardium

Class 4 : Holothuroidea

1. Body is elongated, cylindrical like a cucumber.
2. There are no arms.
3. Endo skeleton is reduced to microscopic spicules. Spines are absent.
4. Body wall is soft (or) leathery.
5. Oral and aboral ends are distinct.
6. Oral end is anterior and has the mouth surrounded by a ring of retractile, some times branched tentacles. Tentacles are modified tube feet.
7. Aboral end is posterior and has anus.
8. Ambulacral grooves are absent. Body surface is however differentiated into ambulacral and inter ambulacral areas.
9. Tubefeet occur in two rows in ambulacral zone, pedicellariae are absent.
10. Intestine is coiled. Gonads discharge into cloaca which also contains one (or) two respiratory trees.
11. The larva is auricularia.

Class Holothuroidea is divided 5 orders:

1) Aspidochirota 2) Dendrochirota 3) Elasipoda 4) Malpadonia and 5) Apoda. Out of these five, first and second orders are more common.

Order 1 : Aspidochirota

a) Oral tentacles are peltate (or) leaf like, usually 20 in number
b) A pair of well developed respiratory trees are present.

Eg: ***Holothuria***.

Order 2 : Dendrochirota

a) Oral tentacles are branched like trees.
b) Respiratory trees are present.

e.g.: ***Cucumaria, Thyone***

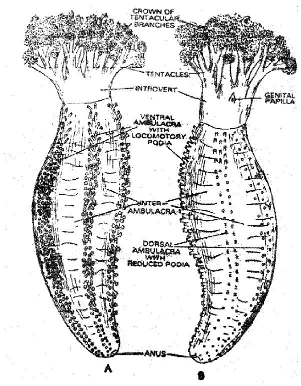

Fig.174 Cucumaria

Order 3 : Elasipoda

Respiratory tree is absent.
e.g. ***Deima, Benthodytes***.

Order 4. Molpadonia

Tube feet are absent. Posterior end tail like
e.g. ***Malpodia, Caudina***

Order 5. Apoda.

Body is worm like. Tube feet and respiratory trees absent
e.g. ***Synapta, Chiridota.***

Sub Phylum 2: PELMATOZOA

1. Pelmatozoa are attached by aboral surface or by aboral calcareous stalk in the early part of life.
2. Mouth and anus also lie on oral surface.
3. Ambulacral grooves are open narrow and ciliated and function as food grooves, conveying food towards the mouth.
4. Arms are branched and bears numerous pinnules.
5. Tube feet are short and lack both ampullae and suckers, they function only as respiratory and tactile organs.
6. Spines, madreporite and pedicillaria are absent.

Sub-Phylum pelmatazoa includes single living class namely *Crinoidea.*

Class : CRINOIDEA

a) Body is enclosed in a cup like theca.
b) Viscera extends into arms.
c) Food grooves, continue on the arms and their branches.

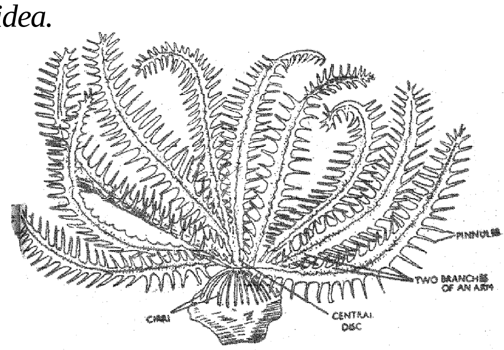

Fig.175 Antedon

It includes single living order viz., Articulata.

Order : Articulata

Calyx incorporates the lower arm ossicles. Mouth and ambulacral grooves are exposed (open).

Eg: ***Antedon*** (sea lily), ***Metacrinus***.

8.1.4 SUMMARY

Echinoderms are a group of exclusively marine, spinyskinned, penta radially symmetrical animals with an endoskeleton and a water-vascular system. This phylum forms the highly advanced group among invertebrates. The common examples of this group are star-fishes, sea-urchins, sea-cucumbers etc. Phylum Echinodermata is divided into two sub-phyla, namely Eleutherozoa and Pelmatozoa. They are divided into five classes

8.1.5 KEY TERMINOLOGY

Abductor muscle : A muscle which pulls a part away from the main axis of the body.

Abductor muscle : A muscle which pulls a part towards the main axis of the body.

Amoebocytes : Cells with amoeboid properties, i.e., monug and feeding with the help of psedopodia.

Benthic : Animals that inhabit the bottom of the sea.

Brakish : Slightly salty.

Carnivarous : Flesh eating

Enterocoelous : Coelom develops from embryonic archenteron

Extra cellular : Occurring outside the cell

Indirect development : A development which includes larval stage.

Metamorphosis : A rapid and complete transformation from larval to an adult form.

Olfactory : Connected with sense of smell.

Peduncle : A short stalk bearing an organ

Sexual dimorphism : A state in which males and females can be distinguished externally.

Stato cyst : An organ of balance

Tactile : Connected with sense of touch.

8.1.6 MODEL QUESTIONS

Essay type:

1. Enumerate the general characters of the Phylum Echinodermata.
2. Classify the phylum Echinodermata upto order with examples.

Short Notes:

1) Holothuroidea
2) Ecinoidea
3) Crinoidea
4) Asteroidea

8.1.7 REFERENCE BOOKS

1. **Invertebrate Zoology** by P.S. Dhani & J.K. Dhani.
2. **Echinodermata** by R.L. Kotpal.
3. **Invertebrate Zoology** by E.L. Jordan & P.S. Verma.

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Lesson 8.2
ASTERIAS (STAR FISH)

CONTENTS

8.2.1 OBJECTIVE

This unit describes in detail the Structure, Body wall, Water vascular system, Digestive system, Perihaemal and haemal systems, Respiratory, Excretary, Nervous and Reproductive systems.

8.2.2 INTRODUCTION

Asterias is the most common and widely distributed echinoderm. It is commonly known a star fish (or) sea-star because of its star shaped body.

Habitat: It is commonly found at the bottom of the seas preferring rocky areas. The bottom dwelling animals are called benthic animals.

Habits: The starfish is carnivorous and nocturnal. Inspite of having a hard integument it can bend and twist in variety of ways. It possesses great power autotomy and regeneration.

Classification:
Phylum: Echinodermata
Sub-Phylum: Elutherozoa
Class: Asteroidea
Order: Forcipulata
Genus: Asterias
Species: rubens

8.2.3 EXTERNAL CHARACTERS

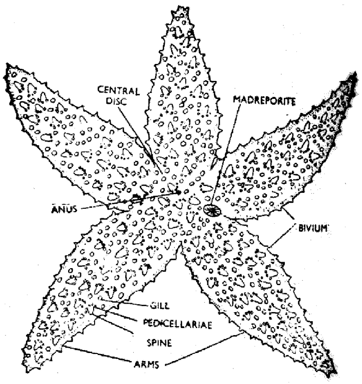

Fig.176 Asterias aboral view

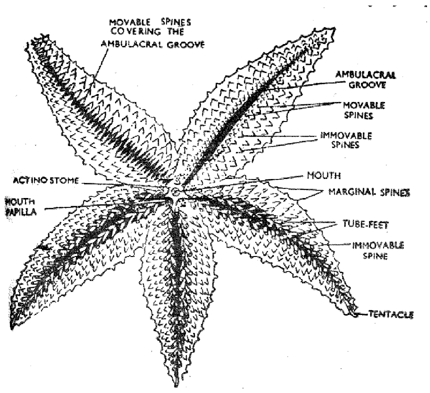

Fig.177 Asterias oral view

The external characters of Star fish can be studied by observing oral and aboral surfaces.

Oral surface: It is the flat lower surface facing the substratum. It is also known as actinal surface. The following structures can be observed on the oral surface.

Mouth: Mouth is a circular aperture present at the centre of the oral surface of the central disc. It is also known as actinosome. Mouth is surrounded by a soft membrane, the peristonimal membrane (or) peristome.

Ambulacral grooves: These are five narrow channels that raidate out from the angles of the actinosome, extending upto the tip of each arm. Each groove is provided with four rows of tube feet.

Tube feet: These are soft, extensive, tubular structures arranged in four rows in each ambulacral groove. Each tube feet ends in a sucker which provide firm attachment to the surface it is applied. They mainly act as organs of locomotion and capturing food. They also help in respiration and attachment to the substratum. They are sensory also.

Spines: They are short, stout projections from the calcareous plates, the ossicles, embedded in the body wall and covered by epidermis. They project both on the oral and aboral surface. On the oral surface they show definite arrangement. Two (or) three rows of movable spines on either side of each ambulacral groove. These are called ambulacral spines.

Aboral surface: Following structures are found on aboral surface.

Dermal Branchia (or) Papulae: These are very samll, soft hollow filiform processes protruding through minute pores in the integument between the ossicles on the aboral surface. They can be completely retracted into the body. They serve as respiratory and excretory organs.

Pedicillariae: Pedicillariae occur between spines on the oral as well as aboral surfaces. They are pincer like bodies. Each consists of a flexible stalk and three calcerous plates; a basillar plate and two movable jaws attached to basillar plate. The jaws can be opened and closed by abductor and adductor muscles respectively. They remove debris settling on the body, they also protect delicate dermal papallae.

Madreporite: It is a small flat slightly projected and sieve like porous plate on the aboral surface close to the base of two arms. The arms having madreporite between their bases are collectively called bivium and the other three as the trivium.

Anus: It is a small aperture present in the middle of the aboral surface.

8.2.4 BODY WALL

Structure: The body wall of Asterias consists of four tissues which from outside are – epidermis, dermis muscular coat and coelomic epithelium.

Epidermis: Epidermis is composed of ciliated columnar epithelium. It secretes outside itself a thin layer of cuticle. Scattered in the epidermis are spindle shaped neuro-sensory cells and club-shaped gland cells. Processes of neuro sensory cells pass into nerve fibres and nerve cells beneath the epidermis. Gland cells secrete mucous which forms a protective layer.

Dermis: Dermis is formed of fibrous connective tissue developed from mesoderm. It is the thickest layer of the body wall and has two regions. Outer and inner. Outer region secretes calcareous plates the ossicles which forms the endoskeleton. The inner region contains a number of spaces, the perihaemal spaces.

Muscular coat: It consists of smooth muscle fibres. It is differential into an outer circular muscular layer and inner longitudinal muscle layer which help in bending of arms.

Coelomic epithelium: Coelomic epithelium consists of cuboidal cilitated epithelium. It is also called Perietal Peritonium.

Functions: The body wall protects the soft delicate internal organs from injury. Endoskeleton produced by body wall gives support and strength. The peritonium secretes coelomic fluid.

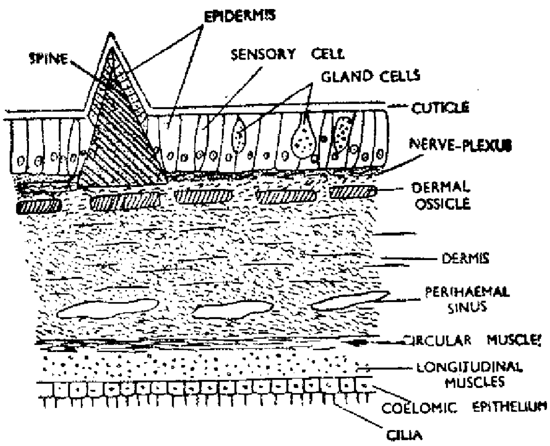

Fig.178 V.S of Body wall

8.2.5 ENDOSKELETON

Endoskeleton is made up of calcareous ossicles. It gives rigidity to the body. The ossicles are united by connective tissue and muscle fibres. This provides flexibility to the body. Two rows of ambulae ossicles are present on the sides of ambulacral grooves called ambulacral ossicles.

8.2.6 COELOM AND COELOMIC FLUID

Asterias has a spacious perivisceal cavity in the central disc and the arms. It is a true coelom and is lined by coelomic epithelium (or) peritonium. The coelomic epithelium covering the viscera is called the visceral peritonium and that living the body wall is called parietal peritonium.

The coelom is filled with colourless coelomic fluid and contains small amounts of proteins and nutrients and a large number of amoebocytes. It bathes the tissues of the body and performs the functions of circulatory system.

8.2.7 DIGESTIVE SYSTEM

Digestive system consists of an alimentary canal and digestive glands.

Alimentary canal: The alimentary canal is complete. It extends vertically along the oro-aboral axis in the central disc and is therefore very short. It consists of the following parts.

a) Mouth: Mouth is present in the middle of the central disc on the oral side. It is surrounded by spincter muscles. Mouth leads into oesophagus.

b) Oesophagus: The oesophagus is a very short vertical tube. It opens aborally into the stomach.

c) Stomach: The stomach is the largest part of the alimentary canal. It is divided by a constriction into the distinct parts – lower cardiac stomach and upper pyloric stomach. Cardiac stomach is large sac occupying the central disc.

The pyloric stomach is smaller than cardiac stomach. It opens above into the intestine. From the pyloric part a tube passes into each arm called pyloric caeca.

d) Intestine: The intestine is a short narrow tube that runs straight upwards to open out at the anus. Intestine gives of a pair of small branches, the intestinal caeca. They secrete a brownish substance probably excretory in nature.

e) Anus: The anus is a very small opening on the aboral surface.

Digestive glands: The digestive glands of Asterias are five pair of long pylaric caeca. The pyloric caeca are lined by ciliated columnar epithelium having glandular and storage cells here and there. The glandular cells secrete digestive juices like proteases, amylases and lipases that digests proteins, starches and fats respectively. The storage cells absorb the digested food and store in chiefly as lipids.

Food: Star fish is carnivorous. It takes worms, crustaceans snails, bivalves, small star fishes and fishes.

Ingestion and digestion: Small prey may be taken into the stomach and digested, but usually digestion is performed outside the body and the products of digestion swallowed. Digestion is thus extracellular in star fish. Some intra cellular digestion takes place in the pyloric caeca.

Absorption and Distribution: The food is chiefly absorbed in the pyloric caeca. Distribution of food to various parts of the body takes place through the coelomic fluid.

Egestion: Undigested food is largely thrown out through the mouth only. Very little is sent out through anus.

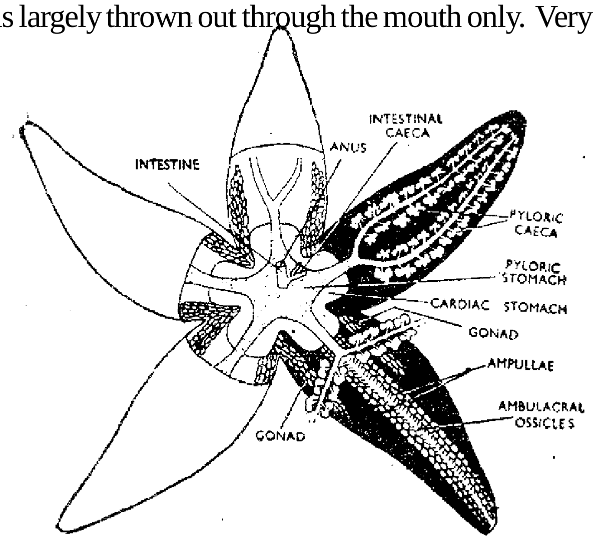

Fig.179 Anatomy of Asteries

8.2.8 WATER VASCULAR SYSTEM (or) AMBULACRAL SYSTEM

Water vascular system is a unique feature of echinoderms. It is derived from the coelom and gets separated during the development of the animal. It consists of the following parts.

a) Madreporite: It is situated on the aboral surface between bivium. It is hard, circular and calcareous plate. Water enters through madreporite into the water vascular system.

Madreporite is sieve like, bearing many pores each leading into a pore canal. The pore canals unite to form collecting canal, which open into small sac, the ampulla of madreporite, lying just beneath the madreporite.

b) Stone canal: The ampulla opens into the stone canal. It is 'S' shaped and extends downwards supported by series of calcareous rings hence stone canal. On one side its wall projects into its cavity that bifurcates into two lamellae rolled spinally. At its oral end, the madreporite canal (or) stone canal opens into ambulacral ring vessel (or) circular water vessel.

Ambulacral ring canal: The ambulacral ring vesel runs around the oesophagus.

Tiedman's bodies: On the inner side of the ring vessel there are nine small vesicles, the racemose glands (or) tiedman's bodies. Their function is not exactly known but they are supposed to produce phagocytic coelomocytes.

Radial canals: The ring vessel gives off five slender channels called the radial ambulacral vessels, that extend upto the tip of the arm and terminate in the terminal tentacles.

Lateral canals (or) Podial canals: During its course each radial ambulacral vessel gives off on either side a series of short tubes, the podial canals that open into the tube feet. The opening of the podial canal into the tube foot is provided with a valve that prevents the backward flow of fluids.

Tube feet: There are four rows of tube-feet in each ambulacral groove. A tube foot consists of an upper sac like ampulla, middle tubular podium and a lower sucker. The tube feet have strong longitudinal muscles.

The various parts of the ambulacral system have a muscular wall lined internally by ciliated epithelium, the beating of cilia help in pushing the water current forward.

Course of water current: The whole system is filled with a watery fluid which is practically identical with sea water. Water enters through the pores of madreporite and circulates through the system by the beating of cilia that lines the entire system.

The ambulacral system chiefly helps in locomotion and attachment to the substratum. It also plays an important role in respiration.

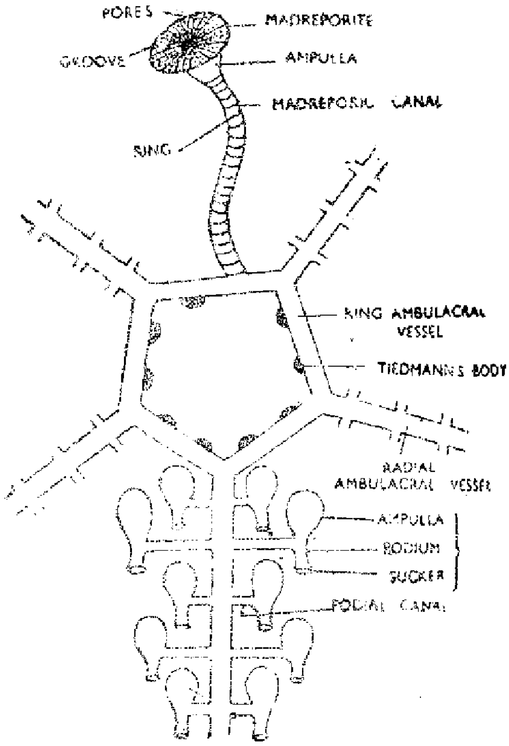

Fig.180 Water vascular system

8.2.9 PERIHAEMAL SYSTEM

Perihaemal system like the ambulacral system is derived from the coelom. It consists of an axial sinus, an aboral ring sinus, oral ring sinus, perihaemal sinus in the body wall.

1.Axial sinus: It is a wide tube surrounding the stone canal and the axial gland. At the same end, it opens into the aboral ring sinus.

2.Aboral ring sinus: It lies around the intestine just beneath central disc. It gives off ten genital branches each extends towards a gonad which it surrounds by enlarging into a genital sinus.

3.Oral ring sinus: At the oral end, the axial sinus opens into the oral ring sinus which runs round the oesophagus. From the outer part of the oral ring sinus arise five radial hyponeural sinuses which extends into each arm between the radial nerve and the ambulacral vessel.

4.Perihaemal sinus: These are small spaces in this dermis of the body wall.

The perihaemal system like the ambulacral system is lined by cuboidal ciliated epithelium.

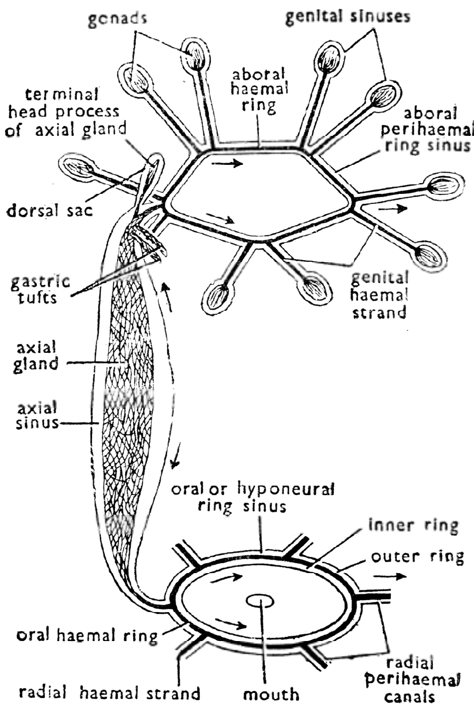

Fig 181 *Asterias.* Diagrammatic representation of haemal and perihaemal systems.

8.2.10 HAEMAL (OR) CIRCULATORY SYSTEM

The circulatory system of Asterias is of open type (or) lacunar type. It is enclosed in the coelomic sinuses forming the perihaemal system. It consists of an axial gland, an aboral haemal ring and an oral haemal ring.

1.Axial gland: The axial gland also called the heart and brown gland form the main part of the haemal system. It is nearly vertical organ enclosed in the axial sinus and surrounds the stone canal. The axial gland contains fluid filled with coelomocytes. The coelomocytes contain brown pigment, hence the axial gland is also known as brown gland.

2.Aboral haemal ring: At its aboral end, the axial gland communicates with stone canal and joins, aboral haemal ring present in the aboral ring sinus. It sends five pairs of haemal branches to the gonads.

3.Oral haemal ring: At its oral end, the axial gland tapers and joins the oral haemal ring. the oral haemal ring divides the oral ring sinus of the perihaemal system into outer and inner parts. From the oral haemal ring arise five radial haemal branches which send short branches to the tube feet.

The head process of the axial gland is contractile and causes circulation of the fluid and coelomocytes in the haemal system. The haemal system probably serves to distribute the nutrients to certain parts like tube feet gonads etc.

8.2.11 RESPIRATORY SYSTEM

Respiration in Asterias is brought about by the dermal papulae scattered over the aboral surface and by the tube feet. Both these structures have thin wall and enclose extensions of coelom. Oxygen from sea water diffuses through the thin wall of these organs into coclonic fluid. The coelomic fluid distributes it to all the internal organs and brings CO_2 from them to the respiratory organs for sending out.

8.2.12 EXCRETORY SYSTEM

Special excretory organs are absent in the Asteria. The nitrogenous waste chiefly ammonia pass from various tissues into coelomic fluid from where they diffuse out through dermal papulae into surrounding water. The coelomocytes wandering in the coelom ingest waste particles and pass out through the papulae. The intestinal caceae also secrete brownish substance which is excretory in nature.

8.2.13 NERVOUS SYSTEM

Nervous system of Asterias is confined to the body wall. It consists of four parts: 1) Epidermal (or) Ectoneural, 2) Deeper hyponerual, 3) Aboral (or) Coelomic, and (4) Visceral nervous system.

1. Epidermal Nervous system: Epidermal nervous system is situated within the epidermis. It includes:

a)Circum oral nerve ring: It runs round the mouth and sends fibres to peristome, mouth and oesophagus.

b)Radial nerve cords: Radial nerve cords arise from angles of circum oral nerve ring and extends outwards one through each arm and ends in the eye at the base of terminal tentacle.

c)Sub-Epidermal nerve plexus: It is present beneath the epidermis all over the body surface, including the papullae, pedicellaria and spines.

2. Deeper nervous system: The deeper nervous system is situated on the oral side just beneath the perihaemal sinuses and little above the epidermal nervous system. It includes nerve ring round the mouth and double radial nerves (or) lange's nerve the each arm. deeper nervous system is motor in function.

3. Aboral Nervous system: Aboral nervous system is present just out side the parietal peritonium on the aboral side. It is connected with the epidermal nervous system. It innervates aboral muscles of the arm.

4. Visceral nervous system: The visceral nervous system is situated in the wall of alimentary canal.

Sense organs: The sense organs of star fish include neurosensory cells and eyes.

a)Neuro sensory cells: Neurosensory cells occur here and there in epidermis. They act as tactile receptors and chaemo receptors. Tactile receptors are abundant in suckers of the tube feet. The chaemoreceptors are numerous in terminal tentacles of the arms where they are olfactory in nature.

b)Eyes: The eyes are small bright red spots at the base of the terminal tentacle of each arm. Eyes are sensitive to light.

8.2.14 REPRODUCTIVE SYSTEM

Asterias is unisexual animal. The males and females are indistinguishable externally Ovaries and testis have similar form and structure. There are five pairs of gonads. The size of the gonads increase in size during breeding season. From gonads arise a small gonoduct that opens out by a minute genital pare situated on the aboral side. Accessory glands and copulatory organs are absent. When gonads are mature the spermatozoa and ova are discharged by male and female star fishes into sea water.

Fertilisation is external in the sea water. Development is indirect. During development a free swimming ciliated and bilaterally symmetrical larva called Bipinnaria larva is formed.

8.2.15 SUMMARY

Starfish is a radially symmetrical, pentagonal, star-shaped animal with a body consisting of a central disc from with five symmetrically-arranged arms (rays) radiate. Starfishes are common marine organisms in the sandy and rocky shores. The animal has two surfaces-the oral (lower) and aboral (upper) surfaces. Aboral surface is convex and dark-brown in colour and is directed upwards in the natural position. The oral surace is flat, slightly pale in colour and directed downwards in the natural position of the living animal. Mouth is situated in the centre of the disc ventrally. Anus is situatd nearly in the centre of the aboral or upper surface of the disc. The starfish feeds on bivalve molluscs, crustaceans, worms, etc.

The starfish slowly creeps on solid objects. In starfish and in all other echinoderms, heart and blood vessels are absent, but there is a system of canals known as perihaemal system representing teh circulatory system. The water vascular or ambulacral system is a speciality of the echinoderms. It is a system of canals filled with sea-water containing some amoeboid corpuscles. The dermal branchiae are respiratory in function. There is no definite excretory system. It is performed by the amoeboid corpuscles present int the coelom. Sexes are separate and alike externally. The gonads are 5 pairs, one pair in each inter-radius. Numerous ova and sperms are shed into the sea-water. It is interesting to note that during metamorphosis, a bilaterally symmetrical larva changes into a radially symmetrical starfish.

8.2.16 KEY TERMINOLOGY

Abroal surface : It is anus bearing surface convex and dark brown in colour and is directed upwards in naturnal position

Bivium: The two arms between which the madraporite lies are lenous as bivium.

Madreporite: Circular, Flat, Calcareous and sieve-like plate situated on the aboral surface

Oral surface: Mouth bearing surface. It is flat, slightly pale in colour and directed down wards in natural position.

Perheamal system : It is a system of canals, representing the cirualatory system. These canals run parallel and encircle the water vascular system.

Pedicellariae: Small, pincer-like bodies. These are nothing but the modified spiens.

Tiedmann's bodies: Small and Yellowish lymphoid glads connected to ring canal.

Tube feet: Main locomotory structures of starfishes.

8.2.17 MODEL QUESTIONS

Essay Type

1) Give an account of external characters of Asterias.
2) Describe the digestive system of Asterias and process of digestion.
3) Give an account of water vascular system of Asterias.
4) Give an account of Perihaemal and Haemal system of Asterias.

Short Notes:

1) Body wall
2) Tube feet
3) Pedicillaria
4) Nervous system
5) Axial gland

8.2.18REFERENCE BOOKS

1. **Invertebrate Zoology** by P.S. Dhani & J.K. Dhani.
2. **Echinodermata** by R.L. Kotpal.
3. **Invertebrate Zoology** by E.L. Jordan & P.S. Verma.

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Lesson 9.1
HEMICHORDATA

CONTENTS

9.1.1 Objective

The purpose of this lesson is to

1. to know the general characters & classification.
2. to have an idea about the structure of Balanoglssus & Tornaria larva
3. to develop a concept about the systematic position of Hemichordata.

9.1.2 Introduction

Hemichordates includes a small group of worm like marine animals. Balanoglossus is the best example to study the Hemichordates Balanoglossus is a Burrowing animal. The body is divided into proboscis, collar and trunk. Recently zoologists included phylum Hemichordata in the non-chordates as an Independent phylum close to Echinodermata. Earlier zoologists regarded hemichordata in the phylum chordata.

9.1.3 General Characters of Hemichordata

1. They are marine worm like animals. They may lead solitary or colonial life. Generally they live in ‘U’ shaped tubes. The body is soft and adapted for burrowing life.
2. The body exhibits bilateral symmetry and is not segmented and they are triploblastic.
3. The body is divisible into three parts, proboscis, collar and trunk.
4. Some genera bear tentaculated arms in the collar.
5. coelom is in the form of five cavities. Proboscis coelom is unpaired, collar and trunk have paired coelomic cavities. Proboscis contains a hollow outgrowth from gut called buccal-diverticulum (or) stomochord regarded as notochord in the past.

6. Single layered epidermis in present in the body wall. It contains mucous secreting glands. These are abundant on the proboscis.
7. Digestive system is complete, either straight with terminal mouth (or) 'U' shaped.
8. Many pharyngeal gill slits are present for respiration.
9. The circulatory system is of open type (capillary system in absent). It includes a dorsal heart, two longitudinal vessels, a dorsal and a ventral, inter connected by small lateral vessels.
10. Excretory system comprises of a single proboscis gland (or) glomerulus present in the proboscis and connected with blood vessels.
11. Nervous system is in the form of intra epidermal nerve net. It forms mid dorsal and mid ventral nerve cords. Both are connected together by a circular nerve strand.
12. Sexes may be separate (or) united. The Gonads may be in several pairs (or) only in one pair.
13. Fertilization occurs externally. Development includes a free swimming larval stage.
14. Asexual reproduction occurs by budding in one group.

9.1.4 CLASSIFICATION

The phylum Hemichordata is divided into two classes:
1) Enteropneusta, 2) Pterobranchia

Class: ENTEROPNEUSTA

1) The Enteropneusta are free, solitary, burrowing animals.
2) The body is long and worm like
3) Proboscis tapers anteriorly
4) Collar is simple. It does not possess tentaculated arms.
5) Numerous 'U' shaped gill slits are present with tongue bars.
6) Alimentary canal is straight with terminal anus.
7) Nerve cord is present in the collar region.
8) Sexes are separate and gonads are numerous and sac like
9) Development usually includes a free swimming ciliated 'TORNARIA' larva. Asexual reproduction in lacking.
Examples: Balanoglossus, Saccoglossus

Class: Pterobranchia

1) The pterobranchia are sedentary, colonial, tube dwelling animals.
2) Body is short and vase shaped.
3) Proboscis is shield shaped.
4) Collar bears tentaculated arms with cilia. Trunk bears an aboral stalk.
5) There is only a single pair of gill slits which lack tongue bars.
6) Alimentary canal is 'U' shaped with anus near the mouth.
7) There is no nerve cord in the collar.
8) Sexes may be separate (or) united only single pair of gonads are present.
9) Development may be direct (or) with larval stage. Asexual reproduction occurs by budding.

Class: Pterobranchia is divided into two orders:

1) Rhabdopleurida, 2) Cephalodiscida

Order: Rabdopleurida

1) Rhabdoplurida have two tentaculated arms in the collar region.
2) Gill slits are absent.
3) Single gonad is present
4) All the individuals in a colony are connected together by a common stolon.
   Example: Rhabolopleura.

Order: Cephalodiscida

1) They may be solitary (or) may live in groups (Gregarious) several individuals live separately
2) Only one pair of gill slits are present.
3) A pair of gonads are present.
   Example: Cephalo discus

9.1.5 BALANOGLOSSUS – EXTERNAL CHARACTERS

The colour varies in different parts of the body of Balanoglossus. The body emits strong and offensive smell similar to lodoform. Skimy substance secreted by the skin emits bright greenish luminiscence.

Shape and size

The body is delicate and soft. It is worm like elongated and cylindrical in shape. The entire body is ciliated and is enveloped by mucus secretion. It is bilaterally symmetrical and measures 4” to 2’, the body is divided into 3 regions – Proboscis, Collar and trunk.

a) **Proboscis:-** The proboscis is the anterior part of the body. It is conical in shape tapering anteriorly. It has a thick muscular wall and encloses a cavity, the proboscis coelom that opens out by a minute aperture the proboscis pore situated dorsally near its base. Water enters the proboscis coelom through this pore and makes proboscis turgid. Turgidity makes it an effective burrowing organ. The posterior narrow part of the proboscis is called the neck (or) Proboscis stalk. It is joined with collar.

b) **Collar:-** the collar is the short middle part of the body. It over laps the proboscis stalk infront and a small anterior part of the trunk behind. It is also muscular and encloses a cavity, the collar coelom. Collar forms a funnel like structure in the anterior portion. This is known as collarette. Mouth is present between the collarette and proboscis stalk on the ventral side.

c) **Trunk:-** It is posterior and largest part of the body. It further shows 3 regions. The anterior branchiogenital, the middle hepatic and posterior abdominal. The branchiogenetal region bears on the dorsal surface of its anterior half two rows of small pores the gill pores (or) branchial pores. The gill pores increase in number as the animal grows. The branchiogenital region shows dorsally a pair of longitudinal prominences. These mark the position of gonads inside and are called genital ridges. The hepatic region is marked by numerous small paired transverse folds the hepatic caecae on the upper side. The abdomen slightly tapers posteriorly and bears a terminal anus.

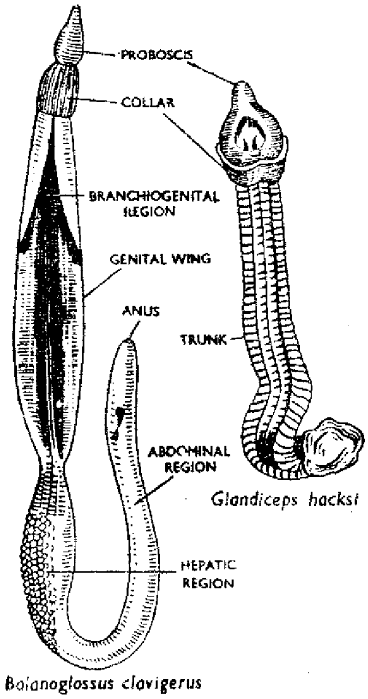

Fig 182 Two Species of tongue worm (Balanoglossus)

9.1.6 TORNARIA LARVA

In Balanoglossus the development is indirect with a tornaria larva. Tornaria larva resembles bipinnaria larva of star fish and auricularia larva of sea-cucumber.

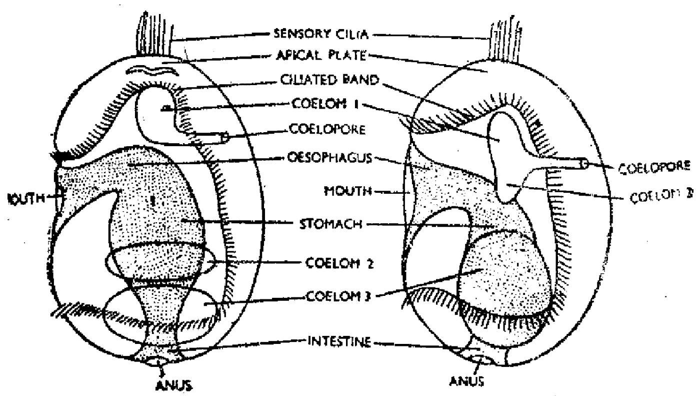

Fig 183 Tornaria Larva

Morphology: Tornaria larva has an ovoid, transparent body with two ciliated bands. The anterior. Circumoral band of short cilia and the posterior telotroch of larger cilia. The circum oral band serves to collect food which consists of minute organisms. The telotroch is ring like and functions as the main locomotor organ. At the anterior end is an ectodermal thickening, the apical plate with apical tuft of sensory cilia, a pair of eye spots and nerve cells. The alimentary canal consists of ventral mouth, oesophagus, stomach, intestine, and posterior anus. On the dorsal side is a pore, the dorsal pore leading into a thin walled sac which later becomes proboscis coelom of the adult. Other coelomic cavities, heart vesicle and other internal organs are formed.

Metamorphosis: Metamorphosis of tornaria larva involves several changes. The thin skin becomes thick. Size of the larva decreases probably due to loss of water. Ciliated bands, apical plate with sensory cilia and eye spots disappear. A constriction develops to separate the proboscis from the collar region. The dorsal pore persists as the proboscis pore. The trunk region elongates. Notochord and gill slits begin to appear as outgrowths from the alimentary canal. Gonads appear.
Larva now sinks and becomes constricted into 3 regions assuming the adult form.

9.1.7 AFFINITIES OF HEMICHORDATA

Hemichordata show affinities with chordates, Echinoderms and Annelids.

Affinities with CHORDATA

1) Hemichordates show at least two fundamental chordate characters.
2) The structure, functions and development of gill slits are similar to those of chordates.
3) Dorsal tubular nerve cord is single and non-ganglionated as in chordates.
4) The third fundamental character of a chordata is the presence of notochord. In hemichordates the roof of buccal cavity has peculiar skeletal structure which extends into proboscis. Earlier, it was considered as notochord later it was called stomochord. But many scientists called it baccal diverticulum. It resembles notochord in the following characters.

a) The buccal diverticulum is mid dorsal in position like notochord.
b) It develops from gut and has vacuolated cells.

Differences with the chordates

In hemichordates, the gill slits are dorsal in position but in chordates they are lateral in position. The so called notochord (Buccal diverticulum) is very short. In chordates it occupies almost entire length of the body. In hemichordates there is no sheath covering the notochord (*Buccal diverticulum*). In chordates notochrod is surrounded by two sheaths outer elastic connective tissue and inner fibrous connective tissue sheath. In hemichordates notochord develops from fore gut but does not get separated from it. In chordates the notochord develops from fore gut but gets separated. In hemichrodates the dorsal nerve cord is restricted to the collar region. In other parts of the body, it is in the form of intra epidermal nerve net. In chordates single hollow tubular nerve cord occupies the entire length of the body. It differentiates into brain in the anterior region. Numerous gonads are present in hemichordata. In chordates only a pair of gonads are present. Blood flow in hemichordates is of annelidan type i.e. blood flows anteriorly in dorsal blood vessel and posteriorly in the ventral vessel. It is just reverse in the case of chordates. In hemichordata heart is dorsally situated. In chordates, it is ventrally situated. Serological and biochemical tests reveal that hemichordates resemble in vertebrates in general and with echinoderms in particular.

Affinites with Echinoderms

Bipinnaria larva of Asterias resembles tornaria larva of Balanoglossus. The cleavage and formation of gastrula is similar in both. In both the larvae the ciliary band takes a similar course. In both coelom develops from the archenteron. The digestive tract is similar in both i.e., mouth is ventral and anus is posterior. The blastopore transforms into anus in both. In adult condition both have a poorly developed nervous system. Heart vesicle of hemichordates may be homologous to madreporic vesicle of echninoderm larva.

Differences with Echinoderms

1. Eye spot of Tornaria is absent in Echinoderm larval forms.
2. Apical tuft of cilia, Telotroch are absent in Bipinnaria and auricularia larvae of Echinodermata. But these are present in Tornaria Larva of Hemichordata.
3. The protoceol is paired in Echinoderms, while unpaired in tornaria larva.

Affinities with Annelida

Both hemichordates and annelids are tube dwellers. Both ingest mud. Faecal matter is in the form of worm castings in both. Blood vascular system of Hemichordata resembles with that of Annelida. Blood flows anteriorly in the dorsal vessel and posteriorly in the ventral vessel in both the groups. Tornaria larva may be modified trochophore larva of annelids.

Differences with Annelida

Nervous system is basically different in both. Excretory system is in the form of nephridia in annelida. Hemichordates have no definite excretory organs. Glomerulus is excretory in nature. Pharyngeal gill slits are present in hemichordata and are absent in Annelida.

Hemichordates are closer to the Echinodermis than to the chordates. But exhibit some differences with Echinoderms. In 1959, Hyman assigned the position of an independent phylum to Hemichordata in the Invertebrata.

9.1.8 SUMMARY

Earlier Zoologists regarded hemichodata in the phylum chordata due to some obvious affinities with chordates. Recently zoologists included phylum hemichordate in non-chordates as an independent phylum close to echinodermata on grounds of general organization

Balanoglossus is the most familiar hemichoralate genus and is commonly called as tongue worm or acon worm. It lives in shallow coastal waters in U-shaped burrows in the bottom sand. The body can be divided into (a) proboscis (b) collar and (c) trunk. The body of the animal is brightly coloured. Proboscis is yellow or orange or red in colour development is indirect with a larval stage called tornaria.

Hemicordates are closer to echinoderms than to the chordates. It appears most reasonable to place them in the inverbrates as an independent phylum. Echinoderms, hemichordates and chordates have arisen from a common ancestral stock, probably the dipleura larva, that has given rise, on the one hand, to echinoderms and on the other hand to hemichordates and chordates.

9.1.9 KEY TERMINOLOGY

Affinites: Relationship with other animals.

Branchio-genital region: The region of trunk which has gillpores and reproductive organs.

Buccal diverticulum: Short, hollow and stiff structure present on the roof of the buccal cavity of Balanoglossus.

Proboscis gland: Blood plexus formed by efferent vessel.

Tongue bar: Hollow partition separating the limbs of gill slits.

9.1.10 MODEL QUESTIONS

Essay Type

1) Give an account of general characters of Hemichordata.
2) Discuss the affinities of Hemichordata.

Short answers:

1) Notochord
2) Tornaria larva
3) Enteropneusta
4) Pterobranchia

9.1.11 REFERENCE BOOKS

1. **Invertebrate Zoology** by P.S. Dhami & J.K. Dhami.
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Lesson 10
LARVAL FORMS OF INVERTEBRATA

CONTENTS

10.0 OBJECTIVE

The purpose of this unit is to i) bring out the differences between different larvae of invertebrates ii) to show the evolutionary advances in larval forms from polifera to echinodermata iii) to have a comprehensive outlook of all the larvae of invertebrates.

10.1 INTRODUCTION

Larval form is a transition stage through which the embryo develops into an adult. Larval stage occurs only in the life history of individual where the development is indirect (where the young one do not resemble the adult). In such cases, the young one transfers into adult through metamorphosis. Generally all most all larval forms are free swimming planktonic forms. Soon after fertilisation, zygote is formed where in the cleavage occurs forming a blastula which leads later to gastrula. After gastrulation an young larva is hatched out, which finally metamorphoses into an adult. If we observe the larvae in the different phyla of invertebrates from porifera to Echinodermata, we find a transformation of organisation from simplicity to complexity in a gradual manner.

10.2 AMPHIBLASTULA

In sponges, sperms leave the sponge by means of water currents and enter other sponges in the same manner. After a sperm has reached a flagellated chamber it enters a choanocyte or amoebocyte. These cells act as carriers and transport the sperms to the egg. After the carrier with it sperms has reached the egg, the carrier fuses with the egg and transfers the sperms to it.

The fertilised egg begins its development with in meschyme of the parent. The cleavage is holoblastic and first three divisions are vertical, that produce eight primordial cells. The next cleavage is horizontal and unequal. This produce eight large cells called macromeres which produce the future epidermis, and eight small cells called micromeres, give rise to future choanocytes. At this stage, the embryo rests just beneath the maternal choanocyte layer.

The future choanocyte lies or micromeres divide rapidly, elongate and acquire flagella on their inner ends facing the blastocoel. While the future epidermal cells or Macromeres remain undivided for some time, and form large, granular, rounded cells. In the middle of the macromeres an opening is formed that acts as a mouth, which ingests adjacent maternal cells. This stage is called Stomoblastula by Duboseq and Tyzet.

Now it undergoes a process called ‘Inversion’. The embryo turns inside-out through the mouth as such, flagellar ends of micromeres come to lie outside. At this stage, the embryo is known as Amphiblastula.

Amphiblastula occurs in most of the calcarea. It is more or less oval in form and consists of one half of small narrow flagellated cells and the other half of large rounded granular cells. Amphiblastula reaches the adjacent radial canal and escapes through the osculum of the parent. The larva leads a free-swimming existence for a few hours with the flagellated half directed forwards.

After swimming for some time, the flagellated part of the larva invaginates or is over grown by the macromeres. Now amphiblastula larva changes into a gastrula with an opening, the blastopore. The larva then fixes itself to rocks or sea weeds by its blastoporal end and develops into an young sponge.

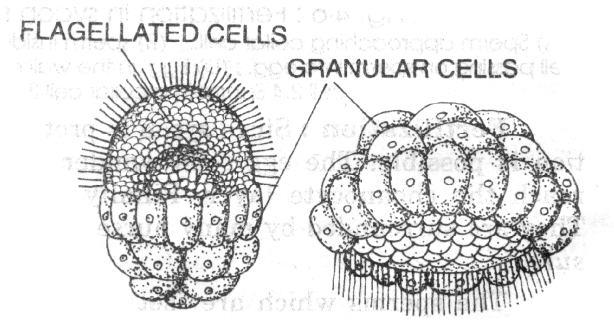

Fig 184 Amphiblastula

10.3 EPHYRA

In many semaestomes including Aurelia cleavage produces a hollow blastula that undergoes invagination and form typical planula larva. After a brief free swimming existence planula settles to the bottom and becomes attached by anterior end and then develops into a little polyploid larva called a "schyphistoma" which looks like a hydra. In winter, it undergoes transverse fission or strobilisation and releases saucer shaped structures called 'ephyra larva'. A schyphistoma may live for several years. The ephyra is almost microscopic, has a deeply incised bell margin and has completely developed adult structures.

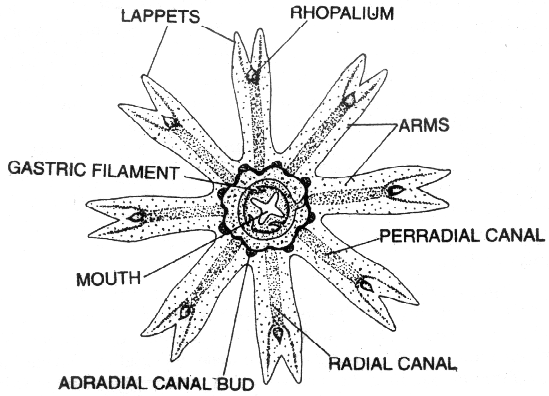

Fig 185 Ephyra larva

From each strobila about 12-16 ephyra larvae are formed which lie one above the other as a pile of saucers and connected with one another through muscular strands. Its umbrellar margin is produced into eight bifid lobes or arms. Four of them are the perradial and other four are interradial in position. All of them are separated from one another by adradial clefts. Each arm at its distal end has a pair of marginal lappets with a deep groove having a tentacle. The tentacle later becomes a tentaculocyst or rhopalim. Each ephyra has a gastric cavity derived from schyphistoma. Gastric cavity develops gastric pouches. On the exumbrellar side, stomach is closed but on subumbrellar side a short manubrium having four sided mouth is formed.

Ephyra swims freely in sea water and feeds on Crustaceans and Protozoans and grows in size. Mesoglea is increased. Space between the oral artnes is filled up. Four oral arms and marginal tentacles appearance and it transforms into an adult.

10.4 TROCHOPHORE LARVA

This is characteristic larva seen in the life history of some annelids and molluscs. This was known as Loven's larva according to the name of its discoverer Loven (1840). The name trochophore was given by Lankestar (1877). This larva exhibits affinities with Muller's larva, ctenophora, pilidim larva (Nemertimes) Veliger (bivalves) and also with rotifers.

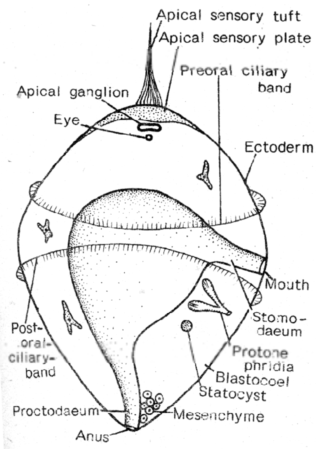

Fig 186 Trochophore

It is a microscopic, oval pear shaped and transparent in nature The anterior end is broader than posterior end. And the entire body is covered with Cilia with which it floats on the surface waters. There is apical plate or sensoroly plate which bears a long tuft of cilia. At the middle of the body there is double row or pre oral band of cilia which is called prototroch. Behind the mouth also there is an other circlet of cilia in the form of a band which is called metatroch. In some there is a third band at the posterior end called as telotroch which surrounds the anus. The epidermis is thickened to form a plate called 'Ventral plate' which is the rudiment of trunk in the adult.

Mouth is present near the midventral line of the body which leads into stomodaeum, bulbous stomach, intestine and anus. The alimentary canal is a bent tube. Between the gut and the epithelium a fluid filled space is present. Blastocoel consists of floating mesenchyme cells, larval muscles and nerves. A pair of nephredia are present which represent flame cells. Below the apical plate there is a bunch of sensory cells, cerebral ganglia, a pair of eyes and an otocyst are also present. There are some undifferentiated mesodermal cells which later give rise to coelom.

After a few days of free swimming life feeding on plankton and micro organisms, it metamorphoses into adult. The anterior prototroch forms the prostonim and area around the mouth becomes peristomeum. The trunk rudiments elongate and forms segments for which setae are developed later. The ciliary bands disappear and mesodermal cells form the coelom. Protonepheridia are replaced by adult nephridia. The larva settles down at the bottom and metamorphosis takes place into an adult.

10. 5 NAUPLIUS

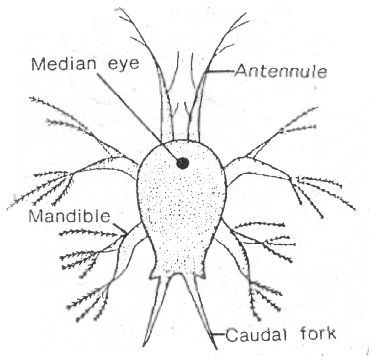

Fig 187 Nauplius

The earliest and basic type of Crustacean larva is the microscopic nauplius larva. It has three pairs of appendages, uniramous first antennae and biramous second antennae and the mandibles. There is no trunk segmentation and a single median or nauplius eye is present on the front of the head. Development proceeds from anterior to posterior. Body is divisible into an anterior broad head and a posterior abdomen which is bilobed. Abdomen bears a pair of anal spines. All the appendages are provided with spines and help in swimming. First pair of appendages become the antennules of the adult, second pair become the antennae and the third pair become the mandibles of the adult. The mouth is present between the bases of antennae and mandibles and is protected by labrum in front. The second and third pairs of appendages bear gnathal endites which help in masticating the food. Alimentary canal is simple and is divisible into foregut, mid gut and hind gut which opens outside by anus. A pair of antennary sacs are present to perform excretion. Nervous system is in the form of a mass of cells in the head and vascular system is absent. The nauplius of cirripedia are different because of dorsolateral and ventromedian spines and frontal organ at the antennae.

10.6 Zoea Larva

Body is divisible into cephalothorax and abdomen. It bears eight pairs of appendages and buds of six more and resembles the adult cyclops. The cephalothorax is immensely developed and covered by a helmet like carapace which is produced into two long spines, an anterior median rostral and a posterior median dorsal. Two lateral spines are also usually present. The paired lateral and stalked compound eyes becomes well formed and movable. The first two pairs of maxillipedes are well formed and remaining six pairs are thoracic appendages which appear in the form of buds. The long abdomen is distinct and made up of 6 segments and terminates in a caudal fork, but still lacking in appendages and it swims by means of thoracic limbs.

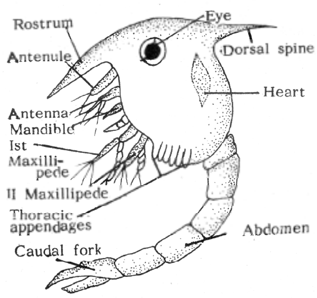

Fig 188 Zoea larva

This is the second important larva of Crustacea, the first being the nauplius. Protozoea stage is succeeded by the zoea stage. In many Decapoda (crabs etc.) however, young is hatched directly at the zoea stage. The zoea after sometime changes into metazoea stage. Zoea feeds on diatoms, zooplankton, rotifens, copepods etc.

10.7 MYSIS (SCHIZOPOD) LARVA

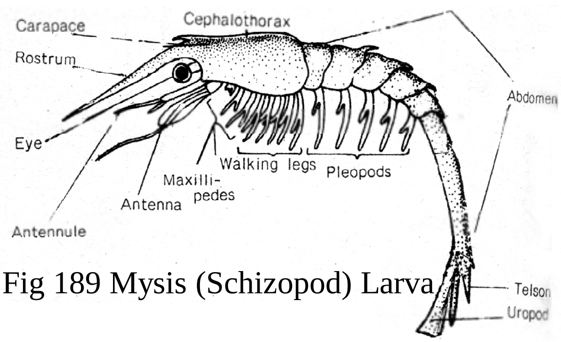

Fig 189 Mysis (Schizopod) Larva

Zoea larva metamorphoses into Mysis I which also feeds on phyto and zooplankton. It is so called because it resembles the adult Mysis. This is the last stage in the development of prawn. It has 13 pairs of appendages and all the thoracic appendages are biramous. Even the 5 pairs of posterior thoracic legs are biramous with flagellar exopodites which take the locomotory function. The abdomen develops similar to that of the

adult form with 5 pairs of biramous pleopods

and a pair of uropods and telson. The mysis larva metamorphosis into adult prawn by the loss of exopodites on the thoracic legs and by enlarging abdomen. Cephalothorax is covered by carapace with a rostral spine and there are a pair of stalked compound eyes.

In the life history of lobster, the embryo is hatched in the mysis stage.

10.8 GLOCHIDIUM LARVA

It is characteristic larva seen in Mollusca. It is a minute larva about 0.1 to 0.5 mm wide. The shell consists of two, triangular and porous valves united dorsally and free ventrally. The shell encloses the body which is cleft from below upwards and differentiated into the dorsally placed body proper and right and left

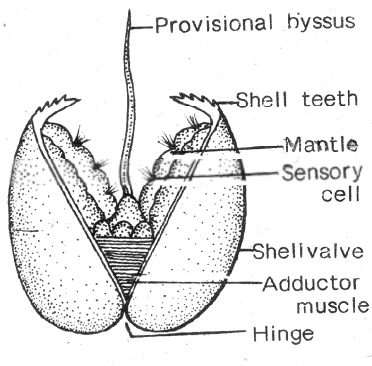

Fig 190 Glochidium

mantle lobes. The mantle lobes are very small and their margins bear on each side three or four peculiar brush like sensory organs. The valves clap together by the action of a single massive adductor muscle extending transversely between the two valves. The foot is not yet developed. The midventral surface of the body has a grandular pouch, which secretes a long sticky thread, the provisional byssus.

Tremendous number of glochidia are produced and when they are matured they are expelled into sea water and slowly sink to the bottom or scattered by water currents. They cannot show any movements and if they come into contact with a fresh water fish, they get attached to the skin, gills or tail with their hooked valves. The host tissue grow over the larva and encysts it. The larva derives its nourishment from the host tissues and after 4-10 weeks if metamorphoses into adult.

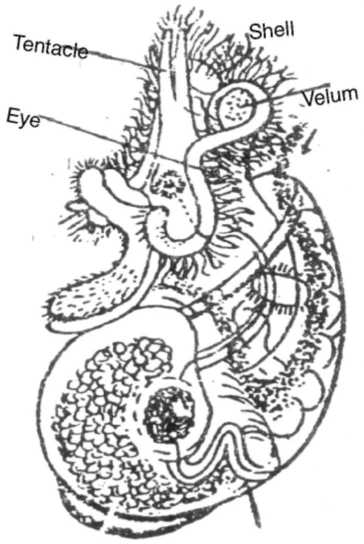

Fig 191 Veliger Larva

10.9 VELIGER LARVA

The development of a free swimming trochophore, succeeded by a valiger larva is typical in molluscans except cephalopods. The shell and shell gland are present in the form of a single dorsal plate, which then forms laterally and ventrally. As a result, the dorsal plate becomes folded and forms the two valves characteristic of bivalves. The ciliary girdle of trochophore (prototroch) forms an outward extension or lateral lobes on each side as a protrusion. This structure is called velum which helps in swimming. Velar lobes are muscular and bear two circles of cilia with a ciliated groove inbetween. At the base of the lobes tentacles and eyes are present. On the ventral side, foot makes its appearance as a round structure. Dorsal surface of posterior lobes forms an operculum. At this stage, shell is conical in the beginning and later becomes spiral and it encloses the visceral mass and also the velar lobes.

Veliger is a planktonic feeder leading free swimming life Torsion occurs. It can swim with the help of velar lobes and at the same time crawl with the help of foot. After 2-4 weeks it grows in size, becomes spiral due to unequal growth of the body settles at the bottom and metamorphoses into adult.

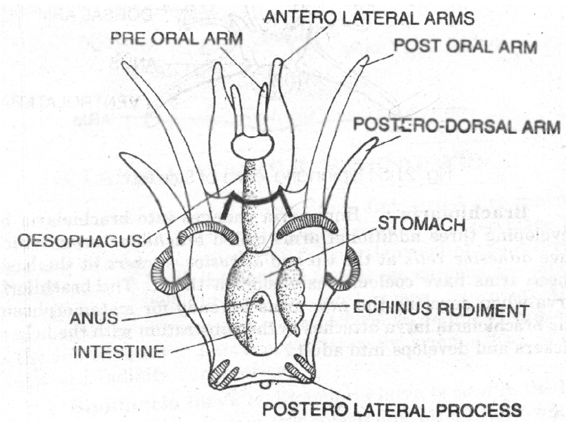

Fig 192 Echinopluteus

10.10 ECHINOPLUTEUS

This is a larval form of echinoidea which is planktonic form and conical in shape. The pre-oral lobe is reduced and it is flattened on one side which becomes the oral surface. Stomodael invagination takes place and an alimentary canal is formed with mouon, oesophagus, stomach and small intestine.

It displays five or six pairs of elongated arms supported by calcareous rods and bearing ciliated band. The arms are preoral, anterolateral, anterodorsal, post oral, posterodorsal and postero lateral arms. Posterolateral arms are short and directed backwards if present. Ciliated band borders all the arms. During later larval life the adult skeleton begins to form and the echinopluteus gradually sinks to the bottom. There is no attachment as in asteroids and metamorphosis is very rapid taking place in about an hour.

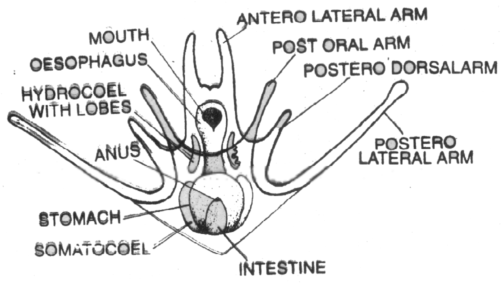

Fig 193 Ophiophluteus

10.11 OPHIOPHLUTEUS

1The larva of Ophiuroidea in sometimes known as ophiopluteus. In this larva the preoral lobe is small. The primitive ciliated band is single and not divided as in bipinnaria. It resembles echinopluteus. It is a microscopic free swimming pelagic larva. The difference that exists in between echinopluteus and ophiopluteus is in the number of paired arms on the body. These are four pairs of arm like processes supported by calcareous rods. They are preoral, posterodorsal, posterolateral and postoral. The posterolateral are always the longest and directed forwards so that the larva has the appearance of 'V'. Internal development will be completed and the posterior end of the larva becomes bulb like.

The metamorphosis is very rapid and just takes place in an hour. The larva will not attach to the substratum.

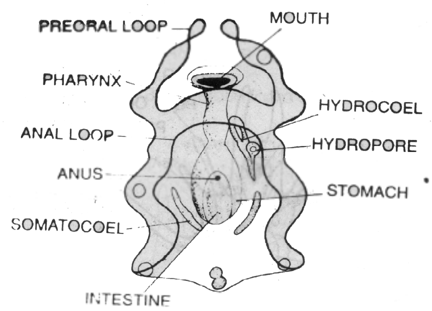

Fig 194 Auricularia Larva

10.12 AURICULARIA LARVA

One of the most primitive of echinoderm larva is the auricularia (Holothuroidea). It is a microscopic transparent and pelagic form. Its body is elongated with a celiated band partly around the preoral lobe, partly on the body folds and anal loop. The larva bears paired processes similar to the arms of other echinoderm larvae and the arms are supported by calceruous particles and not by calcareous rods. The ciliated band shows a wavy course along the sides of the larva while forming the oral and anal loop. The alimentary canal has a mouth, oesophagus, stomach and intestine.
An apical thickening called sensory plate is formed with cilia.

10.13 Doliolaria larva

This is larval form seen in Crinoidea. It is somewhat barrel shaped with an anterior apical tuft and a number of transverse ciliated bands. It is essentially like the doliolaria of holothuroids.

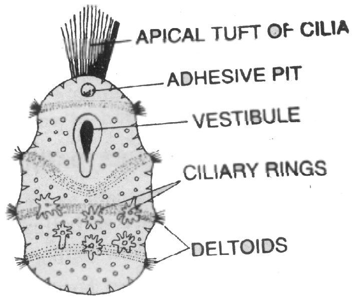

Fig 194 Auricularia Larva

Doliolaria of crinoidea is called as vitellaria or yolk larva. It is slightly flattened ventrally. It has an apical sensory plate with an apical tuft of cilia at the anterior end. There are about 4-5 ciliated bands on the body. These ciliated bands are not continuous but discrete. There is an adhesive pit on the midventral line near the first ciliated band. Mouth is in between second and third ciliated bands.

After a short free swimming life (few days) the larva settles at the bottom and attaches by the adhesive pit. The internal organs are
rotated at an angle of 90^o from ventral to posterior position.
There is an extended metamorphosis resulting in the formation of a minute stalked sessile crinoid.

10.14 SUMMARY

Larval form is a transition stage through which the embryo develops into adult. It occurs in the individual where the development is indirect. All most all larval forms are free swimming and planktonic forms.

Amphiblastula occurs in most of the Calcarcaus, with oval structure and consists of one half of small narrow flagellated cells and other half of large round granular cells.

In many semeastomes including aurilia consists of a characteristic larva called ephyra which is microscopic, which has a deeply incised ball margin and has completely developed adult structures.

Trochophore is characteristic larva of some annelids and molluscs which is a microscopic, oval, pear shaped, transparent and the entire body is covered with cilia.

Nauplius is the earliest and basic types of Crustacean larva. It is microscopic with three pairs of appendages i.e., first antenadeae, second antennae and mandilles and with a median eye.

Zoea is also seen in crustaceans. Body is divisible into cephalothorax and abdomen, with eight pairs of appendages and resemble the adult cyclops.

Mysis larva succeeds the Zoea larva. It is the last stage in the development of prawn, with thirteen pairs of appendages.

Glochidium is the characateristic larva seen in mollusca. It is a minute larva with the shell consisting of two triangular and porous valves united dorsally and free ventrally.

Veliger succeeds the trochophore larva typical in mulluscans except cephalopods. The shell and shell gland are present in the form of a simple dorsal plate and forms two valves characteristic of bivalves.

Echinopluteus is a larval form of echinoidea which is a planktonic form and conical in shape with five or six pairs of elongated arms supported by Calcareous rods and bearing ciliated band.

Ophiopluteus is the larva of ophiuroidea which resembles echinophiteus, microscopic, free swimming palagic larva. It differs with echinopleuteus in the number of paired arms on the body.

Auricularia larva is one of the most primitive of echinoderm larva which is microscopic, transparent and pelagic. Body is elongated with a ciliated band partly on the preoral lobe, body folds and anal loop.

Doliolaria is a larval form of crinoids, which is barrel shaped with an anterior apical tuft and a number of transverse ciliated bands.

10.15 KEY TERMINOLOGY

Larva: A transition stage through which the embryo develops into adult.

Inversion: It occurs in Amphiblastula where the embryo turns outside through the mouth as such flagellar ends of micromores come to lie outside.

Strobilisation: Schyphistoma which looks like hydra undergoes transverse fission and releases saucer shaped structures called “Ephyralarva”.

Metamorphosis: Transformation of the larval form into adult after some free swimming life.

Plankton: microscopic (plant or animal) organism which depend on water current for locomotion, as such they lack locomotory organelles.

Pelogic: Organisms which live in surface waters and have locomotory organs.

10.16 MODEL QUESTIONS

1. Write a brief essay on invertebrate larval forms.
2. Write an account of Nauplius, Zoea and Mysis larvae of Crustacea.
3. Write an account of Trochophore glochidium and veliger larvae of molluscans.
4. Write in detail about the larvae of echinoderms.

Short Answer Questions:

1. Amphiblastula
2. Ephyra
3. Trochophore
4. Nauplius
5. Zoea
6. Mysis
7. Glochidium
8. Veliger
9. Echinopluteus
10. Ophiopluteus
11. Auricularia
12. doliolaria

10.7 REFERENCE BOOKS

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PART - II

CELL BIOLOGY

Lesson 1
CELL STRUCTURE

CONTENTS

1.0 OBJECTIVE

The purpose of this unit is to

- to introduce cell and cell theory.
- to explain the structure of a typical cell
- to show the differences between the prokaryotic and eukaryotic cells
- to describe the electron microscopic structure of cell and its organells

1.1 INTRODUCTION

All animals and plants are constituted of certain structural units, which are repeated in each animal or plant. Such a concept was originally put forward by Aristotle (384-322 B.C.). Many centuries later Robert Hook (1665) observed these units in a piece of cork under a primitive microscope and coined the term 'Cell'. The concept that cell is the basic unit of life is known as cell theory. All-through in the beginning of 19^{th} century, several workers gave the idea of cell theory, the credit for formulating cell theory is given to German botanist M.I. Schleiden and a German Zoologist. T. Schwann (1839). A.G. Lowey and P. Seikevitz (1963) have defined a cell as "a unit of biological activity delimited by a semipermeable membrane and capable of self-reproduction in a medium free of other living systems". This definition does not cover viruses because they are the self-reproductive biological units which do not have a finite semipermeable membrane and are capable of self reproduction only within living cells. As viruses are primitive and simpler units of life they demand priority in discussion.

1.2 Viruses

The viruses are the simplest forms of life which instead of having cellular organisation similar to bacteria, blue green algae, plants and animals, contain definite, genetically determined macromolecular organisation, genetic material and characteristic mode of inheritance.

Size & Structure

These are microscopic entities and range in between 10 to 250 mμ or 100Å – 2500 Å in size. Viruses posses a regular geometrical and macromolecular organisation. Basically, all viruses consist of a core of only one type of nucleic acid (DNA or RNA) which remains wrapped in a coat of protein called capsid. The capsid is composed of numerous protein molecules called capsomeres. They are of different shapes, such as hollow prism, hexagonal, pentagonal, lobular, or any other shape. The arrangement of capsomeres determines the shape of the virus particle. Thus they have three different types of symmetry such as cubic (Eg. Bacteriophage x174; Adeno virus etc.), helical (Bacteriophage and Tobaccomosaic or TMV) and complex (pox virus, vaccine virus).

Some viruses have no capsid around the nucleic acid core while certain highly specialised type viruses contain a membranous envelope around the capsid. The envelope besides containing the molecules of proteins, may contain molecules of lipid and polysaccharides. The capsid protects the viral chromosome during the extracellular phase of the virus life cycle. Some of the proteins of the capsid probably bind the virus to the cell surface, prior to the entry of viruses into cells. Some viral surface proteins include enzymes that aid in penetrating surface layers of cells.

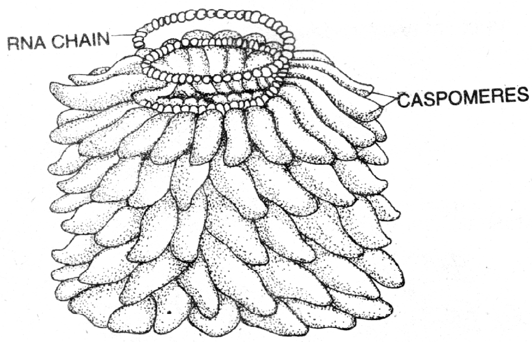

Fig.1 Tobacco Mosaic virus (TMV)

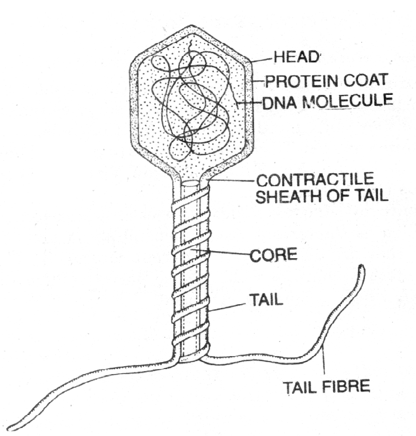

Fig.2 Bacterio phase

Different kinds of Viruses

Viruses are classified into three groups acording to the type of host. They are:

(A) Bacterial viruses or bacteriophages.
e.g. T_4 bacteriophage that infects the colon bacillus *Escherichia coli*.

(B) Plant viruses – Viruses that parasitize plant cells and disturb their metabolism.
e.g. Tobacco mosaic virus (TMV), Turnip Yellow Virus (TYV), Potato virus etc.

(C) Animal viruses – They infect the animal cells and cause different fatal diseases in animals including man.
e.g. Small pox virus, Herpes virus, poliomyelitis and Human Immunodeficiency Virus (HIV).

1.3 Classification cells of cellular organisms

The organisms with only one cell in their body are called **Unicellular organism** (Eg. blue green algae, bacteria, some algae, protozoa etc.). The organisms having many cells in their body are called **multicellular organisms** (Eg. most plants and animals). The celllar organisms may have only one kind of cell from the following two major types of cells.

A. Prokaryotic cells
B. Eukaryotic cells

1.4 Prokaryotic cells: (Pro = primitive, karyon = nucleus) Bacteria, blue green algae etc., are the most primitive cells from morphological point of view. They are essentially one envelope systems organised in depth. They consist of central nuclear components (viz, DNA molecule, RNA molecule and nuclear proteins) surrounded by cytoplasmic ground substance, with the whole enveloped by a plasma membrane. Neither the nuclear apparatus nor the respiratory enzyme systems are separately enclosed by membranes, although the inner surface of the plasma membrane itself may serve for enzyme attachment. The cytoplasm of a prokaryotic cell lack in well defined cytoplasmic organelles such as endoplasmic reticulum, golgi complex, mitochondria, centrioles etc. The prokaryotic cells are so small that simple organic molecules could traverse the cell 100 or 200 times a second and diffusion alone suffices to take care of metabolic transport needs. Some important prokaryotic cells are the following:

The Pleuronemonia Like Organisms (PPLO)

The pleuropneumonia like organisms or PPLO are the bacteria like organisms which differ with the later only in lacking the cell wall and mesosomes and in having very simple organisation, small size and a deformable cytoplasmic or plasma membrane around their prokaryotic cells. The diameter of the smallest PPLO are 0.1 – 0.3 μ and of the largest of a micron. The most widely studied genus of PPLO is mycoplasma.

Bacteria: The bacteria are microscopic unicellular, achlorophyllous, asexually reproducing prokaryotes which occur in fresh and salt water in soil, in plants and in animals. They lead either saprophytic or parasitic mode of existence.

Size & Structure: Bacterial cells are very small about 125 μ in diameter. There are three basic shapes of bacteria – spheroidal – coccus, rod shaped or cylindrical (bacillus) and spiral (spirillum). Spheroidal forms occur simply or in doubles or in groups.

All bacteria fundamentally contain prokaryotic cells in their body. A typical bacterial cell has an outer covering and cytoplasm. The outer covering of bacterial cell wall is made up of three layers:

(1) Plasma membrane: Thin layer of lipid protein molecules and it contains oxidative or respiratory chain enzymes and multienzyme complexes which are usually done by mitochondria of eukaryotic cells. Plasma membrane also contain mesosomes and desmosomes.

(2) Cell Wall: Plasma membrane is followed by a strong rigid cell wall. The bacterial cell wall besides containing carbohydrates, lipids, proteins, phosphorous and certain inorganic salts and contains an aminoacid (diaminopimelic acid) and derivative of glucose called muramic acid.

(3) Capsule: Outside to the cell wall of most bacteria occurs a slimy capsule which is composed of largely polysaccharides.

Cytoplasm: The cytoplasm of bacterial cells is dense colloidal and contains granules of glycogen, proteins and fats. It lacks most of the important membrane delimited cellular organelles of eukaryotic cells, such as endoplasmic reticulum golgi complex, mitochondria, lysosomes, centrioles etc. Bacterial ribosomes freely occur in cytoplasm and are of 70 S types. The genetic information is stored in a DNA molecule in a distinct nuclear region often called nucleoid and lacks any delimiting membrane.

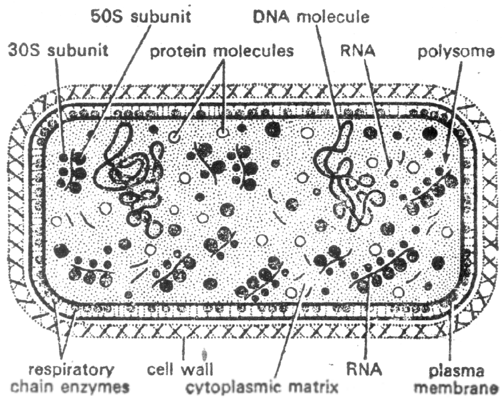

Fig.3 Tipical bacterial cell

Blue Green Algae

These are another group of prokaryotes which include in about 2000 species resembling bacteria in many regards. A few blue green algae are unicellular and from as single separate cells, but most species are multicellular. A typical cell of a blue green algae is basically composed of an outer gelatinous or slimy layer, a middle cell wall and an inner most plasma membrane. The cytoplasm lacks endoplasmic reticulum, golgi mitochondria and lysosomes. It contains numerous free 70S ribozomes and photosynthetic pigments such as chlorophyll and carotenoids.

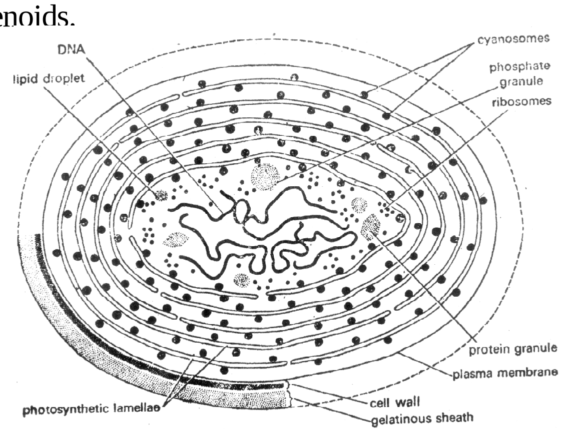

Fig.4 Blue-green olgae

1.5 Eukaryotic cells : (Eu = good; karyotic = nucleus)

Eukaryotic cells are essentially two envelope systems and are very much larger than prokaryotic cells. secondary membranes envelop the nucleus and other internal organells and to various extents, they pervade the cytoplasm as endoplasmic reticulum. The eukaryotic cells are present in all plant and animals. Though they have different shape, size and physiology, but all the cells typically composed of plasma membrane, cytoplasm and its organelles.

Shape: The plant and animal cells exhibit various forms and shapes. Typically the animal cell is spherical in shape but the shape of the cell may be irregular, triangular tubular, cuboidal, polygonal, cylindrical, oval, rounded or elongated in different animal and plant cells. The shape of the cell may vary from animal to animal and from organ to organ. Even the cells of the same organ may display variations in the shape. Generally, the shape of the cell remains correlated with its functions. For example, the epithelial cells have flat shape and the muscle cells are elongated. Moreover, external or internal environment may also cause shape variations in the cell due to internal or mechanical stress or pressure and surface tension etc.

Size: Mostly the Eukaryotic cells are microscopic in size but definitely they are larger than bacterial cells. The size of cell varies from 1 μ to 175000 μ (175 mm). The ostrich egg cell is considered as largest cell with 175mm diameter. The longest nerve cells have been found to have the length of 3 or 3.5 feet.

Number: The body of unicellular or acellular organisms (protozoa and protophyta) consists of single cell. The number of cells in the multicellular organisms usually remains correlated with the size of the organisms and therefore small sized organism has less number of cells in comparison to large sized organisms.

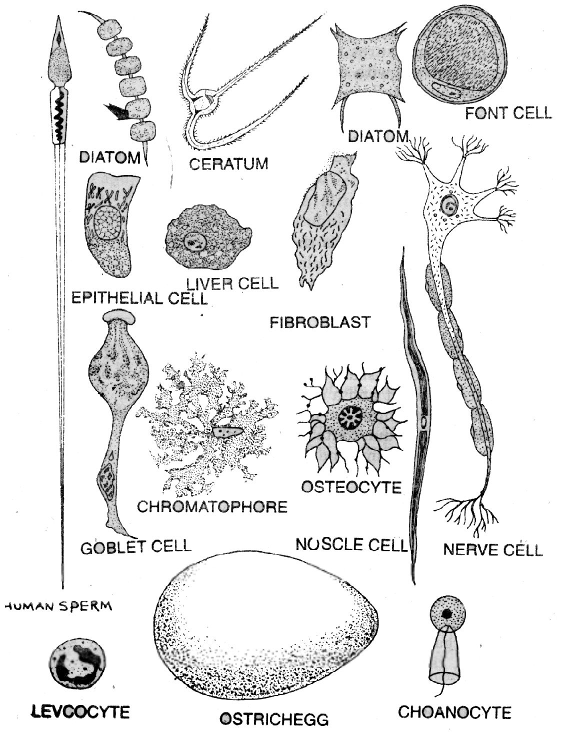

Fig.5 Various types of eucaryotic cells

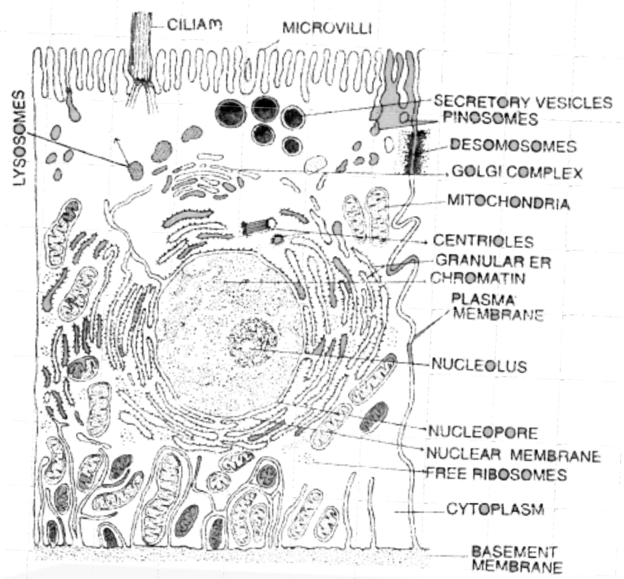

Fig.6 Typical eucaryotic cell

Structure: An Eukaryotic cell consists of following components.

(A) Cell wall and plasma membrane
(B) Cytoplasm, and
(C) Nucleus

(A) Cell wall: The protoplasm of plant cells is separated from the external world by the cell wall which is extremely lacking in animal cells. It is semi rigid, laminated external and non-living covering of the cell. It is made up of a polysaccharide cellulose. It provides protection and support to the plasma membrane and cytoplasm. The canal like connections of cell wall, by which the cells are connected to adjacent cells are called “plasmodesmata”.

Plasma membrane: Most plant and animal cells have an external covering known as plasma lemma, cell membrane or plasma membrane. It is living, ultra thin, elastic porous, semipermeable membranous covering of cell. It provides mechanical support and external form to the protoplasm. It also delimits the protoplasm from the exterior, checks the entry or exit of undesirable substances and due to its semipermeability it transmits necessary materials to and from the cell. It is made up of an outer and inner layers of proteins and a middle layer of lipids. It is found to contain many pores through which the exchange of molecules occur.

Cytoplasm: The plasma membrane is followed by the cytoplasm which is composed of following structures.

A. Cytoplasmic matrix: The space between the plasma membrane and the nucleus is filled by an amorphous, transluscent, homogenous colloidal liquid known as hyaloplasm or cytoplasmic matrix. The matrix consists of various inorganic molecules such as water, salts of Na, K and other metals and various organic compounds viz., carbohydrates, lipids, proteins, nucleoproteins, nucleic acids and a variety of enzymes. The peripheral layer of matrix is relatively non-granular, viscous, clear and rigid and is known as the plasmagel, cortex or cortical layer or ectoplasm. The inner portion of the cytoplasmic matrix is granular, less viscous and known as endoplasm.

Cytoplasmic structures: Cytoplasmic matrix contains suspended living and non-living structures. The non-living structures are called paraplasm, deutoplasm or inclusions, while the living structures are membrane bounded and are called organoids or organelles. The cytoplasmic inclusions include stored food and secretory substances in the form of oil drops, yolk granules, pigments, secretory granules and glycogen granules. The organoids or organelles perform various important biosynthetic and metabolic activities. They are microtubules, centrosome, basal granules, cilia, flagella, endoplasmic reticulum, golgi complex, lysosomes, vacuoles ribosomes, mitochondria and plastids.

Microtubules & Microfilaments: The cytoplasm is traversed by numerous ultrafine tubules of tubulin protein called microtubules. Their function is transport of water ions or small molecules, cytoplasmic streaming, (cyclosis) and formation of fibres or asters of the mitotic or meiotic spindle during cell division. Moreover, they form the structural units of the centrioles, basal granules, cilia and flagella.

Centrosome: It contains dense cytoplasm and is located near the nucleus of the cell of animal cells. During cell division, the centrosome forms two rods shaped granules known as centrioles. Each centriole consists of nine fibrillar units and each fibrillar unit is found to contain three microtubules. At the time of cell division, the centrioles form the spindle of microtubules which help in the separation and movement of chromosomes during concluding stages of cell division.

Basal granules (Kinetosomes): The cells which are having locomotory organelles such as the cilia or flagella contain spherical bodies known as basal granules or kinetosomes at the base of the cilia and flagella. The kinetosomes remain embedded in ectoplasm and are composed of nine fibrils. Each fibril consists of three microtubules out of which two enter the cilia or flagella. The basal granules may contain both DNA & RNA.

Cilia & Flagella: The cells of many unicellular organisms and ciliated epithelium of multicellular organisms consists of some hair like cytoplasmic projections outside the surface of the cell. These are known as cilia and flagella. They help in locomotion of the cell. They contain nine outer fibrils around two large central fibrils. Each outer fibril consists of two microtubules. The cilia and flagella are originated from the bassal granules and chemically consists of tubulin and dynein proteins and adnosine triphosphate (ATP).

Endoplasmic reticulum: The cytoplasmic matrix is traversed by a vast reticulum or network of inter connecting tubules and vesicles which is known as endoplasmic reticulum or ER. The endoplasmic reticulum is having a single vast interconnected cavity which remains bounded by a simple unit membrane. The membrane of endoplasmic reticulum is supposed to be originated by inpushings of plasma membrane because it resembles the plasma membrane in structure.

The membranes of Endoplasmic reticulum may be either smooth or rough depending on the presence or absence of ribosomes on them. The membrane of endoplasmic reticulum is found to be continuous with the nuclear membrane and plasma membrane. It forms ultrastructural framework of cytoplasmic matrix and also provides the mechanical support to it. It also acts as an intracellular circulatory system and it circulates various substance into and out of the cells by the membrane flow mechanism. Further, the endoplasmic reticulum acts as a storage and synthetic organ. For example, it synthesizes lipids, glycogen, cholesterol, glycerides, hormones etc.

Golgi complex: In cytoplasmic matrix, a stack of flattened, membrane bound, parallely arranged organelles occur in association of endoplasmic reticulum and is known as Golgi complex. Each Golgi complex is composed of many lamallae, tubules, vesicles and vacuoles. The membranes of Golgi complex are lipoproteinous and these are supposed to be originated from endoplasmic reticulum. The function of golgi complex is storage of proteins and enzymes which are secreted by ribosomes and are transported by endoplasmic reticulum to them. Golgi complex has most important secretory function. It secretes many secretory granules and lysosomes. In plant cells, Golgi complex is known as dictyosome and secretes necessary material for cell wall formation during cell division.

Lysosomes: The cytoplasm of animal cells contains many tiny spheroid or irregular shaped, membrane bounded vesicles known as lysosomes. These are originated from Golgi complex and contain many digestive enzymes. Their function is the digestion of food material which comes in the cell by pinacocytosis and phagocytosis. The lysosomes of plant cells are membrane bounded storage granules containing hydrolytic digestive enzymes and are composed of spherosomes, aleurone grains and vacuoles.

Cytoplasmic vacuoles: The cytoplasm of many plant and some animal cells (i.e., Ciliate protozoans) contain numerous small or large sized, hollow liquid filled structures, the vacuoles. These vacuoles are supposed to be greatly expanded endoplasmic reticulum or Golgi complex. The vacuoles of animal cells are bounded by a lipoproteinous membrane and their function is storage, transmission of the materials and maintenance of internal pressure of the cell.

The vacuoles of plant cells are bounded by a single, semipermeable membrane known as tonopalst. These vacuoles contain water, phenols, flavonols, anthocyanins alkaloids and storage products such as sugars and proteins.

Microbodies: The cytoplasmic matrix of many kinds of cell viz., yeast, protozoa cells of higher plants, hepatocytes (liver cells) and kidney cells, contain certain roughly spherical, membrane bound particles (0.3 – 1.5 μ diameter). These particles have a central granular or crystalloid core containing some enzymes occur in intimate relation with endoplasmic reticulum, mitochondria and chloroplasts are called microbodies. The microbodies use molecular oxygen like mitochondria, but instead of having cytochromes and capacity of ATP synthesis like mitochondria, they contain enzymes for hydrogen peroxide metabolism, purine metabolism, gluconeogenesis (synthesis of glucose from non-carbohydrate precursors) and photorespiration.

Ribosomes: Many minute spherical structures known as ribosomes are attached to the membranes of Endoplasmic reticulum and forms granular or rough type of ER. The ribosomes are originated in the nucleolus and consists of mainly the ribonucleic acids and proteins. Each ribosome is composed of two structural units, a smaller subunit known as 40S subunit and a larger subunit known as 60 S subunit. The ribosomes remain attached with the membranes of endoplasmic reticulum by the 60S subunits. The 40 S subunits occur on the larger subunit and form a cap like structure. The ribosomes consists 3 types of RNA's known as ribosomal RNA or rRNA viz., 5 S, 18 S and 28 S rRNA's. The 28 S and 5 S rRNA's occur in the larger (60 S) subunit while 18 S rRNA occur in the smaller ribosomal subunit. The ribosomes also occur freely in the cytoplasm. They are sites of protein synthesis and during protein synthesis they form into polysomes or polyribosomes.

Mitochondria: In the cytoplasm of most cells occur many large sized, rounded or rod like structures known as mitochondria. They occur singly or in groups and their shape and size vary from cell to cell. The mitochondira are bounded by two membranes of lipoproteins. The outer membrane forms the bag like structure around the inner membrane which gives outmany finger like projections in the lumen of mitochondria. The folds of inner mitochondrial membrane are known as criestae. The space between outer and inner mitochondrial membranes as well as the central space is filled up by a viscous mitochondrial matrix. The matrix, outer and inner membranes are found to contain many oxidative enzymes and coenzymes. The functions of mitochondria are cellular respiration or oxidation of food or synthesis of energy. The mitochondria also contain circular DNA molecule and ribosomes and are capable of synthesis of certain proteins.

Plastids: Plastids occur commonly in plant cells and their diameter varies from 4 μ to 6 μ. They may be colourless or coloured. The colourless plastids are known and leucoplasts and coloured plastids are called chromoplasts. The leucoplasts have storage function and store starch and lipids and may be called amyloplasts and lipoplasts, respectively. Chromoplasts have many forms and pigments and those having the chlorophyll are the most important. These are known as chloroplasts and have complicated organisation. They contain DNA, ribosomes and complete protein synthetic machinery. They help in the biosynthesis of foodstuffs by the process of photosynthesis.

Nucleus: It is a centrally located spherical cellular component which controls all the vital activities of the cytoplasm and carries the hereditary material DNA in it. The nucleus consists of three structures: (1) nuclear membrane, (2) nucleoplasm and chromosomes, and (3) the nucleolus.

Nuclear membrane: The nucleus is bounded by two membranes of lipoprotein which are known as nuclear membrane. They form a kind of envelope around the nucleus and is known as nuclear envelope. This contains many pore like octagonal perforations through which to and fro movement of chemical substances takes place. The outer membrane of the nuclear envelope remains continuous with the membranes of endoplasmic reticulum and plasma membrane.

Nucleoplasm and chromosomes: The space between the nuclear membrane and nucleolus is filled by a watery substance known as nucleoplasm or karyolymph. The nucleoplasm contains dissovled phosphorous, ribose sugars, proteins, nucleotides and nucleic acids. The nucleoplasm contain certain thread like elongated structures known as chromosomes. The chromosomes appear only during cell division, otherwise they appear in the form of chromatin granules. The chromatin granules or chromosomes fundamentally consists of large molecules of DNA and many nucleoproteins.

Nucleolus: The nucleoplasm contains a conspicuous darkly stained spherical body known as nucleolus. Chemically nucleolus is composed of large amount of ribosomal proteins and ribosomal RNA. The nucleolus stores the rRNA molecules which are synthesised by nucleolar organiser region of DNA called rDNA and provides the raw materials such as different kinds of RNA's and ribosomal proteins for the biogenesis of ribosomes.

The cellular organelles perform various important biological functions which are shown in the following figure.

1.6 SUMMARY

Cell is a unit of biological activity delimited by a semipermeable membrane and capable of reproduction in a medium free of other living systems.

Viruses are simplest forms of life which instead of having cellular organisation, contain definite genetically determined macromolecular organisation, genetic material and characteristic mode of inheritance.

Prokaryotes are essentially envelope systems consisting of central nuclear components and surrounded by cytoplasmic ground substance with the whole enveloped by a plasma membrane. E.g. Bacteria, Blue green algae and PPLO.

Eukaryotic cells are two envelop systems, secondary membranes envelop the nucleus and other internal organelles.

Though they have different shape, size and function, all the plant and animal cells are typically composed of plasma membrane nucleus cytoplasm and its organelles.

Cell wall is semi rigid laminated external and non-living covering made up of cellulose which provide protection and support and exclusively present in plant cells.

Plasma membrane is living ultra hlm, elastic, porous, semipenneable membrane covering the cell.

The space between the plasma membrane and the nucleus is filled by an amorphous, transluscent homophorous colloidal liquid know an cytoplasmic matrix which contains suspended living and non-living structures.

The organalles perform various important biosynthetic and metabolic activities. They are microtubules, centrosome basal granules, cilia, flagella, endoplasmic reticulum, golgi complex, lysosomes, vacuoles, ribosomes, mitochondria and plastids.

1.7 KEY TERMINOLOGY

Cell: Robert Hook (1665) observed units in a piece of cork under microscope and coined the term ‘Cell’.

Cell theory: The concept that cell is the basic unit of life is called as cell theory.

Unicellular organism: The organisms with only one cell in their body.

Multicellular organisms: The organisms having many cells in their body.

Prokaryotic cells: The cells where in nuclear component is not enclosed by membranes.

Eukaryotic cells: The cells where in the nucleus is enclosed by nuclear membrane.

Cell Wall: It is a semi-rigid, laminated, external and non-living covering of the cell, made up of cellulose and provides protection and support to cell.

Plasma membrane: It is a living, ultra thin, elastic, porous semi-permeable membranous covering of the cell.

Cytoplasmic Matrix: The space between the plasma membrane and the nucleus is filled by an amorphms, transluscent, homogenous colloidal liquid known as hyaloplasm or cytoplasmic matrix.

Centrosome: It contains dense cytoplasm located near the nucleus of animal cells and forms spindle during cell division.
Endoplasmic reticulum: It is a vast reticulum of network of interconnecting tubules and vesicles, forms skeletal, circulatory system of the cell and it is synthetic and storage organ.
Golgi complex: Sack of flattened, membrane bound parallelly arranged organelles occur in association with endoplasmic reticulum and helps in storage and secretion.
Lysosomes: Tiny, spheroid, membrane bounded vesicles containing the digestive enzymes.
Ribosomes: Many minute spherical structures, attached to ER or occur freely in the cytoplasm.
Mitochondria: Many large sized, rounded or rod like structures bounded by two membranes and is responsible for cellular oxidation of foods.
Nucleus: Centrally located spheroid cellular components which controls all the vital activities of the cell.

Plastids: They occur in plant cells and help in the synthesis of foodstuffs by the process of photosynthesis.

MODEL QUESTIONS

1. Describe in detail about the typical Eukaryotic cell.
2. Give an account of the Electron microscopic structure of animal cell.
3. Write an account of different cell organelles of a Eukaryotic cell.
4. Short notes questions:
   a) Prokaryotes
   b) Viruses
   c) Plasma membrane
   d) Cell wall
   e) Endoplasmic reticulum
   f) Golgi complex
   g) Lysosomes
   h) Ribosomes
   i) Mitochondria
   j) Plastids
   k) Nucleus

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Lesson 2.1
PLASMA MEMBRANE

CONTENTS

2.1.0 OBJECTIVES

The purpose of this unit is:

1. To describe the structure of plasma membrane
2. To describe the chemical composition of plasma membrane
3. To explain the specialised structures of plasma membrane
4. To explain the physiology of plasma membrane

2.1.1 INTRODUCTION AND ISOLATION OF PLASMA MEMBRANE

Cell surface in all cells is enclosed in a cell membrane or plasma membrane or plasmalemma. It is exceedingly thin (70A°—100A°), elastic, semi permeable trilaminar, lipoproteinous, living limiting membrane which separates the cellular protoplasm with their external environment. The term cell membrane was coined by C. Nageli and C. Cramer in 1855 and the term plasma-lemma has been given by J.Q. Plowe in 1931. Modern cytologists prefer the term plasma membrane for the membrane to avoid confusion (De Robertis *et al.,* 1975). Plasma membrane lies between the cell wall and the cytoplasm in the bacterial and plant cells and it is the outer limiting membrane of most animal cells.

Variety of cells including liver cells, muscles, amoeba and sea urchin eggs have been used for the isolation of plasma membranes. They are more easily obtained from erythrocytes and their purity can be tested by electron microscopy, enzyme analysis and certain other criteria. To obtain plasma membrane from human crythrocytes the cells are treated with hypotomic solutions that produce swelling and then loss of haemoglobin content. The remaining membrane is generally called a red cell ‘ghost’.

2.1.2 CHEMICAL COMPOSITION

The plasma membrane is composed of mainly protein, lipid and a small percentage of oligosaccharides that may be attached to either the lipids (glycolipids) or the proteins (glycoproteins). There is a wide variation in the lipid-protein ratio between different cell membranes.

A. Lipid Fraction of Plasma Membrane

The plasma membrane contains about 20 to 79 per cent of lipids. The main lipid constituents of plasma membranes are phospholipids, cholesterol and galactolipids. Their proportions vary in different cell membranes. The phospholipids are of two kinds — neutral phospholipids and acidic phospholipids. Neutral phospholipids such as phosphatidylcholine, phosphatidyl ethanolamine and sphingomylin have no net charge at neutral pH and they tend to pack tightly in the bilayer. Acidic phospholipids such as phosphatidyl inositol, phosphatidyl serine, cardiolipin, phosphatidyl glycerol are negatively charged in the membrane are associated principally with proteins by way lipid-protein interactions. Acidic phospholipids form only 5 to 20 per cent fractions of the total phospholipids of the plasma membrane.

A lipid molecule basically consists of two parts, a head (glycerol) which is water soluble or hydrophilic and two tails (fatty acids) which are insoluble or hydrophobic. Different lipid molecules of plasma membrane of different cells are composed of a variety of fatty acids. For instance, red cell ghost of mammals contains the fatty acids such as palmitic, stearic, oleic and arachidonic acids.

B. Carbohydrate Fraction of Cell Membrane

The common *oligosaccharides* of plasma membrane of mammalian erythrocytes and liver cells are hexose, hexosamine, fructose and sialic acid. All these are usually remain bounded to proteins. Sialic acid is sensitive to neuraminidase and it is attached to proteins by N-acetylgalactosamine on the outer surface of the membrane. A small amount of sialic acid exists in the form of gangliosides (i.e., glycolipids) in the plasma membrane of liver cells.

C. Protein Fraction of Plasma Membranes

It is the main and one of the significant fraction of plasma membranes. They play an important role not only in the mechanical structure of the membrane, but also as carries of channels serving for transport. They may also be involved in regulatory or ligand recognition properties. Besides the structural proteins, there occur enzymatic proteins and also the antigens and various kinds of receptor molecules in the plasma membrane. Different plasma membranes maintain their distinctive characteristics due to diversity of proteins.

D. Peripheral and Structural Proteins

The structural proteins of plasma membranes have recently been classified into two groups. The peripheral or extrinsic proteins and the integral or intrinsic proteins. The peripheral proteins are associated with membrane surface and therefore separated by mild treatment. They are soluble in aqueous solutions and are usually free of lipids. The most common examples of peripheral proteins are spectrin in erythrocytes, ATPase, Cytochrome-C found in mitochondria.

Integral proteins represent more than 70 per cent of the two protein types. They extend the lipid bilayer and require drastic procedures for isolation. They are insoluble in water solutions and need the presence of detergents to be maintained in a non-aggregated form. The integral proteins may be attached to oligosaccharides to form glycoproteins or to special phospholipids to form lipoproteins. The most common example of integral proteins are rhodopsin found in retinal cells and cytochrome oxidase found in mitochondrial membrane. Red cell ghost contains an integral glycoprotein called glycophorin, which has a mol. wt. of 55,000. At the outer surface red cell ghost glycoproteins contains protein bound antigens for the ABO blood groups H and Le blood groups and others. Among the most hydrophobic integral proteins of membrane proteolipids are present which has strong association with lipids.

E. Enzymes of plasma membrane

In any cell in which active transport occurs it is likely that enzymes occur in the surface of the cell. A part of structural protein of a plasma membrane is enzymatic protein. About 30 enzymes were reported in isolated plasma membranes. The commonly found are 5-nucleotidase, Mg^{++} ATpase, $Na^{+}K^{+}$ activated Mg^{++} ATPase, alkaline phosphatase, adenyl cyclase, acid phospho monoesterase and RNA ase. The plasma membrane of Eukaryotes lack the enzymes for respiratory chain and glycolytic pathway.

The enzyme Na^{+} - K^{+} activated -Mg^{+} ATPase is one of the most important enzyme of plasma membrane because of its role in ion transfer across the plasma membrane.

2.1.3 STRUCTURE OF PLASMA MEMBRANE

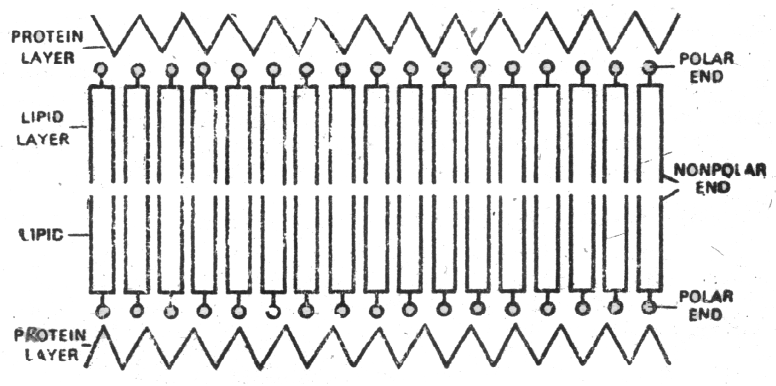

Fig.7 Ultra structure of plasma membrane
Danielli and Davson model

From a simple kind of reasoning early workers concluded that plasma membrane contained an important lipid content since fat solvents were formed to destroy the membrane and fat soluble substances were shown to pass across the membranes much more readily than hydrated molecules. The lipid bilayer theory (Gorter and Grendel, 1925) was also supported by electrical measurements. Danielli and Davson postulated that proteins cover the outer surface of plasma membrane. Following theories and models have been suggested for the possible molecular structure of plasma membrane.

A. Lamellar Theory

As visualised by Danielli & Davson the plasma membrane consists of two layers of lipid molecules arranged radially with their hydrocarbon chains (tails or non-polar ends) towards each other and with their respective polar groups (heads) arranged outwardly and inwardly the entire double layer of lipid molecules being sandwiched between two layers of proteins. In the Davson-Danielli model the proteins are usually represented as being in the globular (alpha) configuration. In the lamellar model of Robertson the proteins are represented in the extended (beta) configuration. Both indicate proteins-lined pores through which water soluble substances might enter.

This lamellar view of membrane structure has led to Robertson's "Unit membrane" concept which implies that all membranes have this same fundamental molecular pattern despite differences in functional and metabolic properties and despite ultrastructural variations. Thus unit membrane occurs around the cell as plasma membrane and also in endoplasmic reticulum, nuclear envelope, golgi complex, lysosomes microbodies, mitochondria, plastids and other membrane bound cytoplasmic structures.

B. Micellar Theory

Hilfeir and Holfmann (1953) suggested that biological membranes may have a non-lamellar pattern, consisting instead of a mosaic of globular sub units known as micelles which have a lipid core and a hydrophilic shell of polar groups. Lipid micelles are possible building blocks for membranes since they tend towards spontaneous association. Hence the protein components of the membrane may form a monolayer on either side of the plane of the lipid micelles.

According to De Robertis *et al.,* (1975) some workers have postulated that intracellular membranes have micellar structures while plasma membrane has lamellar configuration and there occur a structural transformation (globular-bilayer transformation) between the two.

C. Fine Structure

The electron microscopic structure of thickness of plasma membranes varies between (75-105A^{o}). Membranes are found to have a trilaminar or tripartite structure consisting of two dense outer layers each about 25A^{o} thick separated by a pale interphase also of 25A^{o}. The less dense middle layer of the plasma membrane corresponds to the hydrocarbon chains of the lipids while dense outer and inner layers correspond to protein layers.

D. Fluid Mosaic Model

This was put forward by different cell biologists in 1970s and the present knowledge about the molecular organisation of biological membranes is indirect and comes from chemical analysis and application of several biophysical techniques. This model postulates: (1) lipid and integral proteins are disposed in a kind of mosaic arrangement, and (2) the biological membranes are quasifluid structures in which both the lipids and the integral proteins are also able to perform translational movements with in the overall bilayer. The concept of fluidity implies that the main components of the membrane i.e., lipids and oligosaccharides are held in place by means of non-covalent interactions (Gitler 1972). This type of structure can be supported by the fact that the components of cell membrane can be dispersed by solvents, detergents or denaturating agents, that do not involve the breaking of truely chemical bonds. It is necessary to remember that not only the lipids, but also many of the intrinsic and glycoproteins of the membrane are amphipathic molecules. The term amphipathy coined by Hartles in 1936 refers to the presence with in the same molecules of hydrophilic and hydrophobic groups. Further the amphipathic molecules are tend to constitute liquid crystalline aggregates in which the polar groups are directed towards the water phase and the non-polar groups are situated inside the bilayer.

The integral proteins of the membrane are intercalated to a greater extent or lesser extent into a rather continuous lipid bilayer. This arrangement is based on the fact that these integral proteins are also amphipathic with polar regions protruding from the surface and non-polar regions embedded in the hydrophobic interior of the membrane (Singer & Nicholson, 1972). This arrangement of intrinsic or integral proteins in the plasma membrane may explain why different enzymes and antigenic glycoproteins may have their active sites exposed to the outer surface of the membrane. It is conceivable that a protein of appropriate size or a cluster of proteins subunits may pass across the entire membrane.

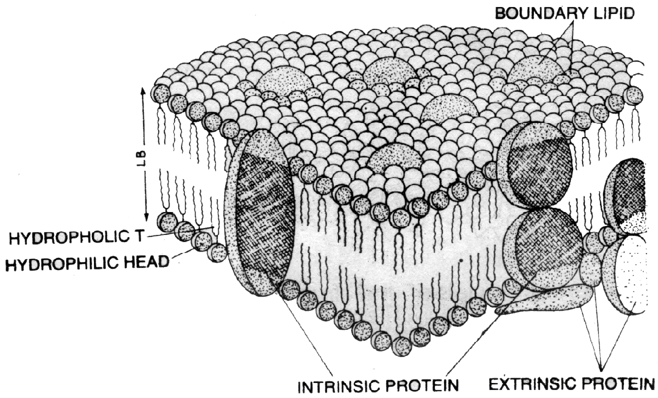

Fig.8 Fluid mosaic model

The mosaic nature of the membrane and fluidity of lipids and integral proteins are supported by various biochemical and biophysical techniques.

Mobility of lipid molecules depend on (1) the saturation of the lipid tails and (2) on the ambient temperature. The mobility of lipids molecules is also influenced by proteins.

E. Inter Cellular Space

The plasma membrane of two adjacent cells usually remain separated by a space of 10 to 150 A^o wide. This inter-cellular space is uniform and contains a material of low electron density which can be considered as cementing distance.

2.1.4 SPECIALISED STRUCTURES OF PLASMA MEMBRANE

To perform certain functions like absorption, secretion, transportation etc., these are certain modifications in the plasma membrane. Most specialized, important structures of plasma membrane are the following.

A. Specialisations due to out pushings or Evagination

Microvilli

The columnar epithelial cells of intestinal epithelium have to perform active absorption of digestive food. The free surfaces of these epithelial cells give out minute finger like cytoplasmic processes of plasma membrane which are known as the microvilli. The microvilli are 0.6 to 0.8 μm long and have the diameter of 0.1 μm (1000A^o) represent cytoplasmic process covered by the plasma membrane. With in the cytoplasmic

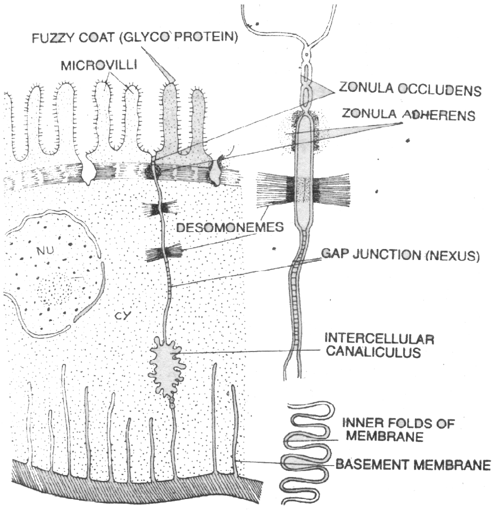

Fig.9 Specializations of plasma membrane

core fine microfilaments are observed which in the cytoplasm form a terminal web. The outer surface of the microvilli is covered by a coat of filamentous material (fuggy coat) composed of glycoprotein macromolecules. A cell may contain about 300 microvilli. The narrow spaces between the microvilli form a kind of seive through which substances may pass during the process of absorption. Microvilli increase the surface area of absorption. They occur in low number in the hepatic cells mesothelial cells of the convoluted tubules of the kidney and epithelial cells of gall bladder, uterus and yolk sac.

B. Specialisation due to in Pushings or Invaginations

The bases of certain cells perform active transportation like the cells of kidney and contain many invaginations or infoldings of the plasma membrane. At the base of these folds these develop a septa and thus narrow compartments of basal cytoplasm are formed. These foldings contain many mitochondria which provide energy to the plasma membrane for the active transportation of solutes.

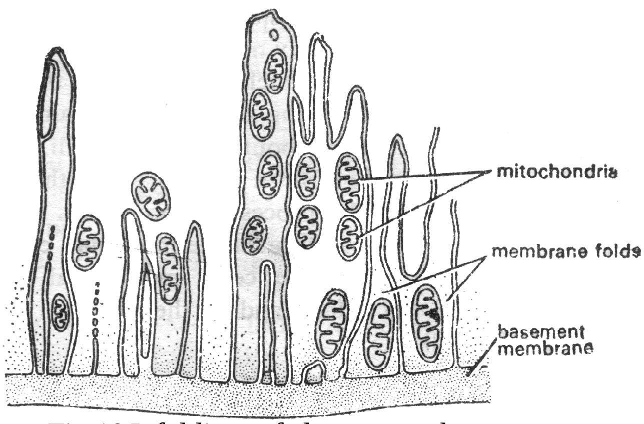

Fig.10 Infoldings of plasma membrane

C. Specialisation in plasma membrane due to contact

The plasma membrane of adjacent cells often remain separated by a uniform inter cellular space but at certain places the plasma membrane of adjacent cells may come too close or may go too far. The specialisations of plasma membranes are as follows.

1. Desmosones or Macula Adherens

In some epithelial cells, the plasma membrane of adjacent cells become thicker in certain regions and from these thickened areas may fine filaments known as tonofibrils or tonofilments are radiated towards the interior of the cell. Such thickened areas of plasma membrane are known as desmosomes. The desmosomes are formed by a circular area of 0.5 μ in diameter and plasma membrane of two adjacent cells are separated by a distance of 300A°-500A°. With in the intercellular gap a coating material occurs which sometimes forms a discontinuous middle dense line. This extra cellular material contains acid mucopolysaccharides and proteins. The extracellular coating material provides cellular adhesion at the desmosomes and the tonofibril filaments provide intracellular mechanical support and they are restricted only to veterbrate tissues.

2. Hemidesmosomes

Kelly (1966) has reported half portion of the desmosomes at the basal surfaces of the certain epithelial cells and named then as hemidesmosomes. They resemble with desmosomes in finer details but their outer side remain coated with collagen fibrils.

3. Septate Desmosomes

These are present in invertebrate epithelia, and here the two plasma membranes remain separated by a distance of 150 to 200A° and both remain joined by many transverse parallel septa. These septa are found to be continuous up to outer proteimaceous layers of plasma membranes. The septate desmosomes lack the inter cellular cementing substance and tonofilaments of desmosomes. They act like attachment or adhesive devises of cells and they also permit inter cellular communication and electrical coupling.

4. Terminal bars (*Zonula Adherens*)

The terminal bars are also known as intermediary junctions or *Zonula adherens*. The terminal bars are similar to desmosomes except they lack in the tonofibrils. The plasma membrane is thickened with dense cytoplasm. The terminal bars occur in the intermediate portion of the plasma membrane of columnar cells just below the surface.

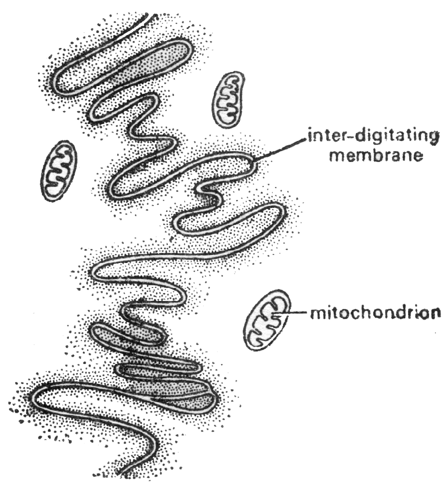

Fig.11 Inter digitations of plasma membrane

5. Inter digitations

At some places the plasma membrane of two adjacent cells give out finger like projections known as inter digitations. The inter digitations may become further complicated by the development of desmosomes and terminal bars, etc.,

6. Tight junctions of *Zonula occludens*

At certain places the plasma membrane of two adjacent cells fuse so internally that the inter cellular space become wanting. Such fusions of the plasma membrane are known as tight junctions or *Zonula occludens*. The tight junctions act as barriers for diffusion of the substances through these regions. They occur in brain cells and act as blood brain barriers and the synaptic barriers.

7. Gap Junctions or Nexus

The cells of Myocardial tissue contain a inter cellular gap of 20A^{o} wide between their plasma membranes. These gaps are found to be hexagonal (70-75A^{o} wide) in tangential sections. These hexagonal gaps are known as gap junctions. When the inter cellular gap becomes 40-70 A^{o} wide, then such junctions are called close junctions.

2.1.5 PHYSIOLOGY OF PLASMA MEMBRANE

The plasma membrane acts as a thin barrier which separates the inter cellular fluid or the cytoplasm from the extra cellular fluid in which the cell live. The important physiological functions of plasma membrane are as follows.

A. Permeability

It is a thin elastic membrane around the cell which allows small ions and molecules of various substances. This nature is called permeability. According to permeability following types of the plasma membranes have been recognised.

1. Impermeable Plasma Membranes: The plasma membrane of the unfertilized eggs of certain fishes allows nothing to pass through except the gases. Such membranes can be termed as impermeable membranes.

2. Semi permeable membranes: The membranes which allow only water but no solute particles to pass through then, they are known as semi permeable membranes. These were not recognised in animal cells.

3. Selective permeable plasma membrane: The plasma membrane and other intra cellular unit membranes are very selective in nature. Such membranes allow only certain selected ions and small molecules to pass through them.

4. Dialysing plasma membrane: The plasma membrane having certain extraneous coats around it as the basement membranes of endothelial cells act as a dialyser. The water molecules and crystalloids are forced through them by the hydrostatic pressure forces.

B. Osmosis

The plasma membrane is permeable to water molecules. The to and fro movement of water molecules through the plasma membrane occurs due to the differences in the concentration of solutes on its either sides. The process by which the water molecules pass through a membrane from a region of higher water concentration to the region of lower water concentration is known as Osmosis. The process in which the water molecules enter in to the cell is known as Endosmosis while the reverse process is known as Exosmosis. While the reverse process is known as Exosmosis. In plant cells due to excessive exosmosis the cytoplasm along with the plasma membrane shrinks away from the cell wall. This process is known as plasmolysis.

A cell contains a variety of solutes in it. For example the mammalian erythrocytes contain the ions of potassium, calcium, phosphate, dissolved haemoglobin and many other substances. If an erythrocyte is placed in a 0.9% solution of sodium chloride (NaCl) then it neither shrinks nor swells. In such case because the inter cellular and extra-cellular fluids contain same concentrations and no osmosis takes place. This type of extra cellular solution or fluid is known as isotonic solution. If the concentration of NaCl solution is increased above 0.9%, then the erythrocytes are shrinked due to excessive exosmosis. Such solutions which have the higher concentration of solutes than the intracellular fluids are known as hypertonic solutions. If the concentrations of NaCl solution decreases below 0.9% the erythrocytes will swell up due to endosmosis. The extracellular solutions which contain less concentration of the solutes than the cytoplasm are known as hypotonic solutions.

The amount of water inside the cell causes a pressure known as hydrostatic pressure. The hydrostatic pressure which is caused by the osmosis in known as osmotic pressure. The plasma membrane maintains a balance in between the osmotic pressure of the intracellular and intercellular fluids.

C. Diffusion (passive transport)

When two kinds of molecules are placed together they tend to mix with each other by a process known as the diffusion. The diffusion of certain solutes of substances takes place through the plasma membrane. Such diffusing solute particles require no energy for the diffusion process through the plasma membrane. The diffusion of ions through the plasma membrane depends on the concentration and electrical gradients.

High concentration

Diffusion ¬ ↑ Active transport
Ø ↑
Low concentration

D. Active Transport

This is the movement of molecules or ions through the plasma membrane from lower concentration to higher concentration against concentration gradient. They require energy for such movement. The energy is provided by adenosine triphosphate (ATP). This occurs in nerve cells and kidney cells. Through the pores of plasma membrane some chemical compounds such as urea, glycerol etc. could pass actively. Large molecules of certain proteins for example ribonuclease has been found to actively pass through the plasma membrane of living plant cells, eggs, flagellates etc.,

E. Poermease System

The genetically determined permease system involves a specific membrane protein specialized for transport and located at plasma membrane. The E. coli contains about 30 to 60 such permease systems for the transport of various molecules.

F. Endocytosis & Exocytosis

Sometimes the plasma membrane participates actively in the ingestion of certain large sized foreign or food substances. The process by which the foreign substances are taken in and digested by the cell is known as endocytosis. In the process of exocytosis the cells which have secretory function such as pancreatic cells pass out their enzymatic secretions outside the cell. Depending on the nature of foreign food substances the endocytosis is divided into: (1) Pinocytosis (pinacocytosis) (2) Phagocytosis.

1. Pinacocytosis

If the ingestion of the fluid material in bulk takes place by the cell through the plasma membrane the process is known as pinacocytosi

In the process of pinacocytosis the particle free globules of fluid named as pinosomes by Lewis are surrounded and ultimately engulfed by the clasping folds of the cytoplasm. The plasma membrane forms membranous vacuoles around the pinosomes. In later stages the pinosomes are transported to the interior of the cell where they are fused with lysosomes to form the digestive vacuoles. The digestion of food substances takes place in the food vacuoles and the digested food is diffused in to the surrounding cytoplasm.

The micro pinacocytosis is one which occurs at the submicroscopic level. In this process the cytoplasm invaginates to form vesicles of 650A^{o} diameter which have opening on both outer and inner surface which suggest the possible transportation of fluids through these vesicles to the cell. *E.g*. Endothelial cells, Schwann cells etc.,

2. Phagocytosis

Sometimes the large sized food or foreign particles are taken in by the cell through the plasma membrane. The process of ingestion of large sized solid substance by the cell is known as phagocytosis. It occurs in most protozoans and certain cells of multicellular organism. It occurs very actively in granular leucocytes and in the cells of mesoblastic origin.

During the process of phagocytosis first the particle adheres to the mass of the protoplasm and then the particle actually penetrates the cell. This is subsequently by the plasma membrane which ultimately pinches of from the cell surface to form a vesicle or vacuole around the solid particle. The membrane bound vesicles or vacuoles are known as phagosomes. They move to the interior of the cell and fuse with the pre existing lysosomes to form digestive vacuoles. The food is digested by the hydrolytic enzymes of lysosomes and the digested food is ultimately diffused from the digestive vacuoles to the surrounding cytoplasm.

According to physical and chemical nature of the foreign substance following types are recognized.

1. Ultra phagocytosis or Colloidoplexy: Here the plasma membrane ingests smaller colloidal particles. Eg. Leucocytes and macrophagic cells of mammals.

2. Chromopexy: If the cell ingests colloidal chromogen particles phagocytotically, it is known as chromopexy. Eg. some mesoblastic cells.

G. Emeiocytosis

In some cells like pancreas a process reverse to that of endocytosis occurs. The vacuoles which have secretary products (enzymes) move from the interior of the cytoplasm towards the surface of cytoplasm. At the surface these vacuoles fuse with the plasma membrane and discharge their stored products to the exterior of the cell. This process is known as emieocytosis or cell vomiting or exocytosis.

2.1.6 ORIGIN OF PLASMA MEMBRANE

Different concepts have been forwarded by different workers concerning its origin.

1. According to some workers the plasma membrane is an independent organalle and it enlarges with cell growth autonomously.

2. According to many workers the plasma membrane is originated by self assembly of its component chemical molecules. Thus small complexes of membrane are originated in the cytoplasm and are inserted as blocks into the pre existing membrane. It includes many sequential steps. They are polymerisation of building blocks in to lipid and protein molecules. Next self assembly of lipid and protein molecules in to a basic membrane. Finally specialized functional components i.e., enzymatic proteins are inserted in the membrane system.

2.1.7 SUMMARY

- Cell surface in all cells is enclosed in cell membrane or plasma membrane.
- It is exceedingly thin, elastic, semipemeable, trilaminar, lipoproteinous living limiting membrane.
- Plasma membrane is composed of mainly protein, lipid and a small percentage of oligsaccharides that may be attached to either the lipids or the proteins.
- Plasma membrane has a trilaminar or tripartite structure two dense outer layers (proteins) separated by middle layers (lipids).
- Fluid mosaic model was proposed regarding the molecular organisation of biological membranes.
- To perform certain functions like absorption, secretion, transportation etc., there are certain modifications in the plasma membrane. They are microvilli, invaginations, Desmosomes, Hemidesmosomes, septate desmosomes, terminal bars, interdigitations, tight junctions, gapjunctions etc.
- The important physiological functions of plasma membrane are permeability, osmosis, diffusion, active transport, permease system, endocytosis, exocytosis, pinocytosis, phagocytosis, emteocytyosis etc.

2.1.8 KEY TERMINOLOGY

Plasma Membrane: Cell surface in all cells is enclosed in a cell membrane or plasma membrane which is thin, elastic, semipermeable, trilaminar, lipoproteinous, living limiting membrane.
Ghost: To obtain plasma membrane from human erythrocytes the cells are treated with hypoptonic solution which produce swelling and loss of haemoglobin. The remaining membrane is called as 'ghost'.

Unit membrane: All membranes have some fundamental pattern despite differences in functional and metabolic properties and ultrastructural variations. In all the cells membrane occurs around the cell as plasma membrane and also other cell organelles. That is why it is called as unit membrane.
Trilaminar structure: Plasma membrane contains two dense outer layers made up of proteins, which are separated by a less/dense middle layer made of lipids. This is called trilaminar structure.
Fluid mosaic model: Lipids and integral proteins are disposed in a kind of mosaic arrangement and biological membranes are quasifluid structures in which both the lipids and integral proteins are able to perform translational movements with in the over all bilayer.

Intercellular space: The plasma membranes of two adjacent cells usually remain separated by a space of 10-150A^{o}. This intercellular space is uniform and contains a material of low electron density.

Microvilli: The free surfaces of the epithelial cells gives out minute finger like cytoplasmic processes of plasma membrane which are known as microvilli.

Osmosis: The process by which the water molecules pass through a membrane from a region of higher concentration to a region of lower concentration is known as osmosis.

Active transport: The movement of molecules or ions through the plasma membrane from lower concentration to higher concentration using energy or ATP (against concentration gradient).

Phagocytosis: The process of ingestion of large sized solid substances by the cell is known as phagocytosis.

Pinocytosis: If the ingestion of the fluid material in bulk takes place by the cell through plasma membrane, it is known as pinocytosis.

2.1.9 MODEL QUESTIONS

1. Write an account of structure and chemical composition of plasma membrane.
2. Describe the specialised structures of plasma membrane.
3. Write an account of physiology of plasma membrane.

Short Answer Questions:

1. Fine structure of plasma membrane
2. Chemical composition of plasma membrane
3. Fluid mosaic model
4. Microvilli & out pushings
5. Desmosomes and Hemidesmosomes
6. Enzymes of plasma membrane
7. Interdigitations, Tight junctions and gap junctions
8. Permeability of plasma membrane
9. Osmosis and diffusion
10. Active transport
11. Phagocytosis and pinocytosis
12. Exocytosis and Endocytosis

2.1.10 REFERENCE BOOKS

1. Cell and Molecular Biology by De Robertis and De Robertis.
2. Elements of Cytology by Norman & Cohn.
3. A text book of cytology, genetics and Evolution by P.K. Gupta.
4. Cytology by P.S. Verma and Agarwal.
5. Cell Physiology by Arthur C. Geise.

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Lesson 2.2
CYTO SKELETON

2.2.1 Objective : It enables to understand the skeletal frame work of the cell.

2.2.2 Introduction : In eukaryotic cells the ground substances of the cytoplasm contains complex networks of fibrous protein structures. These are collectively known as Cytoskeleton. It forms an intracellular frame work it is composed of micro tubules, micro filaments and Intermediate filaments. Cytoskeleton is involved in 1) to define and control the shape of the cell 2) Cell movements 3) Cell divisions. All these componenets are composed of protein sub-units that can assemble and disassemble rapidly.

2.2.3 Microtubules : Microtubules were discovered by De Roberts and Franchi. The term 'micro tubule' was coined by Slautterback in 1963. Micro tubules are unbranched hallow cylindrical organellas . They are very fine tubes having an external diameter of about 24mm and with walls about 5mm thick. They are made up of helically arranged globular subunits of a protein called Tubulin.. They are several microns in length. At intervals, cross-bridges (arms) some times project from their walls and these are probably involved in linking with adjacent microtubules as occurs in celia and flagella. Growth of micro tubules occurs at one end by addition of tubulin sub-units. Microtubules are involved in the structural composition of centriolses, basal bodies, cilia and flagella.

Functions:

a) Microtubules play an important role in determining the shape of the cell.
b) During cell division the microtubules radiate from each end of the cell to spindle apparatus which helps in the movement of chromosomes to opposite poles.
c) Microtubules play a key role in the structure and movement of cilia & flagella
d) They are involved in the movements of other cell organells such as golgi vesicles, mitochondria etc.,

2.2.4 Microfilaments : Microfilaments are very fine protein filaments present in the cytoplasm of eukaryotic cells. It has a diameter of about 7mm. They are made up of actin protein which is found in muscle cells. Micro filaments often occur in sheets or bundles just below the cell surface membrane and at the interface between stationary and moving cytoplasm where cytoplasmic streaming is taking place. They are probably involved in endocytosis and exocytosis.

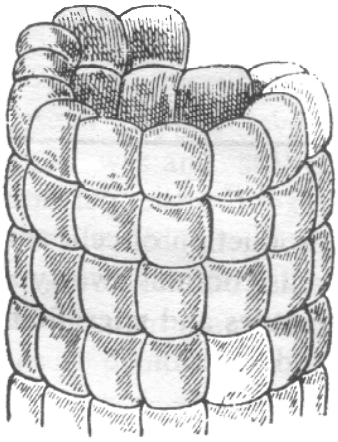

Fig.12 Sub-unit structure of micro tubule

A much smaller proportion of myosin filaments is also found in cells. Intraction between action and myosin are the cause of muscle contraction. Microfilaments are involved in cell motility. Actin filaments may operate alone in some cases and with myosin in others micro filaments are being assembled and disassembled in cells showing mobility. Microfilaments are involved in cytokinesis during cell division. It is brought about by construction of a ring of micro filaments.

Intermediate filaments : Many eukaryotic cells have tough, rope-like bundles of proteins known as intermediate filaments. They are made up of a variety of proteins like Keratin, vimentien, desmin, peripherin, lamin etc. they provide mechanical stability to cells.

Lesson 2.3

GOLGI COMPLEX

Contents:

2.3.1 Objective : The purpose of this lesson is to understand the historical aspects, structure, chemical composition, origin and functions of Galgi complex.

2.3.2 Introduction:

The Galgi Complex was discovered in 1898 by an anatomist Camillo Galgi. Unlike the endoplasmic reticulum, the membranes of the Galgi complex are smooth and not crusted with ribosomes. The Galgi complex appears as a group of granules or rods or vesicles nearer to nucleus or centrosome and these bodies are collectively known as galgi complex or galgiapparatus. These are variously described as dictiosomes idiosomes, Galgisomes etc. With suitable strains such as silver salts or osmium tetroxide or methylene blue, the galgi complex is easily identified and is easily distinguished from the mitochondria.

2.3.3 Defination : Galgi complex is canalecular system with stacked sacs, that stains with osmium tetraoxide and silver salts.

2.3.4 Occurance : The golgi complex is present in all types of cells except erythrocytes (RBC) and prokaryotic cells. It is more abundant in secretory cells than in non-secretory cells.

2.3.5 Distribution : The position of golgi complex is fixed for each cell type. In invertebrate cells, and plant cells the golgi complex is scattered through out the cytoplasm and is said to be diffused form. In cells that have polarized structure, it is disposed between the nucleus and the apical pole. This is described as localized form. In nerve cells it is circum nuclear. The golgi complex is surround by a zone form which most ribosomes, glycogen and mitochondria are absent. This zone is called zone of exclusion.

2.3.6 Number: The golgi bodies are more in number in secretory cells than in non-secretory cells. In liver cells a rough estimation indicates that there are about 50 golgi complexes per cell.

2.3.7 Size : The golgi complex is large in nerve cells and gland cells but small in muscle cells. The size is linked to the functional state. The golgi complex hypertrophies during hyper function and becomes reduced during hypofunction.

2.3.8 Structure : The electron microscope reveals that the golgi complex consists of three structural components. They are cisternae, vacuoles and vesicles (granules).

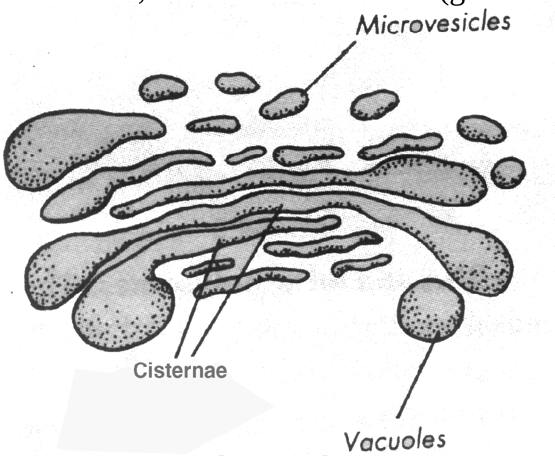

Fig.13 Golgi complex

a) Cisternae : The golgi cisternae are flattened, parallel sacs piled one upon the other to form stacks. The number of cisternae in a stack varies from species to species and some times form one developmental stage to another. In most animal and plant cells there are 3-8 cisternae in a stack. The cisternae are separated from one another by a space of about 130A^0. The membrane is homologus to the unit membrane and 60-70 A^0 . thick. The space in the cisternae is 60-150 A^0 wide. Each cisternae has a convex and concave surface. No connections are seen between the cisternae.

Mullenhaver and whalley (1963 suggested that the golgi complex is polarized and has a 'forming face' and 'maturation face' the forming or proximal face is generally convex and closer to the nuclear envelop or E.R the maturing or distal face is concave and encloses a region containing large secretory vesicles. At the forming face are present small vesicles or tubules called transition vesicles. These transition vesicles converge up on the golgi complex to form new cisternae. The trasition vesicles are formed form the E.R. the secretory vesicls containing secretory products are budded of from maturation face of the golgi cisternae.

b) Vacuoles; on the convex surface of the cisternae are present numerous large bag-like structures called 'vacuoles'. These are derived from the distal portion of the cisternae. Each vacuole is about 300-600 A0 in diameter.

c) Vesicles: The small vesicles are situated at the free ends of the cisternae. These are many in number and are formed by pinching off of the cisternae. Each vesicle is about 40 A^0 in diameter.

2.3.9 Chemical composition:

The chief chemical components of the golgi complex are proteins (60%) lipids (40%) enzymes like thiamine-pyrophosphatase and several glycosyl transferases (transfer oligosacharides to the glycoporteins) low level of RNA DNA, and polysaccrharides.

2.3.10 Origin :

In the dividing cells the Golgi complex is formed from the pre-existing fragments, i.e., the daughter cell with roughly half the number of Golgi complexes increases by self duplication. It is believed that the Golgi complex arises from the granular E.R. The granular E.R. first changes to smooth E.R. and then becomes the Golgi cisternae. The cisternae on the forming face are constantly being formed by fusion of vesicles derived from the E.R. These cisternae on the maturing face are believed to form the secretory vesicles.

2.3.11 Functions :

The Golgi complex may be considered as an intermediary compartment interposed between the E.R. and the extra cellular space. Through the Golgi complex various substances (fluids, macromolecules, cell wall units and other cell constituents) are exported to out side.

1) Glycosidation of proteins and lipids : The Golgi complex plays a major role in glycosidation of lipids and proteins to produce glycosphingolipids and glycoproteins.

2) Secretion : The main function of Golgi complex is cell secretion (exportable proteins, enzymes etc.), Secretion may be continuous (the secretory products are discharged without storage liver)

or discontinuous (the secretory products are stored in secretory granules or zymogen granules. – Pancreas, parotid gland etc.) The process of secretion includes the following six steps.

a) The ribosomal stage : The synthesis of proteins by polysomes attached to the rough E.R.

b) The cisternal stage : The synthesized proteins are enter into the lumen of the rough E.R.

c) Intracellular transport : In this stage the secretory vesicles diffuse through the rough E.R. and enter the transitional vesicles. The transitional vesicles move to the formative face of the golgi cisternae and fuses with it. Condensing vacuoles are formed at the maturation face of the Golgi cisternae.

d) Concentration of the secretion : By a process of concentration (loss of water) the condensing vacuole is converted into zymogen granule or secretory granules.

e) Intracellular storage : The secretory products are stored in the secretory or zymogen granules. These are released when appropriate stimulus acts on the cell.

Golgi complex mainly involved in the packaging of maternal for export from the cell across plasma lemne by a process of reverse pinocytosis. There is a long list of materials known to be packaged and transported through Golgi complex. (Animals : The Zymogeni of pancreatic ells, mucous secretions, lactoprotein of mamory gland cells, compounels of thyroxin, melanin granules and other pigments tropocollagen and collagen.)

f) Exocytosis : The discharge of the secretory granules is effected by a process called exocytosis. In this process the secretory vesicles move towards the apical region of the cell. The membrane of the secretory vesicles fuse with the plasmamembrane, so that the contents are placed outside the cell.

3) Formation of Primary Lymosomes : The Golgi complex is involved in the formation of primary lysosomes.

4) Storage and metabolism of fats : Fats are broken down in the digestive tract and are absorbed into the epithelial cells of the intestine as fatty acids and monoglycerides. These substances are used in the synthesis of lipids. The lipids are stored in the form of lipoproteins (chilomicrons).

5) Acrosome formation : The acrosome of supermatozoa is formed from the Golgicomplex

6) Plant cell wall formation : Durign cytokinesis a cell plate is formed between the two daughter nuclei. The cell plate is formed by the Golgi complex. The cell plate later develops into the cell wall.

7) Sulphation : Golgi complex take part in sulphate metabolism.

8) Regulation of fluid balance : In certain protozoa the Golgi complex is concerned with regulation of fluid balance like that the contractile vacuole.

2.3.12 SUMMARY

Galgi complex was discovered in the cytoplasm of nerve cells by Camillo Galgi in 1898. it is also called dictiosome Idiesome lipochondria etc. it is present in all eukaryotic cells except mammalian RBC. The golgi complex appears in two principal types 1) Localized type (fixed form) and 2) diffused type (scattered). Galgi complex is seen in the form of three components. 1) Cisternae 2) Vacules and 3) Vesicles Galgi complex consists of phospholopids and proteins.

The apparatus is prominently seen in the secretory cells of lever, pancreas, salivary and endocrine glands. In animal cells, the galgi complex involves in secretory activity storage synthisis of enzymes hormones, detoxification, acrosome formation etc.,

2.3.13 KEY TERMINOLOGY

Cisternae : Flattened parallel sacs

Diffused form : Scattered throught the cytoplasm

Forming face: A face which is convex and closer to the nuclear envelop or endoplasmic reticu lum of cisternae called forming face.

Localized form : Fixed form between the nuclus and the apical pole.

Maturation face : A face which is concave and a encloses a region containing large secretory vesicles called maturation face.

Zone of exclusion : Galgi complex is surrounded by a differtiated region of cytoplasm where ribsomes, mitrochondria etc. organelles are absent. This is called zone of exclusion.

2.3.14 Model questions

1) Write an essay on Golgi complex

2) Write short notes on a) History and structure of golgicomplex b) Functions of golgicomplex

2.3.14 Reference books

i) Cytology by Varma & Agarwal

ii) A text book of animal histology by A.K. Berry.

Lesson 2.4

LYSOSOMES [Lyso = Break down, some = body]

2.4.1 Objective
2.4.2 Introduction
2.4.3 Definition
2.4.4 Discovery
2.4.5 Occurrence
2.4.6 Distribution
2.4.7 Size
2.4.8 Shape
2.4.9 Structure
2.4.10 Polymorphism
2.4.11 Chemical composition
2.4.12 Origin
2.4.13 Functions
2.4.14 Summary
2.4.15 Model questions
2.4.16 Refference books

2.4.1 Objective :

It provides an insite in understanding the structure and functions of lysosomes.

2.4.2 Introduction :

Lysosomes were formarly identified as pericanalicular dense bodies lososomes consists of high content of acid phosphates and other hydrolytic enzymes. Because of their enzymatic properties they were named lysosomes. Lysosomes exhibit polymorphism

2.4.3 Definition :

Lysosomes are cell organelles bounded by a single layer of unit membrane containing acid-hydrolases and concerned with cellular digestion. They are commonly called suicidal bags or digestive vacuoles.

2.4.4 Discovery :

Lysosomes were first observed in 1949 in liver cells and were named as Pericanalicular bodies. In 1955 de duve renamed them as lysosomes because they contain lytic (digestive) enzymes.

2.4.5 Occurance :

Lysosomes are absent in prokaryotic cells and RBC of mammals. They have been found in most of the animal cells, Neurospora, yeast and other fungi. In plant cells the large vacuole may acts as lysosome generally lysosomes are most abundant in cells that are phagocytic and secretory in function. Eg. Liver cell, Pancreas, spleen, W.B.C. etc.,

2.4.6 Distribution : They are distributed through out the cytoplasms.

2.4.7 Shape : They have no characteristic shape. Generally they are spherical or irregular in shape.

2.4.8 Size : Each lysosome measures from 0.2 to 0.8 microns in diameter.

2.4.9 Structure : Lysosomes are round structures bounded by a single lipo-protin membrane (Unit membrane). The lysosomal membrane is resistant to the enzymes that it contains. The entire process of digestion is carried out within the lysosomes. The membrane protects the rest of the cell from the possible destructive effect of the enzymes. Certain substance and factors cause instability of lysosome membrane. Such substance are called labilizers Eg. Freezing, thawing, U.V-rays, A,K,E,D vitamins. Certain substance strengthen the lysosomes membrane. They are called stabilizers. Eg.Cartisone, cholestero, choroquine etc.,

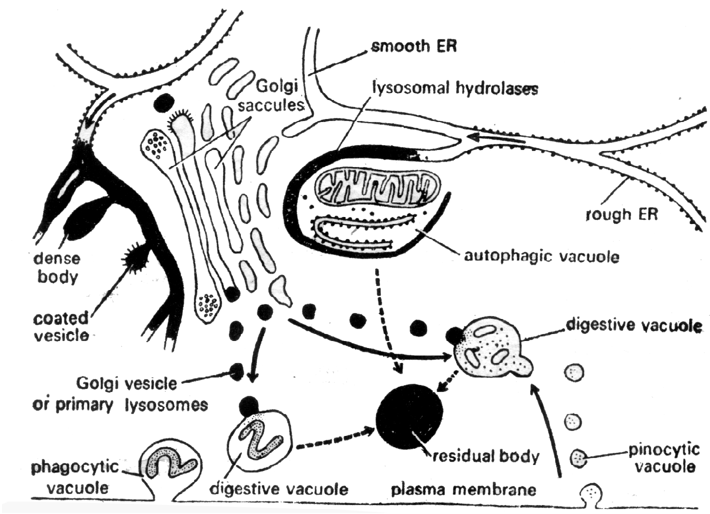

Fig.14 Formation of Lysosomes

2.4.10 Polymorphism in Lysosomes : Lysosomes show polymorphism. There are two basic types of lysosomes 1) Primary Lysosomes and 2) Secondary lysosomes. The secondary lysosomes are of three types 1) digestive vacuole 2) residual bodies and 3) autophagic vacuoles.

1) **primary lysosomes (storage granules) :** These are small sac-like bodies enclosing digestive enzymes. The enzymes of the primy lysosomes are synthesized by the ribosomes and accumulate in the E.R. From the E.Rthe enzymatic content in transported into golgi complex for final packing. From the golgi complex the primary lysosomes are budded off containg hydrolytic enzymes. Since these store enzyme, they are also called storage granules.

   Ribosomes® Endoplasmic reticulum ® golgi complex ® primary pysosomes

2) **Digestive vacuoles:** These are also known as hetero phagosomes or Secordary lysosomes. These are formed by the fusion of primary lysosomes with phagosomes. Phagosomes are formed in the cell due to phagocytosis of food or harmful microorganisms. The digestive vacuole contains engulfed materials and enzymes. The materials are progressively digested by the enzymes. In the destive vacuole.

3) **Residual bodies:** After digestion and absorption of digested food (amino acides, glucose and fatty acids) into the surrounding cytoplasm, the digestive vacuoles are left twith undigested substances. Now they are called residual bodies. They come to the cell surface, fuse with the cell membrane and discharge these contents to the outside.

   In vertebrates, a suitable mechanism is absent in the cells for the removal of these residual bodies. As a result they get accumulated in the lysosomes and are known as lipofucin granules. Their number increases with the increasing age of the cell. They may be the main cause of aging process in animals.

4) **Autophagic vacuoles:** (Cytolysosomes or autophagosomes: Autophagic vacuole is a lysosome containing part of their own cell (Mitochondria, part of E.R) in the process of digestion. By this way the cell achieves the break down of its worn out, part with out damaging the cell. By this mechanism the cell obtains energy at the time of starvation.

2.4.11 Chemical composition : The membrane of the lysosomes is formed of proteins and lipids. The lysosome contains acid phosphates and 36 types of hydrolytic enzymes. Oxidative enzymes are absent. Since most of the lysosomal enzymes function better under acidic conditions (PH = 4.6) they are collectively called as acid hydrolases.

2.4.12 Origin : Golgibodies are involved in the formation of lysosomes. The enzymes of the lysosomes are synthesized by the rough E.R.

2.4.13 Functions of Lysosomes :

Intracelluar digestion : Digestion of substances within the cell is called intracellular digestion. It may involve autophagy and heterophagy.

a) Autophagy : Lysosomes are involved in the digestion of ooher cell organelles like mitochondria, E.R etc., this function is called authophagy Unwanted materials from the cells are also removed by this process. They are first enclosed by a single membrane derived from smooth E.R. This structure is then fused with primary lysosomes to form autophagic vacuole. (Secondary lysosome) In the autophgagic vacuole the cell organells or unwanted materials are digested. It occurs at the time of starvation to facilitate survival. It is also part of the normal turnover of cytoplasmic organcells (i.e. old ones are replaced by new ones)

b) Cytophagy : Heterophagy is the intake of exogenous (out side) materials into the cell and the subsequent break down of this material by enzymes. The bulk intake of exogenous material (harmful, bacteria, proteins, facts, carbohydrates) into the cell is called Endocytosis (Phagocytosis and pinocytosis). Digestion of these substances occur in the digestive vacuole (secondary lysosome).

1) **Extracellular digestion :** The lysosomal enzymes may be released outside the cell by exocytosis. The enzymes take part in the hydrolysis of extra cellular material. Lysososmal enzymes are involved in bone erosion. Saprophytic fungi utilize extracellular digestion for nutrition. It helps in the removal of dead cells.

2) **Developmental process :** Many developmental process involve the shedding or remodeling of tissues. A large amount of larval tissue is destroyed during metamorphosis of insects, amphibian and other animals. This is accomplished by lysosomal enzymes. For example degeneration of the tadpole tail takes place by the action of enzymes. This distruction takes place in an organized and sequential manner. The products of tissue digestion are utilized in the synthesis of tissues of the adult forms. Thus lysosomes are involved in differentiation and metamorphosis.

3) **Autolysis :** (Cellular digestion): Lysosomes are involved in the digestion of damaged, old and diseased cells. During this process the lysosomal membrane is dissolved and they discharge the enzyme into the cell. These enzymes cause death of the cell (cell suicide) hence lysosomes are celled Atom bombs of cell.

4) **Cell hormone secretion and crinophagy :** Lysosomal enzymes are involved in the secretory activity of certain cells. For example thyroid hormones are released from the thyroid gland cells by the action of the lysosomal enzymes.

The name Crinophagy has been applied to a mechanism by which secretory granules, produced in excess of physiological needs may be removed. This is a special case of autophagy which was first observed in the pituitary gland.

5) **Fertilization :** The sperm acrosome of the spermatozoan (which develops from the Golgi complex) can be considered as a special lysosome. The acrosome contains protease, hyalurodinase and acid phosphatase. During fertilization of oocyte, hyalurodinase disperses the cells around it. The proteases digest the egg membranes and make way for the entry of sperm into the oocyte.

6) **Lysosomes and Human diseases :** There are about 20 congenital diseases called storage diseases which are caused due to accumulation of substances (glycogen, glycolipids etc.,) in lysosomes. These diseases are due to the absence of certain lysosomal enzymes.

a) The enzyme DNA are released from the lysosomes may cause mutatious in DNA resulting in cancer.

b) Due to over supply of vitamin A, lysosomes present in chondroblasts and osteoblasts rupture and cause damage to cartilage and bone.

In the absence of the enzymes glycosidase, glycogen accumulate in cells resulting in Pompes disease.

2.4.14 Summary

Lysosomes were discovered and named by Christian de duve in 1955 in the liver celts. They are found in all eukaryotic cells except mammalian RBC. They are spherical or irregular sac like structures covered by a single unit membrane. These are filled with digestive enzymes or hydrolyses like acid phosphalases, proteases and ribonuclease. They exhibit polymorphism. Polymorphism is the result of the association of primary lysosomes with the different materials that are phagocytized by the cell. There are four types of lysosomes of which only the first is the primary lysosome. The other three may be grouped together as secondary lysosomes. i.e, digestive vacuoles, Autophagosomes and residual bodies. Lysosomes play a vital role in extracellular and intra cellular digestion.

2.4.15 Key terminology

Autophagosomes : These are lysosomes which dissolve cytoplasmic inclusions of the same cell as and when needed.

Digestive vacuoles : It is formed by the fusion of primary lysosome with the phagosome or engulfed vasicle.

Primary lysosomes : It is a newly formed lysosome from golgi complex

Residual bodies : These are lysosomes which are having undigested material

2.4.16 Model Questions :

1) Write an essay about lysosomes

2) Write short notes on Types of lysosomes

2.4.17 Refference books

1) Cytology by Verma & Agarwal

2) Cell and molecular biology by de Robertis & de Robertis

Lesson - 2.5

MITOCHONDRIA

2.5.1 Objectives :

The purpose of this lesson is to develop an ideal about structure of Mitochondria and role of mitochondria in cellular respiration.

2.5.2 Introduction :

Mitochondria are granular or filamentous or rod shaped structures present in the cytoplasm. They are the major sites of aerobic respiratory activity within the cell. They are considered as "power houses" or "power plants" of the cell. They are semi-autonomous, self replicating cell organelles. They are described as cell with in a cell. Mitochondria were first discovered by Kolliker (1882) in striated musele cells and he named them as sarcosomes. However the credit for the discovery of Mitochondria is given to Flemming and Altman (1894). They described them as bioblasts. The name mitochondria was coined by C.Benda (1897). The role of mitochondria in cellular respiration was discovered by Michaelis (1898).

2.5.3 Occurance:

Mitochondria are present in all eukarryotic cells except in RBC of mammals they are absent in prokaryotic cells (bactriria).

2.5.4 Distribution:

Generally mitochondria are evenly distributed through out the cytoplasm are able to move to areas in the cells where a lot of activity takes places and ATP as is greater. In other cells they are located permanently near the region of the cell where more energy is needed. In muscle cells they are intimately associated with myofibrils. In sperm cells they are confirmed to middle piece. In the nerve cells they are concentratred in the region of impulse transmission.

2.5.5 Number :

The number of mitochondria per cell varies considerably and depends on functional state of the cell. Cells which have high energy requirement (high metabolic activity possess large number of mitochondria, where as less active cells possess few mitochondria. For example yeast cells have smallest number of mitochondria.

Kidney cell – 300-400, Liver cell – 1000-600, Oocytes – 3,00,000, Chaos chaos – 50,000

2.5.6 Shape :

The shape of mitochondria is variable. In general they are rod like or filamentous they are able to change shape. The shape of mitochondria varies from one cell type to another. The shape is more or less constant in those performing the same function. They may be spherical, elongated cup shaped and even branched.

2.5.7 Size:

The size of the mitochondria is highly variable. In most cells the length ranges form 1.5 – 10 microns and width 0.25 – 1 micron.

2.5.8 Structure:

Mitochondria can be observed in living condition by staining with janus green B vital dye). The ultrastructure of mitochodrian shows envelopes, matrix and cristae. The mitochondrian consists of two membranes, outer membrane and inner membrane. Each membrane is $60A^0$ thick and is made up of lipo-protein layers. (unit membrane structure) the space between the outer and inner membranes is called outer chamber or perimitochondrial space. It's thickness is about 60-80 A^0. It is filled with a fluid containing enzymes. The inner memberane encloses a cavity known as Inner chamber. The inner chamber is filled with mitochondrial matrix. The matrix contains filamentous or granular material, ribosomes DNA, Ca^{++} and Mg^{++} ions.

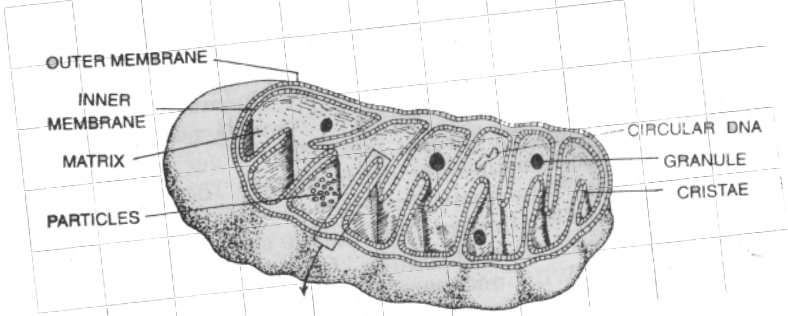

Fig.15 Structure of Mitochondria

2.5.9 Cristae :

The inner membrane forms finger like projections in to the matrix called mitochondrial cristae. The number and arrangement of cristae are variable. In kidney cells cristae are arranged transversely like stock of coins. In nerve cells and muscle cells the cristae are arranged longitudinally to the long axis of mitochondria. In protozoans insects and edrinal gland the cristae are tubular instead of lamellar. Cristae divide the matrix in to compartments. The cristae increase the surface area of the inner membrane.

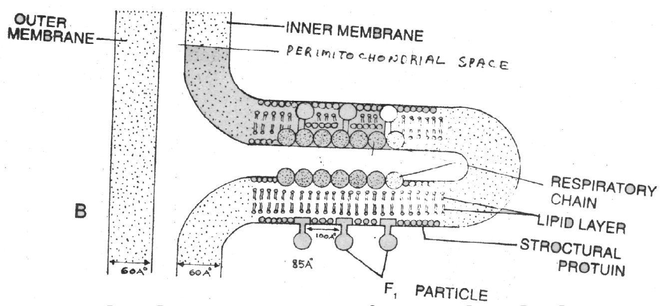

Fig.16 Molecular organization of a mitochondrial cristae

2.5.10 F_1 Particles (or) elenenrtary particles (or) fernande-Margan particles (or) oxyosomes :

H- Fernandz and Morgan (1962) discovered that the inner memberance of the mitochondria is lined with numerous, small, tennis rocket, shaped particles called F_1 particles or elementary particles or oxysomes. The F_1 particles are regularly placed at a distance of 100 A^0 . It has been caluculated that the number of F_1 particles may be 104-105 per mitochondrian. Each F_1 particle consists of three parts – head, stalk and base.

Head : It is polyhydral and 8-10 mm in diameter.

Stalk : It is 5mm length and 3-4nm wide.

Base : It is cuboidal with 4x10 nm measurements. The F_1 particles represent a special atp ase involved in coupling of oxidation and personal relation. The F_1 particles are homologous to quantosomes of chloroplast.

2.5.11 Chemical composition :

The two membranes of mitochondria are similar to that of unit membrane structure. Chemically they are formed of proteins (65%-70%) and lipids (25%-30%) Mitochondria contain various enzymes that help in oxidative – phosphorylation. The inner membrane contains enzymes for kerb's cycle. The matrix also contains DNA, RNA, ribosomes and inorganic elements like Fe, Cu, S, Hg, etc., Due to the presence of DNA, RNA, and ribosomes mitochondria can replicate and synthesise their own proteins. So they are known as semi-autonomous cell organells or cell with in cell.

2.5.12 Mitochondrial DNA/mDNA :

Mitochondria contains one or more DNA molecules called mitochondrial DNA (mDNA). It is double helical and circular in shape. It measures about 5 microns in length. The presence of mDNA was first discoved by Nass (1963). It can self replicate. The mDNA resembles that of bacterial DNA. The mDNA helps in the synthesis of RNA and proteins required by the mitochondria.

2.5.13 Origin of mitochondria :

The life span of mitochondria is about 5-10 days. There are several theories regarding the biogenesis of mitochondria.

1. By the division of pre-existing mitochondria: The new mitochondria originate by the division of the pre existing mitochondria. The mitochondria are distributed in to the daughter cells during cell division. During interphase the mitochondria divide by fission or budding or by septum formation.

2. Origin from the E.R. or P.M: Robert son has suggested that mitochondria may be formed from plasma membrane or endoplasmic reticulum by invagination.

3. De nova origin: Harvey (1951) has suggested that mitochondria may be synthesized from simpler building blocks. MDNA and nuclear DNA take part in the synthesis of new mitochondria.

4. Prokaryotic origin: According to Altmann and Schimper (1890) the mitochondria might have originated from prokaryotic cells like bacteria. The bacteria entered the eukaryotic cells as parasites. In the course of time they maintained a symbiotic relationship with the eukaryotic cells. The symbiotic bacteria later become the mitochondria. The similarities between the mitochondria and bacteria supports the symbiotic orgin of mitochondria

1. In both cases the DNA is circular and double helical.
2. In both the ribosomes are 70s type.
3. Certain bactiria have numerous projections extending from the plasma membrane forming mesosomes. These can be compared to cristae.
4. The enzymes for electron transport system are localized in the inner surface of the P.M. in bacteria, where as they are present –lining the inner membrane of mitochondria.
5. The general dimensions of bacteria and mitochondria are similar.

2.5.14 Functions :

1. Source of energy
2. Palade suggested that middle piece of spermatozoa of most animals is formed by mitochondria.
3. Green (1960) predicted that mitochondria are building sites of facts.
4. Mitochondria are actively engaged in the synthesis of steroid hormones.
5. Lowez and Srivastav (1965) stated that mitochondria play the main role in yolk formation in the developing ovum.

   Mitochondria as source of energy: Altman has suggested that the mitochondria are concerned with cell respiration. During this process energy is released in the form of ATP due to break down of materials (carbohydrates, fats, proteins). Hence mitochondria are described as “power houses of the cell” during cellular respiration food materials are oxidized in the presence of O_2 into CO_2 and

H_2O. One of the most important fuels is glucose.

$$C_6H_{12}O_6 + 6O_2 ® 6CO_2+6H_2O + Energy$$

Under aerobic conditions glucose metabalism takes place in four stages. They are 1) Glycolsis 2) Pyruvic acid oxidation 3) Krebes citric acid cycle 4) electron transport system.

Glycolysis: The break down of glucose to pyruvic acid is called glycolysis. It occurs in the cytoplasm of the cell. In glycolysis one molecule is split in to two molecules of pyruvic acid. The splitting taken place in nine separate steps. During this process two molecules of ATP are formed from ADP and four hydrogen atoms are passed to NDA.

Glucose ® Pyruvate + ATP + H_2

Glycolysis is also called Embeden – Meyer Hof path way.

Pyruvic acid oxidation: Under aerobic conditions the pyruvic acid molecule is metabolized to a molecule of acetyle coenzyme-A. The three carbon pyruvic acid molecule is oxidized yielding one molecule of CO_2 and two carbon fragment known as acetyle group. The acetyle group combines with a coenzyme-A forming acetyle coenzyme A.

Fats and amino acids can also be used as energy sources after first being converted in to acetyl co-a.

One Mole Glucose ® two mole of puruvate +2ATP+H2

Pyruvate acid +O_2® Acetyle group + CO_2

Acetyle group +COA® Acetyle coA

When oxygin is available, the two pyruvate molecules are broken down completely to CO_2 and water releasing the remaining energy stored in the bonds. These stages of kreb's cycle and electron transport chain-takes place within mitochondria.

Krebs cycle or tricarboxylic acid cycle: In the kreb's cycle the acetyle group (CH_3CO) released from CoA and joined to four carbon compound called oxaloacetric acid, a six carbon compound Citric acid is there by produced. In the course of the kreb's cycle citric acid is oxidized to form CO_2 and oxaloacetic acid. Kerbs cycle takes place under aerobic conditions. The enzymes for the kerb's cycle are located in the matrix of the mitochondria.

The energy stored in pyruvate molecule is used to form three molecules of from NAD_{ox} and one molecule FAD_{red} from FAD_{ox} and ATP from ADP. The oxaloacetic acid is formed in the last step of the krebs cycle. The krebs cycle can agin begin another actyl group combines with the oxalic acid molecule.

Electron transport chain : (oxidative phosphorelation)

In the electron transport chain the electrons accepted by NDA and FDA during the preceeding reactions (glycolysis and krebs cycyle) are passed to a series of electrons carries cytochrome system. The cytochromes of respiratory chain act as carriers of electrons(the cytochrome in the electron chain pass the electrons). which pass the electrons rapidly from one to another are usually referred to as electron carriers). As the electrons are passed down hill along this electron transport chain energy is released. This energy is trapped by ADP and inorganic phosphate molecule to form ATP. The process of ATP formation is known as oxidative phosphorylation.

$$\text{ADP+ pi+ energy} \rightarrow \text{ATP}$$

At the end of the chain the electrons are accepted by protons (hydrogen atoms) and combine with oxygen to produce water.

Each time one pair of electron passes from NAD to oxygen, three molecules ATP are formed from ADP and inorganic phosphate. Each time a pair of electrons passes from FAD two molecules of ATP are formed. In this process 36 ATP molecules are formed. A single glucose molecule yield 38 ATP molecules (2 from glycolysis and 36 from krebs cycle.)

Conclusion

Mitochondria are the centers of oxidative phosphorylation and ATP synthesis. In them the fuel molecules (earbohydrates, fats) are completely and finally oxidized and the chemical energy contained in them is extracted as metabolic energy. The oxidation process is always coupled or linked with phosphorelation of ADP. In this process ADP molecules capture the released energy, undergo phosporylation and produce ATP. In the energy-bonds of ATP energy is conserved in a biologically available about the extraction, trapping and conservation of energy through the transformation of the potential chemical energy of fuel molecules to the Potential biological energy of ATP molecules.

2.5.15 Summary

Mitochondria are the minute granular, filamentous or rod-like bodies found scattered in the cytoplasm of both animal and plant cells. They are also known as chondriosomes or power houses of cell. They differ in size, shape and distribution in the various cells. The most important function of the mitochondria is their respiratory activity. They carry important enzymes concerned with cell respiration and the energy released in the process is used in producing ATP molecules. The respiratory efficiency depends upon the number of their cristae, enzymes, co-enzymes etc., kerb's cycle occurs in the matrix of the mictochondrion and electron transport along the cristae. The cristae are covered with stalked granules termed oxysomes which are thought to be the locaton of enzymes involved in electron transport. The respiratory mechanism of mitochondria includes a series of chemical reactions ultimately liberating energy.

2.5.16 Key terminology

Cristae : Finger like inard projections (towards matrix) of the inner membran of the mitochondrion.

F_1 particles : Small, tennis rocket shaped particles present in the innermembrane of the mitochondria.

Matrix : A substance that is filled in inner chamber of the mitochondria

2.5.17 Model questions

1) Explain why mitochondria are also called as power houses of a cell

2) Write short notes on structure of mitochondria

Lesson 2.6

CHROMOSOMES [Chroms = Colour, Soma = body]

2.61 Objective

The purpose of this lesson is to understand the structure, chemical composition, types of chromosomes and giant chromosomes.

2.62 Introduction :

Chromosomes are self-duplicating coloured, rod-shaped or filamentous bodies located inside the nucleus. They are seen only during metaphase & enaphas stages of cell division. In the interpahse they are not visible. Chromosomes are in the form of chromatin net-work in the interphase nucleus/ chromosomes are carriers of hereditary units calles genes.

2.6.3 History :

Chromosomes were first discovered by Hofmeister (1848). The term chromosome was coined by Waldeyer (1889). W.Rouxu (1883) suspected the involvement of chromosomes in the mechanisms of inheritance. Sutton and Boveri (1901) proposed Chormosomal theory of inhertonce. According to this theory, chromosomes are physical carriers of genes (hereditary units)

Chromosomes are in maximum condensed state in Metaphase and pachytene substage of meriosis. Chromosomes can be stained by unsing dyes like haematoxylin, acetocaramine and acetorcine

2.6.4 Number :

The chromosomal number is constant for each species. This was discovered by Ven Beneden. It is species specific. All the members of a species have the same number of chromosomes. The chromosomal number varies from species to species. A prokaryotic cell has a single circular chromosome. A eukaryotic cell contains more than one linear chromosomes.

1.	Homo sapien (man)	46
2.	Oryctologus (rabbit)	44
3.	Golumbia livia (pigeon)	80
4.	Rana (frog)	26
5.	Culex (Mosquito)	06
6.	Hydra	32

whole collection of chromosomes present in the nucleus of somatic cell is known as chromosomal complement. The term genome is used to describe a haploid set of Chromosomes. A cell with one genome (single set chrosomes) is called haploid. It is represented by "n" or "x". A cell with two genomes (two sets chromosomes)is called diploid. It is represented by '2n' or '2x'. Somatic cells have diploid number of chromosomes. If more than two sets of chromosomes are present, we can use the term polyploidy. For example triploids (3n) have three sets of chromosomes, tetraploids (4n) have four sets of chromosomes. Polyploidy was discovered by

Lutz. Polyploidy can be induced by using colchicine.

In some cases one one or more chromosomes are missing or added to the normal somatic chromosome number (2n). This condition is described as aneuploidy. The different types of aneuploids are Monosomic (2n-1), trisomic (2n+1), Nullisomic (2n-2) and Tetrasomic (2n+2) etc.,

The lowest haploid chromosomal number recorded in eukaryotes is two (n=2). Eg Mesostoma (flat worm) and Ophiotrocha (Polychaeta). In Ascaris megalocephala only one chromosome is found, but this is a compound chromosome which divides into as many as 190 chromosomes in somatic cell. In animal the highest recorded chromosomal number is 127 in Euphagurus scotensis

In somatic cells chromosomes occur in pairs known as homologous pairs the two chromosomes of a homologous pair are similar in size, shape, structure and carry the same number and type of genes. They always come from two different parents. One is called maternal chromosome and the other is paternal chromosome.

2.6.5 Types of chromosomes :

In eukartotes chromosomes are of two types : Autosomes and allosome.

a) Autosomes or Somatic chromosomes The chromosomes which carry genes that control somatic characters are called autosomes. They are more in number.

b) Allosomes orsexchromosomes or heterosomes; The chromosomes which carry genes useful in sex determination are called Allosomes or Heterosomes or sexchromosomes. X and Y chromosomes are known as sex chromosomes. For example in a diploid cell of human beings out of 23 pairs of chromosomes 22 pairs are autosomes and 1 pair is allosomes (Man 44xy,Woman 44xy).

2.6.6 Structure:

Size : The average length of the chromosome varies from 0.5 microns to 30 microns in length and 0.2 microns to 3 microns in diameter. The giant chromosomes reach a length of 300 microns.

Shape : The shape of a chromosome is determined by relative length of arms and position of centromere. Portions of chromosome present of either side of centromere are called arms. The ratio of length of long arm to that of short arm is called arm ratio.

Arm Ratio = Length of long arm

Length of short arm

chromosomes are classified into Four types . They are as follows :

1) Metacentric : In this type the centromere is in the middle of the chromosome. So the two arms are almost equal in size. The chromosome appear 'v' shaped during anaphasic movement.

2)Sub-meta centric : In this type the centromere is situated some distance away from the middle (mid-point). So one arm of the chromosome is shorter than the other. These chromosomes appear 'L' shaped during anaphasic movement.

3)Acrocentric : In this type the centromere is located near the end of the chromosome. So the chromosome has one very long arm and the other very short arm. The chromosome is rod shaped.

1) Telocentric : In this type the centromere is located at the tip of the chromosome. This chromosome is rod shaped. It has only one arm. Telocentric chromosomes are very rare.

2.6.7 Fine Structure of the Chromosome :

The chromosome consists of a coiled thread called Chromonema. The word chromonema was coined by Vijdovsky (1912). Dupraw proposed the folded model theory of Chromosome. According to this theory the chromosome consists of a tightly folded fibre (chromonema) which has a diameter of 20-30mm. The folded fibre is supposed to contain DNA and histone helix in a super coiled condition. The metaphasic chromosome consists of two chromotides (chromonema) which are held together by a centromere.

The two sister chromatids of each chromosome are coiled in relation to each other. This is referred to as relational coiling. It is of two types.

1) Paranemic coiling : in this type the chromosomal threads can be easily separated

2) Plectonemic coiling: In this type the chromosomal threads are twisted together, so that they can not be separated easily. The chromosome coils through out its length. The degree of coiling differs in meiotic and mitotic chromosome. Chromosomes have two distinct coils major and minor coils. The minor coils are small and perpendicular to the major coils. In mitotic chromosomes a helical structure similar to major coils are observed. This is called somatic coiling.

Paranemic coils

Plectonemic coils

Fig.17 Two types of coils of chromonemal threads

Chromomeres : The chromomeres are bead-like, darkly stained regions present on the chromosome. These are the tightly folded regions of the chromonema. The region between the chromomeres is called interchromomere

Centromere or Primary constriction: The narrow region of the chromosome than the rest of the chromosome is called centromere to this region of the chromosome are attached the mitotic spindle during cell division. It does not absorb colour under electron microscope it appears as thin, dense, plate-like body in which a number of spindle fibers are attached. It may be partly responsible for organizing the spindle. The position of the centromere is constant for a particular chromosome centromere place an important role in the movement of chromosomes towards poles during anaphase of cell division. In the metaphasic chromosome four granules can be seen with in the centromere. These granules are called centromeric chromomeres.

Depending upon the number of centromeres the chromosomes are classified into monocentric (single centromere) dicentric (two centromeres) Polycentric : (Many centromeres) : In some chromosomes the centromere is diffused through out the chromosome (Eg. Ascaris megalocephala). The chromosomes lacking the centromere is called accentric, It does not take part in mitosis as spindle fibres can not be attached to it.

Secondary Constrictions : In addition to the primary constriction (centromere) some chromosomes may have one or more secondary constrictions.

Nuclear organizer (or) Secondary construction : Normally in each diploid set of chromosomes, two homologous chromosomes have additional constrictions called nuclear organizers. They are so named because the nucleolus is formed from these regions during teleophase.

Satellite : The portion of the chromosome present distal to secondary constriction. It is called satellite. Chromosomes bearing satellite is called SAT chromosomes. (Sino Acid Thymonuclinoco). There are at least two SAT chromosomes in a diploid nucleus. In a SAT chromosome, nucleolus is attached to secondary constructions.

Telomere : The tips of the chromosomes are called telomeres (Muller). It differs in structure and composition from the rest of the chromosome. It has a unique polarity. It prevents joining of chromosomes with one another.

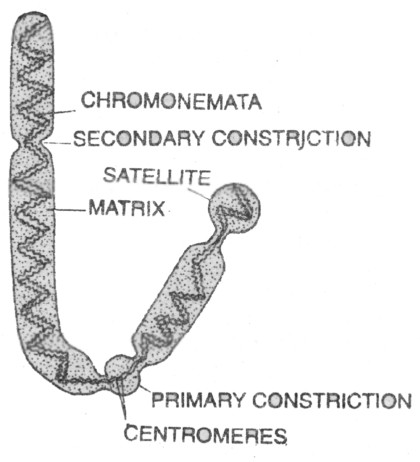

Fig.18 Structure of Chromosomes

2.6.8 Karyotype :

[A set of chromosomes of an individual or species is called Karyotype] The physical appearance of all the chromosomes of a given species is called karyotype.

A species can be characterized by its karyotype, since the number, size and shape of the chromosomes are constant within species. The karyotype differs from species to species.

2.6.9 Idiogram : The karyotype is characteristic of a species. It may be represented by a diagram called Idiogram. In this diagram the pairs of homologus chromosomes are arranged in a series of decreasing size.

2.6.10 Heterochromatin and euchromatin :

Certain regions of the chromosomes of the entire chromosomes take more stain (Fuelgin – basic) and are dark in colour. It is because in these regions the chromonima is more coiled and compact. These regions are called heterochromatin (Hietz). The other regions take less stain and are lightly coloured because in these regions the chromonema is less coiled. These regions are called euchromatin. This property of differential staining is called heteropicrosis : chromosomes which remain condenced during interphase are called hetrochromosomes Eg. The sex chromosomes of insects, one of the two X chromosomes in woman. The non condensed chromosomes which extend during interphase are called euchromosomes. For many years the heterochromatin regions of the chromosomes were considered to be divoid of genetic activity. In recent times, however, important genes are recognized to be present in the heterochromatin regions. Euchromatin is involved in transcription as it contains active genes.

2.6.11 Homologous chromosomes :

Chromosomes which are similar in size, shape and heredity are called homologous chromosomes. Homologous chromosomes exists in pairs, one chromosome of a pair is derived from the male parent (Paternal chromosome) and the other from the female parent (maternal chromosome)

2.6.12 Chromosome map :

A diagram showing the order of genes along a chromosome is called chromosome map. The arrangement of genes on chromosomes is linear. The position of gene one chromosome is called locus. The unit of distance between genes on a chromosome is called Morgan unit. The genes occupying the corresponding loci on the homologous chromosomes are called alleles.

2.6.13 Chemical composition :

Chromosomes of eukaryotic cells are composed of DNA (45%) and histone proteins (45%) with small amounts of chromosomal RNA (3%). The chromosomes of prokaryotic cells (bacteria) are composed of DNA only. The histone proteins are bounded to the DNA. This DNA protein complex is called chromatin. The histone proteins form a precise architectural 'skeleton' for the DNA

2.6.14 Nucleosomes :

TheDNA helix conbines with group of eight histone molecules to form structures called Nucleosomes. They appear like beaeds on a string. The term nucleosome was coined by oudet (1975). Each nucleosome is formed of chain of DNA having 140 base pairs making 1 ¾ turns and twist around a hsitone octomer. The chore of nucleosome consists of 4 histones – H_2A, H_2B, H_3, H_4. Another histone is associated with linker region of DNA. The nucleosomes are again coiled having about 6 nucleosomes per turn. The super coiled fibre is refered to as solenoid.

2.6.15 Functions :

1) chromosomes are the physical carriers of heredity
2) They control cell metabolism

Mutations and variations are caused by chromosomes.

2.6.16 GAINT CHROMOSOMES

In certain cells special type of giant chromosomes may be observed. They are characterized by their enoromous size. The gaint chromosomes are recognized in to two types. 1. Polytene chromosomes (salivary gland chromosomes), 2. Lamp brush chromosomes.

POLYTENE CHROMOSOMES

Discovery : Polytene chromosomes were first observed by Balbiani (1881)

Occurrence : Polytene chromosomes are found in tissues of salivary glands, gut, trachea, fat body cells, malpighian tubules of many insects of the order dipteria sPolyutene chromosomes are also called salivary gland chromosomes.

Polytene cells : The cells that contain Polytene chromosomes may be called Polytene cells. These cells do not undergo mitosis.

The Polytene chromosomes are formed as a result of endomitosis. During endomitosis the DNA duplicates and the resulting DNA strands (chromatids) do not separate but remain aligned side by side. For example a salivary gland charomosomes of Drosophila melanogaster contains about 1000 DNA fibres which arise form 10rounds of DNA replication.

Structure: In D.melanogaster the volume of polytene chromosomes is about 1000 times grater than that of the normal somatic chromosome. The total length of the four chromosome set is 2000 microns compared to 7.5 microns in somatic cells. In polytene chromosomes the homologus chromosomes pairs as in meotic prophase. This phenomenon is called somatic pairing. The polytene cells are in permanent interphase. The centromers of all the four pairs of chromosomes unite forming a chromocenter.

Bands and inter-bands: All along the length of the polytene chromosomes a series of dark bands altrrnate with the clear zones called interbands. The dark bands represent reigions where the DNA is more tightly coiled. In the inter bands the DNA fibres are less coiled. The dark bands are feulgin positive and stains darkly. The interbands are feulgin negative and do not take the stain. It is supposed that each band represent a gene. That shows in drosophila 5000 genes are present. Recent investigations show that the interbands also bear genes.

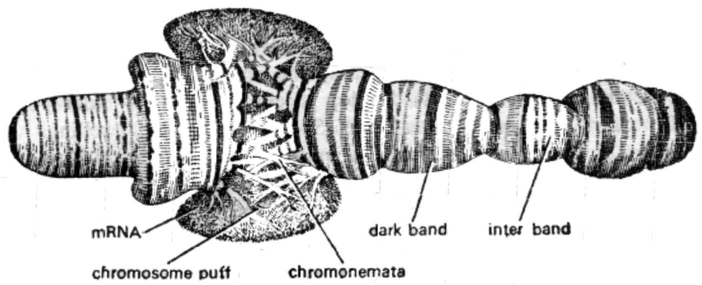

Fig.19 Polytene chromosome of an insect

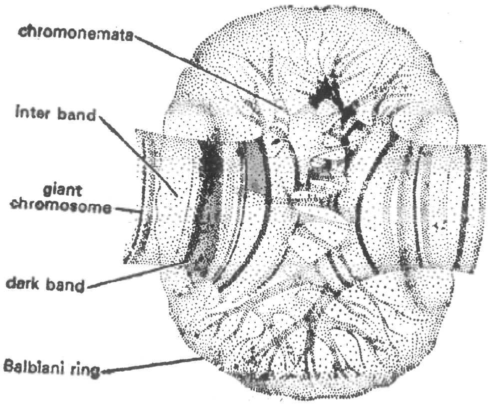

Fig.20 A balbiani ring of a polytene chromosome

Chromosome puffs: The bands of polytene choromosomes became enlarged ar certain regions to form swellings called puffs of Balbiani rings. That is at these regions the Dna unfolds in to open loops and actively synthesizes the m-RNA. Puffs are the morphological expression of transcription and conseqyently protein synthesis, puffs can be induced experimentally by the hormone and by temperature shock.

LAMP-BRUSH CHROMOSOMES

Discovery: Lamp-brush chromosomes were first discovered by Flemming (1882) in amphibian oocytes. The detailed structure of this chromosome was given by Ruckert in 1892. The functional significance in relation to this structure was discovered by H.G.Gallan. The lamp-brush chromosomes were so named because they appear like brushes once used to clean the chimneys of oil lamps.

Occurance: Lamp brush chromosomes occur at the diplotene stage of meiotic prophase in oocytes of all animal species.

Size: In many animals the lamp brush choromosomes may be more than 1000 microns in length and 20 microns in width.

Structure: since these chromosomes are found in meiotic prophase they are present in the form of bivalents. Each bivalent has four chromatids two in each homologue. The two chromosomes of a bivalent are held together by ehiasma. The axis of each choromosome consists of a row of chromomeres. Each chromosome consists of a main asxis and many lateral loops. At the regions of chromomers each chromatid forms characteristic lateral loops. They arise one on each side of the axis along the chromosomes. The chromomers are feulgin positive heterochromatian and the loops are feulgin negitive (euchromatin). The loops are surrounded by a matrix. The matrix is formed of RNA and poteins. The matrix gives fuzzy appearance. The lamp brush loops represent units of genetic activity (transcription) in which DNA is uncoiled and intense RNA synthesis takes place. Synthesis of proteins takes place in the lateral loops.

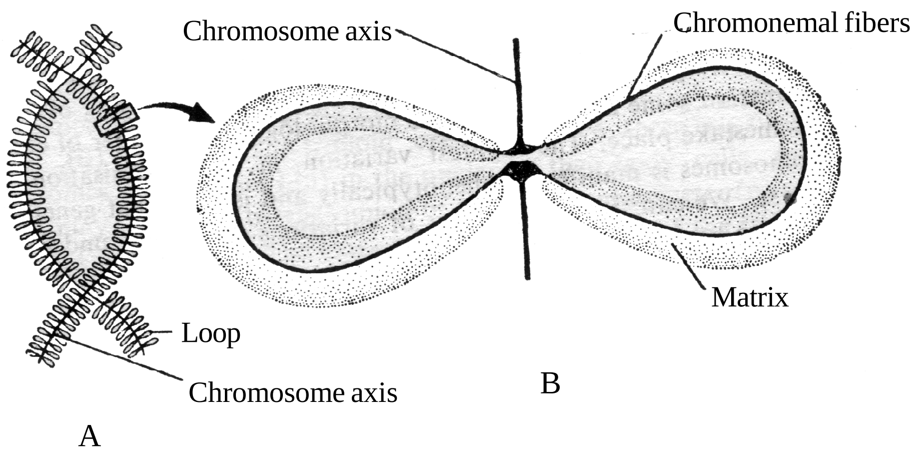

Fig.21 A) Lamp brush chromosome (at low magnification)
B) Loop magnified

2.6.17 SUMMARY :

Chromosomes ar deeply staining protoplasmic bodies. The name chromosome was coined by waldeyer in 1888. the number of chromosomes is characteristically constant to every species, but varies from species to species. In interphase stage, the nucleus has chromation fibres in the form of net work. During cell division the chromosomes become deistinet and rod like. Chromosome differ greatly in size in different organisms. Based on the position of the centromere, they are classified into telocentric, acrocentric, submeta centric and meta-centric. Chromosomes are the vehicles for the transmission of hereditary characters to offspring. Some cells at certain peculear stages contain large nuclei with giant or large sized chromosomes. The giant chromosomes are the polytene or lamp brush chromosomes.

2.6.18 KEY TERMINOLOGY

Acro centric chromosome: A rod like chromosome having the centromere at one end thus giving a vary short arm and an extremely long arm

Sub meta centric chromosome : J shaped chromosome

Metacentric chromosome : The chromosome have equal or almost equal arms and are thus V shaped.

Telocentric chromosome : It is a Rod like chromosome and have a centromere on the proximal end.

Telomere: The extremities of a chromosome are termed as telomere.

SAT chromosomes: The chromosome which bears a satellite is called a SAT chromosome.

2.6.19 Model Questions

1) Write an essay about chromosomes.

2) Write short notes on

a) Structure of metaphase chromosome

b) Giant chromosomes.

2.6.20 Reference Books

1) Cell biology by Varma and Agarwal

2) Cell phiosiology by Arthur C.Geise

3) Cell and Molecular biology by de.Roberties & de.Roberties