BSCZO- 104

B. Sc. I YEAR

PRACTICAL ZOOLOGY

DEPARTMENT OF ZOOLOGY

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY

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BSCZO-104

Practical Zoology

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Course 4: Practical Zoology

Course code: BSCZO104 **Credit: 3**

11	**Minor dissections /Permanent slide preparation:** Permanent preparations / Minor dissections of the following: Paramecium Porifera: Sponge spicules and gemmules. Coelenterates: Obelia colony, Obelia medusa. Arthropoda: Mouth parts of honey bee, butterfly, cockroach and grasshopper.	321-354
12	**Cytological study:** a. Study of mitosis and meiosis using available material. b. Study of permanent slides showing stages of cell division, giant chromosome, , mitochondria, Golgi body etc	355-409
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UNIT 1: PROTOZOA (STUDY OF PERMANENT SLIDES)

Contents

1.1-Objectives:

- To study General characters of Phylum Protozoa and its classification up to order.
- Study of permanent slides & study of Protozoan's with particular reference to *Amoeba*, *Paramecium, Ceratium, Noctiluca* , *Euglena, Plasmodium* , *Monocystis, Trypnosoma, Leishmania* , *Entamoeba* and *Giardia* .

1.2-Introduction

- The Protozoa are heterogeneous assemblage of some 50,000 cellular or single- cell organism found worldwide in most habitats. Protozoa means 'first animal' the simplest form of animal life. Protozoa are unicellular microorganisms (eukaryotes) that lack cell walls. They are found in marine habitat or soil, in fresh water bodies, symbiotic, some forms are parasites in other organisms. Protozoa depends on nutrition, temperature, pH, and some depends on sunlight.
- Protozoa were defined as unicellular protists with animal-like behavior, such as movement. Protozoa were regarded as the partner group of protists to protophyta, which have plant-like behavior, e.g. photosynthesis. The term protozoan has become highly problematic due to the introduction of modern ultra structural, biochemical, and genetic techniques, which have showed that the group does not form a clade as required by modern classifications. Modern unicellular clades within Eukaryotes which may be viewed as approximately collectively replacing the class of protozoa include: *Excavata, Amoeba, Chromalveolata* and *Rhizaria*.
- Protozoan's are usually single-celled heterotrophic eukaryotes containing non-filamentous structures that belong to any of the major lineages of protists. They are restricted to moist or aquatic habitats (i.e., they are obligate aquatic organisms). Many protozoan species are symbionts, some are parasites, and some are predators of feces bacteria and algae. There are an estimated 50,000 protozoan species.

- The Protozoa are considered to be a subkingdom of the kingdom Protista, although in the classical system they were placed in the kingdom Animalia. More than 50,000 species have been described, most of which are free-living organisms; protozoa are found in almost every possible habitat. The fossil record in the form of shells in sedimentary rocks shows that protozoa were present in the Pre-Cambrian era. Anton van Leeuwenhoek was the first person to see protozoa, using microscopes he constructed with simple lenses. Between 1674 and 1716, he described, in addition to free-living protozoa, several parasitic species from animals, and *Giardia lamblia* from his own stools.

1.3- General Characters of phylum Protozoa:-

1. Protozoa are microscopic animalcules with very simple organization.
2. These are unicellular, having one or more nuclei.
3. The body may be naked or protected either with the pellicle or with skeleton in the form of test or cyst.
4. The single cell of the body performs all the vital activities i.e. there is no physiological division of labour.
5. Animalcules may be "free living, commensal or parasitic. The free living forms are aquatic, inhabiting fresh and slat waters. These may be solitary or colonial. The parasitic forms reside on or inside the body of animals and plants.
6. Nutrition may be holozoic (animal-like), holophytic (plant-like), saprozoic (subsisting on dead organic matter.) saprophytic (feeding on liquid food) or parasitic.
7. The digestion is intracellular and is accomplished inside the food vacuole.
8. Locomotory organs may be pseudopodia or flagella or cilia or absent.
9. Respiration and excretion are brought about through the general body surface. The contractile vacuoles help in osmoregulation and excretion.
10. Asexual reproduction by binary fission, multiple fission and budding and Sexual reproduction by gamete formation or by the conjugation of adult.

Classification of Protozoa:-

Outline Classification of Phylum Protozoa:-

Subphylum: 1. Sarcomastigophora

Superclass: 1. Mastigophora

ClassA. Phytomastigophorea = (Phytoflagellata)

Orders: 1. Chrysomonadida 4. Euglenida
2. Cryptomonadida 5. Chloromonadida
3. Dinoflagellida 6. Volvocida

Class B. Zoomastigophora (Zooflagellata)
1. Rhizomastigida 2. Kinetoplastida
3. Choanoflagellida 4. Diplomonadida
5. Hypermastigida 6. Trichomonadida

Super class: 2 Opalinata

Order: Opalinida

Superclass: 3 Sarcodina

Class: A Rhizopodea

Subclass :(a) Lobosia

Orders: 1**.** Amoebida 2. Arcellinida (=Testacida)

Subclass b. **Filosia** **Subclass** c: **Granuloreticulosia**

Order: 1. Foraminiferida

Class B. Piroplasmea

Order: Piroplasmida

Class C. Actinopodea

Subclass a. Acantharia b. Heliozoia
c. Radiolaria d. Proteomyxidia
e. Mycetozoa

Subphylum: II Sporozoa

Class A. Telosporea

Subclasses: a. Gregarinia b. coccidian

Classes B Toxoplasmea C. Haplosporea

Subphylum: III Cnidospora

Classes A: Myxosporidea B: Microsporidea

Sub-phylum: IV Ciliophora

Class:a. Ciliata

Subclass:a. Holotricha

1. Gymnostomatida 2. Trichostomatida
3. Chonotrichida 4. Apostomatida
5. Astomatida 6. Hymenostomatida

Subclass: b. Peritrichia

Order: 1. Pertrichida

Subclass: c. Suctoria **Order:** suctorida

Subclass: d. Spirotrichia Orders: 1. Heterotrichida

2. Oligotrichida **3.** Hypotrichida

1.4-Study of Protozoan's:

1.4.1 Amoeba and Paramecium

Amoeba:-
Systematic position

Phylum:	Protozoa
Subphylum:	Sarcomastigophora
Class:	Rhizopoda
Order:	Amoebida
Genus:	*Amoeba*
Species:	*proteus*

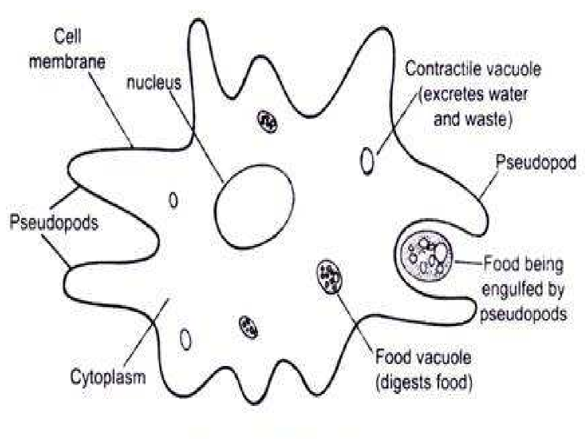


Fig: 1 Amoeba

Habit and Habitat:

Amoeba proteus is widely distributed. It is commonly found on the bottom mud or on underside of aquatic vegetation in fresh water ponds, lakes, springs, pools and slow running streams. It is rarely found in, free water as it requires a substratum to glide on from place to place.

Distribution: - It is found all over the world.

Identifying Characters:-

1 Animal is **irregular shape**, with simple or branched pseudopodia measuring 250 to 600 microns in diameter.
2 Cytoplasm is differentiated into **ectoplasm** and **endoplasm.** Ectoplasm contains ectoplasmic ridges.
3 Body of the animal is covered by a thin, delicate and permeable plasma membrane, called as plasma lemma.
4 **Endoplasm** contains nucleus, food vacuole, contractile vacuoles, water globules and crystals.
5 Permanent posterior end is called as uroid.
6 Withdrawal of pseudopodium and new pseudopodium containing endoplasm is present
7 Feeding may be studied by giving carmine. Nutrition is holozoic.
8 Reproduction by binary fission & Multiple fission
9 Amoeba proteus move by the formation of pseudopodia.Pseudopodia are blunt, finger like extensions of the ectoplasm containing endoplasm (lobo podium).

Special significance: *Amoeba* has unique phylogenetic significance and it is referred as immortal. Recently certain free living *Amoeba* has been found to be pathogenic causing meningeo encephalic.

Identification: Since the animal has pseudopodia and above feature, hence it is *Amoeba* ***proteus.***

Paramecium:-

Classification

Phylum …	Protozoa
Subphylum….	Ciliophora
Class …	Ciliata
Subclass…	Euciliata
Order……	Holotricha
Suborder……	Trichostomata
Family…..	Paramecidae
Genus……	*Paramecium*

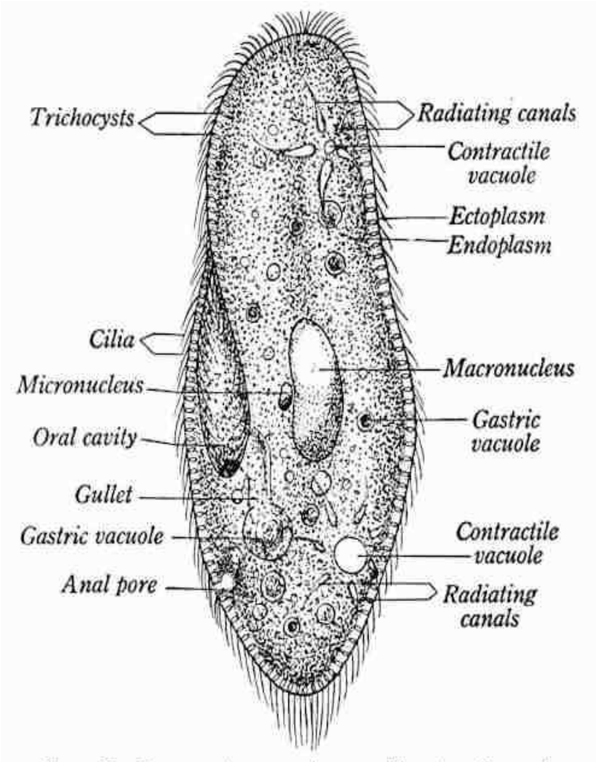


Fig.2 Paramecium

Habit and habitat: - *Paramecium* is best known **ciliate**, found in fresh water ponds, rivers, lakes, streams and pools, etc.

Distribution: - It has cosmopolitan distribution.

Identifying Characters:-

1 Commonly called as slipper animalcule, being microscopic, elongated, slipper- shaped cigar-shaped or spindle shaped.
2 Most familiar and extensively studied protozoans.
3 Pellicle covers the body. It is clear firm and elastic cuticular membrane. Pellicle has series of polygonal or hexagonal depressions for trichocysts.
4 *Paramecia* propel themselves by whiplash movements of their cilia, which are arranged in tightly spaced rows around the outside of their body.
5 The beat of each cilium has two phases: a fast "effective stroke," during which the cilium is relatively stiff, followed by a slow "recovery stroke," during which the cilium curls loosely to one side and sweeps forward in a counter-clockwise fashion.

6 The densely arrayed cilia move in a coordinated fashion, with waves of activity moving across the "ciliary carpet," creating an effect sometimes likened to that of the wind blowing across a field of grain.

7 *Paramecia* live mainly by heterotrophy, feeding on bacteria and other small organisms. A few species are mixotrophs, deriving some nutrients from endosymbiontic algae (chlorella) carried in the cytoplasm of the cell.

8 Osmoregulation is carried out by contractile vacuoles, which actively expel water from the cell to compensate for fluid absorbed by osmosis from its surroundings

9 The number of contractile vacuoles varies from one, to many, depending on species

10 *Paramecia* reproduce asexually, by binary fission. During reproduction, the macronucleus splits by a type of amitosis, and the micronuclei undergo mitosis. The cell then divides transversally, and each new cell obtains a copy of the micronucleus and the macronucleus.

11 Fission may occur spontaneously, in the course of the vegetative cell cycle. Under certain conditions, it may be preceded by self-fertilization (auto gamy), or it may follow conjugation, a sexual phenomenon in which *Paramecia* of compatible mating types fuse temporarily and exchange genetic material.

12 During conjugation, the micronuclei of each conjugant divide by meiosis and the haploid gametes pass from one cell to the other. The gametes of each organism then fuse to form diploid micronuclei. The old macronuclei are destroyed, and new ones are developed from the new micronuclei.

13 Auto-gamy or conjugation can be induced by shortage of food at certain points in the *Paramecium*.

Identification: - Since the animal contains slipper- shaped body and two contractile vacuoles while are star –shaped and has all above features hence it is *Paramecium*.

1.4.2 Euglena:-

Classification:-

Phylum … Protozoa

Subphylum … Plasmodroma

Class…. Mastigphora

Order… Euglenoidina

Genus... *Euglena*

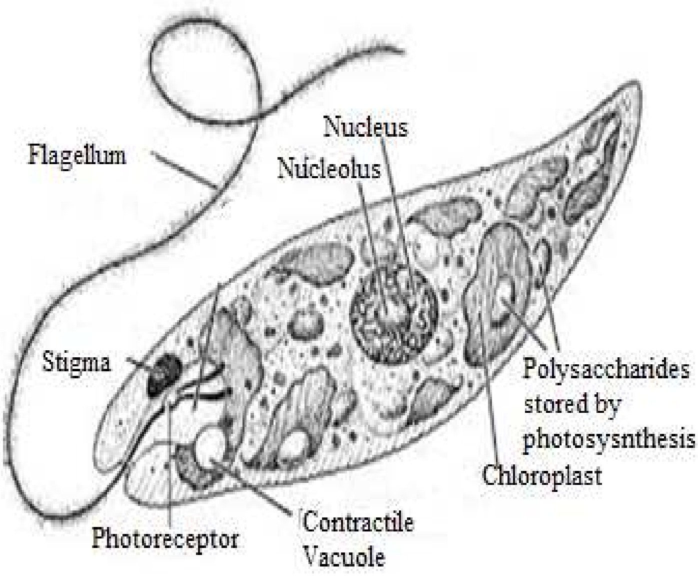


Fig.3 Euglena

Habit and Habitat:

- *Euglena* is solitary flagellate found commonly in freshwater ponds, ditches, pods,

And slow running, stream and in brakish water.

Distribution: Cosmopolitin.

Comments:

- Body of animal is simple fuse form, spindle shaped plump like red or green colour.
- *Euglena* measure 50 to 100 microns in length.
- Outer covering is called as pellicle which are marked by an spiral striations called as myonemes
- Anterior end has funneled shaped cytosome which leads into a flask –shaped cytopharynx.
- On one side is a red mass of hematochrome called stigmata which is photosensitive
- Endoplasm contains nucleus ,chloroplast and other ultra structural organelles
- Nutrition holophytic or saprophytic and reproduction by longitudinal division or encystment.

- *Euglena* does not take solid food but lives entirely by autotrophic and saprozoic nutrition. It
- Is unique animal with floral mode of nutrition and funnel mode of life and reproduction?
- *Euglena viridis, E .rubra, E. sanguine* and *E.fusiformis* are common spices they respond to various stimuli such as light heat etc.

Special feature:

- *Euglena* is unique animal with floral mode of nutrition and faunal mode of reproduction.

Identification: Since the animals have chloroplast and all above features, hence it is *Euglena.*

1.4.3:- Ceratium & Noctiluca

Ceratium:-

Classification:

Phylum: Protozoa

Subphylum: Plasmodroma

Class: Mastigophora

Order: Dinoflagelleta

Genus: *Ceratium*

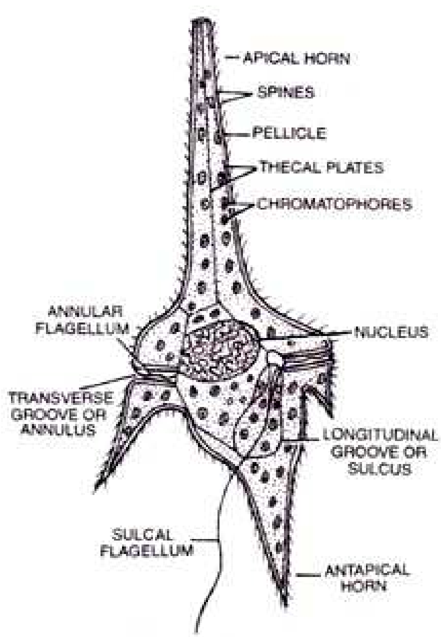


Fig.4 Ceratium

Comments:

1. Body of *Ceratium*, Fig. 4. Is usually covered with a grooved cellulose wall known as lorica or theca.
2. The covering of the body consists of variable number of plates which are variously sculptured.
3. Shape of the body is triangular due to the presence of an anterior or apical and two lateral spines or horns.
4. There are two grooves on the shell or theca, a transverse and a longitudinal, each containing a flagellum which projects out through a pore.
5. Transverse groove is called annulus and runs like a circular or spiral girdle around the body.
6. Longitudinal groove or sulcus extends obliquely backwards.
7. Single large and central nucleus.
8. Chromatophores are numerous, green in freshwater forms and yellow or brown in marine forms.
9. Nutrition is holophytic or holozoic. Reserve food material starch and oil.
10. Reproduction by fission. Cyst formation also occurs.

Habit and habitat: *Ceratium* is found in freshwater ponds, lakes and in marine plankton.
Distribution: *Ceratium* is common is U.S.A (Woods Hole.)

Noctiluca:-

General Characters:

- Most of them are solitary.
- Most of two flagella of unequal length.
- Cellulose cell wall of plates.
- Ceratium -blooms colour water brown and have fish/septic odor.

Classification:-

Phylum: Protozoa

Subphylum: Plasmodroma

Class: Mastigopora

Subclass: Phytomastigina

Order: Dinoflagellata

Genus: *Noctiluca*

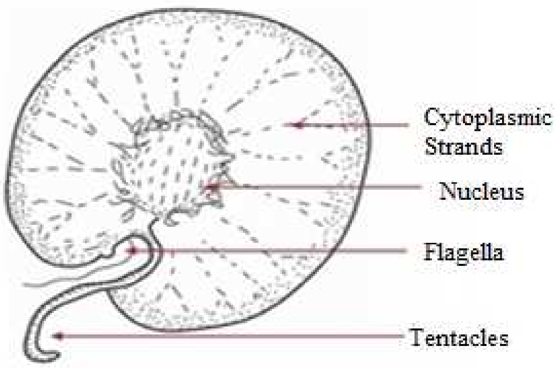


Fig. 5 Noctiluca

Habit and habitat: *Nocitiluca* is the most common marine pelagic and bioluminescent floating on the sea usually near the shores often in vast numbers. Sometime their number become so large that they form a thick scum on sea surface cove ring several acres.

Distribution: It is abundantly found in the Atlantic and Pacific oceans.

- **Comments :**
  - Body more or less is the gelatinous spherical with indistinct grooves and measuring Approximate ly 1 mm in length.
  - Body is covered by a stout pellicle.
  - Cytoplasm is highly vacuolated and is differentiated into ectoplasm and endoplasm. Cytoplasm is further differentiated into central cytoplasm and peripheral cytoplasm.
  - Mouth is elongated having pouch like cytopharynx.
  - Nutrition is holozoic .two flagella procure food particals.
  - Reproduction is by gamete formation and fission or by swarm spore formation.

Special features: Whenever the uniform light is seen in the sea, it is undoubtedly due to dinoflagellates, which own the old mystery,"**the burning of sea**"

Idetification: Since the protozoan cantains protoplasmic strands and all above Features, hence it **is Noctiluca**.

1.4.5 Trypanosome Gambians & Plasmodium

Systematic position:

Phylum: Protozoa

Subphylum: Sarcomasigophora

Super class: Mastigophora

Class: Zoomastigophora

Order: Kinetoplastida

Genus: *Trypanosoma*

Species: *gambians*

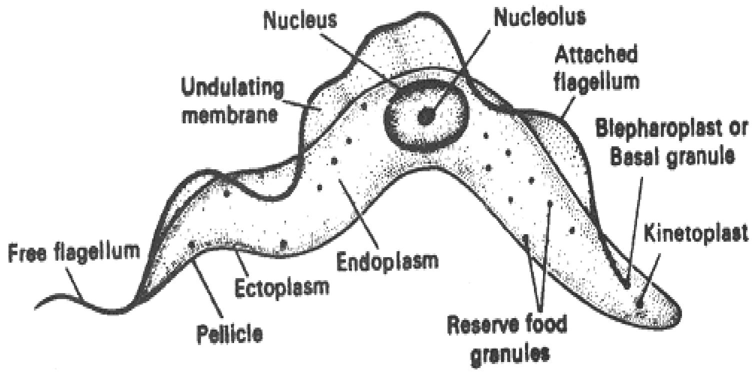


Fig.6 Trypanosoma

Distribution:-

It is found in Africa and America. It has been reported from India also.

Comments

- Unicellular, microscopic, simple animal commonly found in Africa.
- It is an endoperasite found in blood and other tissues of man and other vertebrates. It causes Trypanosomiasis or Sleeping sickness

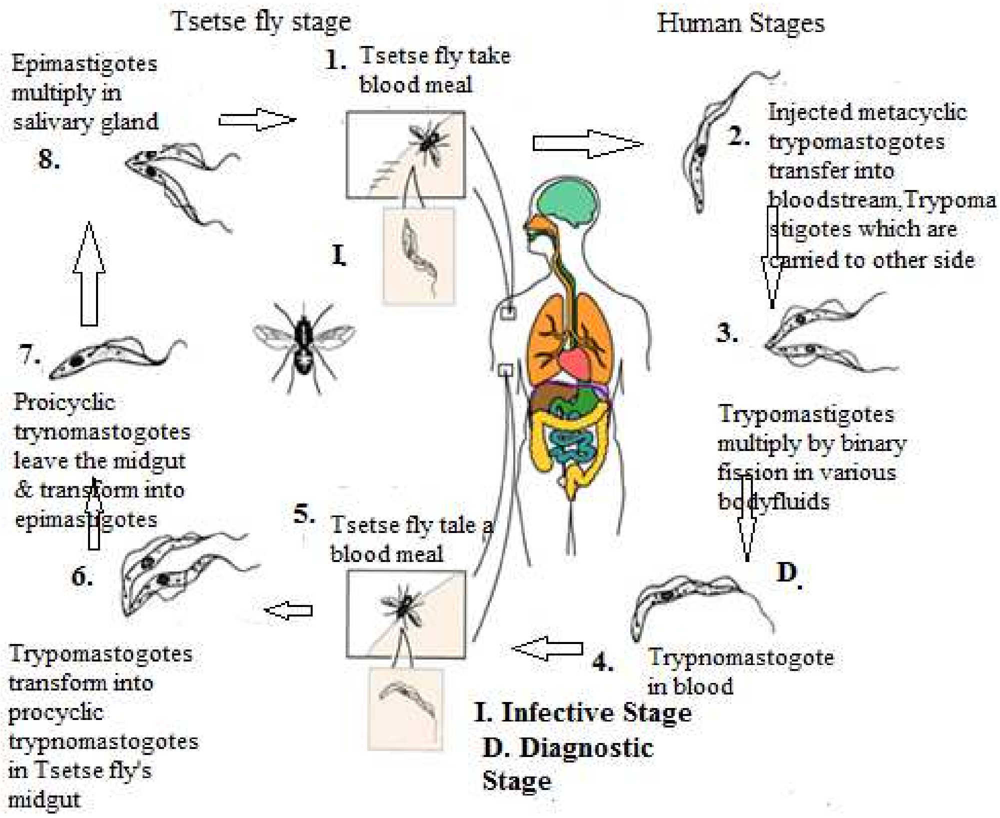


Fig.7 Life Cycle of T.gambiense

- It is digenetic i.e. it completes its life cycle in two hosts: principal host in man and intermediate host is a blood sucking insect Glossina palpalis or Testse fly.
- It is a polymorphic species exists in man and a crithidial forms in testse fly
- A single flagellum arises from a basal body placed near the posterior end

- Reproduction take place by longitudinal binary fission

Host:

It is an endoparasite in blood and tissues of man and other vertebrate's like Pig, Buffaloes and antelopes etc; which are its reservoir hosts.

Symptoms of the Disease:

Several species of trypanosome are known *T.cruzi* cause Chagas disease, *T.brucei* causes Nagana disease but *T.gambiense* and *T.rhodesiense* causing sleeping sickness are by farther most important and well known among the trypanosome species. The parasite invades the cerebrospinal fluid resulting in a recurrent fever. The patient become weak, anemic and loses weight. Strong tendency to fall asleep is observed in the Initial stages and can lead to coma and death if untreated**.**

Mode of Transmission:

It is transmitted by the bite of the tsetse fly

Therapy:

The perasites are very difficult to control once they haveentered the C.S.F. Druge like Melarcin oxide Orsanine and Pentamedine are effective remedies for the parasite**.**

Prevention:

1. Eradication of its vector by clearing bushes and spraying insecticides.
2. Killing of reservoir hosts.

Plasmodium:-

Classification:

Phylum: Protozoa

Subphylum: Plasmodroma

Class: sporozoa

Subclss: Telosporidia

Oder: Haemosporidia

Genus: *Plasmodium*

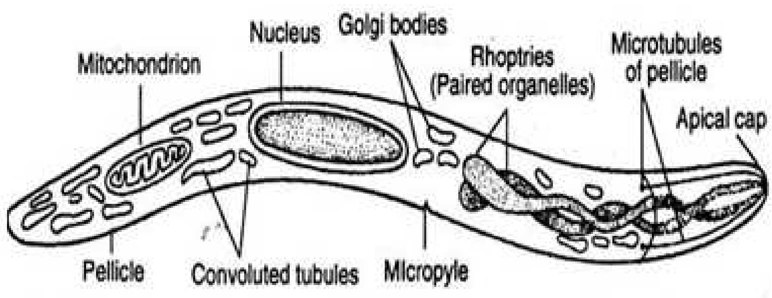


Fig. 8 Ultra structure of sporozoit of Plasmodium

Comments:

- *Plasmodium* is an intracellular blood parasite of man and other vertebrates and causes malaria.
- The life history of plasmodium (Fig.8.40) is completed in two hosts, viz., partl in definitive, host the man and partly in intermediate host, the female anopheles mosquito.
- When an infected female anopheles mosquito bites a man, sporozoites are introduced in the blood from where they reach in live cells through blood streams and multiply to form merozoites.
- After a few schizogenous cycles in the liver, the merozoites enter the red blood corpuscles (R.B.C) and feed on the contents of R.B.C.
- After 2-8 schizogenous changes in the main blood stream, the merozites assume different shapes and known as gametocytes.
- Gametocytes cannot develop further in the blood of man; therefore they wait for female anopheles mosquito to suck them with the blood.
- When gametocytes are sucked in by the female anopheles with the blood of man, they undergo sporogony for further development.
- There are four species of Plasmodium causing different types of fever:
  1. Plasmodium vivax causes benign tertian fever.
  2. P. Falciparum causes malignant tertian, fever;
  3. P. Malariae causes quratan fever.
  4. P. Ovale causes ovale or mild tertian fever.

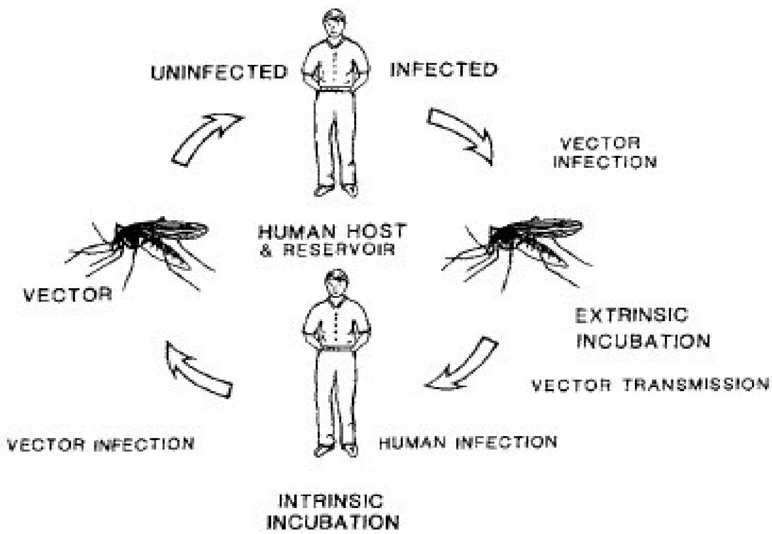


Fig.9 Life cycle of Plasmodium

Habit and Habitat:

Plasmodium is found in as an intracellular parasite in the blood of vertebrates. It is widely distributed in tropical & temperature countries of world but they are no longer a problem in colder countries of the world. Countries like India, Sri-Lanka, Bangladesh Nepal & Pakistan etc are worst affected. In India state like Bihar & Uttar Pradesh suffer a great setback by the infection of this parasite. In fact the infection of plasmodium is a global problem.

Monocystis:-

Classification:

Phylum: Protozoa

Subphylum: Plasmodroma

Class: Sporozoa

Subclass: Telosporidia

Order: Gregarinida

Genus: *Monocystis*

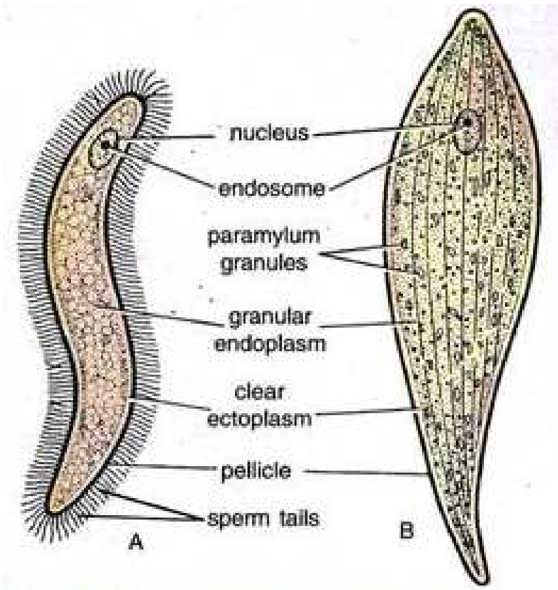


Fig. 10 Monocystis

Comments:-

- The trophozite (vegetative phase of *Monocystis*) is elongated, flattened, club-shaped and pointed at both ends of the body
- The body of trophozoite is covered with firm pellicles.
- The cytoplasm is distinctly divided into a dense superficial ectoplasm and a central semifluid mass. The endoplasm.
- Ectoplasm contains the myonemes, while the endoplasm contains large nucles and the reserve food material in the form of paramylum.
- Contractile vacuole, mouth, gullet, cilia and flagellum are absent.

- Nutrition is affected entirely by the absorption of fluid juice of the host through the surface.
- Reproduction by spore formation.
- Life cycle is completed within a single host.

Habit and habitat:-

- *Monocystis* is a parasite living in the seminal vesicles of earthworm.

Distribution:

- *Monocystis* is cosmopolitan in distribution.

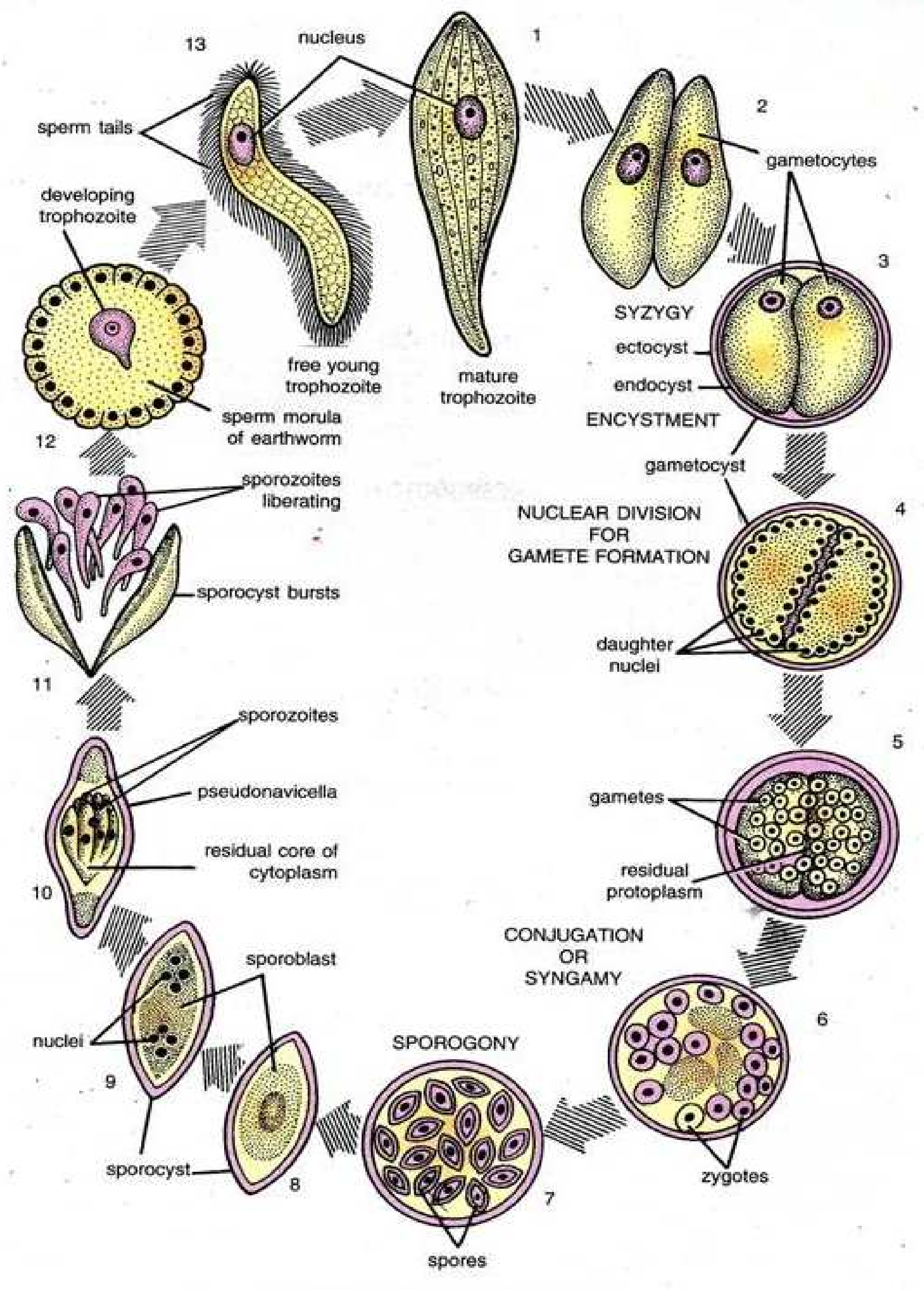


Fig.11 Life history of Monocystis

Monocytis is a parasite and its spore is probably released from the seminal vesicles of earthworm by the death and decay of earthworm. Each spore containing eight sporozoites which are released from the spore following the ingestion by another worm and action of its digestive juices on the spore.Two trophozoit come together and are surrounded by a common two layered cyst wall and are known as gametocytes.

And each trophozoites then divides producing a number of small cells called gametes and these gametes are finally unite together in a pair form the Zygote and these zygote become lemon shaped and secrete a thin hard wall about itself which is known as sporoblast.

1.3.6: Study of Leishmania, Entamoeba & Giardia:

Leishmania:-

Classification:-

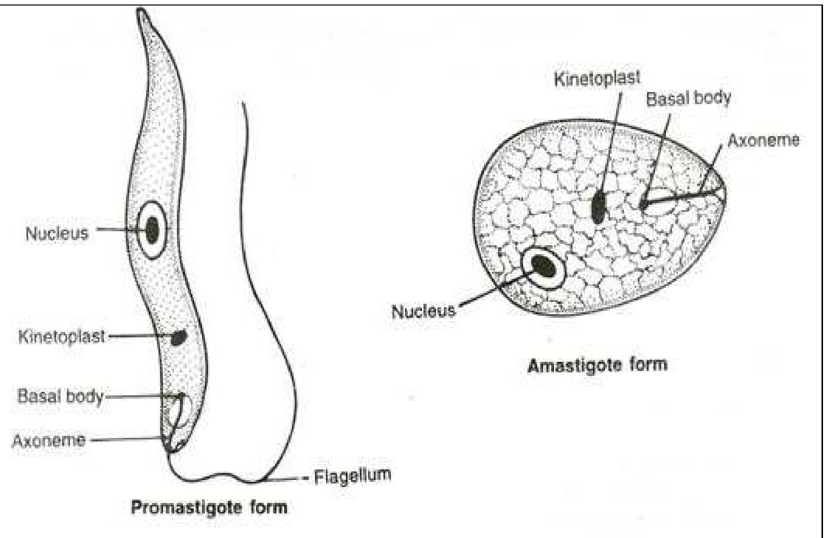
Phylum: Protozoa Subphylum: Sarcomastigophora Class: Zoomastigophorea Order: Kinetoplastida Family: Trypanosomatidae Genus: *Leishmania*	

Fig. 12 Leishmania

Distribution:-

It is found as an intracellular parasite in Leucocytes and cells of liver, spleen, bone marrow, etc.

Morphology and Life Cycle:-

- *Leishmania* spp. are digenetic or heteroxenous parasites, whose life cycle involves two
- Hosts, a vertebrate and an invertebrate, the sandfly
- Hemoflagellates may have several morphological stages that differ from one another in the placement of the kinetoplast relative to the nucleus, as well as the location and origin of the flagellum3
- In *Leishmania* the life cycle stage in the vertebrate is the amastigote and in the insect, the promastigote. *Leishmania* exist in two basic body forms
  (a) The amastigote, the intracellular form in the vertebrate host, and
  (b) Promastigote, the extracellular form in the sandfly (*Phleobotomus* spp and *Lutzomyia* spp.) Vector
- Amastigotes are taken up from the blood of an infected host when the female sandfly bites, and in the sandfly gut they develop into promastigotes where they multiply by binary fission; promastigotes move anteriorly into the proboscis, and are introduced into the vertebrate host when the sandfly bites again. 5

- The promastigotes injected by the sandfly during feeding are phagocytized and develop in to intracellular amastigotes.
- The amastigote, literally "without a flagellum," is the intracellular, non-motile form in the vertebrate host, and it divides by longitudinal binary fission at 37^{o}C. Intracellular zamastigotes are 3-6 um in length and 1.5-3.0 um in width.7
- The amastigote is also called the Leishman-Donovan (LD) body. The amastigote is not really devoid of a flagellum, it is simply that the flagellum does not protrude beyond the body surface and by light microscopy cannot be seen.

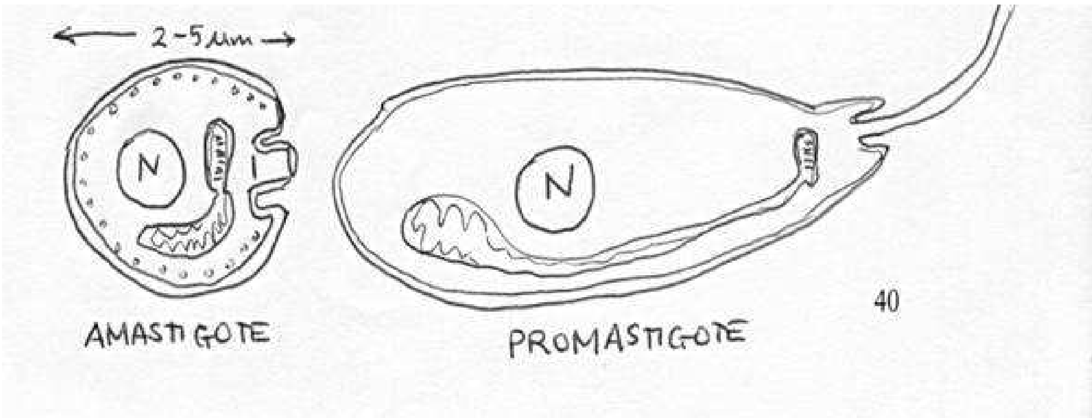


Fig.13 different stage of *Leishmania*

- The promastigote, literally the body form with "an anterior flagellum" is 15-30 mm in body length and 5mm in width.

- it is extracellular, motile, and grows and divides by longitudinal binary fission at 27^{o}C in the sand.

- Promastigotes can be grown in vitro at 25^{o}C temperature on NNN medium, which has a solid phase of blood agar and a liquid phase containing a physiologic salt solution. Liquid media that support promastigote growth are also available.

- Amastigotes usually are grown inside tissue culture cells and can also be grown extracellularly at 37^{o}C under special conditions

Leishmania donovani is a digenetic parasite passing its life cycle in two different hosts.

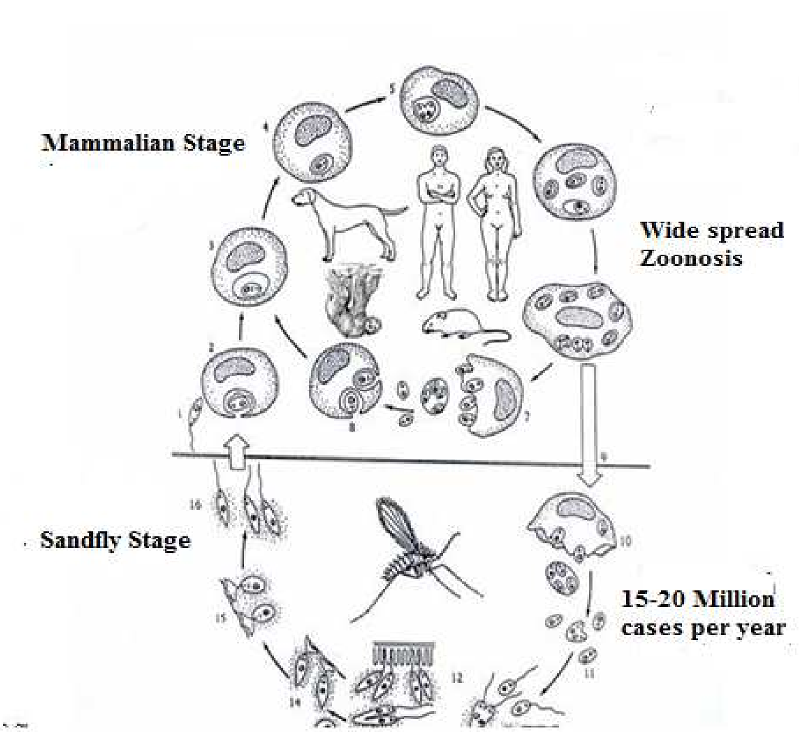


Fig.14.Digenetic Life Cycle of Leishmania

Definitive host:

In humans the metacyclic promastigotes are injected by sandfly through the skin during its blood meal. When sandfly bites using its proboscis it rejects the parasites that are stored inside the hollow tube. Some promastigotes may enter the blood stream directly where some are destroyed by macrophagic cytolysis. But many are also taken up through phagocytosis by mononuclear phagocytes in liver, spleen and bone marrow. Inside the cells they undergo spontaneous transformation into oval-shaped amastigotes. Granulocytes selectively kill the promastigotes by oxidative mechanism; while amastigotes are resistant .Then the surviving amastigotes undergo cell division using simple binary fission. Multiplication continues until the host cell can no longer hold and ruptures. In a fully congested cell there can be as many as 50 to 200 amastigotes, which are released into tissue cavities. Each individual amastigote is then capable of invading fresh cells. As a result, the entire tissue is progressively infected and destroyed. A number of free amastigotes then enters the blood stream where many are phagocytosed by macrophages. These free and phagocytosed amastigotes in peripheral blood are then sucked up by blood-feeding sandfly.

Intermediate host:

L. donovani undergo further development only in the digestive tract of the female sandfly. Hence only females are responsible for transmitting the infection. Once the amastigotes are ingested, they enter the midgut of the sandfly. Then they undergo structural modification into flagellated promastigotes, becoming larger and considerably elongated. They get attached to the gut epithelial lining where they multiply rapidly by binary fission. (They are also capable of sexual reproduction by genetic hybridisation in the sandfly gut.) They then migrate back towards the anterior part of the digestive system such as pharynx and buccal cavity. This process is known as anterior station development, which is unique in *Leishmania.* A heavy infection of pharynx can be observed within 6 to 9 days after initial blood meal. The promastigotes become infective only by this time, and the event is called the metacyclic stage the metacyclic promastigotes then enter the hollow proboscis where they accumulate and completely block the food passage. Immediately upon biting a human, the parasites are released, which invariably results in infection. The stages of development in sandfly can be described as follows:-

1. Soon after entering the gut, the amastigotes get coated with peritrophic matrix, which is composed of chitin and protein complex. This protects the parasites from the digestive enzymes of the host.
2. The amastigotes travel as far as the abdominal midgut and first transform into a weakly motile "procyclic promastigotes" on the gut wall within 1–3 days.
3. The young promastigotes secrete a neuropeptide that stop peristalsis of the gut. The surface lipophosphoglycan (LPG) of the promastigote serves as an attachment to the gut epithelium. These factors prevent the expulsion of promastigotes during excretion of the insect.
4. During 4–7 days the peritrophic matrix is degraded by the activity of chitinases. This release the more actively motile "nectomonad promastigotes" which migrate anteriorly until they reach the opening of the thoracic gut.
5. Another transformation takes place by which they turn into "leptomonad promastigotes". These are fully motile and capable of binary fission. Multiplication and migration towards thoracic midgut cause congestion of the pharynx and buccal cavity.
6. Here they secrete promastigote secretory gel (PSG), which is composed of soluble acid phosphatase and phosphoglycoprotein.
7. After 6–9 days the promastigotes become metacyclic. Some are also transformed into Non-replicating promastigotes, which also become metacyclic. The sandfly is able to regurgitate and eject the parasites from its proboscis with the help of PSG when it bites.

Reservoir host:-

Dogs are known to be susceptible to *L. donovani* infection. Especially in the New World, infection is a zoonotic disease, involving different canine species, including domestic dog and the two fox species, *Lycalopex vetulus* and *Cerdocyon thous*. In the Mediterranean region domestic dogs and the three fox species *Vulpes vulpes*, *V. corsac* and *V. zerda* are common reservoir hosts. In Africa and Brazil, some marsupials and rodents are also reported to harbour *L. Donovan.*

Symptoms of the Disease:-

Different species of Leishmania, diseases cause y them and the symptoms are:

1 L.donovan: cause **Kala Azar** or **dum dum** fever: Darking of skin, enlargement of spleen and liver, fever and anaemia..
2 L.tropica causes **OrientalSores**: disfiguration of ear, face, fore arms and legs.
3 *L.brasiliensis*: Cause **American Lishmaniasis**: inflammation of mucous membrane of nose and throat and enlargmen of spleen and liver, spleen lymph nodes etc.

Mode of transmission:

All species are transmitted by small blood-sucking sandflies, notably *Phlebotomus* spp. in the Old World and *Lutzomyia* spp. in the New World. Only the females feed on blood. Amastigotes ingested during feeding transform in the midget or hindgut into promastigotes which multiply by binary fission. The parasites migrate forward to the foregut and proboscis where some become swept away by saliva into the bite site when the fly feeds.

Treatment:-

- Some cutaneous infections require no treatment as lesions may heal within several months.
- Systemic therapy with pentavalent antimonials (sodium stibogluconate or meglumine antimonate) is the treatment of choice for disfiguring and visceral infections.
- The development of antimonial drug resistance, however, is a growing problem in many endemic areas, including South America, India and the Middle-East. Pentamidine or amphotericin B can be used if antimonials are ineffective, and miltefosine and aminosidine (paromomycin) have shown promise as treatment options, especially when combined with immunotherapy using the tumour-necrosis factor-alpha (TNF-?) inhibitor pentoxifylline.

Control:-

- Preventive measures include protection from sand fly bites but this can be difficult as they are so small that they can penetrate most mosquito nets. Reducing the size of reservoir host populations (especially dogs) has proven beneficial in many endemic urban areas.
- Cutaneous infections, however, are acquired in forests away from human habitation, as the reservoir hosts are wild animals (esp. rodents). The prevention of sand fly bites in forest areas is almost impossible but may be minimized by the use of protective clothing, insect repellants and insecticidal sprays in houses.
- Killing of reservoir hosts like infected street dogs.

ENTAMOEBA HISTOLYTICA

CLASSIFICATION

Phylum protozoa

Sub phylum Sarcomastigophore

Class Rhizopoda

Order Lobosa

Genus *Entamoeba*

Species *histolytica*

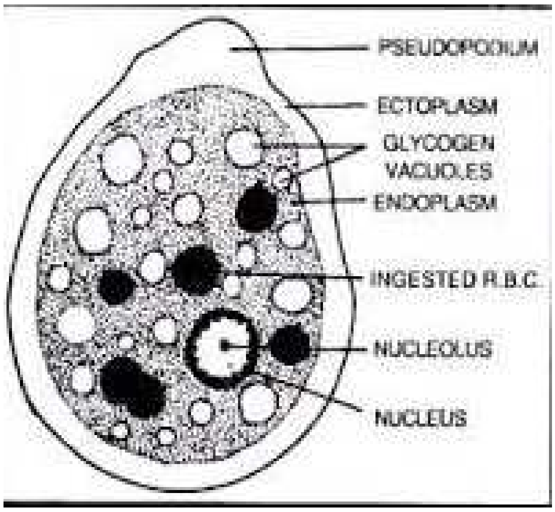


Fig. 15 Entamoeba histolytica

Distribution:-

Entamoeba histolytica is worldwide in distribution, but its prevalence is greater in tropics and subtropics than in the temperate zones. It has been reported that incidence of infection is high in Mexico, China, India and parts of South America.

Habits and Habitat:-

Entamoeba histolytica is a microscopic endoparasite of man .it is commonly found in the upper part of the large intestine and is very often lodged in the river, lungs, brain and testes.

Commment:-

- *Entamoeba histolytica* is a small microscopic parasitic *Amoeba* .in its life cycle, it occur in three distinct forms.
- Trophozoite or magna form.
- Precystic or minuta form.
- Cystic forms.

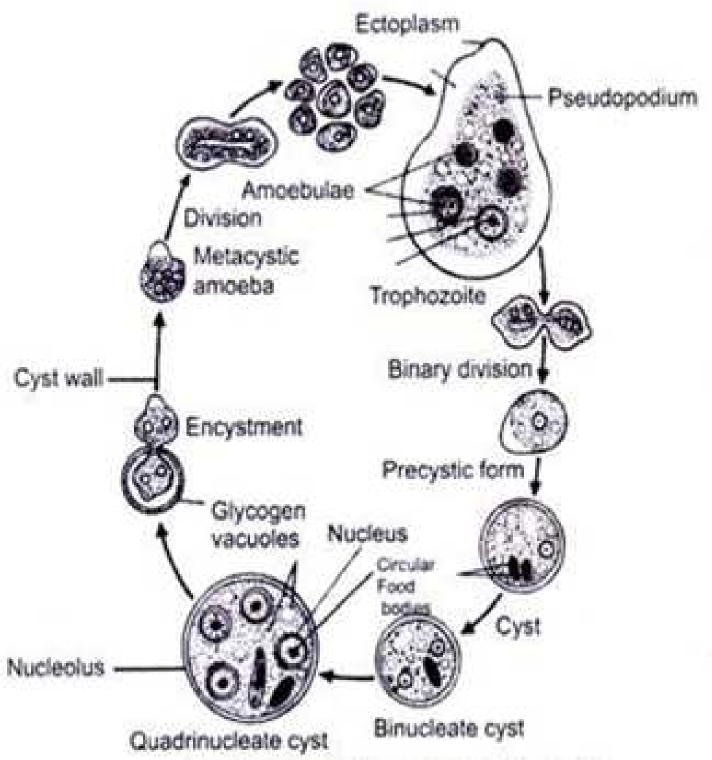


Fig.16 Lifecycle of E. histolytica

Trophozoite:

This stage is disease causing.

- This is growing stage measuring 18 – 30 microns in size.
- Cytoplasm is divided into clear hyaline ectoplasm and granular endoplasm.
- A dot shaped karyosome is present in the centre of the nucleus .the nuclear membrane is lined with chromatin granules.
- Mitochondria are absent an respiratory enzymes are present along the endoplasmic reticulum
- Nutrition is holozoic and its feeds on the cells of the intestinal wall.

Pre Cystic stage

1. Trophozoites multiply asexually by binary fission within the wall of large intestine. Some of the daughter cells invade fresh host cells while others become pre cystic or minute forms.
2. Pre Cystic forms are smaller in size with blunt pseudopodia; endoplasm is free of red blood cells and other ingested food particles.
3. Nucleus is like the Trophozoite stage.

Cystic stage:-

1. In the lumen of the intestine pre cystic or minute forms round up and secrete a tough but flexible cyst wall around them.
2. The single nucleus in the cyst undergoes two mitotic divisions to form a tetra nucleate cyst.
3. Tetra nucleate cysts are the infective stage .they pass out with stools.

HOST:-

Entamoeba histolytica is found in the colon region of the large intestine as an endo parasite .it can also lodge in the river, lungs, brain and testes.

Symptoms of the disease

1. *Entamoeba histolitica* causes amoebiasis in man.
2. It invades the mucosa and sub mucosa layers in the large intestine and causes ulcers which later forms abscesses.
3. Blood, mucous, cell debris and swarms of entamoeba are given out with the stool
   And Trophozites enter the blood circulation and reach liver, lungs, brains and gonads where they erode tissues a forms abscesses which can at a time prove fatal.

Mode of transmission:-

1. It occurs by ingestion of food or water contaminated with faecal matter

Treatment:-

Drugs likes Emetine, Vioform, Terramycin and Metronidazole are known to be effective.

Prevention:-

Hygenic handling of food and water and municipal hygine are necessary to prevent infection by Entamoeba histolytica.

Giardia:-

Classification

Phylum Protozoa

Subclass Sarcomastigophora

Class Zoomastigophorea

Order Diplomonadida

Genus *Giardia*

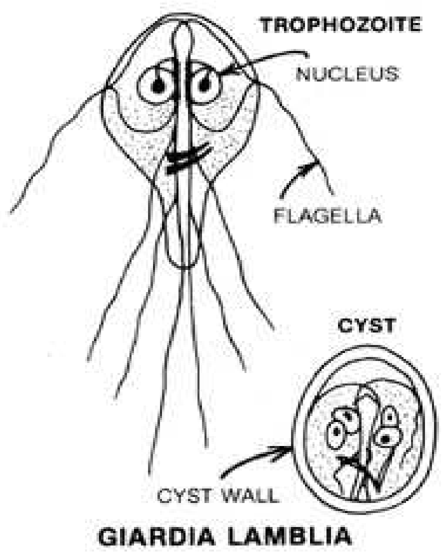


Fig.17 Giardia

Comments:-

- It is live in the intestine of man as an endoparasite and cause **Giardiasis**
- It has two nuclei and bears four flagella on either side of the body
- Its fee on vitamins and amino acids contained in food within the intestine.
- Giardia intestinalis trophozoites are pear-shaped and 10–20 µm long.
- Other characteristics include: flagella, median bodies, sucking disks and two big nuclei. Giardia intestinalis cysts are oval to ellipsoid and 8–19 µm long
- Immature cysts have two nuclei, whereas mature cysts have four.

Causal Agent:-

Giardia intestinalis is a protozoan flagellate (Diplomonadida). This protozoan was initially named *Cercomonas intestinalis* by Lambl in 1859. It was renamed *Giardia lamblia* by Stiles in 1915 in honor of Professor A. Giard of Paris and Dr. F. Lambl of Prague. However, many consider the name, *Giardia intestinalis*, to be the correct name for this protozoan. The International Commission on Zoological Nomenclature is reviewing this issue.

Life Cycle:-

Cysts are resistant forms and are responsible for transmission of giardiasis. Both cysts and trophozoites can be found in the feces (diagnostic stages)

- The cysts are hardy and can survive several months in cold water. Infection occurs by the ingestion of cysts in contaminated water, food, or by the fecal-oral route (hands or fomites)
- In the small intestine, excystation releases trophozoites (each cyst produces two trophozoites)
- Trophozoites multiply by longitudinal binary fission, remaining in the lumen of the proximal small bowel where they can be free or attached to the mucosa by a ventral sucking disk.
- Encystation occurs as the parasites transit toward the colon. The cyst is the stage found most commonly in non-diarrheal feces.
- Because the cysts are infectious when passed in the stool or shortly afterward, person-to-person transmission is possible. While animals are infected with *Giardia*, their importance as a reservoir is unclear.

Host:-

It inhibits the intestine of man and other vertebrates like rat, rabbit, dog, cat etc.

Symptoms:-

- Bad breath and farts.
- Dehydration.
- Diarrhea or greasy floating stools.
- Fatigue.
- Loss of appetite.
- Nausea & Stomach ache
- Weakness

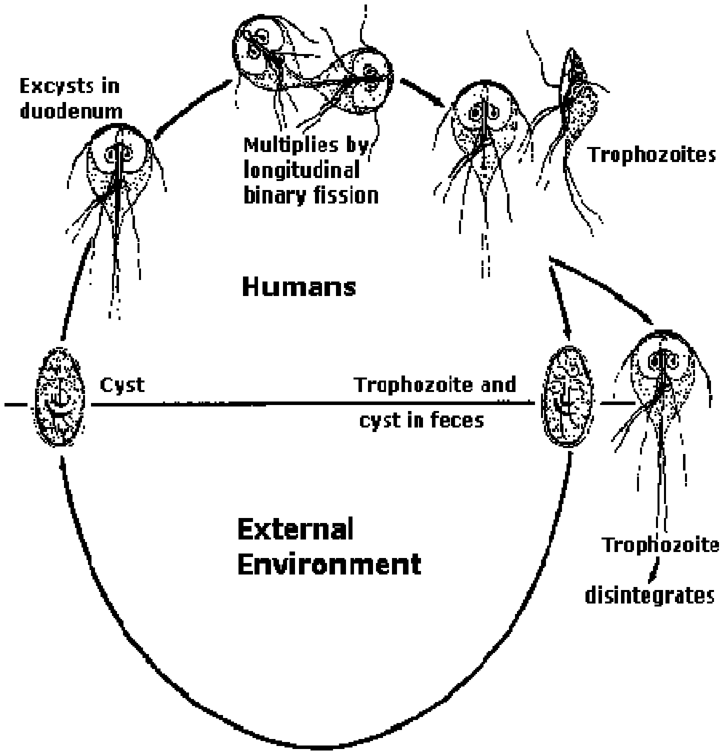


Fig.18 Life cycle of Giardia

Diarrhea can be fatal, if you do not drink enough water with salt and glucose. Another not so recognizable effect is the lack of B12-vitamin. This is due to the impaired absorption (malabsorption) in the damaged intestinal wall. 50 % of giardiasis cases are asymptomatic. Symptoms begin usually within two weeks after becoming infected. In healthy individuals the sickness normally persists up to three weeks, but sometimes longer

Diagnosis:

By examining stool samples under a microscope. Common microscopical techniques include: wet mount with iodine, trichrome or immune fluorescent antibody staining and/or enzyme immunoassays. Several stool samples are usually needed on different days because cysts and trophozoites are not always present in the feces. Trophozoites can also be found from duodenal fluid or from biopsies taken during endoscopy.

Mode of Transmission:-

It occurs by ingestion of food or water containing protozoan cysts. It is transmitted

by unprotected sexual intercourse.

Treatment:

It accomplished with antimicrobial drugs such as: metronidazole, nitazoxanide (good for treating children), tinidazole, paromomycin, quinacrine and furazolidone.

Prevention:

Prevention is achieved by protected sexual intercourse and good personal hygiene.

1.5 Summary:-

Protozoa means 'first animal' the simplest form of animal life. Protozoa are unicellular microorganisms that lack cell walls. It can grow in marine habitat or soil fresh water symbiotic parasites in other organisms. Protozoa depends on nutrition, temperature, pH, and some depends on sunlight. There are an estimated 50,000 protozoan species. They are aquatic (fresh and salt water) free living parasitic, symbiotic or commensally. They possess different types of locomotory organs. They may bear flagella (flagellates). Locomotory organs are absent in the parasitic forms. The osmotic concentration of cell body (Osmoregulation) is maintained by one or more contractile vacuoles. Asexual reproduction takes place by fission or budding. Sexual reproduction are occurring the fusion of gametes or conjugation **Eg. Free living**- *Euglena, Amoeba, Paramecium, Noctiluca* , *Elphidium* (Polystomella). **Parasitic**- *Monocystis, Entamoeba, Plasmodium* , *Trypanosome, Giardia* etc. Encystment occurs to tide over the unfavorable conditions and to help in the dispersal of race.

A phylum protozoon is a larger and varied group and possesses a number of problems in its classification. The conventional scheme followed by Hyman (1940), Hickman (1961) and Storer (1965) etc. recognizes two subphyla on the basis of organs of locomotion and five classes. *Paramecium* (Gr., Paramekos- oblong + Caudata-tail) is an elongated and sliper shaped animal. *Paramecium* is a typical ciliate microscopic organism. It is ten species known in world. Ciliates are characterized by the presence of cilia as locomotor organelles. *Paramecium* is occurrence in fresh water ponds, lakes, rivers and streams. Its size varies in different species being 120-250µ in *P.aruelia* and 170-290µ in *P. caudatum.* Its body asymmetrical with flat oral and a convex aboral or dorsal surface. The body is covered by a thin firm but elastic pellicle. **T**he entire body surface is covered by a uniform covering of hair like protoplasmic processes, the cilia. In *Paramecium*, there is a broad, shallow oral groove on the ventral surface. *Paramecium* has two contractile vacuoles, one anterior and one posterior. The function of the contractile vacuoles is osmoregulation. *Paramecium* reproduces asexually by transverse binary fission. Ordinarily *Paramecium* multiplies by binary fission for long periods of time, but at intervals this may be joining of two animals along their oral surfaces for sexual process of conjugation.

1.6 Glossary:-

Ampulla –	A small bladder like sac.
Asexual reproduction-	Reproduction without involving gametes
Binary fission –	The organism divides into approximately equal halves.
Budding –	It is a form of asexual reproduction.
Cilia –	Microscopic hair-like projection.
Commensalism-	Association of two different species in which at least one is benefitted and the other is neither benefited.
Conjugation-	A method of sexual reproduction.
Contractile vacuole-	A space in the cytoplasm of certain species of protozoa where fluids collect before being periodically discharged to the outside.

Cytopharynx – Pharynx of a protozoan such as *Paramecium*.

Ectocommensal – Pertaining to an organism that lives on the external surface of other organism, the host, without either benefiting or injuring.

Food vacuole- Intra- cellular digestive organelle.

Holophytic – Type of nutrition, found in green plants and in some mastigophores.

Locomotion - Movement involving the organism as a whole.

Micronucleus – In organism with micronuclei, smaller nucleus most useful in reproductive activity.

Mitosis – Cell division during which chromosomes appear to become doubled longitudinally, the halves of each one passing into separate daughter cells.

Multiple-fission- Type of asexual reproduction in which the nucleus perform several mitotic divisions before any cytokinesis.

Pellicle- The protective layer on the surface of some protozoans. E.g. *Paramecium*.

Pseudopodia – Blunt temporary protoplasmic projections found in *Amoeba*.

Sessile – Attached, not free –moving.

Sexual reproduction- Reproduction involving the gametes.

Siliceous – Containing silica.

Stigma – A sensitive pigment or eye spot in certain Protozoa.

Syngamy- Union of gametes in sexual reproduction forming a zygote.

Taxonomic- Classification of organism.

1.7- References:-

1. Poddar T., Mukhopadhya S., Das S.K (2015) an advanced laboratory Manual of Zoology.
2. Verma P.S., (2014) A manual of practical Zoology, Invertebrates.
3. Rastogi V.B. (1999) Lower non-chordate & Economic Zoology.

1.8-Suggested Reading:

- Invertebrate Zoology, Author - E. L. Jorden and P. S. Verma.
- A text book of Invertebrate Zoology, Author –Dr. S. N. Prasad.
- Biology of the Invertebrate Zoology, Author –Jan A.Pechenik.
- Invertebrate Zoology, Author –D.T.Anderson.
- Invertebrate Zoology, Author –Fatik Boran Mondal
- Modern text book of Zoology Invertebrate, Author –R.L.Kotpal.
- Invertebrate Zoology, Author –Paul A.Meglitsch and Frederick R. Schram
- Text book of invertebrate Zoology, Author – G.S.Sandhu.
- An Advanced Laboratory Manual of Zoology-T.Poddar & S Mukhopadhyay.
- A Manual of Practical Zoology Invertebrates-Dr.P.S.Verma

UNIT: 2 PORIFERA

Contents

2.1 Objectives

The study of Identification, systematic position Up to order level and the general study of Porifera.

2.2 Introduction

Animals belonging to phylum Porifera are commonly called Sponges as these bear pores i.e. they are porous and they are sessile animals which remain attached to rocks, shells or other substrata, growing like plants. Sponges are marine organisms distributed from Arctic to Tropic seas except those belonging to family Spongillidae, distributed in freshwater. Body shape is cylinder or vase like, assymetrical or radially symmetrical. These are multicellular organisms having diploblastic body consisting of outer layer of ectoderm, inner endoderm and an intermediate mesenchyme. Spongocoel is the internal space of the body which is either hollow or permeated by numerous canals lined with choanocytes (collared flagellated cells).Canal system is present which helps in nutrition, respiration, excretion and reproduction in sponges. Mouth is absent and digestion is intracellular. Skeleton consists of spicules (calcareous or siliceous) or fibres (spongin).Asexual reproduction (by buds and gemmules) as well as sexual reproduction (by ova and sperms) takes place in sponges. Fertilization is internal, holoblastic cleavage, indirect development including freee-swimming ciliated larval stage called Amphiblstula or Parenchymula. Sponges exhibit great power of regeneration.

Classification

PHYLUM-PORIFERA

Class

1. CALCAREA

- Skeleton consisting of calcareous spicules.
- Canal system may be Asconoid, Syconoid or Leuconoid

2. HEXACTNELLIDA

- Skeleton consisting of six rayed triaxon siliceous spicules.
- Sycon type canal system

3. DEMOSPONGIAE

- Skeleton consisting of siliceous spicules or spongin fibres or both.
- Leuconoid type canal system

Order1. Homocoela

- Asconoid sponges.
- Radially symmetrical, cylindrical body
  Examples: *Leucosolenia, Clathrina*.

Order 2. Heterocoela

- Syconoid or leuconoid sponges
- Vase shaped body
  Examples: *Sycon* or *Scypha*, *Grantia*.

Class 2. Hexactinellida

Orders ↓

Order1.Hexasterophora

- Spicules are hexasters (star like).
- Attached to hard objects without root tufts
  Examples: *Euplectella, Farnera*.

Order 2. Amphidiscophora

- Spicules are amphidiscs.
- Attached to substratum by root tufts.
  Example: *Hyalonema, Pheronema*.

Class 3. Demospongiae

Orders ↓

Order1. Myxospongida

- Simple structure.
- Skeleton absent
  Examples: *Oscarella, Halisarca.*

Order 2. Tetractinellida

- Tetraxon spicules.
- Spongin present
  Examples: *Chondrilla, Chondrosia*.

Order 3. Monoaxonida

- Monoaxon spicules
- Found in abundance throughout the world in freshwater and marine environment.
  Examples: *Spongilla, Tethya, Cliona, Chalina, Microciona.*

Order 4. Keratosa

- Skeleton consisting of spongin fibres only.
- Body is rounded and massive.
  Examples: *Euspongia, Hippospongia*.

2. 3- Leucosolenia:-

2.3.1 General Characters:

1. It is a marine colonial sponge inhabiting shallow waters below tide mark, not found in calm water. It is abundant in Northern Atlantic Coast and very common in Europe.
2. The colony of *Leucosolenia* is whitish yellow in colour consisting of vase like simple or branching bodies about 25 mm long, joined together by horizontal tubes at the base.
3. The body surface is perforated by numerous pores called **Ostia** or incurrent pores through this water enter the body of sponge.
4. Each vertical tube terminates into **osculum** at distal end through which water moves out of the body of sponge.
5. Calcareous spicules are **monoaxon** (spicules growing along single axis) or **triaxon** (spicules consisting of three axes crossing at right angles) type.
6. Simplest type of canal system *i.e.* **Ascon type** the course taken by water current is:

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

7. Asexual reproduction by **Branching** and **Budding**.
8. Sexual reproduction by ova and spermatozoa, indirect development including **Paranchymula larva**.

2.3.2 Identifying character:

Presence of osculum, Ostia and colonial structure.

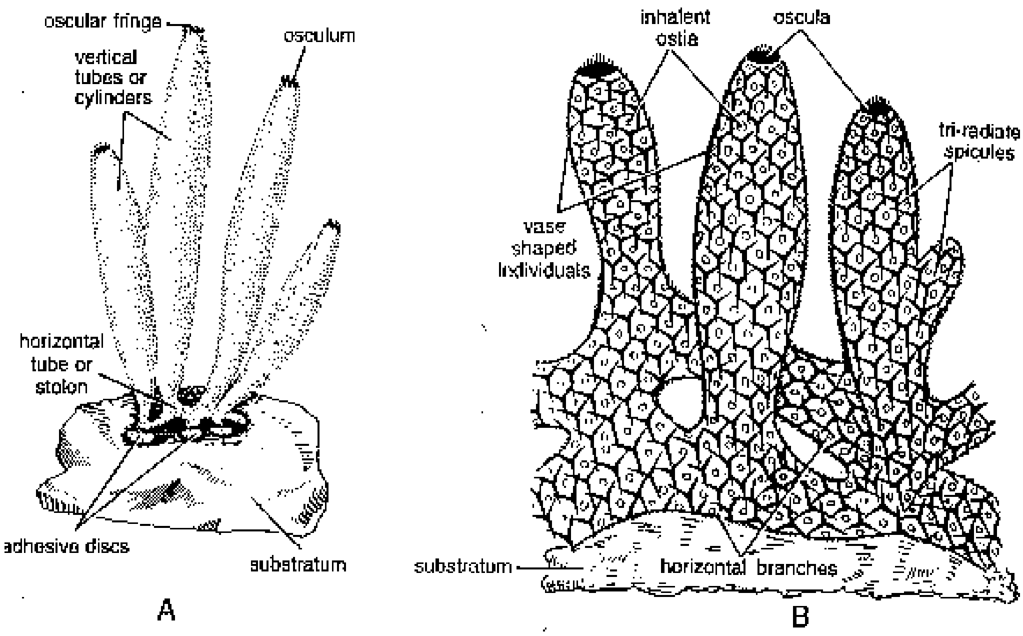


Fig.2.1 A. Colony B. Portion of colony (magnified)

2.3.3- Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body Organization, radially symmetrical).
Class...............Calcarea (Skeleton having calcareous spicules)
Order ....Homocoela (Ascon type canal system)
Genus ....*Leucosolenia*

2.4 Grantia:-

2.4.1 General Characters:-

1. It is a marine sponge found attached to substratum in shallow and well oxygenated waters, distributed in Europe.
2. Body is slender; vase- shaped measuring about 20-25 mm in length and 5-6 mm in diameter.

3. **Osculum** is present at the distal end of each cylindrical tube. It is encircled by a fringe of large monoaxon spicules forming an **oscular fringe**.
4. The **dermal membrane** spreads over the entire surface of sponge forming a cortex, provided with special **cortical spicules** arranged parallel to the surface.
5. Due to the development of **cortex,** incurrent passages become more irregular and branching and **subdermal spaces** may be present
6. **Syconoid** type canal system. water current passes through ostia → incurrent canal → prosopyles → radial canal → apopyles → spongocoel → osculum → exterior
   Reproduction takes place by sexual as well as asexual methods.

2.4.2- Identifying character:-

Identifying characters are similar to *Sycon* except the presence of dermal membrane spreading over the entire surface of sponge forming a cortex.

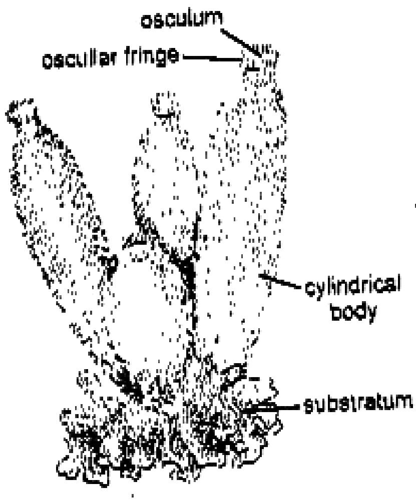


Fig.2.3 *Grantia*

2.4.3- Systematic Position:-

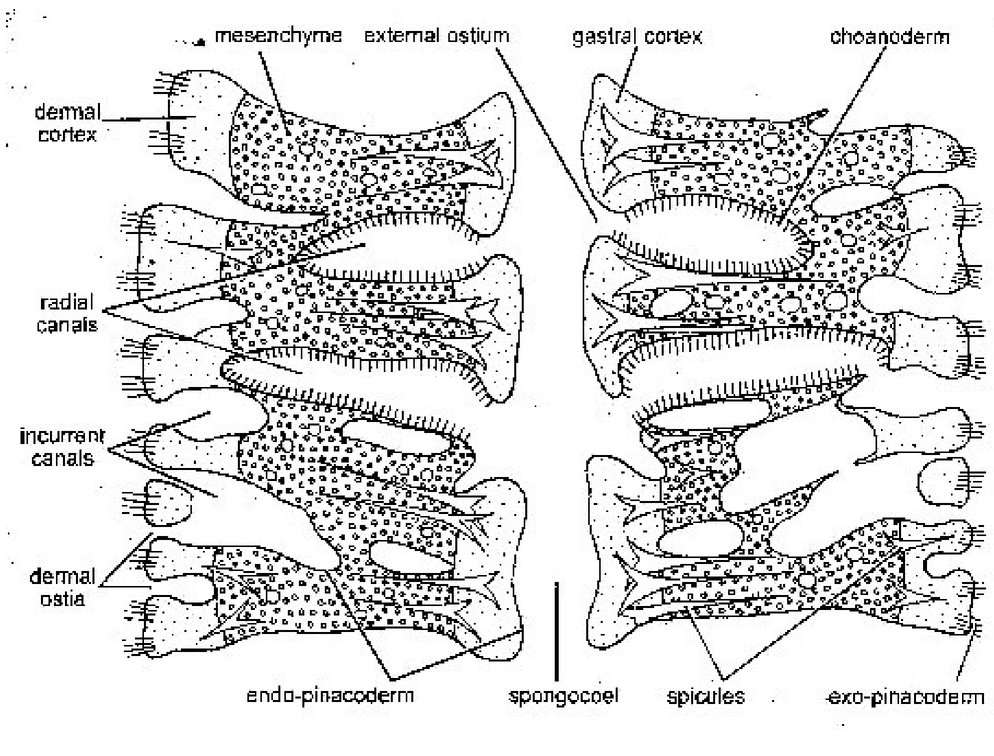
Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class...............Calcarea (Skeleton having calcareous spicules)
Order ....Heterocoela (Sycon type canal system)
Genus ....*Grantia*

2.4.4 (a) L.S. of *Grantia:-*

Comments: L.S. of *Grantia* shows the following histological features:

1. Cellular grade of organization and **diploblastic** pattern is visible.
2. Body wall differentiated into outer **ectoderm**, intermediate **mesenchyme** and inner **endoderm** cells.
3. Ectoderm or dermal epithelium is made up of spindle shaped cells called **Pinacocytes**.
4. Entire surface is covered by dermal membrane forming **cortical zone** having cortical spicules. Presence of cortical zone is the only difference between *Sycon* and *Grantia*.
5. Mesenchyme is a gelatinous matrix containing **amoebocytes, archaeocytes, germ cells, gland cells, scleroblast cells, collenocyte cells** and **spicules**.
6. Endoderm forms lining of radial canal having **choanocyte cells.** These are flagellated collar cells which maintain the water current inside the body due to the beating of flagella
7. **In current canals** are channelized, branched and irregular due to the development of **dermal cortex.**
8. **Radial canals** are also branched and irregular.
9. **Spongocoel** is lined with gastral cortex.
10. **Syconoid** type canal system. water current passes through ostia → incurrent canal → Prosopyles → radial canal → apopyles → spongocoel → osculum → exterior.

Identifying character: Presence of dermal cortex, irregular radial canals and, in current canals.



2.4.1 (a) L.S. of *Grantia*

2.4.4 (b) T.S. of *Grantia:-*

Comments: T.S. of *Grantia* shows the following histological features:

1. **Diploblastic** body wall.
2. Body consisting of outer **ectoderm**, inner **endoderm** with an intermediate **mesenchyme**.
3. Dermal membrane forms **dermal cortex** covering the entire surface of the body.
4. **Ostia** open into **incurrent canal** which communicate with radial canal by **prosopyle**.
5. **Radial canals** containing **choanocytes** open into spongocoel by **apopyle**.
6. **Spongocoel** is lined with gastral cortex.
7. **Syconoid** type canal system. water current passes through ostia → incurrent canal → prosopyles → radial canal → apopyles → spongocoel → osculum → exterior.

Identifying character: Presence of well developed dermal cortex and incurrent canals arranged in circular manner.

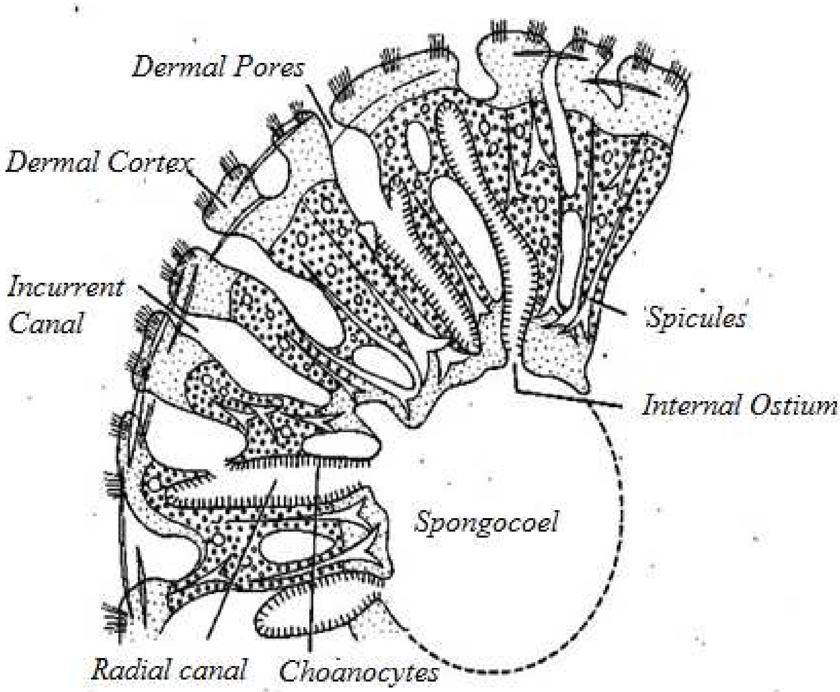


Fig. 2.4.2 (b) T.S. of Grantia

2.5 - Sycon or Scypha:-

2.5.1 General Characters:-

1. Scypha is commonly called **Crown sponge**.
2. It is a small, solitary or colonial marine sponge found in shallow and well oxygenated water. Commonly distributed in Europe from Rhode Island to Greenland.

3. Body is vase-shaped (measuring 20-25 mm in length) opening to exterior by **osculum** at distal end**.**
4. **Osculum** is encircled by **oculars fringe** formed by **monoaxon spicules.**
5. Proximal end or **base** is attached to the substratum.
6. Body wall is thick having **monoaxon, triaxon** and **tetraxon** spicules.
7. Body wall consists of outer **dermal epithelium** and inner **flattened epithelium** which lines the spongocoel separated by a middle layer of mesenchyme.
8. Canal system is **syconoid type**. Water current passes through Ostia incurrent → canal
   Prosopyles → radial canal → apopyles → spongocoel → osculum → exterior.
9. Reproduction by asexual (**budding**) as well as sexual method.
10. Larval stage is called **amphiblastula**.

2.5.2- Identifying character:

Presence of oculars fringe and Ostia.

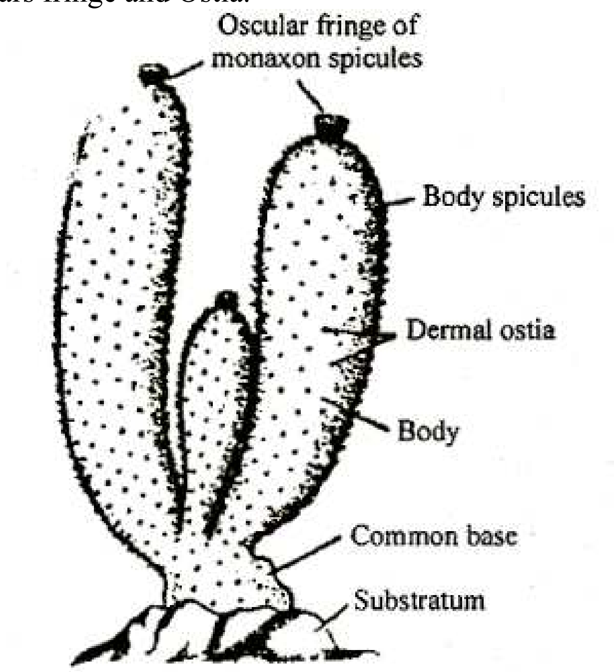


Fig. 2.5 Scyon or Scypha

2.5.3- Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class...............Calcarea (Skeleton having calcareous spicules)
Order ....Heterocoela (Sycon type canal system)

Genus ....*Sycon or Scypha*

2.5.4 - T.S. and L.S of *Scypha*

Comments: T.S. of *Scypha* shows the following histological features:

1. Body layers are **diploblastic**, showing **cellular organization**.
2. Outer **ectoderm,** inner **endoderm** and intermediate **mesenchyme** are present.
3. Ectoderm consists of **pinacocytes** which form the lining of incurrent canals.
4. Gelatinous mesenchyme having calcareous spicules, amoeboid cells, collenocytes, archaeocytes etc is present.
5. Endoderm consists of flagellated choanocyte cells forming the lining of **radial canals**.
6. Radial canals are alternately arranged with **incurrent canals** which are connected to each other by **prosopyle**.
7. Radial canals open into the **spongocoel** by **apopyle** (internal ostium)
8. In T.S. of *Sycon* finger like projections of flagellated chambers arranged in a characteristic circular manner is visible.
9. Canal system is **Syconoid** type and flow of water current is same as described above.

Identifying character: Finger like flagellated radial canals alternating with incurrent canals in a circle.

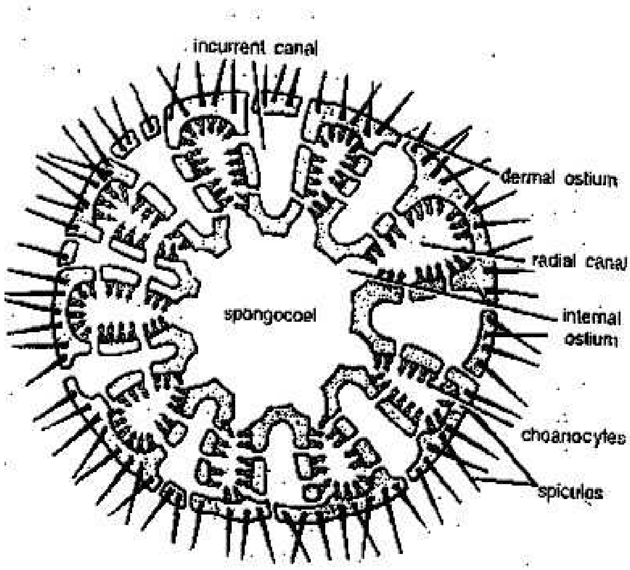


Fig. 2.6.1 (a) - T.S. of Scypha

L.S. of Scypha:-

Comments: L.S. of *Scypha* shows the following histological features:

1. **Diploblastic** body wall consisting of ectoderm, mesenchyme and endoderm.

2. **In current canals** (lined with dermal epithelium) and **radial canals** (lined with choanocytes) alternate with each other.
3. **Mesenchyme** forms intermediate layer containing amoebocytes, spicules etc.
4. **Spongocoel** is lined by flat epithelium.
5. **Prosopyle** forms connection between incurrent canal and radial canal and Apopyle is the opening of radial canal into spongocoel (lined by flat epithelium).
6. Canal system is **syconoid type**.

Identifying character: Finger like radial canals without dermal cortex alternating with incurrent canals.

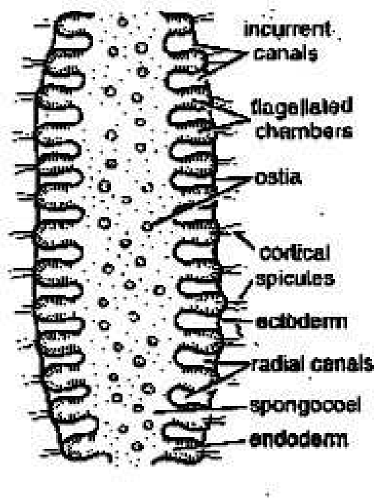


Fig. 2.6.2 (b) - L.S. of Scypha

2.6 – *Hyalonema:-*

2.6.1 General Characters:-

1. *Hyalonema* is commonly called **glass rope sponge** as it appears like ball of glass wool with projecting tufts of **glassy spicules**.
2. It is a marine sponge inhabiting 10-15 metres deep sea water. It is found along the New England coast.
3. Body is round or oval and **radially symmetrical**.
4. The spicules of **root tuft** are compact, elongated and twisted forming an axis or **columella**. It helps the organism in anchoring.
5. Several polyps of a Zoanthidea (anemone) grow in **symbiotic** association with *Hyalonema* at its columella.
6. **Osculum** contains a **sieve plate**.
7. **Spongocoel** can be noticed only when the upper surface of the sponge body is depressed since the excurrent canals open into it, but when the surface is extended into a gastral cone by upward projection of columella, no spongocoel exists.
8. Skeleton consists of small **amphidiscs**. Whole body is covered by small branching six rayed spicules which resemble to Christmas trees.

2.6.2- Identifying character:-

Presence of glossy root spicules tuft, large osculum containing sieve plate and symbiotic polyps.

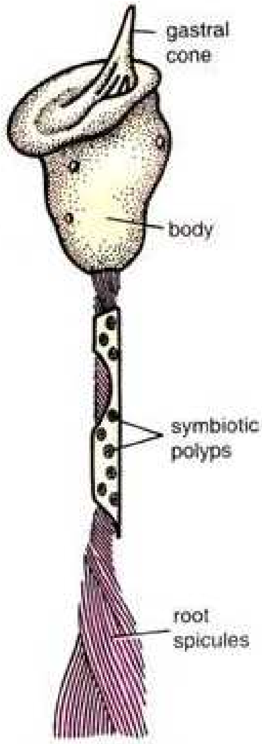


Fig.2.7 *Hyalonema*

2.6.3 Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class..............Hexactinellida (Skeleton having, six rayed triaxon siliceous spicules)
Order ....Amphidiscophora (Spicules are amphidiscs)
Genus ....*Hyalonema*

2.7 – *Euplectella:-*

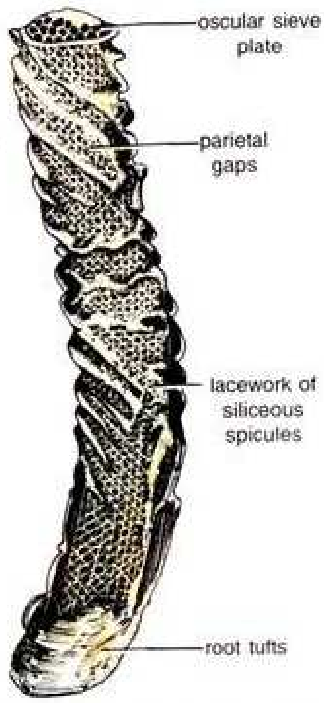


Fig.2.8 Euplectella

2.7.1 General Characters:-

1. It is commonly called **Venus's flower basket** as it appears like knitted elongated basket.
2. *Euplectella* is a **solitory** sponge inhabiting deep sea waters (500-5000 m) distributed near Philippines and West Indies. It measures 15-30 cm in length and 2-5 cm in diameter.
3. Body is long, curved and cylindrical which is fastened in the mud of sea bottom.
4. **Six rayed** siliceous spicules are present which fuse at their tips to form a three dimensional network with **parietal gaps**.
5. At the lower end **root tuft** is formed by long siliceous spicules. It helps *Euplectella* to anchor in the mud.
6. **Oscular sieve plate** is present above the osculum.
7. Canal system is **sycon** type.
8. *Euplectella* shows an interesting feature. It possesses a pair of shrimp imprisoned within its skeleton. This is given as a wedding gift in Japan to signify a close relationship.

2.7.2- Identifying character:-

Knitted basket shaped body, Ostia and oculars sieve plate.

2.7.3- Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class..............Hexatinellida (Skeleton having, six rayed triaxon siliceous spicules)
Order ....Hexasterophora (Spicules are hexasters *i.e.* star like)
Genus ....*Euplectella*

2.8 – *Spongilla:-*

2.8.1 General Characters:-

1. *Spongilla* is commonly known as **fresh-water sponge** as it is found in freshwater ecosystems in Atlantic, Europe and American waters.
2. It is present in the form of profusely **branched colony**.
3. It exhibits greenish colour due to the presence of symbiotic algae like ***Zoochlorellae*** within the body.
4. Body wall consists of very thin **dermal membrane** perforated with dermal pores or **ostia** and several **oscula**.
5. Different types of **monaxon siliceous spicules** are present. They are of large (**megascleres**) and small (**microscleres**) size held together by **spongin fibre**.
6. Canal systen is **Rhagon type** with choanocytes restricted to small **flagellated chambers.** Water current passes through dermal pores → subdermal cavity → incurrent canal → several flagellated chambers → excurrent canal → Osculum.
7. Asexual reproduction occurs by **regeneration** of fragments or by specialized structures called **gemmules**.
8. Sexual reproduction by sperm and ova. Devlopment is indirect involving free swimming larva.

2.8.2- Identifying character:-

Branched colony, ostia and rhagon type canal system.

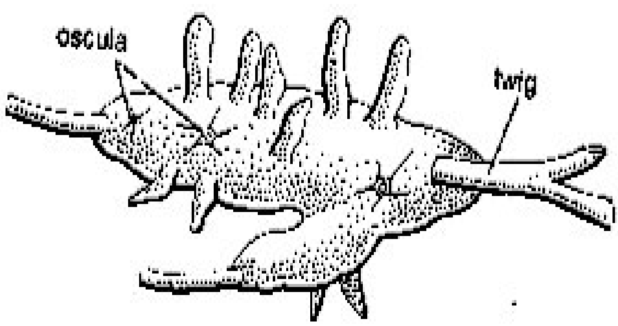


Fig.2.9 Spongilla

2.8.3- Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class..............Demospongia (Skeleton consisting of spongin fibres and siliceous spicules)
Order ....Monaxonida (Spicules are monoaxon)
Genus ....*Spongilla*

2.9 – *Euspongia:-*

2.9.1 General Characters:-

1. Commonly called **Bath Sponge.**
2. It is found on rocky bottoms in warm shallow sea water of Mediterranian, U.S.A., Asia and Australia.
3. Massive body with variable shape often globose, cup shaped or lamelliform.
4. Skeleton consists of network of **spongin fibres** without spicules.
5. Surface of the body contains large openings called **oscula** and small openings called **inhalent canals.**
6. Canal system is **leuconoid** type. Water current passes through dermal ostia → incurrent canal → prosopyle → flagellated chambers → apopyle → excurrent canals → osculum.

7. Dried skeleton of Euspongia is used as a **bath sponge** as it consists of **spongin fibres** having the capacity hold a large amount of water.
8. It is used in offices for wetting postal stamps, paper, currency etc.

2.9.2- Identifying character:-

Oscula, inhalant canals and globose body with meshy spongin fibres.

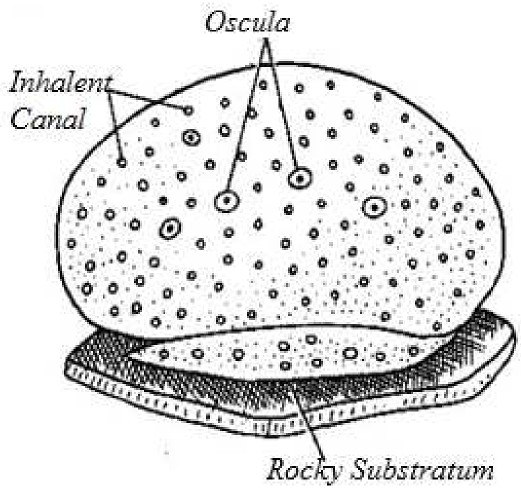


Fig.2.10 Euspongia

2.9.3- Systematic Position:-

Phylum............Porifera (Porous body, cellular grade of body organization, radially symmetrical)
Class..............Demospongia (Skeleton consisting of spongin fibres or siliceous spicules or both)
Order ....Keratosa (Skeleton of spongin fibres only spicules absent)
Genus ....*Euspongia.*

2.10 – Summary-

Phylum Porifera includes asymmetrical or radically symmetrical multi-cellular organism having cellular grade of organization without well defined tissues and organs. They are exclusively aquatic, mostly marine and a few fresh water forms. Sponges are sedentary, solitary or colonial forms with body perforated by pores canals and chambers for the passage of water. Their internal cavities are lined with choanocytes. The skeleton made up of calcareous spicules, siliceous spicules or horny spongin fibres. Digestion is Intracellular, excretory and respiratory organs are absent. Their Classification is based mainly on the type of skeleton found in them. They are of different shapes for eg – cylindrical (*Leucosolenia*) vase shaped (*Scypha, Grantia*), tree like (*Microciona*), leaf like (*Phyllospongia*), cushion like (*Euspongia*), rope like (*Hyalonema*) bowl shaped (*Pheronema*) etc. Sponges are mostly attached to stones, shells, sticks, sea weeds etc. some of them are boring sponges (*Cliona*). Their size varies from a few mm to massive (1-2 meters). Body colour also vary greatly like white, grey, yellow, purple, brown, orange, and red, green. Canal system is very important in sponges. It is mainly of three basic types i.e. ascon type, sycon type and leucon type. The water current moving inside the canal system helps in nutrition, respiration, excretion and reproduction. The water current brings in food and oxygen and takes away carbon di oxide and nitrogens waste. Water current also carries sperms from one sponge to another for fertilization. Sponges reproduce both asexually as well as sexually. Asexual reproduction takes place by regeneration, formation of reduction bodies, budding and gemmule formation. Development includes unequal holoblastic cleavage after fertilization. Larval stage is called amphiblastula. Sponges are economically important including beneficial as well as harmful sponges. The dried fibrous skeleton of many sponges like *Spongia, Euspongia* etc are used for bathing, polishing, washing, scrubbing etc. Many organisms like crustaceans live as commensals within the body of sponges. Some sponges like *Cliona* are harmful for other animals like oysters, clams, barnacles etc as it bores into the shells of these animals and completely destroy them.

2.11 - Glossary:-

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

Commonsalism: An association of individuals of two different species in which at least one is benefitted and the other is neither benefited nor harmed.

Dermal: Pertaining to the skin.

Distal: Away from the point of attachment, for eg. The hand is the distal part of the arm.

Ectoderm: Outer layer of cells in gastrula. This gives rise to the epidermis, sense organs and nervous system.

Endoderm: Innermost layer of the early embryo which gives rise to the lining of the digestive tract.

Epidermis: Outer cellular layer of cells covering the external surface of the body.

Exoskeleton: A supporting structure present on the outer side of animal body.

Fertilization: Union of gametes i.e Sperm and Ova to form a zygote.

Gamete: A mature reproductive or germ cell either sperm or ovum.

Gemmule: A multicellular vegetative bud of certain sponges.

Habitat: Environment in which an animal lives.

Hermaphrodite: An individual possessing both male and female reproductive organs.

Holoblastic: Cleavage resulting in the division of an entire cell.

Intra-Cellular: Within the cell.

Larva: An immature free living stage in the life cycle of various animals which undergoes metamorphosis to become an adult.

Mesenchyme: It consists of gelatinous transparent matrix called mesoglea or mesohyl.

Mesoglea: Non cellular jelly like substance present in between the ectoderm and endoderm in coelentrates.

Osculum: Relatively large external opening of the central cavity (spongocoel) through which water leaves the body of a sponge.

Ostium: An opening to a canal system in sponges.

Pelagic: Inhabiting open water away from shore like in ocean.

Porifera: Phylum to which sponges belong. It means a pore bearing organism.

Prosopyle: Opening between incurrent canal and radial canal in sponges.

Regeneration: Growth of a lost part of the body.

Reproduction: When an organism produces other organisms of its own kind.

Scleroblast: An amoebocyte like cell in sponges which secrete spicules.

Sedentary: Organisms that don't move i.e**. s**tay at one place.

Sessile: Attached.

Siliceous: Containing silicon di oxide or silica.

Solitary: Living alone not in a colony.

Spicule: Solid thorn like structure that compose the structural framework of sponges.

Spongin: Chemical secreted by spongioblasts to form spongin fibres.

Spongocoel: Central cavity of a sponge.

Symbiosis: An association between two individuals of different species for mutual benefit.

2.12- Self Assessment Questions:-

Q1. What is the scientific name of common bath sponge?
Q2. In which type of canal system flagellated chambers are found?
Q3. Name one freshwater sponge.
Q4. Name the order having star like spicules.
Q5. What is the common name of *Hyalonema*?
Q6. Which sponge have amphiblastula larva in its life cycle?
Q7. Which is the simplest type of canal system in Porifera?
Q8. Which sponge is harmful to Oyester industry?
Q9. What is the function of gemmules?
Q10. From which part does water enters the body of sponge?
Q11. From which part does water leaves the body of sponge?
Q12. Which algae are present in the cellular system of *Spongilla*?

2.13 – References:-

Jordan, E.L., Verma, P.S. 2009: Invertebrate Zoology publ. S.Chand and Co. New Delhi, 1127 pp.

Verma, P.S. 2012: A Manual of Practical Zoology Invertebrates, 15th edition, publ. S.Chand and Co. New Delhi, 497 pp.

Lal, S.S. 2011: Practical Zoology Invertebrate, 10th edition, publ. Rastogi Publication, Meerut, 512 pp.

Kotpal, R.L. 2011: Modern Text Book of Zoology Invertebrates Rastogi Publication, Meerut. 883 pp.

2.13 - Suggested Readings

Edward, R and Barnes, R 1994: Invertebrate Zoology, 6th edition, Saunders College Publishing, Harcourt Brace And Co., Orlando, Florida, 1100pp.

Parker, T.J. and Haswell, W.A. 1897: A Textbook of Zoology. Publ. Macmillan And Co. Ltd. Vol I and II.

2.14 - Terminal Questions/Answers:-

Long answer questions:

Q1. Briefly describe canal systems in sponges**.**
Q2 Comment on skeleton in sponges.
Q3. Give an account of reproduction in sponges.
Q4. Describe economic importance of sponges.

Fill in the Blanks:

a) *Sycon* reproduces asexually by.............. and............... .
b) .... Type of canal system is present in sponges belonging to order Homocoela.
c) Amphidisc spicules are present in............ .
d) In *Euspongia* skeleton is composed of........... .
e) .... Is commonly known as Venus flower basket.
f) .... Shows symbiotic association with Zoanthid polyps.
g) In Spongilla .... type of canal system is present.
h) .... Are the flagellated and collared cells responsible for maintenance of water current within the body of sponges?
i) Common name of Sycon is.............. .
j) In..................... Skeleton consisting of spongin fibres only.

Answers

a) budding and regeneration b) Ascon c) *Hyalonema* d) Spongin fibres e) *Euplectella* f) *Hyalonema* g) Rhagon type h) Choanocytes i) Crown sponge j) *Euspongia*

Multiple Choice Questions:-

1) Most primitive group of animals which are multicellular
   (a) Coelentrata
   (b) Echinodermata
   (c) Porifera
   (d) Protozoa

2) Ascon type of canal system is found in
   (a) *Leucosolenia*
   (b) *Hyalonema*
   (c) *Spongilla*
   (d) *Grantia*

3) Which of the following sponge is present in river?
   (a) *Sycon*
   (b) *Hyalonema*
   (c) *Spongilla*
   (d) None

4) Sponges are characterised by
   (a) Choanocytes
   (b) Canal system
   (c) Porous body
   (d) All of these

5) Which cells show totipotency in sponges?
   (a) Archaeocytes
   (b) Amoebocytes
   (c) Choanocytes
   (d) None of these

6) Sponges are classified on the basis of
   (a) Skeleton
   (b) Locomotory organs
   (c) Shape
   (d) Number of ostia

7) In sponges Gemmules are formed due to
   (a) Regeneration
   (b) External budding
   (c) Internal budding
   (d) None of these

8) Skeleton of sponge is secreted by
- (a) Myocyte
- (b) Sclerocyte
- (c) Porocyte
- (d) Amoebocyte

9) Body wall in sponges is
- (a) Acellular
- (b) Diploblastic
- (c) Triploblastic
- (d) None of these

10) Sponges regenerate due to the presence of
- (a) Choanocytes
- (b) Spicules
- (c) Archaeocytes
- (d) Thesocytes

Answers

1) (c) 2) (a) 3) (c) 4) (d) 5) (a) 6) (a) 7) (c) 8) (b) 9) (b) 10 (c)

UNIT 3: COELENTERATE

Contents

3.1 Objectives:-

The study of Identification, systematic position Up to order level and the general study of Coelenterates.

3.2 Introduction:-

These are the Multicellular organisms with tissue grade of organization and are aquatic, mostly marine except a few freshwater forms like *Hydra*. They are sedentary or free swimming, solitary or colonial and show the radial or biradial symmetry with central gastro vascular cavity opening to exterior by mouth. Diploblastic body consisting of outer layer of ectoderm, inner endoderm and an intermediate non cellular gelatinous mesogloea. Acoelomate i.e. coelom is absent. Mouth is encircled by tentacles bearing nematocysts (stinging cells) meant for capturing food, adhesion, offence and defense.

General Characters:-

1. They exhibit the phenomenon of **polymorphism** i.e occurence of different types of individuals or **zooids**. Zooids are mainly **Polyps** (sessile and asexual zooid) and **Medusae** (free swimming and sexual zooid).
2. Usually **carnivorous,** digestion **extracellular** as well as **intracellular**. Anus is absent.
3. Respiratory, circulatory and excretory systems are absent.
4. Reproduction takes place by both ways **asexual** (budding) and **sexual** (by formation of gametes).
5. **Planula** larva is present in the life cycle. **Alternation of generation (metagenesis)** takes place in which asexual polypoid generation alternates with sexual medusoid generation.

Classification

PHYLUM-COELENTRATA

Class

1. HYDROZOA
2. SCYPHOZOA
3. ACTINOZOA (ANTHOZOA)

1. HYDROZOA
   - Polypoid generation or medusoid generation or both.
   - Solitary or colonial.

2. SCYPHOZOA
   - Exclusively medusoid, polyps absent.
   - Umbrella shaped medusae without velum.

3. ACTINOZOA (ANTHOZOA)
   - Exclusively polypoid, medusae absent.
   - Gastrovascular cavity divided by 8 or more mesenteries.

Order1: **Hydroidea**

- Polypoid stage is predominant.
- Medusae present or absent.

  Examples: *Hydra, Obelia.*

Order2: **Hydrocorallina**

- Calcareous exoskeleton.
- Polyps are dimorphic i.e. gastrozooids and dactylozooids.

  Examples: *Millepora, Stylaster.*

Order 3: **Trachylina**

- Dominant medusoid stage, polyps poorly developed or absent.
- Sense organs are statocysts or tentaculocysts.

  Examples: *Gonionemus, Cunia.*

Order 4: **Siphonophora**

- Exhibit Polymorphism.
- Polyps without tentacles and incomplete medusae which are rarely freed.

  Examples: *Physalia, Porpita.*

Class2: Scyphozoa

Order1: **Stauromedusae**

- Globet, bell or trumpet shaped body.
- Sessile, sedentary attached by an aboral stalk.
- Tentaculocysts- absent.

  Examples: *Haliclystus, Lucernaria.*

Order2: **Cubomedusae**

- Body cuboidal with four flat sides.
- Found in warm and shallow waters of tropical and subtropical regions.
- Tentaculocysts- 4.

  Examples: *Charybdaea, Tamoya.*

Order 3: **Coronatae**

- Free swimming, inhabiting deep waters of ocean.
- Conical, dome shaped body.
- Tentaculocysts- 4-16.

  Examples: *Pericolpa, Periphylla.*

Order 4: **Semaeostomae**

- The umbrella is flat, saucer or bowl shaped.
- Mouth is square
- Tentaculocysts- 8.

  Examples: *Aurelia, Cynaea.*

Order 5: **Rhizostomae**

- Found in tropical and subtropical oceans.
- Saucer or bowl shaped.
- Tentaculocysts- 8 or more.

  Examples: *Rhizostoma, Cassiopeia.*

Class3: Actinozoa (Anthozoa)

- They are exclusively polypoid, medusoid stage absent.
- Gastrovascular cavity is divided by 8 or more mesenteries.

Sub-class A. Octocorallia

- Colonial marine forms.
- Polyps always bear 8 pinnate hollow tentacles.

Order1: **Stolonifera**

- Polyps arise singly from a creeping base or stolon.
- Skeleton consist of loose spicules or of compact tubes and platforms.

  Examples: *Tubipora, Clavularia.*

Order2: **Telestacea**

- Lateral polyps on single or branched stems.
- Skeleton of calcareous spicules.

  Examples: *Telesto.*

Order 3: **Alcyonacea**

- Colony mushroom shaped or branched into stout blunt processes.
- Lower part of the polyp fused into a fleshy mass only oral ends protrude out (soft corals).

Examples: *Alcyonium, Xenia.*

Order 4: **Coenothecalia**

- Skeleton is massive consisting of calcium carbonate.
- Commonly known as blue corals found in the Indo-Pacific coral reef.

  Examples: *Heliopora.*

Order 5: **Gorgonacea**

- Tree or feather like branched colony containing short polyps.
- Axial skeleton consisting of calcareous spicules or horn like material called gorgonin.

  Examples: *Gorgonia, Corallium.*

Order 6: **Pennatulacea**

- Elongated colony divided into proximal stalk and distal rachis (feather like).
- Main stem is supported by calcareous or horny skeleton

  Examples: *Pennatula, Renilla.*

Sub-class B. Hexacorallia

- Tentacles and mesenteries are six or multiples of six.
- Polyps are usually monomorphic.

Order1: **Actiniaria**

- Muscular body, cylindrical without skeleton.
- Pedal disc present on aboral end.

  Examples: *Metridium, Adamsia, Actinia*

Order2: **Zoanthidia**

- Solitary or colonial.
- Skeleton and pedal disc are absent but some calcareous bodies are present within the body wall.

  Examples: *Zoanthus, Epizoanthus.*

Order 3: **Ceriantharia**

- Without pedal disc.
- Numerous mesenteries.

  Examples: *Cerianthus.*

Order 4: **Madreporaria**

- Solitary or colonial hard corals.
- Hard calcareous skeleton is present.

  Examples: *Madrepora, Favia.*

3.3 – Obelia:-

3.3.1 General Characters:-

1. *Obelia* is commonly called as **sea-fur**. It is sedentary marine colonial form attached on the surface of sea weeds, molluscan shells, rocks and wooden piles in shallow waters. It is widely distributed throughout the world.
2. It is a **trimorphic** colony present in the form of filamentous sea weed measuring several centimeters in height.
3. The basal horizontal portion is known as **hydrorhiza or stolon**. It helps in attachment with the substratum. It gives up vertical branches called hydrocaulus.
4. Hydrorhiza and hydrocaulus are covered by **chitinous perisarc** which encloses soft inner coenosarc.
5. **Coenosarc** is the living, hollow cellular tube made up of ectoderm, endoderm and mesoglea.
6. The trimorphic colony of *Obelia* posses three types of zooids **polyp** (hydranths), g**onangium** (blastostyle) and **medusa** (sexual zooid).
7. Polyp is the **nutritive zooid**. It is a bell shaped cup made up of lower **hydrotheca** and upper **hypostome**. Hypostome carries a ciclet of numerous **tentacles** provided with **nematocysts**.
8. **Blastostyle** is the club shaped **reproductive zooid** enclosed within a covering called **gonotheca**. It gives rise to buds which develop into medusa.
9. **Medusa** is the free swimming reproductive zooid consisting of upper exumbrellar (convex) and lowers sub-umbrellar (concave) sides. It is provided with marginal tentacles, four radial canals bearing gonads, a ring canal and a central hanging **manubrium** on the concave side.
10. It reproduces by asexual as well as sexual methods. Life history of *Obelia* exhibits **alternation of generation**.

3.3.2 - Identifying character:-

Alternate branches of polyps and blastostyles.

3.3.3 - Systematic Position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class …………….....Hydrozoa (Hydroids, medusa with velum)
Order ……………...Hydroidea (Polypoid generation well developed)
Genus ……………..*Obelia*

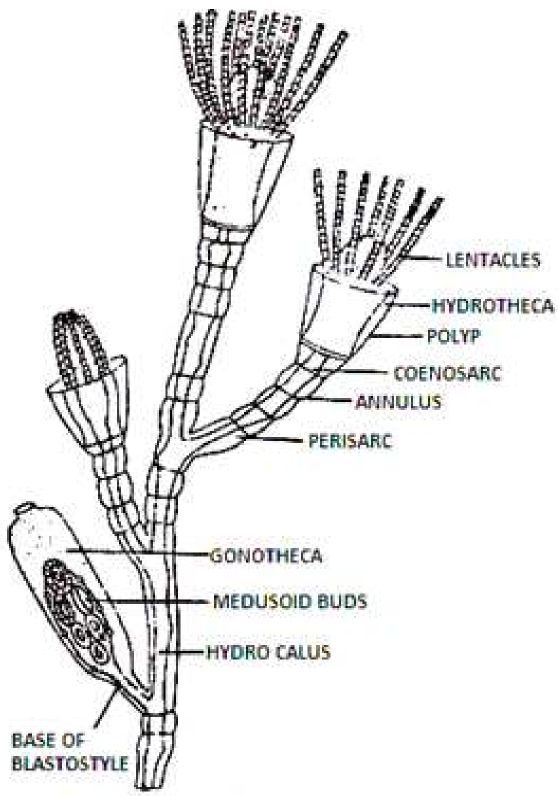


Fig 3.1: Obelia Colony

3.4– Physalia:-

3.4.1- General Characters

1. *Physalia* is a colonial hydroid commonly called **Portuguese man of war**. It is a marine, colonial, swimming or floating pelagic animal. Distributed in tropical and subtropical seas.
2. Colony consists of large gas filled **pneumatophore** or float which is bright blue in colour. It floats above the surface.
3. Pneumatophore contains **gas glands**. It produce a gas having 90% nitrogen, 9% oxygen and 1% argon while swimming the pneumatophore is filled with gas and when animal has to sink the gas is released out.
4. Beneath the float three main types of zooids hang down

(i) **Gastrozooids** – Nutritive zooids having mouth but tentacles are absent.
(ii) **Dactylozooids** – these help to caphere the prey for food. They have numerous nematocyst bearing tentacles.
(iii) **Gonozooids** – Reproductive zooids bearing clusters of male and female medusa.

5. Tentacles are large and bear **stinging batteries** or **nematocysts** to kill fishes.
6. The members of *Physalia* colony show division of labour.

3.4.2 - Identifying Character:-

Pneumatophore (float), hanging gastrzooids, tentacles and gonozooids.

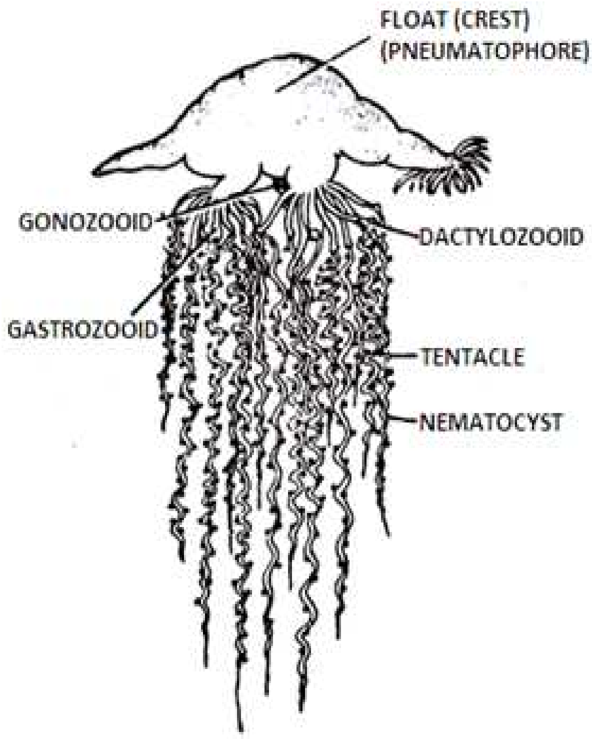


Fig 3.2: Physalia

3.4.3 - Systematic Position

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class ……………....Hydrozoa (Hydroids, medusa with velum)
Order ……………...Siphonophora (Polymorphic colonies, numerous polypoid and medusoid zooids)
Genus ……………..*Physalia* (The Portuguese man -of -war)

3.5 *Porpita*

3.5.1 - General Characters

1. *Porpita* is a colonial marine hydroid found in tropical and sub-tropical water of the Pacific, Atlantic and Indian oceans.
2. It is commonly known as **blue button**.
3. The colony is **disc shaped** resembling to medusa.
4. Body is disc like with a **chitinous**, chambered **pneumatphore** containing air. It opens to exterior by pores.
5. A large central **gastrozooid** bearing mount leading to wide gastric cavity is present on the ventral side.
6. Numerous **gonozooids** bearing medusa encircle the gastrozooid.
7. Numerous long dactylozooids bearing nematocysts are present on the margin of disc.
8. The reproductive zooids are liberated as free **medusa**.

3.5.2- Identifying character:

Presence of central disc surrounded by tentacles.

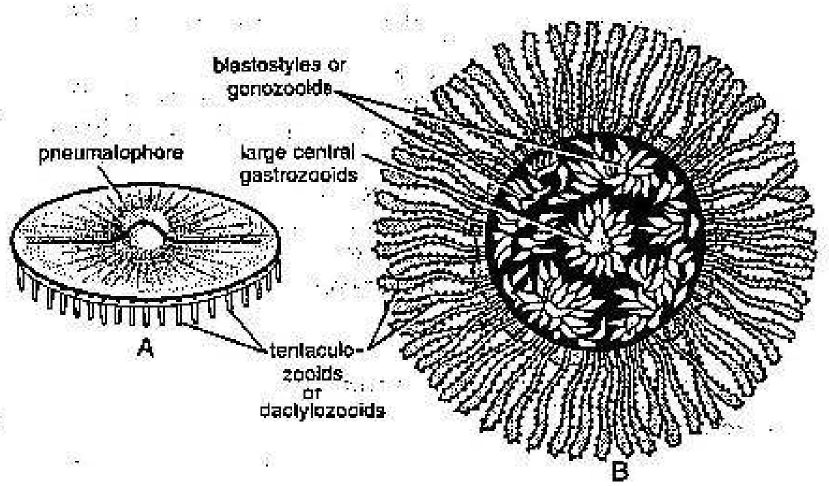


Fig.3.3: Porpita A Dorsal view B Oral ventral side

3.5.3 Systematic position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)

Class ……………....Hydrozoa (Hydroids, medusa with velum)

Order ……………...Siphonophora (Polymorphic colonies, numerous polypoid and medusoid zooids)

Genus ……………..*Porpita*

3.6 Vellella

3.6.1General Characters:-

1. *Vellella* is commonly called **little sail**. It is most beautiful open sea form consisting of deep blue colony.
2. It is commonly distributed in warm seas.
3. The float or **pneumatophore** is a chambered disc containing air in the chambers and having **vertical sail** on the top.
4. Large single **gastrozooid** hangs in the centre. At ventral side it bears mouth.
5. Numerous medusa bearing **gonozooids** are present around the gastrozooid.
6. Tentacle like **dactytozooids** bearing nematocysts is present on the margin of disc.
7. Gonozooids produce free **medusa.**
8. It exhibits the phenomenon of **polymorphism**.

3.6.2- Identifying character:

Presence of sail and single gastrozooid

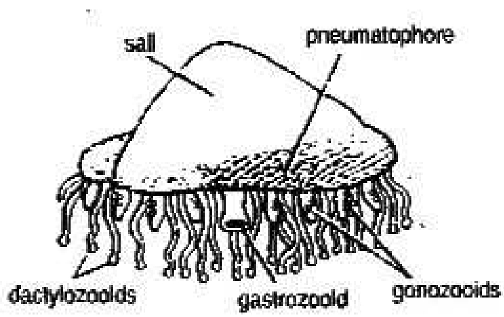


Fig 3.4: Velella

3.6.3 Systematic Position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class ……………....Hydrozoa (Hydroids, medusa with velum)
Order ……………...Siphonophora (Polymorphic colonies, numerous polypoid and medusoid zooids)
Genus ……………..*Velella* (Little sail)

3.7- *Tubipora*

3.7.1 General characters

1. *Tubipora* is commonly called **organ pipe coral**. It is highly calcified coral.
2. It is a marine colonial **plypoid anthozoa** distributed in warm waters of Atlantic, Indian and Pacific Oceans.
3. The colony consists of long parallel upright polyps enclosed in vertical skeleton tubes arising from **basal plates**.
4. Polyps are united by horizontal platforms at definite intervals formed by fusion of **spicules.**
5. Mesogleal spicules become closely fitted to form a continous tube for each polyps.
6. Skeleton is internal and covered by **ectoderm** in living condition.
7. The polyps are green in colour but skeleton becomes dull red due to the presence of **iron salts.**
8. Reproduction take place **asexually** by budding..

3.7.2- Identifying Character:

Compact red coloured vertical tubes.

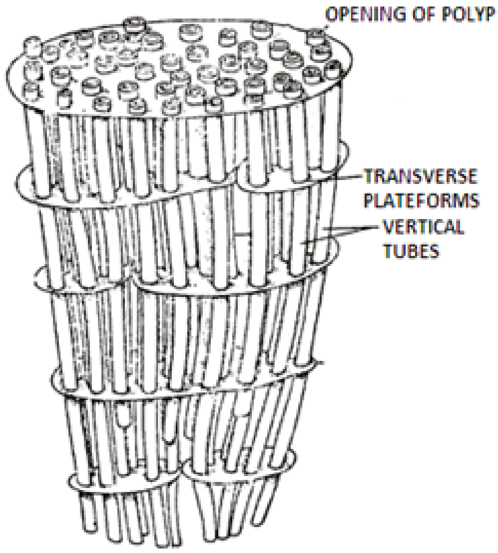


Fig. 3.5: Tubipora A Portion of living colony B Portion of dead coral

3.7.3: Systematic Position

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class ……………....Anthozoa (Only polypoid generation, sedentary, solitary or colonial)
Order ……………...Stolonifera (Polyps not fused but communicate with each other through basal plate)
Genus ……………..*Tubipora* (Organ pipe coral)

3.8 Millepora:-

3.8.1-General Characters:-

1. It is commonly known as **stinging coral** as its powerful nematocysts are painful to man.
2. It is a **colonial** marine coral distributed throughout the tropical shallow waters of West Indies and U.S.A.

3. Colony consists of upright leaf like calcareous growth, white or yellowish in colours.
4. The surface of colony bears pores of 2 sizes the larger **gastropores** and smaller **dactylopores.**
5. Colony has two types of zooids i.e. **gastrozooids** – shorter having mouth and tentacles and **dactylozooids** – long, slender, hollow tentacles without mouth.
6. Medusae originate from **coenosarcs**. They don't have mouth and tentacles and are short lived.
7. Dried colonies form irregular mass.

3.8.2-Identifying Character:

Presence of gastropores and dactylopores

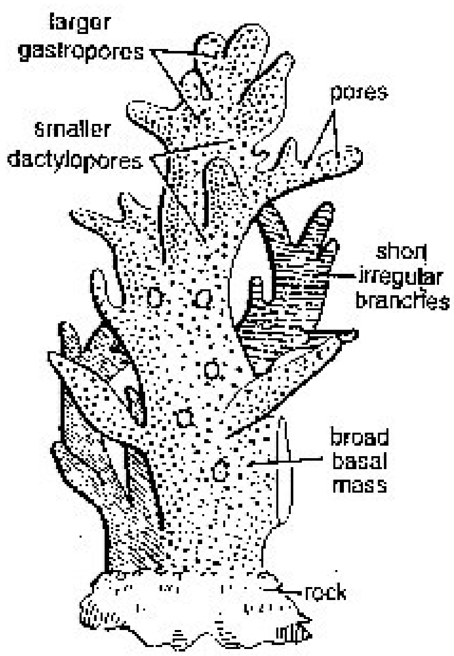


Fig 3.6: Millepora

3.8.3-Systematic position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class ……………....Hydrozoa (Hydroids, medusa with velum)
Order ……………...Hydrocorallina (Coenosarc secretes exoskeleton, dimorphic polyps)
Genus ……………..*Millipora*

3.9 – *Aurelia*

3.9.1 – General Characters:-

1. *Aurelia* is commonly known as **Jelly-fish**. It is a solitary, marine, medusoid form inhabiting warm and temperate seas throughout the world.
2. Body is transparent, bluish white in colour. Inner organs are visible from body surface.
3. Circular body measuring about 90 mm in diameter having convex **aboral** (exumbrellar) and concave **oral** (sub umbrella) surface.
4. Four red or purple **horse-shoe shaped gonads** are visible from aboral surface.
5. Mouth is four cornered each corner continues into four long and narrow oral lobes hanging down from oral surface.
6. Subumbrellar margin contain marginal tentacles having **stinging cells** and 8 marginal **lappets** having sense organs called **tentaculocysts (rhopalium).**
7. Jelly fish is **carnivorous** feeding on small animals like molluscs, crustaceans, protozoans, nematodes etc.
8. It swims by rhythmic contractions of umbrellar surface.
9. *Aurelia* is **dioecious** i.e. male and female individuals are separate.
10. Life cycle shows **alternation of generation**.

3.9.2 Identifying Character:

Jelly like texture, marginal tentacles and oral arms

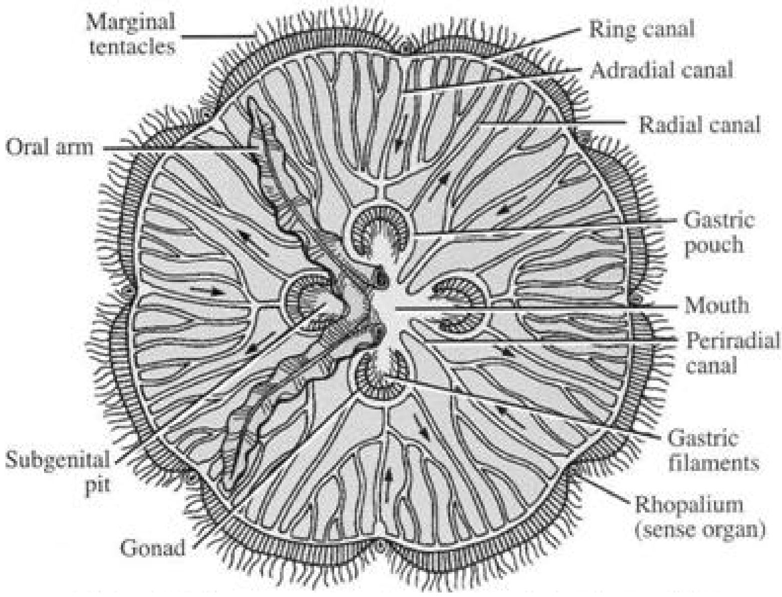


Fig. 3.7: Aurelia oral view

3.9.3- Systematic Position

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)
Class ……………....Scyphozoa (Medusa well developed, hydroid reduced)
Order ……………...Semaeostomeae (Free swimming scyphomedusae with umbrella like disc and oral lobes)
Genus ……………..*Aurelia* (Jelly fish)

3.9.4 – Larval stages of Aurelia:

Life cycle of Aurelia includes 3 larval stages as follows –

(A) Planula Larva:

Comments:

(i) Fertilized egg undergoes cleavage to form morula and gastrula which further give rise to ciliated larva called **planula larva**.
(ii) It becomes elongated and **ciliated**.
(iii) Planula larva consists of ciliated **ectoderm, mesoglea, endoderm** and **coelenteron**.
(iv) Fully developed planula larva is present on the frills of oral arms of *Aurelia*.
(v) Planula larva escapes and gives rise to next larval stage called **scyphistoma larva**.

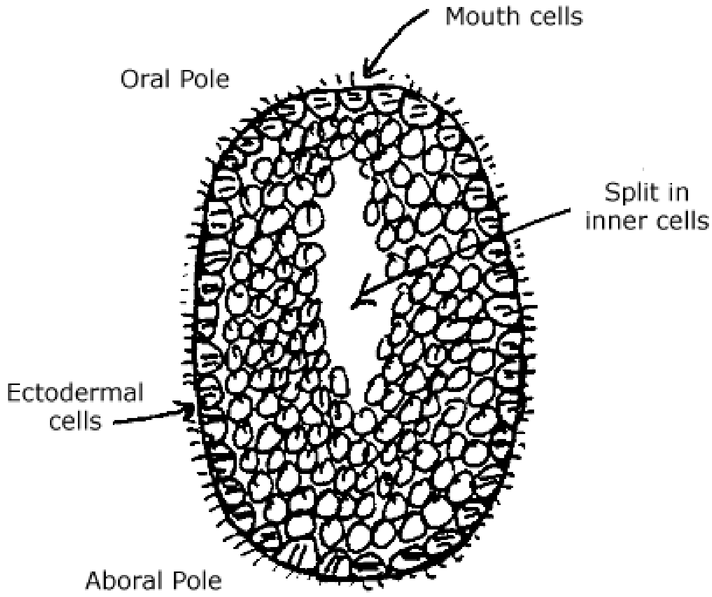


Fig. 3.8. (A) Planula larva

(B) Scyphistoma Larva:

Comments:
(i) The planula larva swims for some time and attaches to a substratum by **aboral** end.
(ii) Cilia are lost and a **mouth** opens at its free distal end.
(iii) The larva is metamorphosed into about 5 mm high, small trumpet-shaped or hydra like polyp.
(iv) It consists of an adhesive **basal disc** containing stalk like organ having oral end containing **mouth, manubrium** and **tentacles**.
(v) The number of tentacles vary from 16 to 32. These are named as **Perradia** (1^{st} four), **interradial** (next four tentacles) and remaining are **adradial** tentacles.
(vi) In autumn and winter scyphistoma undergoes process of budding or transverse fission at oral ends known as **strobilization**.
(vii) During strobilization the scyphistoma with segmented body break at intervals each segment forms an **ephyra larva**.

(viii) During the favourable conditions several ephyrae are produced at one time (**polydisc strobilization**). During unfavorable conditions single ephyra is produced at a time **(monodisc strobilization).**

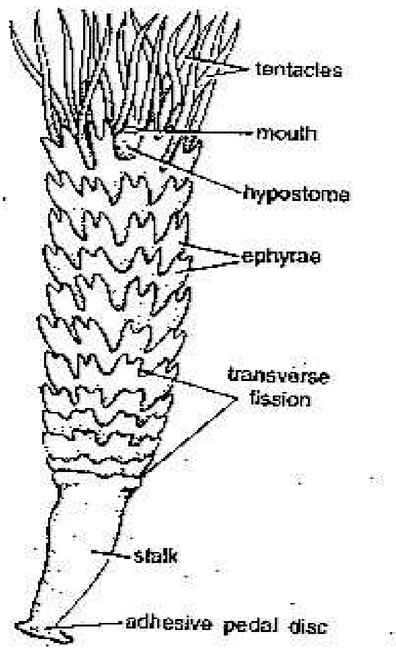


Fig. 3.8. (B): Scyphistoma Larva

(C) Ephyra Larva

Comments:

(i) Scyphistoma larva gives rise to Ephyra larva.
(ii) It is small medusoid from.
(iii) Saucer-shaped or umbrella like body having tetramerous symmetry.
(iv) 8-long forked arms having marginal lappets are present.
(v) 8-prominent tentaculocysts are present in the notches between marginal lappets.
(vi) Manubrium with the mouth is present in the middle on ventral surface.
(vii) Ephyra larva swims actively in the water and metamorphoses into adult Aurelia.

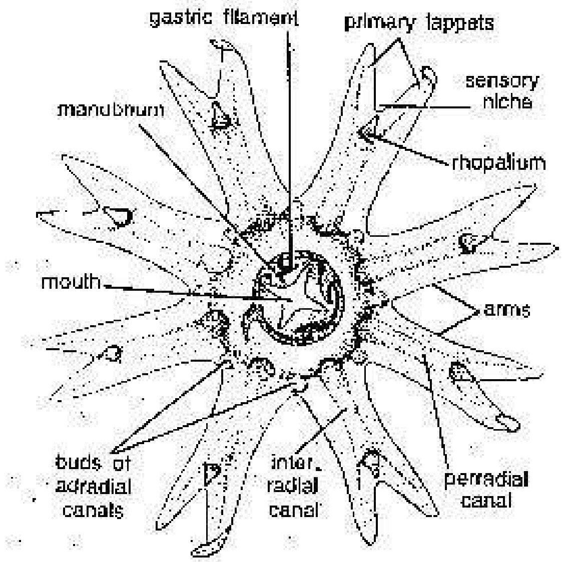


Fig 3.8(C): Ephyra Larva

3.10 – *Gornonia*

3.10.1 General Characters:-

1. *Gorgonia* is commonly known as **sea fan.** It inhabits shallow tropical seas near Malaya, West Indies and Indo-Pacific Ocean.
2. It forms **branching colonies** of yellow and red colour growing up to 50 cm in height.
3. Body consists of plant-like branching stems and a short main trunk attached to the substratum by a **pedal disc**.
4. Numerous small **anthocodia (retractile polyps)** are present in rows on either side of stems of branches.
5. Skeleton consists of an **axial rod** present throughout the body. It is made up of **gorgonin** (flexible horn like ectodermal material).
6. It contains numerous **spicules** in the mesoglea.
7. Sexes are separate.

3.10.2 Identifying Character:

Fan shaped body.

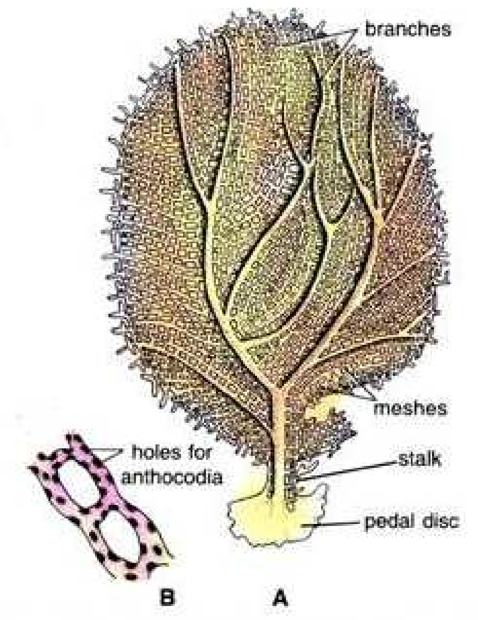


Fig 3.8 – Gornonia A- Complete specimen B- A magnified portion

3.10.3 Systematic Position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)

Class …………….....Anthozoa (Only polypoid generation, sedentary, solitary or colonial)

Order ……………...Gorgonacea (Horny corals, short polyps not touching base)

Genus ……………..*Gorgonia* (Sea fan)

3.11 – *Alcyonium:-*

3.11.1 General Character:-

1. *Alcyonium* is commonly known as dead men's finger or soft coral. It is found attached to rocks and stones in Indo-Pacific Ocean.
2. Colony conists of a **stalk** and thick soft **leathering lobes**.

3. The promixal part i.e. stalk is devoid of zooids and the distal lobes posses zooids.
4. Fleshy mass called **Coenonchyma** is present above stalk from which polyps project out.
5. Each polyp contains 8-**pinnate tentacles**.
6. **Spicules** are found throughout the mesoglea which give support to coenonchyme.
7. **Gonads** develop during breeding season on the mesenteries of polyps. Fertilization is external.
8. Life cycle includes free swimming **Planula larva** which fixes itself to substratum and give rise to a new colony by budding.

3.11.2 Identifying Character:

Presence of star shaped polyps and finger like soft body.

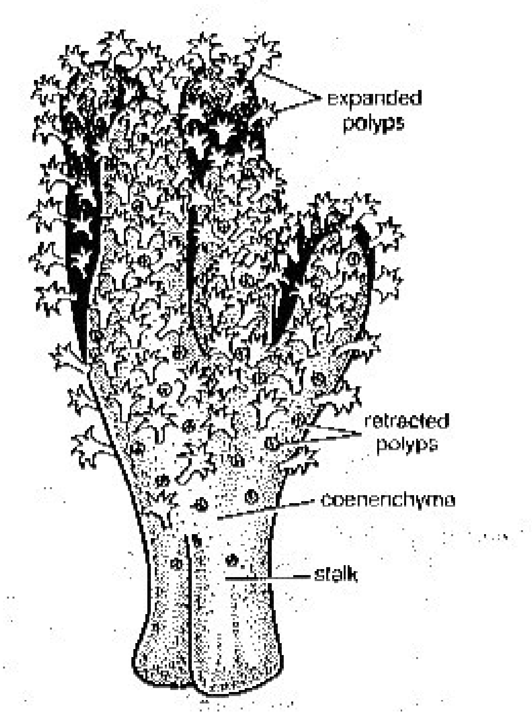


Fig 3.9: *Alcyonium*

3.11.3 Systematic Position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)

Class …………….....Anthozoa (Only polypoid generation, sedentary, solitary or colonial)

Order ……………...Alcyonacea (Basal plate forms fleshy mass)

Genus …………….*Alcyonium* (Dead man's finger)

3.12 Adamsia:-

3.12.1 – General Character:-

1. *Adamsia* is found attached on the empty gastropod shells inhabited by hermit crab (*Euparagus*). It is distributed in shallow water of U.S.A. and Indian Ocean.
2. Body is large, cylindrical and divided into three parts – pedal disc, coloumn and oral disc.
3. **Pedal** is flat, sucker like and bilobed. It helps in attachment to molluscan shell.
4. **Coloumn** is cylindrical bearing a band of cinclidal tubercles at its base.
5. **Oral disc** bears a central mouth encircled by numerous (500 approx) nematocyst bearing tentacles.
6. *Adamsia* shows a good example of commonsalism (mutual benefit). *Adamsia* is carried to different places **hermit crab** living inside empty mollusc shell and gets variety of food. Hermit crab gets protection inside the shell as well as *Adamsia* covers its body and protects the crab from attacks of enemies by stinging with **nematocysts.**

3.12.2 – Identifying Character:

Adamsia living in commensalism on a **molluscan shell** inhabited by **hermit crab** (*Euparagus*)

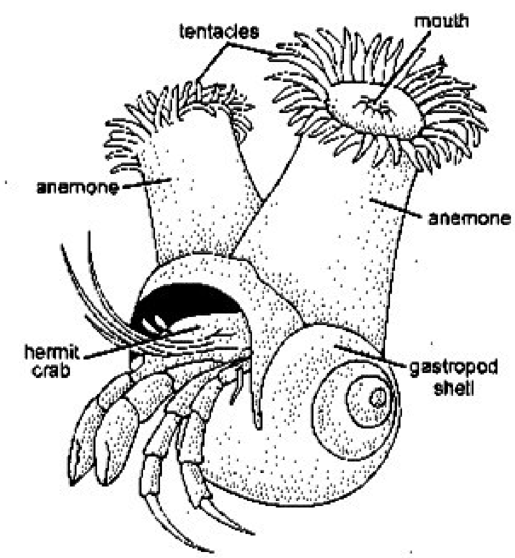


Fig 3.10 – Adamsia

3.12.3 – Systematic Position:

Phylum …………...Coelentrata (Tissue grade organization, diploplastic and acoelomate)

Class ……………....Anthozoa (Only polypoid generation, sedentary, solitary or colonial)

Order ……………...Actiniaria (Skeleton absent, mesenteries of septa in multiple of six)

Genus ……………..*Adamsia*

3.13– Hydra

3.13.1 General Characters:-

1. *Hydra* is a solitary, freshwater and **cosmopolitan** hydrozoan found attached to some objects in lakes, ponds and streams all over the world but most common in India, Canada and U.S.A.
2. It is a **polypoid**, tubular and cylindrical coelenterate and measures about 1 cm when fully extended.
3. Proximal end is called **basal disc** and contains gland cells which secrete adhesive secretion for attachment.
4. The free distal or oral end bears mouth situated on a conical projection called **hypostome**.
5. Hypostome is encircled by 6-10 hollow, slender tentacles provided with **nematocysts.**
6. Body wall is **diploblastic** consisting of an outer **ectoderm** and inner **endoderm** separated by **mesoglea.**
7. Mouth leads to **gastrovascular** cavity.
8. Lateral buds may be present on the sides of the body which give rise to new individuals by **budding**.
9. **Gonads** are present as buds on the body. **Testes** are situated near the oral and end while **ovaries** near the base.
10. Reproduction by both **asexual** (budding) and **sexual** methods. *Hydra* posses great power of **regeneration**. Thus extensively used for experimental studies on regeneration.
11. *Hydra viridis* contains symbiotic green alga Zoochlorellae.

3.13.2 Identifying Character: -

Raised hypostome and polypoid body:

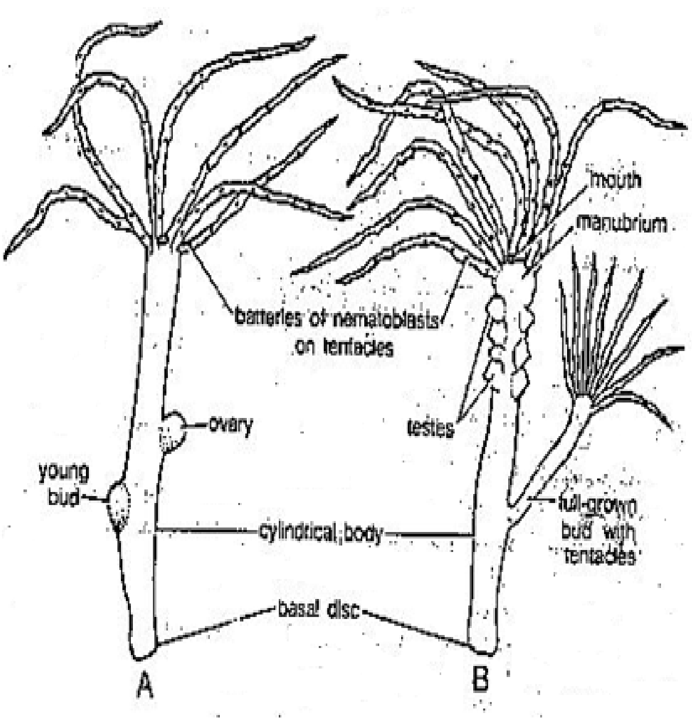


Fig: 3.11 Hydra A Female B Male

3.13.3 Systematic Position:-

Phylum ……………Coelentrata (Tissue grade organization, diploplastic and acoelomate)

Class ……………....Hydrozoa (Hydroids, medusa with velum)

Order ……………...Hydroidea (Polypoid generation well developed)

Genus ……………..*Hydra*

3.14-Summary:-

The Coelentrata may be defined as “diploblastic metazoa with tissue grade of organization having nematocysts and a single gastrovascular cavity or coelonteron." The tissues consist of ectoderm and endoderm with an intermediate gelatinous layer called mesogloea. All the functions of the body are carried out by tissues and never by organs. Coelenterates exhibit the phenomenon of polymorphism i.e. representation of a single organism by more than one kind of individual (zooids) which are stucturally and functionally different from each other. Most Hydrozoa exhibit dimorphism i.e. showing two forms: polyp (nutritive zooid) and medusa (reproductive zooid). Some hydrozoan colonies are trimorphic. Siphonophora shows the highest degree of polymorphism (three types of polypoid zooid and four types of medusoid zooid). Modification of polypoid zooids include: Gastrozooid (respionsible for digestion and ingestion of liquid food), Dactylozooid (for defence and obtaining food), Gonozooid (they bear male and female medusae). The medusoid zooids are modified into Pneumatophore (gas filled vesicle or bladder it helps in swimming), Phyllozooids (leaf like zooids, protective in function), Nectocalyces (muscular zooid, helps in swimming) and Gonophores (degenerate medusae, mouth, tentacles and sense organs are absent). Polymorphism is the phenomenon of division of labour. Skeleton is either endoskeleton or commonly endoskeleton. They are usually carnivorous extracellular as well as intracellular digestion. Coral reef is the mound of lime stone whose upper surface is near the sea, it is formed by the action of corals. Most of the corals belong to class Anthozoa and a few to Hydrozoa. Reproduction takes place by sexual as well as asexual methods. Development is indirect, usually including a ciliated planula larva. Life cycle shows metagenesis (Alternation of generation) in which asexual polypoid generation alternates with sexual medusoid generation.

3.15-Glossary:

Alternation of generation: Alternate succession of sexual (haploid) and asexual (diploid) generation in the life cycle of an organism.

Atoll: Horse shoe or ring like island consisting of a belt of coral reef surrounding a central lagoon.

Barrier reef: Reef separated from shore by wide deep channel.

Basal disc: Flattened foot of some coelentrates which attaches to substratum by secreting some sticky substance.

Body cavity: Cavity located between body wall and internal organs of an organism.

Budding: A form of asexual reproduction in which a new individual develops from some generative anatomical point of the parent organism.

Calcareous: Containing lime or calcium.

Chitin: A complex organic substance or a polysaccharide forming the exoskeleton.

Cnidaria or Coelentrata: Phylum including animals possessing cnidoblast structures.
Cnidoblast: Type of cell in which nematocyst is found.
Commonsalism: An association of individuals of two different species in which atleast one is benefitted and the other is neither harmed nor benefitted.
Dactylozooid: Sensory polyp of Hydrozoa.
Dioecious: Having male and female reproductive organs in separate individuals.
Diploblastic: Derived from two embryonic germ layers, ectoderm and endoderm.
Ephyra: Free swimming larva of scyphozoan coelenterates.
Fringing reef: Coral ridge build up from ocean bottom.
Gastrovascular: Serving the function of both digestion and circulation.
Hydranth: Expanded end of a branch of hydroid colony specialized for vegetative function.
Hydrocaulus: Main stalk like stem of a hydroid colony.
Hydrorhiza: Basal root like portion of a hydroid colony used for attachment with the substratum
Hydrotheca: Transparent membrane that extends from the perisarc and surrounds the main part of the hydranth.
Hypostome: Structure surrounding mouth in coelentrates.
Lappet: Flap like projection.
Manubrium: A structure projecting from the middle of sub-umbrellar surface of medusa. It bears mouth at its free end.
Mesogloea: Non cellular jelly like substance present between ectoderm and endoderm in coelentrates.
Metagenesis: Alternation of sexual with asexual generation in the life cycle of coelentrates.
Metazoa: Multicellular animals.
Monoecius: Organism having both male and female reproductive organs.
Mutualism: An association between two species in which both the individuals are benefitted.
Nematocyst: A stinging capsule found in coelentrates it is produced by a cell called cnidoblast.
Pedal: Related to feet.
Pelagic: Inhabiting in open water away from shore.
Regeneration: Replacement by growth of lost part of the body.
Strobilation: Budding in the segments of sessile scyphozoan coelentrate larvae
Tentaculocyst: Sense organs of some coelentrates.
Zooid: A single animal form that is a part of polymorphic colon

3.16 - Self Assessment Questions:-

Q1. Members of which class form coral reefs?
Q2.Name the different larval stages in the life cycle of aurelia.

Q3. Which zooid is dominant in Aurelia?
Q4. Which larva is found in Obelia?
Q5. What is Polymorphism?
Q6. How Hydra does reproduce asexually?
Q7. What is polyp?
Q8. What is medusa?

3.17 – References:-

Jordan, E.L., Verma, P.S. 2009: Invertebrate Zoology publ. S.Chand and Co. New Delhi, 1127 pp.

Verma, P.S. 2012: A Manual of Practical Zoology Invertebrates, 15th edition, publ. S.Chand and Co. New Delhi, 497 pp.

Lal, S.S. 2011: Practical Zoology Invertebrate, 10th edition, publ. Rastogi Publication, Meerut, 512 pp.

Kotpal, R.L. 2011: Modern Text Book of Zoology Invertebrates Rastogi Publication, Meerut. 883 pp.

3.18 - Suggested Readings:-

Edward, R and Barnes, R 1994: Invertebrate Zoology, 6th edition, Saunders College Publishing, Harcourt Brace And Co., Orlando, Florida, 1100pgs.

Parker, T.J. and Haswell, W.A. 1897: A Textbook of Zoology. Publ. Macmillan And Co. Ltd. Vol I and II.

3.19 Terminal Questions/Answers:-

Long answer questions:

Q1. Briefly describe locomotion in Hydra**.**
Q2 Describe the life history of Obelia.
Q3. Give an account of different zooids found in Obelia colony.
Q4. Comment on coral reefs.

Fill in the Blanks:

k) Nematocysts are present in.............. .
l) .... is responsible for division of labour in coelenterates.
m) .... is commonly called Portuguese man of war.
n) Sea anemone belongs to class........... .
o) Adamsia and Hermit crab show the phenomenon of...............
p) .... Is commonly called dead man's finger.
q) .... Have fan shaped body.
r) Nematocysts are responsible for .... and...............
s) .... Consists of quill like bilaterally symmetrical body.
t) Hydra is considered immortal because of.............

Answers

a) Coelenterates b) polymorphism c) *Physalia* d) anthozoa e) Commensalism f) *Alcyonium* g) *Gorgonium* h) offence and defence i) *Pennatula* j) Regeneration

Multiple Choice Questions

2) Float is absent in
(a) Physalia
(b) Vellela
(c) Porpita
(d) Obelia

2) Exclusively polypoid coelentrate is
(a) *Pennatula*
(b) *Hydra*
(c) *Millepora*
(d) *Obelia*

3) Which of the following has symbiotic relationship with Zoochlorellae algae
(a) *Hydractinia*
(b) *Millepora*
(c) *Hydra*
(d) None

4) In the life cycle of Aurelia planula larva changes into
(a) Adult
(b) Ephyra larva

(c) Scyphistoma larva
(d) None of these

5) Body cavity of *Hydra* is called
(a) Haemocoel
(b) Coelenteron
(c) Coelom
(d) None of these

6) The stolon of Obelia is called
(a) Hydrorhiza
(b) Hydranth
(c) Polyp
(d) Medusa

7) Obelia colony is
(a) Dimorphic
(b) Trimorphic
(c) Monomorphic
(d) None of these

8) Relationship between Adamsia and hermit crab is called
(a) Commensalisms
(b) Parasitism
(c) Symbiosis
(d) Mutualism

9) Nematocysts are found in
(a) Annelida
(b) Protozoa
(c) Coelentrata
(d) None of these

10) Both polyp and medusa are present in
(a) Hydrozoa
(b) Scyphozoa
(c) Actinozoa
(d) All of these

Answers

1) (d) 2) (a) 3) (c) 4) (c) 5) (b) 6) (a) 7) (b) 8) (a) 9) (c) 10 (a)

UNIT 4: PHYLUM: PLATYHELMINTHES (Flatworms)

Contents

4.1 Objectives:-

The study of Identification, systematic position Up to order level and the general study of Platyhelminths.

4.2 Introduction:-

Platyhelminths are bilaterally symmetrical and dorso-ventrally flattened. Body wall is triploblastic (form 3 germ layers- epidermis, mesodermis and endodermis) below the endodermis longitudinal. Circular and oblique muscles are present. Acoelomate (true coelom is absent) and unsegmented except class Cestoda.They are free living, parasitic or commensals.Adhesive organs like hooks, suckers and spines are present with adhesive secretions.

General characteristics:-

1. They show a blind sac body plan i.e. mesodermal tissue called mesenchyme/parenchyma is present between the internal organs and all these are filled in a sac like body having no other opening.
2. Digestive system is absent in Cestoda and Acoela but in others consist of mouth, pharynx and blind intestine without anus.
3. Respiration and circulatory system are absent.
4. Excretory system consists of single or paired protonephridia with flame cells or bulb except Acoela.
5. Nervous system is primitive, ladder like. It contains a pair of cerebral ganglia with longitudinal nerve cords connected by transverse nerves.
6. Sense organs are commonly present in Turbellarians but greatly reduced in parasitic form.
7. Generally they are hermaphrodite with few exceptions.
8. Reproductive system is highly evolved and complex. Sexual and Asexual reproduction both are present. Fertilization internal.
9. One or more hosts are required to complete their life cycle and larval forms usually present.

Outline classification:

Phylum Platyhelminthes

Classes

Turbellaria

- They are mostly free living but some are commensals or parasitic
- Life-cycle simple

Trematoda

- Endo/ecto pasitic, Commonly called as flukes
- Life- cycle simple/ complicated

Cestoda

- Endoparasitic in the intestine of vertebrte
- Life cycle complicated with hooked embry & usually involves to or most host

Sub-class

Cestodaria

-Body is undivided
-Larva with 10 hooks
-Only single set of reproductive organs

Eucestoda

- Body is divided into fewto many segments rarely undivided
- -Larva with 6 hooks
- More than one set of reproductive organs present in each segment

1. Class: Turbellaria

Order-Acoela

- Exclusively marine.
- Oviducts and yolk glands absent.
- Ex. *Convoluta,Ectocotyle*

Order- Rhabdocoela

- Freshwater, marine and terrestrial form.

- Few compact gonads & oviducts present.
- Ex. *Monodiscus*

Order- Alloecoela

- Mostly marine.
- Small numerous testes and a pair of ovaries present.
- Ex.*Otoplana*

Order- Tricladida

- Freshwater, marine and terrestrial form.
- Two to numerous testes and a pair of ovaries with yolk glands.
- Ex. *Planaria*

Order- Polycladida

- Exclusively marine.
- Testes and ovaries are numerous and sscattered.
- Ex. *Notoplana*

2. Class: Trematoda

Order-Monogenea

- Ecto or endo parasite or commensals.
- Only single host in life cycle.
- Ex. *Polystoma*

Order-Digenea

- Mostly endoparasites in vertebrates and invertebrates.
- Two or three intermediate host are present.
- Ex. *Fasciola hepatica* (Liver fluke), *Schistosoma* (Blood fluke).

Order-Aspidobothria

- Endoparasite in the gut of fishes and reptiles.
- No alteration of host.
- Ex. *Aspidogaster*

3. Class: Cestoda

(A) **Sub-class:Cestodaria(**Monozoic, no scolex and strobilia

Order-Amphilinidia

- Suckers are absent.
- Endo-parasite (occur in intestine of fishes).
- Ex. *Amphilina*

Order- Gyrocotylidea

- Sucker present (only anterior).
- Endoparasite of fishes.
- Ex. *Gyrocotyle*

(B) **Sub-class: Eucestoda** (Polyzoic, Scolex, neck and Strobilia present)

Order- Tetraphyllidea

- Endoparasite in intestine of elasmobranch fishes.
- Scolex with 4 leaf like suckers.
- Ex. *Phyllobothrium*

Order-Pseudophyllidea

- Found in the intestine of vertebrates.
- Scolex has 2 to 6 suckers.
- Ex. *Bothriocephalus*

Order-Diphyllidea

- Endoparasite in the intestine of elasmobranch fishes.
- Scolex contains two suckers and stalk with spiny head.
- Ex. *Echinobothrium*

Order- Trypanorhyncha

- Found in spiral valve of alimentary tract of elasmobranchs.
- Four suckers and four protrusible spiny proboscides present in scolex.
- Ex. *Tetrarhynchus*

Order-Taenioidea

- They are endoparasite, found in intestine of birds and mammals.
- Scolex has four suckers.
- Ex. *Taenia solium*

4.1 *Dugesia (=Planaria; Euplanaria)*

4.1.1 General characters:

1. Planaria (Dugesia) is found in freshwater streams, springs, ponds, lakes and shallow rivers of cold running water (See fig. no. 4.1).
2. They are found in India , Myanmar, U.K ,U.S,A and U.S.S.R
3. Body elongated leaf like, bilaterally symmetrical, with a broader anterior end and pointed posterior end & dorsoventrally flattened.
4. They are brown or black in color with size vary from 2 to 15 mm.
5. Head is broad, blunt, and triangular with laterally on either side auricles or two eyes.
6. Digestive system comprises of mouth (on ventral surface), everted pharynx (proboscis) and branched intestine.
7. Proboscis is covered with the proboscis sheath.
8. Intestine forks into three diverticulated branches, one anterior and two posterior.
9. Genital pore is situated a little posterior to the mouth.
10. Reproduction is sexual and asexual.
11. Planarians are used in experiment for regeneration and grafting.

4.1.2 Identifying characters:

Presence of auricles, a pair of simple eyes.

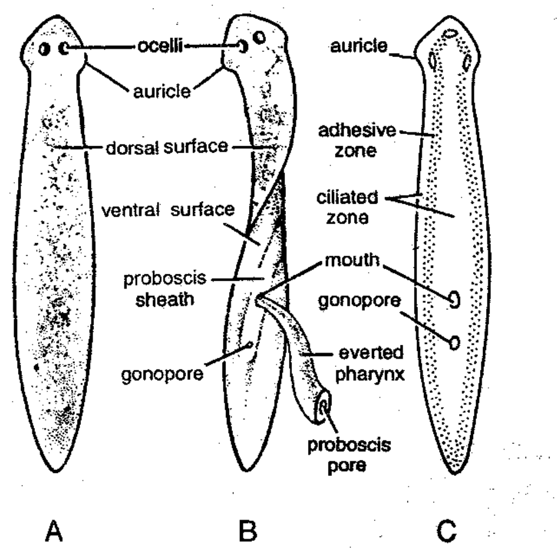


Fig. 4.1 *(A) Dorsal surface; (B) Body twisted to show a part of ventral surface; (C) Ventral surface*

4.1.3 Systematic position:

Phylum---- Platyhelminthes - Flatworms, acoelomate

Class---- Turbellaria - Ciliated epidermis, adhesive organs present

Order---- Tricladida - Gonopore single, pharynx protrusible, intestine with three branches

Genus--- *Dugesia (Euplanaria)*

Species--- *tigrina*

4.2 Liver fluke *Fasciola hepatica*:-

(A) Fasciola hepatica:(Liver fluke)

4.2.1General characters:

1. *Fasciola hepatica* is found in the bile duct of liver of sheep as endo parasite (See fig. no. 4.2).

2. Body is leaf –like, dorso – ventrally flattened measures 25-30 mm in length and 4-5 mm in breadth.
3. Anterior end is produced into a conical projection is known as cephalic cone.
4. Posterior end is large more rounded in front than behind.
5. Mouth is situated ventrally at anterior end and surrounded by oral sucker.
6. Digestive system comprised of pharynx, oesophagus and diverticulated intestine.
7. They are Hermaphrodite.
8. Excretory pore is found at the posterior extremity.
9. Eggs pass to the exterior through median genital pore situated between oral and ventral sucker.
10. Life Cycle comprises of an intermediate host, Lymnaea (a mollusc).
11. They causes a disease known as liver rot.

4.2.2 Identifying characters:

It has cephalic cone, acetabulum, anterior end is broad and rounded while posterior end is bluntly pointed.

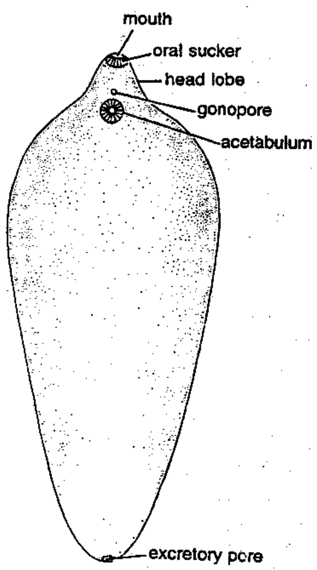


Fig. 4.2*Fasciola hepatica*

4.2.3 Systematic position

Phylum ---Platyhelminthes - Flatworms, acoelomate

Class ---- Trematoda - Body wall without opidermis and cilia, parasitic nature suckers

are well developed.

Order ----Digenea - Endoparasitic,many larval stages present,Two suckers without hooks

Genus ----*Fasciola*

Species--- *hepatica*

4.2.4 T.S of *Fasciola hepatica*

(i) T.S of *Fasciola hepatica* through Testes

Comments:

1. Section passes through the posterior three-fourth region (as shown in fig. no. 4.3).
2. Outermost covering of the body made up by cuticle. It forms numerous scales.
3. Musculature composed of outer circulars, middle longitudinal and inner oblique muscles.
4. Various stages of development of spermatozoa are seen in the transverse sections of testes.
5. The sections of vitelline ducts and vitelline glands are clearly visible on the lateral sides.
6. The space between body wall and internal organs (Mesenchyme) is filled with mesenchymal cells.
7. Coelom is totally absent.

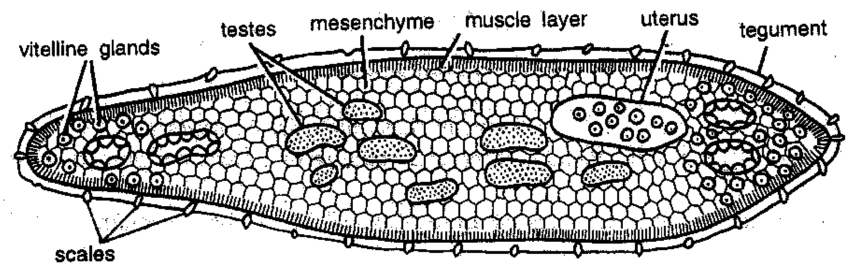


Fig. 4.3 T. S. of *Fasciola hepatica* through testes

(ii) T.S of *Fasciola hepatica* through Uterus:

Comments:

1. Epidermis is absent. Body wall consists of outer circular, longitudinal, and inner oblique. It is surrounded by cuticle (as shown in fig. no. 4.4).
2. Sections of uterus, ovary and few portion of gut are seen.
3. Fertilized eggs are seen in the section of uterus.
4. On the lateral side vitelline glands and vitelline ducts cut into small sections.
5. Coelom is absent.
6. The space between the body wall and the internal organs is filled with mesenchymal cells.

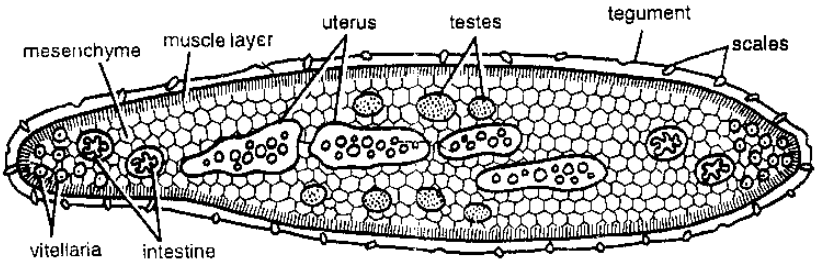


Fig. 4.4 T.S of *Fasciola hepatica* through Uterus

(iii) T.S of *Fasciola hepatica* through Posterior Sucker

Comments:

1. Body wall consists of cuticle and muscle layers. Epidermis is absent (as shown in fig. no. 4.5).
2. Cuticle is the outermost layer provided with numerous scales.
3. Musculature composed of outer circulars, middle longitudinal and inner oblique muscles.
4. Coelom absent.
5. The interior of the body is filled with parenchyma.
6. On lateral side vitelline glands and few intestinal caeca are present.
7. On ventral surface a large, muscular posterior sucker or acetabulum is seen.

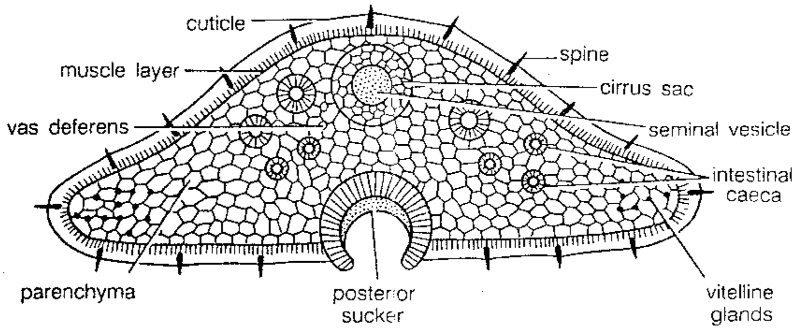


Fig. 4.5 T.S of *Fasciola hepatica* through Posterior Sucker

4.2.5 Developmentalstages of *Fasciola hepatica*:-

(i) Eggs of *Fasciola hepatica*

Comments

1. Fertilized Eggs are brown in color and oval in shape (as shown in fig. no. 4.6).
2. About 3000 or more such capsule may occur at a time in the uterus of a single fluke.
3. A Fertilized egg measured about 63to 90 microns in width and 130 to 150 microns in length.

4. The fertilized eggs received yolk cells from vitelline glands and they get enclosed in a chitinous shell (egg shell).
5. Each egg (hardens shell) has an operculum or lid.
6. Segmentation of complete eggs (capsule) starts in uterus.
7. First division is holoblastic & devides the zygote(Fertilized egg) into two unequal cells---
   (i) **Propogatory cells** (small):- Propagatory cell divided into two cells, one of which forms endoderm and mesoderm of the larva
   (ii) **Somatic cells** (larger) :- Somatic cell divides and forms ectoderm of the larva.
8. Fully embryonated egg has miracidium larva, few yolk cells and germ cells.

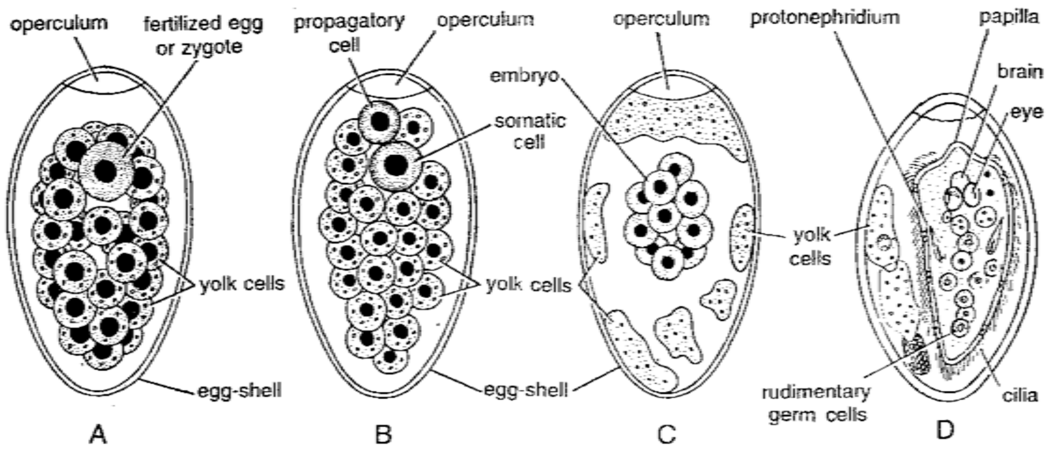


Fig. 4.6 Early stages of development of *Fasciola hepatica*
(A) Fertilizaed egg; (B) Two celled stage;
(B) Many celled stage; (D) Miracidium in capsule

(ii) Miracidium Larva of *Fasciola hepatica*

1. Fertilized eggs (Zygote) or encapsulated embryodevelops into Miracidium larva after 4-15 days (as shown in fig. no. 4.7).
2. Hatching is initiate by a proteolytic hatching enzyme.
3. It is free swimming, microscopic, dorso-ventrally flattened, and conical in shape and covered with ciliated epidermal plates.
4. Epidermal plates (hexagonal) are taxonomic importance, which are 21 in number and arranged in 5 rows
   (i) First row has 6 plates (2 dorsal, 2 ventral and 2 lateral)
   (ii) Second row has 6 plates (3 dorsal and 3 ventral)
   (iii) Third row has 3 plates (1 dorsal & 2 ventro-lateral)
   (iv) Fourth row has 4 plates (2 right and 2 left)
   (v) Fifth row has 2 plates (1 left and 1 right)
5. Body wall contains ----
   (i) Muscle layer

(ii) Glandular epithelium
(iii) Delicate fluid-filled mesenchyme cells

6. Anterior end is produced into a conical papilla, which is mobile and non-ciliated.
7. Internal structures apical gland is non functional, cephalic or penetration glands secrete secretions, brain, two eye spots, two flame cells,rudimentary gut and germ cells are seen.
8. Miracidium is multicellular organism.
9. Miracidium larva swims in search of intermediate host (a molluscan), if it gets a suitable host it change into next larval stage (Sporocyst).
10. If Miracidium larva doesn't comes in contact with intermediate host thelarva dies after 24 hrs.

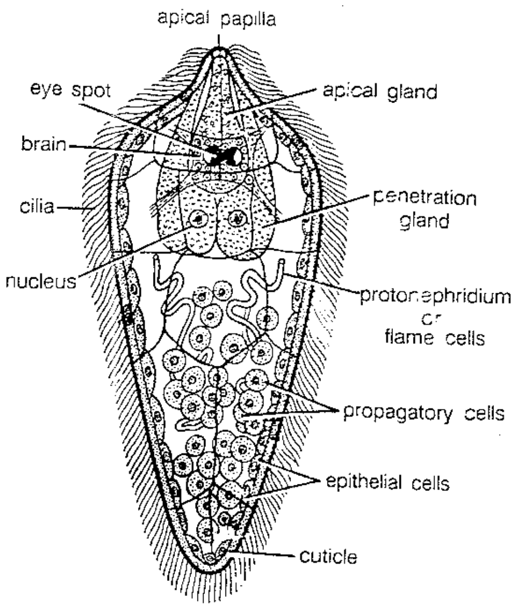


Fig. 4.7 Miracidium Larva of *Fasciola hepatica*

(iii) Sporocyst of *Fasciola hepatica*

1. Miracidium larva on getting a suitable snail penetrates into the body of snail and metamorphoses into intramollusca phase, called sporocyst larva (as shown in fig. no. 4.8).
2. This larva stage develops from Miracidium larva in the pulmonary chamber of snail.
3. It penetrates through pulmonary chamber and during this process cilia and hexagonal cells, brain eye spots apical &penetration gland are degenerated.
4. Sporocyst is an elongated sac- like structure covered with cuticle. Measuring about 1 mm in diameter.
5. Sporocyst is non-feeding stage.
6. Body wall consists of epithelial cells, muscles and mesenchyme.
7. Ciliated epidermis is absent which is lost in the process of penetration and it replaced by a thin cuticle.

8. Body sac has flame cells and germ cells.
9. Germ cells multiply and give rise to next larval stage known as redia larva. Each sporocyst produces 5-8 rediae.

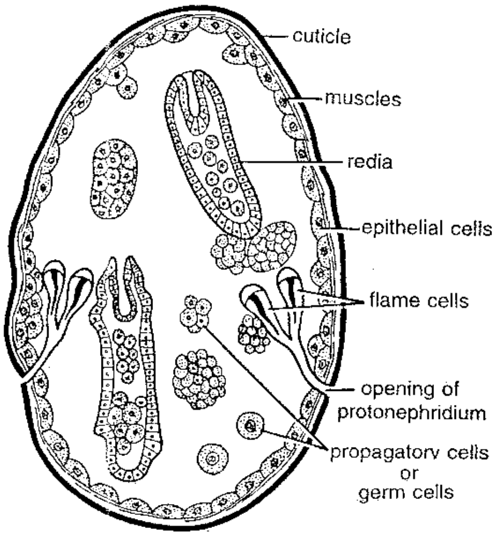


Fig. 4.8 Sporocyst of *Fasciola hepatica*

(iv) Redia Larva of *Fasciola hepatica*

1. Redia Larva develops when the germ cells of the sporocyst multiplies (as shown in fig. no. 4.9).
2. Each redia is an elongated and cylindrical structure about 1.3 mm to 1.6 mm long.
3. Anterior end bears the mouth, muscular swelling or collar (which helps in locomotion)
   And a permanent birth pore.
4. Two stumpy processes known as lappets or procruscula ventro-laterally at the posterior end which helpful in locomotion.
5. The space between the body wall and intestine contains few germ cells. It gives rise to second generation the daughter rediae.
6. Daughter redia and cercaria come out from mother redia through birth pore.

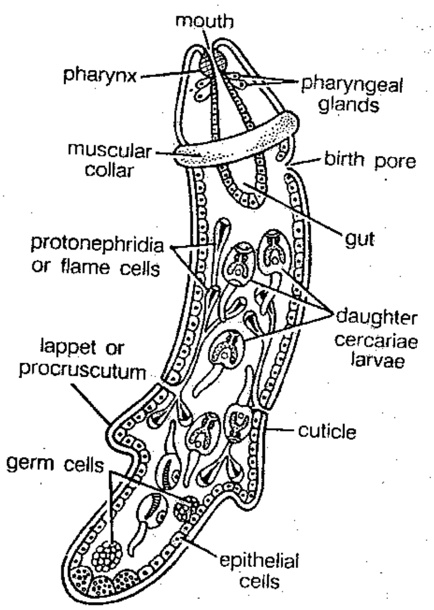


Fig 4.9 Redia Larva of Fasciola *hepatica*

(v) Cercaria Larva of *Fasciola hepatica*

1. Each redia produces 14 – 20 cercaria larvae (as shown in fig. no. 4.10).
2. After leaving the body of redia they enters in the digestive glands of snails.
3. Body of cercaria is flat and oval bearing a tail measuring 0.25 to 0.35mm in length and it is free swimming.
4. Body wall consists of cuticles, muscles and mesenchyme.
5. It has higher grade of organization and close resemblance with the adult fluke.
6. It has two suckers----
(i) anterior oral sucker surrounding the mouth and
(ii) ventral sucker situated in the middle of the body.
7. Body and tail are covered with backwardly directed spines.
8. Digestive system comprises mouth, oral sucker, muscular pharynx,oesophagus and inverted U shaped (forked) intestine.Acetabulum is present just below the forkofintestine.
9. Flames cells are present as exceratory organ and opens into a pair of excretory tubule which unite in front of tail to form an excretory vesicle or bladder.
10. Body space is filled with parenchyma and cystogenous glands on each side which form the cyst of thenext larva.
11. Rudimentary reproductive organs (Genital rudiments) are also present.
12. Cercaria larva has a very active life. After 2 or 3 days of active life its loses its tailand undergoes encystment to become metacercaria larva.
13. The encysted larva (Meta cercaria) is finally swallowed by sheep (final host).

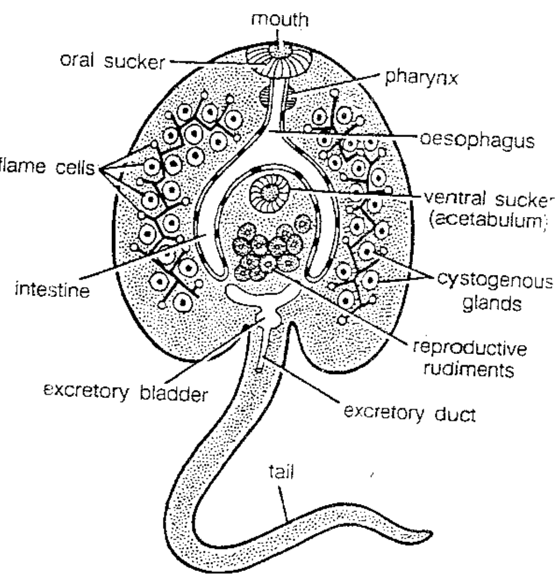


Fig. 4.10 Cercaria Larva of Fasciola hepatica

(vi) Metacercaria larva

1. They are round in shape with a diameter of 0.2 mm (as shown in fig. no. 4.11).
2. Metacercaria are basically juvenile fluke.
3. They are also called marita (Juvenile fluke).
4. Metacercaria has a round form,thick hard cyst and large number of flame cells.
5. They lacks a tail and cystogenous gland cells.
6. Its excretory bladder opens out directly through a single pore.
7. Cyst provides protection against short period of desiccation.
8. A single grass blade can have thousands of metacercria larva.

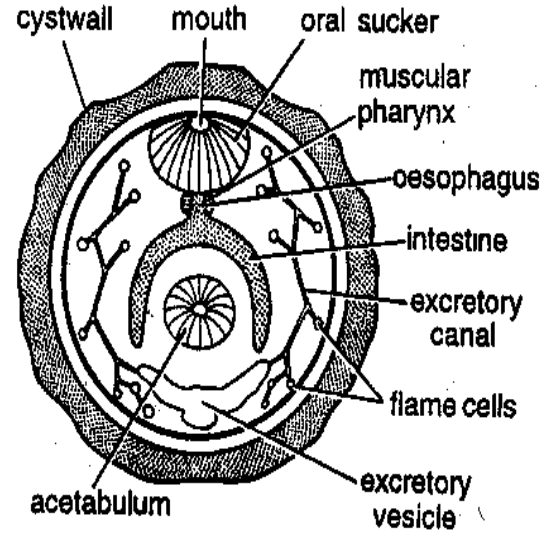


Fig. 4.11 *Metacercaria larva*

(B) Taenia solium

4.2.1 General characters:

1. Commonly known as Tape Worm. Taenia solium is found in large intestine of man (see fig. no. 4.12).
2. Body comprises of scolex (head), neck and strobila (body).
3. Scolex is about 1 mm in diameter.In addition to suckers, scolex contain rostellum, which is pigmented and provided with a double row of hooks(number of hooks are about 28 to 32 in number).
4. Body comprises of large number of segments nearly 800 or more, these segments called proglottid.
5. Each segment(Proglottid) contain one set of male and female reproductive organs, part of execratory, nervous system and a lateral genital opening.
6. Life cycle involves two hosts

(i) Man-definitive host

(ii) Pig- intermediate host

7. When pigs eat contaminated human faeces becomes infected by bladder worm (Cysticercus larva).
8. Larva or bladder worm stage doesn't cause any damage to pig.
9. Human are infected by eating pork (pig meat) and *Taenia solium* develops into intestine of adult man.

4.2.2 Identifying characters:

Contains scolex, neck, great number of segments and all above characters, it is called *Taenia solium.*

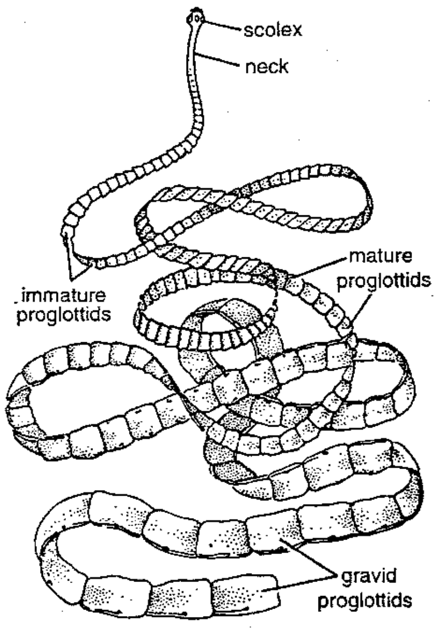
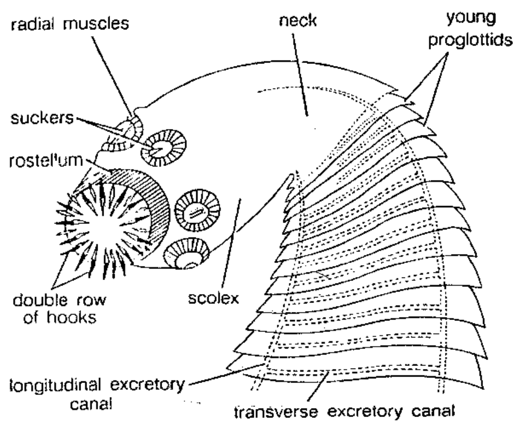


Fig. 4.12 *(A) Taenia solium*



(B) Scolex of Taenia solium

4.2.3 Systematic position:

Phylum Platyhelminthes : Flatworms, acoelomate

Class - Cestoda : Endoparasitic, many segments (proglottids)

Subclass - Eucestoda : Ribbon like, anterior end with an expanded scolex having adhesive structure, each segment with more than one set of reproductive organs.

Order - Taenioidea : Endoparasite , scolex with four suckers

Genus- *Taenia*

Species- *solium*

4.2.4(I) Mature Proglottid of *Taenia solium:-*

1. Each Mature Proglottid is square in shape.
2. Lateral side of each Proglottid contains lateral longitudinal nerve cords and lateral execretory canals.
3. A set of male and female reproductive organs is present in each mature Proglottid.
4. Male genital system consists of follicular testes, vasa efferentia, vas deferens and cirrus.
5. Female genital system consists of ovarian lobes (bilobed ovary), oviduct,ootype,vagina, uterus, Mehli's glands and compact vitellaria.
6. Oviducts divides into two ducts, one leading to vagina opening and other into uterus.
7. Vitelline gland lie behind ovary.
8. Male and female reproductive organs open into genital atrium.
9. The genital atrium opens by a common gonopore on a swollen genital papilla.

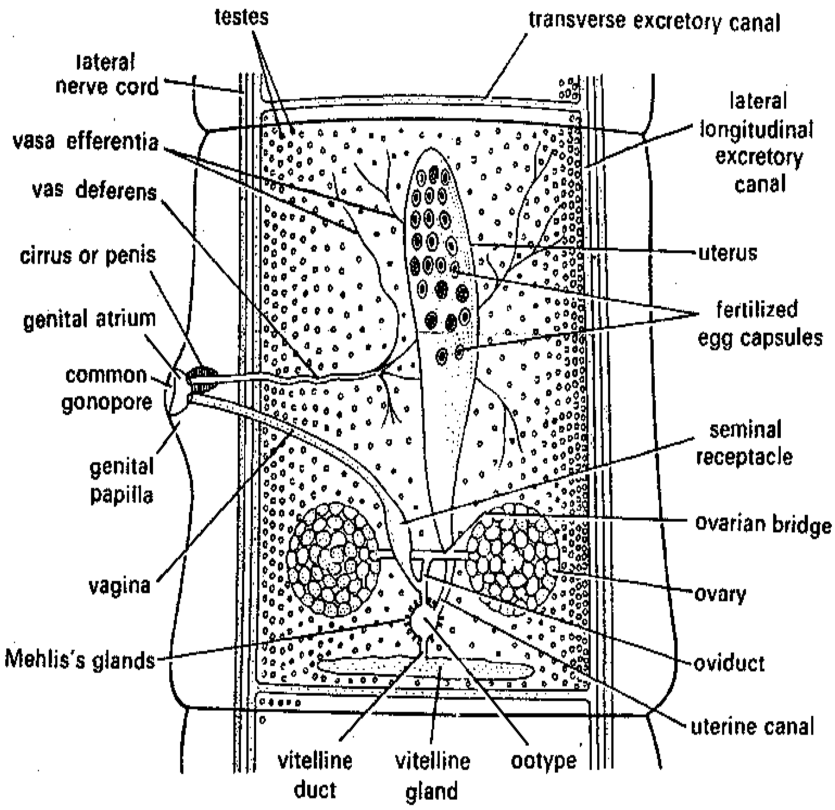


Fig. 4.13 *Mature Proglottid of Taenia solium*

4.2.4 (II) Gravid (ripe) proglottid of *Taenia solium:-*

1. The gravid are situated posteriorly (see fig. no. 4.14).

2. Each gravid proglottid is longer than broad and a highly branched uterus (7-13 lateral branches on each side) filled with fertilized eggs.
3. Other structure have disappeared in ripe proglottid.
4. Ripe proglottids are detachment from strobila by the process of apolysis and pass out from the intestine of host with faeces.
5. Sometimes, the gravid segment burst in the intestine and liberate several onchophores, show wriggling movement.

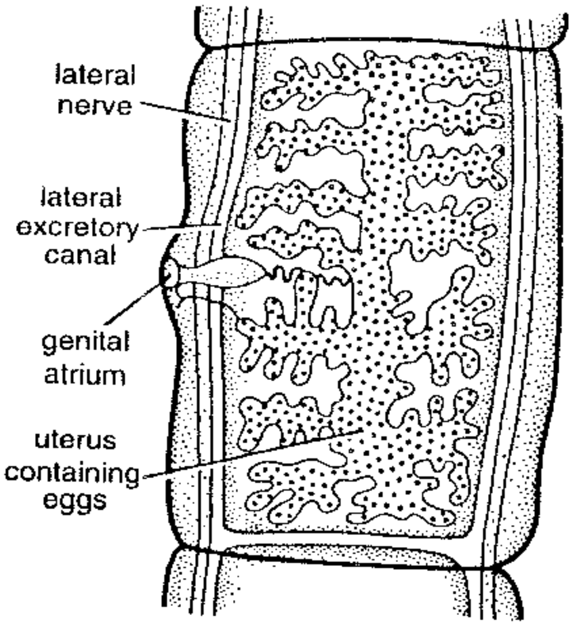


***Fig 4.14** Gravid (ripe) proglottid of Taenia solium*

4.2.5 Developmentalstages of *Taenia solium*

Cysticercus Larva of *Taenia solium*

1. Cysticercus larva is commonly called as bladder worm and develops in the muscles of pig(Intermediate host) (see fig. no. 4.15).
2. The onchospheres reaches pig stomach through human faeces.
3. The onchosphores further migrates to the muscles where hook are lost and the cells in the center of the embryo disappears and thus producing a single layered large ovoid bladder known as bladder worm or cysticercus.
4. Encysted larva consists of a sac or bladder like structure having proscolex , contains suckers and hooks .
5. Cysticercus larvae can be obtained after removing the cyst wall. If the larvae can be kept in normal saline solution the scolex is evaginated in 5 to 10 minutes.
6. Cysticercus consists of a sac or bladder –like structure, having invaginated proscolex measuring 6-18 mm in length.
7. The further development occurs when it is eaten by man.

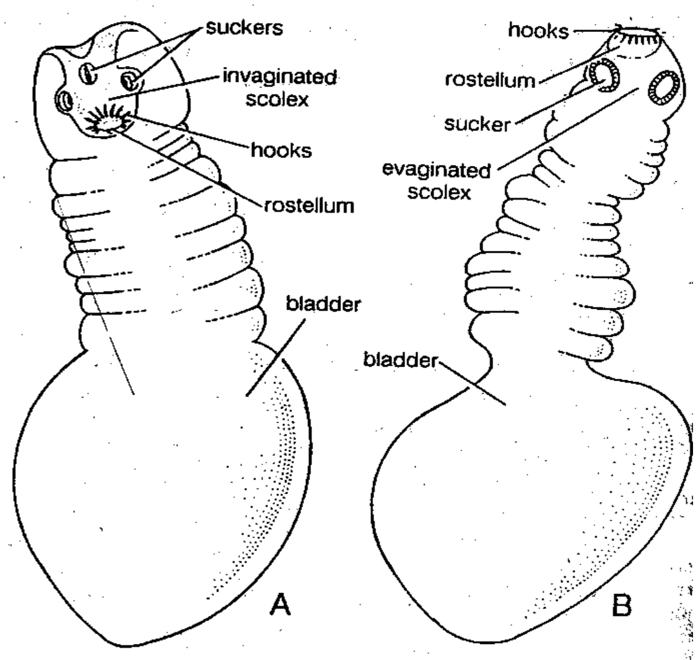


Fig. 4.15 *Cysticercus larva*

4.3*Schistosoma* (Blood fluke)

4.3.1 General characters:

1. They are commonly known as blood Flukes (see fig. no. 4.16).
2. They are parasitic in nature.*Schistosoma* lives in the hepatic portal system and mesenteric vessels of man.
3. They are greyish or pinkish in color.
4. Adult males are 10 to 15 mm long. They have deep grooves called gynecophoric canals in which adult females typically lies. Males have many small nodules (tubercles) on their dorsal surfaces and many tiny spines on their suckers and inside their gynecophoral canals.
5. Females are longer (16-22 mm), smoother, and more slender. Both sexes have two suckers, one anterior and one ventral, which are used to grip venule walls.
6. Eggs, which can be found in the urine of infected hosts, are 110-170 um long by 40 to 70 mm wide.
7. It is the only trematode in which sex is separated while other trematodes are hermaphrodite.
8. Digestive system is simple and consists of oesophagus and forked intestine. Pharynx is absent.
9. Male reproductive system consists of 4-5 testes, vasa deferens ans seminale vesicle.
10. Female reproduction has an elongated ovary,oviduct,vitellaria and uterus.
11. Schistosoma has only one intermediate hosti.e., Snail.

12. Infection takes place on the penetration of cercaria through skin or by drinking contaminated water.
13. It causes a disease known as Schistosomiasis (Bilharzia).

4.3.2 Identifying characters:

Female of *Schistosoma* is found in the gynecophoric canal of the male

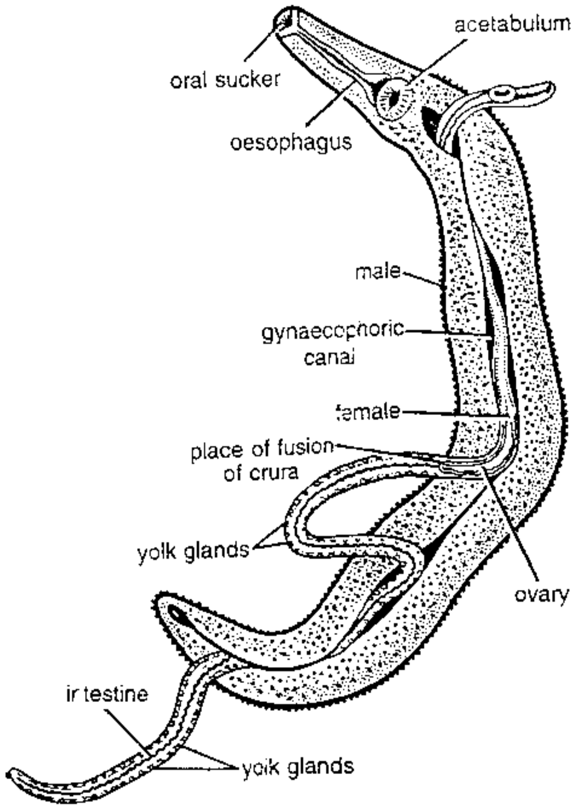


Fig. 4.16 *Schistosoma* (Blood fluke)

4.3.3 Systematic position:

Phylum ---Platyhelminthes - Flatworms, acoelomate

Class ---- Trematoda - Body wall without opidermis and cilia, Parasitic nature suckers are well developed.

Order ---- Digenea - Endoparasitic,many larval stages present, Two suckers without hooks

Genus ---- Scistosoma

Species--- *haematobium*

4.4 Summary of Platyhelminthes:

The phylum Platyhelminthes is derived from two greek word Platys (flat) + helmins (worm). Platyhelminthes commonly known as the flatworms, have nearly 29,000 species. Platyhelminthes include both free-living and parasitic species. Majority of them are **obligate** parasite.

Characteristics of Platyhelminthes

1. Triploblastic and no body cavity.
2. Dorso- ventrally flattened body.
3. Alimentary canal with single opening, anus absent.
4. Excretion takes place through protonephridia with flame cell.
5. No skeleton, respiratory organ, circulatory system.
6. Movement is controlled by longitudinal, circular, and oblique layers of muscle.
7. Behavior organization through learning.

They have a definite sensory organs. Eye spots or photoreceptors in free living forms (a few have light sensing organs) and nervous tissues at one end of their body giving them a distinct head and tail. They also have distinct upper and lower (dorsal and ventral) body surfaces. They have a number of organs and even the beginnings of organ systems and a more distinct 3rd layer of cells in their body plan. The evolution of this connective tissue, called parenchyma, the cells of which serve as storage reservoirs as well as protecting the internal organs, is a major step forward toward the more complex body plans of higher animals.

However they still no anus, instead they have only a blind ending gut, or no gut at all. Those species with a gut must therefore excrete there digestive waste products through their mouth

There is diversity within the life cycles of different Platyhelminthes. All Parasitic Platyhelminthes have complex life cycle between different habitats as they change life cycle stages and have different hosts. They reproduce both asexually and sexually.

4.5 Glossary:

Acoelomate: An animal that doesn't have a coelom (flatworms, tapeworms,flukes, etc.)

Adhesive glands: Attachment glands in turbellarians that produce a chemical that attaches part of the turbellarian to a substrate.

Cercariae: Disk-shaped larva or flukes with tail-like appendages.

Cysticercus: The cyst which forms part of the life cycle of the tapeworm *Taenia solium* that is only in human.

Cysticercosis: Parasitic tissue infection caused by larval cysts of the pork tapeworm.

Flame cells: one of the hollow cells that kills the branches of the excretory tubules of certain.invertebrates, having a tuft of continuously moving cilia.

Flukes: Worms that belong to class Trematoda.

Mesoderm: The middle layer of three germ layers in an early embryo of bilaterian animals.

Metacercariae: Infected Larvae.

Miracidium: The ciliates first-stage larva of a trematode.

Nephridiopore: The external opening of a nephridium.

Onchosphere: A tapeworm embryo that has 6 hooks.

Operculum: Organ serving as a lid or cover.

Parenchyma: Tissue composed of mature, alternate, but relatively unspecialized cells.

Proglottid: Segment of tapeworm with male and female reproductive organs.

Releaser glands: A gland in turbellarians that secretes a chemical that dissolves the organism's attachment to a substrate.

Rhabdite: A minute smooth rodlike or fusiform structure found in the tissues of many Turbellaria.

Scolex: The head of a tapeworm bearing suckers and hooks for attachment.

Sporocyte: A cells that produces haploid spores during meiosis.

Strobila: The body of a tapeworm consisting of a string or similar segments.

4.6 Self assessment questions:

1. The nervous system of flatworm can be described as
(a) Nerve net (b) nerve ladder (c) nerve chord (d) nerve ring

2. The infective stage of the liver fluke is
(a) sporocyst (b) redia (c) miracidium (d) cercaria

3. Tapeworm attach the digestive lining of the host by means of their
(a) proglottids (b) stylets (c) osculum (d) scolex

4. Rhabdities are present in cells of Epidermis in
(a) Cestoda (b) Trematoda (c) Turbellaria (d) None

5. Fasciola Heptica lives in
(a) liver of sheep (b) blood of sheep (c) spleen of sheep (d) Intestine

6. Intermediate host of *T. solium* is
(a) Cow (b) Pig (c) Sheep (d) Snail

7. *T. Solium* lacks alimentary canal because
(a) It doesn't need food (b) lives in intestine (c) saprozoic mode of feeding (d) none

8. Flame cells are component of ________ system in Platyhelminthes
(a) Reproductive (b) Exceratory (c) Nervous (d) Respiratory

9. Each segment of Tape worm is called
(a) Glottid (b) Progiottid (c) Epigiottis (d) Nephrostome

10. Platyhelminthes are called
(a) Body is segmented (b) Body is elongated(c) Flat body (d)body covered by cuticle

11. Planaria belongs to class
(a) Trematoda (b) Turbellaria (c) Hexacinellida (d) Cestoda

12. Liver Fluke belongs to class
(a)Cestoda (b) Trematoda (c) Turbellaria (d) Hydrozoa

13. Secondary host of liver fluke is
(a)Sheep (b) Goat (c) Pig (d) Snail

14. Sheep liver fluke is ___________ parasite
(a)Digenic (b) Polygeriic (c) Mozogeriic (d) None

15. Flat worms are
(a) Acoelomates) (b)Coelomates (c) Pseudocoelomates (d) None

16. Sexual reproducing Platyhelminthes consists of both male and female organ on same individual, hence called
(a)hermaphrodites (b) homodites (c) hetrodites (d)homophrodites

17. Blood Fluke is called
(a) *Schistosoma haematobium* (b) *Ascaris lumbricoid* (c) *Planaria Dugesia* (d) *Taenia saginata*

1(d) 2(d) 3(d) 4(b) 5(a) 6(b) 7(c) 8(b) 9(b) 10(c) 11(b) 12(b) 13(a) 14(a) 15(a) 16(a) 17(a)

4.7 References:

1. R LKotpal: Text book of Zoology of Invertebrates, Rastogi Publication, 2007.
2. P. S. Verma: A manual of Practical Zoology Invertebrates, S. Chand Publication.
3. S. S. Lal: Practical Zoology Invertebrate, Rastogi Publication.
4. B N Pandey: Animal diversity volume 1, Tata McGraw Hill Education Private Limited.
5. V P Agrawal and L D Chaturvedi: A text book of Zoology, Jagmander Book Agency.

4.8 Suggested readings:-

- Manuals of Zoology E K Ayer, vol. 1 and 2.
- Cleveland Hickman, Jr. and Larry Roberts &Susan Keen and Allan Larson and David Eisenhour:Animal diversity, 7th edition, McGraw Hill Education Private Limited, 2015.

4.9 Terminal question / answer

(A) Give reason---

1. Why Platyhelminthes are called Flat worms?

   Ans. These worms have paper thin structure.

2. Why there is no evidence regarding evolution history of platyhelminthes?

   Ans. They possess soft bodies which can’t be preserving as fossils.

3. How important is Platyhelminthes to mankind?

Ans. They are parasitic in nature which effect human beings and their live stock.

4. How planarians are affecting human beings?

Ans. Planarians feed on fish eggs affecting the yield of fish in water bodies.

5. Why Acoela are the simplest turbellarians?

Ans. They lack intestine, oviducts and shed their eggs through skins.

6. Why Flame cells are so called?

Ans. They appear like a flickering candle flame.

7. Why few species of turbellaria are green?

Ans. Green color is due to presence of algae on their skin.

8. Why proglottids close to scolex are least mature?

Ans. Proglottids are produced continuously behind the scolex.

9. Why nervous system of Platyhelminthes are called as ladder like?

Ans. They have two longitudinal nerve cords having frequent connections between them.

10. Why *Taenia solium* is major cause of acquired epilepsy?

Ans. The most severe form is neurocysticercosis, which affects the brain and is a *major cause* of *epilepsy*.

(B)Fill in the blanks—

1. The study of flatworms is called…………….
2. The body of tapeworm consists of ………..,..………… and …………..
3. Planaria is a member of class…………
4. The shelled embryo of *Taenia solium* is called…………
5. Sporocyst larva devides to form …………. Larva.

Ans. 1. Helminthology 2. Scolex, neck, proglottid 3. Turbellaria 4 Oncosphere 5. Redia.

UNIT-5: PHYLUM: ASCHELMINTHES (Round worms)

Contents

5.1 Objectives:-

To study the General characters of Phylum Aschelminthes and its classification up to order and Identification of specimens and microscopic slide.

5.2 Introduction:-

Phylum Aschelminthes (Round worms) inhibit aquatic and terrestrial environment and are well known parasites. They are Bilaterally symmetrical and unsegmented worms.Triploblastic and pseudocoelomate animals with organ system grade of body organization.Body size mostly small, some microscopic, while others few millimeters to a meters or even more in length. Body mostly cylindrical or flattened, body wall with cuticle and cilia absent. The digestive system includes straight and complete alimentary canal with mouth and anus, muscular and highly specialized pharynx.

General Characteristics:-

1. Respiratory and circulatory systems are absent.
2. Execratory system includes a system of canals, protonephridia or glandular organs or both for osmoregulation.
3. Nervous system simple and consists of a circumenteric nerve ring having anterior and posterior longitudinal nerves.
4. Sense organs are pits, papillae, bristles and eye spots.
5. Sexes are usually separate. Male is smaller than female.
6. Tubular gonads are continuous with their ducts. Paired female organs open by a vulva but a single male gonad opens into cloaca.
7. Asexual reproduction does not occur.
8. Eggs shelled cleavage determinate and spiral. Fertilization is internal and development is direct (no special larval stages).

Outline classification:-

Phylum- Aschelminthes

Class

↓

Nematoda

(Gr. nema=thread+eidos=form)

- Free living / parasitic, elongated roundworms.
- Cuticle and syncytial epidermis is present.
- Absence of Cilia, respiratory and circulatory systems.
- Digestive system complete with muscular pharynx and glands
- Dioecious female larger than male.

Order 1- Enploidea:

1. Cuticle not ringed,often with cuticular bristles.
2. Anterior end with six labial papillae.
3. 10-12 bristles in 1 or 2 circlets.
4. Examples : *Enoplus, Anticoma*

Order 2 – Dorylaimoidea

1. Cuticle smooth without bristles.
2. Anterior end with 2 circlets of papillae of 6 and 10 each.
3. Rear part of pharyns enlarged.
4. Examples : *Dorylamius, Tylencholaimus*

Order 3 – Mermithoidea

1. Smooth and filiform, parasitic mainly in insects in juvenile stages or free living as adults in soil or water.
2. Head sense organs reduced to usually 6 papillae.
3. Pharynx long and blind. Intestine also blind which serves as food store.
4. Examples : *Mermis,Paramermis*

Order 4 – Chromadoroidea

1. Aquatic nematodes having smooth or ringed cuticle.
2. Cuticle heavily ornamented with bristles, knobs, punctations etc.
3. Pharynx with a posterior bulb.
4. Examples : *Paracytholaimus, Paracanthonchus*

Order 5 – Araeolaimoidea

1. Cuticle smooth, sometimes with bristles.
2. Labial papillae present.
3. Anterior end usually with 4 cephalic bristles.
4. Examples : *Plectus, Odontophora*

Order 6 –Monhysteroidea

1. Cuticle smooth or slightly ringed, often with bristles.
2. Anterior end with 4, 6 or 8 bristles, or multiples thereof.
3. Examples : *Cylindrolaimus, Siphonolaimus*

Order 7 – Desmoscalecoidea

1. Cuticle heavily ringed with prominent bristles throughout or in restricted areas.
2. Anterior end with 4 bristles.
3. Marine nematodes.
4. Examples : *Desmoscolex, Tricoma*

Order 8 – Rhabditoidea

1. Free living or parasitic with ringed or smooth cuticle.
2. Pharynx with posterior bulb.
3. Caudal glands absent.
4. Examples : *Rhabditis, Diploscapter*

Order 9 – Rhabdiasoidea

1. Smooth nematodes without definite pharyngeal bulb.
2. Hermaphrodite, parthenogenesis occurs.
3. Parasitic stages in animals.
4. Examples : *Entomelas, Rhabdias*

Order 10 – Oxyuroidea

1. Pharynx with a posterior bulb.
2. Caudal alae forming a cuticular bursa.
3. Females with a long pointed tail and males with 1 spicule or 2 equal spicules.
4. Examples : *Enterobius, Oxyuris*

Order 11 – Ascaroidea

1. Mouth surrounded by three prominent lips.
2. Tail of female blunt; male without caudal alae and possess two equal or nearly equal spicules.
3. Buccal capsule absent.
4. Example: *Ascaris*

Order 12 – Strongyloidea

1. Mouth without conspicuous lips but often with leaf crowns.
2. Males with copulatory bursa supported by muscular rays. Typically 13 in numbers.
3. Pharynx without bulb.
4. Examples : *Ancylostoma, Necator*

Order 13 – Spiruroidea

1. Mouth with two lateral lips; sometime 4 or 6 small ones.
2. Males without bursa spicules unequal and dissimilar.
3. Pharynx without bulb.
4. Examples : *Thelazia, Rictularia*

Order 14 – Dracunculoidea

1. Without definite lips or cuticularized buccal capsule.
2. Males with equal filiform spicules.
3. Vulva not functional.
4. Examples : *Dracunculus, Micropleura*

Order 15 – Filiarioidea

1. Filiform worms without lips.
2. Buccal capsule small or rudimentary.
3. Bursa wanting, spicules unequal and dissimilar.
4. Examples: Wuchereria*, Loa loa.*

Order 16 – Trichuroidea or Trichinelloidea

1. Body filiform anteriorly.
2. Mouth without lips.
3. Provided with a cirrus, spicules if present one only.
4. Examples: *Trichinella, Trichuris*

Order 17 – Dioctophymoidea

1. Moderate to very long sized nematodes.
2. Mouth without lips surrounded by 6, 12 or 18 papillae.
3. Males with muscular bursa but without rays.
4. Examples : *Dictyophyme, Hystrichis*

5.3 *Ascaris lumbricoides* (Round worm)

5.3.1 General characteristics:-

1. *Ascaris*is a common endoparasite in the small intestine of the man.
2. It causes ascariasis in man especially in children. Infection by eating raw & uncooked vegetables.
3. Shows sexual dimorphism with separate male and female individuals. Male measures 15 to 30 cm and female 20 to 35 cm in length.
4. Body is elongated, cylindrical, pointed at both ends.
5. Surface of the body is marked with four longitudinal lines.
6. Mouth provided with a median dorsal and a pair of symmetrical sub median ventral lips.
7. Excretory pore is small and lies at the ventral surface with distance of 2 mm away from the anterior end.
8. Tail end of male is ventrally curved containing cloacal aperture, through which two equal isospicules projections.
9. Female genital aperature lies about one-third of the body from the anterior end.
10. Life history is simple and no intermediate host.

5.3.2 Identifying characters:-

Unsegmented, cylindrical body, posterior end is curved in male, female has pointed tail.

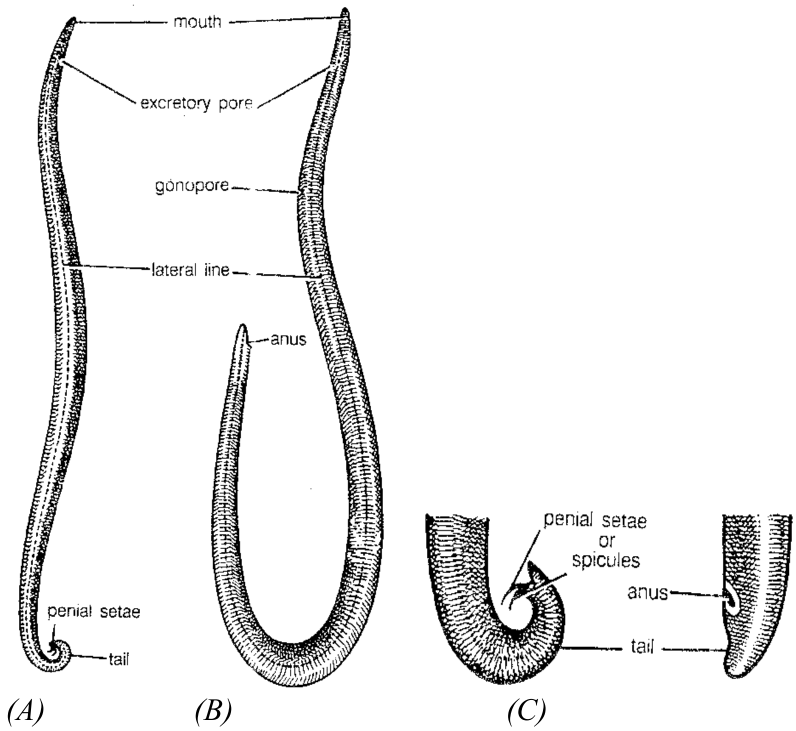


Fig. 5.1 *Ascaris lumbricoides*
(A) Male(B) Female (C) Posterior end of male and female Ascaris

5.3.3 Systematic position:

Phylum ---Aschelminthes -Unsegmented, Pseudocoelomate

Class --- Nematoda -Cilia absent, round worm, alimentary canal straight

Order ---Ascaroidea - Living in Intestine of vertebrates, mouth with three lips, Pharynx without a posterior bulb.

Genus -*Ascaris*

Species –*lumbricoides*

5.4 *Ancylostoma duodenale*:-

5.4.1 General characteristics:

1. *Ancylostoma duodenale* is commonly called as **hook worm**.
2. It is found asendoparasite in the intestine of man.
3. Mature worm is cylindrical in shape, narrow anteriorly and white or ivory grey in color.
4. Males measures 8-11 mm in length where as female measures 10-13 mm in length.

5. Anterior end in both sexes is bent dorsally and is provided with large and cup shaped buccal capsule for attachment with mucous membrane of the intestine.
6. Buccal cavity is oval and the buccal capsule is made of articulated grooved portion. Capsule contains a pair of chitinous plates and a median dental process or teeth.
7. Digestive system consists of mouth, pharynx, intestine, rectum and anus in female cloaca in males.
8. Exceratory pore mid ventral in position just behind the nerve ring
9. Female has pointed tail end while Male is provided with a copulatory bursa which is broader than long and supported by fleshy rays.
10. Fertilization is internal and occurs in the intestine of host.
11. Fertilized eggs are passed out with the faeces.
12. Mode of infection is penetration of skin of host by the infective larval stage.

5.4.2 Identifying characters:

It contains teeth in buccal capsule, bursa in males.

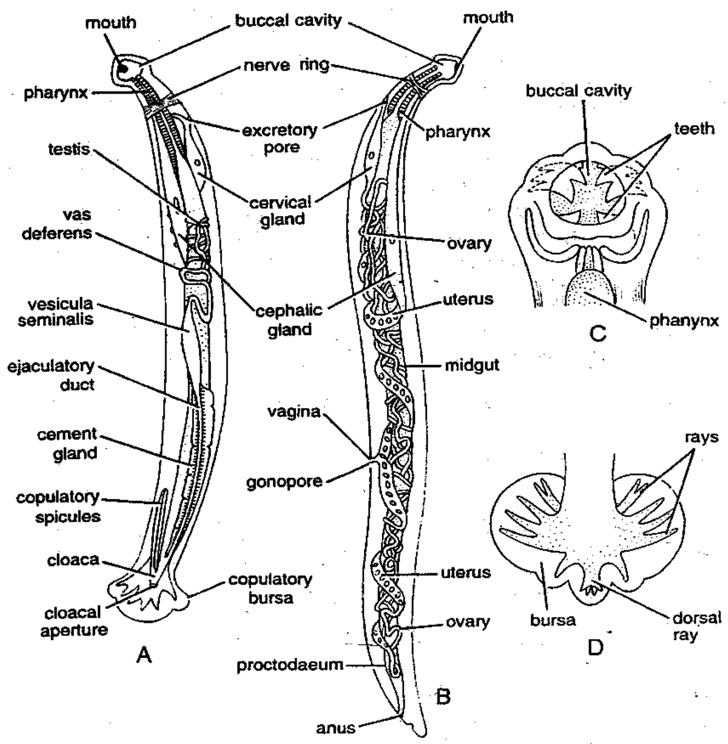


Fig. 5.2 *Ancylostoma duodenale*

(A) Adult male (B) Adult female (C) Anterior end (D) Posterior end

5.4.3 Systematic position:-

Phylum ---Aschelminthes -Unsegmented or superficially segmented, Pseudocoelomate Vermiform

Class --- Nematoda- cilia absent, alimentary canal straight

Order --- Strongloidea - Living in Digestive Tract of vertebrates, female with ovijecters,male with a copulatorybursa,pharynx without bulb.

Genus ---*Ancylostoma*

Species--- *duodenale:*

5.5 *Dracunculusmedinensis* (guinea worm)

5.5.1 General characteristics:-

1. Worms are cylindrical, elongated with blunt anterior end. Posterior extremity hooks like for anchorage in sub-cutaneous tissues.
2. Males measures 12 to 29 mm in length and 0.4 mm in breadth while females arevmuch larger than male measuring 70 to 120 mm in length & 0.9 to 1.7 cm in breadth
3. Its anterior part of pharynx is muscular but posterior part is glandular.
4. The sexes are different.
5. Posterior end of male is curved having 4 pairs of pre-anal and 6 pairs of post-anal papillae, pair of equal filiform copulatory spicules and gubernaculums. The tail end of female is straight.
6. Female are viviparous
7. Life cycle digenetic. Man is definitive host. Cyclops is an intermediate host. Man is infected by taking Cyclops through contaminated water. Cyclops is infected by engesting eggs of *Dracunculus* which are released in water.
8. The adult worms lives in the deep sub-cutaneous tissue especially of the arms, shoulders and legs of man.
9. It cause a disease called as dracunculiasis disease.

5.5.2 Identifying character:-

Since tail end of male contains 10 pairs of caudal papillae and all above features, hence it is *Dracunculusmedinensis.*

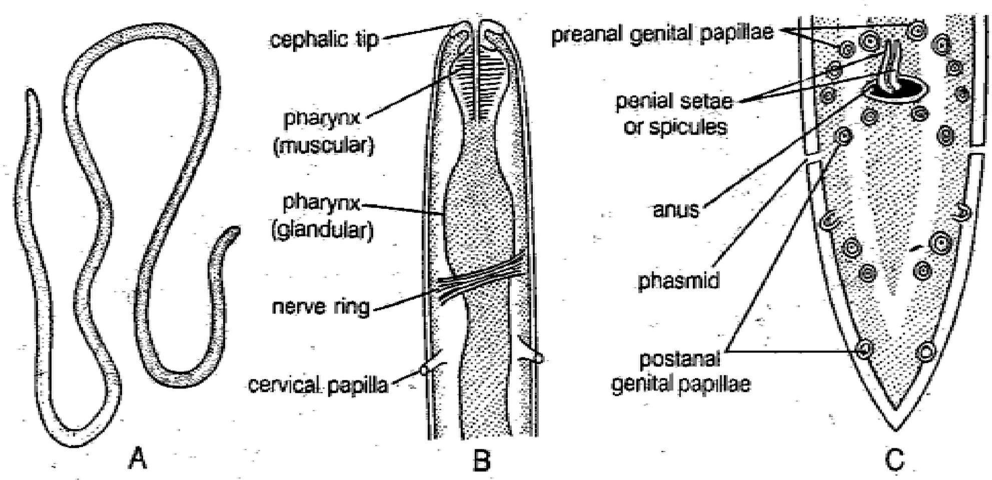


Fig. 5.3 *Dracunculusmedinensis*
(A) Adult worm (B) Anterior end of male (C) Ventral view of tail of male

5.5.3 Systematic position:

Phylum ---Aschelminthes-Unsegmented or superficially segmented, Pseudocoelomate Vermiform

Class --- Nematoda- cilia absent, alimentary canal straight

Order ---Dracunculoidea - Parasitic, mouth without lips, buccal capsules cuticularized, Pharynx muscular and glandular without bulbs

Genus --- *Dracunculus*

Species --- *medinensis*

5.6 *Wuchereriabancrofti*:-

5.6.1 General characteristics:-

1. They are found in lymph glands or ducts in human.
2. Adult worm are filiform & cylindrical in shapes with both ends tapering and terminating bluntly, creamy white in color.
3. Head slightly swollen and provided with two rows of small sessile papillae.
4. Mouth is unarmed and devoid of buccal cavity.
5. They show sexual dimorphism by tail ends. Male has the caudal end curved having unequal spicules in spiracular sheaths (gubernaculum) 12 pairs of caudal papillae while female bearing the vulval opening just behind the anterior extremity of the body.
6. Male is about 40 mm in length and Female is about 80 to 100 mm in length.
7. Female worms give birth to first stage larva microfilaria (juveniles) which are surrounded by delicate membrane or sheath.
8. Microfilaria is long, cylindrical provided with a striated cuticle.
9. Microfilariae are discharged into lymph vessels and are then passed into the blood vessels of the periphery between 10.00 pm and 2.00 am.
10. Culex mosquito serves as intermediate host.
11. Culex sucks blood from human. Then Microfilariae are also transferred.
12. After this development takes places in stomach and thoracic muscles of the mosquito.
13. It causes a disease which is known as Filariasis (Elephantiasis).

5.6.2 Identifying characters:-

12 pairs of caudal papillae are present6 in male at tail end.

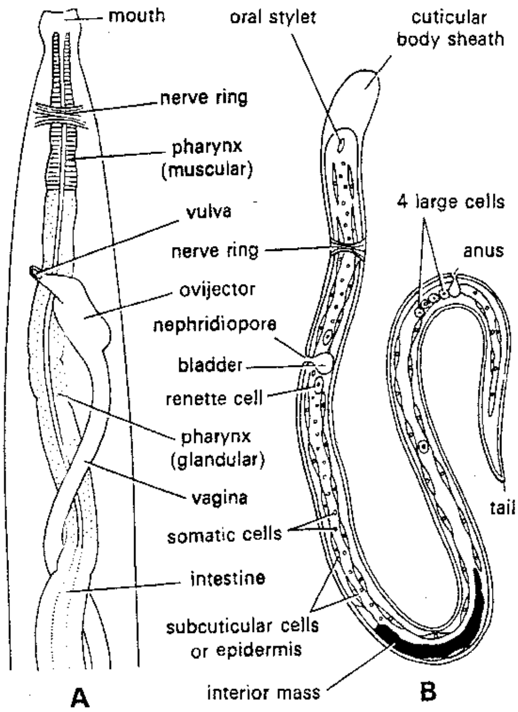


Fig. 5.4 *Wuchereria bancrofti*
(A) Anterior part of female W. bancrofti (B) Microfilaria of W. bancrofti

5.6.3 Systematic position:-

Phylum ---Aschelminthes - Unsegmented or superficially segmented, Pseudocoelomate Vermiform

Class ---Nematoda -Cilia absent, alimentary canal straight

Order ---Filarioidea - Mouth devoid of lips but with buccal capsule,bursa absent.

Genus --- *Wuchereria*

Species ---*bancrofti*

5.7 ***Trichinellaspiralis*** **(**Trichina worm):-

5.7.1 General characteristics:-

1. *Trichinellaspiralis* is an endoparasite found in the intestine of man, pig , rat, black bear , polar bear and other vertebrates.andencysted form in voluntary muscles of host like limbs, chest, diaphragm, tongue, eye and neck.
2. Female worm are larger than male worm. Male worm is 1.4 -1.6 mm in length and Female worm is 3-6 mm in length.
3. Male has pointed anterior end and fleshy posterior end provided with a large conical papillae while female has pointed anteriorly and fleshy posteriorly.
4. A new host acquires infection by eating raw or improperly cooked flesh containing encysted larva.
5. The cyst gets dissolve by digestive juice in stomach or intestine of host.
6. Larvae are liberated in the intestine of host. A further larva penetrates into the mucosa of small intestine.
7. Larva undergoes a series of moults to become adult in small intestine within 2 days.
8. The mouth leads into pharynx which contains large granular cells, called stichosome.
9. Vulva is situated anteriorly.
10. Copulation takes place in intestine. After copulation male dies and pass out of host body.
11. Female then increase to their maximum size and penetrate more deeply into the intestine wall.
12. Female produce large number of small juvenile worms in the intestinal wall which are distributed throughout the body by the lymphatic and blood streams.
13. The juvenile worms penetrate chiefly into the ends of skeletal muscles such as diaphragm and intercostalsmuscle etc , and form lemon – shaped cysts.
14. It causes a serious and dreaded disease known as Trichinosis.
15. Diarrohea, nausea, abdominal pain, hypereosinophilia, thrombosis, muscular pain are the symptom associated with Trichinosis.

5.7.2 Identifying characters:

It shows coiled larva in cyst, hence it is called *Trichinellaspiralis*

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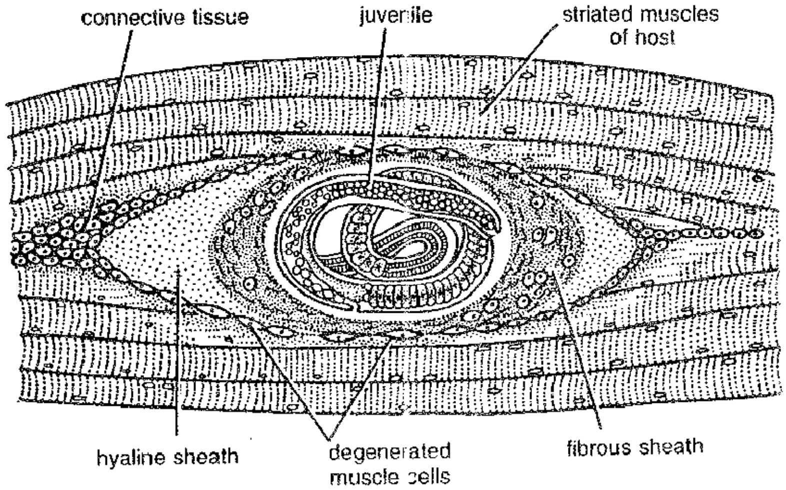


Fig. 5.5*Trichinellaspiralis– Encysted larvae*

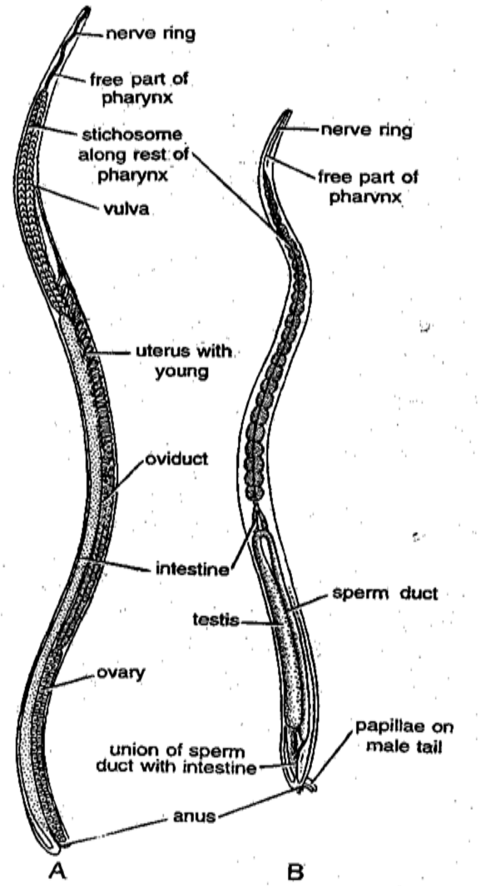


Fig. 5.6_Trichinellaspiralis_

(A)Female (B) Male

5.7.3 Systematic position:-

Phylum ----Aschelminthes-Unsegmented or superficially segmented, Pseudocoelomate Vermiform

Class --- Nematoda- cilia absent, alimentary canal straight

Order --- Trichuroidea -Mouth devoid of lips, pharynx with stichosome, male with Copulatory apparatus.

Genus --- *Trichinella*

Species ---*spiralis*

5.8 *Enterobius vermicularis:-*

5.8.1 General characteristics:-

1. *Enterobius vermicularis* is commonly known as Pin Worm of Man.
2. They lives in caecum, appendix and at the junction of small and large intestines.
3. Female worm are larger than male worm. Male worm is 2 to 5 mm long, with a diameter of 0.1 to 0.2 mm while female is 8 to 13 mm long with a diameter of 0.3 to 0.5 mm.
4. Tail end of Female is long and pointed while that of male is curved, blunt and with a bursa like expansion and a single spicule.
5. Worms are slender and cream coloured.
6. Male is monarchic and female didelphic.
7. There incidence is greater in women and children.
8. No Intermediate host is involved.
9. Female migrates to anus in night and deposits eggs.
10. This cause severe itching at anal and perianal regions. Host is tempeted to scratch.
11. Tiny eggs about 55 μ by 30 μ. Each egg contains a developed larva.
12. Finger and finger nails gets in contact as soon as host scratch.
13. The larva enters the gut with the food to cause a reinfection.
14. Eggs hatch in duodenum. Larva reach small intestine, where they moult twice and become adults.
15. Loss of appetite, insomnia, hysteria, restlessness and inflammation of mucous membrane of infected regions are the symptoms of infection with pin worm.

5.8.2 Identifying characters:

This parasite contains cervical alae, bulbous oesophagus.

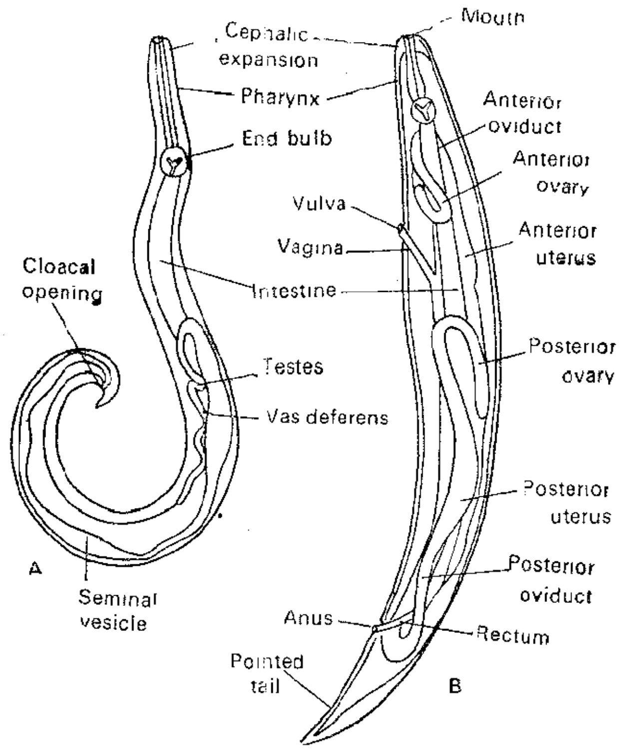


Fig. 5.7--- *Enterobius vermicularis*
(A) Male (B) Female

5.8.3 Systematic position:

Phylum ---Aschelminthes-Unsegmented or superficially segmented, Pseudocoelomate Vermiform

Class --- Nematoda- Unsegmented body, cilia absent, alimentary canal straight

Order --- Rhabditea- 3 or 6 lips, pharynx with a posterior bulb

Genus --- *Enterobius*

Species --- *vermicularis*

5.9 Summary:-

The phylum Nematoda, commonly known as the roundworms, has nearly 24,000 species. Nematodes are the most abundant group of multicellular organisms on earth they are found in almost every imaginable **habitat**, including terrestrial (land-based), freshwater, and saltwater **ecosystems**, as well as within other organisms as parasites. Nematodes can be herbivorous, carnivorous, or parasitic.

The characteristics of nematodes are:-

- Bilaterally symmetrical.
- Body has more than two cell layers, tissue and organs.
- Body cavity is a pseudocoel.
- Body covered in a complex cuticle.
- Has a nervous system with pharyngeal nerve ring.
- Has no circulatory system.
- Many species are endoparasite.

There is diversity within the life cycles of different nematodes; however, all nematodes follow the same basic pattern of growth and reproduction. The nematode life cycle has seven stages, including an egg, four larval stages and two adult stages. Sexual reproduction is generally initiated by adult female nematodes that have attached themselves to a host organism. The female lays eggs that are passed by the host to the external environment where the eggs then pass through three developmental stages before becoming larvae.

Several common human nematode parasites cause intestinal and subcutaneous disease including the ascarids, filarias, ancylostomids (hookworms), *Enterobius* (pinworms/threadworms) and *Trichuris* (whipworms). Nematodes play an important role in the ecosystem. Some nematodes have the potential to harm the ecosystem by killing plants, insects and animals. Some insect parasitic nematodes are effectively used as biological control agents to control the population of pest insects such as mosquitoes. They are also an indicator of soil health.

5.10 Glossary:-

***Ascaris lumbricoides*:**	Worms that live in large intestine
Bilateral symmetry:	Can be split in two equal lateral half
Cephalized:	Head region
Cuticle:	Nonliving outer layer
Definitive host:	Last host
Dioeciously:	Having the male and female organs in separate and distinct individuals.
Hermaphrodite:	An individual in which reproductive organs of both sexes are present
Hookworm:	worm that live in small intestine

Hydrostatic organ:	Keeps everything in balance
Hypodermis:	Innermost germ layer
Intermeidiate host:	A host which is normally used by a parasite in its course of life cycle.
Mesoderm:	Mucsle layer.
Ovaries:	Female gonads which hold eggs.
Oviducts:	Where egg is fertilized
Parasite:	An organism that lives on or in an other organisms
Parthenogenesis:	It is a process of asexual reproduction in which offspring are produced by female without genetic contribution of male.
Pseudocoelmates:	Body has no true body cavity.
Testes:	Male gonad which carry Male gametes.
Triploblastic:	3 germ layers are present.

5.11 Self assessment questions:-

1. There are four bands of muscles in Nematodes, two are dorso-lateral and two

(A) ventro-lateral (B) dorso-ventral (C) dorso-lateral (D) latero-ventral

2. Nematoda means

(A) pointed ends (B) pointed bodies (C) pointed cells (D) peaked heads

3. Nematodes lack respiratory system and

(A) digestive system (B) nervous system (C) circulatory system (D) all of these

4. Nematodes are

(A) Playtheminthes (B)Aschelminthese (C)Polychaetes (D) Annelids

5. Body cavity of Ascaris is pseudocoel because

(A) Contains large cell termed psuedocoelocytes (B) Bound extremely by muscle layer and internally by intestine (C) Very little parenchyma (D)Filled with pseudocoelomic fluid

6. *Ascaris lumbricoides* live in the intestine of

(A) Sheep (B) Goat (C) *Homo sapiens* (D) Pig

7. The Life span of *Ascaris* is

(A) 30 days (B) one year (C) six months (D) 8 to 10 months

8. Infected stage of *Ascaris lumbricoides* is

(A) Egg (B) Fourth Juvenile (C) Second Juvenile (D) Adult worm

9. Hook worm caused a disease named

(A)Ascariasis (B) elephantiasis (C) Ancylostomiasis (D) Enterobiasis

10. Elephantiasis is caused by

(A) *Ascaris lumbricoides* (B) *Wuchereia bancrofit*

(C) *Enterobius vermicularis*(D) *Fasciola hepatica*

11. What is the scientific name of pinworm of man?

(A)*Trichuris trichiura* (B)*Enterobius vermicularis*

(C)*Dracunculus medinensis* (D)*Trichinella spiralis*

12. Man acts as the only host in

(A) Trichinosis (B) Enterobiasis (C) Ascariasis (D) Strongyloidiasis

13. Phenomena by which male and female can be differentiated morphologically is called

(A) Variation (B) Polymorphism (C) Sexual Dimorphism (D) none

14. Cuticle in *Ascaris lumbricoides* is adaption for

(A) Parasite (B) growth (C) reproduction (D) locomotion

1(a) 2(a) 3(c) 4(b) 5(b) 6(c) 7(a) 8 (c) 9(b) 10(b) 11(b) 12(c) 13(c) 14(a)

5.12 References:

1. R L Kotpal: Text book of Zoology of Invertebrates, Rastogi Publication, 2007.
2. P. S. Verma: A manual of Practical Zoology Invertebrates, S. Chand Publication.
3. S. S. Lal: Practical Zoology Invertebrate, Rastogi Publication.
4. B N Pandey: Animal diversity volume 1, Tata McGraw Hill Education Private Limited.
5. V P Agrawal and L D Chaturvedi: A text book of Zoology, Jagmander Book Agency.

5.13 Suggested readings:

- Manuals of Zoology E K Ayer, vol. 1 and 2.
- Cleveland Hickman, Jr. and Larry Roberts &Susan Keen and Allan Larson and David Eisenhour: Animal diversity, 7th edition, McGraw Hill Education Private Limited, 2015.

5.14 Terminal questions/ answer:

1. What are pseudocoelomates?
   Ans. They don't have true coelom.
2. How Nematode can bend its body from side to side and is unable to crawl?
   Ans. Long muscle present just below the epidermis are aligned longitudinally along the inside body.
3. Why itching is more in a person having pin worm infection?
   Ans. Female Pin worm lay eggs at night.
4. Body cavity is not true coelom in Nematode.
   Ans. Body cavity is not lined with epithelial layer derived from the mesoderm.
5. Why blood sample are taken at night for diagnosing filarial?
   Ans. Lower Temperature attracts more microfilariae to circulate in blood. It is also the time where mosquito generally bites.
6. Why *Ancylostoma duodenale* is an S shaped worm
   Ans. It's flexure at the frontal ends.
7. Why there is no evidence regarding evolution history of platyhelminthes?
   Ans. They possess soft bodies which cannot be preserving as fossils.
8. Why in some nematodes development does not occur beyond the morula stage in intestine.
   Ans. Development eggs require optimal conditions of oxygen, moisture and temperature which are not available in the intestine of the host.

Fill in the blanks:

1. Nematodes are……………. (Aschelminthese)
2. There are………………….lips in Ascaris. (Three)
3. The scientific study of parasitic worms is known as ………………… (Helminthology)
4. Adult filarial worms live only in ……………………. system. (Lymphatic)
5. Excretory system of *Ascaris* is …………… shaped. (H)
6. First and last moults of *Ascaris* occurs in ………………… of humans. (Intestine)
7. Pseudocoelom develops from ………………………… (Blastocoel)
8. Amphids are the blind invaginations of the……………

UNIT 6: PHYLUM ANNELIDA

Contents

6.1-Objective:-

To study the General characters of Phylum Annelida and its classification up to order and Identification of specimens and microscopic slide.

6.2 Introduction:

Annelida (L., anellus=little rings) known as ringed worms or segmented worms are mostly aquatic, marine or freshwater, some burrowing or tubicolous, terrestrial, free living or sedentary forms. Body elongated, triploblastic, bilaterally symmetrical, metamerically segmented, truly coelomate and vermiform. Body has more than two cell layers, tissues and organs. Epidermis of a single layer of columnar epithelial cells, covered externally by a thin cuticle not made of chitin.Body wall is contractile, consists of an outer epidermis, longitudinal and circular muscles.Appendages when present are unjointed.Nervous system consists of a anterior nerve ring and segmental ganglia connected by ventral nerve cord. Digestive system straight and complete.Blood vascular system is closed type. Respiratory pigment is haemoglobin or erythrocruorin dissolved in blood plasma.Respiration through general body surface and by gills. Locomotroy organs are segmentally arranged paired setae. Excretory system consists of paired nephridia that excrete nitrogenous waste. Sexes may be separate or united.Development is direct and indirect. Direct development in monoecious and indirect development in dioecious forms. Trochophore larval stage occurs in case of indirect development.

Classification:-

Class1. Polychaeta (Gr., Poly=many+ chaete=bristles)

1. Polychaeta is fresh water and marine.
2. Body is segmented and elongated.
3. Head consists of prostomium and peristomium and bear tentacles, eyes, palps, and cirri etc.
4. Setae numerous, or lateral parapodia.
5. Sexes are separate.
6. Trochophore larva present.

Order 1 Errantia:

1. These are motile and free living polychaetes.

2. Except for head and anus the rest of the body is divisible into segments.

3. Head well developed with eyes and tentacles.

4. Pharynx is protrusible and contains jaws and teeth.

5. Parapodia, provided with cirri are equally developed throughout.

Examples: *Aphrodite, Polynoe, Phyllodoce, Nereis, Glycera, Syllis, Eunice, Diopatra, Histriobdella*.

Order 2. Sedentaria:

1. Tube-dwelling and burrowing forms.

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

3. Head poorly developed without eyes and tentacles.

4. Pharynx is non protrusible without jaws and teeth.

5. Gills when present localized to anterior segments.

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

Class 2. Oligochaeta (Gr., Oligo=few+ chaete=bristles)

1. Some freshwater and mostly terrestrial forms.

2. Body with conspicuous external and internal segmentation.

3. Head indistinct, without sensory organs.

4. Parapodia are absent.

5. Setae are usually arranged segmentally.

6. Hermaphrodite. No larval stage.

Order 1. Archaeoligochaeta

1. They are mostly fresh water.

2. Body comprises of few segments.

3. Setae are present.

4. Poorly developed gizzard.

5. Female reproductive openings present after that of male reproductive openings.

6. Reproduction asexual and sexual.

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

Order 2. Neooligochaeta:

1. Mostly terrestrial earthworms.

2. Body consists of many segments.

3. Setae are present.

4. Well developed gizzard.

5. Male reproductive openings present after that of female reproductive openings.

6. Reproduction sexual.

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

Class 3. Hirudinea: (L., hirudo, leech)

1. Mostly freshwater but some are found in marine or terrestrial environments.

2. Generally ectoparasitic, blood sucking or carnivorous.

3. Body is elongated, dorso-ventrally flattened or cylindrical.

4. Parapodia and setae are absent.

5. Usually suckers are present.

6. Hermaphrodite.

7. Reproduction sexual.

8. Development is direct without free-swimming larval stage.

Order 1. Acanthobdellida:

1. Mostly parasitic on the fins of salmon fishes.

2. Body comprises 30 segments only.

3. Body cavity is spacious and incompletely divided by septa.

4. Setae present in first 5 anterior segments.

5. Acanthobdellida forms a connecting link between Oligochaeta and Hirudinea.

Example: *Acanthobdella*.

Order 2. Rhychobdellida

1. Only aquatic leeches.

2. Each typical body segment consists of 3, 6 or 12 rings.

3. Blood is colourless.

4. Coelom is reduced to sinuses without botryoidal tissues.

Examples: *Glossiphonia, Pontobdella, Pisciola, Branchellion*.

Order 3. Gnathobdellida

1. Freshwater and terrestrial forms.

2. Body segments typically consist of 5 rings of annuli.

3. Proboscis is absent.

4. Blood is red-coloured.

Examples: *Hirudinaria*, *Haemopis*, *Hirudo*, *Herpobdella*.

Class 4 Archiannelida:

1. Exclusively marine forms.

2. Body elongated and worm-like.

3. Parapodia are usually absent.

4. Hermaphrodite.

Examples: *Protodrillus, Nerilla, Polygordius, Saccocirrus*.

Class 5 Echiuroidea

1. Marine, found between rocks in shallow water.

2. The body is more or less cylindrical.

3. Parapodia absent.

4. Sexes are separate.

5. Larva trochophore.

Examples: *Echiurus*, *Bonellia*.

Class 6 Sipunculoidea:

1. Sipunculoidea is found in sand or mud.
2. Body is elongated, grayish or yellowish in colour without segmentation.
3. Parapodia are absent.
4. Sexes are separate.
5. Larva similar to trochophore.

Examples: *Sipunculus*, *Phascolosoma*.

Class 7 Priapulida

1. Found widely distributed at moderate depths, burrowing in sand or mud.
2. Body worm-like, cylindrical, unsegmented with superficial segmented trunk.
3. Mouth is anterior and anus is posterior.
4. Sexes are separate.
5. Development is unknown.

Example: *Priapulus*.

Class 8 Myzostomaria

1. Ecto or endoparasite.
2. Body is flat, worm-like, unsegmented and oval or disc-like in shape.
3. Five pairs of parapodia.
4. Protandric hermaphrodites.
5. Larva trochophore.

Example: *Myzostoma*.

6.3 IDENTIFICATION, SYSTEMATIC POSITION UP TO ORDER AND GENERAL STUDY:

6.3.1 (a) Nereis

Systematic position:

Phylum Annelida

Class Polychaeta

Order Errantia

Genus *Nereis*

Comments:

1. *Nereis* (Fig. 6.1) is commonly called rag worm.

2. The body is long, slender, elongated, dorso-ventrally flattened segmented and is divisible into head, trunk and pygidium.

3. Head consists of two parts, the prostomium and peristomium. Prostomium bears a pair of tentacles, two pairs of eyes and a pair of short two jointed palps. Peristomium bears four tentacles and a slit-like mouth.

4. Trunk is made up of several segments, each bearing a pair of lateral parapodia which are locomotory organs. Setae project beyond the outer margin of each parapodium.

5. Pygidium or anal segment is without parapodia but bears a pair of appendages known as anal cirri and a terminal anus.

6. Respiration happens via blood capillary network of parapodia.

7. Aimentary canal is straight and extends from mouth at the anterior end to the anus at the posterior end.

8. Sexes separate. Fertilization is external.

9. The sexual phase of *Nereis* is known as *Heteronereis*.

Habit and habitat:

Nereis is found in burrows in sand or rocks in intertidal and shallow marine waters.

Distribution:

Nereis is cosmopolitan in distribution and found in coastal waters of Europe, North Atlantic, Pacific oceans and U.S.A.

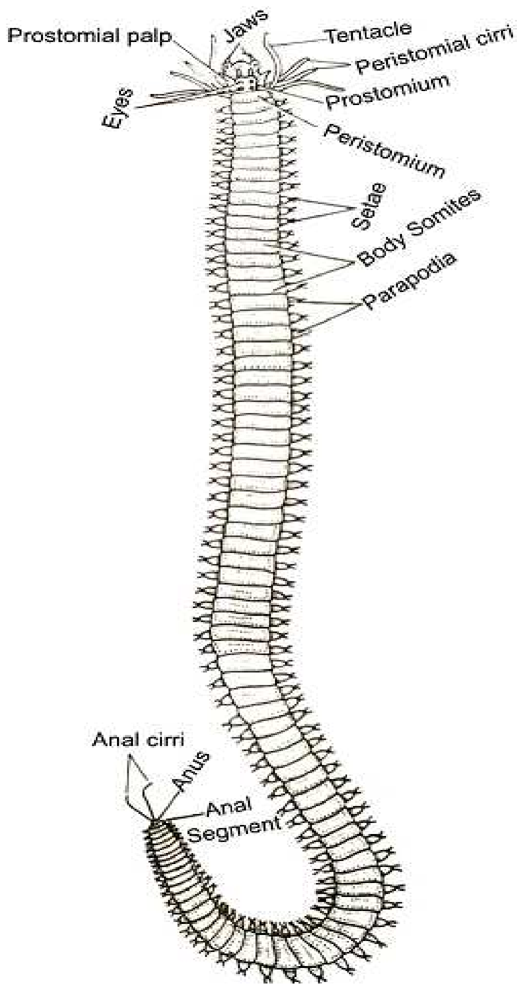


Fig. 6.1. *Nereis*

6.3.1 (b) Heteronereis

Systematic position:

Phylum Annelida

Class Polychaeta

Order Errantia

Genus *Heteronereis*

Comments:

1. *Heteronereis* (Fig. 6.2) is the sexual phase of *Nereis*.

2. The body of *Heteronereis* is divisible into an anterior atoke or asexual region and a posterior epitoke or sexual region.

3. It comes out to the water surface and leads an active free swimming life.

4. Eyes become greatly enlarged and highly sensitive to light.

5. The peristomial cirri become longer.

6. Parapodia become enlarged, develop additional foliaceous outgrowths and setae become oar-shaped which help in active swimming.

7. Due to excessive development of gonads, the muscles and alimentary canal are reduced.

8. There is no marked sexual dimorphism in most species.

Habit and habitat:

Heteronereis is a free-swimming worm found in sea.

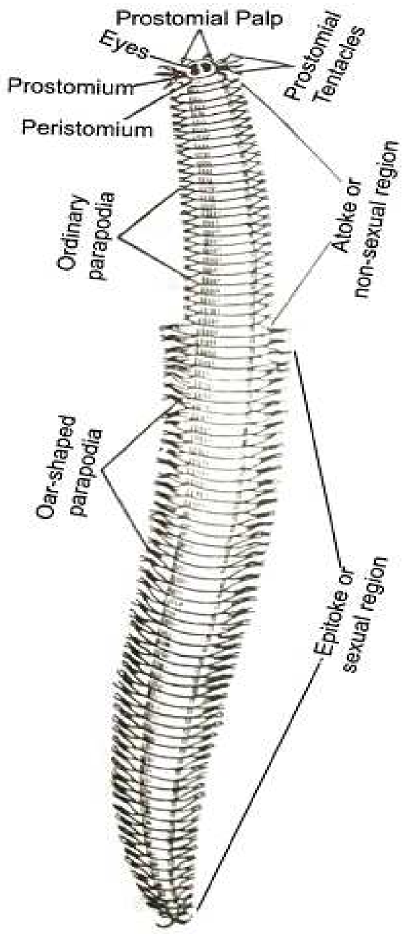


Fig. 6.2. *Heteronereis*

6.3.2 (a) Aphrodite

Systematic position:

Phylum	Annelida
Class	Polychaeta
Order	Errantia
Genus	*Aphrodite*

Comments:

1. *Aphrodite* (Fig.6. 3) is commonly called as sea mouse.

2. It measures about 12 cm in length.

3. Body is short, oval and dorso-ventrally flattened.

4. Ventral surface is flat, segmented and forms a creeping sole.

5. Stiff setae and hollow bristles are present on the dorsal surface.

6. Segments clearly visible on the underside.

7. Head is small, situated anteriorly beneath the dorsal felt and bears a single small median tentacle and two large lateral palps.

8. Intestine is characterized by long branching segmental caeca which digest minute food particles.

9. Respiration takes place through dorsal body surface.

10. Anus is situated at the posterior extremity on the dorsal surface.

11. Sexes are separate and fertilization is external.

Habit and habitat:

Aphrodite is a marine burrowing form found just below the intertidal zone usually on sandy muddy bottoms.

Distribution:

It is found in both sides of Atlantic and in the Mediterranean Sea.

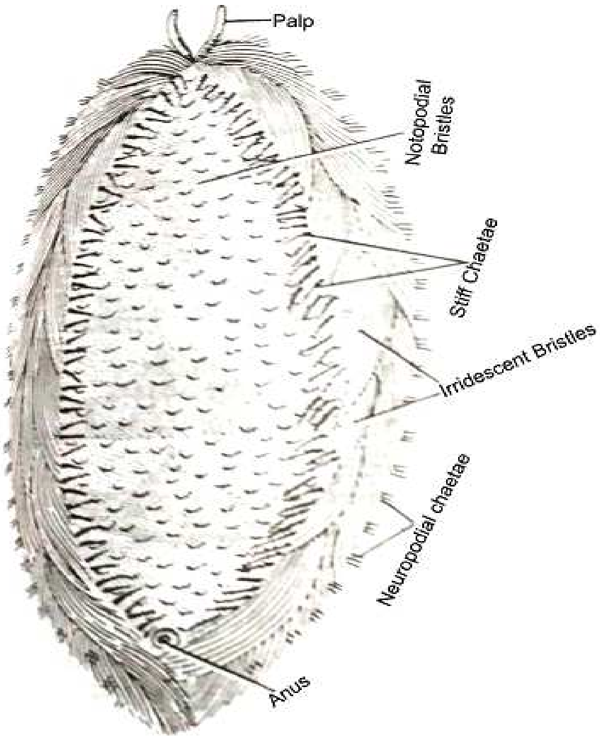


Fig.6.3. *Aphrodite*

6.3.2 (b) Arenicola

Systematic position:

Phylum Annelida

Class Polychaeta

Order Sedentaria

Genus *Arenicola*

Comments:

1. *Arenicola* (Fig.6. 4) is commonly called lug-worm or lobe-worm.

2. Body is cylindrical, segmented, elongated and worm-like measuring up to 25 cm in length.

3. Body consists of three regions: anterior, middle and posterior.

4. Anterior region comprises prostomium, peristomium and six segments bearing chaetae and parapodia.

5. Middle region is made up of thirteen segments bearing parapodia and gills.

6. Posterior region comprises of variable number of segments devoid of parapodia, setae and gills.

7. Mouth lies ventral to the prostomium.

8. The anus opens through the last segment.

9. Sexes are separate with external fertization.

10. *Arenicola* is generally used as bait in fishing.

Habit and habitat:

Arenicola is a marine worm, lives in burrows deep into the sandy sea bottom or intertidal areas.

Distribution:

Arenicola is found in Europe and Northern America.

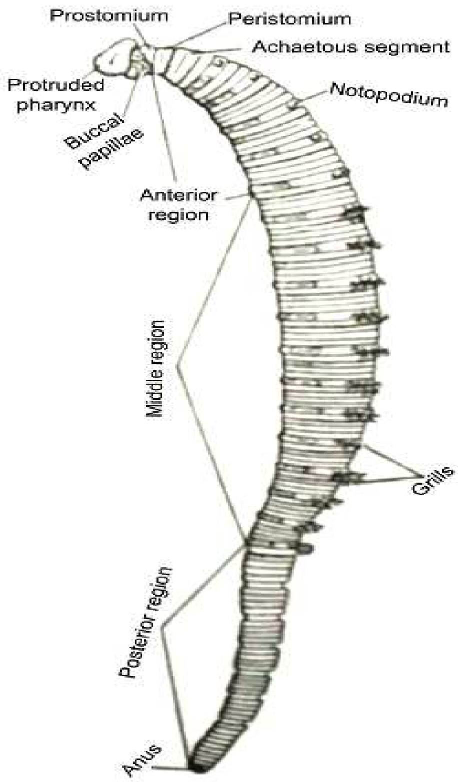


Fig. 6.4. Arenicola

6.4 IDENTIFICATION, SYSTEMATIC POSITION UP TO ORDER AND GENERAL STUDY:

6.4.1 (a) Pheretima

Systematic position:

Phylum Annelida

Class Oligochaeta

Order Neooligochaeta

Genus *Pheretima*

Comments:

1. *Pheretima* (Fig. 6.5) is commonly called earthworm.

2. Body is bilaterally symmetrical, narrow, long, elongated and cylindrical measuring upto 150 mm in length.

3. Anterior end is tapering and posterior end is blunt.

4. Body is divided into 100-120 ring-like segments by a distinct series of annular grooves.

5. Each segment is provided with setae arranged in a ring with each setae arising from a setigerous sac of the skin. The setae help in locomotion by holding the earth.

6. Mouth is crescentic aperture situated just below the prostomium.

7. The clitellum is a circular band of glandular tissue which completely surrounds the segments from 14^{th} to 16^{th} segment.

8. Hermaphrodite.

9. A pair of male genital pore is situated ventrally in the eighteenth segment while female genital pore are situated at the ventral surface of fourteenth segment.

10. Anus is situated at the terminal end of the last body segment called anal segment.

11. Reproduction is usually sexual.

12. Development takes place in cocoons.

13. Earthworm is used as bait in fishing and as food by many uncivilized people. It also has use in medicines, education, experiments and in agriculture as producer of organic fertilizer.

Habit and habitat:

Pheretima are burrowers found in the soil rich in decaying organic matters usually in pastures, lawns, gardens, irrigated farm lands, near the banks of ponds, lakes and rivers.

Distribution:

Found all over world.

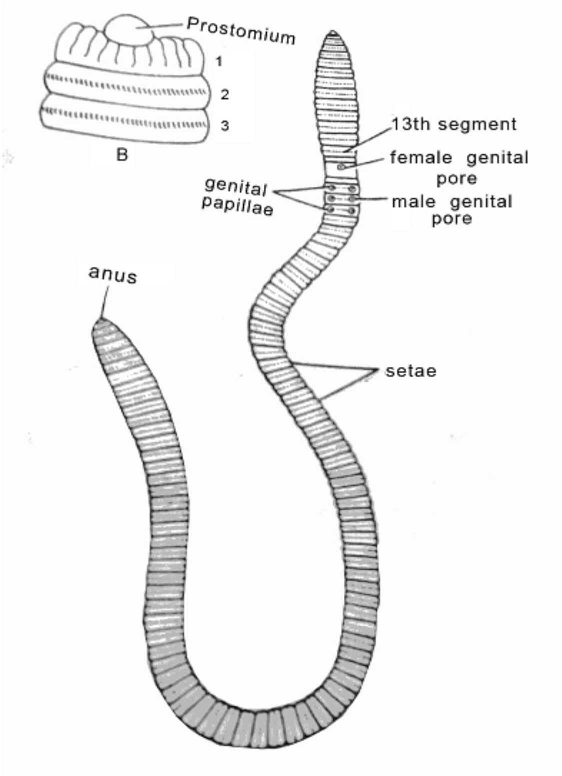


Fig.6. 5. Pheretima

6.4.1 (b) Pontobdella

Systematic position:

Phylum Annelida

Class Hirudinea

Order Rhynchobdellida

Genus *Pontobdella*

Comments:

1. Body is rough, cylindrical, elongated and has warts arranged in regular circles.

2. Body has a saucer-shaped anterior sucker and a cup-shaped posterior sucker.

3. Eyes, parapodia, jaws and gills are absent.

4. Proboscis is protrusible.

5. Crop has a single undivided caecum lying beneath the intestine.

6. Nephridia are absent.

7. Hermaphrodite.

8. Sexual reproduction is common.

Habit and habitat:

Pontobdella (Fig. 6.6) is a marine leech. Mostly ectoparasitic on sharks, rays and skates. A few species show parental care.

Distribution:

Pontobdella is found in Europe and U.S.A.

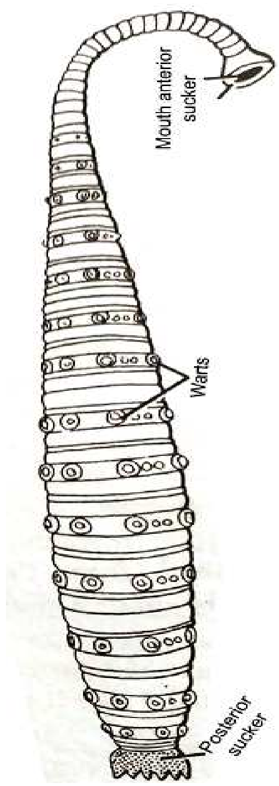


Fig. 6.6. *Pontobdella*

6.4.2 Hirudinaria

Systematic position:

Phylum Annelida

Class Hirudinea

Order Gnathobdellida

Genus *Hirudinaria*

Comments:

1. *Hirudinaria granulosa* (Fig. 6.7) is commonly called Indian cattle leech.

2. Body is soft, elongated, vermiform and bilaterally symmetrical with dorsal surface green and ventral surface orange yellow in colour.

3. During extension of the body is dorso-ventrally flattened while during contraction it is cylindrical.

4. Body of leech is divided into 33 segments. The segments are further divided into annuli or rings.

5. Anterior and posterior suckers are well developed. Anterior sucker is oval bearing triradiate mouth and is formed by the fusion of prostomium with a few somites of anterior region. The posterior sucker is circular in outline and forms a muscular disc at the posterior end. Both the suckers serve as powerful organs of adhesion and locomotion.

6. Five pairs of eyes are present on the dorsal side.

7. No special respiratory organs. Respiration happens via skin.

8. Locomotion by creeping/crawling on the surface.

9. Alimentary canal is a straight tube extending from mouth to anus. Small aperture or anus is situated mid-dorsally on the 26^{th} segment at the root of the posterior sucker.

10. Excretory system consists of segmentally arranged seventeen pairs of nephridia arranged from six to twenty-two segments, opening by nephridiopores on the ventral surface.

11. Hermaphrodite.

12. Male genital aperture is situated mid-ventrally in the second and third annuli of 10^{th} segment and female genital aperture between second and third annuli of 11^{th} segment.

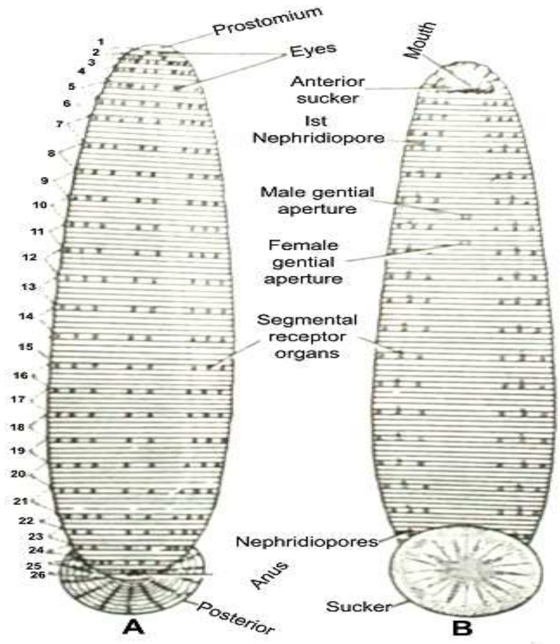
13. Sexual reproduction is common.

Habit and habitat:

Hirudinaria is found in freshwater tanks, ponds, lakes, slow streams and swamps. It is sangivorous (blood sucking) in habit.

Distribution:

Hirudinaria has cosmopolitan or worldwide distribution specially found in India and Myanmar.



A. Dorsal view B. Ventral view

Fig. 6.7. *Hirudinaria granulose*

6.5 T. S. Through Body Segment of *Nereis & Hirudinaria:-*

Comments:

1. Body wall consists of outer cuticle, inner epidermis and musculature (Fig.6.8).

2. The cuticle is thin, chitinous and tough and has many minute pores.

3. Epidermis lies beneath the cuticle and is a single layer of cells comprising glandular, sensory and columnar cells.

4. Musculature consists of three types of muscles: circular, longitudinal and oblique muscles.

(i) Circular muscles form a continuous layer below the epidermis.

(ii) Longitudinal muscles consist of two dorso-laterals bundels and two ventro-laterals bundles.

(iii) Two pairs of oblique muscles connecting mid ventral body wall to the base of parapodia and helps in movement.

5. Parapodia lie on both the lateral sides distinguishing into notopodia and neuropodia.

6. Sections of dorsal ciliated organs, dorsal and ventral blood vessels, ventral nerve cord, gut, gonads, and nephridia can also be seen.

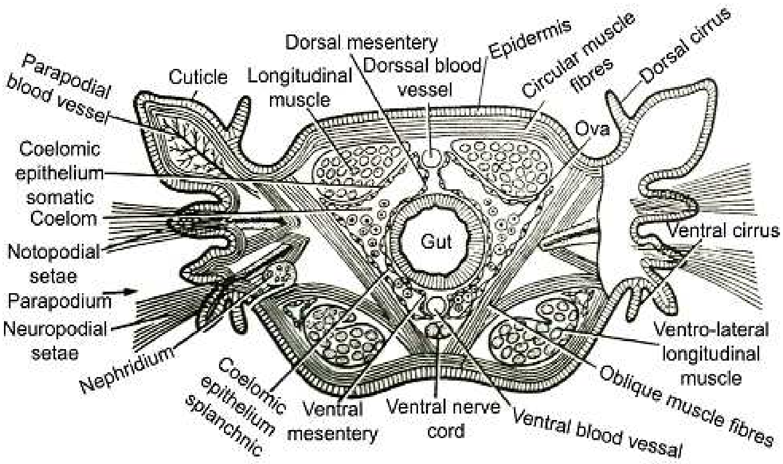


Fig. 6.8. T. S. through body segment of *Nereis*

T. S. of *Hirudinaria* through Buccal Cavity

Comments:

1. Body wall consists of a cuticle membrane, epidermis, dermis and musculature (Fig.6.9).

(i) Cuticle is delicate, thin, colourless and transparent membrane having pores.

(ii) Epidermis consists of narrow, elongated and hammer-shaped cells and single cell in thickness. It lies below the cuticle.

(iii) Dermis consists of fibrous connective tissue, short muscle fibres and haemocoelomic channels. It lies just below the epidermis.

(iv) Musculature consists of longitudinal, oblique, circular, dorso-ventral and radial muscles.

2. Sections of a medio-dorsal jaw and two sections of ventro-lateral jaws are seen embedded in the mucous membrane crypts of the buccal cavity.

3. Jaws are lined with thick cuticle.

4. Haemocoelomic capillary and anterior sucker glands are seen.

5. Botryoidal tissue is not seen in this section.

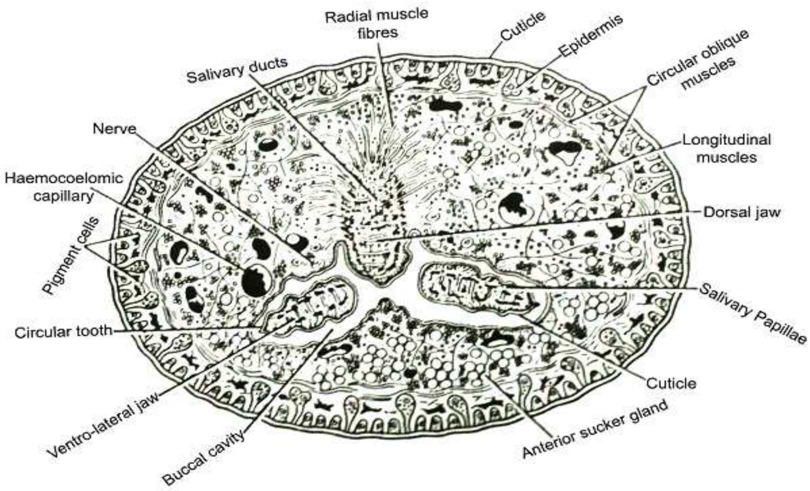


Fig. 6.9. T. S. *Hirudinaria* through Buccal Cavity

T. S. of *Hirudinaria* through Crop with Diverticula

Comments:

1. Body wall consists of the following layers (Fig.6.10):

(i) Cutile is the outermost layer of body wall. It is delicate, thin, colourless and transparent layer and has minute pores through which epidermal glands open out.

(ii) Epidermis is single layered and it comprises of elongated, narrow and hammer-shaped cells. It lies below the cuticle. It contains various epidermal glands: slime glands, sucker glands, prostomeal glands and clitellar glands.

(iii) Dermis lies below the epidermis and consists of fibrous connective tissue, short muscle fibres and haemocoelomic channels.

(iv) Musculature lies just below the dermis and consists of circular and oblique, longitudinal, dorso-ventral and vertical muscle fibres.

2. Sections of crop and its two diverticula are present in the centre. Botryoidal tissues lie around those diverticula.

3. A thin epithelial lining of prismatic cells cover the crop wall.

4. Sections of dorsal and lateral haemocoelomic channels, nephridia and ventral haemo-coelomic channel enclosing the ventral nerve cord can also be seen.

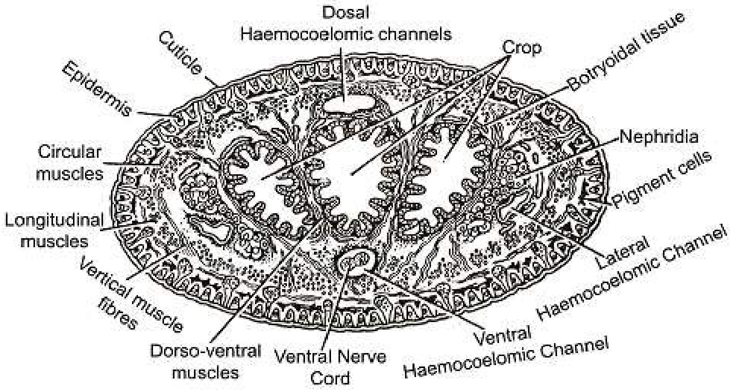


Fig. 6.10. T. S. of *Hirudinaria* through Crop with Diverticula

T. S. of *Hirudinaria* through Crop without Diverticula

Comments:

1. Body wall consists of usual layers which are as follows (Fig.6.11):

(i) Cutile is the outermost layer of body wall. It is delicate, thin, colourless and transparent layer and has minute pores through which epidermal glands open out.

(ii) Epidermis is single layered and it comprises of elongated, narrow and hammer-shaped cells. It lies below the cuticle. It contains various epidermal glands: slime glands, sucker glands, prostomeal glands and clitellar glands.

(iii) Dermis lies below the epidermis and consists of fibrous connective tissue, short muscle fibres and haemocoelomic channels.

(iv) Musculature lies just below the dermis and consists of circular and oblique, longitudinal, dorso-ventral and vertical muscle fibres.

2. Sections of crop are present in the centre.

3. Botryoidal tissues are seen below the muscle layers

4. A thin epithelial lining of prismatic cells cover the crop wall.

5. Crop diverticula are absent.

6. Sections of lateral haemocoelomic channels, dorsal haemocoelomic channel, and ventral haemocoelomic channel enclosing the ventral nerve cord are seen.

7. Sections of two large nephridial vesicles are seen on either side of the crop.

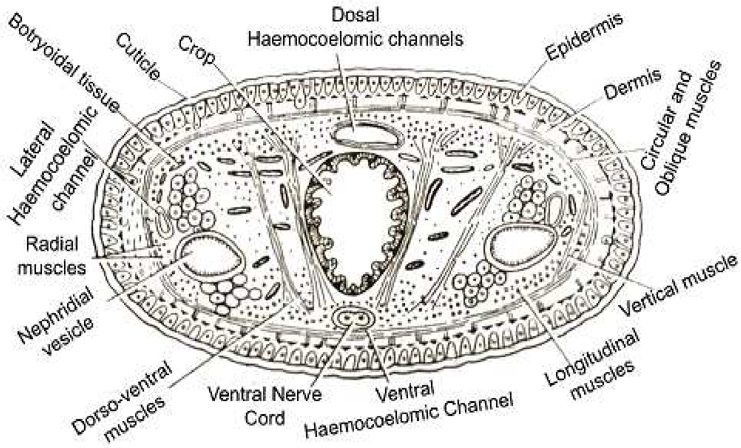


Fig. 6.11. T. S. of *Hirudinaria* through Crop without Diverticula

T. S. of *Hirudinaria* through Rectum and Posterior Sucker

Comments:

1. Body wall consists of the following layers (Fig.6.12).

(i) Cutile is the outermost layer of body wall. It is delicate, thin, colourless and transparent layer and has minute pores through which epidermal glands open out.

(ii) Epidermis is single layered and it comprises of elongated, narrow and hammer-shaped cells. It lies below the cuticle. It contains various epidermal glands: slime glands, sucker glands, prostomeal glands and clitellar glands.

(iii) Dermis lies below the epidermis and consists of fibrous connective tissue, short muscle fibres and haemocoelomic channels.

(iv) Musculature lies just below the dermis and consists of circular and oblique, longitudinal, dorso-ventral and vertical muscle fibres.

2. Botryoidal tissues is scattered within the body cavity.

3. A section of rectum is present in the centre and is lined by an epithelium of prismatic cells.

4. The crop diverticulum is seen on both the lateral sides of rectum.

6. Dorsal haemocoelomic channel, ventral haemocoelomic channel and lateral haemocoelomic channels enclosing the ventral nerve cord are present.

7. A section of posterior sucker, containing posterior sucker glands, lies below the rectal section.

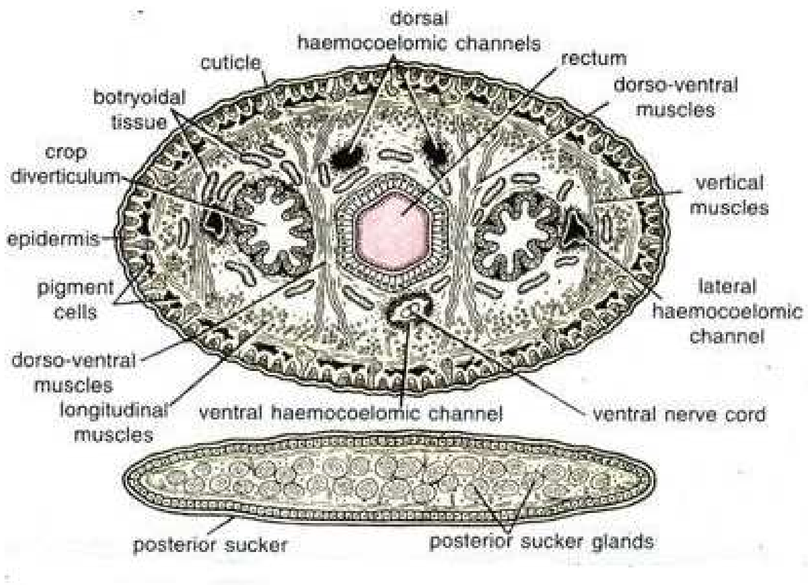


Fig.no 6.12 T. S. of Hirudinaria through Rectum and Posterior Sucker

6.6 Trochophore Larva of *Nereis:-*

Comments:

1. Trochophore larva (Fig. 6.12) is formed from gastrula and is top-like and transparent. It has a thin external ectodermal epithelium.

2. It has a mouth, a curved gut, ectodermal oesophagus, an endodermal stomach and an ectodermal anal opening.

3. It exhibits bilateral symmetry with the anterior end of the body broader than the posterior end.

4. The gut walls are lined by cilia.

5. Eyes lie below anterior apical sensory plate.

6. The apical organ forms the prostomium with brain, tentacles and eyes.

7. Above the mouth there is a strong locomotor ciliary band called Prototroch. The Prototroch encircles the body around the middle.

8. The gut is enclosed by a spacious blastocoel. The blastocoel has mesenchyme cells, larval mesoderm and a pair of larval nephridia. There is a statocyst near the nephridia.

9. Trochophore is called panktotrophic larva because it feeds on plankton and other microscopic organisms.

10. It drifts about in the sea swimming by its prototroch.

11. Segmentation of mesodermal bands marks the start of metamorphosis. Later the larva grows rapidly from the anal end externally marked with segmentation.

12. The larval setae are dropped, tentacles, palps and parapodia are formed and larval nephridia are replaced by permanent nephridia.

13. The young worm settles at the bottom of the sea and starts forming its burrow and gradually attains adulthood.

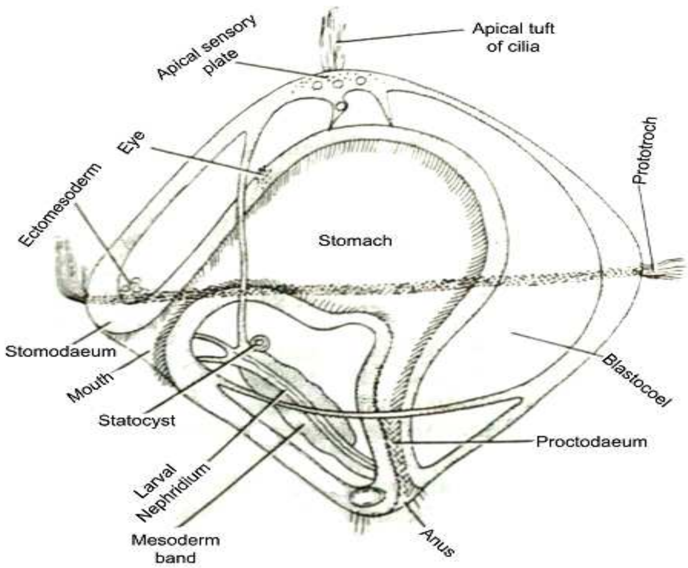


Fig.6.12. Trochophore larva

6.7 Parapodium of *Nereis & Hetronereis*

Comments:

1. Parapodia of *Nereis* (Fig. 6.13) are lateral, mucular, flattened outgrowths of the body wall.

2. The dorsal part (notopodium) bears dorsal cirrus and bundles of long setae.

3. The ventral part (neuropodium) bears a ventral cirrus and similar bundle of setae.

4. The notopodial and neropodial setae are embedded in the setigerous sacs.

5. Both notopodium and neuropodium are supported by dark coloured thick chitinous internal rod called aciculums.

6. Parapodia help in respiration and locomotion.

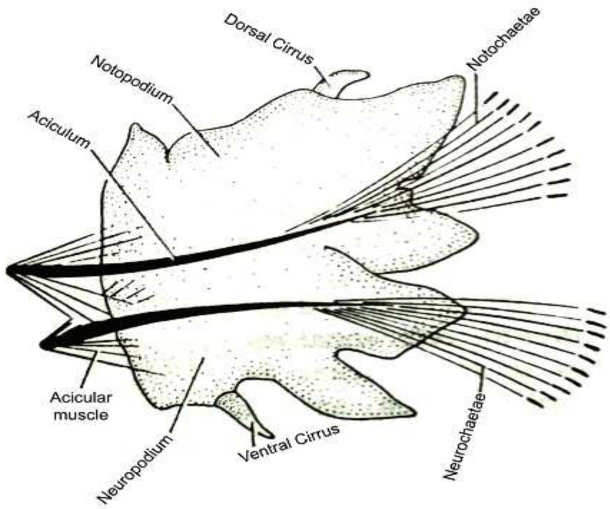


Fig. 6.13 Parapodium of *Nereis*

Parapodium of Heteronereis

Comments:

1. Body of Heteronereis (Fig. 6.14) is divided into anterior asexual region called atoke and posterior sexual region called epitoke. Parapodium of Heteronereis has similar structure as that of *Nereis* with following modifications.

2. Parapodium of the posterior sexual part of the body become large and develops foliaceous outgrowths.

3. Neruropodial lobe is larger than notopodial lobe.

4. Neuropodial and Notopodial setae become flattened and oar-shaped and are arranged in a fan-like manner.

5. Dorsal cirrus is larger than the ventral cirrus.

6. Changes in setae and lobes facilitate active swimming and efficient respiration.

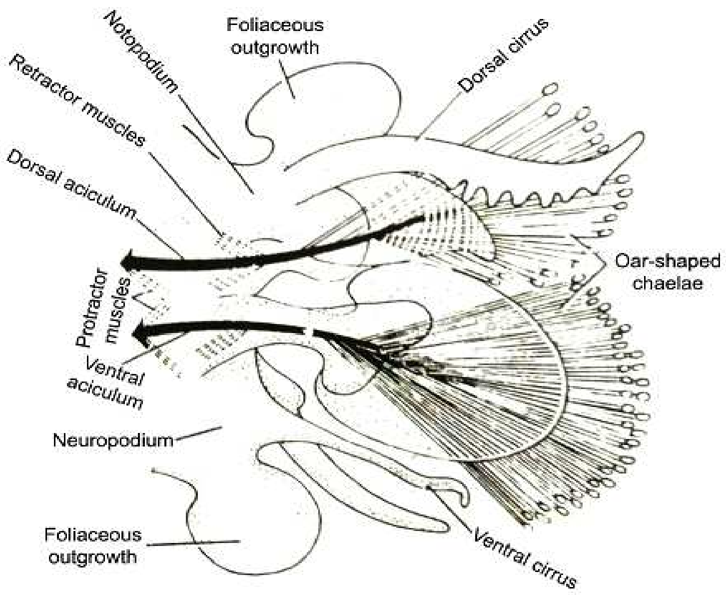


Fig. 6.14 Parapodium of *Heteronereis*

6.8- Summary:-

Name of phylum Annelida was first coined by Lamarck for the higher segmented worms (Gr., annulus - little ring + eidos - form). Annelids are elongated, bilaterally symmetrical and highly organized animals, in which the organs have grouped in to definite systems. Appearance of metamerism represents their greatest advancement, so that they are called segmented worms in order to distinguish them from flatworms (Platyhelminthes) and roundworms (Nematodes) which are not segmented. Their paired appendages, when present, are never jointed. Their coelom, nephridia and cephalization are better developed than those of the un-segmented worms.

They are the first animals to have a closed vascular system. Nervous system is fundamentally is similar to that of Arthropoda and embryology is not much different from that of mollusca.

Annelids mostly aquatic, some terrestrial. Burrowing or tubicolous. Locomotory organs are segmentally repeated chitinous bristles, called setae or chaetae, embedded in skin. May be borne by lateral fleshy appendages or parapodia. Blood vascular system is closed. Hermaphroditic or sexes separate cleavage spiral and determinate. Larva, when present, is a trochophore. Regeneration is common. Modern classification of phylum Annelida was proposed by Fauchold (1977) and Parker (1980). About 8,700 known species of annelid are divided into four main classes **(A. Class – Polychaeta; B. Class – Oligochaeta; C. Class – Hirudinea and D. Class - Archiannellida)**, primarily on the basis of the presence or absence of parapodia, setae, metamers, and other morphological features.

6.9- Self assessment question

Long answer type questions:-

1. Classify phylum Annelida upto orders with suitable examples.

2. Describe coelom, metamerism and reproduction in annelids.

Short answer type questions:-

1. Write a short note on phylum Annelida.

2. Name few genera in which direct and indirect development occurs.

Multiple choice questions:-

1. *Aphrodite* is commonly known as

   (a) Sand worm (b) Sea mouse
   (c) Clam worm (d) Lug worm

2. The annelid larva is

   (a) Cercaria (b) Bipinnaria

   (c) Trochophore (d) Tadpole

3. Connecting link between Annelida and Arthropoda is

   (a) *Peripatus* (b) *Chaetopterus*

   (c) *Scolopendra* (d) *Julus*

4. Clitellar region in earthworms is formed by

   (a) 12^{th}, 13^{th} and 14^{th} segments (b) 14^{th}, 15th and 16^{th} segments

   (c) 16^{th}, 17^{th} and 18^{th} segments (c) None of these

5. Leech is

   (a) Sanguivorous (b) Carnivorous

   (c) Omnivorous (d) None of these

   Answers

1. (b), 2. (c), 3. (a), 4.(b), 5.(a)

6.10-References:

Baird W. (1869) Descriptions of some new Suctorial Annelides in the Collection of the British Museum. *Proceedings of the Zoological Society of London* 1869: 310–318.

Bass, N.R. and Brafield, A.F. (1972). The life cycle of the polychaete *Nereis virens*. J.Marine biological associtionof the united Kingdom.52:701-726.

Blanchard R. (1893) Révision de Hirudinées du Musée de Turin. *Bollettino dei Musei di Zoologia ed Anatomia Comparata* 8: 1–32.

Brafield, A.F.and Chapman, G. (1972).Gametogenesis and breeding in a natural population of *Nereis virens*. J.Marine biological associtionof the united Kingdom.47:619-627.

Dales, R. P. (1950). The reproduction and larval development of *Nereis diversicolor.* O. F. Millller. J. Mar. BioI. Assoc. U.K. 29:321-360.

Douglas , Harper(2010). Online Etymology Dictionary.

Fauchold, K. (1977). The polychaete worms. Definitions and keys to the orders, families, and genera. Natural History Museum of Los Angeles County, Science Series. 28: 1-190.

Moore, J.P. (1927). The segmentation (metamerism and annulation) of The Hirudinea: Arhynchobdellae. In: Harding WA, Moore JP. (Eds) *The Fauna of British India.* Taylor and Francis, London, 1–12, 97–302.

Richardson LR. (1969) A contribution to the systematics of the hirudinid leeches, with description of new families, genera and species. Acta Zoologica Academiae Scientiarum Hungaricae 15: 97–149.

UNIT 7: ARTHROPODA

Contents:-

7.1- Objectives

1. To understand different body parts and their functioning.
2. Detailed study of some important arthropoda.
3. Understading habitat of *Palaemon*.
4. Understanding the nervous system and reproductive system of *Palaemon*.

7.2- Introduction

Phylum arthropoda (Gr., arthros = joint + podos = foot) is the largest phylum and most varied in the animal kingdom. Von Siebold gave the name arthropoda. It includes well over one million described species and many million remain unstudied. Some of the more well-known arthropods include insects, crustaceans, spiders, scorpion and centipede as well as the fossil trilobites. Arthropods are mainly terrestrial but marine and freshwater species are also well known. Arthropoda varies tremendously in their habitats, life histories, and dietary preferences.

Arthropod bodies are divided into segments. However, a number of segments are sometimes fused to form integrated body parts known as tagmata. This process of fusion is called tagmosis. The head, thorax, and abdomen are examples of tagmata. Exoskeleton serves as protection and provides places for muscle attachment. Arthropods must molt because their exoskeletons don't grow with them. However, in most species some appendages have been modified to form other structures, such as mouthparts, antennae, or reproductive organs. Arthropod appendages may be either biramous (branched) or uniramous (unbranched). In insects, the anterior portion of the heart is extended into a tube that is called an aorta which directs the blood forward as it goes out into the body cavity.

General Characters

1. Arthropoda (Gr., arthros+podos= jointed legs) includes insects, arachnids, myriapods, and crustaceans. are bilaterally symmetrical, triploblastic and metamerically segmented animals.
2. Body can be divided into head, thorax and abdomen; head and thorax are often fused to form Cephalothorax.
3. Exoskeleton made up of chitin secreted by epidermis.
4. Body is segmented and each segment bears a pair of jointed appendages.
5. Coelom largely a blood-filled haemocoel.
6. Muscles are mostly striated, usually capable of rapid contraction.
7. Digestive tract is complete. The mouth and anus lie at opposite ends of the body.
8. Circulatory system is open with tubular dorsal heart. Blood is colourless.

9. Respiration by general body surface, gills, tracheae or book lungs.

10. Nervous system has dorsal nerve ring.

11. Excretory organs are malpighian tubules (in insects) and green glands (in Crabs and prawn).

12. Sexes are generally separate. Sexual dimorphism is seen.

13. Fertilization is internal, oviparous and ovoviviparous.

14. Development is direct or indirect and may include a number of larval forms.

14. Parental care is well marked in many arthropods.

Classification:-

Arthropoda is a heterogenous group including a wide variety of animals. Since there are divergent views concerning their phylogeny, therefore there is no definitive system for classifying this phylum. However we can simply classify it under following:

Subphylum I: Trilobitomorpha (Gr., tria=three + lobos= lobe+morphe= form)

1. Most primitive of all arthropod groups.

2. Mostly marine and bottom dwellers i.e., benthozoic.

3. All were extinct. These are mostly preserved as fossils.

4. Body can be divided into 3 regions - head, thorax and abdomen.

5. Biramous appendages are there on all segments except the last one (Kotpal, 2005).

Examples: *Triarthrus*, *Dalmanites.*

Subphylum II: Chelicerata (Gr., Chele= claw+ Keros=horn+ata=group)

1. Body divided into an anterior cephalothorax covered by carapace and a posterior abdomen.

2. There are six pairs of appendages. First pair is of preoral chelicerae with claws, one pair of pedipalps and four pairs are of walking legs.

3. Antennae and jaws are absent.

Subphylum Chelicerata has been divided into two classes:

Class1. Merostomata (Gr., meros = thigh + Stoma = mouth)

1. Marine and aquatic chelicerates.

2. Median, simple and lateral compound eyes.

3. Abdomen with 5 to 6 pair of appendages.

4. Excretion by coxal glands.

5. Respiration by book gills.

Subclass 1. Xiphosura (Gr., xiphos = sword + aura = tail)

1. Cephalothorax (Prosoma) with a broad, horse-shoe shaped carapace.

2. Abdomen is unsegmented and ends in a long telson.

3. Respiration by gills attached to the abdominal appendages.

Example: *Limulus* (King crab).

Subclass 2. Eurypterida (eurys = broad + pteryx = wing)

1. Extinct, marine and giant water scorpion.
2. Cephalothorax small with 6 pairs of appendages covered by dorsal carapace.
3. Abdomen has twelve segments.

Examples: *Eurypterus* and *Pterygotus*.

Class 2. Arachnida (Gr. arachne = spider)

1. Mostly terrestrial, some aquatic.

2. It has simple and non compound eyes.

3. Cephalothorax (prosoma) with 2 chelicerae, 2 pedipalps and 4 pairs of walking legs.

4. Abdomen without appendages.

5. Respiration by tracheae, book lungs or both.

6. Excretory organs are malpighian tubules.

7. Dioecious, oviparous, courtship before mating.

Arachnida has been divided into following 10 orders.

Order 1. Scorpionida (= True Scorpions)

1. Cephalothorax covered with carapace.

2. Abdomen differentiated into 7 –segmented mesosoma and 5-segmented metasoma with a poison sting.

3. Respiration by 4 pair of book lungs.

Examples: *Palamnaeus*, *Buthus*, *Androctonus*.

Order 2. Pseudoscorpionida (False scorpions)

1. Tiny false scorpions found under the bark of trees.

2. Cephalothorax covered with carapace, abdomen 11 segmented.

3. Sting and telson absent.

Examples: *Chelifer*, *Microcreagris*.

Order 3. Araneae (True Spiders)

1. Prosoma and opisthosoma are joined by a narrow pedicel.

2. Opisthosoma with 3 pairs of spinnerets. The Telson is absent.

Examples: *Achaearanea* (House spider), *Lycosa* (wolf spider), *Argiope* (writing spider), *Agelena* (funnel-web spider).

Order 4. Solifugae

1. False Spiders, Sun Spiders or Wind Spiders.

2. Prosoma is divided into a large anterior and a small posterior part.

3. Opisthosoma has 10 or 11-segments.

4. Chelicerae large form pincers; male with flagellum for sperm transfer.

Example: *Galeodes* (Sun Spiders).

Order 5. Palpigradi

1. Small-sized microwhip scorpions.

2. Carapace formed of two plates.

3. Opisthosoma is 11-segmented.

Example: *Koenenia*.

Order 6. Uropygi

1. Whip scorpions.

2. Abdomen 12- segmented. Last segment has a long flagellum.

3. Pedipalps large with terminal pincer.

Examples: *Mastigoproctus*, *Thelyphonus*.

Order 7. Amblypygi

1. Flattened scorpion-spiders.

2. Abdomen 12-segmented, Chelicerae moderate.

3. First pair of legs is long and sensory.

Example: *Charinus*.

Order 8. Ricinulei

1. Rare, small and heavy bodied arachnids.

2. Chelicerae pincer-like.

3. Opisthosoma 6-segmented.

Examples: *Ricinoides*, *Crytocellus*.

Order 9. Phalangida or Opioliones

1. Spider-like harvest-men.
2. Body is elliptical.
3. Prosoma is broadly joined to opisthosoma.

Examples: *Phalangium*, *Leiobunum*.

Order 10. Acarina

1. Free-living or parasitic.
2. Body is small, oval and unsegmented.
3. Prosoma and opisthosoma are not differentiated.
4. Chelicerae and pedipalps are small.

Examples: *Sarcoptes* (Itchomite), *Ixodes* (sheep tick), *Dermacentor* (dog tick).

Subphylum III. Mandibulata (L. mandibula = mandible + ata = group)

1. Body can be divided into head, thorax and abdomen.
2. Head consists of one or two pairs of antennae, one and two pairs of maxillae and one pair of mandibles.
3. Compound eyes are common.
4. Development through larval stages.
5. Sexes usually separate with sexual dimorphism.

Subphylum mandibulata has been divided into six classes.

Class 1. Crustacea (Gr. Cursta = hard shell)

1. Crustacea are mainly aquatic (mostly marine, few freshwater) and few live in moist places on land.
2. Head joined with thorax to form cephalothorax.
3. Exoskleton is chitinous, hard and calcareous.
4. Head 5-segmented with 2 pairs of antennae, 2 pairs of maxillae and 1 pair of mandibles.
5. Respiration takes place through general body surface or gills.
6. Excretion by antennal glands.

7. Sexes are separate or united and development with nauplius stage.

8. Generally free living but some are parasitic.

Subclass 1. Cephalocarida

1. Body made of a horseshoe-shaped head and 19 trunk segments.

2. Eyes absent and antennae short.

3. Hermaphrodite; life-histroy completes in a metanauplius larva.

Example: *Hutchinsoniella*.

Subclass 2. Branchiopoda

1. Primitive, small-sized and mostly freshwaterand free living.

2. Trunk appendages leaf-like and serve for locomotion, respiration and feeding.

3. Antennules and 2nd maxillae reduced or absent.

4. Abdomen ends in a pair of jointed or unjointed caudal stylets.

5. Parthenogenesis commom.

Oreder 1. Anostraca

1. Fairy shrimps with nineteen or more trunk segments. Only anterior 11-19 segments bear appendages.

2. Eyes stalked and carapace absent.

3. Caudal stylets not jointed.

Examples: *Artemia*, *Eubranchipus*.

Order 2. Notostraca

1. Commonly called Tadpole shrimps bearing 25 to 45 trunk segments.

2. Carapace shield-like. Eyes sessile (without stalk) and stylets jointed.

3. Antennae reduced.

Examples: *Lepidurus*, *Apus*.

Order 3 Diplostraca

1. Commonly called Clam shrimps or water fleas.
2. Carapace bivalve and does not enclose the head.
3. Eyes sessile or fused. Styles unjointed.
4. Antennae biramous and large, used for swimming.

Examples: *Daphnia*, *Cyzicus*.

Subclass 3. Ostracoda

1. Commonly called Seed shrimps. They are small-sized with poorly segmented body.
2. Trunk appendages 2 pairs and leg-like.
3. Mandibles provided with palps.
4. Antennae and antennules and large, used in swimming.

Order 1. Myodocopa

1. Carapace with anennal notches.
2. Antennae biramous.

Example: *Cypridina, Phylomedes.*

Order 2. Podocopa

1. Carapace unnotched. Two pairs of trunk appendages.
2. Second antennae uniramous, leg like with claws.

Examples: *Cypris*, *Darwinula*.

Order 3. Platycopa

1. Carapace unnotched. One pair of trunk appendages.
2. Second antennae uniramous.
3. Antennae not used for swimming.

Example: *Cytherella*.

Order 4. Cladocopa

1. Carapace unnotched.
2. Second antennae biramous.Both pairs of antennae used for swimmimg.

Example: *Polycope*.

Subclass 4. Mystacocarida

1. Primitive and microscopic body.
2. Antennae and antennules prominent.
3. A single median eye present. Compound eyes absent.
4. Abdomen limbless and a pair of caudal styles.

Example: *Derocheilocaris*.

Subclass 5. Copepoda

1. Body small, divisible into head, thorax and abdomen.
2. Compound eyes absent and median eye present.
3. Antennae smaller and antennules long.

Examples: *Cyclops*, *Ergasilus*, *Caligus*.

Subclass 6. Branchiura

1. Commonly called Fish lice. They are ectoparasites of skin and gill chambers of fishes and some amphibians.
2. Body dorso-ventrally flattened.
3. Head and thorax covered with carapace.
4. One pair of sessile compound eyes present.
5. Antennae and antennules reduced.
6. First maxillae modified into suckers.
7. Abdomen unsegmented and bilobed.

Examples: *Argulus*, *Dolops*.

Subclass 7. Cirripedia

1. Commonly called Barnacles, they are sessile, attached or parasitic.
2. Carapace forms two folds of mantle and covered externally by calcareous plates.
3. Thoracic limbs 6 pairs, cirriform and biramous.
4. Antennae and compound eyes are absent in adult.
5. Antennules become cement glands for attachment.
6. Abdomen rudimentary with caudal styles.

Order 1. Thoracica

1. Hermaphrodite, non-parasitic and with or without stalk.
2. Mantle present with calcareous plates.
3. Thoracic appendages 6 pairs and ciriform.

Examples: *Lepas*, *Balanus*.

Order 2. Acrothoracica

1. Sessile; unisexual; bore into mollusc shells or corals.
2. Mantle reduced to a chitinous disc.
3. Trunk appendages 4 pairs and cirriform.

Examples: *Alcippe*, *Cryptophialus*.

Order 3. Ascothoracica

1. Parasitic in echinoderms and corals.
2. Mantle bivalve or saccular.
3. Appendages are absent but antennules remain present.

Examples: *Laura, Petrarca.*

Order 4. Apoda

1. Parasitic without appendages. Body resembles a maggot.

2. Mantle absent.

3. Hermaphrodite.

Example: *Proteolepis*.

Order 5. Rhizocephala

1. Adult degenerate, parasitic and sac-like.
2. No trace of segmentation
3. Peduncle forms root-like absorptive branches ramifying throughout host’s tissues.

Example: *Sacculina*.

Subclass 8. Malacostraca

1. Body large-sized and made of 19 segments.

2. Cephalothorax made of head and one or more thoracic segments.

3. Carapace well formed and absent.

4. Compound eyes sessile or paired.

5. Abdomen ends into telson; caudal styles absent.

Order 1. Nebaliacea

1. Primitive marine crustaceans.

2. Carapace bivalved with an adductor muscle.

3. Instead of 6, there are 7 abdominal segments.

4. Telson with a pair of caudal style.

Example: *Nebalia*.

Order 2. Mysidacea

1. Marine crustaceans.

2. Body elongated, uropods form a fan-tail.

3. Carapace covers almost entire thorax.

Example: *Mysis*.

Order 3. Cumacea

1. Head and thorax greatly enlarged.
2. Carapace fused to 3 to 4 thoracic segments.
3. Abdomen narrows with uropod.

Examples: *Diastylis*, *Cumopsis*.

Order 4. Isopoda

1. Body dorso-ventrally flattened.
2. Head and 1 or 2 thoracic segments form cephalothorax.
3. Carapace absent.
4. Abdomen is usually short.

Examples: *Asellus*, *Oniscus*.

Order 5. Amphipoda

1. Mostly marine crustaceans.
2. Body laterally compressed.
3. Carapace absent; eyes sessile.

Examples: *Caprella*, *Gammarus*, *Cyamus*.

Order 6. Stomatopoda

1. Mostly marine forms.
2. Mantis shrimp; body flattened; carapace small.
3. Abdomen large, broader than cephalothorax.
4. Heart is elongated.

Example: *Squilla*.

Order 7. Decapoda

1. Marine forms.
2. Carapace well developed.
3. First 3 pairs of thoracic limbs form maxillipedes.
4. Gills in 3 series present on thorax.

Examples: *Palaemon, Palinurus*, *Cancer, Eupagurus*, *Penaeus*, *Leucifer*, *Astacus*, *Hippa*, *corcinus*.

Class 2. **Myriapoda**

1. Terrestrial and air breathing arthropods.
2. Body worm-like and elongated with numerous segments each bearing one or two pairs of legs.
3. Head is distinct bearing a pair of eyes, many jointed antennae and two or three pairs of jaws.
4. Respiratory organs are the tracheae
5. Excretory organs are Malpighian tubules associated with hindgut.
6. Sexes are separate.

Order 1. Diplopoda (Gr., diplos = double + pous = foot)

1. Body elongated, cylindrical and divisible into 5 head segments and 4 thorax segments.
2. Mandibles and maxillae 1 pair.
3. Eyes simple and genital openings in the 3rd abdominal segment.

Examples: *Julus*, *Spirobolus.*

Order 2. Chilopoda (Gr., Cheilos = lip + pous = foot)

1. Body dorso-ventrally flattened and divisible into head and trunk.
2. Head with 1 pair of antennae, 1 pair of mandibles and 2 pairs of maxillae.
3. First pair of legs modified into poison claws.

Examples: *Scolopendra, Scutigera, Lithobius.*

Order 3. Pauropoda (Gr., pauros = small + pous = foot)

1. Less than 2 mm long; eyes are absent.

2. Body divisible into head and 11-12 trunk segments.

Example: *Pauropus*.

Order 4. Symphyla (Gr., syn = together + phylon = tribe)

1. Body is slender and made of head and 15 to 22 trunk segments.
2. Without eyes.
3. Genital pores located ventrally on the 4^{th} trunk segment.

Examples: *Hanseniella*, *Scutigerella*.

Class 3. Insecta (L., insectus = cut or divided)

1. Body divided into head, thorax and abdomen.
2. Head with compound eyes (1pair), antennae (1 pair), mandibles (1 pair) and maxillae (2 pairs).
3. Mouthparts modified for different feeding habits.
4. Respiration by tracheae. Spiracles lateral.
5. Thorax bears 3 pairs of legs and 1 or 2 pairs of wings.
6. Excretion by Malpighian tubules.
7. Unisexual. Fertilisation is internal.

Subclass (1) Apterygota

1. These are primitve wingless insects.
2. Abdomen with cerci and style-like appendages.
3. Metamorphosis is reduced or absent.

Order1. Protura

1. Insects without wings.
2. No antennae, true eyes and metamorphosis.

Example: *Acerantulus*.

Order 2. Collembola

1. No eyes, tracheae, Malpighian tubules.

2. Mouthparts chewing or sucking type.

3. Abdomen 6-segmented.

4. Metamorphosis absent.

Examples: *Achoruted*, *Sminthurus*, Springtails.

Order 3. Thysanura

1. Body covered with minute silvery scales.

2. Antennae long; mouthparts chewing.

3. Abdomen 11-segmented; telson long.

Example: *Lepisma* (silver fish).

Subclass 2. Pterygota

1. Wings present.

2. Abdominal appendages absent but cerci present.

3. Metamorphosis complete or incomplete.

Division (a) Exopterygota

1. Wings develop externally as buds.

2. Metamorphosis gradual. Young stages are nymphs

Order 1. Orthoptera

1. Wings 2 pairs. Forewings straight and leathery. Hindwings membranous and folded at rest.

2. Mouth parts chewing.

3. Prothorax large.

Examples: *Periplaneta* (Cockroach), *Poecilocercus* (Grasshoppers), *Schistocerca* (Locust), *Gryllus* (Cricket), *Mantis* (Praying mantis), *Carausius* (Stick insect) and *Phyllium* (Leaf insect).

Order 2. Isoptera

1. Wings 2 pairs. Held flat on back.

2. Mouthparts chewing.

3. Social insects with well developed caste-system.

Example: *Termites* or white ants.

Order 3. Dermaptera

1. Forelibs small, leahery; hindwings large and semicircular.

2. Mouthparts chewing.

Example: *Forficula* (Earwig).

Order 4. Ephemeroptera

1. Wings 2 pairs, membranous; forewings longer and triangular; hindwings smaller and rounded.

2. Adult mouth parts vestigial.

3. Abdomen carries long cerci and caudal filament.

Example: *Ephermera* (Mayfly).

Order 5. Odonata

1. Wings 2 pairs and membranous.

2. Eyes very large.

3. Mouthparts chewing. Predaceous.

Examples: Dragon flies, Damsal flies.

Order 6. Plecoptera

1. Wings 2 pairs and membranous.

2. Antennae long.

3. Mouthparts of chewing type.

Examples: *Isoperla* (Stone-fly) and Perla.

Order 7. Psocoptera

1. Wingless or forewings larger than hindwings.

2. Antennae present.

3. Mouthparts of chewing type.

Examples: Book lice (wingless), Bark lice (winged).

Order 8. Mallophaga

1. Wings absent; body small; head large; eye degenerate; legs clasping.

2. Mouth parts of chewing type.

Examples: Bitings lice of mammals, bird lice.

Order 9. Anoplura

1. No wings; body broad and flat; head small.

2. Mouth parts piercing and sucking type.

3. Ectoparasites on mammals.

Example: *Pediculus* (Human louse)

Order 10. Thysanoptera

1. Wings 2 pairs, fringed with long hairs.

2. Mouth parts rasping and sucking type.

Example: *Thrips*.

Order 11. Hemiptera

1. Wingsless or wings 2 pairs. Forewings thickened at base, membranous at tip.

2. Mouth parts of piercing-sucking type forming beak.

Examples: *Belostoma* (Giant water bug), *Cimex* (bedbug), Cicada, Aphid and *scale insects.*

Division (b) Endopterygota

1. Wings develop internally in pupal case.
2. Metamorphosis complete with larval and pupal stages.

Order 1. Neuroptera

1. Wings large and membranous.
2. Antennae long and cerci absent.
3. Mouth parts chewing type.
4. Larvae carnivorous. Abdominal gills in aquatic larvae.

Examples: *Crysopa* (Lacewing), *Myrmeleon* (Antlion).

Order 2. Coleoptera

1. Forewings leathery and hindwings membranous.
2. Antennae modified. Mouth parts chewing type.

Example: Beetles.

Order 3. Mecoptera

1. Wings long, narrow and membranous.
2. Mouth parts chewing type and on a prolonged beak.
3. Tip of abdomen curved and sting-like in male.

Example: *Panorpa* (scorpion-fly)

Order 4. Trichoptera

1. Wings long, hairy, folded roof-like over abdomen.
2. Antennae long.
3. Mouthparts rudimentary.
4. Larve pupates within a tube.

Example: Caddis flies.

Order 5. Lepidoptera

1. Wings membranous, covered with overlapping scales.
2. Mouth-parts of sucking type.
3. Life-cycle includes caterpillar larva.

Example: Butterflies, Moths.

Order 6. Diptera

1. One pair of wings; hindwings knob-like.
2. Mouth-parts of piercing-sucking type or sponging type.
3. Larva limbless and worm-like called maggot.

Example: *Musca* (House fly), *Drosophilla* (Fruit fly), *Culex* (Mosquito).

Order 7. Hymenoptera

1. Two pair of wings that are membranous and hooked together during flight.
2. Mouth parts sucking or chewing type.
3. Some show social behavior.

Example: *Apis* (Honey bee), ants, *Vespa* (Wasp).

Order 8. Siphonoptera

1. Small and laterally flattened. Secondarily wingless.
2. Mouth-parts of piercing-sucking type. Legs long, leaping.
3. Ectoparasites on birds and mammals.

Examples: *Pulex* and *Xenopsylla* (Fleas)

7.3 LIMULUS

Systematic position:

Phylum Arthropoda

Class Merostomata

Genus *Limulus*

Comments:

1. *Limulus* (Fig. 7.1) is commonly known as king crab.

2. It is bilaterally symmetrical, triploblastic metamerically segmented animal with jointed appendages.

3. Body is divided into anterior prosoma, posterior opisthosoma and a spine like tail or telson.

4. Prosoma is covered by a horse-shoe shaped carapace. It bears a pair of simple eyes and a pair of compound eyes. It bears 6 pair of appendages surrounding the mouth. The first pair of chelicerae is small, trisegmented and chelate. Rest of the five appendages consists of four pairs are chelate legs and a last pair of non-chelate leg.

5. Opisthosoma is hexagonal and movably articulated with prosoma. It consists of 6-segmented mesosoma and 3-segmented metasoma. It bears six pairs of appendages, the first pair is fused and forms the genital operculum and the remaining five pairs of appendages are flap like and membranous and are used for respiration.

6. The telson is used to flip itself over if stuck upside down and to steer in the water.

7. Excretion takes place through coxal glands.

8. Sexes are separate. Fertilization is external.

Habit and habitat:

Limulus is marine form and found in shallow waters along sandy and muddy shores of sheltered bays and estuaries. It feeds on molluscs, annelid worms and other benthic invertebrates.

Distribution:

It is found along the eastern coast line of Asia, Gulf of Mexico and North America (Kotpal, 2005).

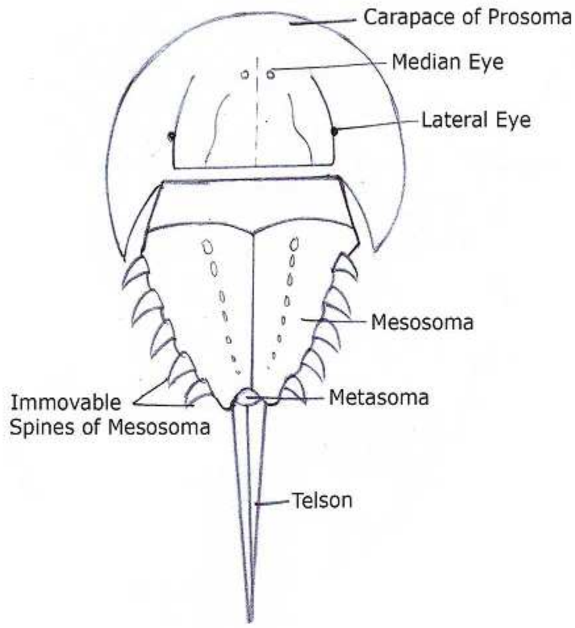


Fig. 7.1 *Limulus*

ARANEA:

Systematic position:

Phylum Arthropoda

Class Arachnida

Order Araneida

Genus *Aranea*

Comments:

1. *Aranea* (Fig. 7.2) is commonly known as orb-webbed spider.

2. Body can be divided into prosoma and opisthosoma connected by a cylindrical region called pedicel.

3. Prosoma is covered by carapace that bears 4 pairs of simple eyes. It bears 6 pair of appendages, a pair of chelicerae, a pair of pedipalps and 4 pair of walking legs. Chelicera is used to deliver venom to kill prey and is also used to capture and crush prey.

4. Opisthosoma is soft; egg shaped and houses the internal organs. It bears three pairs of spinneret or spinning organ which emit silk.

5. Respiration happens via book lungs or tracheae or both.

6. Excretion by malpighian tubules and coxal glands.

7. Sexes are separate.

8. Fertilization is internal but indirect. Usually the male die after mating, mostly killed by the female**.**

Habit and habitat:

Aranea is found in houses, gardens, under rocks, logs or the bark to trees. Most species are nocturnal and all are predatory.

Distribution:

They are found all over the world.

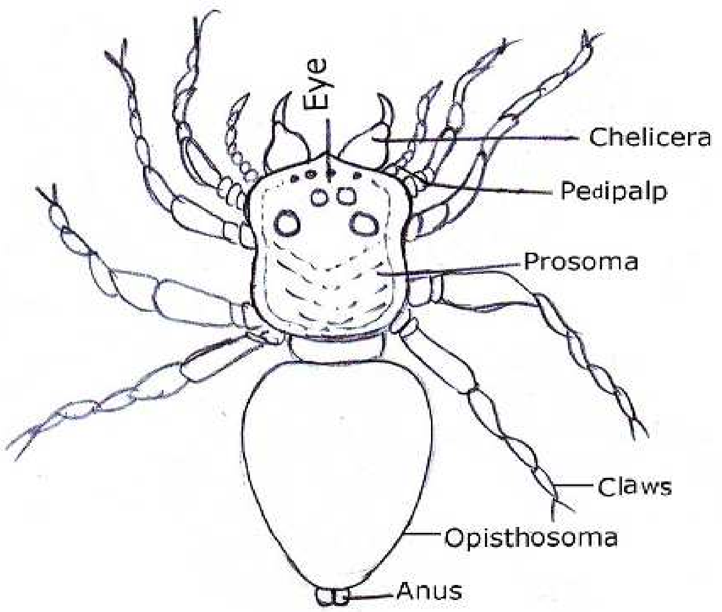


Fig. 7.2 *Aranea*

Palamnaeus

Systematic position:

Phylum	Arthropoda
Class	Arachnida
Order	Scorpionidea
Genus	*Palamnaeus*

Comments:

1. *Palamnaeus* (Fig. 7.3) is commonly known as scorpion.

2. Body is bilaterally symmetrical, triploblastic, coelomate, metamerically segmented animal with jointed appendages.

3. Body is differentiated into anterior prosoma, middle mesosoma and posterior metasoma.

4. Prosoma is covered by carapace that bears a pair of median eyes and 2-5 pairs of lateral eyes. It has six segments, each with a pair of appendages, *i.e.*, one pair of chelicerae, one pair of pedipalp and four pairs of walking legs.

5. Opisthosoma consists of two parts anterior mesosoma and posterior metasoma.

6. Mesosoma is seven segmented, the first segment bears genital operculum, the second segment bears a pair of pectines and each of the third, fourth, fifth and sixth segments have a pair of stigmata. The seventh segment is without any appendages (Rastogi, 2015).

7. Metasoma is tail like and comprises five caudal segments and a last segment or telson bearing the sting.

8. Sexes are separate.

9. Viviparous.

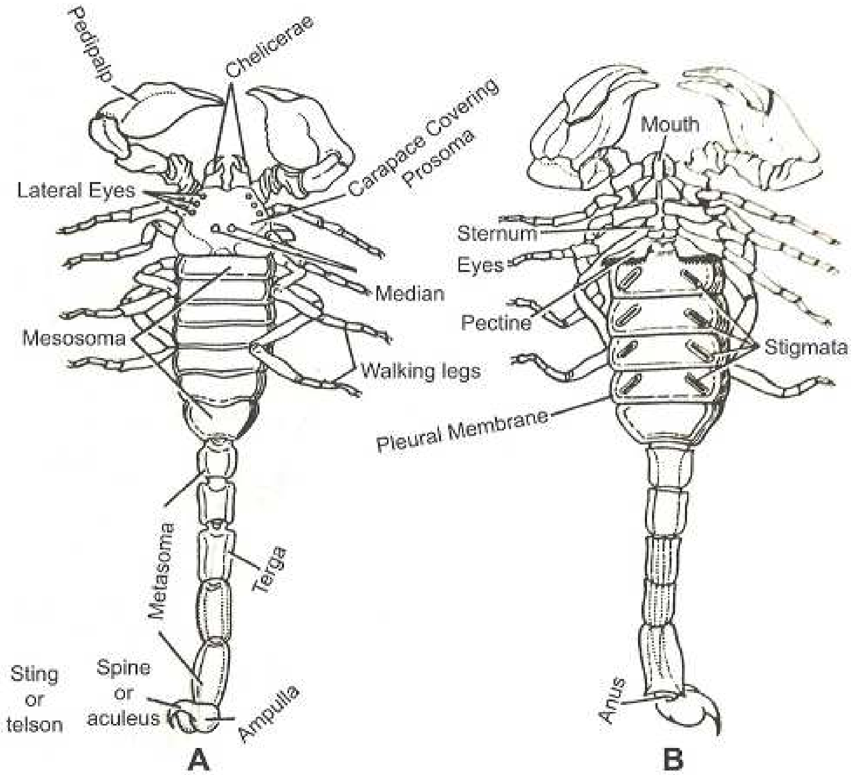
10. *Palamnaeus* are harmful to mankind; its sting can cause swelling at the sting site, extreme pain, fever and in some cases collapse.

Habit and habitat:

Palamnaeus is nocturnal, carnivorous and secretive animal. It is found in sand or under stones.

Distribution:

Palamnaeus are found on the land masses the world over except Antarctica.



A. Dorsal View B. Ventral View
Fig. 7.3 *Palamnaeus*

Apus

Systematic position:

Phylum Arthropoda

Class Crustacea

Order Notostraca

Genus *Apus*

Comments:

1. *Apus* (Fig. 7.4) is commonly called as tadpole fish or tadpole shrimp.

2. Body is elongated measuring about 20-30 mm in length.

3. Head is broad and depressed and contains a pair of eyes, a median eye and a dorsal organ above. Antennules and antennae are present below the head.

4. Horse-shoe shaped carapace, covering two-third of the anterior dorsal surface, bears shell glands on its lateral surface.

5. Anal segment bears a pair of caudal styles.

6. Sexes are separate.

7. Development includes nauplius larva.

Habit and habitat:

Apus is found in freshwater. It is omnivorous.

Distribution:

Apus is found in most parts of the world.

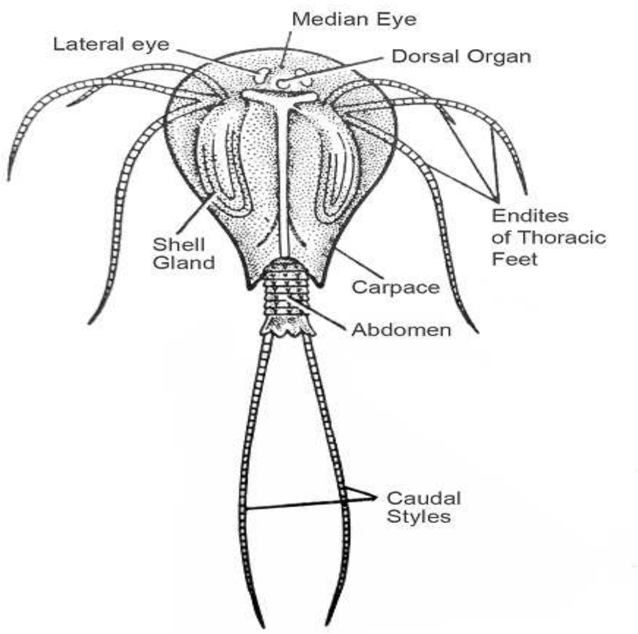


Fig. 7.4 Apus

Lepas:

Systematic position:

Phylum	Arthropoda
Class	Crustacea
Order	Thoracica
Genus	*Lepas*

Comments:

1. *Lepas* (Fig. 7.5) is commonly known as ship or goose barnacle.

2. *Lepas* is bilaterally symmetrical, triploblastic metamerically segmented animal with jointed appendages.

3. The body is covered by a thick chitinous exoskeleton and by 5 calcareous plates-a pair of scuta, a pair of terga and a median dorsal carina.

4. The body or capitulum is supported by a long, flexible stalk called peduncle. It is found attached to ships and vegetation with the help of peduncle.

5. Mouth consists of a pair of mandibles and two pairs of maxillae.

6. Thorax bears six pairs of appendages.

7. It is bisexual.

8. Development includes a free-swimming cypris larva (Yadav and varshney, 2015).

Habit and habitat:

Lepas is a marine animal that inhabits warmer seas. They feed upon minute organisms gathered from water and kicked into mouth by the thread like feet.

Distribution:

Lepas is found all over the world.

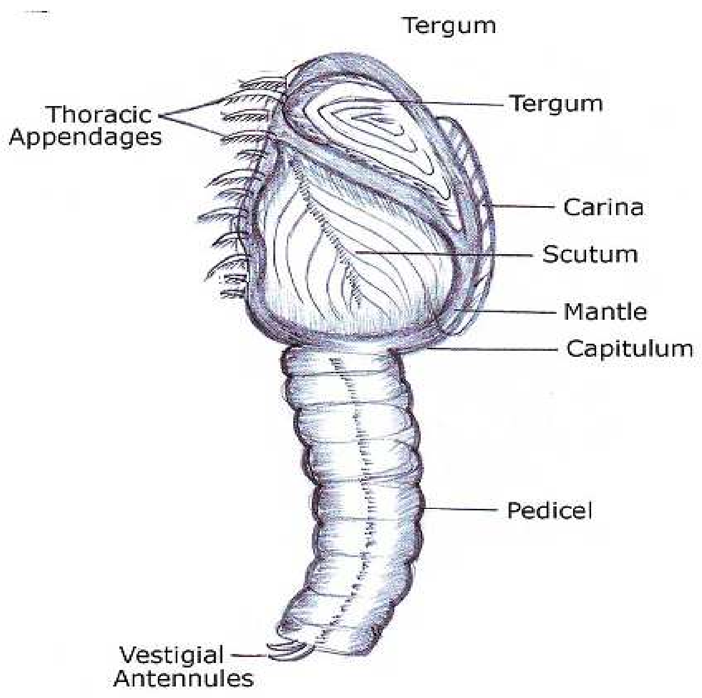


Fig. 7.5 *Lepas*

Balanus

Systematic position:

Phylum	Arthropoda
Class	Crustacea
Order	Thoracica
Genus	*Balanus*

Comments:

1. *Balanus* (Fig. 7.6) is commonly called as rock barnacle or acorn barnacle.

2. Body is bilaterally symmetrical, triploblastic metamerically segmented animal with jointed appendages.

3. Body is surrounded by a calcareous shell consisting of six plates: an unpaired rostrum, an unpaired carina and two pairs of carino-lateral plates.

4. A four-fold cover, consisting of two scuta and two terga covers the shell opening.

5. Six pairs of thoracic legs are provided that can protrude out of the shell opening to collect food particles.

6. Hermaphrodite. Development is indirect involving a nauplius larva.

Habit and habitat:

Balanus is found attached to rocks and molluscan shells.

Distribution:

Balanus is cosmopolitan in distribution. It is mainly found along North Atlantic coast, Pacific coast, West Indies and Washington to Alaska.

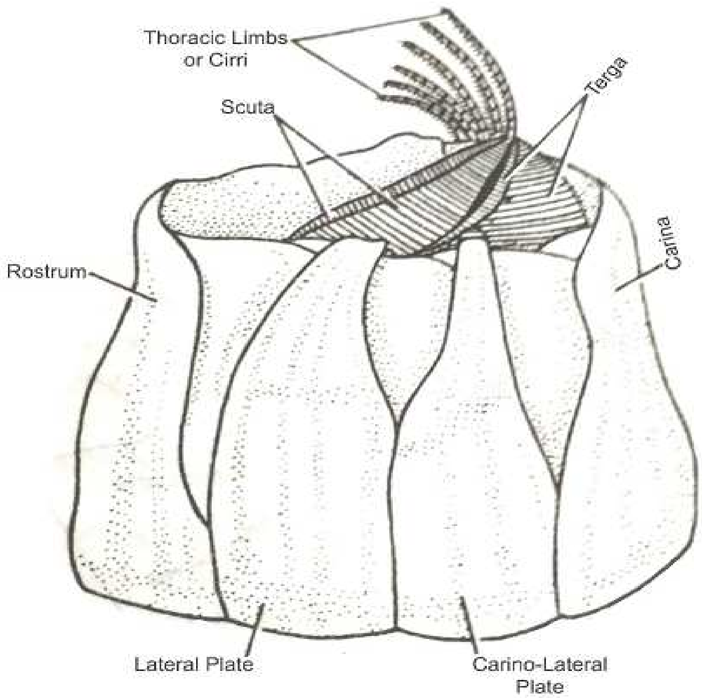


Fig. 7.6 *Balanus*

Sacculina

Systematic position:

Phylum	Arthropoda
Class	Crustacea
Order	Rhizocephala
Genus	*Sacculina*

Comments:

1. *Sacculina* (Fig. 7.7) is commonly known as root-headed barnacle.

2. It lives as a parasite on crab's abdomen.

3. The body is made up of two parts- a thin sac and a peduncle. The sac appears like a fleshy tumour attached to the abdomen by a peduncle. The peduncle consists of numerous root-like filaments which protrude body of the host to derive nutrition.

4. Appendages, segmentation, alimentary canal and anus are absent.

5. Hermaphrodite, *i. e.* sexes united.

6. Larva is cirripede-nauplius.

7. The female *Sacculina*, attached to male crab, causes hormonal imbalance in the crab that makes it infertile (parasitic castration).

Habit and habitat:

Sacculina live in marine environment.

Distribution:

Sacculina is cosmopolitan.

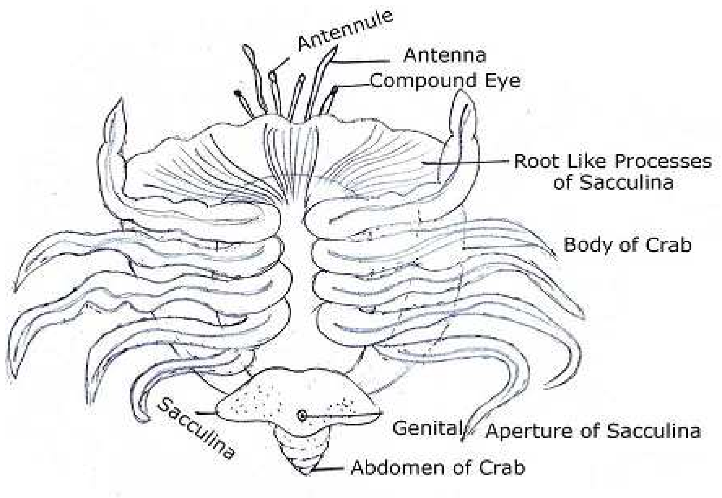


Fig. 7.7 Sacculina

Palaemon

Systematic position:

Phylum Arthropoda

Class Crustacea

Order Decapoda

Genus *Palaemon*

Comments:

1. *Palaemon* (Fig. 7.8) is commonly known as prawn.

2. Body is elongated, spindle shaped and bilaterally symmetrical.

3. *Palaemon* species are of pale-yellow, pale-blue and greenish color with brown tinge or with orange-red patches. Preserved specimens become deep orange-red.

4. The body can be divided into two regions, anterior cephalothorax and posterior abdomen.

5. Cephalothorax is a large, rigid, unjoited, immovable and cylindrical structure. It consists of 13 segments, 5 of the head region, and 8 of the thorax region (Kotpal, 2005).

6. Abdomen is rounded, jointed and compressed laterally. It consists of 6 movable segments and a terminal conical structure, called telson. Each abdominal segment bears a pair of jointed appendages called pleopods or swimmerets.

7. The prawn uses its walking legs for movement at the water-bed.

8. Respiration happens *via* gills, epipodites and lining of branchiostegites.

9. Excretion through a pair of antennary or green glands, a pair of lateral ducts, an unpaired renal or nephroperitoneal sac and the integeument.

10. Sexes are separate. Sexual dimorphism is well developed.

Habit and habitat:

Palaemon is found in freshwater ponds, lakes, streams, ditches and rivers. It is a nocturnal creature. It hides at the bottom during the day and comes to the surface at night in search of food. It feeds mainly on algae, moss and other aquatic weeds.

Distribution:

Palaemon is commonly found in India.

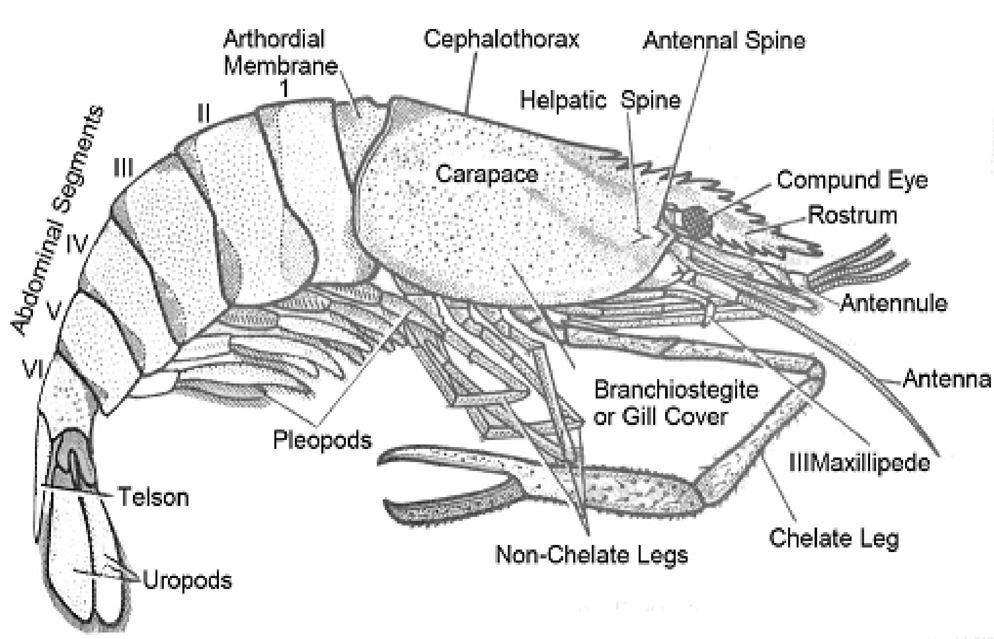


Fig. 7.8 Palaemon

Palinurus: Lobster:

Systematic position

Phylum	Arthropoda
Class	Crustacea
Order	Decapoda
Genus	*Palinurus*

Comments:

1. *Palinurus* (Fig. 7.9) is commonly called spiny lobster.

2. Body is covered with spines and is greenish brown in colour.

3. Size ranges from 15 to 45 cm.

4. The Body is divided into cephalothorax and abdomen.

5. The cephalothorax consists of the head having five segmentes and the thorax having eight segments.

6. The abdomen consists of six segments and a telson.

7. Each body segment bears a pair of appendages on its ventral side.

7. Sexes are separate

8. Development includes phyllosoma larva.

Habit and habitat:

Palinurus is a marine, bottom-dwelling crustacean. This is an omnivorous animal feeding on worms, molluscs, corals, algae etc.

Distribution:

Palinurus occurs in Asia, Europe and India.

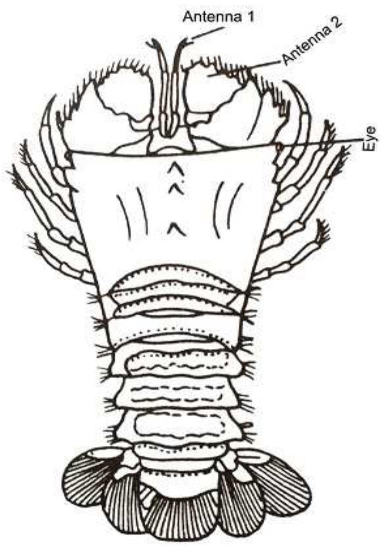


Fig. 7.9 Palinurus

Eupagurus

Systematic position

Phylum	Arthropoda
Class	Crustacea
Order	Decapoda
Genus	*Eupagurus*

Comments:

1. *Eupagurus* (Fig. 7.10) is commonly known as hermit crab.
2. Body is asymmetrical, elongated and divisible into cephalothorax and abdomen.
3. Body is extremely modified in order to live inside the molluscan shells.
4. Cephalothorax is broad and flattened.

5. Head bears a pair of compound eyes, a pair of large antennae and a pair of short antennules. Thorax bears five pair of legs. First, fourth and fifth pair of legs are chelate whereas rest of the legs are non chelate. Front two legs are of different sizes the large left claw is used for defense purpose and the smaller right claw is used for scooping food and water (Verma, 2015).

6. Abdomen is soft and is spirally twisted.

7. Abdominal appendages of the left side are reduced while those of the right side are absent (Fig. 10).

Habit and habitat:

Eupagurus inhabits the abandoned shells of gastropods. It is a nocturnal creature, generally silent during the day. It leads a commensal life.

Distribution:

Eupagurus is cosmopolitan. It is found at Bombay and Goa beaches, from Alaska to Lower California and Florida.

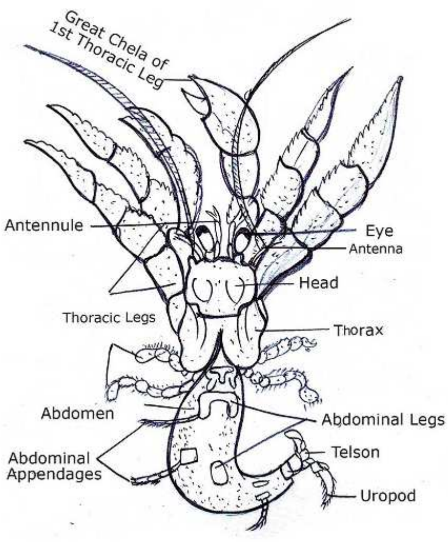


Fig. 7.10 *Eupagurus*

Carcinus

Systematic position

Phylum Arthropoda

Class Crustacea

Order Decapoda

Genus *Carcinus*

Comments:

1. *Carcinus* (Fig. 7.11) is commonly called rock crab or true crab.

2. Body is dorso-ventrally compressed and consists of a cephalothorax and an abdomen.

3. Cephalothorax is enlarged and is convered by a broad flat shell called carapace. It bears a pair of small antennules, a pair of longer antennae, five pairs of thoracic legs and a pair of compound eyes. The first pair of thoracic legs has claws (Rastogi, 2015).

4. Mouth parts present on the ventral surface are covered by the flat, plate-like third maxillipedes.

5. Abdomen is greatly reduced and it bears pleopods. Uropods are absent.

6. The abdomen of the female is wider than that of the male. Female has four pairs of pleopods that help in carrying eggs. Male has two pairs of pleopods that act as copulatory organs.

7. Development is indirect through zoea and megalopa larval stages.

Habit and habitat:

Carcinus is found buried in mud of shallow waters or buries itself amongst rocks. It typically walks sideways. It is mostly omnivorous feeding on algae, molluscs, worms, fungi, bacteria etc.

Distribution:

Carcinus is cosmopolitan in distribution.

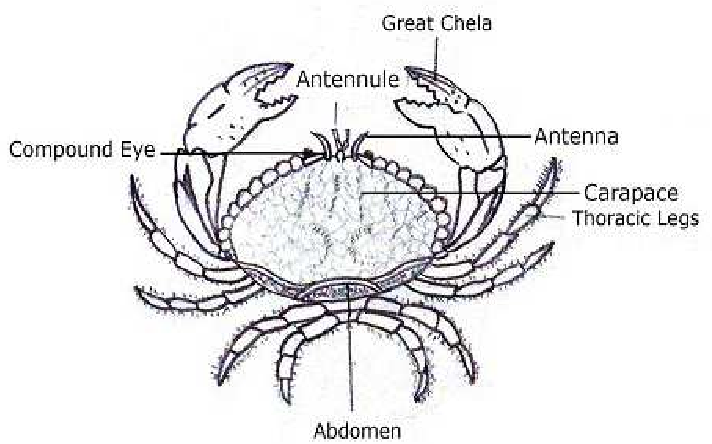


Fig. 7.11 *Carcinus*

Lepisma

Systematic position

Phylum	Arthropoda
Class	Insecta
Order	Thysanura
Genus	*Lepisma*

Comments:

1. *Lepisma* (Fig. 7.12) is a primitive wingless insect commonly known as silver fish.

2. It is triploblastic, bilaterally symmetrical, metamerically segmented animal with jointed appendages.

3. Body is covered with silvery scales and is divided into head, thorax and abdomen.

5. Head bears a pair of long, jointed antennae and a pair of eyes.

6. Thorax bears three pairs of legs.

7. Abdomen eleven segmented with a pair of long anal cerci and a median caudal filament.

8. Mouth parts are biting and chewing type.

9. Silver fish consume matter that contains polysaccharides such as starch used in adhesives. It causes considerable damage to the books and clothing by chewing off starch, sizing or any other articles containing glue.

10. Development direct without metamorphosis.

Habit and habitat:

Lepisma is household pest and a nocturnal insect. It is commonly found in cool places, damp, books and clothes.

Distribution:

Lepisma is cosmopolitan in distribution. It is found in Africa, America, Europe, Asia and Australia.

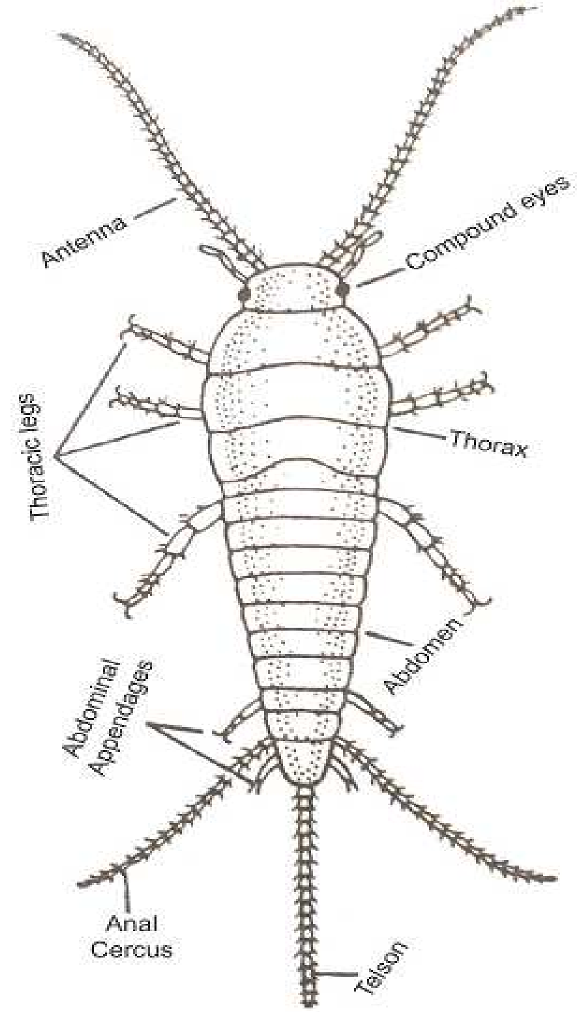


Fig. 7.12 *Lepisma*

Odontotermes

Systematic position

Phylum	Arthropoda
Class	Insecta
Order	Isoptera
Genus	*Odontotermes*

Comments:

1. *Odontotermes* (Fig. 7.13) is commonly called as termite.

2. Body is soft, elongated and cylindrical and has three distinct regions: head, thorax and abdomen.

3. Head and thorax are small as compare to abdomen.

4. Head bears a pair of compound eyes, a pair of antennae and the mouth.

5. Thorax bears three pairs of walking legs.

5. Abdomen bears of ten segments. The ninth segment bears a pair of anal cerci. It is swollen to accommodate the large number of fertilized eggs.

6. Mouth parts are biting type.

6. Social and polymorphic insects. They live together in large communities.

7. Colony consists sexually mature males and females (kings and queens), sterile workers, soldiers and nasutes.

8. Wings are well developed.

9. Termites are known to cause huge economic loss they damage the household furniture and other materials made up of wood.

Habit and habitat:

Termite is nocturnal, and lives in tunnels constructed inside wood and earth. Some termites make huge mounds using excavated mud, wood and excreta mixed with saliva. They feed upon vegetation, wood, faecal matter of termites and the dead of the colony (Wikipedia).

Distribution:

Termites are found all over the world.

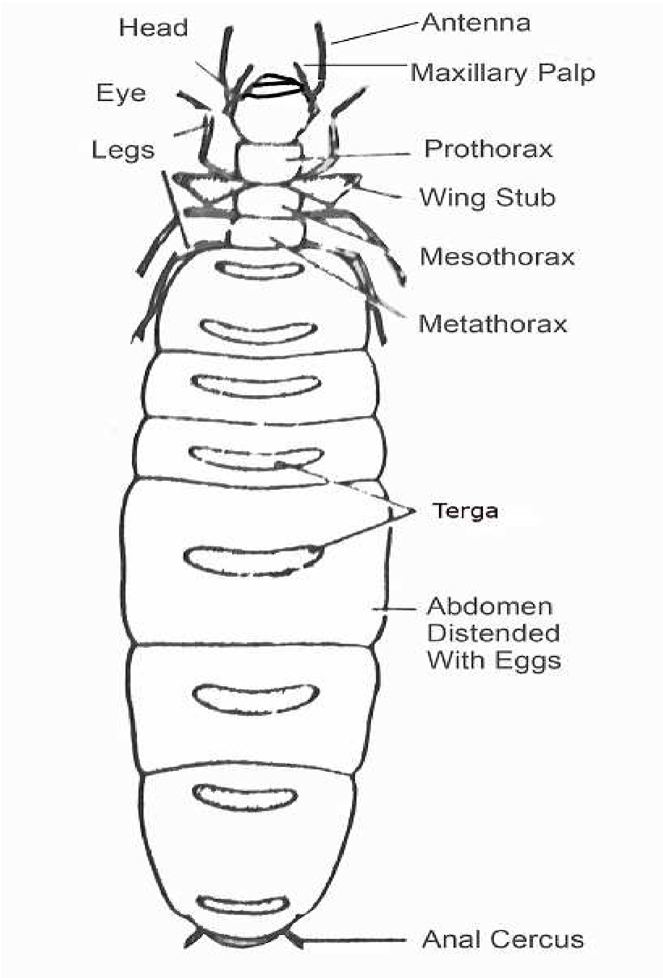


Fig. 7.13 *Odontotermes*

Pediculus

Systematic position

Phylum Arthropoda

Class Insecta

Order Anoplura

Genus *Pediculus*

Comments:

1. *Pediculus* (Fig. 7.14) is commonly called human louse.

2. Body is dorso-ventrally flattened and consists of head, thorax and abdomen.

3. Head is small and bears a pair of five segmented antennae, a pair of compound eyes and mouth.

4. Thorax bears three pairs of legs having claws.

5. Abdomen is large and consists of nine segments.

6. Mouth parts are piercing and sucking type.

7. The last abdominal segment of male is pointed and that of female is bilobed.

Habit and habitat:

Pediculus humanus is found as an ectoparasite of man.

Distribution:

Pediculus humanus has worldwide distribution.

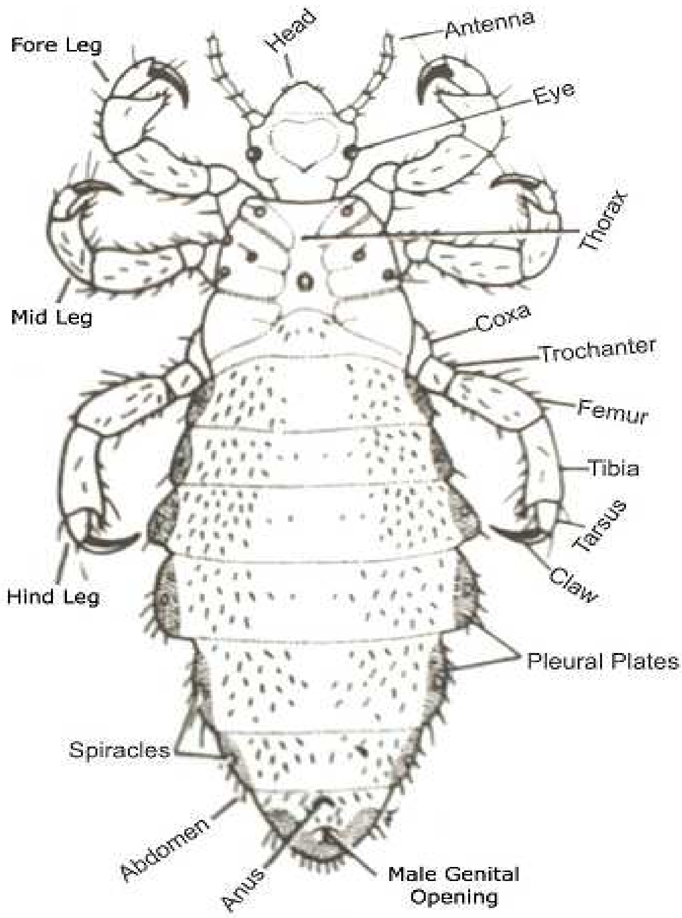


Fig. 7.14 *Pediculus*

Schistocerca

Systematic position

Phylum Arthropoda

Class Insecta

Order Orthoptera

Genus *Schistocerca*

Comments:

1. *Schistocerca gregaria* (Fig. 7.15) is commonly called as locust.

2. Body is divisible into head, thorax and abdomen.

3. Head bears a pair of joint antennae or feelers, a pair of large compound eyes, jointed appendages called palps and mouth.

4. Mouth parts are biting and chewing type.

5. Thorax bears two pairs of wings and three pairs of legs. The hind legs are large and used for jumping

6. Fore-wings are hard and thick, while hind-wings are larege, membranous.

7. Abdomen consists ten segments with eleventh vestigial segment.

8. This locust is most destructive to crops and vegetarian.

9. Sexes are separate. The males have a boat shaped tip of the abdomen while females have two valves on the tip of the abdomen.

Habit and habitat:

Schistocerca gregaria is found in the deserts and in tropical region of the world.

Distribution:

Schistocerca gregaria is worldwide distribution.

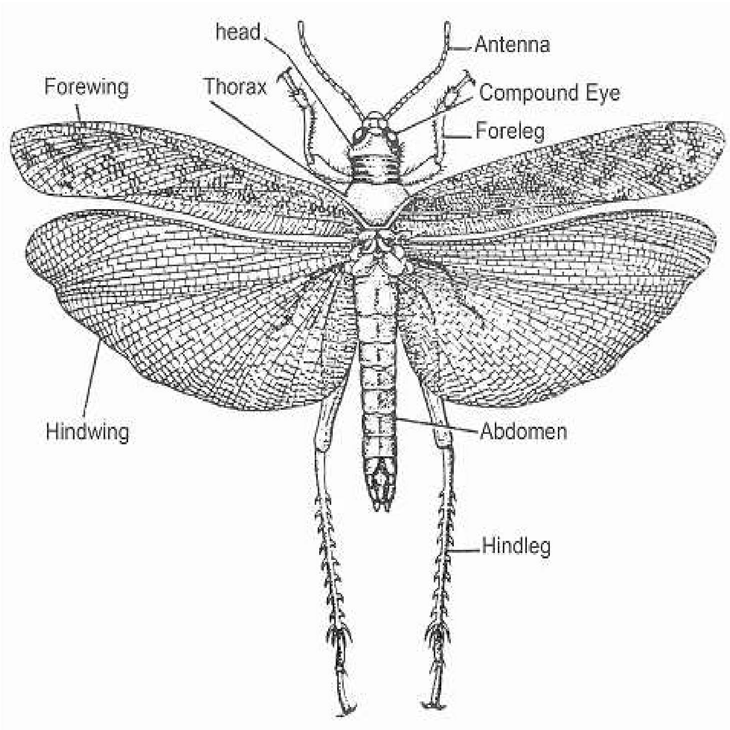


Fig. 7.15 *Schistocerca*

Papilio

Systematic position

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Genus *Papilio*

Comments:

1. *Papilio* (Fig. 7.16) is commonly known as butterfly.

2. Body consists of head, thorax and abdomen.

3. Head bears a pair of compound eyes and a pair of long antennae with swollen rounded ends and mouth (Yadav and Varshney, 2015).

4. Mouth parts are of siphoning type.

5. Thorax bears three pairs of legs and two pairs of wings that are covered with broad pigmented scales.

7. Abdomen is composed of ten segments and is covered with scales.

8. Development includes caterpillar larva.

9. Butterflies are nectarivores and feed from nectar of flowers.

Habit and habitat:

Butterflies are common insects that are seen in gardens. They are diurnal.

Distribution:

Butterflies are cosmopolitan in distribution.

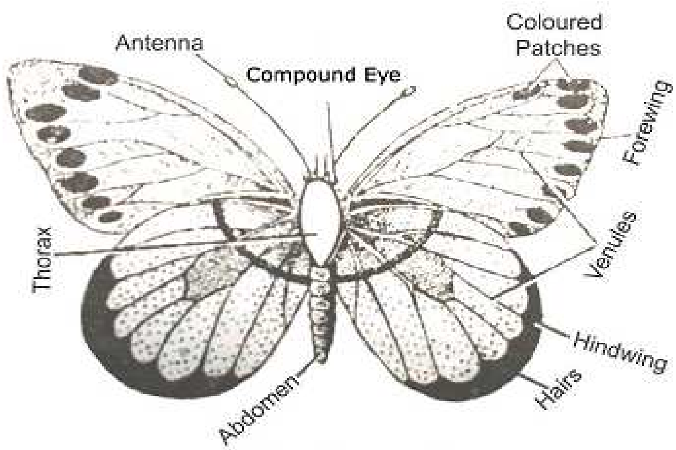


Fig. 7.16 *Papilio*

Bombyx

Systematic position

Phylum	Arthropoda
Class	Insecta
Order	Lepidoptera
Genus	*Bombyx*

Comments:

1. *Bombyx* (Fig. 7.17) is commonly called as silk moth.

2. Body consists of head, thorax and abdomen.

3. Head bears a pair of plumed antennae and a pair of compound eyes.

4. Thorax bears three pairs of legs and two pairs of wings which are covered with scales.

5. Hindwing is smaller than forewing.

6. The abdomen is consists of ten segments.

7. Mouthparts are siphoning type.

8. Moths are nocturnal. They come on the light during the rainy season.

Habit and habitat:

Bombyx is reared for silk. The adults have a short lifespan and don not feed.

Distribution:

Bombyx are cosmopolitan in distribution.

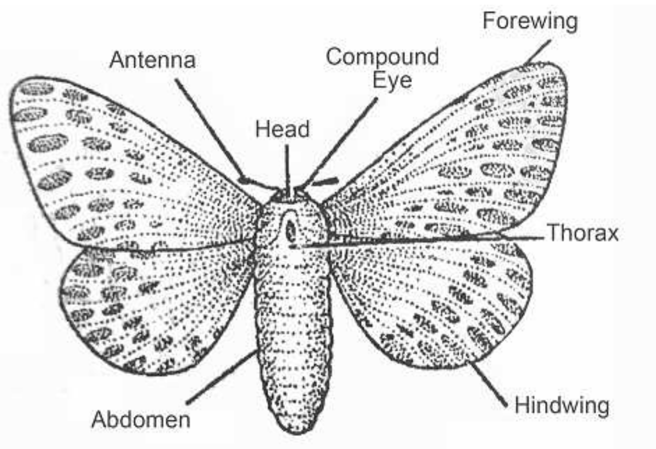


Fig. 7.17 Bombyx

Xenopsylla

Systematic position.

Phylum	Arthropoda
Class	Insecta
Order	Siphonoptera
Genus	*Xenopsylla*
Species	*cheopis*

Comments:

1. *Xenopsylla cheopis* (Fig. 7.18) is commonly known as rat flea.
2. Body is divisible into three segments: head, thorax and abdomen.
3. Body is laterally compressed without wings and covered with hard plates called sclerites.
4. Integument is heavily sclerotized, brown in clour and armed with backwardly directed spines and bristles.
5. Head contains simple eyes, antennae and mouth. The mouth parts are piercing and sucking type.
6. Thorax is compact with segmention and has three pairs of legs. The hind legs are longest and strongest and help in jumping.

10. Abdomen is ten segmented.

11. The adult flea is active and slips through hair with great ease.

Habit and habitat:

Xenopsylla cheopis is an ectoparasite of mammals specially rats. It feeds on blood. It is known to transmit plague from rats to man.

Distribution:

Xenopsylla cheopis is found in India, Sri Lanka, Myanmar and Malaysia.

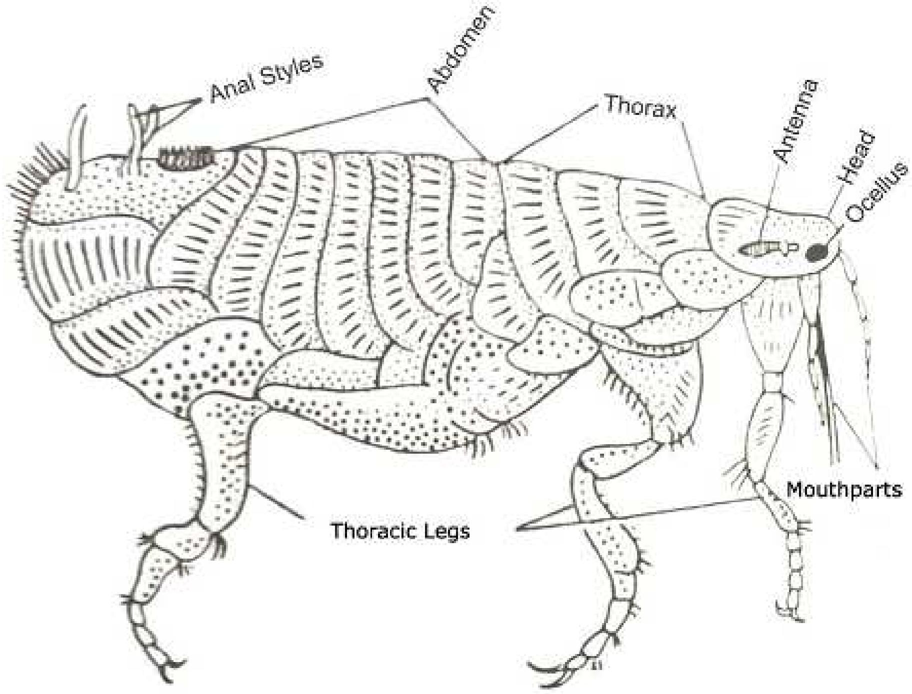


Fig. 7.18 *Xenopsylla*

Apis

Systematic position

Phylum	Arthropoda
Class	Insecta
Order	Hymenoptera
Genus	*Apis*

Comments:

1. *Apis* (Fig. 7.19) is commonly known as honey bee.

2. *Apis* is a social insect and lives in a highly organized petennial colony in bee hive.

3. The body is divided into three distinct regions; head, thorax and abdomen.

4. Head contains mouth, compound eyes and a pair of antennae. Mouth parts are chewing and lapping type.

5. Thorax contains three pairs of legs and two pairs of wings.

6. Abdomen is segmented and contains spiracles for breathing.

7. Honey bee colony consists of a queen, male drones and sterile female workers.

8. Female worker bees have the ovipositor modified to form sting.

9. Female worker bees do duties like - food collection, bringing nectar, making wax cells, looking after the young ones, building and cleaning the hive, etc.

10. The queen is larger in size than workers and drones. It has a longer abdomen and its duty is to lay eggs only.

11. The drones are the male members of the colony, without stings. They mate with queen and die after mating.

12. The honey bees are economically important insects as they are the source of honey and bees wax.

13. Bee keeping is called apiculture.

Habit and habitat:

Apis lives in colonies of couple of thousands bees. A colony consists of a single egg laying female or queen, several hundred male drones and thousand of sterile female workers. The worker bees collect nectar from the nectaries of flowers (Wikipedia).

Distribution:

Cosmopolitan. Honeybee is commonly found in India, Europe and Africa.

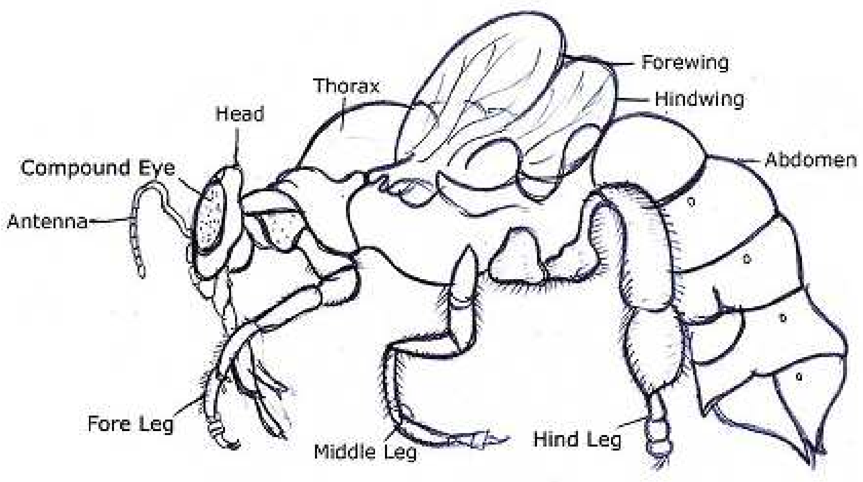


Fig. 7.19 Apis

Julus

Systematic position

Phylum	Arthropoda
Class	Myriapoda
Order	Diplopoda
Genus	*Julus*

Comments:

1. *Julus* (Fig. 7.20) is commonly called millipede or wire worm.

2. Body is elongated, cylindrical and consists of a large number of segments.

3. Body is divided into head, thorax and abdomen.

4. Head contais a pair of large mandibles, eyes and a pair of antennae having seven joints.

5. Thoracic segments each having a pair of legs, while abdominal segments bear two pairs of legs each.

6. Microscopic holes called ozopores (Stink glands) present along the sides of the body, secreting noxious substance as a defence mechanism.

7. Sexes are separate.

Habit and habitat:

Julus is found hidden usually in dark and damp places under stones or wood or in decaying leaves. It feeds on decomposing vegetation faeces and organic matter mixed with soil.

Distribution:

Julus is cosmopolitan in distribution; found in India, Europe and U.S.A.

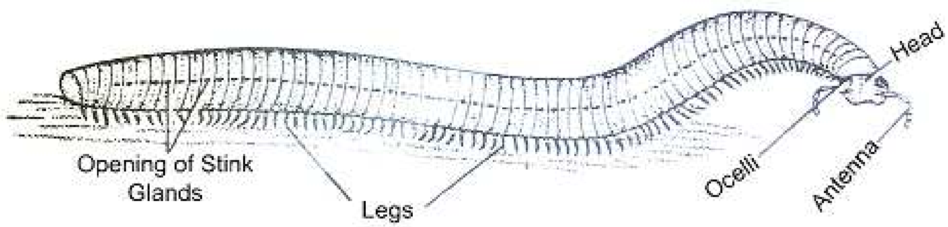


Fig. 7.20 *Julus*

Scolopendra

Systematic position

Phylum	Arthropoda
Class	Myriapoda
Order	Chilopoda
Genus	*Scolopendra*

Comments:

1. *Scolopendra* (Fig. 7.21) is commonly known as centipede.

2. Body is elongated and dorsoventrally flattened with numerous segments.

3. Body is divided into small head and a long trunk.

4. Head bears a pair of antennae, eyes, a pair of mandibles and two pairs of maxillae.

5. Trunk has 22 identical segments each (except first) has a pair of walking legs.

6. First pair of trunk appendages or maxillipedes bears a sharp claw through which opens the poison gland (Verma, 2005).

7. Sexes are separate.

8. It is nocturnal and mostly carnivorous.

9. *Scolopendra* is harmful to mankind because of their venomous bite.

Habit and habitat:

Scolopendra commonly occurs under stones, in rotten logs and in houses in damp places.

Distribution:

Scolopendra is found in India and U.S.A.

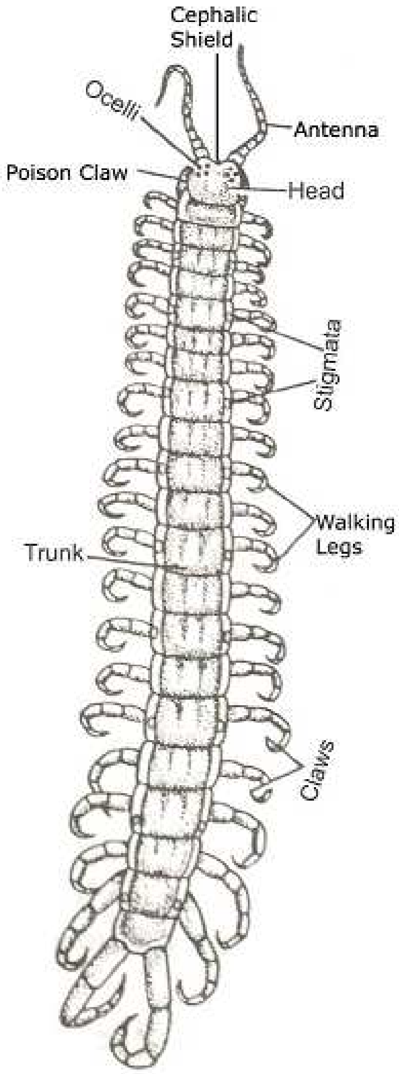


Fig.7.21. *Scolopendra*

Aphid

Systematic position:

Phylum	Arthropoda
Class	Insecta
Order	Hemiptera
Genus	*Aphid*

Comments:

1. *Aphid* (Fig. 7.22) is commonly known as plant lice.
2. Body is soft, short and pear-shaped and is divided into head, thorax and abdomen.
3. Head is quite distinct, bears large antennae and well developed compound eyes.
4. Mouth parts are piercing and sucking type.
5. Thorax bears three segments each having a pair of legs.
6. Abdomen consists of eight segments. Nine pairs of lateral abdominal spiracles are present.
7. Aphids are sometime winged or wingless.
8. It is viviparous.
9. They show the phenomena of parthenogenesis.

Habit and habitat:

Aphid is found on plants and sucks their juice. Some of the species are monophagous.

Distribution:

Aphid is distributed throughout the world.

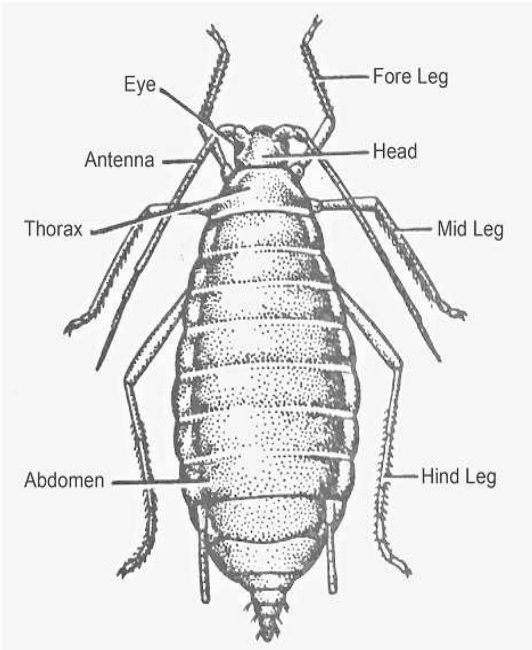


Fig. 7.22. *Aphid*

Cimex

Systematic position:

Phylum	Arthropoda
Class	Insecta
Order	Hemiptera
Genus	*Cimex*

Comments:

1. *Cimex* (Fig. 7.23) is commonly known as bed bug.
2. Body is dorso-ventrally flattened and oval, measuring 5 mm in length.
3. Body comprises of head, thorax and abdomen.
4. Head is short and broad and bears a pair of compound eyes, a pair of antennae and proboscis.
5. Mouth parts are piercing and sucking type.
6. Thorax is divisible into a prothorax, mesothorax and a metathorax. It bears three pairs of legs.

7. Wings are absent.

8. Abdomen is large and bears seven segments. In male has a pointed tip abdomen while female has a curved abdominal end.

9. Sexes are separate.

10. Its bite causes skin rashes and allergy in humans.

Habit and habitat:

Cimex is found inhabiting beds, or other places where peoples sleep. It is also found in luggage, backpacks, clothing, electronic items and furnitures. It is nocturnal. It is hematophagous and sucks human blood.

Distribution:

Cimex is widely distributed all over the world.

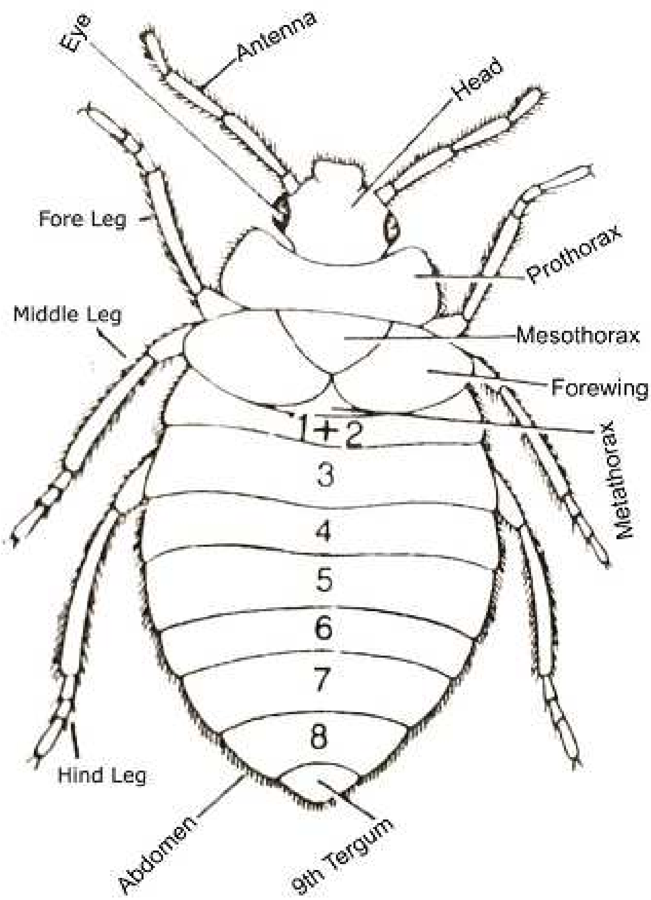


Fig. 7.23. *Cimex*

Ixodes

Systematic position:

Phylum	Arthropoda
Class	Arachnida
Order	Acarina
Genus	*Ixodes*

Comments:

1. *Ixodes* (Fig. 7.24) is commonly called sheep tick.

2. It is small compressed leathery body with no sign of segmentation.

3. Head, Thorax and abdomen are fused into a single body segment.

4. Mouthparts have a pair of palps, a pair of chelicerae and a barbed, needle like hypostome. Mouth parts are piercing and sucking.

5. In males scutum covers entire dorsal surface while in female it is smaller.

6. Four pairs of slender legs. Behind the fourth pair of legs is a pair of prominent spiracles leading into convoluted tracheae. Respiration happens via spiracles and tracheae.

7. Genital aperture is situated in approximate midline between the coxae.

8. Anus is situated on the posterior ventral side.

9. Female is larger than male.

10. Ixodes can cause anaemia, fever, dermatosis in sheep and other domestic animals.

Habit and habitat:

Ixodes is an ectoparasite, found on the body of sheep. It typically lives on the surface of warm blooded animals and feed on their blood.

Distribution:

Ixodes is commonly found in worldwide, especially in warm and humid areas.

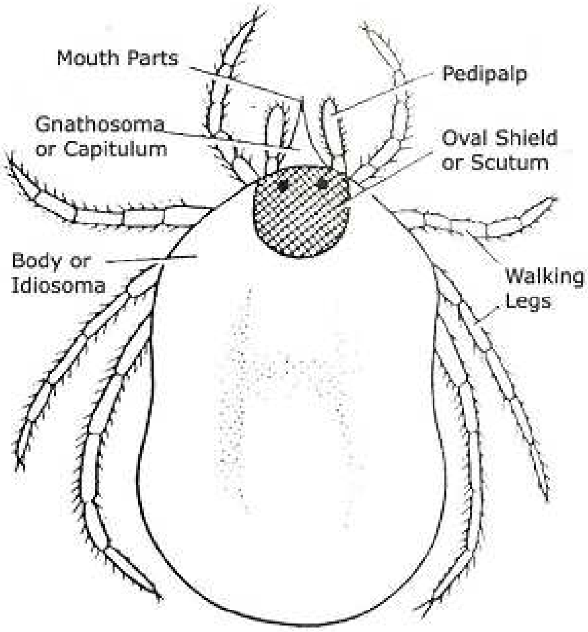


Fig. 7.24 *Ixodes*

Sarcoptes

Systematic position:

Phylum	Arthropoda
Class	Arachnida
Order	Acarina
Genus	*Sarcoptes*

Comments:

1. *Sarcoptes* (Fig. 7.25) is commonly known as mite.
2. Body is rounded and dorso-ventrally flattened.
3. No external division into head, thorax and abdomen.
4. The body is covered with spines which are sensory in function.
5. Eyes and trachea are absent.

6. The mouth parts produce a head-like structure, the gnathosoma that bears a pair of chelicerae and a pair of pedipalpi.

7. Legs are short and stumpy. Four pairs of legs, the two anterior pairs are stronger and have terminal stalked suckers while the two posterior pairs are shorter and attached more ventrally and carry long bristles.

Habit and habitat:

Sarcoptes scabiei is a human ectoparasite which causes scabies or itching. Repeated infection of itching turns into eczema. It burrows into the skin and often spend entire life cycle within that burrow.

Distribution:

Sarcoptes is cosmopolitan in distribution.

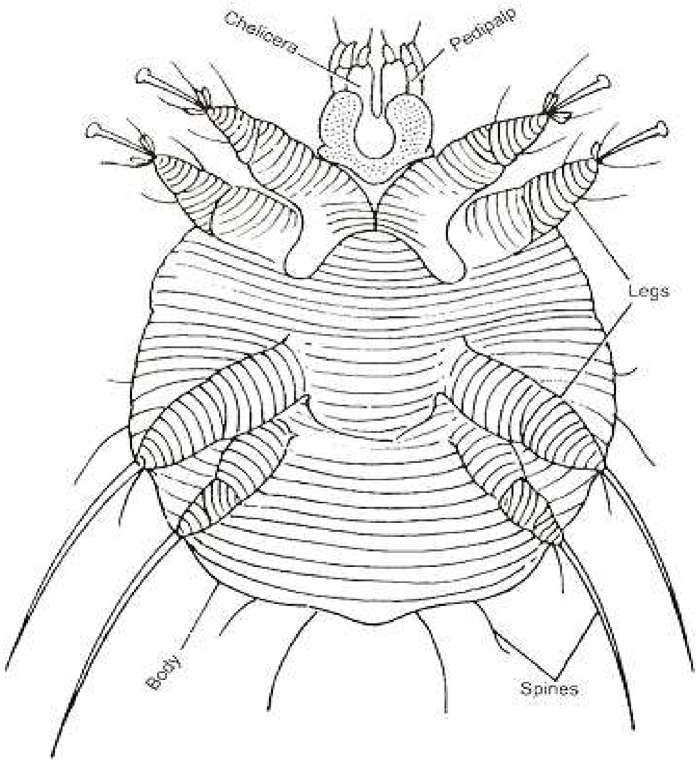


Fig. 7.25 *Sarcoptes*

Nauplius larva

Comments:

1. Nauplius larva (Fig. 7.26) is the first larval stage of many crustaceans.

2. Body is unsegmented and oval in shape. It has a broad anterior head region, middle trunk region and bilobed anal region.

4. Head bears a single median eye and a pair of antennules.

5. Trunk bears a pair of antennae and a pair of mandibles. These two pairs are biramous and are used for swimming.

6. Mouth opens at the anterior end, while anus lies on the posterior extremity.

7. Nauplius larva goes through a number of intermediate stages before it reaches the adult stage. Each such stage is separated by a moult in which the larva sheds hard exoskeleton to allow the animal to grow.

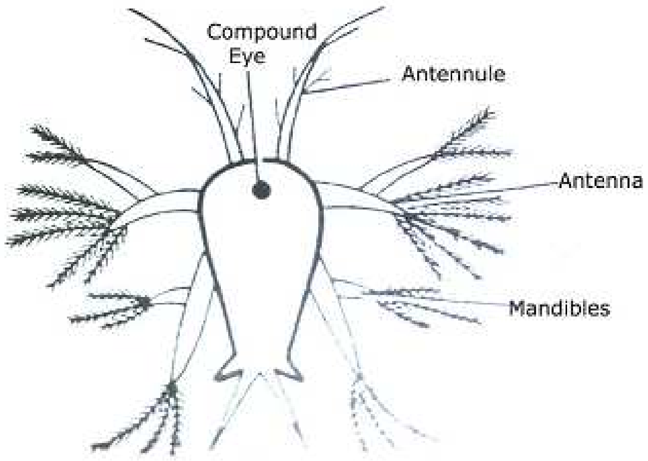


Fig. 7.26 Nauplius larva

Zoea larva

Comments:

1. Zoea larva (Fig. 7.27) is a larval stage of the crustaceans.

2. Body consists of an unsegmented cephalothorax and segmented abdomen.

3. Cephalothorax is covered by a carapace and has a pair of compound eyes.

4. Head contains one dorsal, one rostrum and two lateral spines.

5. It contains mandibles, maxillae, antennules, antennae and two pairs of well developed maxillipedes.

6. Six pairs of thoracic appendages develop as buds. It uses thoracic appendages for swimming.

7. Abdomen comprises of six segments and bears caudal fork.

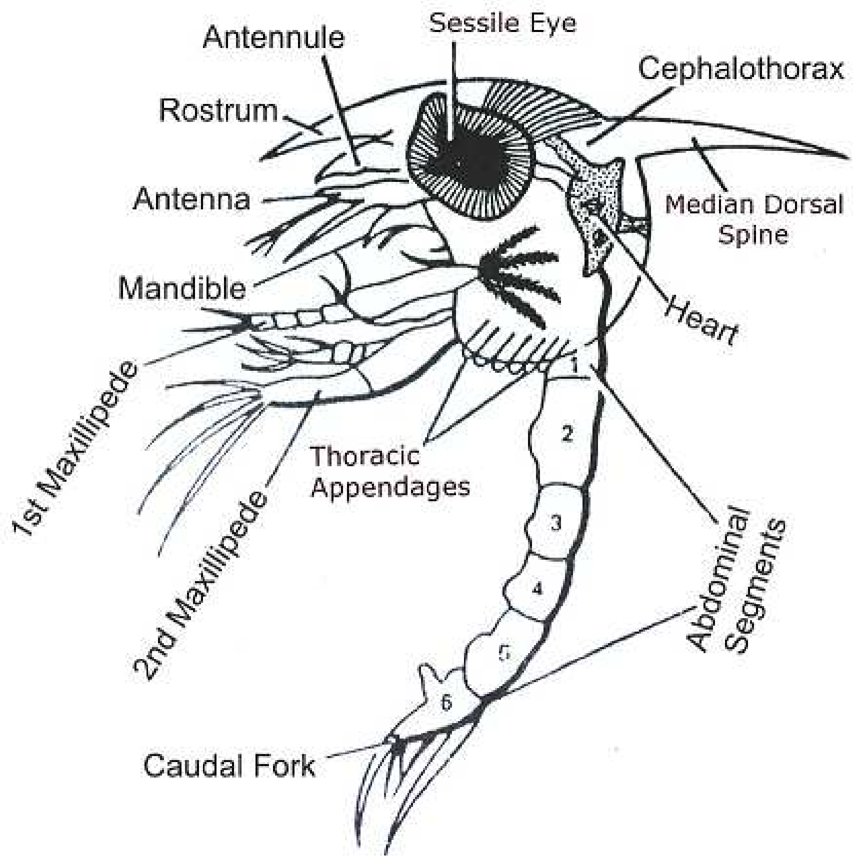


Fig. 7.27 Zoea larva

Megalopa larva

Comments:

1. Megalopa larva (Fig.7.28) is the larva of crab and it develops from zoea larva.

2. It has a large, broad and crab-like unsegmented cephalothorax bearing a median spine.

3. It has a pair of large and stalked eyes.

4. Antennae are large while antennules are small.

5. Thoracic appendages are well developed.

6. Abdomen has six segments bearing biramous pleopods and a telson. Pleopods are used for swimming.

7. Megalopa leads a pelagic life for some time and later on sinks down to the bottom and moults into adult.

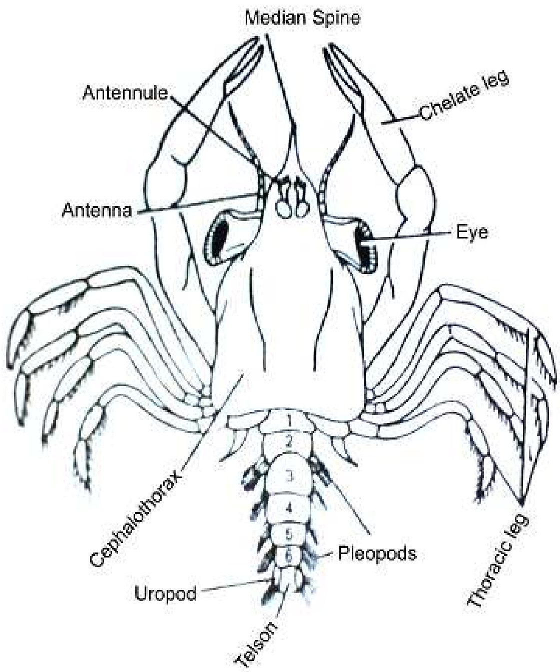


Fig. 7.28 Megalopa larva

Mysis larva

Comments:

1. Mysis (Fig. 7.29) is a stage in Arthropoda such as *Peanaeus*.

2. The body appears similar to the adult *Mysis*.

3. Body is divisible into cephalothorax and abdomen.

4. Cephalothorax bears a pair of compound eyes, a rostrum, a pair of antennules and a pair of antennae.

6. It bears seven pairs of biramous thoracic appendages and used for locomotion.

7. Abdomen bears five pairs of biramous pleopods. The last abdominal segment has a telson and a pair of uropods.

8. Mysis larva metamorphoses into the adult prawn.

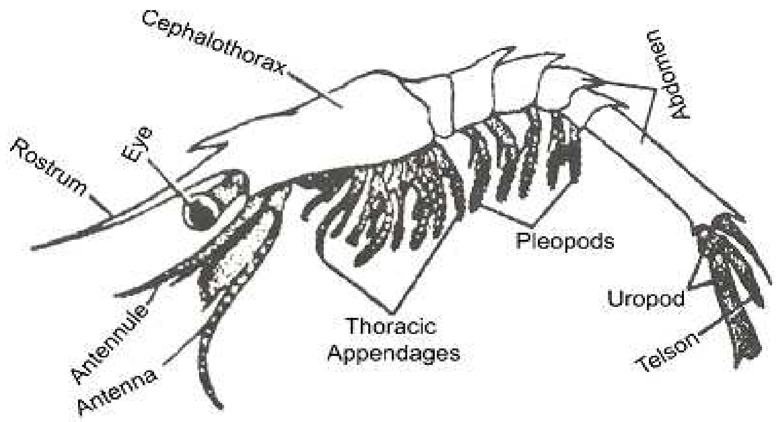


Fig. 7.29 Mysis larva

Larva of culex

Comments:

1. Culex larva (Fig. 7.30) appears out of eggs that hatch out in two or three days.
2. Body of larva is elongated and transparent. It is divided into head, thorax and abdomen.
3. Head is rounded and bears mouth parts, a pair of compound eyes and a pair of antennae.
4. Single rounded thoracic segment bears three pairs of lateral tufts of hairs.
5. Abdomen consists of nine segments each having a few bristles or hairs.
6. Eighth abdominal segment contains respiratory siphon with two spiracles.
7. Last abdominal segment bears tracheal gills and tufts of hairs.
8. Culex larva hangs with head downwards at an angle with the surface of water.
9. Larva feeds on microorganisms and organic matter.

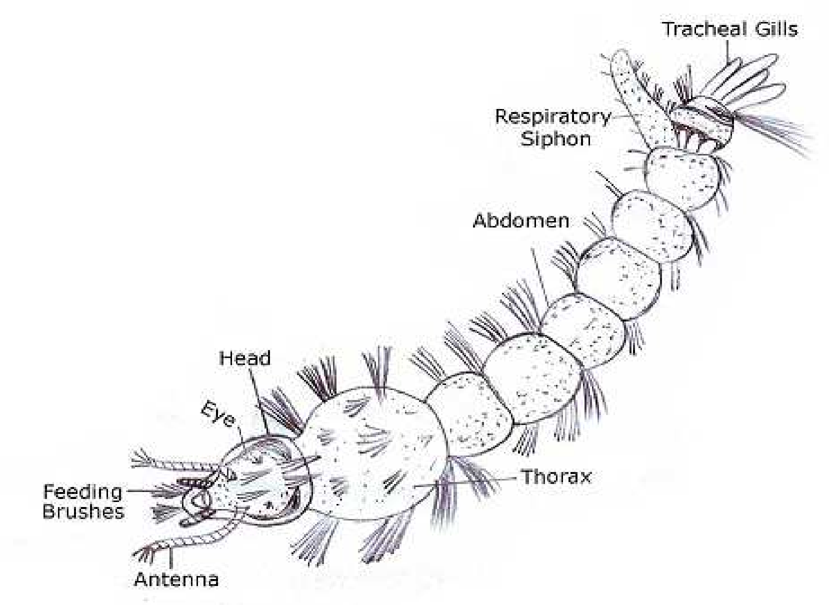


Fig. 7.30 Larva of Culex

Larva of Anopheles

Comments:

1. Culex larva (Fig. 7.31) appears out of eggs that hatch out in twenty four to forty eight hours.

2. Body of larva is divisible into head, thorax and abdomen.

3. Head is long and contains a pair of eyes, a pair of antennae and feeding brushes.

4. Thorax broad unsegmented and is provided with tufts of hairs.

5. Abdomen consists of nine segments and each has palmate hairs.

6. Respiratory siphon is absent. Eighth segment has a raised chitinous quadrilateral plate with two spiracles.

7. Last segment of abdomen bears tracheal gills for respiration.

8. Anopheles larva lies horizontally with head parallel to the water surface (Verma, 2015).

9. Larva feeds on algae, bacteria and other microorganisms.

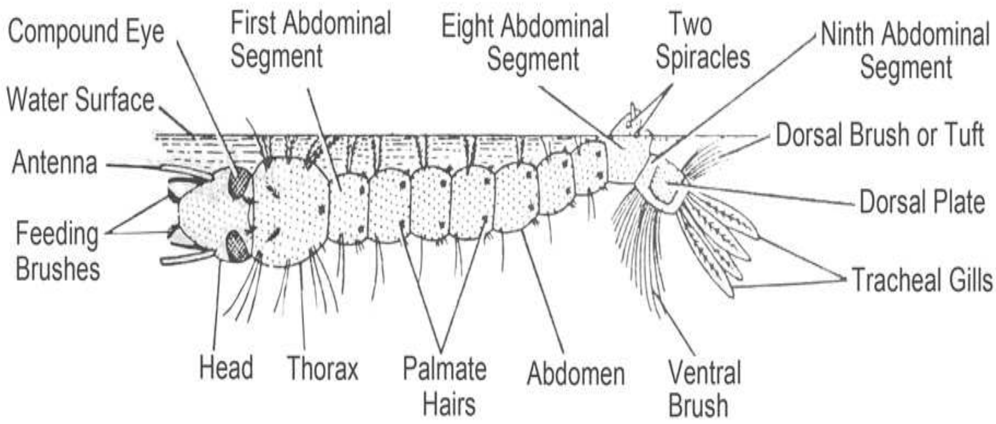


Fig. 7.31 Larva of Anopheles

Pupa of Culex

Comments:

1. Culex larva (Fig. 7.32) moults four times to change into pupa.
2. Body is comma-shaped and comprises of cephalothorax and abdomen.
3. Cephalothorax bears a pair of long and narrow respiratory trumpets on its dorsal surface.
4. Abdomen consists nine segments provided with tufts of bristles.
5. Last abdominal segment contains two chitinous leaf-like paddles used for swimming.
6. It does not feed and has occasional tumbling movement in water.

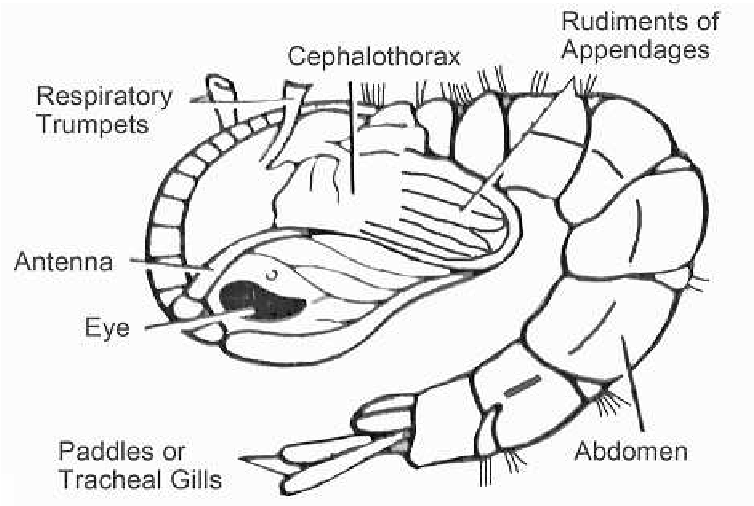


Fig. 7.32 Pupa of Culex

Pupa of Anopheles

Comments:

1. Anopheles larva (Fig. 7.33) moults four times to become pupa.

2. Body of pupa comprises of cephalothorax and abdomen.

3. Cephalothorax bears a pair of short and broad respiratory trumpets with a terminal opening (Wikipedia).

4. Abdomen consists of nine segments and is more strongly curved than in Culex.

5. Eighth abdominal segment bears two paddles for swimming.

6. It does not feed and has occasional tumbling movement in water.

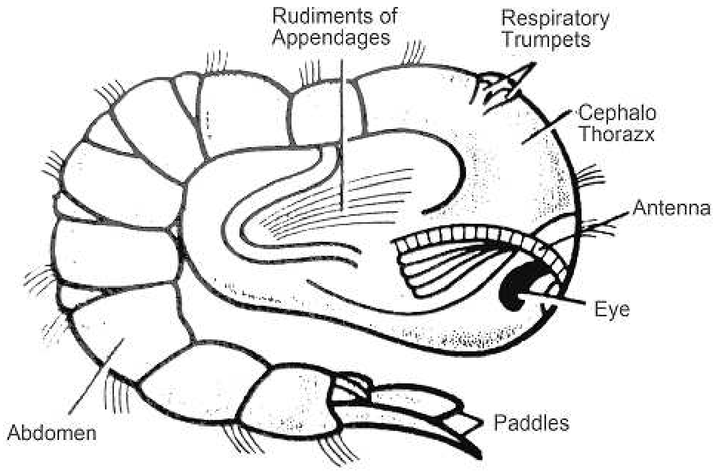


Fig. 7.33 Pupa of Anopheles

7.4-Summary:-

Phylum arthropoda (Gr., arthros = joint + podos = foot) is the largest phylum and most varied in the animal kingdom. Arthropods are mainly terrestrial but marine and freshwater species are also well known. Arthropod bodies are divided into segments. A number of segments are sometimes fused to form integrated body parts known as tagmata. This process of fusion is called tagmosis. The head, thorax, and abdomen are examples of tagmata. However, in most species some appendages have been modified to form other structures, such as mouthparts, antennae, or reproductive organs. Arthropod appendages may be either biramous (branched) or uniramous (unbranched).

Arthropods have a well-developed, mesodermal, solid nerve cord, ventral and well-developed sense organs. They range in size from microscopic plankton to life-forms that are a few meter long. Arthropods primary internal cavity is known as hemocoel.Respiration occurs in various ways for e.g. some species have gills, while others employ tracheae, or book lungs. Generally, the sexes are separate in phylum arthropoda. Fertilization usually occurs internally, and most species are egg laying. While some species exhibit direct development, in which eggs hatch as miniature versions of adults, other species pass through an immature larval stage and undergo a dramatic metamorphosis before reaching adult form. Some specific species are known to spread severe disease to humans, livestock, and crops.*Palaemon* is commonly known as prawn. It is found in freshwater streams, ditches, lakes, ponds, rivers and reservoirs. It is a nocturnal animal hiding at the bottom during the day and coming to the surface at night in search of food. It is omnivorous, feeding on small organisms, like algae, minute insects, mosses, debris etc. It walks slowly at water bottom with the help of its 10 walking legs and swims actively to the surface with the help of its 10 pleopods.

7.5 REFERENCES:

1. Kotpal, R. L. (2005): Modern text book of Zoology Invertebrates (Animal Diversity-I). Rastogi Publications pp 705-773.

2. Rastogi V. B. (2015): Invertebrate Zoology. Publisher- Kedar Nath Ram Nath.

3. Verma, P. S. (2015): A Manual of Practical Zoology Invertebrates. S. Chand & Company Pvt. Ltd. Ram Nagar, New Delhi-110055.

4. Yadav, V., Yadav, P. Varshney, V. K., Varshney, V. C. (2015): Text Book of Practical Zoology-I. Publisher- Kedar Nath Ram Nath Merrut.

5. Wikipedia.org:

7.6-Self Assesement Question:-

Long Answer Type Questions:-

1. Classify Arthropoda up to orders giving their characters and examples.

2. Write short notes on: (1) *Palaemon* (2) *Sacculina* (3) *Scolopendra* (4) *Lepisma* (5) Termite

3. Describe various types of mouth parts in insects.

4. Write an essay on economical importance of insects.

Short Answer type Questions:

1. Write a short note on beneficial insects.
2. Distinguish between butterflies and moths.
3. Write down sailent features of Phylum Arthropoda.
4. Write zoological names of 5 common insects around you.

Multiple Choice Questions:

1. *Lepas is commonly known as*:

(a) Acorn barnacle (b) Rock barnacle

(c) Goose or ship barnacle (d) Sea barnacle

2. The mouth parts of honey bee:

(a) *Piercing and sucking type* (b) Chewing and lapping type

(c) Sucking and sponging type (d) Biting and chewing type

3. Antennae are absent in:

(a) Spider (b) House flies

(c) Butterflies (d) *Peripatus*

4. Which is viviparous?

(a) *Aranea* (b) *Sacculina*

(c) *Peripatus* (d) *Palamnaeus*

5. Silver fish is a:

(a) Common carp (b) *Lepisma*

(c) *Schistocerca* (d) *Catla catla*

Answer: 1. (c) 2. (b) 3. (a) 4. (d) 5. (b)

UNIT 8: PHYLUM MOLLUSCA

Contents:-

8.1 Objectives

1. The objective of this chapter is to understand the division of mollusca into different classes.

2. To understand different body parts and their functioning.

3. Detailed study of some important molluscs.

4. Understading habitat of *Pila*.

5. Understanding the nervous system and reproductive system of *Pila*.

8.2 Introduction

Phylum mollusca (L., molluscus, soft) includes soft-bodied invertebrate animals such as Octopods, snails, slugs, mussels, clams, oysters, tusk-shells, squids etc. The term mollusca were coined by Johnston. It is a diverse and widespread group, with about 112,000 species. Molluscs are the largest marine phylum, comprising about 23% of all the named marine organisms. Molluscs may be terrestrial or aquatic (freshwater or marine). They are found in all habitats - deserts, forests, lakes, rivers, abysses of sea, coral reefs, underground or even as parasite in the body of other animals. They may be found clinging to the rocks, crawling, and swimming, burrowing or even digging. They have diversified feeding habit and can be herbivores, carnivores or omnivores. They vary in size from giant squids (nearly 2m long) to little snails, a millimeter long. The largest of the molluscan classes is Gastropoda, which is represented by about 35,000 living and some 15,000 fossil species.

The three most universal features defining molluscs are - a mantle with a significant cavity used for breathing and excretion, the presence of a radula, and the structure of the nervous system. The "generalized" mollusc's feeding system consists of a rasping "tongue", the radula, and a complex digestive system. Although molluscs are coelomates, the coelom tends to be small, and the main body cavity is a hemocoel through which blood circulates; their circulatory systems are mainly open. The generalized mollusc has two paired nerve cords, or three in bivalves. Most molluscs have eyes, and all have sensors to detect chemicals, vibrations, and touch. The simplest type of molluscan reproductive system relies on external fertilization, but more complex variations occur. All produce eggs, from which may emerge trochophore larvae, more complex veliger larvae, or miniature adults.

Molluscan shells have always been economically important, having served as money in early days. They have been used in jewellery and buttons. *Octopus*, Scallops, oysters and squids are important food items. The scientific study of molluscs is called malacology.

General characters:-

1. Molluscs are soft bodied, essentially aquatic, mostly marine, few freshwater and some terrestrial animals.

2. Body is soft, bilaterally symmetrical, unsegmented and without jointed appendages and can be divided into head, mantle, visceral mass and foot.

3. The head carries mouth, eyes and tentacles.

4. The mantle is a thick, muscular fold of body wall extended over the viscera and the enclosed space is called as the mantle cavity.

5. Visceral mass contains the visceral organs of the body in a compact form.

6. The foot is ventral in position and is usually thick and muscular being variously modified for creeping, ploughing and seizing.

7. Body cavity is haemocoel. The true coelom is generally limited to the pericardial cavity and the lumen of the gonads and nephridia.

8. Nervous system consists of paired cerebral, pleural, pedal and visceral ganglia joined by longitudinal and transverse connectives and nerves.

9. Circulatory system is closed type. Heart has one or two auricles and one ventricle.

10. Respiration direct or by gills or lungs or both. The respiratory pigment is haemocyanin.

11. Digestive system is complete. Digestive glands are liver or hepatopancreas. Radula is mostly present.

12. Excretion is performed by nephridia or kidneys.

13. Sexes are separate. Fertilization happens externally as well as internally.

14. Development is either direct or with metamorphosis through the trochophore stage called veliger larva.

Classification

Molluscs are classified into six classes according to their symmetry, their food habits, shell, mantle, gill, nervous system, muscles and radula.

Class1. Monoplacophora (Gr., monos = one + plax = plate + pherein = bearing)

1. Body is bilaterally symmetrical with internal metamerism.
2. Shell is flattened and limpet-shaped with spirally coiled protoconch.
3. Foot is broad, flat and bears 8 pairs of pedal retractor muscles.
4. Five pair of gills which are in pallial grooves.
5. There are six pairs of nephridia out of which two are modified into gonoducts.
6. Intestine is highly coiled. Radula present in radular sac.
7. Heart consists of two pairs of auricles and a single ventricle.
8. Nervous system with longitudinal, pallial and pedal cords.

Example: *Neopilina galathea*.

Class 2. Amphineura (Gr., amphi = both + neuron = nerve)

1. Body elongated with reduced head.
2. Radula is present.
3. Shell as 8 dorsal plates or as spicules.
4. Foot is ventral, large, flat and muscular.
5. Fertilization is external. Development happens via intermediate stage of trochophore larva.
6. Organisms are marine.

Subclass 1. Aplacophora

1. Body worm-like without shell and foot.

2. Radula is simple.

3. Calcareous spicules buried in cuticle.

4. A pair of bivalve ctenidia is present.

Examples: *Chaetoderma*, *Neomenia*, *Nematomerina*.

Subclass 2. Polyplacophora

1. Body is dorso-ventrally flattened; head small and without eyes and tentacles. Radula, shell, mantle, foot and external gills present.

2. Mantle cavity is present towards the back side.
3. Shell is in the form of 8 calcareous plates.

Order 1. Lepidopleurina

1. Shell valve are without plates.

2. Ctenidia few and posterior.

Example: *Lepidopleurus*.

Order 2. Chitonida

1. Shell valve are with plates.

2. Gills along whole length of mantle groove.

Examples: *Chiton*, *Chaetopleura*, *Ischnochiton*.

Class 3. Scaphopoda (Gr., scapha = boat + podos = foot)

1. Exclusively marine.

2. Body bilaterally symmetrical, elongated and enclosed in a tusk-like shell open at both ends.

3. Head and eyes absent; mouth with tentacles.

4. Foot conical; radula present.

5. Kidneys are paired and gonad is single.

6. Heart rudimentary.

7. Sexes are separate. Development includes trochophore larva.

Examples: *Dentalium*, *Pulsellum*, *Cadulus*.

Class 4. Gastropoda (Gr., gaster = belly + podos = foot)

1. Mostly marine, some freshwater, terrestrial, and few parasitic on echinoderms.

2. Includes snails and slugs.

3. Body is asymmetrical, unsegmented and generally with a univalve, spirally coiled shell.

4. Head well developed with eyes and tentacles.

5. Foot is large and flat.

Subclass 1.Prosobranchia

1. Mostly marine, few freshwater and terrestrial.

2. Body mass torted and head with a single pair of tentacles.

3. Shell closed by operculum.

4. Head distinct with snout bearing a pair of tentacles and a pair of eyes.

5. Foot is muscular and forms ventral part of the body.

6. Sexes are separate, gonad single, larva trochophore or veliger.

Order 1. Archaeogastropoda

1. One or two bipectinate internal gills.

2. Two kidneys and heart with two auricles.

3. Shell usually coiled.

4. Nervous system not concentrated usually with pedal cords.

5. Sexes are separate.

6. Fertilization is external.

Examples: *Patella*, *Trochus*, *Fissurella*.

Order 2. Mesogastropoda

1. Mostly marine, some freshwater.

2. One auricle, one kidney and one mono-pectinate ctenidium.

3. Radula taenioglossate type having 7 teeth in each row.

4. Single osphradium.

5. Nervous system without pedal cords.

6. Fertilization is internal.

7. Larva is a free-swimming veliger.

Examples: *Pila*, *Turbinella, Crepidula*, *Natica*, *Cypraea*.

Order 3. Neogastropoda

1. Shell with more or less elongated siphonal canal.

2. Nervous system concentrated.

3. Free- swimming veliger suppressed.

Examples: *Murex*, *Magilus*, *Buccinum*, *Melongena*, *Conus*, *Oliva*.

Subclass 2. Opisthobranchia

1. Exclusively marine gastropods.

2. Shell small, without operculum or no shell.

3. Body mass torted or detorted.

4. Gills posterior to heart.

5. One auricle, one kidney and one gonad.

6. Nervous system without pleuro-visceral loop.

7. Hermaphrodite, i.e., sexes united.

Order 1. Cephalaspidea

1. Shell moderately developed.

2. Parapodial lobes present or absent.

3. Head with tentacular shield.

Examples: *Acteon*, *Hydatina*, *Bulla*.

Order 2. Anaspidea

1. Found mostly in tropical and subtropical waters.
2. Shell reduced or internal.
3. Well developed parapodial lobes.
4. Head with a pair of rhinophores.

Examples: *Aplysia*, *Akera*.

Order 3. Pteropoda

1. Pelagic snails with or without shell.
2. Shell reduced or internal.
3. Parapodial lobes well developed.
4. Head with a pair of rhinophores.

Examples: *Corolla*, *Clione*, *Cavolina*.

Order 4. Sacoglossa

1. Shell can be present or absent.
2. Pharynx suctorial.
3. Sperm duct is closed.
4. Parapodia and cerata present.

Examples: *Elysia*, *Oxynoe*.

Order 5. Acochlidiaceae

1. Minute without shell.
2. Found in coarse sand.
3. Visceral mass separated from foot and covered with spicules.

Examples: *Acochlidium*, *Unela*.

Order 6. Notaspidea

1. Shell internal, external or reduced.
2. Mantle present but mantle cavity absent.
3. Gills bipectinate and osphradium on the right side.

Examples: *Tylodina*, *Pleurobranchus*.

Order 7. Nudibranchia

1. Shell absent.
2. Mantle or mantle cavity absent.
3. Internal gills and osphradium are absent.
4. Presence of dorsal outgrowths.

Examples: *Doris*, *Aeolis*.

Order 8. Pyramidellacea

1. Shell spirally twisted.
2. Proboscis long, operculum present but gill and radula absent.
3. Semi-parasitic forms.

Examples: *Pyramidella.*

Order 9. Philinoglossacea

1. Minute naked snails.
2. Head appendages and gills absent.
3. Visceral mass separated from foot only by a groove.

Examples: *Philinoglossa*, *Sapha*.

Order 10. Rhodopacea

1. Vermiform snails.

2. No external appendages.

3. Anus on right side of body.

Examples: *Rhodope.*

Order 11. Onchidiacea

1. Slug-like, naked or without shell opisthobranchs.

2. Pulmonary sac and anus placed at the posterior end

3. Male gonopore placed anteriorly while female gonopore placed posteriorly.

Examples: *Onchidella*, *Onchidium*.

Order 12. Parasita

1. Endoparasitic gastropods found in the interior of holothurians.

2. Shelled embryos.

Examples: *Thyonicola*, *Entoconcha*.

Subclass 3. Pulmonata

1. Mostly freshwater or terrestrial, a few are marine.

2. Detorted body mass.

3. Shell spiral or reduced or absent.

4. Mantle cavity or pulmonary sac with a pore on right side anteriorly.

5. Hermaphrodites.

Order 1. Basommatophora

1. Freshwater or brackish water and marine.

2. One pair of tentacles that is non-invaginable.

3. Eyes at tentacular bases.

4. Separate male and female gonopores.

Examples: *Lymnaea*, *Siphonaria*, *Planorbis*.

Order 2. Stylommatophora

1. Terrestrial pulmonates.
2. Two pairs of tentacles that are invaginable.
3. Second pair of tentacles with eyes at their tips.
4. Male and female gonopores are usually united.

Examples: *Limax*, *Partula*, *Helix*, *Retinella*.

Class 5. Pelecypoda (Gr., pelekus = batchet + podos = foot)

1. Aquatic, mostly marine, some freshwater forms.
2. Body bilaterally symmetrical and laterally compressed.
3. Head, tentacles, eyes, jaws as well as radula absent.
4. Foot hatchet-shaped and extending between mantle lobes.
5. Gills or ctenidia are paired, one on each side.
6. Dioecious, veliger or glochidium larva in the life-history.

Order 1. Protobranchia

1. Gill filaments not folded.
2. Mouth placed at the base of proboscides.
3. Style sac is present in the stomach.

Examples: *Nuculina*, *Nucula*, *Yoldia*, *Malletia*.

Order 2. Filibranchia

1. Gill filaments incompletely fused.
2. Chitinous gastric shield in stomach developed.
3. Foot is small or poorly developed.
4. Style sac with crystalline style.

Examples: *Mytilus*, *Ostrea*, *Pecten*, *Spondylus*.

Order 3. Eulamellibranchia

1. Gills are firm and basket-like.

2. Gill filaments fused completely to form tissue sheets.

3. Foot usually large and byssus reduced or absent.

Examples: *Unio*, *Teredo*, *Anodonta*, *Lamellidens*, *Enis*.

Order 4. Septibranchia

1. Marine forms.

2. Gills absent.

3. Stomach lined by chitin; style-sac reduced.

Examples: *Poromya*, *Cuspidaria*.

Class 6. Cephalopoda (Gr., kephale = head + podos = foot)

1. Exclusively marine.

2. Bodybilaterally symmetrical.

3. Shell internal, external or absent.

4. Head bears highly developed eyes and mouth.

5. Foot modified into tentacles and siphon.

6. Sexes are separate.

7. Development meroblastic without metamorphosis.

Subclass 1. Nautiloidea or Tetrabranchiata

1. Shell external, coiled or straight.

2. Tentacles without suckers.

3. Two pair of gills and that of nephridia present.

Example: *Nautilus*.

Subclass 2. Ammonoidea

1. Extinct.

2. Shell external and coiled.

Example: *Pachydiscus*.

Subclass 3. Belemnoidea or Dibranchiata

1. Shell internal or reduced.

2. Tentacles few and with suckers.

3. One pair of gills and that of nephridia present.

Order 1. Decapoda

1. Ten arms present. Two are long and act as tentacles while rests of the arms are short.

2. Shell is internal and well developed.

3. Mostly scavangers.

Examples: *Loligo*, *Sepia*, *Spirula*.

Order 2. Octopoda

1. Body is short or compact.

2. Eight equal arms.

3. Dorsal mantle cavity present (Kotpal, 2005).

Examples: *Octopus*, *Argonauta*.

8.3 Identification, systematic position and general study

8.3.1- *Chiton and Dentalium*

***Chiton*:**

Systematic position:

Phylum	Mollusca
Class	Amphineura
Order	Chitonida
Genus	*Chiton*

Comments:

1. Body of *Chiton* (Fig. 8.1) is bilaterally symmetrical, unsegmented and dorso-ventrally compressed.

2. It consists of shell, foot, mantle and the visceral mass.

4. Shell is calcareous and is present on the dorsal side and is composed of eight overlapping plates.

5. Head is not distinct. Eyes and tentacles are absent.

6. Foot is ventral, broad, sole-like and muscular, adapted for creeping and adhering.

7. Mantle covers greater part of body and partly covers the edges of the shell plates.

8. Mouth and anus are at opposite ends.

9. Sexes are separate; gonad is single and is located in the front of the heart.

10. Excretory system consists of two nephridia.

11. Development is indirect through trochophore larva.

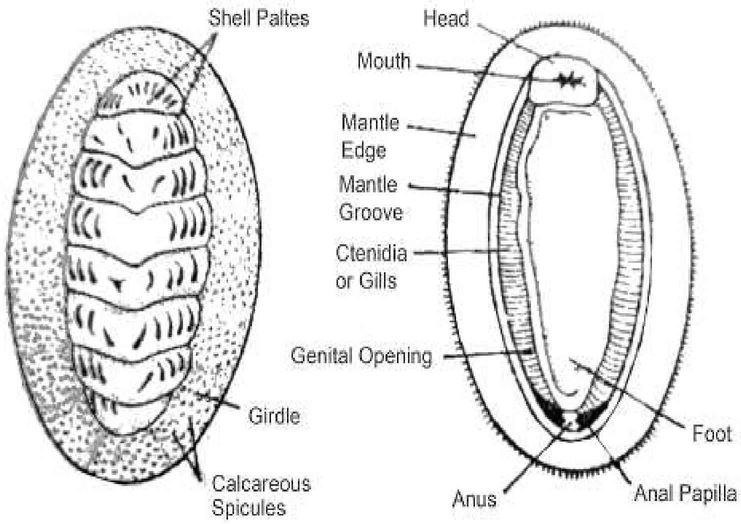
12. Chitons are eaten as food and their shells are used for decoration.

Habit and habitat:

Chiton is marine animal found attached to the rocks and corals between tide marks. It creeps along slowly on a muscular foot (Verma, 2015).

Distribution:

Chiton is found all over the world.



(A) (B)

Fig 8.1. *Chiton* (A) Dorsal view (B) Ventral view

DENTALIUM:

Systematic position:

Phylum Mollusca

Class Scaphopoda

Genus *Dentalium*

Comments:

1. *Dentalium* (Fig. 8.2) is commonly known as tusk shell.

2. It measures 2-5 cm in length.

3. It lies in a tubular, bilaterally symmetrical shell open at both ends.

4. Head and foot project out from the anterior aperture of the shell. Head bears a mouth surrounded by filiform tentacles called captacula. Eyes and osphradium are absent.

5. Mantle is entirely within the shell.

6. The foot is long pointed, spade-like and highly extensible adapted for digging and burrowing.

7. Sexes are separate.

8. Development is indirect and includes a veliger larva.

9. Shell of *Dentilium* is used for ornamental purposes. Its shells were once used by Red Indians of America as currency.

Habit and habitat:

Dentalium is marine and found in the sand at great depth. It feeds on microscopic organisms, detritus and foraminifera.

Distribution:

They are found in all seas except polar.

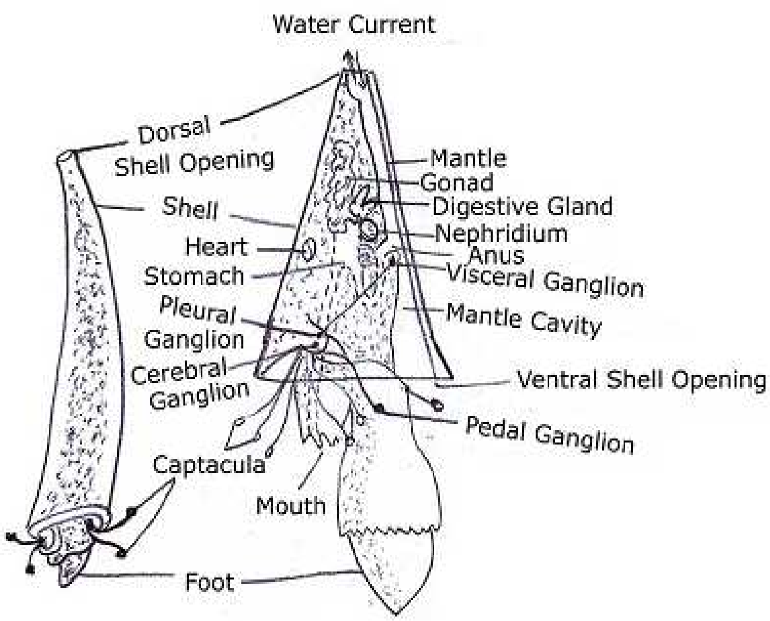


Fig. 8.2 Dentalium

8.3.2- *SEPIA AND PATELLA*

SEPIA:

Systematic position:

Phylum	Mollusca
Class	Cephalopoda
Order	Decapoda
Genus	*Sepia*

Comments:

1. *Sepia* (Fig. 8.3) is commonly called cuttle fish which is a misnomer because it is actually a mollusc and not a fish.

2. Body is soft, unsegmented and bilaterally symmetrical. It is divisible into a large head, a small neck or collar and trunk.

3. The head is well developed, bears a pair of eyes and 10 oral arms which are a modification of foot. 8 oral arms are smaller while two are longer and are called tentacles.

4. Collar is constricted and connects the head with the trunk.

5. The trunk extends into flaps called lateral fins on either side that help the animal in swimming.

6. It is covered by a thick muscular mantle, enclosing a large mantle cavity, on the ventral side which contains viscera.

7. It has a life expectancy of 1-2 years.

8. The Sexes are separate and reproduction is sexual.

9. Ornament makers use cuttle bones as moulds for casting small objects.

Habit and habitat:

Sepia is a marine animal that resides shallow to mid water and is often associated with coral reefs. It is carnivorous, feeds on crustaceans, small fishes and other animals.

Distribution:

Sepia is cosmopolitan in distribution. It is commonly found in Europe, India and Mediterranean region.

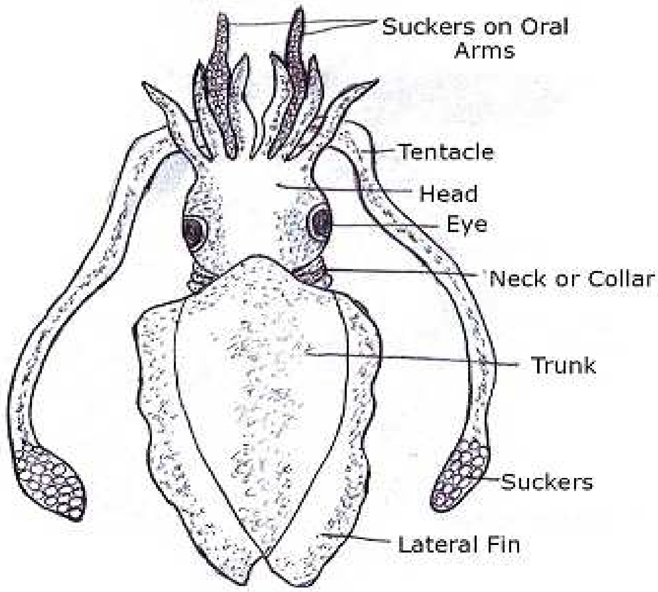


Fig. 8.3 *Sepia*

PATELLA:

Systematic position:

Phylum Mollusca

Class Gastropoda

Order Archaeogastropoda

Genus *Patella*

Comments:

1. *Patella* (Fig. 8.4) is commonly known as true limpet.

2. Shell is oval and rounded without operculum.

3. The head bears one pair of stout, sensory tentacles and eyes.

4. Mantle cavity is restricted anteriorly.

5. Foot is ventral, broad and flat used for adhering and creeping.

6. *Patella* is eaten in several countries like France, Italy and Ireland.

7. The shells of *Patella* are used in decoration.

8. Sexes are separate.

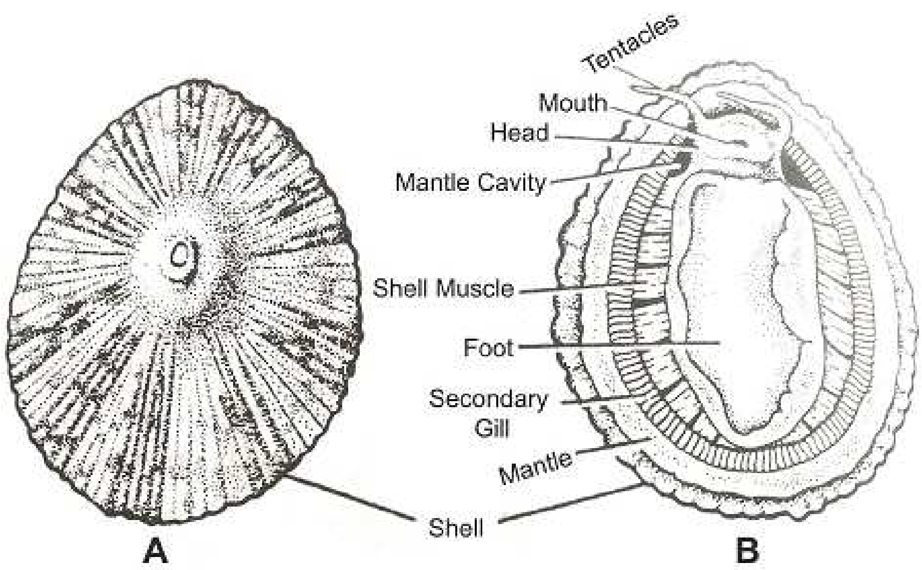
9. Development is indirect involving a free swimming larva.

Habit and habitat:

Patella is a sluggish marine gastropod. It attaches itself to the rocks and feed on minute algae.

Distribution:

Patella is found on the rocky ocean coasts worldwide.



(A) Dorsal View (B) Ventral View

Fig. 8.4 *Patella*

8.3.3- *PILA AND TURBINELLA*

PILA GLOBOSA:

Systematic position

Phylum	Mollusca
Class	Gastropoda
Order	Mesogastropoda
Genus	*Pila*
Species	*globosa*

Comments:

1. *Pila gobosa* (Fig. 8.5) is commonly called apple snail.

2. Shell is univalve and coiled around a central axis in a right handed spiral.

3. Operculum is well developed and closes the aperture or the mouth of the shell.

4. The body is soft and is enclosed in a shell. It consists of head, foot and visceral mass.

5. Head is the anterior fleshy part of the body overhanging the foot. It bears mouth, two pairs of contractile tentacles and a pair of eyes.

6. Foot is the locomotory organ of *Pila* and lies below the head.

7. All visceral organs are contained in this lump like structure that lies above the head-foot complex.

8. Skin of the visceral mass forms a thin and delicate covering called the mantle.

9. Respiratory organs consist of a single ctenidium or gill, a pulmonary sac or lung and a pair of nuchal lobes. Aquatic respiration by ctenidium and aerial respiration by pulmonary chamber.

10. Sexes are separate but without sexual dimorphism.

11. It is found in large numbers in those areas which are rich in aquatic plants like *Vallisneria* and *Pistia* (Rastogi, 2015).

Habit and habitat:

Pila is commonly found in freshwater ponds, lakes, tanks, pools, marshes, paddy fields, streams and rivers of Northern India**.** They are amphibious being adapted for life in water and on land. It creeps slowly using its ventral muscular foot.

Distribution:

Pila is confined to the Oriental and Ethiopian regions.

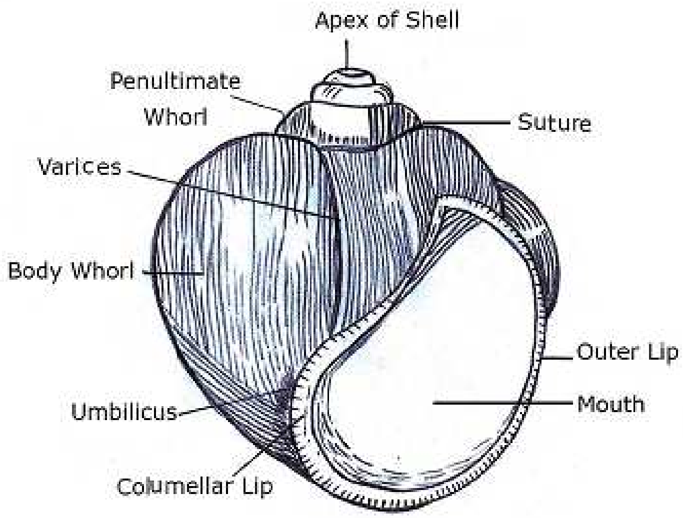


Fig. 8.5 *Pila*

TURBINELLA:

Systematic position

Phylum Mollusca

Class Gastropoda

Order Mesogastropoda

Genus *Turbinella*

Comments:

1. Body of *Turbinella* (Fig. 8.6) is unsegmented and asymmetrical.

2. Body is present in a large, thick fusiform shell.

3. Shell is spirally coiled with 3 or 4 prominent columellar plicae.

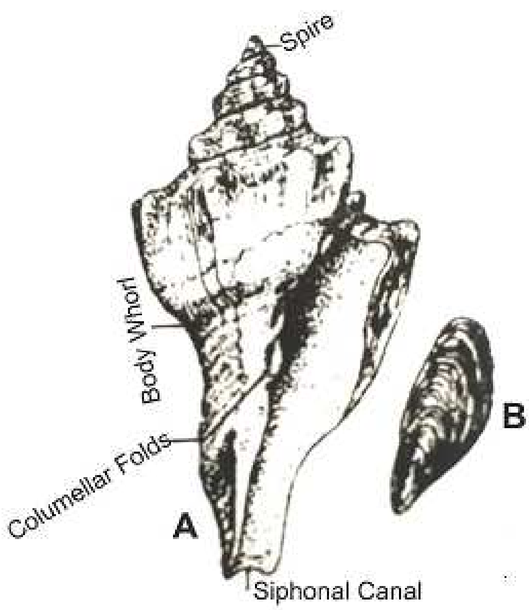
4. Head bears a pair of eyes, a pair of tentacles and an eversible proboscis which bears the mouth.

5. Mantle encloses the visceral mass and forms a collar like margin for the shell aperture.

6. A large foot with a calcareous, heavy operculum projects out of the shell for locomotion and attachment (Yadav and Varshney, 2015).

Habit and habitat:

It is a marine animal found worldwide mostly in tropical shallow waters.



(A) Ventral View (B) Operculum

Fig. 8.6 *Turbinella*

8.3.4- *APLYSIA* AND SLUG

APLYSIA

Systematic position

Phylum Mollusca

Class Gastropoda

Order Anaspidea

Genus *Aplysia*

Comments:

1. *Aplysia* (Fig. 8.7) is commonly known as sea-hare.

2. The body is bilaterally symmetrical, soft and lumpy with a thin flexible plate-like shell covered by mantle.

3. The head has two pairs of tentacles. The posterior pair tentacles become ear-like and are called rhinophores.

4. Mantle possesses unicellular ink glands. These secrete purple ink used for defence.

5. The foot is broad and flat and bears a pair of lateral folds parapodia that help in swimming.

6. Anus lies at the posterior end.

7. It is bisexual. It has a single gonoduct.

8. *Aplysia* feeds mainly on the sea weeds.

Habit and habitat:

Aplysia is a marine gastropod found crawling in sea weeds. It is herbivorous. It changes its color according to the color of sea weeds it eats.

Distribution:

Aplysia is found in most parts of of the world from the Arctic to the Antarctic.

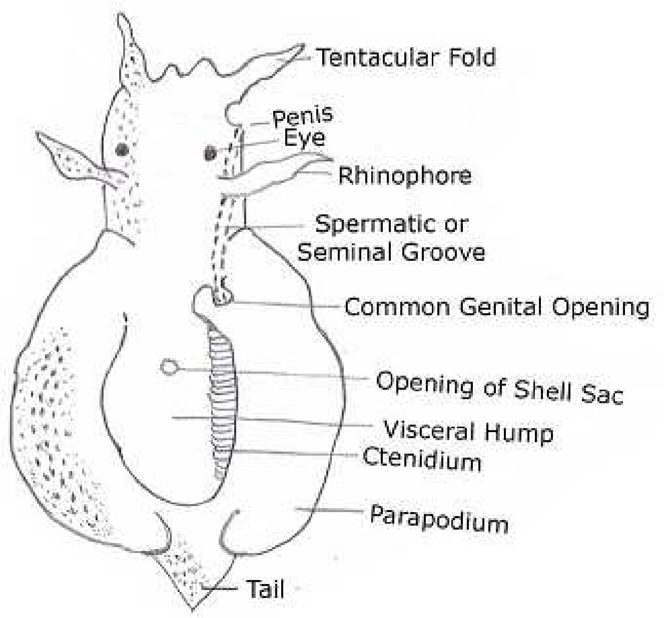


Fig. 8.7 *Aplysia*

EOLIS:

Systematic position

Phylum Mollusca

Class Gastropoda

Order Nudibranchia

Genus *Eolis*

Comments:

1. *Eolis* (Fig. 8.8) is commonly known as sea slug.

2. Body is soft, about 5 cm in length and orange with brown spots.

3. Head bears two pair of cylindrical retractile tentacles and sessile eyes at the base of the posterior pair of tentacles.

4. The mouth is prominent and can be most easily seen from the ventral view. Locomotion happens via foot which is muscular and ventral.

5. Shell, mantle and true gills are absent.

6. Anus is situated at the dorsal surface.

7. It is hermaphroditic.

8. It is used in traditional medicines in the Far East.

Habit and habitat:

Eolis inhabits shallow waters, found often crawling on the underside of sea weeds. It feeds on plankon and decaying matter on the ocean floor along with grazing on the rocks and coral reefs for algae.

Distribution:

Eolis is found in Europe, Rhodes Island to Arctic Ocean and U.S.A.

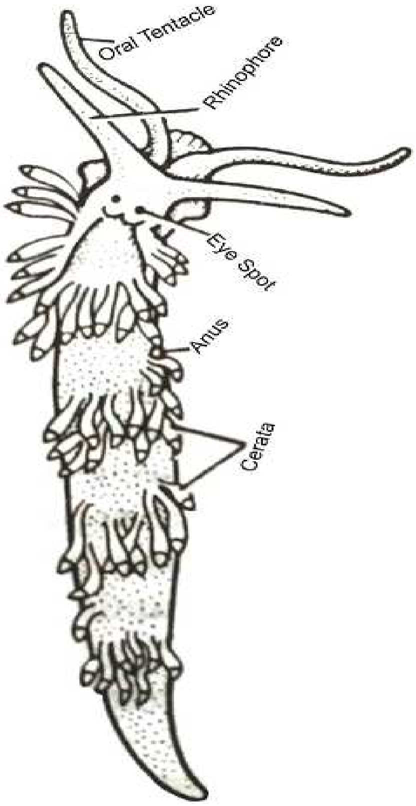


Fig. 8.8 *Eolis*

HELIX

Systematic position

Phylum Mollusca

Class Gastropoda

Order Stylommatophora

Genus *Helix*

Comments:

1. *Helix* (Fig. 8.9) is commonly called garden snail.

2. Body is enclosed in a shell and divisible into head, foot and visceral hump.

3. Shell is thin and bears prominent lines of growth.

4. Head bears two pairs of tentacles, the smaller pair bears smell organs and the larger pair bears a pair of simple eyes.

5. Mouth is located underneath the head.

6. Foot possesses a flat ventral surface and used for creeping.

7. Respiration by pulmonary sac or lung.

8. Hermaphrodite.

9. Some snails may live more than 30 years but most live less than 8 years.

9. Snails are eaten the world over. Snail eggs are a speciality food in certain European countries.

Habit and habitat:

Helix is terrestrial rather than marine. It is generally herbivorous however there are some species that are carnivorous or omnivorous. In winter it hibernates in the soil.

Distribution:

Helix is found in Palearctic region.

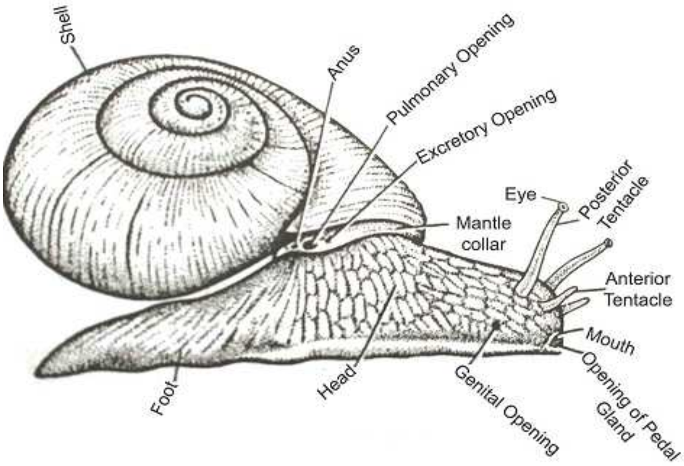


Fig. 8.9 *Helix*

8.3.5 *Mytilus*:

Systematic position:

Phylum Mollusca

Class Pelecypoda

Order Filibranchiata

Genus *Mytilus*

Comments:

1. *Mytilus* (Fig. 8.10) is commonly known as sea mussel.

2. Body is enclosed in a wedge-shaped shell and can be divided into head, foot, visceral mass and mantle.

3. The shell is bivalve with the anteriorly placed umbo and encloses internal structures such as gills, kidney, heart, alimentary canal.

4. A pair of simple eyes is found.

5. A pair of gills is present, each gill having gill filaments.

6. Foot is long, cylindrical and has a ventral groove continuous with a byssus pit.

7. Sexes are separate.

Habit and habitat:

Mytilus is marine, sedentary and found attached to the rocks between tidemarks.

Distribution:

Mytilus is cosmopolitan in distribution. It is commonly found in Europe, India and U.S.A.

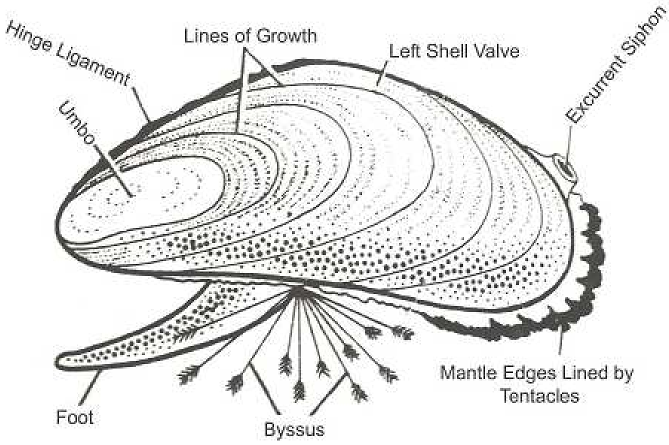


Fig. 8.10 *Mytilus*

OCTOPUS:

Systematic position:

Phylum	Mollusca
Class	Cephalopoda
Order	Octopoda
Genus	*Octopus*

Comments:

1. An *Octopus* (Fig. 8.11) is commonly called devil fish.

2. The body is unsegmented, symmetrical and soft bodied animals.

3. The head bears a pair of eyes. The mouth is surrounded by eight elongated equal arms usually bearing suckers.

4. Shell is absent.

5. It moves around by crawling or swimming.

6. For defence it ejects ink from the ink-gland into the surrounding water, producing a smoky cloud.

7. In males one of the arms, called hectocotylized arm, bears a spoon shaped organ at its end. The arm is used to caress the female and deposit spermatophores beneath its mantle.

8. Sexes are separate.

9. Development is direct.

10. It feed upon crabs, bivalves and fishes etc.

Habit and habitat:

Octopus is a nocturnal marine creature inhabits many diverse regions of the ocean, including coral reefs, pelagic waters and the ocean floor.

Distribution:

Octopus is cosmopolitan in distribution. It is generally found in Europe, India, Pacific and Atlantic coasts.

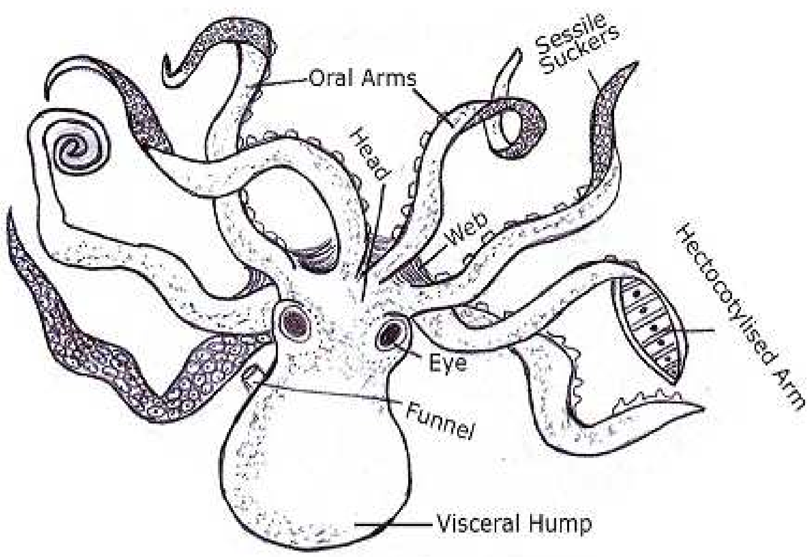


Fig. 8.11 *Octopus*

8.4- T. S. of glochidium larva:

Comments

1. Glochidium larva (Fig. 8.12) is found in the development of pelecypoda or bivalvia.

2. It is a minute larva measuring 0.1 to 0.4 mm, comprises a bivalve shell and false mantle lining the shell.

3. Shell consists of two trinangular valves which are convex externally and concave internally. The valves are attached to each other on dorsal side only.

4. Ventral end of each valve is like curved hook bearing spines.

5. Mantle lobes are small bearing brush-like sensory organs.

6. The closure of the valves is effected by the large adductor muscle present between them.

7. Byssus gland is situated above the adductor muscle which gives rise to a long sticky thread, called provisional byssus.

8. Glochidium larva leads a parasitic life for about 10 weeks before metamorphosis into adult. It does show by attaching itself to the skin or gills or fins of a fish through hooked ventral ends (Wikipedia).

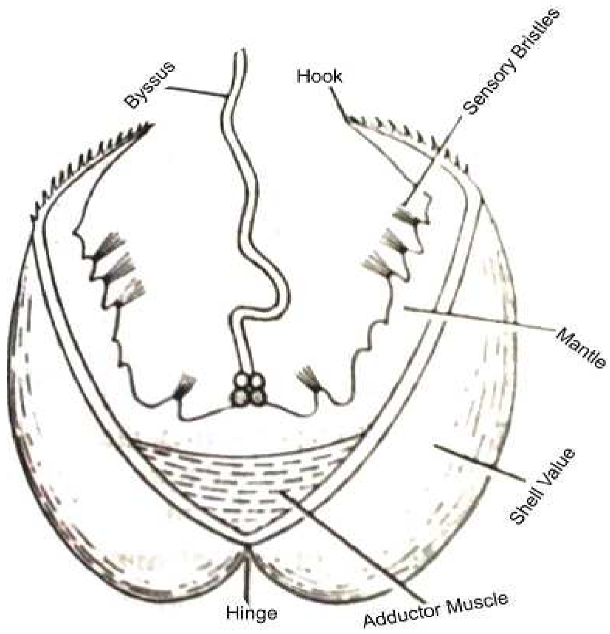


Fig. 8.12 T. S. of glochidium larva of *Unio*

T. S. of *Unio* through Anterior Region:-

Comments:

1. Sections of shell, mantle, foot and other structures are seen (Fig. 8.13).

2. The two shell valves are connected at the top and open at the bottom.

3. Club shaped foot occupies major portion of mantle cavity.

4. Inner and outer gill-laminae are present on either side of the foot. Each gill lamina is made up of two folds called outer and inner gill-lamellae.

5. Sections of keber’s organ, bladder, kidney, rectum, intestine and gonads are seen at their respective places.

6. Pericardial cavity, within the mantle cavity, surrounds a pair of auricles and a ventricle.

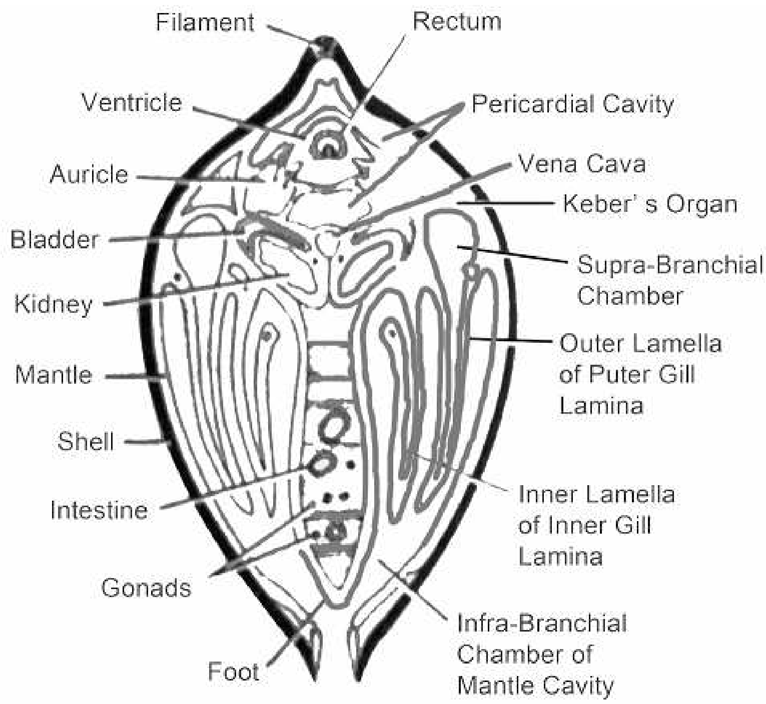


Fig. 8.13 T. S. of *Unio* through Anterior Region

T. S. of *Unio* through Posterior Region

Comments:

1. Sections of shell and mantle are seen (Fig. 8.14).

2. The two shell valves are connected at the top and open at the bottom.

3. Anteriorly section of rectum is seen. Well developed posterior adductor muscle can be seen below rectum.

4. Below the posterior adductor muscle lies the visceral ganglion.

5. Mantle is seen associated with gill-laminae. Each gill-lamina is made up of outer and inner gill lamellae.

6. Supra-branchial chamber and infra-branchial chamber of mantle cavity are seen.

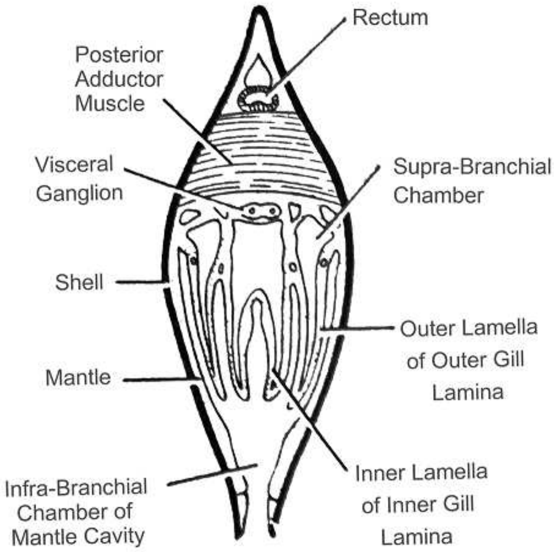


Fig. 8.14 T. S. of *Unio* through Posterior Region

T. S. of Gill of *Unio*

Comments:

1. Each gill is composed of inner laminae and the outer laminae (Fig. 8.15).

2. Each lamina is made of two lamellae; outer and inner lamella.The lamellae are free dorsally but are attached to each other at their anterior, ventral and posterior edges at regular intervals by inter-lamellar junctions forming a series of ventral compartments or water pleats.

3. Each gill-lamella is composed of a series of thin vertical gill-filaments which are connected to one another by horizontal bars or inter-filamentar junctions.

5. Minute apertures or Ostia are present between the gill filaments that open into the water tube.

6. Gill filaments are covered with ciliated epithelium and are supported by internal chitinous rods.

7. Afferent and efferent branchial vessels are present on the outer edges of each inter-lamellar junction (Verma, 2015).

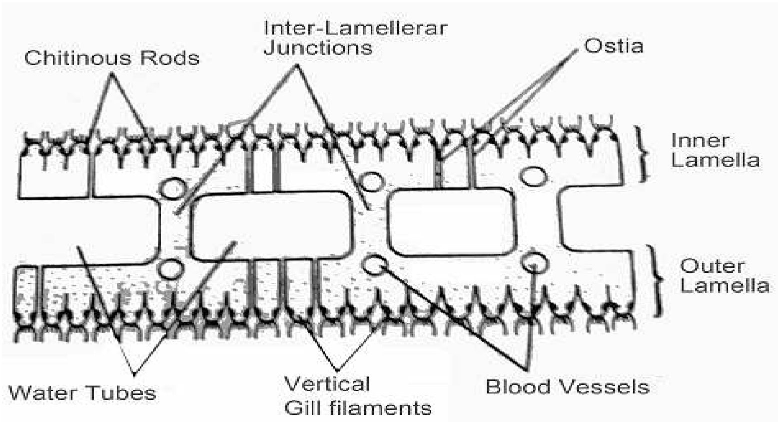


Fig. 8.15 T. S. of Gill of *Unio*

8.5- Summary:-

Phylum mollusca (L., molluscus, soft) includes soft-bodied invertebrate animals such as Octopods, snails, slugs, mussels, clams, oysters, tusk-shells, squids etc. It is a very successful, diverse and widespread group, with about 112,000 species.

The largest of the molluscan classes is Gastropoda, which is represented by about 35,000 living and some 15,000 fossil species.

Molluscs can be segregated into seven classes: Aplacophora, Monoplacophora, Polyplacophora, Bivalvia, Gastropoda, Cephalopoda, and Scaphopoda. These classes are distinguished by, among other criteria, the presence and types of shells they possess. Class Aplacophora includes worm-like animals with no shell and a rudimentary body structure. Members of class Monoplacophora have a single shell that encloses the body. Members of class Polyplacophora are better known as "chitons;" these molluscs have a large foot on the ventral side and a shell composed of eight hard plates on the dorsal side. Class Bivalvia consists of mollusks with two shells held together by a muscle; these include oysters, clams, and mussels. Members of class Gastropoda have an asymmetrical body plan and usually have a shell, which can be planospiral or conispiral. Their key characteristic is the torsion around the perpendicular axis on the center of the foot that is modified for crawling. Class Scaphopoda consists of mollusks with a single conical shell through which the head protrudes, and a foot modified into tentacles known as captaculae that are used to catch and manipulate prey. Molluscan shells have always been economically important, having served as money in early days.

They have been used in jewellery and buttons. The scientific study of molluscs is called malacology.

8.6 References:

1. Kotpal, R. L. (2005): Modern text book of Zoology Invertebrates (Animal Diversity-I). Rastogi Publications pp 705-773.

2. Rastogi V. B. (2015): Invertebrate Zoology. Publisher- Kedar Nath Ram Nath.

3. Verma, P. S. (2015): A Manual of Practical Zoology Invertebrates. S. Chand & Company Pvt. Ltd. Ram Nagar, New Delhi-110055.

4. Yadav, V., Yadav, P. Varshney, V. K., Varshney, V. C. (2015): Text Book of Practical Zoology-I. Publisher- Kedar Nath Ram Nath Merrut.

5. Wikipedia.org:

8.7-Self Assessment Question

Long Answer type questions:

1. Classify Mollusca up to orders, giving their characters and examples.

2. Write short notes on: (1) *Octopus* (2) *Helix* (3) *Aplysia* (4) *Chiton* (5) *Pila*

3. Describe various larval stages of Mollusca.

Multiple choice questions:

1. Devil fish is:

(a) *Unio* (b) *Loligo*

(c) *Chiton* (d) *Octopus*

2. The scientific name of sea mussel:

(a) *Unio* (b) *Mytilus*

(c) *Eolis* (d) *Helix*

3. Torsion is the characteristics of:

(a) Scaphopoda (b) Gastropoda

(c) Pelecypoda (d) Aplacophora

4. Which of the following is not a larva of Molluscs:

(a) Glochidium (b) Veliger

(c) Cercaria (d) Trochophore

5. Radula is found in:

(a) *Pila* (b) *Loligo*

(c) *Sepia* (d) *Unio*

Answer: 1. (d) 2. (b) 3. (b) 4. (a) 5. (c)

UNIT 9: PHYLUM ECHINODERMATA

Contents

9.1- Objectives

1. Understanding the general characters of echinodermata.
2. To understand its classification.
3. To explain some important echinoderms species.
4. Understanding the morphology and habitat of one of the important species of *Asterias*.

9.2-Introduction

Phylum echinodermata (Gr., echinos=spiny+derma=skin, ata=characterized by) includes exclusively marine invertebrates displaying pentamerous radial symmetry and an endoskeleton of calcareous plates and spines. Jacob Klein gave the name echinodermata. This phylum is a collection of about 7,000 living species and constitute some of the most beautiful members of sea fauna, such as starfishes or sea stars, sea urchins, sea cucumber, sea lillies and sand dollars etc. The name 'starfish' is, however, misleading as these animals are not true fishes. A more suitable name suggested for them is 'sea star'. Common genera of sea stars are *Asterias*, *Pentaceros*, *Astropecten*, *Solaster*, *Heliaster*, *Luidia*, *Asterina* etc. Genus *Asterias* includes about 150 species of which most common is *A. Rubens*.

The echinoderms are important both biologically and geologically. Biologically, there are few other groupings so abundant in the biotic desert of the deep sea, as well as shallower oceans. Echinoderms generally have remarkable powers of regeneration of tissue, organs, limbs, and of asexual reproduction, and in some cases, complete regeneration from a single limb. Geologically, the value of echinoderms is in their ossified skeletons, which are major contributors to many limestone formations, and can provide valuable clues as to the geological environment.

General characters:-

1. Echinoderms (Gr. Echinos=hedgehog+derma=skin) are exclusively marine, free living and mostly bottom-dwellers.
2. Body triploblastic, coelomate and symmetrical.
3. Organ system grade of body organization.
4. Body unsegmented with star-like, spherical, globular, discoidal or elongated with radiating arms.
5. Head is absent. Body is generally pentameric.

6. Body surface with five radial areas, the ambulacra, with tube feet and five inter-radial areas, the inter-ambulacra.

7. Coelom is a large cavity lined by ciliated peristomium, coelomic fluid with coelomaocytes.

8. Endoskeleton is made up of spines and calcareous spicules.

9. Water vascular system or ambulacral system present, usually with a madreporite.

10. Sense organs are poorly developed.

11. Nervous system consists of a circum-oral ring and radial nerves. Brain is absent.

12. Respiratory organs include tube feet, respiratory tree, dermal branchiae and bursae.

13. Alimentary canal straight or coiled.

14. Circulatory or haemal or blood lacunar system is typically present.

15. Excretory organs absent.

16. Reproduction is usually sexual but few reproduce asexually or by regeneration.

17. Sexes are separate. Fertilization is external and development indirect through free-swimming larval forms.

Classification

Subphylum 1. Eleutherozoa (Gr., eleutheros=free+zoios=animal)

Class 1. **Asteroidea** (Gr., aster= star + eidos = form)

1. Starfishes or sea stars.

2. Body includes five radiating arms.

3. Tube feet with suckers.

4. Pedicellariae present.

5. Free-living, slow creeping and scavengerous.

Subclass 1. **Somasteroidea**

1. Fossil Palaezoic sea stars. *Platasterias latiradiata* is the only living species.

Subclass 2. **Euasteroidea**

1. Living sea stars.

Order 1. **Phanerozonia**

1. Body with marginal plates and papulae on aboral surface.
2. Tube feet without suckers.
3. Pedicellariae alveolar or sessile type.
4. It mostly lives in burrows in soft bottom.

Examples: *Goniaster*, *Astropecten*, *Oreaster, Luidia*.

Order 2. **Spinulosa**

1. without conspicuous marginal plates but with papulae on both surfaces.
2. Tube feet with suckers.
3. Pedicellariae is rarely present.
4. Aboral surface with low spines.

Examples: *Echinaster*, *Asterina*, *Solaster*, *Pteraster*.

Order 3. **Forcipulata**

1. Marginal plates inconspicuous or absent.
2. Four rows of tube feet present.
3. Pedicellariae pedunculate and straight or crossed.

Examples: *Asterias*, *Heliaster*.

Class 2. **Ophiuroidea** (Gr., ophis = snake + oura = tail + eidos = form)

1. Includes brittle stars and allies.
2. Arms usually five, rarely six or seven, and are long, slender, smooth or spiny.
3. Body flattened with a pentamerous and has rounded central disc.
4. Pedicellariae is absent.

5. Tube feet without suckers.

Order 1. **Ophiurae**

1. Brittle and serpent stars.
2. Small and five-armed.
3. Arms move transversely.
4. Single madreporite.

Examples: *Ophiothrix*, *Ophioderma*, *Ophiopholis, Ophiura*.

Order 2. **Euryalae**

1. Arms are simple and branched, vertical movement.
2. Disc and arm covered by soft skin.
3. one madreporite in each inter-radius.

Examples: *Asteronyx*, *Gorgonocephalus* (basket star).

Class 3. **Echinoidea** (Gr., echinos = hedgehog + eidos = form)

1. Sea urchins and sea dollars.
2. Body spherical, disc-like, oval or heart-shaped.
3. Chewing apparatus or Aristotle's lantern with teeth.
4. Skeleton with movable spines and three-jawed pedicellariae.
5. Sexes are separate.

Subclass 1. **Bothriocidaroida**

1. A single row of plates in each inter-ambulacral area.
2. Without typical lantern.

Examples: Single extinct Ordovician genus *Bothriocidaris.*

Subclass 2. **Regularia**

1. Body pentamerous, globular, with two rows of inter-ambulacral plates.

2. Aristotle's lantern well developed.

3. Mouth central.

4. Madreporite oral.

Order 1. **Lepidocentroida**

1. Test flexible with overlapping plates.

2. Ambulacral plates extend up to mouth lip.

3. Inter-ambulacral plates in more than two rows in extinct forms.

Example: *Palaeodiscus* , *Phormosoma.*

Order 2. **Melonechinoida**

1. Test spherical and rigid.

2. Inter-ambulacral plates in four or more rows.

3. Ambulacral plates continue to mouth lip.

4. Wholly extinct.

Example: *Melonechinus*.

Order 3. **Cidaroida**

1. Test globular and rigid.

2. Two rows of long narrow ambulacral plates and two rows of inter-ambulacral plates.

3. No peristomial gills.

4. Anus aboral and central.

Examples: *Goniocidaris, Histocidaris*, *Cidaris.*

Order 4. **Diadematoida**

1. Test globular usually with compound ambulacral plates.

2. Anus aboral and central.

Examples: *Echinus, Arbacia*, *Diadema*.

Subclass 3. **Irregularia**

1. Body circular or oval flattened oral-aborally.
2. Mouth central or displaced anteriorly on oral surface.
3. Anus marginal, outside the apical system of plates.
4. Tube feet generally not locomotor.

Order 1. **Holectypoida**

1. Test regular with simple ambulacra and centrally located peristome and apical system.
2. Lantern present.
3. Mostly extinct.

Examples: *Echinoneus*, *Holectypus*.

Order 2. **Cassiduloida**

1. Aboral ambulacra area petloid, forming a five-armed figure like petals of a flower.
2. Lantern absent.
3. Mostly extinct.

Examples: *Cassidulus*.

Order 3. **Clypeastroida**

1. Test flattened with oval or rounded shape.
2. Mouth central, anus excentric.
3. Aboral ambulacral areas petaloid.
4. Bottom dwellers.

Examples: *Echinarachinus, Clypeaster, Echinocyamus*.

Order 4. Spatangoida

1. Test oval or heart-shaped with excentric mouth and anus.

2. Four aboral ambulacral areas paloid.

3. Lantern absent.

4. Burrowing forms.

Examples: *Hemipneustes*, *Spatangus*, *Echinocardium lovenia*.

Class 4. Holothuroidea (Gr., holothurion = sea cucumber + eidos = form)

1. Sea cucumbers.

2. Body elongated, bilaterally symmetrical in the oral-aboral axis having mouth at or near one end and anus at or near the other end.

3. Arms and spines are absent.

4. Mouth anterior, surrounded by tentacles.

5. Respiration takes place *via* respiratory tree.

Order 1. Dendrochirota

1. Tentacles irregularly branched.

2. Numerous tube feet.

3. Respiratory tree are present.

Examples: *Cucumaria*, *Thyone*.

Order 2. Aspidochirota

1. Tentacles peltate or leaf-like.

2. Numerous podia or tube feet.

3. Pharynx absent.

4. Respiratory tree present.

Examples: *Holothuria*, *Actinopyga*.

Order 3. **Elasipoda**

1. Tentacles leaf-like.
2. Tube feet webbed together to form fins.
3. Respiratory tree absent.
4. Deep-sea dwellers.

Examples: *Pelagothuria*.

Order 4. **Molpadonia**

1. Fifteen digitate tentacles.
2. Tube feet are absent.
3. Respiratory tree present.

Examples: *Molpadia, Caudina*.

Order 5. **Apoda**

1. Worm-like sea cucumbers.
2. Respiratory tree or tube feet absent.
3. Burrowing forms.

Examples: *Leptosynapta, Synapta*.

Subphylum II. **Pelmatazoa** (Gr., pelmatos = stalk + zooios = animal)

Stalked, sedentary echinoderms.

Class 1. **Crinoidea** (Gr., crinon = lily + eidos = form)

1. Sea lilies.
2. Body attached during part or whole life by an aboral stalk.
3. Mouth and anus on oral surface.
4. Arms with pinnules.
5. Tube feet without suckers; madreporite, spines and pedicellariae absent.

Order. **Articulata**

1. Living sea lillies and feather stars.

2. Calyx pentamerous.

3. Feather stars are sessile and free-swimming.

Examples: *Antedon*, *Neometra*.

9.3- IDENTIFICATION, SYSTEMATIC POSITION AND GENERAL STUDY

9.3.1 ECHINUS & *HOLOTHURIA*

Systematic position:

Phylum	Echinodermata
Class	Echinoidea
Order	Camarodonta
Genus	*Echinus*

Comments:

1. *Echinus* is commonly called sea-urchin (Fig 1).

2. It has a globe-shaped body enclosed within a shell or corona and having very long movable spines. The surface of corona is divided into five ambulacral regions alternating with five interambulacral regions. In each ambulacral region, there are two rows of tube feet.

3. Mouth is present on oral surface and is surrounded by peristome. The chewing apparatus or Aristotle's lantern projects from the mouth. Anus is surrounded by a periproct and is present in the centre of the aboral surface.

4. Water-vascular system is well developed.

5. Development is indirect and involves free swimming echinopluteus larva.

6. Sexes are separate. Gonads are five large masses.

Habit and habitat:

Echinus is marine, found in the sea in the rocky places.

Distribution:

Echinus is widely distributed in the Atlantic, Mediterranean and Pacific Oceans.

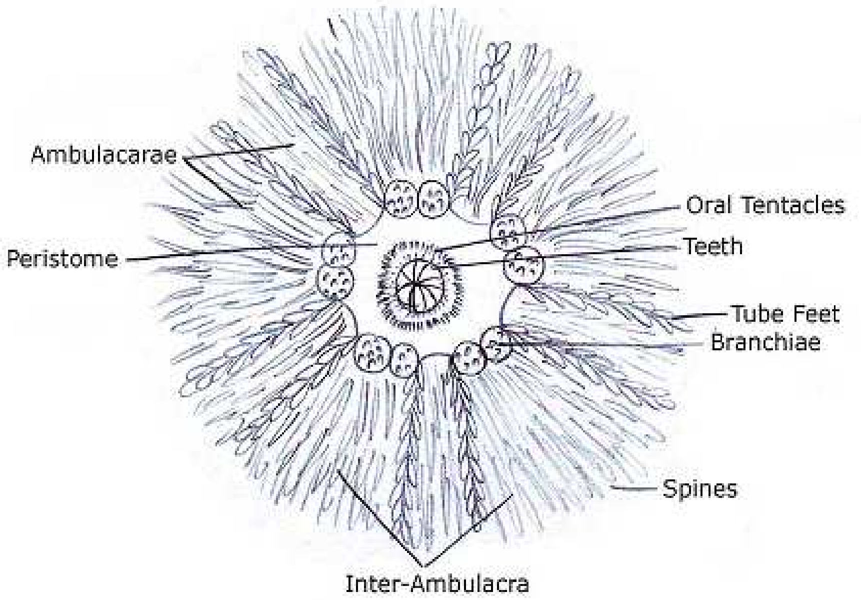


Fig. 9.1 *Echinus*

HOLOTHURIA:

Systematic position:

Phylum	Echinodermata
Class	Holothuroidea
Order	Aspidochirota
Genus	*Holothuria*

Comments:

1. *Holothuria* is commonly known as sea-cucumber (Fig. 9.2).

2. It is found in nearly every marine environment, but is most diverse on tropical shallow-water coral reefs.

3. The body is sausage-shaped, elongated, covered with leathery skin and having well developed respiratory tree.

4. Mouth is anteriorly placed, surrounded by 15-30 peltate tentacles.

5. Sexes are separate.

6. Development includes two larval stages doliolaria and auricularia respectively.

7. *Holothuria* feeds by pushing sand containing organic food into mouth with the help of tentacles.

Habit and habitat:

Holothuria is found in shallow tropical and subtropical waters of Indo-Pacific area, lying together in thousands on the sandy bottom, fully exposed or somewhat hidden under plants or shell bits, etc.

Distribution:

Holothuria is found distributed in India, West Indies and Florida.

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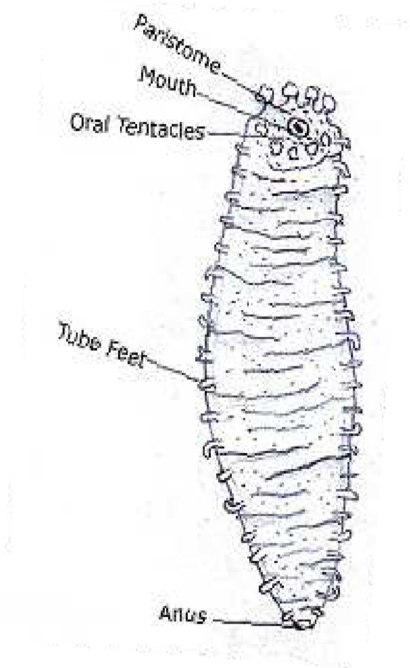


Fig. 9.2 *Holothuria*

9.3.2 *PENTACEROS* and *OPHIOTHRIX*

Systematic position:

Phylum	Echinodermata
Class	Asteroidea
Order	Phanerozonia
Genus	*Pentaceros*

Comments:

1. *Pentaceros* is known as sea pentagon.

2. The body is very thick and regular star-shaped and has a diameter of about 25 cm.

3. Central disc is large and the five arms are short and tapering.

4. Aboral surface is convex and bears rows of definitely arranged spines. Oral surface is concave, having a central mouth, communicating with five ambulacral groves, each bearing two double rows of tube feet.

5. Pedicellariae is small and valvate type.

6. Sexes are separate.

7. Development indirect which includes bipinnaria larva.

8. *Pentaceros* is very harmful to pearl industry as it feeds on pearly oysters (Fig. 9.3).

Habita and habitat:

Pentaceros is marine. It feeds on oysters, thus, it is very harmful to the pearl industry.

Distribution:

Pentaceros is found commonly in the Indo-Pacific Ocean and around the West Indies; in the Bay of Bengal and Arabian Sea.

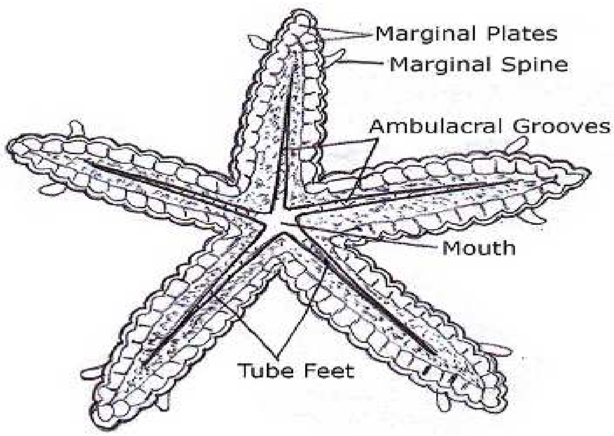


Fig. 9.3 *Pentaceros*

OPHIOTHRIX

Systematic position:

Phylum Echinodermata

Class Ophiuroidea

Order Ophiurae

Genus *Ophiothrix*

Comments:

1. *Ophiothrix* is a commonly known as spiny brittle star.

2. It has a small rounded central disc and five slender jointed arms arising from the lower suface to the disc.

3. The arms are covered on all sides by the plates or shields finged with spines.

4. The oral surface also bears five oral shields and podial-pores.

5. The tube feet without suckers are present on the lower plates of arms.

6. *Ophiothrix* possesses a great power of regenerating its lost arm (Fig.9.4)

Habit and habitat:

It is cosmopolitan but more abundant in tropical waters. It feeds on decaying matter and microbes found on soft muddy bottoms.

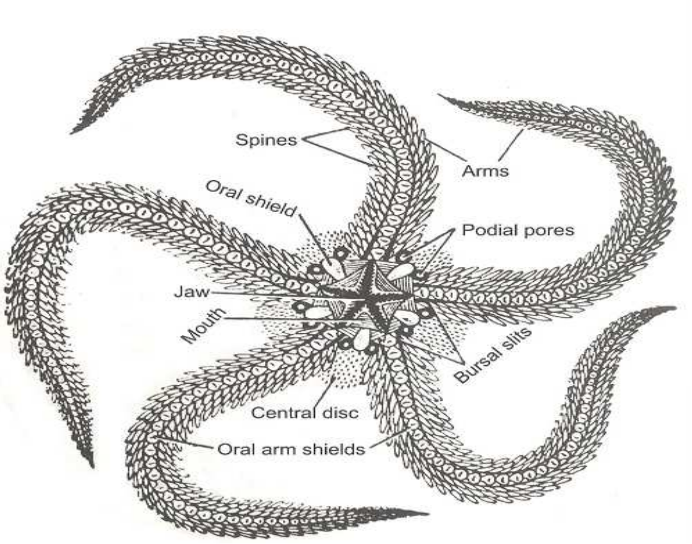


Fig. 9.4 *Ophiothrix*

9.3.2 *ASTERIAS* (STAR FISH) and ANTEDON

Systematic position:

Phylum	Echinodermata
Class	Asteroidea
Order	Forcipulata
Genus	*Asterias*
Species	*rubens*

Comments:

1. *Asterias* is commonly known as starfish or sea star (Fig. 9.5).

2. Average size of *Asterias* ranges from 10 to 25 cm in diameter.

3. The body is star shaped, consisting of a central disc with five radiating arms which are broad at their base and tapering towards their extremities.

4. Mouth is pentagonal and lies in the centre of the disc on oral surface.

5. Aboral surface bears a number of short, stout spines arranged in irregular rows, numerous dermal branchiae among spines and a smaller aperture, the anus which is situated near the centre.

6. Pedicellariae are very small, microscopic bodies scattered all over the body.

7. Water vascular system is well developed.

8. Sexes are separate. Fertilization is external.

9. Development includes a free swimming bippinnaria larva.

Habit and habitat:

Asterias are free-living marine animals that can be found at all water depths as well as crawling over rocks and shells *Asterias* is a marine form and found in the sandy and rocky parts of the sea.

Distribution:

Asterias is found in shallow water in North Temperate seas and found abundantly on North-Atlantic coast. It is found in abundance in India and U.S.A.

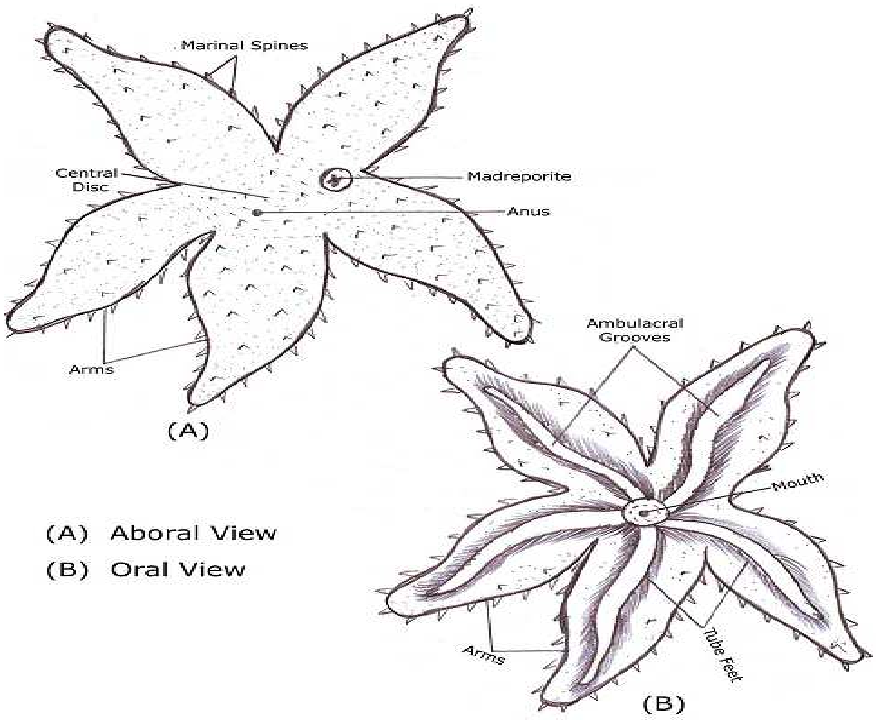


Fig. 9.5 *Asterias*

ANTEDON:

Systematic position:

Phylum	Echinodermata
Class	Crinoidea
Order	Articulata
Genus	*Antedon*

Comments:

1. *Antedon* is commonly known as feather star (fig. 9.6).
2. Body consists of a central disc or calyx and a series of five radiating arms.
3. It has a central leathery disc covered with bony plates with oral and aboral surfaces.
4. Each arm is divided at its base into two, so that there are ten long slender flexible arms, bearing lateral pinnules.
5. Tube feet without suckers present along the edges of ambulacral grooves.
6. Sexes are separate.
7. It has an amazing power of regeneration.
8. Development includes a pentacrinoid larva wih jointed stalk.

Habit and habitat:

It is cosmopolitan marine animal that occurs in shallow as well as deep waters. They are gregarious forms and feed on microscopic living organisms.

Distribution:

Antedon is worldwide in distribution, found in all seas. It is commonly found along Atlantic Coast.

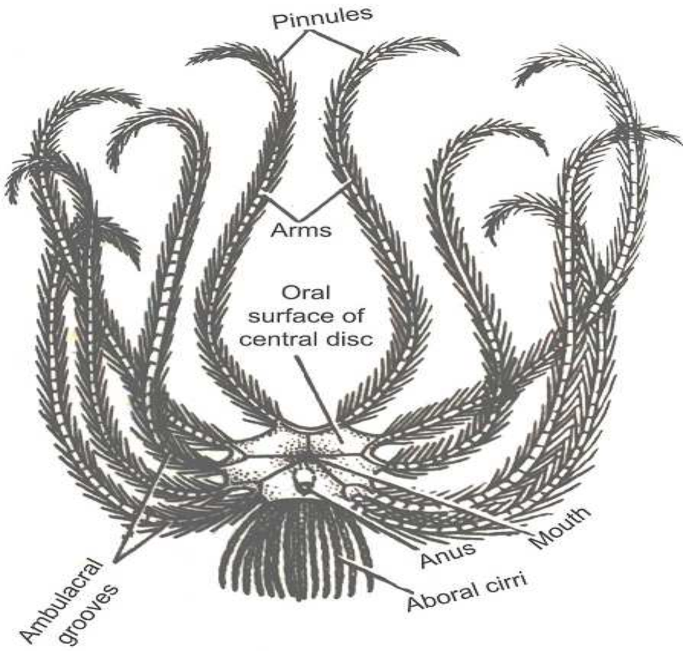


Fig 9.6 Antedon

9.3.5 PEDICELLARIAE OF STAR FISH:

Comments:

1. Pedicellariaes are whitish modified spine-like structures found scattered all over the body.

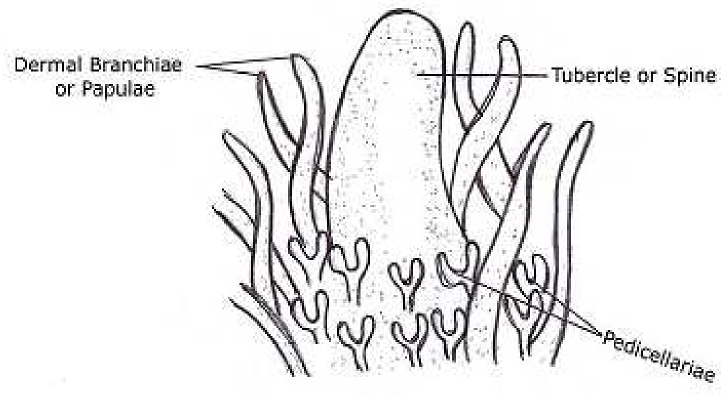
2. On the oral surface they are found attached to the bases of spines, while on the aboral surface they are found in the intervals between the spines.

3. There are two types of pedicellariae, viz., straight type and crossed type.

4. Each pedicellaria consists of a basilar piece and two jaws or valves or blades.

5. The valves or blades are movably articulated with the basilar piece and can be opened or closed on one another like the beak of a bird. The two valves or blades are operated by two pairs of adductor muscles and one pair of abductor muscles.

6. In some starfishes, the pedicellariae may help in capturing of small prey (Fig. 9.7).



Asterias (A) A cluster of pedicellarae, papulae and tubercle

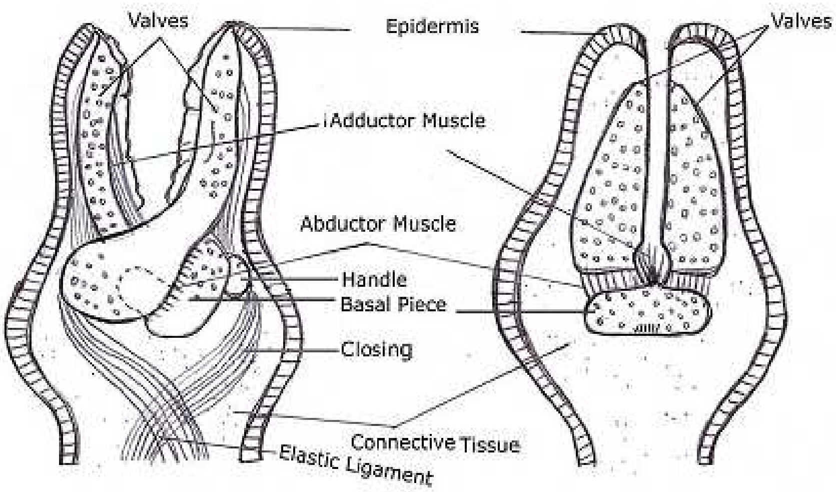


Fig. 9.7 Asterias (B) Crossed type pedicellae (C) Straight type pedicellarae

9.4- Summary

Phylum echinodermata (Gr., echinos=spiny+derma=skin, ata=characterized by) includes exclusively marine invertebrates displaying pentamerous radial symmetry and an endoskeleton of calcareous plates and spines. Jacob Klein gave the name echinodermata.

Echinoderms are exclusively marine, free living and mostly bottom-dwellers. Organ system grade of body organization. *Asterias* are free-living marine animals that can be found at all water depths as well as crawling over rocks and shells. *Asterias* feed mainly upon molluscs, especially bivalves and snails. In addition they act as scavengers on any dead animals. Most *Asterias* possess a pentamerous radial symmetry, secondarily derived from a larval bilateral symmetry. The body is flattened and flexible, with a pigmented and ciliated epidermis. Average size of *Asterias* ranges from 10 to 25 cm in diameter. The aboral and abactinal surfaces are beset with numerous short but stout spines arranged in irregular rows parallel to the long axis of the arms. The mouth is situated in the centre of the oral surface in the form of a five-rayed aperture. Pedicellariae of sea stars are minute, whitish jaw-like structures, found on both the body surfaces, in association with spines. The pedicellariae help in the capture and removal of debris and minute organisms, such as larvae, which may settle on the body surface and interfere with respiration by covering the dermal branchiae and tube feet. In some starfishes, the pedicellariae may help in capturing of small prey. Sea star possesses a complete digestive tract situated in the central disc. Between the mouth and anus it can be differentiated into oesophagus, stomach and intestine. *Asterias* is carnivorous, feeding on any slow moving animal but mainly upon molluscs such as oysters, clams, mussels, snails, etc. The fish crabs and barnacles also make its food. Locomotion is performed with the help of water-vascular system which sets up a hydraulic pressure. *Asterias* or star-fish is unisexual, but there is no sexual dimorphism. The reproductive organs of primitive type and lack copulatory organs, accessory glands and receptacles or reservoirs for storing sperms and ova. There are five pairs of testes or ovaries with one pair at the base of each arm lying freely between pyloric caeca and ampullae of the tube feet. Fertilisation is external. The eggs and sperms are shed in sea-water. The female lays about 200 million eggs in a season.

9.5-References

1. Kotpal, R. L. (2005): Modern text book of Zoology Invertebrates (Animal Diversity-I). Rastogi Publications pp 795-831.

2. Verma, P. S. (2015): A Manual of Practical Zoology Invertebrates. S. Chand & Company Pvt. Ltd. Ram Nagar, New Delhi-110055.

2. **Yadav, V., Yadav, P. Varshney, V. K., Varshney, V. C. (2015)**: Text Book of Practical Zoology-I. Publisher- Kedar Nath Ram Nath Merrut.

9.6-Self Assessment Question

Long answer type questions:

1. Describe phylum Echinodermata and classify it upto orders giving examples.
2. Describe development and life history of any echinoderm you have studied.
3. Give an account of water vascular system of starfish.

Short answer type questions:

1. Write a short note on regeneration and autotomy in starfish.
2. Write a short note on characters of phylum Echinodermata

.

Objective type questions:

1. Sea pentagon is a common name of

   (a) Starfish (b) Sea urchin

   (c) *Cucumaria* (d) *Pentaceros*

2. Aristotle's lanturn is found in

   (a) *Ophiothrix* (b) *Antedon*

   (c) *Echinus* (d) *Cucumaria*

3. Brachiolaria larva occurs in class

   (a) Asteroidea (b) Crinoidea

   (c) Ophiuroidea (d) Echinoidea

4. Locomotary organs of Echinoderms are known as

   (a) Pseudopodia (b) Parapodia

   (c) Tube feet (d) Setae

5. Which of the following echinoderms is called?

   (a) *Asterias* (b) *Echinus*

   (c) *Antedon* (d) *Clypeaster*

Answers: 1. (d) 2. (c) 3. (a) 4. (c) 5. (d)

UNIT 10: STUDY OF LIVING ANIMALS

Contents

10.1- Objectives:-

To study the microscopic Animal and larva of different invertebrates phyla through the permanent slides/whole mount observation

10.2-Introduction:-

The Protozoa are heterogeneous assemblage of some 50,000 cellular or single- cell organism found worldwide in most habitats. Protozoa means 'first animal' the simplest form of animal life. Protozoa are unicellular microorganisms (eukaryotes) that lack cell walls. They are found in marine habitat or soil, in fresh water bodies, symbiotic, some forms are parasites in other organisms. Protozoa depends on nutrition, temperature, pH, and some depends on sunlight.

Protozoa were defined as unicellular protists with animal-like behavior, such as movement. Protozoa were regarded as the partner group of protists to protophyta, which have plant-like behavior, e.g. photosynthesis. The term protozoan has become highly problematic due to the introduction of modern ultra structural, biochemical, and genetic techniques, which have showed that the group does not form a clade as required by modern classifications. Modern unicellular clades within Eukaryotes which may be viewed as approximately collectively replacing the class of protozoa include: Excavata, Amoeba, Chromalveolata and Rhizaria.

Protozoans are usually single-celled heterotrophic eukaryotes containing non-filamentous structures that belong to any of the major lineages of protists. They are restricted to moist or aquatic habitats (i.e., they are obligate aquatic organisms). Many protozoan species are symbionts, some are parasites, and some are predators of feces bacteria and algae. There are an estimated 50,000 protozoan species.

The Protozoa are considered to be a subkingdom of the kingdom Protista, although in the classical system they were placed in the kingdom Animalia. More than 50,000 species have been described, most of which are free-living organisms; protozoa are found in almost every possible habitat. The fossil record in the form of shells in sedimentary rocks shows that protozoa were present in the Pre-Cambrian era. Anton van Leeuwenhoek was the first person to see protozoa, using microscopes he constructed with simple lenses. Between 1674 and 1716, he described, in addition to free-living protozoa, several parasitic species from animals, and *Giardia lamblia* from his own stools.

10.3- Study of living animals:-

10.3.1- Study of *Amoeba:-*

Systematic Position

Phylum	Protozoa (Unicellular)
Sub-phylum	Sarcomastigophora (Cilia wanting, locomotion by pseudopodia)
Class	Rhizopodea (Locomotion and feeding by pseudopodia).
Order	Amoebida (Uninucleate)
Genus	*Amoeba*
Species	*proteus*

General study:-

Amoeba was first discovered by **Roesel Von Rosenhof** in 1775. It is regarded as the simplest of all animals, since its body consists of minute transparent asymmetrical specks of protoplasm having a nucleus but without permanent organelles. It is widely distributed and commonly found in the ooze or bottom mud in fresh water pools, ditches, lakes and slow streams, often in shallow water on the undersides of aquatic vegetation. The side of lotus ponds and the water trough are common source for their collection.

Amoeba is a unicellular microscopic animal and measures about 250 to 600 microns or 1/100 inches. It appears as an irregular colorless and translucent mass of protoplasm with finger-like projections from the body in all directions .These are called Pseudopodia. It keeps changing its shape in one direction and withdrawing in other direction. They are broad to cylindrical with blunt rounded tips and are composed of both ectoplasm and endoplasm. Its body is covered by very thin delicate plasma membrane called **plasma lemma**; these have adhesive properties and serve to bind animalcule to the substratum. Inside the plasmalemma is a dense mass of cytoplasm having several organelles .It is differentiated into an outer ectoplasm and an inner endoplasm .Ectoplasm is thin clear (non granular) and hyaline layer while endoplasm forms the main body completely surrounded by the ectoplasm. Endoplasm is made up of the outer stiff plasmagel and inner more fluid plasmasol. Endoplasmic organelles include a single conspicuous nucleus, a contractile vacuole which circulates with in endoplasm. Along with this, numerous food vacuoles are found scattered in the endoplasm. These are non-contractile and are of the different size .Digestion of food takes place inside the food vacuole. Other organallies like E.R, Ribosome, Golgi body, mitochondria, lysosome are also found inside endoplasm.

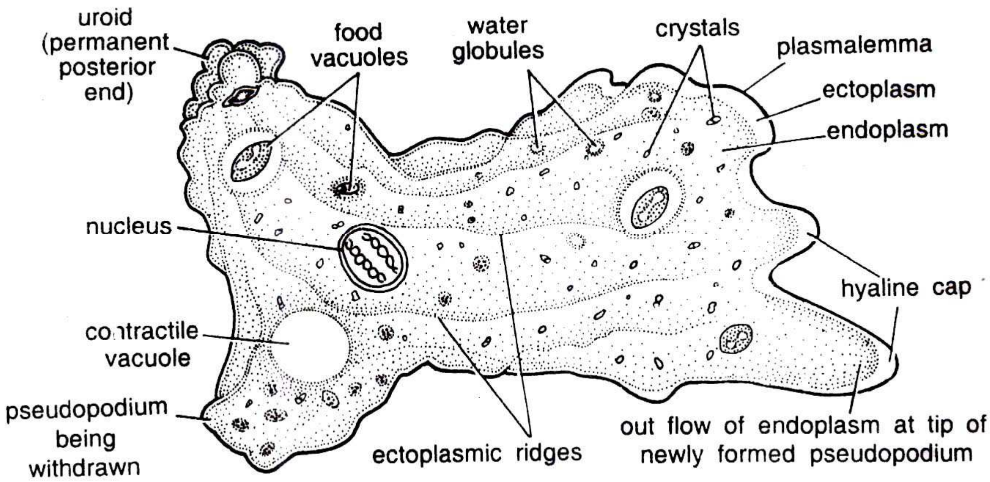


Fig.10.1 Amoeba

Amoeba shows characteristics amoeboid movement by formation of finger like temporary processes, the pseudopodia called lobopodia due to their blunt finger like and rounded tips. These are formed as a result of forward movement of cytoplasm. Many theories have been put forward to explain the formation pseudopodia and the process of locomotion such as .A**dhesion theory, Rolling movement theory, surface tension, contraction theory, sol-gel theory, walking movement theory, folding and unfolding theory, foundation zone contraction theory**.

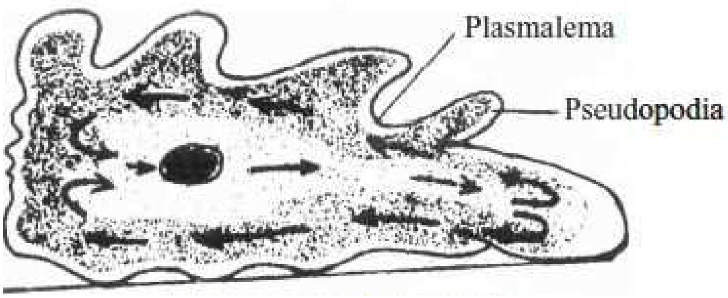


Figure 10.2 - Movement of Amoeba

An *Amoeba* is unable to form its food from simple substance but it requires readymade organism substance for food .Such a mode of nutrition in which solid organism particles are ingested is called **holozoic**. It feeds by phagocytosis, a mechanism in which food is engulfed in a solid form. Its food mainly consists of diatoms, flagellates, ciliates and rotifers. *Amoeba* is able to select its food even in the absence of special sense organ .It can capture and engulfed its food by means of pseudopodia by the formation of food cup when the food comes in contact with the surface the body. According to Rhumbler 1930 *Amoeba* can an ingest its food by circumvallation,circumfluence,import,invagination,pinocytosis.

Digestion is intracellular. It takes place in a primary food vacuole after it gets embedded in the endoplasm. The content of food particles are first acidic due to HCL then alkaline Food is absorbed by diffusion by streaming endoplasm by cyclosis to all parts of the cell. Egestion of undigested residues takes place at any point through no special opening. Respiration in *Amoeba* occurs by diffusion through general body surface (plamalemma).While excretion occurs by diffusion from general body surface. Some amount is dissolved in water which is discharged through the contractile vacuole.

Amoeba responds to the various changes in the environmental condition. *Amoeba* does not have central nervous system and special sense organs so the sensitivity is solely the function of protoplasm. It responds negatively to strong solutions of alkalies, high and low temperature between (20^0 C and 25^0 C). *Amoeba* responds positively to those objects on which it rests, and to the food organism and also towards gravity.

Amoeba reproduces asexually by binary fission, multiple fission and by spore formation. Binary fission resulted the division of parent *Amoeba* into two daughters *Amoeba* by nuclear division followed by cytoplasmic division. Under adverse condition, *Amoeba* reproduces by multiple fission. Under favourable condition 200 spores are also formed in one *Amoeba* called sporulation . While few observers have also described temporary fusion between two *Amoeba*e called conjugation. *Amoeba* has a great power of regeneration. If it is cut into two or more pieces, accidently every piece having nucleus grows into a complete *Amoeba*.

Identifying features:

The animal is of irregular shape with simple or branched pseudopodia and its body is covered by a thin, delicate and permeable plasma membrane called as plasmalemma.

Special feature: It has unique phylogenetic significance and it is referred as immortal. Recently certain free living *Amoeba*e have been found to be pathogenic causing meningo encephalitis

10.3.2 General study of *Paramecium:-*

Systematic Position:-

Phylum Protozoa (Unicellular)

Sub-Phylum Ciliophora (Ciliary movement in all stages).

Class Ciliata (Cilia present throughout life.)

Sub Class Euciliata (Cytopharynx, contractile vacuole, mega and micronucleus present

Order	Holotricha (Equal cilia.)
Sub-order	Trichostomata (Mouth leads into cytopharynx.)
Family	Paramecidae (Oral groove present)
Genus	*Paramecium*
Species	*caudatum*

General Study

Paramecium caudatum is commonly found in freshwater ponds, pools, ditches, streams, lakes, reservoirs and rivers. It is specially found in abundance in stagnant ponds rich in decaying matter, in organic infusions, and in the sewage water. *Paramecium caudatum* is a free-living organism and this species is worldwide in distribution. It is a microscopic organism and visible to the naked eyes as a minute elongate body. It appears light gray or white measuring commonly between 170 to 290 microns in length and may attain a length up to 300-350 microns. *P. caudatum* looks like the sole of a slipper or shoe, hence, the animals in commonly known as slipper animalcule. The body of the animal is asymmetrical in form showing a well defined oral or ventral surface and an aboral or dorsal one. The body is covered by a thin, double layered, elastic and firm pellicle made of gelatin. The pellicle holds the shape of the animal but is elastic enough to permit contractions. The entire body is

Covered with numerous, small, hair-like projections called cilia. When the cilia occur in longitudinal rows all over the body; then it is holotrichous, in which the body cilia are equal.

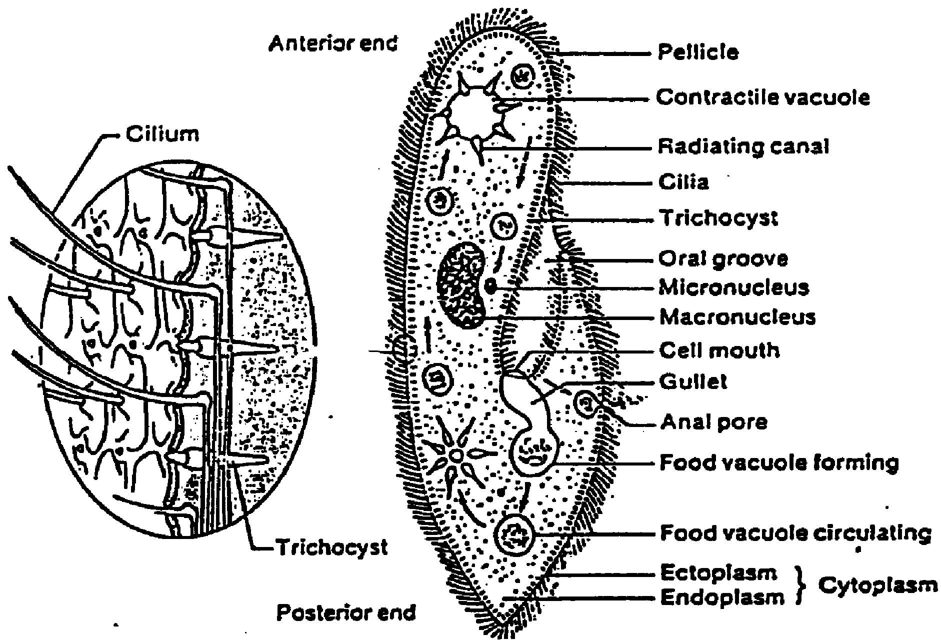


Figure 10.3 Paramecium *caudatatum*

The cilia arise from kinetosomes and from where arises a delicate cytoplasmic fibril called kinetodesma. Oral groove or peristome is situated on the ventrolateral side, which give the animal an asymmetrical appearance. The oral groove leads into a short conical funnel shaped depression called vestibule that leads directly into the cytostome. Extending directly from the cytostome toward the entire of the body is the wide cytopharynx that turns sharply towards the posterior side to become the slender tapering oesophagus.

The cytoplasm is differentiated into a narrow, external or cortical zone called the ectoplasm and a larger, internal or medullary region called the endoplasm .Trichocysts are the spindle shaped bags embedded in the ectoplasm. The endoplasm or medulla is the more fluid and voluminous part of the cytoplasm which contains many cytoplasmic granules. *Paramecium* is heterokaryotic having a large ellipsoidal and granular macronucleus and other small compact micronucleus. There are two large, liquid filled contractile vacuoles which are roughly spherical, non contractile bodies. They contain ingested food particles, principally bacteria and a small amount of fluid bounded by a thin definite. *Paramecium* performs locomotion by two methods, viz., metaboly or body contortions and by cilia .Locomotion brought about by cilia is the main method. The cilia can beat forwards or backwards enabling the animal to swim anteriorly or posteriorly. Cilia of the same transverse row beat together and those of the same longitudinal row beat one after the other from the anterior to the posterior end. This is called metachronal rhythm.

In *Paramecium* nutrition is holozoic. The food comprises chiefly bacteria and minute Protozoa. During Cyclosis digestion occurs by enzymes secreted by protoplasm into the vacuoles. In digestion proteins are changed into amino acids, carbohydrates and fats. The undigested matter is egested through the cytopyge.

The exchange of gases (Oxygen and carbon dioxide) takes place through the semi permeable pellicle by the process of diffusion. *Paramecium* obtains its oxygen from the surrounding water. Carbon dioxide and organic wastes like ammonia are excreted by diffusion outward into the water in the reverse direction.

The responses of *Paramecium* to various kinds to stimuli are learned by study of its reactions and of the grouping or scattering of individuals in a culture. The response is positive negative when it moves away. In avoiding reaction the ciliary beat reverses, and then rotates in a conical path by swerving the anterior end aborally while pivoting on the posterior up. Response to contact is varied in *Paramecium*. While, i.f the anterior end is lightly touched with a fine point. A strong avoiding reaction occurs

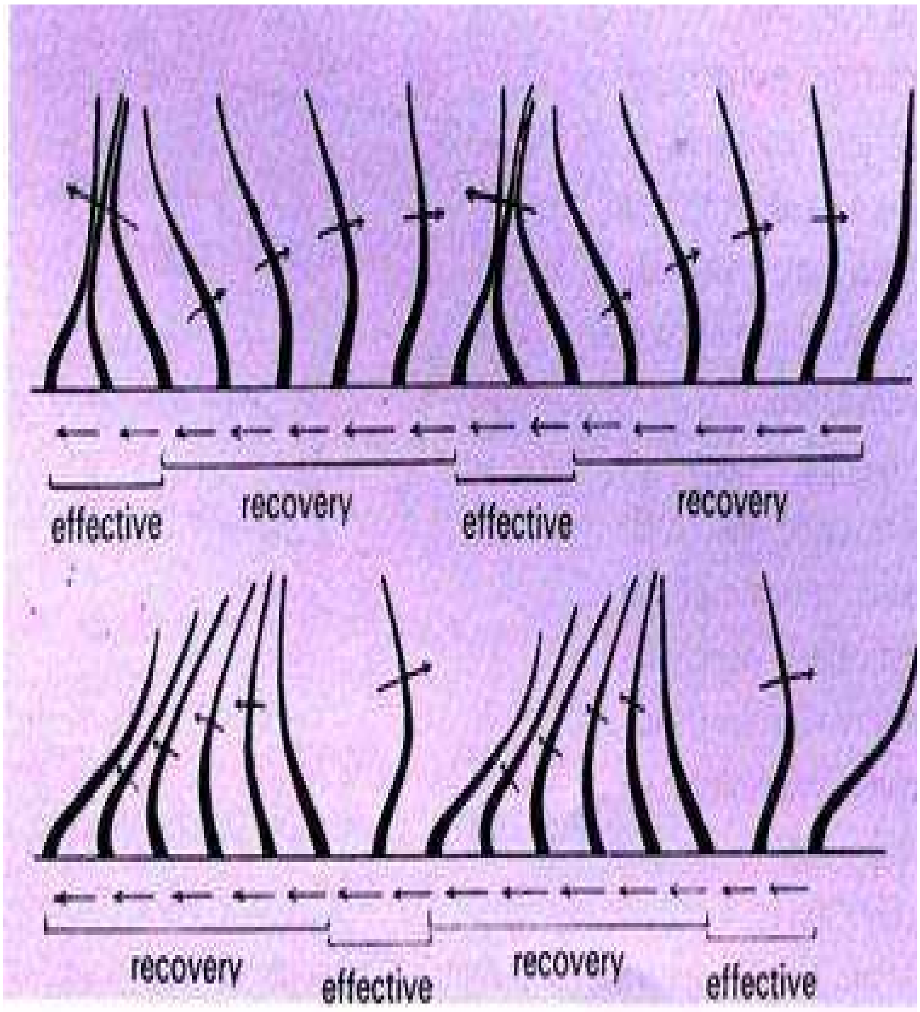


Fig. 10.4 Cilia indicating effective and recovery stroke

Generally Paramecia respond to chemical stimuli by means of avoiding reaction. Paramecia show an avoiding reaction when a temperature change occurs markedly above or below the optimal range (of 24^0 C to 28^0 C). However, when the light intensity is suddenly and sharply increased, a negative reaction is displayed .Paramecia exhibit an immediate negative response to Ultraviolet rays. Paramecia also respond to electric stimuli and positive rheotaxis.

Paramecium reproduces asexually by transverse binary fission and also undergoes several types of nuclear reorganization, such as conjugation, endomixis, autogamy, cytogamy and hemixis, etc. It is a distinctly unique asexual process in which one fully grown specimen divides into two daughter individuals without leaving a parental corps. *Paramecium* reproduces by transverse binary fission during favourable conditions, fission the micronucleus divides by mitosis into two daughter micronuclei, which move to opposite ends of the cell. The macronucleus elongates and divides transversely by amitosis. *Paramecium* multiplies by binary fission for long periods of time, but at intervals this may be interrupted by the joining of two animals along their oral surfaces for of conjugation.

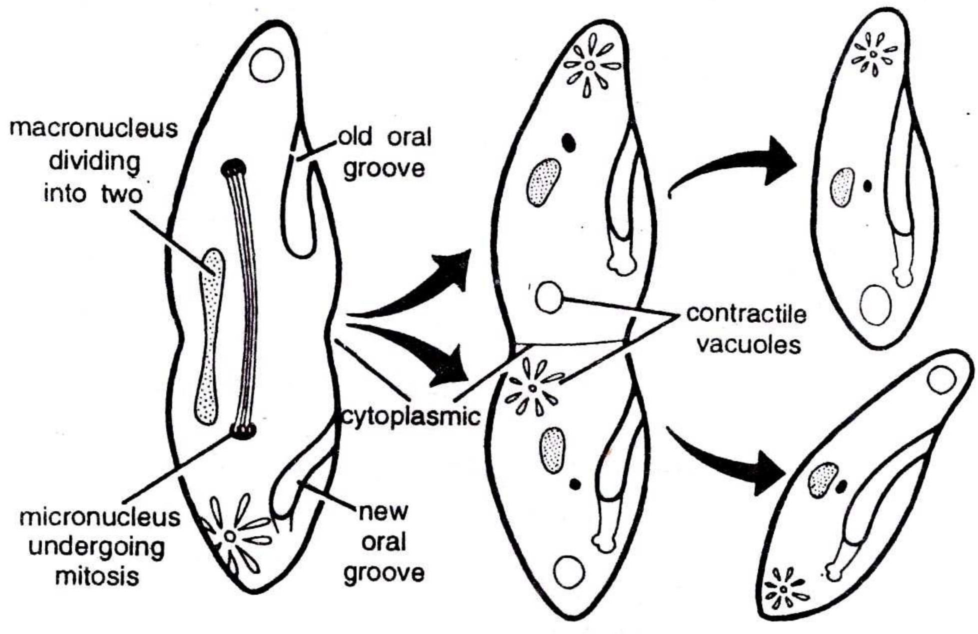


Figure 10.5 Paramecium Showing Binary Fission

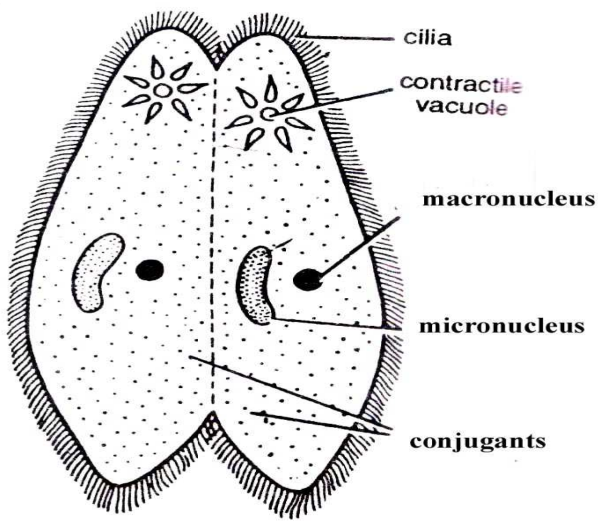


Figure 10.6 Paramecium*:* Conjugation

Kappa particles:- In 1938, T.M. Sonneborn repored that some races (known as killers or killer strain of *Paramecium* produce a poisonous substance, called paramecin which is lethal to other individuals called sensitives. The paramecin is water soluble, diffusible and depends for its production upon some particles located in the cytoplasm of the *Paramecium* (killer strain). These particles are called kappa particles.

Identifying features: -

Since the animal contains slipper-shaped body and 2 contractile vacuoles which are star-shaped and has all above features, hence it is *Paramecium*.

Special features: -

Paramecium has great experimental value in cytogenetically studies. T.M. Sonneborn sensitive strain without Kappa particles. *P. aurelia* is taken as example to explain cytoplasmic inheritance.

10.3.3 General study of *Euglena*

Systematic position:-

Phylum	Protozoa (Unicellular)
Subphylum	Sarcomastigophora (Cilia absent, locomotion by pseudopodia)
Class	Phytomastigophora (Chromatophores present in majority)

Order	Euglenida (Larger forms with one or more flagella)
Genus	*Euglena*

General study:-

Euglena is free-living and solitary. It occurs in stagnant water of ponds, pools and ditches with decaying nitrogenous organic matter. During rainy season it is so abundant that it imparts green colour to the water .**Its** body is fusiform or spindle-shaped with blunt anterior and pointed posterior end. Its size is microscopic varying from 53- 100µ. The blunt anterior end of the body has a funnel shaped depression. Its openings are called cytoplasm or mouth. It leads into a spherical reservoir through a short tube, the cytotpharynx or gullet–The two flagella arise from two tiny granules, the kinetosomes or blepheroplasts lying at the base of the reservoir. The body is enclosed in a tough but flexible pellicle or periplast that lies inside the plasma membrane and is formed of elastic fibrous protein. Due to toughness pellicle gives a definite form to the body. Its elasticity permits slight changes in body form. The cytoplasm is distinguished into:an outer thin, clear layer of ectoplasm, an inner granular and more fluid-like central mass of endoplasm.

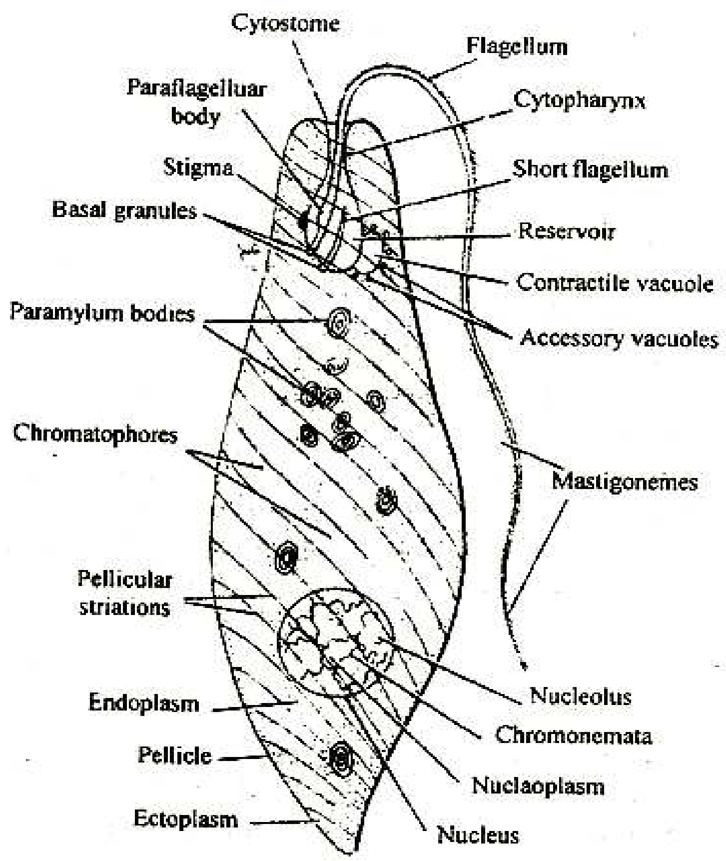


Fig. 10.7 Euglena

Its cytoplasmic inclusions are the chromatophores which are oval, disc-like, plate- like or rod-like chloroplasts. They possess chlorophyll a and b and help in the synthesis of food. The Paramylon body which is a polysaccharide (B-1, 3 glucon).There is a large contractile vacuole that lies on one side of the reservoir. An orange or red-coloured stigma or eye spot lies in contact with the reservoir that is formed of haematochrome and is sensitive to light.

Euglena progresses in two different ways ie by flagellar movement where the long highly contractile flagellum acts as a locomotory organ and the euglenoid movement, where the pellicle being flexible, permits the organism to perform worm like wriggling movements of the body.

***E**uglena* exhibits mixotrophic type of nutrition i.e as it feeds in more than one way-holophytic or autotrophic nutrition- (Plant-like) in bright sunlight *Euglena* synthesizes its food from CO2 and water with the aid of chlorophy II (Photosynthesis which is stored in the pyrenoid bodies or is found scattered as paramylum bodies. Saprozoic nutrition or saprophytic nutrition – In the absence of sunlight .*Euglena* absorbs decaying organic matter by the general body surface .*Euglena* is sensitive to light as it avoids strong light but moves towards moderate light. It orients itself parallel to a beam of ordinary light and swims towards the source of light. *Euglena* also reacts to the stimuli of touch, temperature and chemicals.

In *Euglena***,** Respiration is aerobic. It absorbs dissolved oxygen from the surrounding medium by diffusion. In day-time, oxygen is liberated during photosynthesis. During day-time CO_2 produced during respiration is used in photosynthesis Unused CO_2 escapes out by diffusion through body surface. Nitrogenous wastes also escape the same way.In *Euglena* excess of water is eliminated out by the contractile vacuole. The accessory vacuoles collect excess of water from the endoplasm and release their contents in the main vacuole which gradually increases in size and finally contracts to force the fluid into the reservoir.

Under favourable conditions, *Euglena* reproduces by longitudinal binary fission, multiple fission and palmella stage- To tide over the unfavourable condition *Euglena* secretes a gelatinous cyst around its body. Off its flagellum, stops swimming and gets rounded. *Euglena* divides longitudinally into two but these may divide further forming 4, 16 or 32 daughter individuals. All of them remain entangled in a common cyst forming the so called Palmella stage. On commencement of favourable conditions the cyst and daughter euglenae are set free, which develop flagella and start free existence.

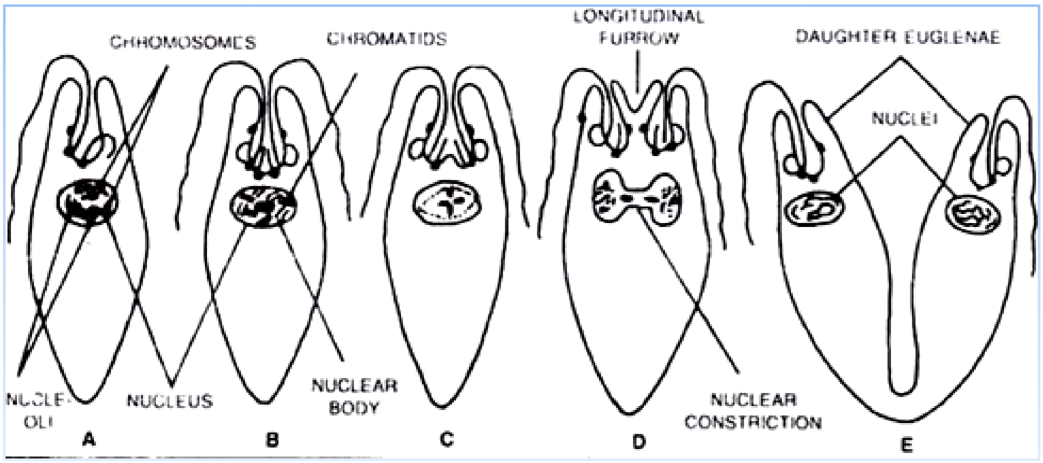


Fig 10.8 Euglena: Longitudinal binary fission

Identifying feature: -

Euglena is a unique animal with floral and faunal mode of reproduction having chloroplast occurring in the form of 7-8 thick bodies surrounding a central paramylum granules and scattered pyrenoid bodies.

Special feature: -

The position of *Euglena* is still a debatable question as it is considered as an animal by zoologists and plant by botanists. It is included in the kingdom -Animalia on the basis of the following facts.

1. The proteinous nature of pellicle and absence of cellulose covering over the body.
2. Presence of contractile vacuole.
3. Presence of photosensitive stigma or eyespot.
4. Saprophytic and even holozoic mode of nutrition among some species of *Euglena*.
5. Movement from place to place
6. Longitudinal division of the body.

10.3.4 General Study of *Hydra:-*

Systematic position:-

Phylum- Coelenterata

Class- Hydrozoa

Order- Hydroidea

Suborder – Anthomedusae

Genus- *Hydra*

General study:-

Hydra belongs to the most primitive Class Hydrozoa of Phylum coelenterata . It is simple in form and structure and serves as a good example for the study of coelenterate organization .*Hydra* one solitary, sessile, fresh water animals. They are cosmopolitan in distribution. They occur in lakes, ponds streams and seasonal ditches. They may be found attached to and hanging downward from underside of soiled object in water as leaves, sticks, stones weeds etc.

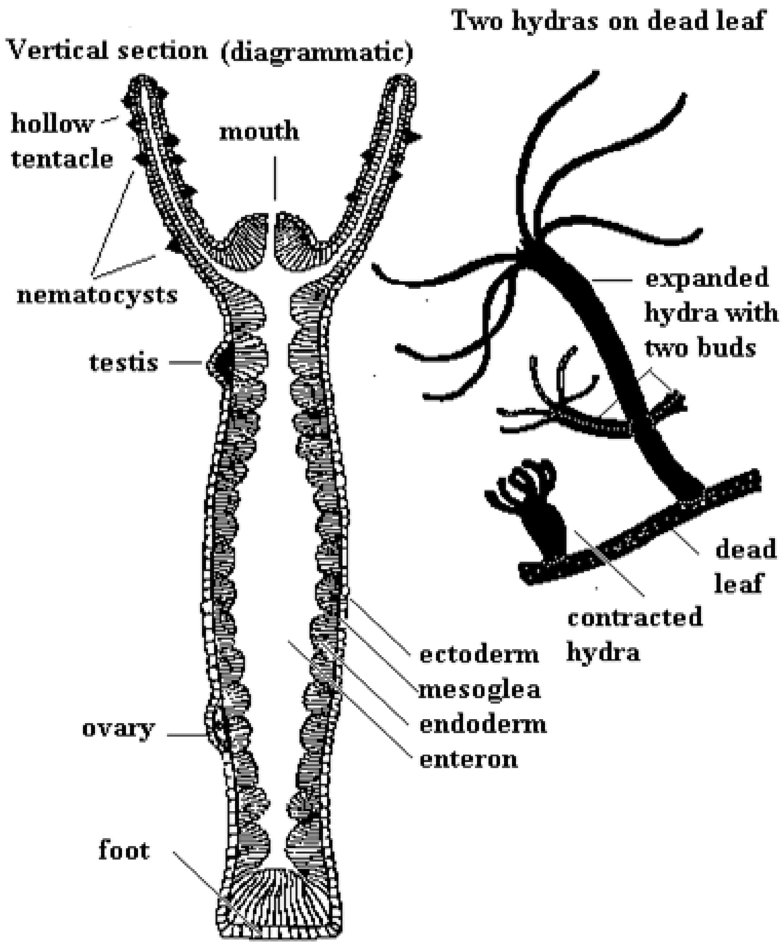


Figure 10.9 Vertical Section of Hydra

Hydra is a polyp like or polyploid coelentrate with a tubular or cylindrical body. Body symmetry is typically radial comprising an oral and aboral axis. Aboral end of the body is closed flattered called pedal disc or basal disc used for attachment to substratum. Distal or free end of the body is produced into hypostome having circular mouth. Hypostome bears 6-10 slender contractile and tubular thread like tentaclels that helps in feeding and locomotion. Other structure like testes occurs near the oral end while rounded ovary near aboral end.

Internally, *Hydra* shows a central cavity called coelenteron, often referred as gastrovascular cavity surrounded by a body wall. There is no anus and excretory pore. Body of *Hydra* is diploblastic; formed of ectoderm and endoplasm between them is mesoglea which is delicate and transparent. The outer layer called epidermis is enveloped by a thin layer of cuticle – It is of following types like epithelio- muscle cell which assist in muscular contraction, next to it are the gland cells which are found on pedal disc and around mouth region. These cells secrete mucus like substance serves for attachment, protection and enlargement of prey.

Then there are interstitial cells between narrow and basal end of epithelio muscle cells .They are small rounded and undiffertiated cells and are capable of developing into any other kind of cells such as reproductive, glandular, stinging and buds etc. Many of these interstitial cells becomes specialized to the form stinging cells called cnidoblasts (Gr: knide, nettle to blastos, germ).These form organs of offence and defense of *Hydra* and help *Hydra* in food capture locomotion and anchorage. During summer interstitials cells in certain restricted region of the body divide and proliferate like reproductive cells forming gonads, which later differentiate into either testes or ovaries.

About 30 different kinds of nematocysts are found among different cnidarians. These kinds are constant for the species and are of taxonomic value. *Hydra* has four basic types of nematocysts, as pentrant or stenotele is the largest (16μ India) volvent or desmoneme is small (9μ long) streptoline glutivant or holotrichous isorhizas 9μ are oval or cylindrical.

Hydra is sessile animals as they are attached by their pedal disc to objects in water. It shows feeling moments as expansion and contraction which is initiated by pacemaker located near the base of hypostome. *Hydra* can also move from place to place in search of food it extends and then bends over so the enlaces attach to the substratum with the help of adhesive glutinant nematocysts.It somersault like an acrobat. It glides due to creeping amoeboid movement of cells of pedal disc. Sometimes *Hydra* can move in an invalid condition using its tentacles as legs. It climbs while changing location by attaching its long tentacles to some objects. Floats on leaf by pedal disc. Swimming is performed by undulating wave like movements of tentacles and body.

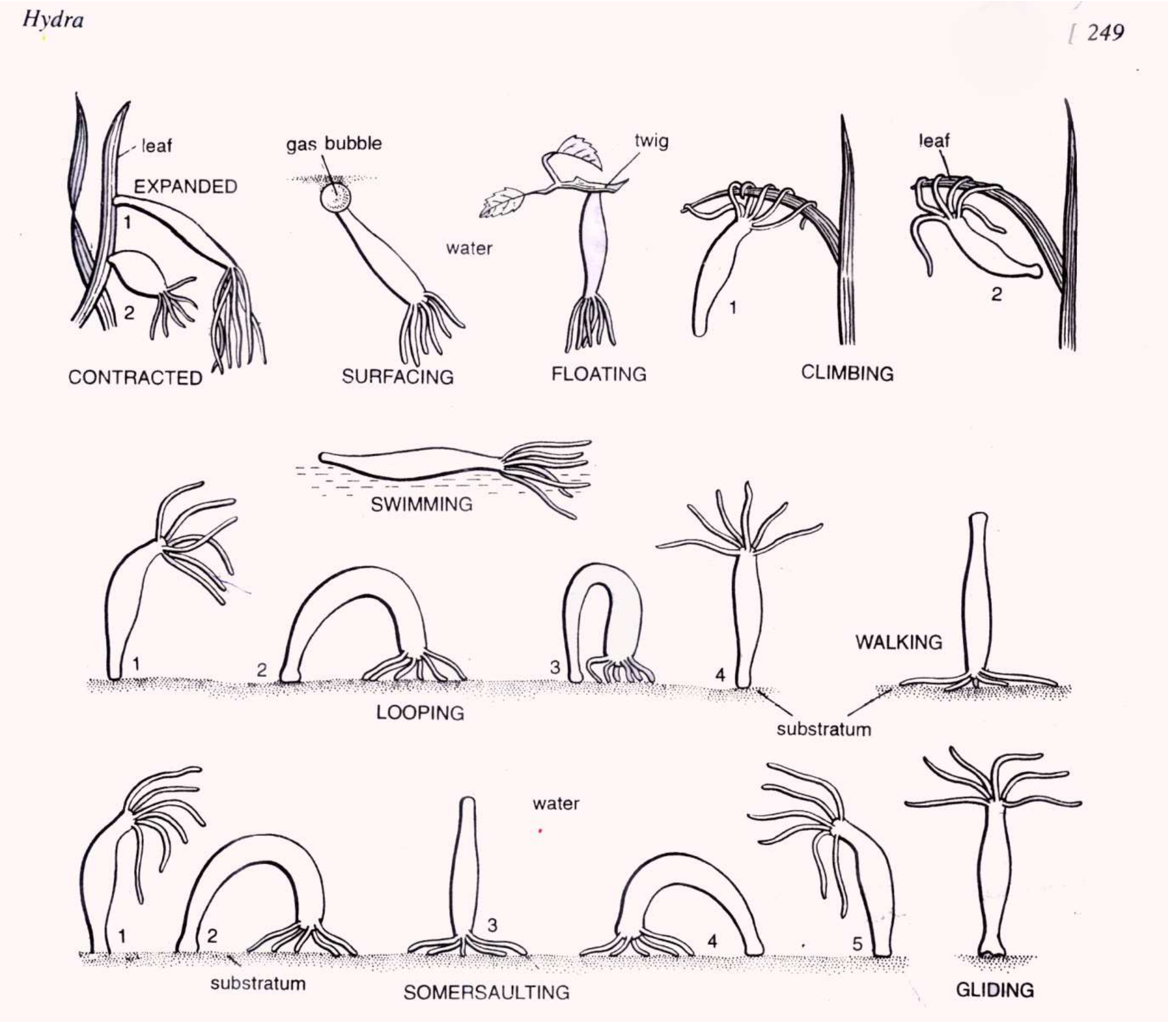


Figure 10.10 Locomotion in Hydra

Hydra is exclusively carnivorous. It feeds on insect larvae crustaceans (Cyclops Daphnia) and annelid worm. It can feed through nematocysts when an organism touches a tentacle; dozens of nematocysts are discharge into it at once. The penetrant puncture the victim & reject the paralyzing hyno toxin

Digestion is both extracellular and intracellular. first the prey is killed by the action of digestive juices ,churning is caused by the expansion and contraction of body wall and lashing movements of flagella, mixed up with digestive juices which is then broken into smaller particles. While during intracellular digestive smaller fragments are engulfed by means of Pseudopodia & digested within food vacuoles. Some gastro dermal cells distribute digested food to all parts of body. Egestions occur by sudden squirt due to muscular contraction of body so that the debris is thrown at distance.

Hydra has neither blood and blood vessel nor any organ for excretion & respiration. Exchange of oxygen and carbon dioxide and excretion of nitrogenous waste matter occurs directly by diffusion .*Hydra* react to various kinds of internal as well as external stimuli. It shows negative reaction to strong and weak light. *Hydra* prefer mostly cool or cold water, It shows negative reaction to the water current and also avoids strong and injurious chemicals.

Hydra reproduces asexually by budding and sexually by formation of gametes. *Hydra* has great power of regeneration (Abraham Trembley in 1745). If a living *Hydra* is cut into two, three or more pieces, each missing part grows and becomes a complete animal. Even it retains it polarity. **Tremble** observed that if head end of a *Hydra* is split into two it results into a Y-Shaped specimen or" two headed individual "By further "splitting" he succeeded in producing seven – headed Hydra.

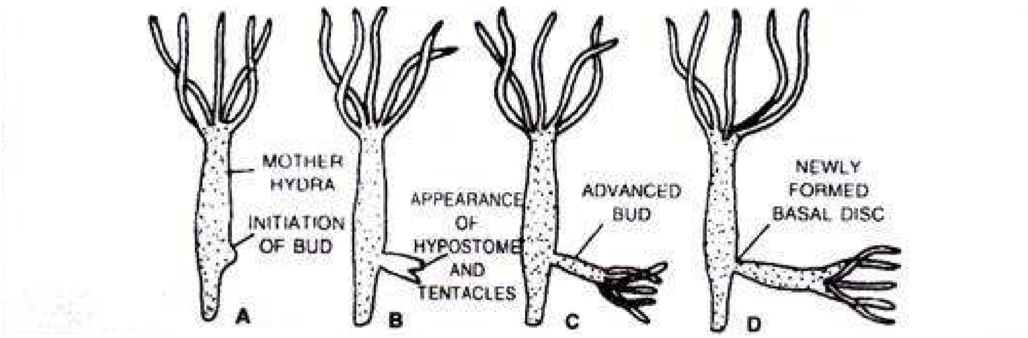


Fig. 10.11 Bud formation in Hydra

10.3.5- STUDY OF RECTAL CILIATES

The rectal ciliates are found in the rectum of frog are *Opalina, Balantidium, Nyctotherus* .To prepare the culture of these ciliates, take a living frog and chloroform it. Dissect and open its abdomen. Make a gentle cut up to cloaca carefully. Take out rectum and cut it and open it in 0.78percent normal saline in a small dish or watch glass. The ciliates coming out of rectum can be seen as moving objects. Observe living rectal ciliates under a stereoscopic binocular microscope.

To prepare the mount of rectal ciliates transfer the rectal ciliates on a clean slide. Apply a pin head Meyer's albumin on the slide and rub with fingers before transferring them into the slide. Albumin helps to stick protozoan by adding a drop or two of 90% alcohol. Let it become dry, then pass through descending series of alcohol as 90%,70% 50%,30% and distilled water. On the surface of the slide add a few drop of haemotoxylin for 1minute.Wash first with distilled water, then with tap water. If excess stains destain with acid water, wash with tap water, nuclei will stain blue. Then dehydrate in ascending series of 30%, 50%70% and 90%alcohol.Stain in eosin, wash and destain in 90% alcohol and keep in 100%.alcohol for 5min.Clear in xylene and mount on DPX. Let the slide become dry and observe under the microscope.

OPALINA

Systematic Position:-

Phylum ………. Protozoa (Unicellular)

Sub-phylum…... Plasmodroma (Cilia absent, locomotion by pseudopodia.)

Class …………. *Opalina*ta (Cilia-like organelles in oblique rows)

Genus ………... *Opalina*

-

Opalinids are entocommensals in intestine and rectum of tadpoles and adult anuran amphibians (frogs and toads) and occasionally other cold blooded vertebrates. It has cosmopolitan distribution. ***Opalina*** is a parasite in the rectum of frogs and toads. Body is oval and flax with longitudinal rows of many equal – sized cilia- like organelles of locomotion. It is multinucleate; each nucleus has both trophochromatin and idiochromatin. There is no cytostome or contractile vacuole. The parasite absorbs digested food of the host. Reproduction is by longitudinal binary fission most of the year, in fission kinetia are not cut but shared equally between two daughter cells; this is an interkinetal division of kinetia. In spring reproduction is by binary plasmotomy in which cell division is repeated again and again without division of the nuclei, so that many daughter cells are produced, each having only a few nuclei, generally three to six. The daughter cells become encysted and pass out of the host into water from where they are swallowed by tadpoles. The cysts dissolve in the intestine of tadpoles and the cells divide to form uninucleate minucleate microgametes or macrogametes. These gametes of tadpoles and the male and female anisogametes fuse to form a zygote. The zygote encysts, then by growth and nuclear division it becomes an adult which emerges from the cyst into the alimentary canal. Previously *Opalina* was placed in Ciliophore, then it was placed in Flagellata, but now it is placed in a separate super class *Opalina*ta since it is neither a ciliate nor a flagellate because of the following reasons:

1. its many nuclei are similar or monomorphic, they are micro-nucleus and macronucleus.

2. In binary fission the cleavage is longitudinal and parallel to kinetia which is shared by the daughter cells and new kinetia are supplied by the primary ones to generally transverse, the cleavage cells receive half of each kinetia which, thus, have genetic continuity.

3. In *Opalina* there is no conjugation which is common in ciliates.

4. In *Opalina* anisogametes are formed and sexual reproduction is by syngamy. While in cilates sexual reproduction is by conjugation or autogamy, and no gametes are formed.

5. It has no chromatophores, contractile vacuole, and gullet as seen in flagellates.

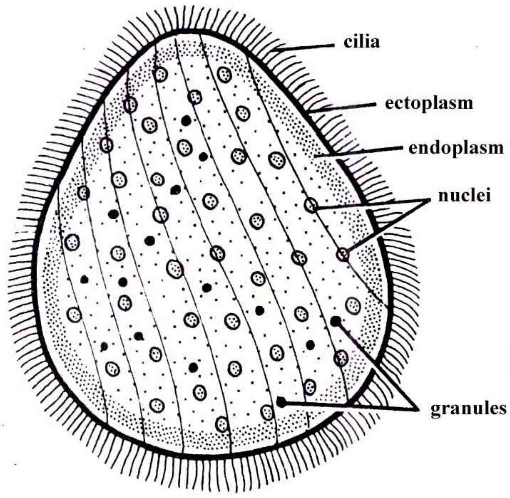


Figure 10.12 Opalina

Identifying features: -

Since the animal has oval flattened body, uniform small cilia At the time of egg laying of their hosts, the *Opalina* divide into small forms, the encysted form pass out in the faeces and when ingested by tadpoles, encysted and then divide into anisogamous gametes. The zygote either encysts again or passes out to infect other tadpoles or all once develops into the adult and all above features hence it is *Opalina*.

BALANTIDIUM

Systematic position:-

Phylum ………. Protozoa	-	Unicellular
Sub-phylum…... Ciliophora	-	Cilia movement in all stages.
Class …………. Ciliata	-	Cilia present throughout life.
Sub-Class…….. Euciliata	-	Cytopharynx, contractile vacuole, mega-and micronucleus present
Order ………… Spirotricha	-	Adoral membranelles extending around peristome in clockwise direction.
Genus		*Balantidium*

Balantidium is commonly found in the intestines of pigs, sheep, camels, opossums, ostriches, cockroaches and man. It is abundantly found in the rectal content of the from *Balantidium* is a ciliate parasitic in the large of pigs, monkeys and man. Some species are parasitic in frog, fish, cockroach and horse. It is an egg-shaped animal pointed at the anterior end and rounded posteriorly. The body has longitudinal rows of small cilia. At the anterior end is a peristome with longer cilia, below the peristome is a mouth leading into short cytopharynx with no cilia (B. entozoan). There is a large sausage-shaped macronucleus obliquely in the middle of the body, and in its concavity near it is a small micronucleus. Unlike most parasitic protozoa there are two contractile vacuoles, one near the middle and a larger one at the posterior end. There are several food vacuoles containing human erythrocytes and fragments, it also ingests starch and yeast from the colon of the host. At the posterior end is a permanent cytoproct. Reproduction is by transverse binary fission and occasionally by conjugation in which there is an exchange of nuclear material and reorganization of the macronucleus, this is followed by binary fission. The parasite also forms thick-walled cysts, but no multiplication takes place in the cyst. In human beings *Balantidium coli* causes ulcers and haemorrhage in the colon and caecum, which cause chronic dysentery. These parasites can be removed by administering small doses of aureomycin and terramycin for 10 to 15 days.

Balantidium is now placed in subclass Holotrichia, order Tricho stomatida and not with Spirotrichia because : 1 Its peristomial ciliature develops from body kinetia which during binary fission form an incomplete band stronger and longer cilia below the middle of the body, while in Spirotrichia the peristomal ciliature develops wither from previous oral kinetosomes or from stomatogenetic kinetia. 2. It has no oral membranelle or buccal ciliature which are conspicuous in Spirotrichia.

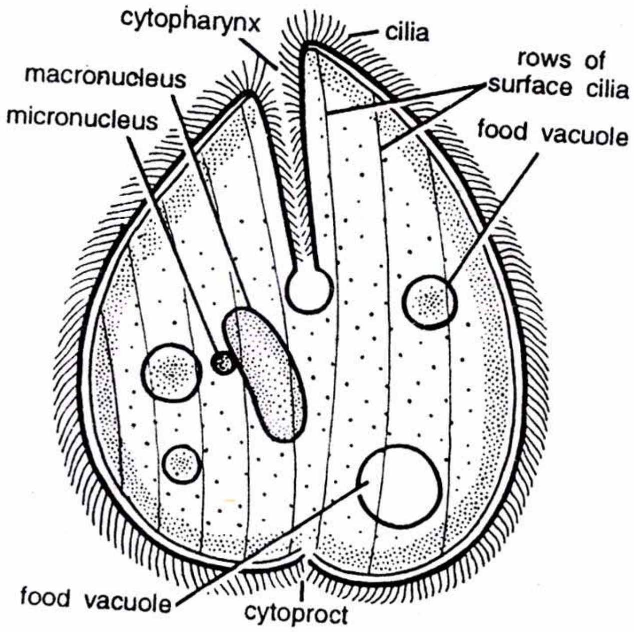


Figure 10.13 *Balantidium*

Economic status:-

The pathogenic species is Bcoli, found in the colon of men, monkeys and pigs. It causes ulcers and dysentery. The natural host for B. coli is the pig in which it is transmitted in the encysted state. Human beings who handle pigs become infected by the cysts. The cysts react with intestinal epithelium where they cause pathological changes. B. coli of pigs serve as biological control for nematode larvae.

Identification: -

Since the parasite has slit like vestibule and all above feature hence it is *Balantidium.*

NYCTOTHERUS

Phylum ………. Protozoa - Unicellular

Sub-phylum…... Ciliophora - Cilia movement in all stages.

Class …………. Ciliata - Cilia present throughout life.

Sub-Class…….. Euciliata - Cytopharynx, contractile vacuole, mega-and Micronucleus present

Order ………… Spirotricha - Adoral membranelles extending around peristome in clockwise direction.

Genus ………. *Nyctotherus*

Nyctotherus is endocommensal found in the alimentary canal of cockroaches, crickets, myriapods, fishes, amphibians and mammals. It is commonly found associated with other rectal ciliates *Balantidiun* and *Opalina.* This commensal is occasionally found in man.

It is cosmopolitan in distribution. It is a parasitic ciliate in the rectum of frogs and intestine of cockroaches. Its body is kidney-shaped with the longitudinal rows of equal-sized cilia, and a row of large adoral cilia on the peristome. The large peristome leads into a long, curved cytopharynx in which cilia are large and wind clockwise. In the anterior half of the body is a large kidney-shaped macronucleus and a small micronucleus, near the posterior end is a single contractile vacuole and at the posterior end is a permanent cytoproct. The animals conjugate with an exchange of nuclear material. The conjugant separate and undergo binary fission. These daughter cells encyst and pass out with the faeces, these cysts are eaten by tadpoles in which they hatch and grow into adults and reach the rectum.

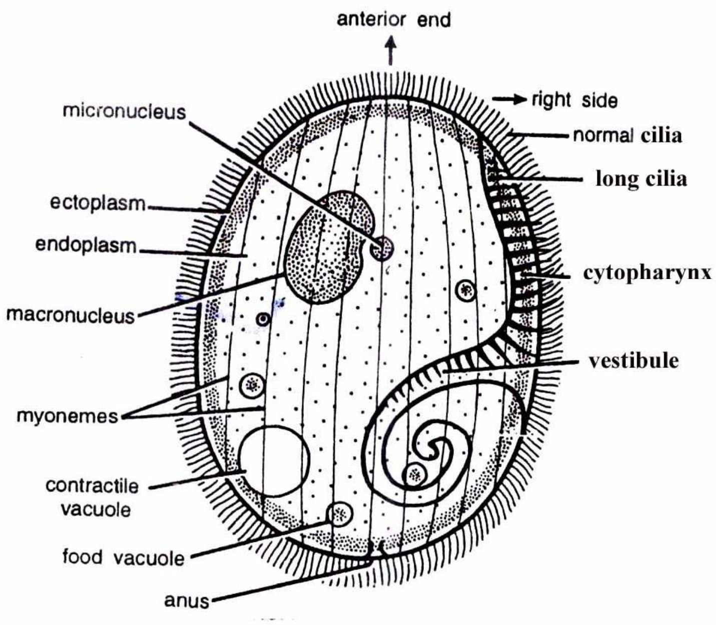


Figure 10.14 Nyctotherus

Identifying features: -

Since the protozoan contains coiled cytopharynx and all above features .It multiplies by binary fission in the rectum of frog tadpoles. When the tadpole is about to metamorphose, smaller preconjugant forms arise which pair and exchange nuclear material. The large exoconjugant found in the rectum of newly metamorphosed frog undergo binary fission which becomes encysted. Hence it is *Nyctotherus.*

10.4- Summary

Protozoa means ‘first animal’ the simplest form of animal life. Protozoa are unicellular microorganisms that lack cell walls. It can grow in marine habitat or soil fresh water symbiotic parasites in other organisms. Protozoa depends on nutrition, temperature, pH, and some depends on sunlight. There are an estimated 30,000 protozoan species. They are aquatic (fresh and salt water) free living parasitic, symbiotic or commensally. They possess different types of locomotory organs. They may bear flagella (flagellates). Locomotory organs are absent in the parasitic forms. The osmotic concentration of cell body (Osmoregulation) is maintained by one or more contractile vacuoles. Asexual reproduction takes place by fission or budding. Sexual reproduction are occurring the fusion of gametes or conjugation **Eg. Free living**- *Euglena, Amoeba, Paramecium, Noctiluca, Elphidium* (Polystomella). **Parasitic**-*Monocystis, Entamoeba, Plasmodium, Trypanosome, Giardia* etc. Encystment occurs to tide over the unfavorable conditions and to help in the dispersal of race.

A phylum protozoon is a larger and varied group and poses a number of problems in its classification. The conventional scheme followed by Hyman (1940), Hickman (1961) and Storer (1965) etc. recognizes two subphyla on the basis of organs of locomotion and five classes.

Paramecium (Gr., Paramekos- oblong + Caudata-tail) is an elongated and sliper shaped animal. Paramecium is a typical ciliate microscopic organism. It is ten species known in world. Ciliates are characteristed by the presence of cilia as locomotor organelles. Paramecium is occurrence in fresh water ponds, lakes, rivers and streams. Its size varies in different species being 120-250μ in P.aruelia and 170-290μ in *P.caudatum.* Its body asymmetrical with flat oral and a convex aboral or dorsal surface. The body is covered by a thin firm but elastic pellicle. **T**he entire body surface is covered by a uniform covering of hair like protoplasmic processes, the cilia. In Paramecium, there is a broad, shallow oral groove on the ventral surface. Paramecium process by three following two methods

10.5 REFERENCES

1. **Verma, P.S.,** 1993, *a Manual of Practical Zoology Invertebrates,* S.Chand & V.K.Agarwal., (S.Chand Publication).

2. **Lal S.S.,** Practical Zoology Invertebrates, (Rastogi Publication).

3. **Agarwal S.C. & Jindal**. Practical Invertebrate Zoology (Pragati Prakashan).

4. **Verma P.S & Jordan E.L.,** Invertebrate Zoology. (S.Chand Publication).

5. Some Figure adopted from Wikipedia.

10.6- Terminal Question/Answer:-

10.8.1- Self assessment questions

1. What is the mode of nutrition in *Amoeba*?
2. What is the function of contractile vacuole in *Amoeba*?
3. How *Amoeba* feeds on flagellates and ciliates?
4. Who was first to describe *Amoeba*?
5. How is the culture of *Amoeba* prepared in laboratory?
6. Who observed first the amoeboid movement?

10.8.2: -Terminal Question/ answers

1 *Amoeba* is capable of regeneration. This is possible only from:

(a) A nucleated bit of *Amoeba* (b) An anucleate bit of *Amoeba*

(c) A young *Amoeba* (d) an old *Amoeba*

2. *Amoeba* was discovered by:

(a) Ross (b) Rosenholf (c) Lamble (d) Losch

3. The food capturing organelle of *Amoeba* is:

(a) Food vacuole (b) Contractile vacuole

(c) Pseudopodia (d) Nucleus

4. Pseudopodia are formed in an *Amoeba*:

(a) When it comes in contact with a food particle

(b) By the movement of the surrounding water

(c) By exchange of salts with the medium

(d) By sol-gel transformation of the cytoplasm

5. *Amoeba* reacts:

(a) Negatively to both weak and strong light.

(b) Positively to strong light and negatively to weak light

(c) Positively to both weak an strong light

(d) Negatively to strong light and positively to weak light

6. *Amoeba* belongs to class Sarcodina, which is characterized by:

(a) Acellular body (b) Pseudopodia for locomotion

(c) Uninucleate body (d) presence of contractile vacuole

7. Body of *Amoeba* has permanent:

(a) Shape (b) organelle for locomotion (c) Anterior end (d) food vacuole

8. *Amoeba* shows positive response for:

(a) dim and intense light (b) solid objects (c) cathode (d) chemicals

9. Minimum number of daughter *Amoeba*e is produced, when surrounding water has:

(a) No food (b) less food (c) plenty of food (d) high temperature

10. Simplest mode of locomotion is:

(a) Swimming (b) creeping (c) floating (d) walking

11. Plasmalemma of *Amoeba* is:

(a) Impermeable (b) Least regenerative

(c) Site for excretion (d) not for respiration

12. If an *Amoeba* is kept in distilled water its contractile vacuole will:

(a) disappear (b) become swollen and full of water

(c) work faster (d) have no effect

13. Nitrogenous wastes in *Amoeba*, are excreted though:

(a) Plasmalemma (b) food vacuoles

(c) Contractile vacuole (d) none of these

14. Mode of nutrition in *Amoeba* is ;

(a) Holozoic (b) mixotrophic (c) saprophytic (d) holophytic

15. Medium inside food vacuole of *Amoeba* is :

    (a) acidic (b) alkaline (c) acidic then alkaline (d) a alkaline then acidic

16. Excretion in *Amoeba* occurs by:

    (a) plasmalemma (b) general body surface (c) cytoplasm (d) all of these

17. In *Amoeba* binary fission occurs when:

    (a) Food is abundant (b) temperature is suitable (c) both (d) pond water dries up

18. An *Amoeba* living in fresh water respires by means of :

    (a) Nucleus (b) food vacuole (c) plasmalemma (d) pseudopodia

19. Locomotory organelles in *Amoeba* are:

    (a) lobopodia (b) cilia (c) flagella (d) myonemes

20. *Amoeba* was discovered by:

    (a) Lancisi (b) Leeuwenhoek (c) Rosenholf (d) Ross

21. During digestion in *Amoeba* the medium is first:

    (a) Acidic (b) highly alkaline (c) neutral (d) slightly alkaline

Answers

1(a), 2(b), 3(c), 4(d), 5(d), 6(b), 7(b), 8(c), 9(c), 10(b), 11(c), 12(b), 13(a), 14(a), 15(c), 16(c), 17(c), 18(c), 19 (a), 20(c), 21(a).

Short Answer type Questions

1. How does the *Paramecium* feed?
2. Mention the organ of offence and defence in *Paramecium*.
3. What are the two functions of contractile vacuole of *Paramecium*?
4. Write the food procuring mechanism exhibited by *Paramecium*.
5. Describe cyclosis.

Study of *Paramecium:-*

Multiple choice questions

1. Movement of food vacuole in *Paramecium* along a definite path is known as:

   (a) Cytokinesis (b) Cyclosis (c) Endomixis (d) Metagenesis

2. The functions of the Trichocysts are:

   (a) offence and defence (b) narcotising prey

   (c) to attain resting condition (d) all of the above mentioned

3. The main functions of the contractile vacuole is:

   (a) pumping out excess water (b) excretion

   (c) osmoregulation (d) respiration

4. What is a trichocyst?

   (a) Spindle shaped structure below pellicle (b) Interlacing

   (c) fusion of cilia and flagella

   (d) Modification of the contractile vacuole a structure concened with photosynthesis

5. Mention a function of the neuro-motor system of *Paramecium*:

   (a) Co-ordination of ciliary beat (b) co-ordination of various stimuli

   (d) control of digestion (d) co-ordination of respiratory movement

   (e) control of osmoregulation

6. Which of the following helps in anchorage and defence of *Paramecium*?

   (a) nematocyst (b) oocyst

   (c) trichocyst (d) statocyst

7. The number of nucleus in *Paramecium* is :

   (a) one (b) two

   (c) three (d) four

8. The number of nucleus in *Paramecium* is :

   (a) hill (b) ross

   (c) lavine (d) grassi

9. ‘Hay-infusion method’ use for the culture:

   (a) *Amoeba* (b) *Paramecium*

   (c) *Euglena* (d) all

10. ‘Caudal tuft’ present in:

    (a) *Amoeba* (b) *Paramecium*

    (c) *Euglena* (d) *Trypanosoma*

11. Vegetative function control by:

    (a) Micronucleus (b) Macronucleus

    (c) both (d) none

12. How many food vacuoles present to *Paramecium*:

    (a) one (b) two

    (c) three (d) four

13. Among them which one is filter feeder:

    (a) *Paramecium* (b) *Amoeba*

    (c) *Trypanosoma* (d) Monocystis

14. A protozoa feeds on protozoans:

    (a) *Paramecium* (b) *Amoeba*

    (c) *Trypanosoma* (d) Plasmodium

15. Protozoa which able to creep on a substratum:

    (a) *Amoeba* (b) *Paramecium*

    (c) *Euglena* (d) none

16. How many paramecia produce after the conjugation:

    (a) Two (b) four

    (c) Eight (d) sixteen

17. Autogamy occurs only in;

    (a) *Paramecium caudatum* *(b) P. aurelia*

    (c) Amoeba *(d) Trypanosoma*

Answers

1(b), 2(d), 3(c), 4(a), 5(a), 6(c), 7(b), 8(a), 9(b), 10(b), 11(b), 12(a), 13(a), 14(a), 15(a), 16(b), 17(b)

Self assessment question-

1. What is the type of nutrition in *Euglena*?
2. What is the palmella stage in reproduction in *Euglena*?
3. Describe the flagellum of *Euglena*.
4. Write on the binary fission in *Euglena*
5. Name in animal which able to heterotrophic as well as autotrophic nutrition>
6. Name the animals which show palmella stage?

Terminal question/answers

1. Coprozoic nutrition is found in:
   (a) *Balantidium* (b) *Euglena* (c) *Noctiluca* (d) *Copromonas*
2. Holophytic (autotrophic) nutrition:
   (a) *Paramecium* (b) *Balantidium* (c) *Euglena* (d) *Nyctotherus*
3. Saprophytic or saprozoic nutrition is found in:
   (a) *Euglena* (b) *Leishmania* (c) *Amoeba* (d) *Monocystis*
4. Photoreceptor organ of *Euglena* is:
   (a) stigma near reservoir (b) Paraflagellar body at the base of flagellum
   (c) stigma and paraflagellar body (d) Chromatophore
5. Lactoflavin (sensitizer) found in:
   (a) eye spot (b) paraflagellar body (d) Golgi bodies (d) Mitochondria
6. *Euglena* is green in colour which is due to:
   (a) Chromatophores (b) Leucoplasts (c) Carotene (d) Pyrenoid and paramylum
7. *Euglena* belongs to class:
   (a) Phytomastigophorea (b) Zoomastigophorea
   (c) Rhizopodea (d) Actinopodea
8. Connecting link between plant and animal kingdom:
   (a) *Paramecium* (b) *Euglena* (c) Bacteria (d) Virus
9. Which is oldest one of the animals:
   (a) *Amoeba* (b) *Paramecium* (c) *Euglena* (d) *Opalina*
10. Osmoregulation is *Euglena* occur with the help of:
    (a) Vacuole (b) food vacuole
    (c) Contractile vacuole (d) none

11. Reserve food in *Euglena* is in form of :
    (a) Starch (b) Glycogen (c) Fatty acids (d) Paramylon

12. Encystment take place in condition of :
    (a) Lack of food (b) drought (c) excessive heat (d) all of them

Answers:

1(d) 2(c) 3(a) 4(c) 5(b) 6(a) 7(a) 8(b) 9(c) 10(c) 11(d) 12(d)

Short Answer type Questions:-

1. What is mesogloea?
2. What are the five types of cells found in gastrodermis of *Hydra* and mention their functions.
3. Illustrate the structure of a cnidoblast.
4.

Study of *Hydra:-*

Multiple Choice Questions:-

1. The body of *Hydra* is :
   (a) Asymmetrical (b) bilaterally symmetrical
   (c) Radially symmetrical (d) diploblastic and radially symmetrical
2. Number of tentacles in *Hydra* is :
   (a) 2 – 4 (b) 6 – 10 (c) 10 – 40 (d) 43-50
3. The nematocysts of *Hydra* are important for.

   (a) catching (b) paralysing (c) testing the quality of food

   (d) testing the quality water
4. The cavity in the body of *Hydra* is called.

   (a) hydrocoel (b) haemocoel (c) coelom (d) coelenteron
5. *Hydra* is an example of the type.

   (a) monoblastic (b) diploblastic (c) triploblastic (d) none of the above
6. *Hydra* was first described by.

   (a) Trembley (b) Linnaeus (c) Leeuwenhock (d) Lamarck
7. Digestion in *Hydra* is initially extracellular and then intra-cellular, the undigested food is egested through.

(a) Individual sells after intracellular digestion (b) Opercula of nematocyst.
(c) Aperture of the pedal disc. (d) Mouth.

8. A piece of *Hydra* will regenerate if.

(a) There is part of basal disc and mouth.
(b) The part has epidermis, gastrodermis and tentacles
(c) Epidermis and gastrodermis is present in that.
(d) only epidermis is present

9. Mouth severs for both ingestion and egestion in.

(a) Leucosolenia (b) Fasciola (c) Hydra (d) Ascaris

10. Discharge of nematocysts in *Hydra* depends upon.

(a) Nervous control (b) entrance of water in capsule
(c) Enzymes and mechanical stimulation. (d) All these

11. The cell of *Hydra* that has poisonous fluid fluid Hypnotxin is.

(a) Cnidonlast (b) interstitial cell (c) glandulo-muscular cells (d) none of these

12. Digestion in *Hydra* is.

(a) Extracellular (b) intracellular (c) both (d) none

13. *Hydra* has no special structures for.

(a) Extracellular (b) respiration (c) nutrition (d) reproduction

14. *Hydra* is

(a) Fresh water polyp (b) solitary and diploblastic
(c) Radially symmetrical (d) all of theses

15. Tentacles of *Hydra* are.

(a) Solid (b) eight (c) not for protection (d) all of these

16. Epidermis of *Hydra* is made is made of

(a) Cnidoblast (b) epithelio-muscular cells (c) interstitial cells (d) all of these

17. *Hydra* was discovered by.

(a) Leeuwenhoek (b) Linnaeus (c) Grant (d) Trembley

18. Which of the following is not found in Hydra?

(a) Regeneration (b) fertilization

(c) gastrovascularisation (d) segmentation

19. The mesoglea of *Hydra* contains.

    (a) Nerve cells (b) sensory cells (c) muscle cells (d) no cells

20. Regeneration in *Hydra* was discovered by.

    (a) Lavern (b) Hymen (c) Huxley (d) Tembley

21. Excretion of nitrogenous wastes in *Hydra* takes place through:

    (a) flame cells (b) nephridia (c) nematocysts

Answers:

1(d), 2(b), 3(b), 4(d), 5(b), 6(a), 7(d), 8(c), 9(c), 10(b), 11(a), 12(c), 13(b), 14(d), 15(d), 16(d), 17(d), 18(d), 19(d), 20(d),21(b).

UNIT: 11 PERMANENT SLIDE PREPARATIONS

Contents

11.1- Objectives

The study of Permanent slide preparation of Obelia colony: Pharyngeal and septal nephridium of earthworm,parapodia of Nereis and Heteronereis,gill,radula and osphradium of Pila,salivary gland, mouth parts and trachea of cockroach, gills lamina of Uniostaocyst and hastate plate of prawn.

11.2-Introduction:-

A microscope slide is a thin flat piece of glass, typically 75 by 26 mm (3 by 1 inch) and about 1 mm thick, used to hold objects for examination under a microscope. Typically the object is placed or secured ("mounted") on the slide, and then both are inserted together in the microscope for viewing. This arrangement allows several slide-mounted objects to be quickly inserted and removed from the microscope, labeled, transported, and stored in appropriate slide cases or folders. Microscope slides are often used together with a cover slip or cover glass, a smaller and thinner sheet of glass that is placed over the specimen. Slides are held in place on the microscope's stage by slide clips, slide clamps or a cross-table which is used to achieve precise, remote movement of the slide upon the microscope's stage.

The following points highlight the seven main processes involved in preparation of permanent slides. The processes are: 1. Killing 2. Fixing and Hardening 3. Staining 4. Dehydration 5. Clearing 6. Mounting 7. Labelling.

11.3- Method of Microscopic Preparations

For microscopic studies the specific material tissue organs or small organism) is mounted on a glass slide. There are two methods of mounting the material on slide.

I. Temporary
II. Permanent

I. Temporary mounting:-

The temporary mount is prepared either in glycerin, water or normal saline. The material is first washed in tap, then stained and differentiated. Drop of mounting medium (glycerine and water) is placed on center of the slide. The material is then transferred into that drop. It is then covered neatly with a cover slip. The excess of glycerine or water is absorbed by piece of blotting paper. Mount prepared by this method can be used for study only for few hours, after which material loses its original form due to diffusion and other post mortem changes.

II. Permanent mounting:-

But for the study of microorganisms, smaller animals and histological studies of tissues, an elaborate technique is employed for making their permanent preparations. These smaller objects are mounted in balsam on a slide. There is a series of processes by which a living organism or its tissue is made fit for microscopic examination in a permanent state. The utility of permanent preparation is that the animal cell or tissue remains as such without undergoing major changes. The permanent preparation includes:

(1) Killing and narcotization
(2) Fixing
(3) Washing
(4) Staining
(5) De-staining or removal of excess of stain.
(6) Clearing or de-alcoholization.
(7) Mounting on slide

1. Killing and Narcotization :-

The first step in permanent preparation is killing instantaneously in order to prevent the change in form of the object as it has in living condition and immediately fixing the objet. Sometimes killing is preceded by narcotization. The narcotics used are chloroform, menthol, ether, alcohol, acetone, etc. the purpose of narcotization and killing in important as to have the same form and chemically constructed tissue or organisms as it had during its lifetime. In certain cases, for smaller animals killing is heating done by the slide.

2. Fixing :-

Fixing is done with various fixative agents for histological elements. Fixative is essential in every type of microscopic preparations, either for sections or for whole mounts and also in larger specimens. The function of fixation is manifold:

1) The tissues become hard and hardening resists further post-mortem changes.
2) Fixative agent coagulates and renders insoluble elements of tissues which are dissolved in further processing.
3) The fixative agent renders insoluble the various constituent elements of cells, alters their refractive indices and thus makes them optically differentiated under the microscope. Because of Brownian motion there is no possibility of material but we must bear in mind that fixed details are the coagulation artifact of the living structures.

Various fixative agents generally used are absolute alcohol, 90% alcohol plus glycerine, picric acid, corrosive sublimate, formal, osmium tetra oxide and nitric acid with or without water. Depending upon the material, corrosive sublimate or alcohol Carnoy's fluid for cytological studies and other fixative for histochemical studies.

3. Washing :-

Washing is essential as by this process the uncombined and excess of fixative agent is removed. The presence of fixative agent in tissues or cells will inhibit good staining. The washing agent depends upon the type of fixative agent used. As alcoholic picric acid in water is removed by 70% alcohol. Formal and corrosive sublimate are washed with water distillate. Sublimate is washed in alcohol.

4. Staining:-

The tissue or cell components are stained in various dyes. The dye makes the tissues distinct in its histological sphere. The various dyes are Orange G. Bordeaux red, Sudan's Congo red, Alizarins oxyquinoine, methylene blue, neutral red, borax carmine, heamatoxylin,e picro-indigo carmine, eosin and Gower's carmine. Mainly two kinds of stains are used.

1. Nuclear stains. Stains the nuclear parts of the cells, such as Delafield's or Erhlich's haematoxylin.
2. Cytoplasmic stains such as borax carmine, picro-indigo carmine, Gower's carmine and eosin, etc., which stain cytoplasm.

For general staining borax carmine is used aqueous stains are prepared in water whereas alcoholic stains are prepared in alcohol. When a single stain is used the process is called as simple or single staining. In some cases two stains, i.e., nuclear and cytoplasmic are used mand this is called as double staining. Generally single stain is used for whole mounts but for protozoan's etc., both cytoplasmic and nuclear stains are used.

Destaining:-

The removal of excess of stain is called as destaining or differentiation. De-staining agents are acid alcohol or acid water. The acid alcohol is used with alcoholic stains while acid water is used with aqueous stains.

5. Dehydration :-

This process is meant for removal of water from the tissues. The dehydration prevents putrefaction or decaying and maintains the same shape and size of tissues or cells. The moisture or water in tissues absorbs various germs of destructive nature so that the tissue may be destroyed, hence the passing the mounting material through various grades of alcohol, such as 30, 50, 70, 90 and 100% alcohols. The tissue is soaked in gradually increasing strengths of alcohol. The lower grads prepared either from 90% or absolute alcohol. The dehydration is carried out in corked or glass-stopper tubes.

6. De-alcoholization or clearing :-

After dehydration, transparency in tissues is obtained by treating with a clearing agent, which removes alcohol and makes the tissue clear and transparent. The clearing agents are wood oil, clove oil, xylol and benzol, etc. Xylol is most commonly employed and it makes the tissues hard and brittle. Clove oil is a superior clearing agent especially in the whole mounts. It also possesses higher index of refraction than balsam mounting media.

7. Mounting:-

Mounting forms the end of permanent preparation the choice of mounting media is not much but they should have the same refractive index as that of the cleared tissue. The refractive index of such a stained, dehydrated and cleared cells is 1.54. Canada balsam or D.P.X has almost the same refractive index. Mounting is an easy process. The tissue is kept over glass slide in a drop of balsam and cover-slip is lowered slightly. After mounting, the excess of balsam on the slide, as generally happens with beginners, should be removed with cotton soaked with the balsam has dried. For much better finishing the edge of the cover-glass may be ringed with cement such as gold seal or a varnish. The air bubbles present in balsam under cover-glass should be removed by gentle heating.

During all the chemical bathing of tissues, two changes of each reagent are necessary. The time of keeping tissue in various reagents may vary from 5 to 15 minute.

8. Precautions and Instructions:-

1. The articles, such as slide, cover slips and instruments should be perfectly cleaned.
2. The working place should be kept in order.
3. During dehydration, the tissues should be kept in tightly closed cork or glass stopper tubes. The opened tube will spoil material by absorbing moisture from atmosphere. Even breathing closely with dehydrating tube is undesirable.
4. The change of solution is done very quickly, reducing time of exposure to atmosphere to minimum.
5. The chemicals used once should not be reutilized.
6. The Canada balsam used should be clean, dust-free and not viscous.

11.4. - Methods for slide preparation

11.4.1- Protozoa (Paramecium)

Classification:-

Phylum ……… Protozoa → Unicellular

Sub-Phylum …... Ciliophora → Ciliary movement in all stages.

Class …………Ciliata → Cilia present throughout life.

Sub Class ……. Euciliata → Cytopharynx, contractile vacuole, mega and micronucleus present

Order …………Holotricha → Equal cilia.

Sub-order ……. Trichostomata → Mouth leads in cytopharynx.

Family………… Paramecidae → Oral groove present

Genus…….. ……Paramecium

Culture preparation of Paramecium:-

It is found abundantly in the ponds and ditches in decaying vegetation. For culturing paramecia boil 20 grains of wheat plus 20-25 hay steams in 500 cc of distilled water for about 10 minutes. Keep it in dark and cool place for about four days and inoculate it with few paramecia by a micropipette, within little days. The culture will found to contain numerous paramecia.

Examination in living condition:-

Take a clean slide .Through the micropipette put a drop of water from the culture medium of Paramecium Examine the slide under low magnification of compound microscope .Observe the fast moving Paramecia and their cytopharynx.

Many protozoan’s’ move very fast. So, they must be slowed down for proper examination. This is done in three ways:

1. Protozoan’s are slowed in 10per methyl cellulose solution. Dissolve 10 gm of methyl cellulose solution50cc of water. Boil, cool and make up to 100 cc .The solution slows down the movement.

2. 2. % sodium carboxymethyl cellulose solution is also good for slowing down protozoan movement. Boil 2gm of sodium methyl cellulose. Cool.

3 .Nickel sulphate acts as anaesthetic .By keeping the animal for 15 min can restrict their movement.

Permanent preparation:-

For the free living and fast moving protozoans, they are first made non motile on a glass slide coated with albumin. Then the small drop of culture containing Paramecium is fixed with an equal drop of 1% of Agar solution melted (1gm of Agar in 100 cc of water distillate) at 45^0 C .The solution become jelly like. The animal may survive for 30 min. They are fixed with 90% alcohol or by a drop of Schaudinn's fixative.

Pass the slide through descending grade of alcohol 90%, 70%, 50% and 30% and distilled water. Stain both nuclei and cytoplasm by double staining .Stain first with Ehrlich's haemotoxylin .Destain in acid water and wash in tap water. Again dehydrate in ascending grade of alcohol. After 90% alcohol stain in cytoplasm Eosin .Keep in 100% alcohol, Clear in xylol and mount on D.P.X.

1) **Feeding experiment**: As *Paramecium* is a ciliary and selective feeder. The cilia direct the food particles into the cytopharynx or gullet. Its food particles consist of bacterial etc. The food is collected into membranous vesicle which is formed just below the gullet. When the vesicle is filled with food it is detached and is called food vacuole.In paramecium food particle is circulated in the body by more or less definite path by slow streaming movement of endoplasm called cyclosis. Digestion and assimilation take place during the journey of food vesicle, First it is alkaline and then acidic and again alkaline.

2) **For observing cyclosis: Take** a drop of culture medium of Paramecia over a slide. Add a little yeast Congo red in a drop of water. The Congo red is taken into the food vacuole .Observe under low magnification along with the movement of Congo red in Food vacuole.

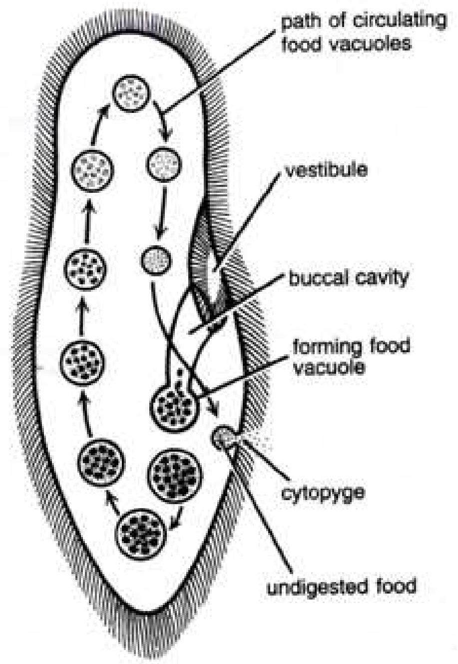


Fig.11.1 Paramecium showing Cyclosis

Distribution: It has cosmopolitan distribution.

Habit and Habitat:

Paramecium caudatum is commonly found in freshwater ponds, pools, ditches, streams, lakes, reservoirs and rivers. It is specially found in abundance in stagnant ponds rich in decaying matter, in organic infusions, and in the sewage water. *Paramecium caudatum* is a free-living organism and this species is worldwide in distribution.

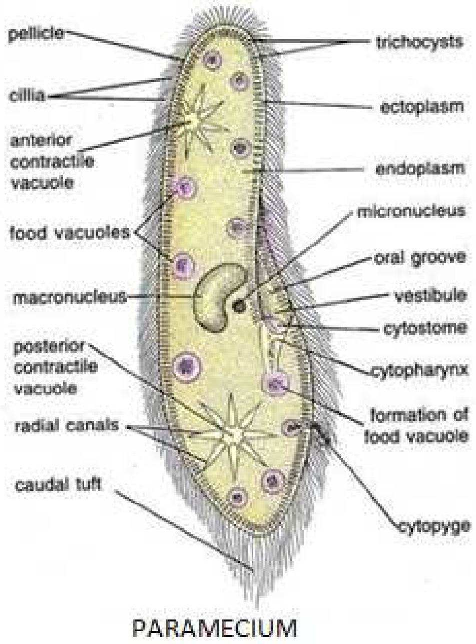


Fig.11.2

Comments:-

1. Commonly called as slipper animalcule, being microscopic, elongated slipper-shaped, cigar-shaped or spindle shaped.
2. Most familiar and extensively studied protozoans.
3. Anterior end is bluntly rounded, while posterior end is pointed.
4. *P. caudatum* measures 80 to 350 microns, while *P. aurelia* 170 to 290 microns.
5. Pellicle covers the body. It is clear, firm and elastic cuticular membrane. Pellicle has series of polygonal or hexagonal depressions for trichocysts.
6. Cilia cover the entire animal. They are hair-like projections of uniform length, except at posterior end where they are longer and at cytopharynx where they form undulating membrane.
7. Infraciliary system consists of basal bodies and kinetodesmata.
8. Cytoplasm contains ecto- and endoplasm. Ectoplasm has myonemes and rod-shaped trichocysts. Endoplasm contains food vacuoles, granules, meganucleus, micronucleus, anterior contractile, posterior contractile vacuole, fat and glycogen.
9. Trichocysts are rod-shaped bodies consisting of lower trichocyst shaft, basal body and projecting cilium. Cilium project through the hexagonal areas. Trichocysts are discharged to anchor with substratum.
10. Reproduction is by binary fission, conjugation, endomixis, hemixis and automixis.
11. Locomotion is ciliary. Nutrition is holozoic and it shows response to light and temperature, etc.

Identification: Since the animal contains slipper-shaped body and 2 contractile vacuoles which are star-shaped and has all above features, hence it is Paramecium.

11.4.2- Porifera (Sponge and Gemmules)

Spicules of Sponges:-

Introduction:-

The body wall of sponges is supported by various minute crystalline and calcareous bodies called as spicules. These are secreted by special mesenchymal cells called scleroblasts.

Spicules provide taxonomic characters and are classified according to the axas and rays called as axon, actine and actinal respectively. These are of two types:

1) Megascleres-Support skelton
2) Microscleres-Smaller and none supporting.
3) These are of following types
a) Monaxon-consist of single axix,straight or curved
b) Tetraxon-Consist of four rays
c) Triaxon-consists of three axes
d) Polyaxon-Having several equal rays

Spicules generally support and protect the body and helps in identification classification and metabolism.

Method for Slide preparation:-

For extraction of spicules, boil a small portion of sponge in 15-20%potassium hydroxide solution in a test tube till cells are dissolved. The spicules settle in the bottom. Decant the KOH solution and wash the spicules several times in tap water. Pass the spicules in ascending series of alcohol, 30%, 50%, 70%, 90% and 100% alcohol. Dealcoholize or clear with xylol and mount on a slide after pipetting the spicules. There is no need of staining.Study under the microscope and note different type of spicules as monaxon, triaxon, tetraxon etc.

Comments:

1. Sponge body wall is supported by various minute, crystalline and calcareous bodies called as spicules, which are secreted by special mesenchymal cells called as scleroblasts.
2. Spicules provide taxonomic character and are classified according to the axes and rays, spoken of as axon, actine or actinal respectively.
3. Spicules are of two types: (i) Megascleres or supporting skeleton, (ii) Microscleres small and non supporting. Kinds of Megascleres are as follows;

(i) **Manaxon** consists of a single axis, straight or curved. They may be styles, rhabds and tylots.
(ii) **Tetraxon** consists of four rays. It also includes triradiate or triactinal spicules.
(iii) **Polyaxon** having several equal rays. Amphidisk spicules are found in fresh water sponges. In this type, the rhabdom contains disks at both ends. The arrangement of different types of spicules could be seen in Sycon.

4. M**icroscleres** are found throughout the mesenchyme and include spires and asters.
5. Spicules support and protect the body. They are helpful in identification, classification and metabolism.

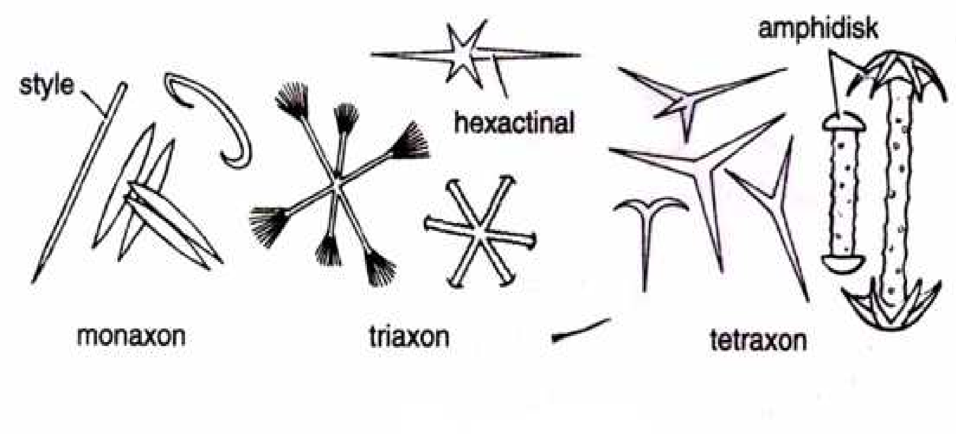


Fig.11.3 Spicules

Identification:-

The clear transparent monaxon or triaxon spicules indicate **Spicule** of sponges.

Gemmules:-

Gemmules are asexual reproductive bodies forming a part of regular life cycle.These are endogenous buds which are diagnostics of Porifers,especially of freshwater and a few marine sponges.Gemmulation or endogenous budding is a peculiar mode of reproduction under unfavourable condition such as excessive cold or drought.

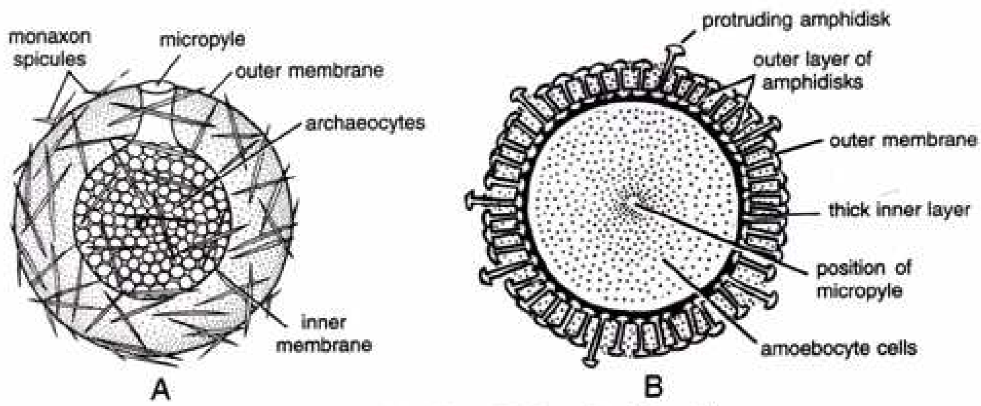


Fig. 11.4. Gemmule of *Ephydatia*. **B.** Gemmule of *Spongilla*.

Comments:

1. Gemmules are asexual reproductive bodies forming a part of regular life-cycle .
2. Gemmules or endogenous buds are diagnostic of Porifera and especially of fresh-water and a few marine sponges.
3. Gemmulation or endogenous budding is a peculiar mode of reproduction under unfavourable conditions such as excessive cold or draught.
4. Gemmules contain outer and inner membrane.
5. Gemmule is rounded structure formed by the aggregation of archaeocytes into groups accompanied by trophocytes which are impregnated with food particles of glycoproteins or lipoproteins.
6. **Scleroblasts** secretes the **amphidisk spicules**, which forms a row in columnar layer between outer and inner membrane
7. Gemmules are resistant to external factors such as freezing and drying. Gemmules of fresh water sponge can be kept for 2 years.
8. They hatch at a temperature of 13-21◦C in about 3 days. After hatching, a gemmule gives rise to a young sponge.
9. A full grown gemmule is usually pierced by opening on one side, called a **micropyle**.

Identification: Since the material has micropyle in mature and amphidisk spicules in immature gemmules and has above all features,hence it is Gemmule whole mount.

11.4.3- Coelenterate (Obelia Colony & Obelia Medusa)

OBELIA:-

Obelia is colonial, mainly sedentary hydrozoan zoophyte attached to the seaweed, hills and rocks.It is mostly found in shallow water and also up to approximately 250 ft.deep.

Method for slide preparation:-

Coelenterates are first narcotized in water mixed with menthol crystal or Magnesium sulphate. After decanting the narcotizing liquid,fix the animal by adding drop by drop formol.(commercial preparation).These are then preserved in 70 %alcohol or 5%formalin solution.

For making permanent mount ,keep the material in 70%alcohol,then stain in borax carmine,if overstain ,destain with acid alcohol. Dehydrate in 70%, 90% and 100% alcohol. Clear in xylol or benzene and finally mount on Canada balsam. Then study under the microscope, draw the diagram, label them and note down the characteristic features.

OBELIA COLONY:-

Classification:

Phylum ………. Coelenterata-	Tissue grade, diploblastic and acoelomate.
Class …………. Hydrozoa	- Hydroids: medusa with velum.
Order ………… Hydroidea	- Polypoid generation well developed
Sub order …….. Calyptoblastea	- Hydranths have hydrotheca and gonophores with gonotheca.
Genus ………... Obelia	

Habit and habitat:

Obelia is colonial, marine, sedentary hydrozoan zoophyte, attached to seaweeds, shells and rocks.

Distribution:-

Its range is from the Arctic region to the Gulf of Mexico and the Pacific coast, and from Southern California to Oregon. it is found in shallow watter and also upto approximately 250 feet deep.

Comments:-

1) It is a dimorphic colony in the form of small seaweed filaments, measuring several cm in height. The filaments may be horizontal and vertical. The colony consists of several parts.
2) **Hydrorhiza**: It is basal or horizontal portion called as stolon or rhizostome, which is meant for attachment to substratum. Hydrorhiza gives vertical branches called hydrocaulus.
3) **Hydrocaulus** gives alternate branches that terminate into individual zooids called as polyps and medusa.
4) **Coenosarc:** Stems and zooids are made of a living hollow, cellular tube called as coenosarcs. It is made up or ectoderm, endoderm and mesogloea.
5) Stems and zooids are made up of two components : (i) Outer protective tough, transparent non-cellular covering called as **perisarc** (ii) **mesogloea** (iii) inner living hollow cellular tube called **coenosarcs**.
6) Zooids consist of polyp and medusa.
7) Medusa grows at the base of polyp-bearing branches and is enclosed in blastostyles. Medusa is composed of upper exumbrellar and lowr sub-umbrellar surfaces, manubrium and gonads. Free medusa occurs in the life cycle. It is a reproductive zooid.
8) Polyp is a bell-shaped cup made up of lower cub-shaped hydrotheca and upper hypostome. Hypostome is a feeding zooid having circlet of 24 nematocyst bearing tentacles.
9) Growth of the colony is sympodial, i.e., each new hydranth arises as bud from the stem, just proximal to the next youngest polyp.
10) It reproduces asexually and sexually.

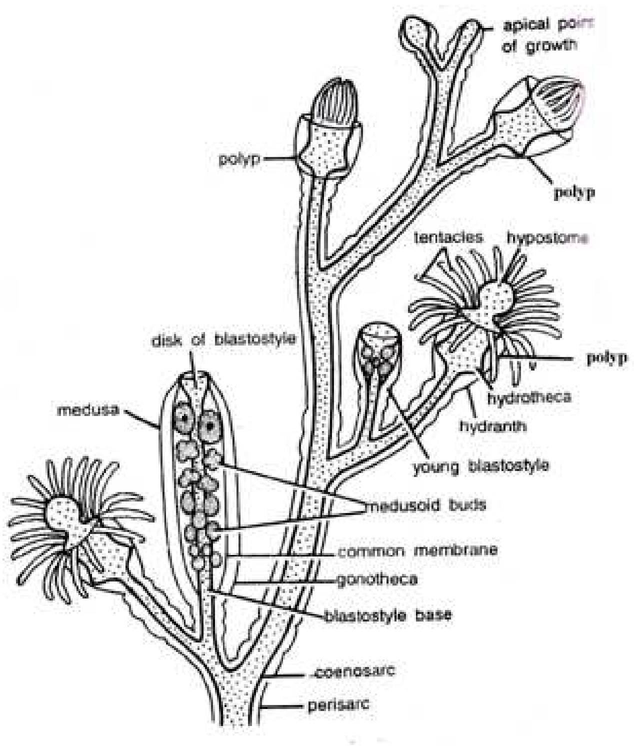


Fig. 11.5 Obelia colony

Identification:

The colony has alternate branches of polyps, blastostyles and all above features, hence it is **Obelia**.

Obelia: Medusa:-

Comments:

1) Medusa is a modified zooid for sexual reproduction.
2) It is a solitary free-swimming zooid, originating from blastostyles.
3) Medusa is umbrella-like and has convex exumbrellar and concave sub-umbrellar surfaces with well defined radial symmetry.
4) Umbrellar edge contains radially symmetrical tentacles.
5) Base of fully grown tentacle is thickened to tentacular bulb which contains a number of stinging cells.
6) In the four radial positions each tentacular bulb contains two otocysts, which are hollow and balancing organs containing calcareous otoliths.
7) **Manubrium** hangs from the centre of sub-umbrella, having mouth.
8) Mouth communicates with 4 radial canals which join with circular canal lining umbrellar margin which all around contains velum.
9) Beneath the radial canals are gonads lying in S**ub-umbrellar** ectoderm.

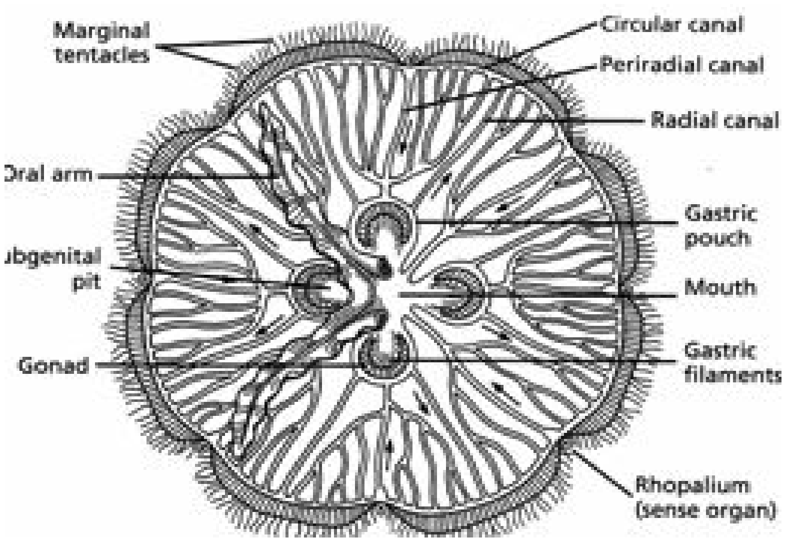


Fig.11.6 Medusa: Obelia

Identification:

Since the mount has circular tentaculated body, 4-radial rounded gonads and all above features, hence it is obelia medusa a very favourite slide-spot.

11.4.4- Arthropoda (Mouth parts of Honey Bee, Butterfly, Cockroach and Grasshopper)

MOUTH PARTS OF INSECTS:-

Insects constitute the largest group of animals in the Animal Kingdom. They have developed different feeding habits as their food differs variously. So for this purpose, they have got certain appendages in their head around the mouth; these appendages together constitute the mouth parts. The mouth parts of insects, therefore, grouped into two main categories; chewing or mandibulate type and sucking or suctorial type

Basically, the mouth parts of insects include a pair of mandibles, a pair of labium or first maxillae and the lower lip represented by and the maxillae and the lower lip represented by fused second pair of maxillae. In chewing type of mouth parts, the mandibles are well developed and the maxillae are simple as found in Orthopterans like cockroaches and grasshopper. These mouth parts are adapted for cutting or biting and chewing or crushing the food. In suctorial type of mouth parts, the mandibles are vestigial, e.g., lepidopteron or absent, e.g., housefly or blade-like, e.g., honeybee or in the form of piercing needles or stylets, e.g., mosquito. The maxillae, however, exhibit modifications in various ways for piercing and sucking the food.

The mouth parts of insects are, however, classified into following five types:

Chewing type:-

These consist of the labrum forming upper lip, mandibles, first maxillae, second maxillae forming lower lip, hypopharynx and the epipharynx.The labrum is median, somewhat rectangular flap-like. The mandibles are paired and bear toothed edges at their inner surfaces; they work transversely by two sets the first maxillae are paired and lie one on either side of the head capsule behind the mandibles. Each possesses a five-jointed maxillary palp which is a tactile organ. The first maxillae help in holding the food. The second maxillae are paled but fused to from the lower lip. Its function is to push the masticated food into the mouth. The hypopharynx is dingle median tongue-like process at whose base the common salivary duct opens. The epipharynx is a single small membranous piece lying under the labrum and bears taste buds. This type of mouth parts are found in Orthopteran insects like cockroaches, grasshoppers, crickets, etc. These are also found in silver fish, termites, earwigs, beetles, some hymenopterans and in caterpillars of Lepidoptera.

2. Chewing and lapping type:-

This type of mouth parts are modified for collecting the nectar and pollen from flowers and also for moulding the wax, as is found in honeybees. They consist of the labrum, epipharynx, mandibles, first pair of maxillae and second pair of maxillae. The labrum lies below the clypeus, below the labrum is a fleshy epipharynx which is an organ of taste. Mandibles are short, smooth and spatulated, situated one, either side of the labrum; used in moulding wax and making the honeycomb. The labium (second pair of maxillae) has reduced paraglossae, the glossae are united and elongated to from the so called retractile tongue, at its tip is a small labellum or honey spoon. The labial palps are elongated. The glossa is used for gathering honey spoon. The labial palps are elongated. The glossa is used for gathering honey and it is an organ of touch and taste. The first pair of maxillae are placed at the sides of labium, they bear small maxillary palps, lacinia is very much reduced but galea are placed at the sides of labium, they bear small maxillary palps, lacinia is very much reduced but galea are elongated and blade-like; The galea and labial palps form a tube enclosing the glossae which moves up and down to collect nectar from flower nectarines. The nectar is sucked up the through the tube, so formed, by the pumping action of the pharynx. The labrum and mandibles help in chewing the food.

3. Piercing and sucking type:-

This type of mouth parts are adapted for piercing the tissues of animals and plants to suck blood and plant juice, and found in dipteran insects like mosquitoes and hemipteran insects like bugs, aphids, etc. They usually consist of labium, labrum and epipharynx, mandibles, maxillae (1^{st} pair) and hypopharynx.

4. Sponging type:-

This type of mouth parts are adapted for sucking up liquid or semiliquid food and found in houseflies and some other flies. They consist of labrum-epipharynx, maxillae, labium and hypopharynx; mandibles are entirely absent.In fact, in this type of mouth parts, the labium, i.e., lower lip is well developed and modified to form a long, fleshy and retractile proboscis. The proboscis is divisible into three distinct parts: (i) rostrum or basiproboscis: it is broad, elongated and cone-shaped basal part of proboscis articulated proximally with the head and bears a pair of elongated and cone-shaped basal part of proboscis articulated proximally with the head and bears a pair of unjointed maxillary palps representing the maxillae, (ii) haustellum or mediproboscis; it is the middle part of proboscis bearing a mid-dorsal oral groove and a ventral weakly chitinized plate-like theca or mentum. A duct and closes the grooved of labrum epipharynx form below. The labrum-epipharynx is a long, somewhat firmed and grooved structure covering the oral groove. The food canal or channel is, thus, formed by labium – epipharynx and the hypopharynx and (iii) labella or distiproboscis; it is the distal part of proboscis and consists of two broad, flattened and oval spongy pads having a series of channels pseudotracheae. These open externally by a double row of tiny holes through which liquid food is taken in.

5. Siphoning type:-

This type of mouth parts are adapted wonderfully for sucking flower nectar and fruit juice, found in butterflies and moths belonging to the order Lepidoptera of class- Insecta. They consist of small labrum, coiled proboscis, reduced mandibles and labium. The hypopharynx and epipharynx are not found.

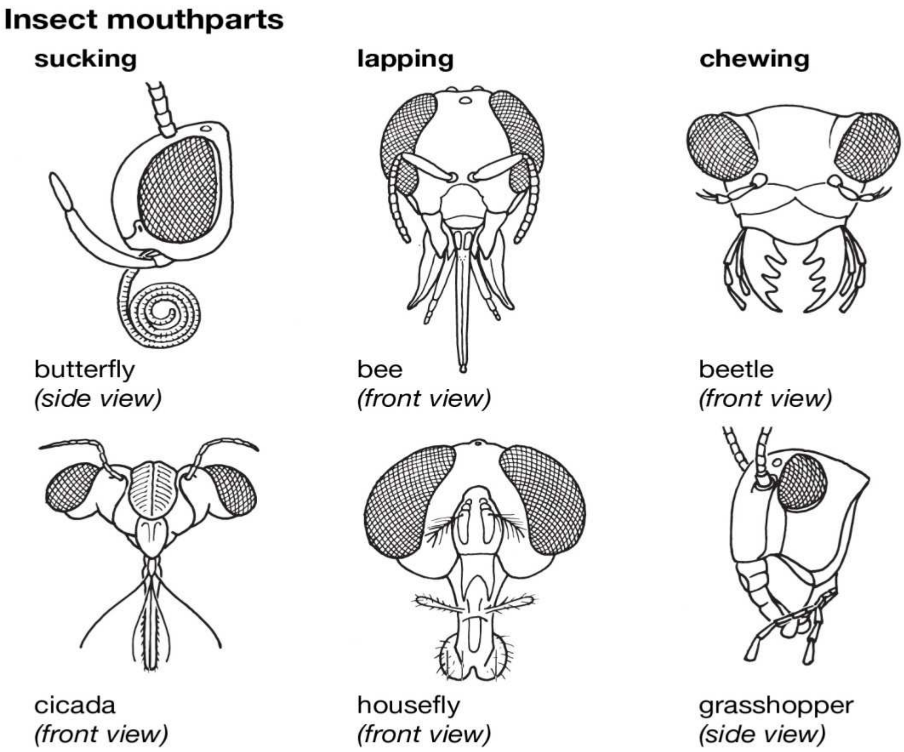


Fig.11.7 Mouth parts of Insects

Slide preparation method:-

For making permanent mount of mouth parts of honey bee, butterfly and cockroach, first cut the head of the above insects. Boil the head in 5% KOH for some time, till the chitin is dissolved. Then wash in water, dehydrate in 30%,50%,70% alcohol. Stain in picro-indigo carmine or acid fuchsin, dehydrate in 90% and absolute alcohol. Clear in xylol or benzene and finally mount in Canada balsam. Study under the microscope draw the diagram and note down the characteristic features,

Butterfly: - Head and Mouth Parts

Comments:-

1) Butterfly, belonging to order Lepidoptera, contains siphoning or sucking mouth parts. Head may be examined under binocular microscope for mouth parts.
2) Head of butterfly is composed of large compound eyes and antennae. It is broad and contains siphoning type of mouth parts.
3) Mouth parts are composed of small labrum in front of clypeus, triangular labium and coiled proboscis.
4) Mandibles are absent
5) Proboscis is composed of elastic cuticle and greatly elongated galeae of maxillae, grooved internally forming food canal for nectar.
6) Proboscis lies in coiled stage, but it immediately uncoils and protrudes in response to a food stimulus, due to rise in blood pressure.
7) Labium is triangular and plate-like containing labial palps.
8) Other joints of maxillae and maxillary palps are reduced or vestigial.
9) Head contains ventral groove for proboscis.

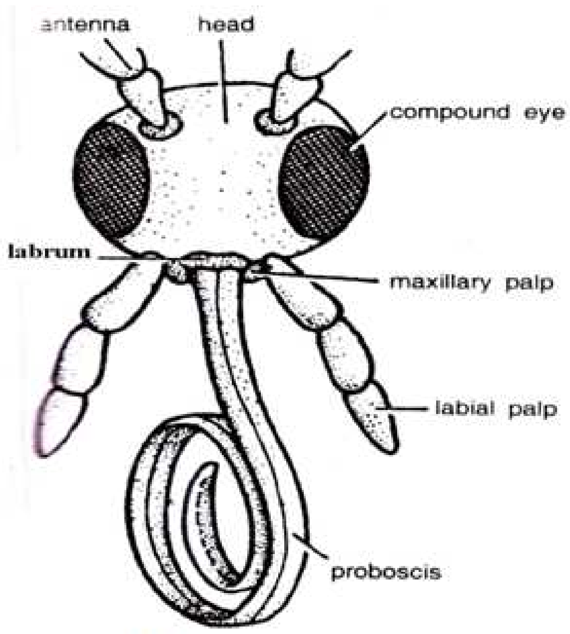


Fig. 11.8 Head and mouth parts of butterfly.

Identification:-

Since the mouth contains coiled proboscis, hence it is the mouth parts of butterfly.

APIS:-

Honey – Bee: Mouth Parts of Worker:-

Comments:

1) Honey-bee belonging to the order Hymenoptera contains rasping and lapping mouth parts, adapted for collection of nectar and pollen.
2) Head is triangular, containing large compound eyes, 3 ocelli antennae and mouth parts.
3) Mouth parts are composed of spoon shaped mandibles, labrum and maxillae devoid of lacinia.
4) Mandibles are smooth and spatulate type, food on either side of the labrum.
5) It contains vestigial maxillary palps and blade-like galea.
6) Labellum is spoon shaped, grooved internally forming a tube and is called as tongue.
7) Epipharynx is soft and triangular lying below the labrum. Cardo and stipes are well developed.
8) Liquid food taken along tongue is converted into honey in honey-sac by enzymes from salivary glands.
9) Prementum contains segmented labial palps, Paraglossae and glossae.
10) Honey-bee also moulds waxes in its hive.

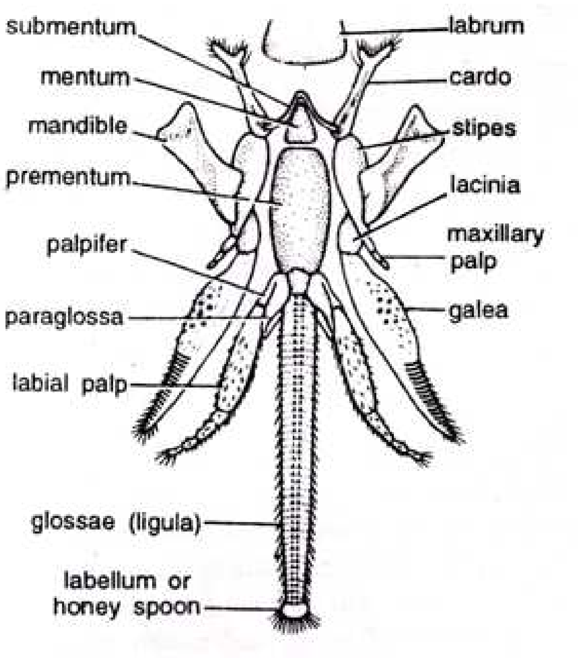


Fig.11.9 *Apis.* Honey-bee. Mouth parts of worker.

Identification: -

Since the mount contains spoon-shaped labellum, hence these are mouth parts of works, honey-bee.

COCKROACH: HEAD AND MOUTH PARTS

Comments:-

1) Cockroach, belonging to order- Orthoptera, contains chewing mouth parts.
2) Head is dorso-ventrally elongated and is composed of antennae, large compound eyes and mouth parts.
3) Mouth parts consist of (i) labrum, (ii) mandibles and (iii) maxillae.
4) Labrum protects the mouth. Mandibles are simple and toothed.
5) Maxilla has two part-cardo and stipes. Stipes contains internally lacinia, medially galea and extemally maxillary palp.
6) Labium is composed of submentum, postmentum and prementum.
7) Prementum carries glossa internally, Paraglossa medially and palpiger externally.
8) Maxillary and labial palps are tasting organs.

Identification:-

Since the mount shows definitely arranged various parts especially labium maxilla and all above features, hence it is mouth parts of cockroach.

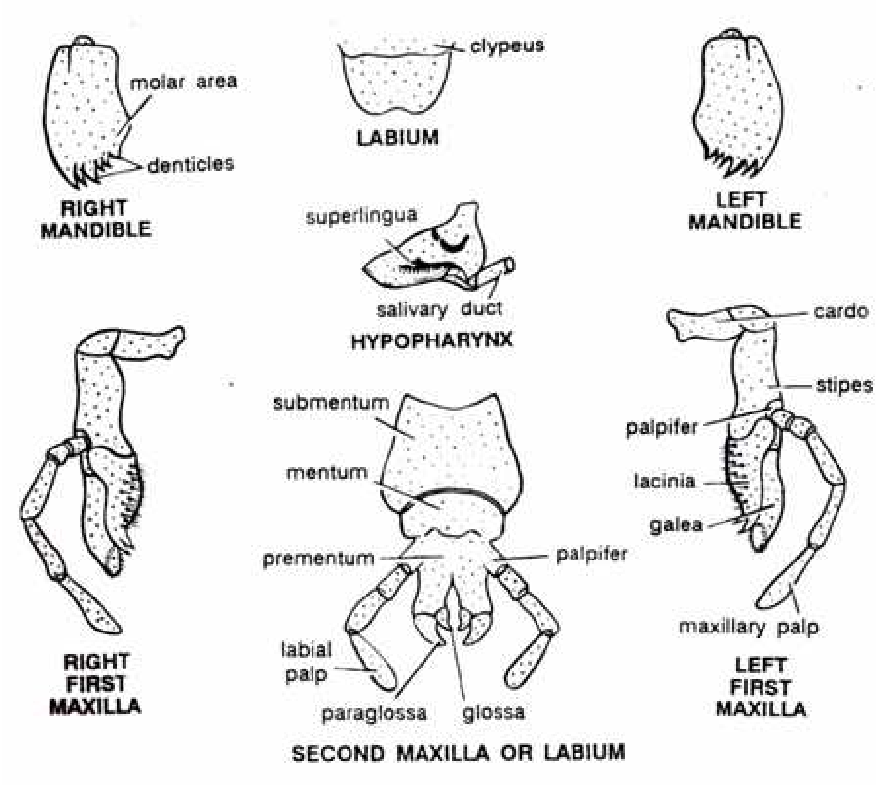


Fig.11.10 Mouth parts of Cockroach

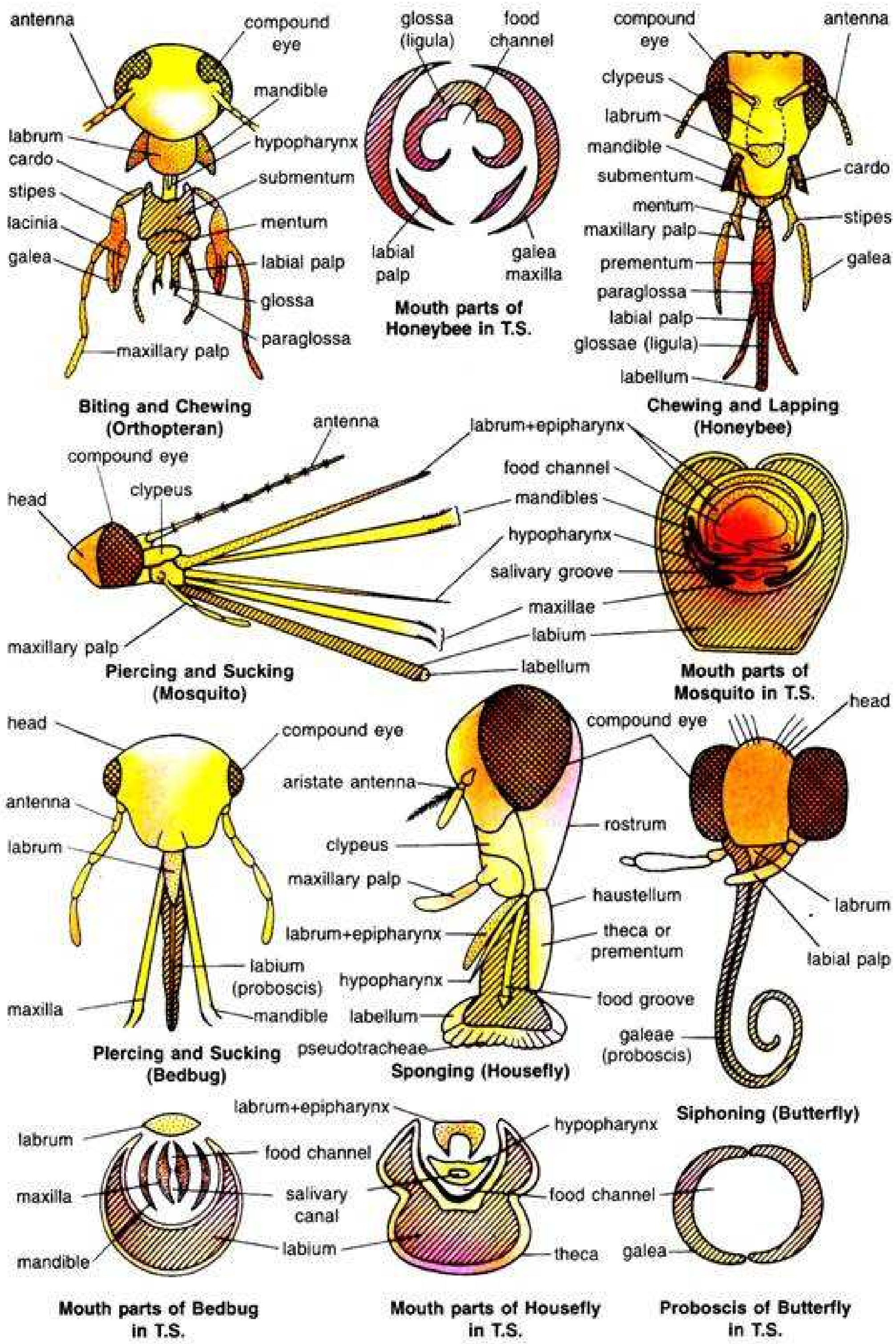


Fig11.11.Mouth parts of insects

APPENDAGES IN COCKROACH:-

(1) Thorax contains 3 pairs of waling legs, which bear dense hairs. Each leg is composed of coxa, **trochanter, femur, tibia** and **5-jointed tarsus,** which ends in a **pulvillus** (Fig. 147

***A. first pairs of legs*:**

(2) It is found in the prothoracic region; inner surface of **tibia** bears **pollen brush; posterior surface of tibia** contains a velar process, which fits into the tarsal notch; and the bristles of the tarsal notch form **antenna comb.**

(3) Anterior edge of the first tarsal segment contains **eye brush** to remove particles from the eyes.

B Second pair of legs:

(4) It originates from **mesothorax** containing 5 **podomers.**

(5) Inner end of Tibia bears spine-like **pollen spur** for removing pollen from the pollen basket. The outer surface bears **pollen brush**. Terminal part of tarsus contains **pulvilus** and **claw**

C. Third pair of leg

(6) It originates from the **metathorax.** The proximal tarsus contains stiff hair, which help in removing the pollen from the body. The tibial podomere is slightly concave and is fringed with long hairs to forming **pollen basket** or **corbicula.**\

(7) Distal end of tibia has stiff bristles called as **pecten.** Just below pecten is a plate like structure called **auricle.** Pecten and auricle form **wax pincher** for removing wax from **abdomen.**

(8) Outer surface of tarsus has **pollen brush** while inner surface has **pollen comb** or **scopa**. Terminal segment of tarsus contain **claw** and **pulvillus.**

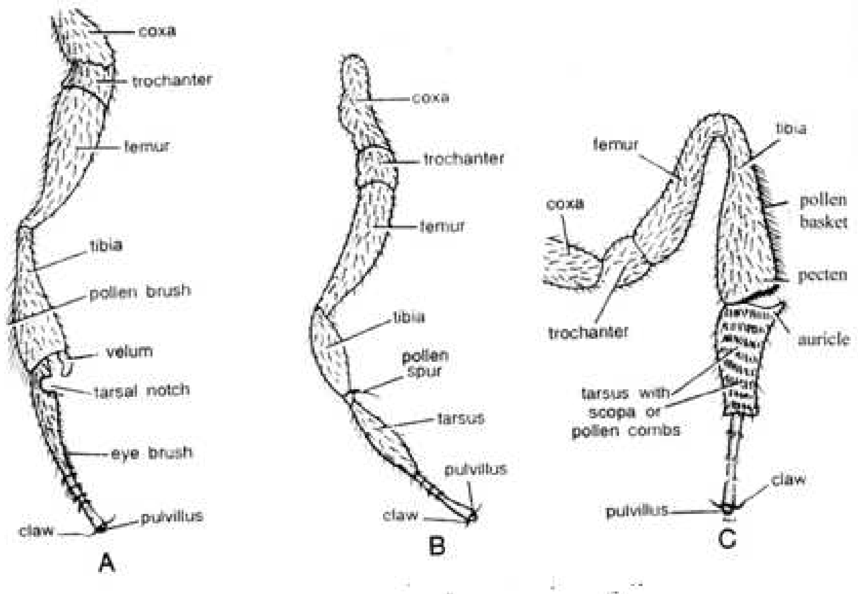


Fig. No.11.12 Leg of Honey Bee A.First Leg B.Second Leg C.Third Leg

HONEY BEE-STING APPARATUS:-

sentcomm

(1) **Sting apparatus** of honey-bee is a modified **ovipositor**, found at the posterior extremity of abdomen in queens and workers)
(2) It is composed of **sting** or **terebra, bulb, levering plates** and **glans.**

(3) Sting is made up of 2 pairs of **gonapophyses :** those of the 8^{th} segment forming **stylets** an of the 9^{th} segment **stylet sheath,** which enclose **poison canal.**

(4) Distally the stylet sheath and **stylet contain pointed spines** or **barbs.**

(5) Stylet sheath is expanded into the bulb at the base of the sting.

(6) There are 3 pairs of plates. The anterior one is triangular **fulcral** plate, the **postero-dorsal** is **quadrate plate** and the innermost is **oblong** plate bearing sting palp.

(7) There are two glands namely **poison gland,** opening into the poison-sac and a small **alkaline gland,** opening into sting bulb. The bite of the **sting** causes burning sensation, pain and swelling of the part concerned.

Identification: Since the mount contains sting and poison gland hence it is sting apparatus of ***Apis.***

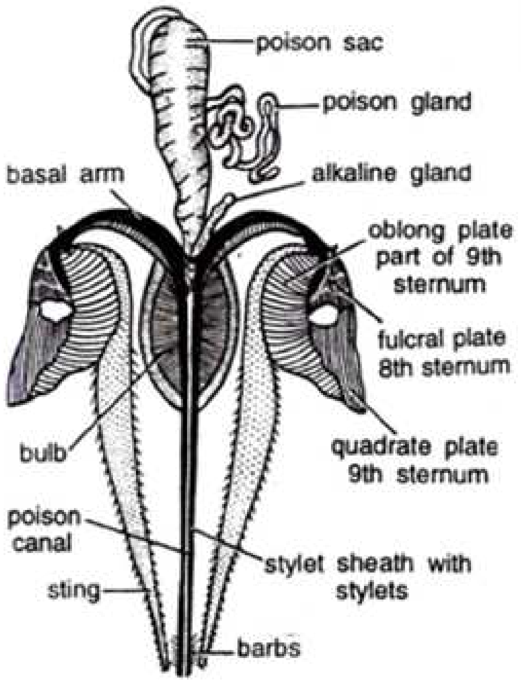


fig.11.13 sting appratus of Honey Bee

Minor Dissections:-

Nervous system of cockroach:-

Procedure: (i) Take a freshly-killed cockroach for dissection; remove wings, cut off antennae and legs close to their bases

(ii) Hold cockroach in left hand and cut the lateral membranes between terga and sterna up to the anterior edge of pronotum.

(iii) Lay the insect in the dissecting dish with dorssl side uppermost and pin it in abdominal stena and coxae of legs. (Another better procedure of fixing cockroach is to float it in petridish containing had melted wax. Allow it to cool and in due course the animal will be embedded and dissection can be done.) Fix the head by pinning between mandibles by means of fine scissors make a rectangular cut in the head around clypeus and anterior epicranium to expose two cerebral ganglia.

(iv)Make a transverse cut along the posterior edge of the ninth segment (tergum) and gently remove other segment very carefully, so that the underlying organs and tissues are not disturbed.

(v) Uncoil intestine and stretch alimentary canal on one side. Remove fat bodies, tracheae and other muscles to expose internal organs. Study and draw the following parts:

(1) **Heart : -**
13 **chambers** in number (3 thoracic and 10 abdominal narrow chambers). Note inter-segmental alary muscles.
(2) **Alimentary canal : -**
(3) Is divided into three parts:
(a) Foregut: It comprises of **mouth, buccal cavity, oesophagus, crop and gizzard.** The buccal cavity, receives the common salivary duct. Crop is meant for storing food. The gizzard has chitinous lining, which is internally produced into six teeth for masticating the food and setae for straining the food.
(b) Mesenteron *or* ***midgut:*** It is a narrow duct originating from gizzard and midgut there are 7 to 8 **hepatic** or **mesenteric caeca**. (Their function is to increase the absorptive area).
(c) Hindgut or ***proctodaeum:*** It includes ileum, colon and rectum. The beginning of ileum is marked by 60-70 fine and long **greenish yellow Malpighian tubules** (excretory in function).

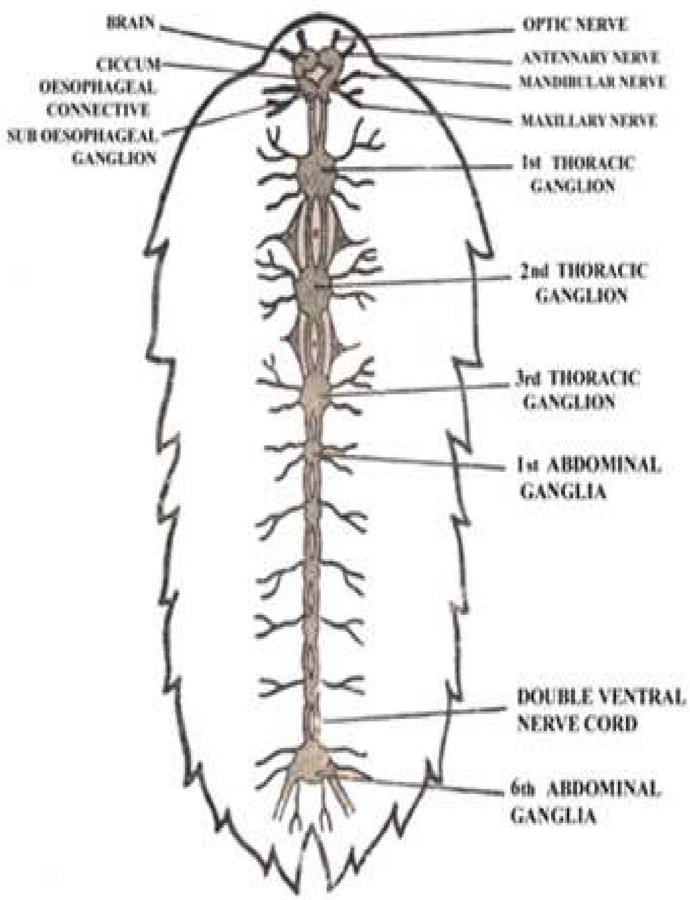


Fig.11.14 Nervous System of Cockroach

Nervous system of Grasshopper:-

Procedure:

Take a freshly chloroformed or preserved grasshopper, cut wings and fix the animal with dorsal side upwards. Make incision in pleura and remove the targal sclerites. Remove terga in head region. Now carefully remove the viscera and expose as clearly as possible the entire nervous system. Start from posterior side and gradually trace the nerve cord up to brain. Observe the following parts:

Entire nervous system is divided into 3 years:-

1. The central nervous system:

It consists of a dorsal brain or supra-oesophageal ganglia situated above oesophagus between eyes and connected to ventral sub-oesophageal ganglion by circum-oesophageal connectives (Fig. 32).

Sub-oesophageal ganglion is formed by the fusion of mandiblur, maxillary and labial ganglia. It gives rise to double ventral nerve cord which extends upto posterior region and shows the following thickenings or ganglia:

(1) **First thoracic ganglion.**

(2)**Second thoracic ganglion.**

(3) **Third thoracic ganglion,** and

(4) **Five pairs of abdominal ganglia.**

2. Peripheral nervous system: The following nerves arise from central nervous system:

(1) A pair of **optic nerves** originates from optic lobes and supplies to **antennules.**

(2) **Ocellary nerves:** They innervate ocelli.

(3) A pair of **antennary nerves** originates from thoracic ganglia.

(4) **Walking leg nerves.** They originate from thoracic ganglia.

(5) **Abdominal nerves** arise from abdominal ganglia and supply to various organs.

3. Sympathetic nervous system: it includes occipital ganglion, frontal ganglion and ingluvial ganglion, which are associated with brain and control involuntary actions of alimentation, heart ganglion, frontal aorta and genital organs.

Instructions: Draw the diagram of your dissection with the help of the practical book.

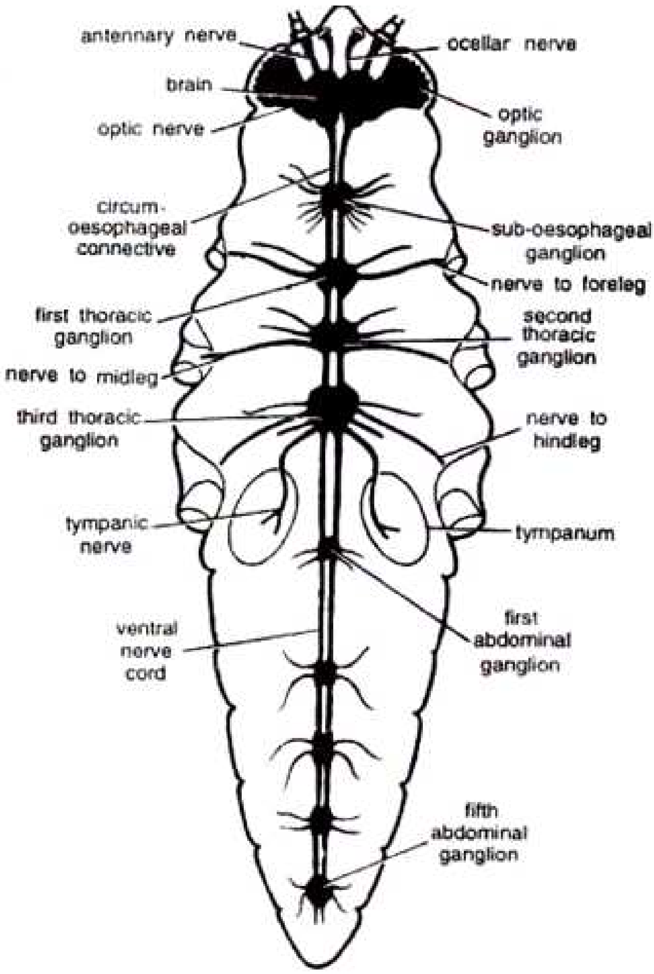


fig.11.15 Nervous System of Grasshopper

11.7 - Glossary:-

Aboral	Opposite the mouth.
Amoeboid	Cell movements resembling those of the amoeba.
Angstrom	One thousand of a micron.
Archenteron	Primitive digestive tract of a metazoan embryo, formed during gastrulation.
Autotrophic	Nutrition. Process of nutrition in which an organism manufactures its own food.
Basal disc	Foot of some Cnidaria which is flattened and attaches to a substratum by secretion of a sticky substance.
Binary fission	the type of asexual reproduction by means of which the organism divides into two approximately equal halves.
Buccal	Pertaining to the mouth or oral cavity.
Cnidaria or Coelenterata.	Phylum of animals all possessing cnidoblast structures.
Cnidoblast	Type of cell in which nematocyst is found.
Coelom	The body cavity lined with tissue of mesodermal origin in which the digestive and other organs lie.
Conjugation	A method of sexual reproduction in which two unicellular animals untie, exchange nuclear material and then divide as in the Paramecium.
Contractile vacuole	A space in the cytoplasm of certain species of protozoa where fluids collect before being periodically discharged to the outside.
Ctenophora	Radiate phylum of animals possessing comb- such as comb-jellies.
Cuticle	Thin non-cellular outermost secreted by the underlying epidermis.
Cyst	The stage of an organism where it is enclosed in a resistant wall.
Cytopharynx	Pharynx or gullet of a protozoan such as Paramecium.
Cytostome	Cell mouth, for example in Paramecium.
Diplobastic	Derived from two embryonic germ layers, ectoderm and endoderm.
Enteron	Digestive tract, especially in Cnidaria.

Entoprocta	Pseudocoelomate, sessile phylum with U-shaped intestine, mouth surrounded by circle of ciliated tentacles, and opening within cirle.
Extracellular	Outside of the cell or cells.
Exumbrella	Convex, aboral surface of the medusa.
Fission	Asexual method of reproduction by division into two or more approximately equal in size.
Food vacuole	Intra-cellular digestive organelle.
Free-living	Capable of independent existence.
Gastrodermis	Lining of coelenterate digestive cavity.
Gastrulation	Process by which two germ layers, ectoderm and endoderm.
Holophytic	Type of nutrition, found in green plants and in some mastigophores, which involves photosynthesis.
Holozoic	Type of nutrition found in most animals, that involves ingestion and digestion of organic material.
Hydranth	Expand end of a branch of a hydroid colony specialized for vegetative function.
Hydrocaulus	Basal portion of a hydroid colony often branched and root-like used for attachment to substratum.
Hydrotheca	Transparent membrane that extends from the perisarc and surrounds the main part of the hydranth.
Hypostome	Region surrounding the mouth in coelenterates.
Inter-cellular	Between cells.
Intra-cellular	Within cells.
Isogamy	Sexual reproduction involving fusion of two similar gametes but from opposite sexes.
Kinetosome	The basal body of a flagellum or cilium.
Lophophore	Anterior tentacle- bearing area of certain coelomates; serves in food capture.
Mesogloea	Non-cellular jelly-like substance lying between the ectoderm and endoderm in coelenterates.
Metagenesis	Alternation of sexual with an asexual generation in reproduction in the life cycle of a coelenterate such as Obelia.

Myoneme	Type of contractile fibril in certain Protozoa.
Nephridiopore	External opening of an excretory tubule or nephridium.
Pedal	Pertaining to father.
Pellicle	The protective layer on the surface of some protozoans, for example, Paramecium.
Penetrant	Largest type of cnidarians nematocyst, containing a coiled tube and spines, used in prey capture.
Peristome	Region around the mouth of a radially symmetrical animal such as hydra.
Phagocyte	Type of white blood cell that engulfs and digests bacteria and other foreign materials.
Pinocytosis	Cellular drinking or intake of fluid.
Plankton	Floating or drifting aquatic organisms, mostly microscopic.
Plasmasol	Relatively liquid cytoplasm.
Pneumoatophore	Air-filled float of siphonophoran hydroids.
Polyp	A tubular coelenterate form.
Prosopyle	One of the surfaces pores opening into a sponge chamber.
Protozoa	A phylum of acellular animals.
Proximal	Near the point of attachment of an organ.
Pseudocoel	A body cavity not completely lined with mesoderm as found in round worms.
Pseudopodia	Blunt temporary protoplasmic projections found in amoeba or in some ameba like cells.
Schizocoel	The coelom formed by the splitting of embryonic mesoderm.
Sedentary	Staying in one place.
Siliceous	Containing silicon dioxide or silica.
Spicule	One of many solid structures that composed the structural framework of a sponge.
Spongocoel	Paragastric or central cavity of a sponge.
Syngamy	Union of gametes in sexual reproduction forming a zygote.

Taxis A movement response

Tentacle A flexible arm likes extension from the body of many invertebrates such as hydra. Used in grasping and movement.

Tentaculocyst Sense organs of some cnidarians.

Triploblastic Derived from three primary germ layers-ectoderm, mesoderm, and endoderm.

Vestibule An outer cavity with an entrance to a (usually) larger, deeper cavity.

Zooid One of the members of a hydroid or siphonophore colony.

11.8 REFERENCES:-

Barnes, R.D. 1980, *invertebrate zoology*, W.B. Saunders Company, Philadelphia and London.

Berril, N.J., 1957, *Indestructible Hydra,* Scientific American, December, 1957.

Berril, N.J., 1966, *Biology in Action*, Heinemann Educational Books Ltd., London, U.K.

Chandler, A.C., and C.P. Read, 1961, I *Introduction to Parasitology,* W.B. Saunders Company, Philadelphia and London.

Cheng. T.C., 1973, *General Parasitology,* Academic Press, New York.

Elliot, A., 1968, *Zoology,* Appletion-Century-Crafts, Division of Meredith Corporation, New York, U.S.A.

Gray, J. and Lissman, H.W., 1938, *Studies of Animal Locomotion,* VII. *Locomotory reflexes in the Earthworm,* J. Exp. Biol., 15 : 506-517.

Hall, R.P., 1953, *Protozoology,* Prentice Hall Inc. Englewood Cliffs, N.J., U.S.A.

Hirschfield, H.I., 1962, *The Biology of the Amoeba,* Annals of the New York Academy of Sciences, Vol. 78, Art 2, pp. 401-704

Hyman, L.H., 1940, *The Invertebraes, Protoxoa through Ctenophora,* Vol. I, McGraw Hill Book Company, New York, U.S.A.

Hyman, L.H., 1959, *The Invertebrates, Smaller Coelomate Groups,* Vol. V, McGraw Hill Book Company, New York, U.S.A.

Hyman L.H., 1967 *The Invertebrates, Mollusca I,* Vol. VI, McGraw Hill Book Company, New York, U.S.A.

Imms, A.D., Richards, O.W., and Davies, R.G. 1957, *A General Text Book of Entomology,* Methuen and Company Ltd., London, U.K.

Jordan,E.L and Verma P.S ,Invertebrates Zoology S.Chand and Company. New Delhi.X Revised Edition.

Kotpal, R.L Modern Text Book of Zoology, Invertebrates Animal Diversity-I,Rastogi Publications.

Manwell, R.D., 1961, *Introduction to Protozoology,* Edwin Arnold Publishers Ltd., London, U.K.

Mast, S.O., 1931, *Locomotion in Amoeba Proteus,* Protoplasma, 14: 321-330

Mayr, E., 1963, *Animal Species and Evolution,* Oxford University Press, New York.

Mercer, E.H., 1959, *An Electron Microscopic Study of Amoeba proteus,* Proc. R. Soc. Lodon B. 150: 216-232

Parker, T.J. and William, A. Haswell edited by A.J., Marshall and W.D. Williams. (7th edition), 1972, *A Text Book of Zoology: Invertebrates,* English Language Book Society and **Macmillan Company, London.**

Russel-Hunter, W.D., 1968, *A Biology of Lower Invertebrates,* The Macmillan Co., New York

Sedgewick, A., 1966, *A Student Text Book of Zoology,* I, III, Central Book Depot, Allahabad.

Sleigh, M., 1975, *The Biology of Protozoa,* Edwin Arnold (Publishers) Ltd. London. Storer, **T.I., and R.L. Usinger, 1965**, *General Zoology,* McGraw Hill Book Company New York, London

Verma, P.S., 1993, *A Manual of Practical Zoology Invertebrates,* S.Chand & Co. Ltd., New Delhi, India.

Verma, P.Srivastava, P.C1998, Advanced Practical Zoology 3ed

Vickerman, K and Cox, F.E.G., 1967, *The Protozoa,* John Murray, London.

Wilson, H.V., 1907, *On some phenomena of coalescence and regeneration in sponges,* J. Exp. Zool., 5: 245-257.

Wichterman, R., 1955, *The Biology of Paramecium,* The Blakiston Company, Inc. Toronto, New York, U.S.A.

Unit 12: CYTOLOGICAL STUDY

Contents:-

12.1- Objectives:-

To study the Meiosis and describe the chromosomal makeup of a cell using the terms chromosome, sister chromatid, homologous chromosome, diploid, haploid, and tetrad and also recognize the function and products of mitosis and meiosis. Compare and contrast the behaviors of chromosomes in mitosis and meiosis. Recognize when cells are diploid vs. haploid and Predict the DNA content of cells in different phases of mitosis and meiosis stage because meiosis is a specialized and rather complicated type of cell division and we have to recall and describe the phases of the cell cycle co-relate the cell cycle stages to changes in DNA content.

12.2 Introduction

Meiosis is a specialized and rather complicated type of cell division, occurring only in the diploid reproductive cells and results in the formation of haploid sex-cells of gametes. The gametes, formed as a result of meiosis, possess half the number of chromosomes as found in the parent cells and their chromosome number is represented by **n,** whereas the zygote formed by the fusion (fertilization) of male and female gametes and the cells derived from it are known as **diploid** and their chromosome number is symbolized **by 2n.** The two similar chromosomes of diploid cells are known homologous chromosomes or homologous pair."The chromosomes of a homologous pair are brought together in the zygote by the union of male and female gametes from the parents.

12.3- Study Of Mitosis And Meiosis:-

Meiosis occurs in the life cycle of each and every living being whether a plant or an animal, but its period of occurrence varies in different groups. In majority of cases it occurs prior to gamete formation. The cells undergoing meiosis are known as **meiocytes.** In animals, the **meiocytes** are the **primary spermatocytes** and **primary oocytes** while in plants these are represented by **sporocytes.** The relative amounts of RNA and DNA are supposed to initiate meiosis in some way. If the ratio of RNA to DNA is high, the cell will undergo meiosis but if reverse is the case it will lead to mitosis.

12.4. – Study Of Permanent Slide

Process of Meiosis:-

The process of meiosis is separated into a sequence of events similar to those of mitosis but these events or stages are repeated twice, i.e., in meiosis, two complete cell divisions follow in close sequence, with or without a short interphase between them. The first meiotic division is known as **reduction division or heterotypic division.** In it the diploid parent cell divides into two daughter cells having haploid chromosome number. The second division is known as

homoeotypic division and it is a simple mitotic division in which the two haploid cells formed as result of heterotypic division divide forming four haploid cells. The two meiotic cell division is further distinguished into phases. These are:-

A. Heterotypic Division or First Meiotic Division or Reduction Division

I FIRST PROPHASE:-

The prophase of first meiotic division is of longer duration and profoundly modified. It is distinguished into following **five** phases or sub stages –

(a) Leptotene
(b) Zygotene
(c) Pachytene
(d) Diplotene and
(e) Diakinesis

1. **Proleptotene :**
The meiocytes or the meiotic cell is comparatively larger in size and possesses a large nucleus. It contains diploid number of chromosomes which form a network. In the beginning, the movement of centrioles, the formation of astral rays and the gradual condensation of the chromatin material proceed in a similar fashion as in the prophase of mitosis. These preliminary steps constitute proleptotene.

2. **Leptotene or Leptonema :**

The leptotene stage initiater meiosis. Due to the condensation of chromatin matter the chromosomes appear in diploid number as long, thin and uncoiled threads or slender filaments longitudinally single rather than double as in mitosis. These threads correspond to the chromonema of the anaphase of mitotic division. Their arrangement is often irregular but they might exhibit some definite orientation. Each chromosome parents a beaded appearance due to the presence of a longitudinal series of dense, bead- like swelling called **chromomeres.** The chromomeres **are** of different sizes and occur in definite sequence on each chromosome. The homologous chromosomes display the same sequence of chromosomes. The DNA and histone synthesis and the chromosomes duplication either starts in this substage or occurs in the later substage but in most cells the duplication is completed by the end of next substage, i.e., **zygotene.** The nucleolus is well marked and increases in size in leptotene and zygotene.

3. **Zygotene or Zygonema**
The zygotene commences with the movement of chromosomes. It is affected by the forces of attraction between the two homologous of a chromosome pair. Thus, the chromosomes of a pair approach each other and each chromosome shortly takes a

position along the side of its partner to form a bivalent. The pairing of homologous is known as **synapsis** and is very intimate and precise, the chromomere to chromomere.

Once the pairing has started at some point along the homologues it proceeds from there in zipper-like fashion. This indicates that the homologous chromosomes are not only similar in appearance, but they also carry the same genes in the same sequence.

The pairing may be completed in any of the following methods:

- The two homologues start pairing progresses towards centromere region - **proterminal apis.**
- The pairing may start near the centromere and then progresses towards the ends -**procentric synapis**
- The pairing starts at random either at one point or at many points simultaneously- **random synapsis**.

In organisms with definitely oriented or polarized chromosomes, pairing usually commences at the ends nearest the nuclear membrane and progresses onwards till completion. This peculiar state of orientation, polarization and association is known as bouquet **stage**.

As the pairing proceeds, the chromosomes continue to condense and become shorter and thicker. Two views have come forward to explain the possible initiation of synapsis.

According to precocity theory put forward by **Darlington,** the chromosomes pair due to their singleness. But this theory does not explain the extra synthesis of DNA and chromosomes duplication at leptotene stage.

The **retardation theory** by Sax and others explains that the pairing of homologous is due to the retardation of cessation of metabolic activities of the cell.

At zygotene the nucleolus increases in size and the centrioles move apart initiating the spindle formation.

4. **Pachytene Stage or pachynema**

With the pairing or synapsis of homologues the nucleus enters the pachytene stage. It represents the stable period in cell division. During this stage the paired chromosomes of bivalent get shortened and thickened due to gradual condensation of chromatin and appear as thick rods of different shapes and sizes, so that the chromosomes are more readily distinguished.

The homologous chromosomes now twist or twin around each other forming relational coils. Each chromosomes starts splitting into two sister chromatids by a vertical or longitudinal furrow. As a result the bivalent is now converted into tetrad.

The time of duplication varies in different types of cells. In some it is said to occure in leptotene, while in others in pachytene.

Their relational coiling gets further complicated due to the coiling of two chromatids of each chromosome. This vigorous coiling exerts considerable starin upon the chromosomes. As a result the weaker chromatids break down at points.

These transverse breaks occur in the non-sister chromatids of a pair at corresponding points. The broken ends are then interchanged between the matching chromatids and are attached to their respective remaining portions.

This exchange and recombination of chromosomal parts is known as **crossing over**. Its completion marks the end of pachytene.

5. **Diplotene or Diplonema**

The separation of homologous chromosomes initiates diplotene. The synaptic forces of attention between them lapse due to breakage at one or more points so that the homologous chromosome uncoil and starts separating.

But the separation is none the less incomplete since the homologous are in contact are known as **chiasmata** (sing. **Chiasma**, meaning, **cross**) which present cross-shaped appearance.

The chiasma is the bivalent varies in the same pair of chromosomes and in different cells of the same individual. By the end of diplotene the chiasmata begin to move along the length of chromosomes from the centromere towards the end.
This displacement of chiasmata is termed as *terminalization.* When the terminalization of chiasmata. The degree of terminalization is generally expressed as coefficient of termination *(T)*.

$$T = \frac{\text{Number of terminal chiasmata}}{\text{Total number of chiasmata}}$$

The average number of chiasmata in bivalent is known as frequency of chiasmata 9Fq)

$$\text{Frequency (Fq)} = \frac{\text{Total number of chiasmata}}{\text{Total number of bivalents}}$$

According to Darlington, two types of repelling forces operate on the chromosome at diplotene. One of the forces is electro negatively charged and operates on the surface of the chromosome throughout its length and the other with electropositive charge is localized on the centromere. The former controls the repulsion of the chromosomes and the latter cause's distal movement of the chiasmata.

6. **Diakinesis:**

The bivalents still contract and get thickened into deeply stained bodies. These migrate to the periphery of the nucleus. The two chromatids of each chromosome become closely oppressed together losing their individual identity.

At the same time the homologues move still apart due to the force of repulsion developed between their centromeres. In doing so the chiasmata move towards the ends.

At this stage the nucleolus and nuclear memebrane disappear and the formation of nuclear spindle starts.

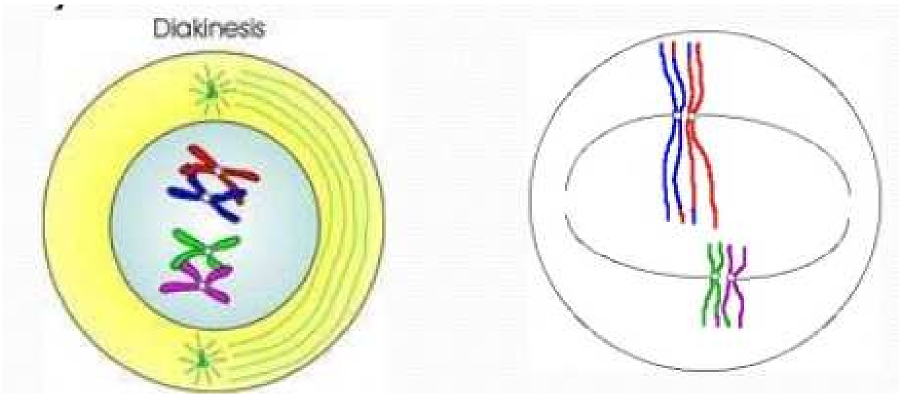


Fig.12.1 Diakinesis

II FIRST METAPHASE (METAPHASE I):-

The metaphase of meiosis is very similar to that of meiosis. At the close of diakiness the nuclear membrane disappears and the formation of amphiaster or achromatic figure or the spindle is completed. In metaphase the bivalents move the equator.

Later on, they orient themselves on the equator in such a way that their centromeres lie one on either side or equidistant from the equatorial plate.

Their centromeres face the pole of the spindle and the arms are directed towards the equator and rest on the equator.

III FIRST ANAPHASE (ANAPHASE I):-

During this stage the bivalents move apart towards the opposite poles of the spindle. The tetrad which was having four chromatids now separates into two dyads due to the complete separation of maternal and paternal chromosomes of the bivalent.

Therefore, each separated half consists of two sister chromatids attached together by a common centromere. This process of separation is known as **disjunction** and this involves the separation of those homologous chromosomes which were brought together in the zygote stage.

By this time the two chromatids of a dyad also separate except at the points of centromere, so that they present V-shaped appearance.

IV FISRT TELOPHASE (TELOPHASE I)

The first telophase commences with the formation of nuclear wall around the haploid group of chromosomal dyads which have already reached the poles of the spindle.

The chromosomes elongate the uncoil. Nucleolus is also formed.

The cell cytoplasm also segments into two. Thus two daughter cells are formed, each of which contains haploid number of chromosomes.

V INTERPHASE:-

It is the resting stage of dividing meiocytes and its duration depends upon the species involved. It may be totally absent and the chromosomes of first anaphase directly pass into second prophase omitting the telophase.

In this condition the nuclear material remains unchanged and the nuclear membrane is not formed. If the interphase is present the nucleus assumes its original form by the development of nuclear net and nuclear membrane. But if at all interphase is present it is of a very short duration.

B. Homeotypic Division:-

The second meiotic division is essentially mitosis, occurring independently in both the haploid sister cells. It may follow immediately after first meiotic division or may not occur until much later.

1. Second Prophase or Prophase II

During second prophase the nucleus and nuclear membrane disappear in both the daughter haploid cells and the formation of spindle starts.

The chromatids are coiled and the dyad has X-shaped appearance having chromatids joined by centromere and arms radiating.

2. Second Metaphase or Metaphase II

The second metaphase is of short duration. The chromatids move towards the centre of the spindle and orient on the equator.

Their centromeres touch the equator but the arms radiate out toward poles. Later on, the centromere in each dyad divides into two.

3. Second Anaphase or Anaphase II

The chromatids with their independent centromeres from sister chromosomes and move apart towards the opposite poles of the spindle.

The chromatids of second anaphase are not short and compact bodies like those of first anaphase but are very similar to the chromosomes of anaphase in mitotic division.

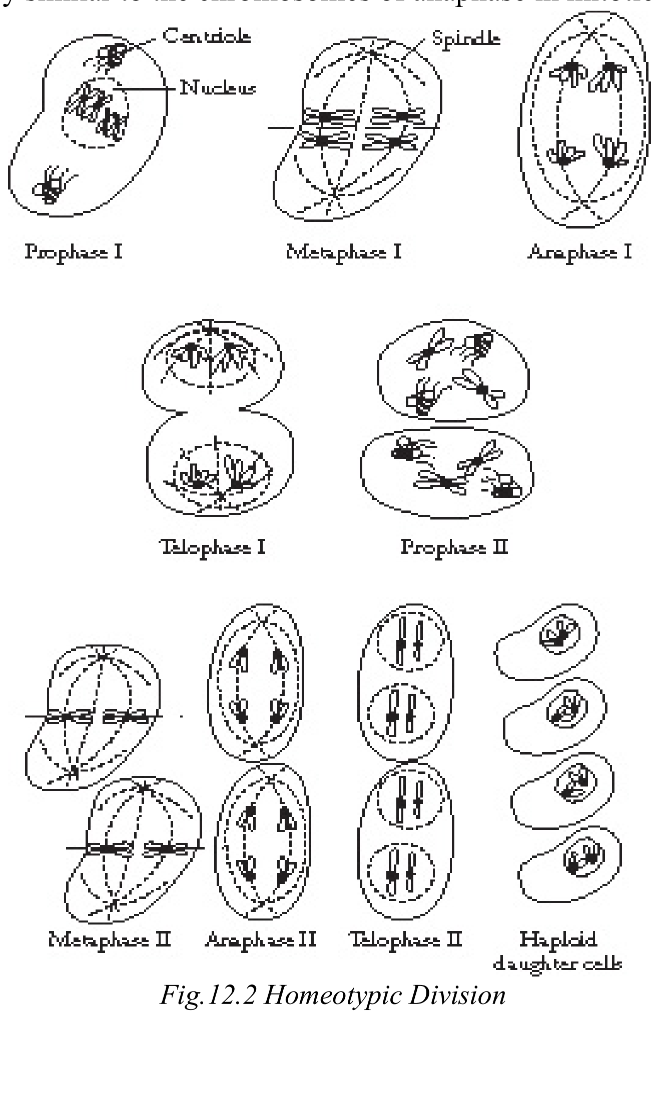


Fig.12.2 Homeotypic Division

4. **Second Telophase or Telophase II**

The chromosomes at each pole uncoil and thin out to form the nuclear net. Each group gets surrounded by a nuclear membrane. Nucleolus reappears. Thus two nuclei are recognized in each cell.

Significance of Meiosis

The significance of meiosis is threefold:-

1. The meiosis is a logical and necessary part in the life cycle of sexually reproducing animals since it leads to the formation of gametes or sex cells that participates in fertilization. These are haploid cells having only one member of each homologous pair.

2. The meiosis is concomitant of doubling chromosome number due to gametic fusion. The gametes formed as a result of meiosis are haploid and the zygote formed by their fusion is diploid. Thus, it is only means for restoring the chromosome number characteristics of the species.

3. Meiosis results new combination of genetic material. During crossing over, the hereditary factors from male and female parents get mixed due to breakage and exchange of chromatids in pachytene. Thus, the gametes produced are not all alike but with variable combination of genes. The random segregation of chromosomes and the new alignments of genes in them resulting from crossing over ensure genetic variations in the population. The inherited variability leads to the evolution of organisms.

Cytological Study Exercise:-

(1) - Object: To study the meiosis by using available material**.**

Requirement: - Living grasshoppers, Chloroform, normal saline, Carnoy's fluid, acetocarmine, slides, cover-slip, blotting paper and microscope.

Procedure: - Take a chloroformed grasshopper and dissect it in normal saline. Take out its testis and fix them in Carnoy's fluid for 2-12 hours. Take a small lobe of testis and stain it in acetocarmine. Put the stained lobe on a clean slide and cover it with a cover slip. Warm the slide over the flame of a sprit lamp and then put a blotting paper over it, press it smoothly by your thumb. Examine the slide under microscope.

Result: The cells of testis lobes are spread out and became distinct. Carefully observe different stages of meiosis under microscope and draw them in practical notebook.

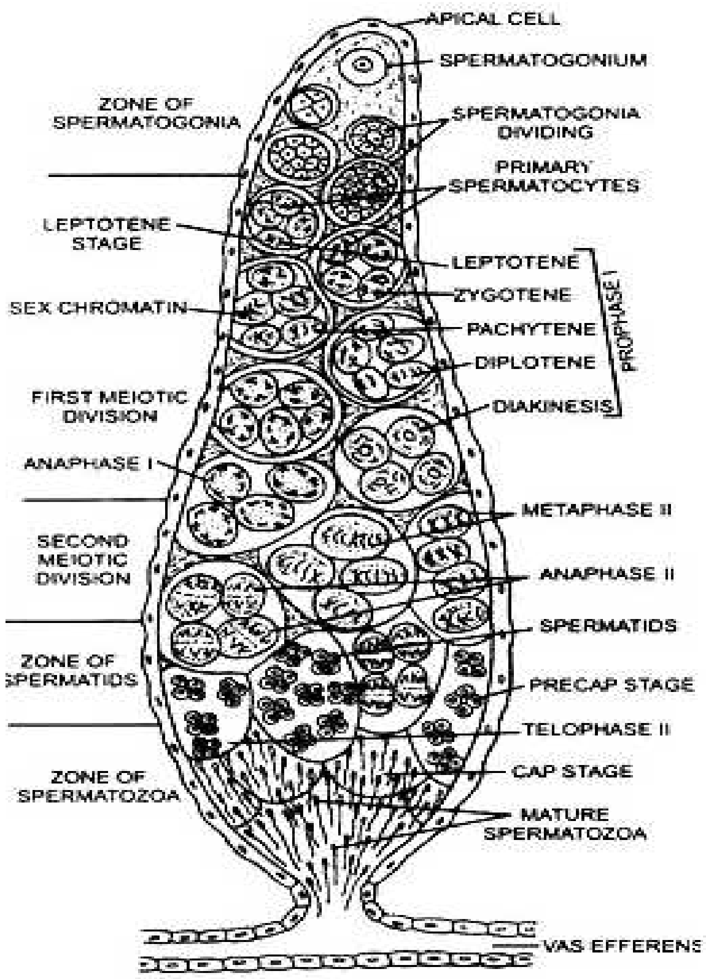


Fig. 12.3 T.S of one follicle of testis of Grasshopper to show the stage of meiosis

Cell Division :-

The process of cell division is found to be essentially the same in all living organisms and the events are chiefly centered in the nucleus. Three types of cell divisions have been distinguished.

(i) **Amitosis or direct cell division.**
(ii) **Mitosis or indirect cell division.**
(iii) **Meiosis or reduction division.**

Amitosis:-

Amitosis or direct type of cell division is characterized by the splitting of the nucleus followed by that of cytoplasm. It is seen in unicellular organism like protozoan's and the cells of foetal membranes.

The beginning is marked by the elongation of the nucleus. Due to the appearance of depression or constriction in the middle line, the nucleus assumes dumb- bell –shaped appearance. The depression increases in size and splits the nucleus into two.

Simultaneously, the cell body or the cytoplasm is also constricted into two equal or approximately similar halves. During the process of amitotic cell division there is complete absence of nuclear events and the mechanism is very simple.

Mitosis:-

Objective: (B) To study the Mitosis

Definition:-

Mitosis involves the exact replication of parent cell followed by its division into two daughter cells which are identical and contain the same number of chromosomes as found in the parent cell.

Introduction:-

This nuclear division was first observed by **Straburger (1870)** in plant cell and **Flemming (1882)** in animal cells. Flemming used the **term mitosis** (**Gr. Mitos, thread**) for this process with reference to the thread-like appearance of chromosomes early in the cell division. An illustrated account of behavior of chromosomes during the period of cell division has been given by **Darlington**. The cell division where chromosomal duplication (i.e. longitudinal splitting of chromosomes) is followed by the nuclear division so that each daughter cell possesses the same number of chromosomes as present in the parent cell.

Mitosis, division of a living cell nucleus (control centre), leading to the production of two offspring or daughter cells, normally with the same genetic information. Mitosis is the standard way that cells multiply. It occurs all the time in the human body and other multi-cellular living things, especially during growth to make more cells, and during maintenance to replace damaged and worn-out cells. In single-celled organisms, it represents asexual reproduction. In plants, it is the basis of asexual or vegetative reproduction (making cells for sexual reproduction involves another type of cell division). Genes exist as chemical codes on lengths of the chemical deoxyribonucleic acid (DNA) inside the nucleus. During a cell's "resting" period, or interphase, the DNA copies or replicates itself to form two complete sets. Mitosis then occurs in four main stages.

Process of Mitosis

The process of mitosis is characterized by the duplication of chromosomes, their separation into two and then their movement to opposite poles so as to construct two daughter nuclei.

It is followed by the constriction of cytoplasm to form two daughter cells.

The replication and distribution of chromosomes is known as **karyokinesis** while the division of cell cytoplasm and separation into two daughter cells is called **cytokinesis.**

It means cell division can be separated into two categories:

- The nuclear division or **karyokinesis,** and
- The division of the cytoplasm or **cytokinesis.**

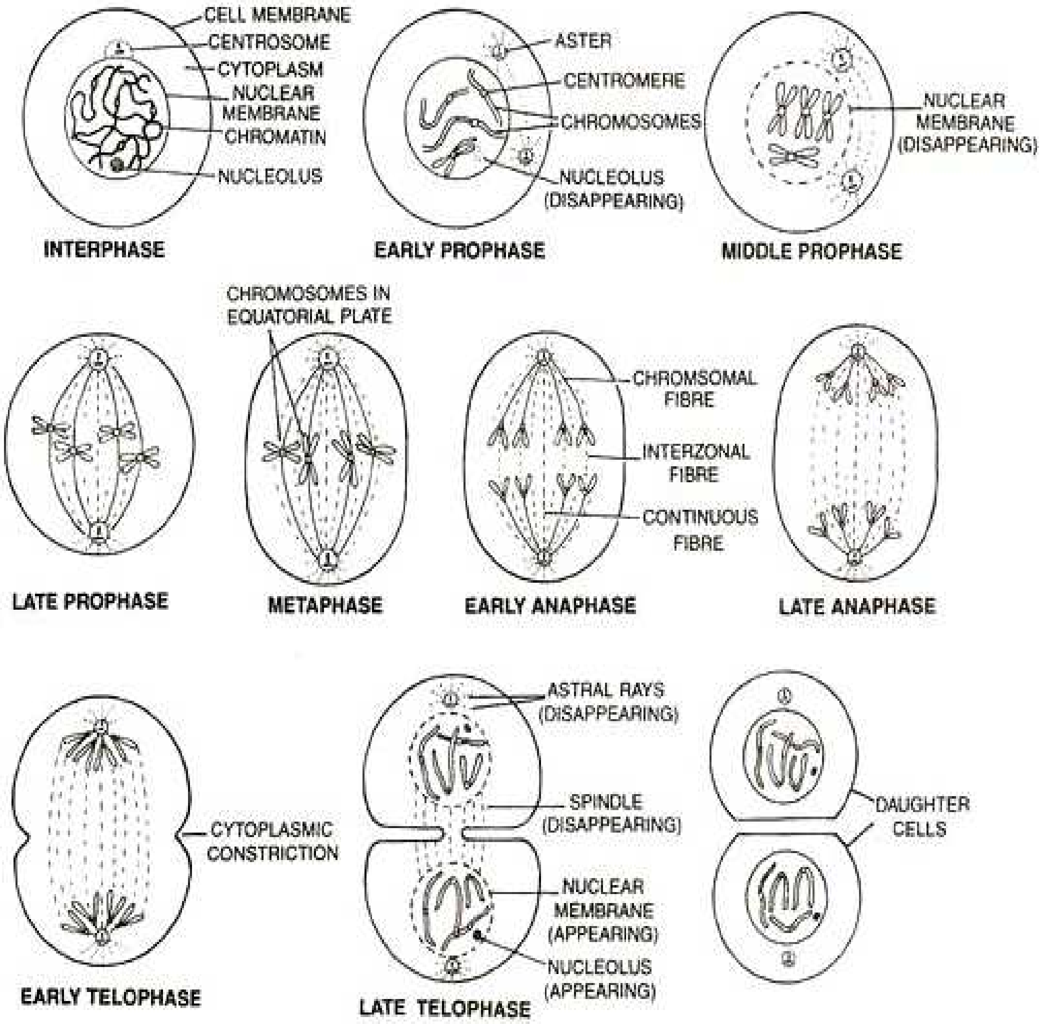


Fig. 12.4 cell division in Animal Cell

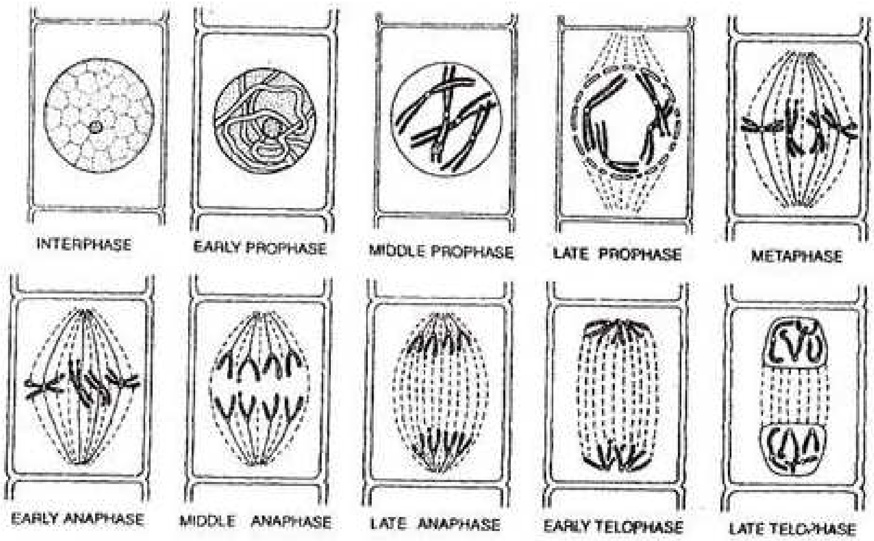


Fig. 12.4 cell division in plant Cell

Karyokinesis:-

The process of karyokinesis includes the division of cell nucleus into two daughter nuclei, It is divided into prophase, metaphase, anaphase and telophase.

1. **Prophase**
   The nuclear division (mitosis) begins with prophase. The important events during this phase are given below-

   (A) Nuclear Changes:

   (a) The chromatin materials of nucleus gradually condense into distinct chromatin thread by losing water.

   (b) The chromatin threads coil like cylindrical spring and in so doing they gradually become shorter and thicker and form the chromosomes.

   (c) The proteinous matrix gets deposited around the chromosomes, so that these gradually become shorter and thicker and form chromosomes.

   (d) Each chromosome is already doubled due to the doubling of DNA contents in interphase.

   (e) By the end of prophase the two chromatids of each chromosome become more distinct and each chromosome appears to be splitted up lengthwise.

(B) Cytoplasmic Events:

(a) The centriole divides into two and then one of the daughter centrioles moves towards the opposite pole.

(b) Astral rays radiate out from each daughter centriole.

(2) Metaphase

The metaphase is marked by the appearance of spindle and arrangement of chromosomes on the equator of spindle.

a) The microtubules in the cytoplasm of the cell orient in between the centrioles of the opposite poles and form the spindle. Such a spindle is known as **amphiaster.**

b) The chromosomes from periphery of the nucleus migrate towards equator of the spindle, lie on the equator and are attached to the chromosomal fibres of the spindle, whereas the arms are orient towards the poles.

c) Each chromosome becomes more compact and short and its two chromatids separate except at the centromere which has not divided so far.

(3) Anaphase

(a) The centromere of each chromosome divides and allow the separation of two sister chromatids into two daughter chromosomes.
(b) The daughter chromosomes move apart and migrate towards opposite poles.
(c) The movement of chromosomes is governed by the contraction of spindle fibres, the centromere is pulled first towards the pole of the spindle and the arms of chromosomes are dragged behind.
(d) In anaphase, the arms of daughter chromosomes are directed towards the equator and centromeres towards the poles of the equator.

(4) **Telophase**

(a) Chromosomes reach poles of the spindle and form two groups.
(b) Chromosomes begin to uncoil and form chromatin net.
(c) The nuclear wall and nucleolus reappear.

Mitotic apparatus or mitotic spindle:-

The mitotic spindle is formed of spindle fibres extending between the two centrioles and the astral rays radiating out from each centriole.

Structure of Spindle Fibres:-

Spindle fibres are formed of microtubules, arranged in parallel bundles. These are about 250-270Å in diameter and with a 50-70 Å thick wall. The number of microtubules composing the spindle of yeast cells (Moor, 1967).

Chemical Composition of Spindle Fibres:-

The spindle fibres represent long chain protein molecules oriented in longitudinal direction between the two poles. The protein chain are linked by bonding of protein monomers by –SH and-S-S bonds. These contain 90% proteins and 5% RNA.

Formation of Spindle Fibres:-

- Spindle fibres are cytoplasmic in origin and about 15% of the cytoplasmic proteins form the spindle.
- The formation of spindle starts in the late prophase and is completed in metaphase.
- Commonly it begins outside the nuclear membrane more or less simultaneously with the disappearance of nuclear membrane.
- During the formation of microtubules of the spindle, the polymerization of protein monomers to from amorphous gel and the formation of secondary bonds through-SH-and-S-S-groups takes places.
- The process is initiated by the release of RNA from the nucleus.

Types of Spindle Fibres: -

The spindle fibres of the three types-

- **Continuous Fibres:** These extend from one pole of the spindle to the other poles.
- **Chromosomal Fibres:** these fibres extend from pole of the spindle to the centromere of chromosomes. These are also called **kinetochore microtubules.**
- **Interzonal Fibre :** These appear in anaphase and telephase and extend between the centromeres of separating chromatids (daughter chromosomes)

Role of Spindle Fibres: -

Spindle fibres help in the movement of chromosomes from equator to the pole of spindle.

Chromosomal Movement during Cell Division:-

Cell division is characterized by the movement of chromosomes and of a number of other cellular structures. These movements are:

(1) Movement of spindle poles or centrioles to the opposite sides of the cell during prophase.
(2) Oscillatory movement of chromosomes to the equator of spindle during prometaphase.
(3) Movement of chromosomes from the equator of spindle towards poles during anaphase A.
(4) Elongation of spindle during anaphase B.

Duration of Mitosis:-

- The time required for mitosis differs with species and environment.
- Temperature and nutrition, in particular, are important factors.
- The entire sequence of phases may be completed in 6 minutes to many hours.
- Normally the entire cycle of cell division takes approximately 18 hours, about 45 minutes from prophase to the end of telophase and about 17 hours for the interphase.
- Different phases of mitosis are of different duration.
- Anaphase is the shortest, the prophase and telophase the most prolonged, and the metaphase of intermediate duration.

Mitotic Poisons: -

- There are certain substances that affect the cells in mitosis or prevent them from entering it.
- These are commonly known as mitotic poisons.
- The **colchicine** inhibits spindle formation and holds the cells in metaphase**.**
- The enzymes ribonuclease is prophase poison.
- Mustard gas fragments and agglutinates the chromosomes.
- Higher concentration of some of these poisons may lead to the immediate death of the cells.

Significance of Mitosis:-

- Mitosis is a significant aspect in the growth of living matter.

- It ensures that the new cytoplasm is accompanied by an appropriate amount of governing nuclear material.
- Individual cells cannot grow indefinitely and their size remains within economical limits with respect to the intake of foodstuffs and their transformation into energy and new cytoplasm.
- As a result of mitosis each new cell receives a set of chromosomes to regulate the activities of the cytoplasm.
- Mitosis ensures a continuous succession of similarity endowed cells, because from one dividing cell two daughter cells with exactly the same number and the same type of chromosomes are formed.
- Thus, no matter how many consecutives cell divisions have taken place, all the cells have an array of chromosomes identical to the parent cell from which they have descended by division.
- Mitotic divisions help not only in the increase of size by cell accumulation but also in replacing the old and damaged tissue by the new cells.
- In plants these do not cease to divide even when the plant is mature but continuously go on cutting new cells from the cambium.

Cytological Exercise:-

The study of cells necessarily involves sophisticated equipments and techniques.

Following is very simple and elementary methods are being described here to study cell division and making preparations of certain cell components.

(1) Objective: To observe the stages of mitosis using onion root tips.

Requirements:
- Onion root tips fixed in Carnoy's fluid.
- Microscope glass slide.
- Cover-slip.
- Acetocarmine.
- Sprit lamp.
- Blotting paper and
- Microscope.

Procedure:

- Take a drop of acetocarmine on a clean microscopic slide and put on it one or two tips.
- Place a cover slip over it and tap it gently by a needle.
- Warm the slide over the flame of a sprit lamp and then put a blotting paper over it, press it smoothly by your thumb.

- Examine the slide under microscope.

Result:-

The cells and their chromosomes are spread out and become distinct. Observe carefully the different stages of mitosis.

Cytological Exercise

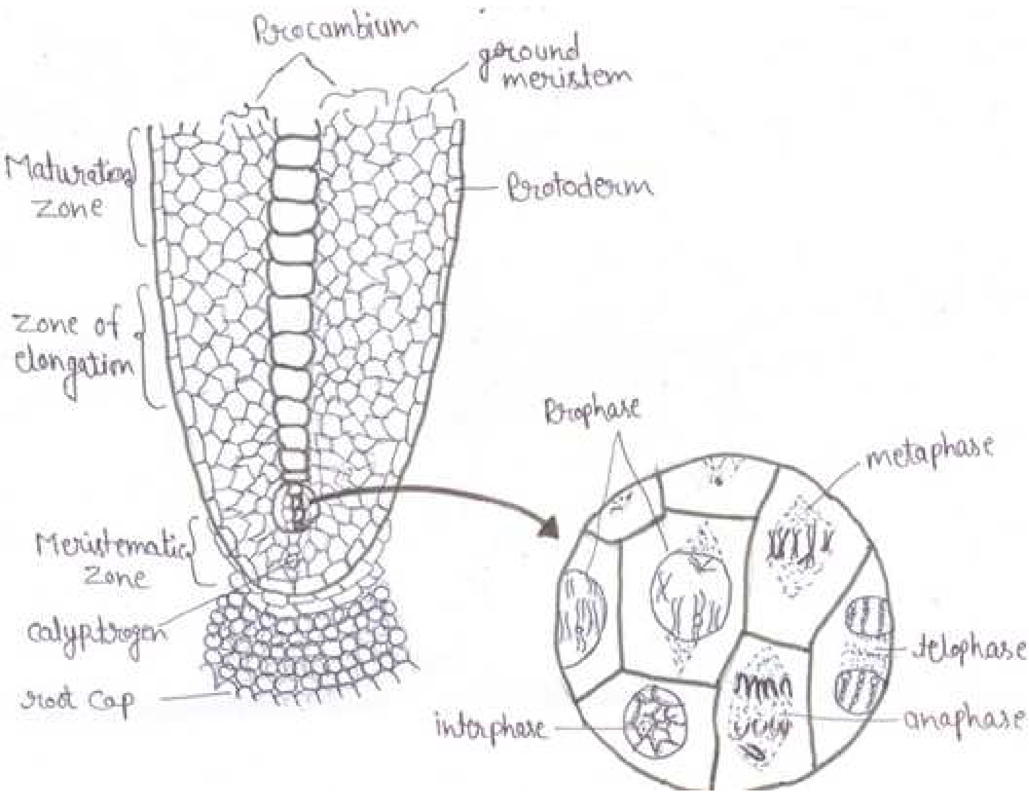


Fig.12.5 onion root tip showing different stage of mitosis

12.4. – Study of permanent Slide:-

What is a cell?

Unicellular organisms are capable of:-

(i) Independent existence and
(ii) Performing the essential functions of life.

Anything less than a complete structure of a cell does not ensure independent living. Hence, cell is the fundamental structure and functional unit of all living organisms.

Anton Von Leeuwenhoek first saw and describe a live cell. Robert Brown later discovered the nucleus.

The invention of the microscope and its important leading to the electron microscope revealed all the structural details of the cell.

Introduction:-

During cell division oxidative process are minimum and the deficiency of oxygen has no visible effect on the process and speed of mitosis. It is, therefore, presumed that the dividing cell obtains energy by **glycolysis**.

No doubt prior to division, when DNA synthesis takes place in the nucleus, the oxygen consumption is normal. Swan (1957) has suggested that an energy reservoir is created inside the cell before it enters cell division. Recently, **Allfrey and** coworkers (1975) and later have suggested that nucleus synthesis ATP through oxidative phosphorylation mechanism.

There are several evidences in support of the view that the oxidative processes are maximum in premitotic period and minimum during active mitosis:

(a) Oxygen consumption is minimum during cell division and deficiency of O2 or concentration of carbon monoxide has no effect on the process of mitosis.

(b) Certain glycolytic enzymes (lactic acid dehydrogenase, triphosphate dehydrogenase, aldolase) are present in high concentration in the nucleus, whereas enzymes associated with respiration and oxidative phosphorylation in cytoplasm are absent from the nucleus.

(c) Mitochondria fragment into granules which completely disappear during mitosis (Agrell, 1955; Chevermont and Fredric, 1952). This reconstitution starts during terminal stages of mitosis.

The body of multicelluar organism is formed of different types of cells and tissues. These cannot be studied directly by the microscope. The required tissue is separated from the body and is prepared in a wway that it becomes suitable for fixing them properly. The following techniques are often employed for the study of tissues or cells:

1. Teasing or Dissociation

The tissue to be studied is teased either directly in the stain or saline solution with the help of needles on a microscopic slide. It is covered with a cover slip and studied under microscope. The muscular tissue is studied by this method.

2. Smear Technique

Fluid tissue containing cells (blood) or small fragments of tissue such as aspirated bone marrow are smeared on the microscopic slide so that a thin film is formed on the slide. It is then fixed immediately, stained and maintained. The smear technique is very popular in **exfoliate cytology** (study of superficial cells shed from mucous membrane) or in the study of chromosomes and cell division.

3. Sectional Method

In this method the specimen is cut into very thin sections. For this purpose tissue is first fixed by immersion in some fixative and is embedded in paraffin wax or colloidin. Thereafter, is cut into thin sections which are stained and then studied under the microscope.

Cytological Study of Preserved Cells: -

Fixation:

As soon as the living processes of a tissue are grossly disturbed either by death or by the removal of tissue from animal body, some changes begin.

These changes are introduced by the onset of **autolysis (auto digestion), by** the attack of bacteria and moulds and by drying or due to osmotic effect. Some of these changes can be minimized by fixation.

The fixation is the process that brings about sudden death of the cells or tissues in such a manner that their morphological and chemical composition is retained either by the use of chemicals or by freezing.

Aims and Effects of Fixation:

(a) Fixation hardens the tissues and gives them a consistent from.
(b) It prevents autolysis and bacterial decomposition.
(c) It coagulates the tissue, renders the contents insoluble and prevents loss of easily diffusiable substances.
(d) It avoids cell shrinkage and distortion in form due to postmortem changes.
(e) Improves the optical differentiation of cell components by changing refractive indices and thus increases their visibility.
(f) Prepares the tissue for staining.

(g) It fortifies tissue against the harmful effects of various stages in the preparation of sections.

A. Chemical Fixation: The tissue is fixed by some chemical compounds such as formaldehyde, mercuric chloride, picric acid, chromic acid, osmium tetraoxid, acetic acid and ethyl alcohol. These are called fixative.

1. **Simple Fixatives**

(a) Formalin: 4-10% formalin solution is used for fixing golgi apparatus, mitochondria and enzymes. It fixes and hardens the tissue but causes little or no shrinkage.

(b) Mercuric Chloride: It is an intolerable fixative and is used only in combination with some other fixatives. It hardens and causes shrinkage in the tissue but does not distort it. It precipitates the proteins and fixes lipids.

(c) Picric Acid: it precipitates proteins and nucleoproteins. It produces shrinkage. Commonly it is not used for cytological studies.

(d) Chromic Acid: 0.5-1% chromic acid is used to fix those tissues which are studied for Golgi complex and mitochondria. It precipitates all proteins and fixes carbohydrates.

(e) Osmium Tetraoxide: 0.5-2% solution of osmium tetraoxide is used for fixing cytoplasm, golgi complex, mitochondria and fat. It fixes lipids and causes their blackening. It forms additive compounds with proteins, its penetration is poor but fixation is very nice. It is extensively used for electron microscopy.

(f) Potassium dichromate: 2.5-5% potassium dichromate solution is used in conjunction with some other chemical substance. It renders protein insoluble in water and fixes lipids. It is used for the fixation of chromosomes.

(g) Acetic Acid: Glacial acetic acid is never used alone because of its swelling effect. It is used along with other fixative to counteract their shrinkage effect. It precipitates nucleoproteins but not the cytoplasmic proteins. It destroys golgi complex and mitochondria. It is, therefore, used for the fixation of nucleus and chromosomes.

(h) Ethanol: 70% to absolute alcohol is used as fixative.

2. **Compound Fixatives**

   Since each of the primary fixative listed above has its virtues and defects, none of them is ideal to preserve and allows the observation of every component of the tissues and cells.

   As a practice a mixture of two or more reagent is used as a fixative to make use of the special properties of each.

   The most essential feature of a fixative should be its quick penetration power. Some of them are mentioned below:

   (a) 19% formal saline: It is mixture of formaline and normal saline solution.

   (b) Formal alcohol (FAA): A mixture of 10ml formaline, 90 ml of 90% alcohol and 5ml glacial acetic acid is called formal alcohol. It is used as a fixative for polysaccharides and nucleoproteins.

   (c) Carnoy's solution: It is mixture of ethanol (absolute alcohol) 60ml and glacial acetic acid 10 ml and 30ml chloroform. It fixes nucleoprotein and chromosomes. It combines the properties of ethanol and acetic acid.

   (d) Bouin's fluid: It is mixture of 75 parts picric acid, 25parts formalin and 5 parts glacial acid. It precipitates all proteins, penetrates rapidly and produces little shrinkage. It is used for the histological studies. It fixes chromosomes.

Procedure of Fixation:-

When a piece of tissue is immersed in the fixative, cellular death does not occur instantaneously and "post-mortem" changes due to anoxia, changes in the concentration of hydrogen ions and enzymatic action (autolysis) may occur.

The fixative penetrates the tissue by diffusion in such a way that the most external cells are fixed more rapidly and better than the central ones. Thus, every fixed tissue has a gradient of fixatation, progressive dilution with the liquid of the cells.

The rate of penetration of the fixative depends upon the type of protein barrier of precipitation produced at the periphery of the tissue. If the precipitate is very fine as in the case of osmium tetraoxide, it forms a barrier preventing further passage of the fixative.

Mechanism of staining:-

It is a well known fact that proteins, certain polysaccharides and nucleic acids have the property of ionization. But the ionization of proteins depends upon pH of the medium.

At pH values above isoelectric point, acid groups become ionized and below isoelectric point, all the basic groups dissociate. Thus, at a pH above isoelectric point, the proteins react with basic dyes and exhibit basophilic property.

The intensity of staining depends upon the degree of acidity or alkalinity of the medium. The basophilic or acidophilic property of cell components also depends on the fixative used.

12.4.1- Study of permanent Slide showing stage of cell division:-

The onion cell which is a typical plant cell has a distinct **cell wall** as its outer boundary and just within it is the **cell membrane**.

The cells of human cheek have an **outer membrane** as the delimiting structure of the cell. Inside each cell is a dense membrane bound structure **called nucleus**. The nucleus contains the **chromosomes** which in turn contain the gentle material, **DNA**. Cells that have membrane bound nuclei are called **eukaryotic** whereas cells that lack of a membrane bound nucleus are **prokaryotic**.

In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell. The cytoplasm is the main area of cellular activities in both the plant and animal cells. Various chemical reactions occur in it to keep the cell in the "living state".

Besides the nucleus, the eukaryotic cells have other memebrane bound distinct structure called **organelles** like the endoplasmic reticulam (ER), the **golgi complex, lysosomes, mitochondria, micro bodies and vacuoles.** The prokaryotic cells lack such membrane bound **organelles.**

Ribosomes are non-membrane bound organelles found in all cells both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles **chloroplasts (in plants)** and **mitochondria** and on **rough ER.**

Animal cells contain another non-membrane bound organelle called **centrioles which helps in cell division.**

Cells differ greatly in size, shape and activities. For example, **Mycoplasmas, the** the smallest cells, are only 0.3μm in length while bacteria could be 3 to 5 μm. The largest isolated single cell is the egg of an ostrich. Among multicellular organism, human red blood cells are about 7.0 μm in diameter.

Nerve cells are some of the longest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread like, or even irregular. The shape of the cell may vary with the function they perform.

The ability to grow and reproduce is a fundamental property of living organisms. However, growth of single cells is fundamentally limited. As new proteins, nucleic acids, carbohydrates, and lipids are synthesized, their accumulation causes the volume of a cell to increase, forcing the plasma membrane to expand to prevent the cell from bursting.

But cells cannot continue to enlarge indefinitely; as a cell grows larger, there is an accompanying decrease in its surface area/volume ratio and hence in its capacity for effective exchange with the environment.

Therefore, cell growth is generally accompanied by cell division, whereby one cell gives rise to two new daughter cells. (The term daughter is used by convention and does not indicate that cells have gender.)

For single-celled organisms, cell division increases the total number of individuals in a population. In multicellular organism, cell division either increases the number of cells, leading to growth of the organism, or replace cells that have died.

In an adult human, for example about 2 million stem cells in bone marrow divide every second to maintain a constant number of red blood cells in the body.

Although often cell growth and cell division are coupled, there is a notable exception. A fertilized animal egg typically undergoes many divisions without the growth of its cells, dividing the volume of the egg into smaller and smaller parcels. Here as well, however, tight regulation of where and when cells divide is crucial.

When cells grow and divide, the newly formed daughter cells are usually genetic duplicates of the parent cells, containing the same (or virtually the same) DNA sequences.

Therefore, all the genetic information in the nucleus of the parent cell must be duplicated and carefully distributed to the daughter cells during the division process. In accomplishing this task, a cell passes through a series of discrete stages, collectively known as the **cell cycle**.

12.4.2- Study of permanent Slide showing stage of giant chromosomes

Chromosome is single large DNA molecules and its associated proteins, containing many genes, stores and transmits genetic information. These are popularly known as hereditary vehicle.

Lamp brush Chromosomes

In the oocytic nuclei of those animals which have large yolky eggs, the prophase of first meiotic division is extremely extended.

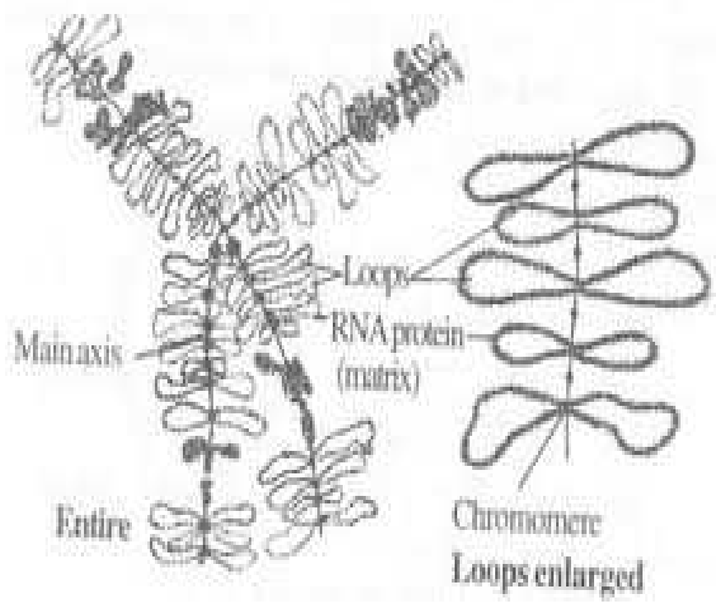


Fig.12.6 Lamp brush *Chromosomes*

During this phase the oocyte grows and synthesizes nutrients for the future embryo. In them, the chromosomes become greatly enlarged and assume unusual configuration. A large number of loops project out from the chromatid axis, giving a lampbrush appearance. Hence, these chromosomes are called **lampbrush chromosomes.**

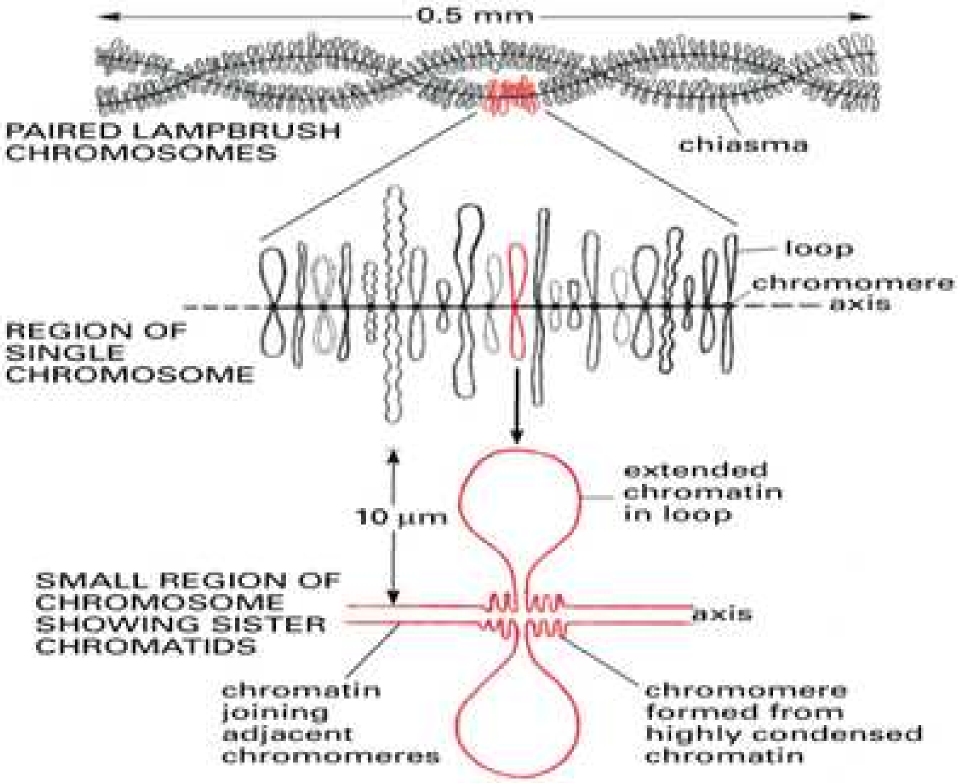


Fig.12.7 Lampbrush *chromosome*

The lampbrush chromosomes are bivalent each consisting of two chromatids. This persists during the prolonged diplotene phase of first meiotic prophase.

History: -

Lampbrush chromosomes were first observed by **Flemming (1882)** in amphibian occyte.
A detailed study was made by **J. Rucert** (1892) in the oocytes of sharks.

Occurrence:-

Lampbrush chromosomes are found in the oocytes of insects, sharks, ambhibians, reptiles and birds which produce large and yolky eggs. These have also been found in plants and invertibrates like Sagitta, Sepia and Echinaster.

Size:- Lampbrush chromosomes are enough to be seen under light microscope. These may be as long as 1,000 µm or more and about 20 µ in width. In salamander oocyte these may attain a length of about 5,900 µ.

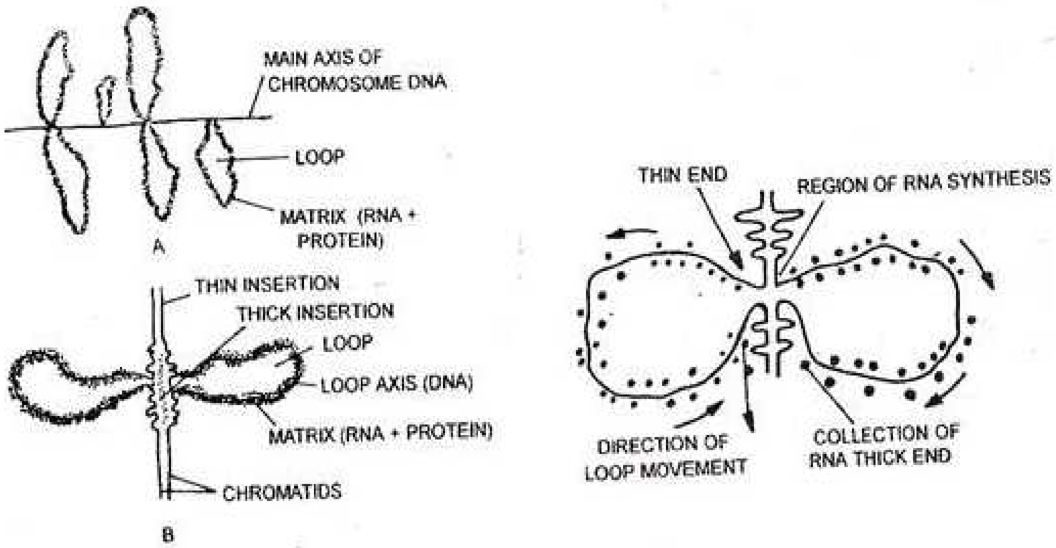


fig.12.8 Lampbrush chromosome. (A) Gross structure (B) Enlarged view (C) Synthesis of RNA in a loop of lampbrush chromosome

Structure:- A lampbrush chromosome (in diplotene stage) consist of two homologous chromosome of the pair is formed of two chromatids which lie parallel and form of high density loops which are lightly coloured, and arise on both sides of the chromosomal axis.

The chromosomal axis, the chromomeres and the loop axis all are formed of DNA. The chromomeres are found in pairs, one chromosome on each chromatid.

These are about 0.25 to 2.0 µm in diameter and are spaced about 2 µm from entire to centre along chromatid axis. These probably represent heterochromatic regions where axial filament remains tightly coiled.

The lateral loops arise from the chromomeres either 2 or in multiple of two. These extended on either side of the chromosomal axis about 550 µm and are about 30-50Å (3-5nm) in diameter. Each loop consists of an axial fibre formed of DNA.

It is surrounded with the matrix composed of RNA and proteins. This gives fuzzy appearance to lateral loops.

Electron Microscopic Structure:-

Electron microscope studies by Miller and Beaty (1969) on Lampbrush chromosomes of salamander oocyte have shown the presence of dense granules on the loop axis of DNA.

These dense granules represent large molecules of enzyme RNA polymerase. On getting attached to DNA, these initiate RNA synthesis. Arising from these RNA polymerase molecules are seen fine fibrils of RNA.

Each loop is considered to be long operon consisting of a series of identical copies of the same structural genes (cistrone) rseparated by spacer DNA. Each gene locus probably produces a very long RNA molecule. This interacts with protein to form ribonucleoprotein.

- According to Callan and Liyod (1960) a chromosome is the master gene with solenoid which produces several identical copies of its own. These extended out as a lateral loop formed of linear strand of nucleosomes, representing the transcriptionally active stage. These are called Salve gene copies.

- According to spinning out and retraction hypothesis, a chromomere is fully transcribed from end to end by spinning out a transient loop. The new loop material spins out on one side of a chromomere at the end of loop and returns to a condenced stage on the other side after completing the synthesis of RNA.

- These are associated with the rapid synthesis of yolk and protein in the maturing ovum. These disappear by the end of first prophase when chromosomes become thick and more condensed.

Polytene Chromosome:-

Polytene chromosomes are one of the giant chromosomes found in animals and plants. In animals it is found in the salivary glands, Malpighian tubules, the epithelium cell lining of the gut and in the fatty cells of the larvae of certain Diptera.

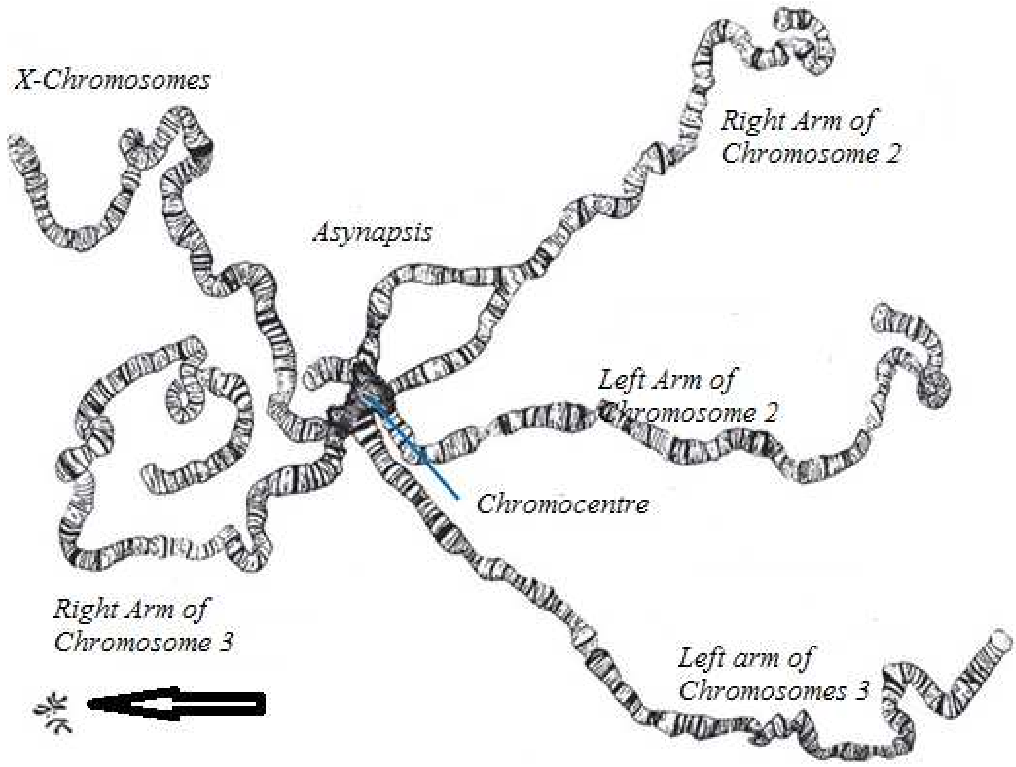


Fig 12.9 Polytene chromosome

The polytene chromosomes of salivary glands in Drosophila larvae of certain Diptera

The polytene chromosomes of salivary glands in Drosophila larvae can be demonstrated easily in laboratory. It can also be demonstrated in the larvae of Chironomous fly.

Preparation of Polytene Chromosomes from Drosophila Larvae:-

Preparation of Culture: -

- Take a small specimen jar. Make a mixture of the pulp of apple, banana and lemon.
- Take 2 gm of moldex add it in 40 ml boiling water.
- Cool it and add in pulp of fruits prepared.
- Place the jar in the culture of Drosophila flies, keep it open for 2-3 days during which some of the flies will visit the jar for feeding and lay eggs.
- Now cover the jar with fine muslin cloth. Within a week larvae will appear.
- Observe carefully for 3rd instar larvae which will be white coloured.

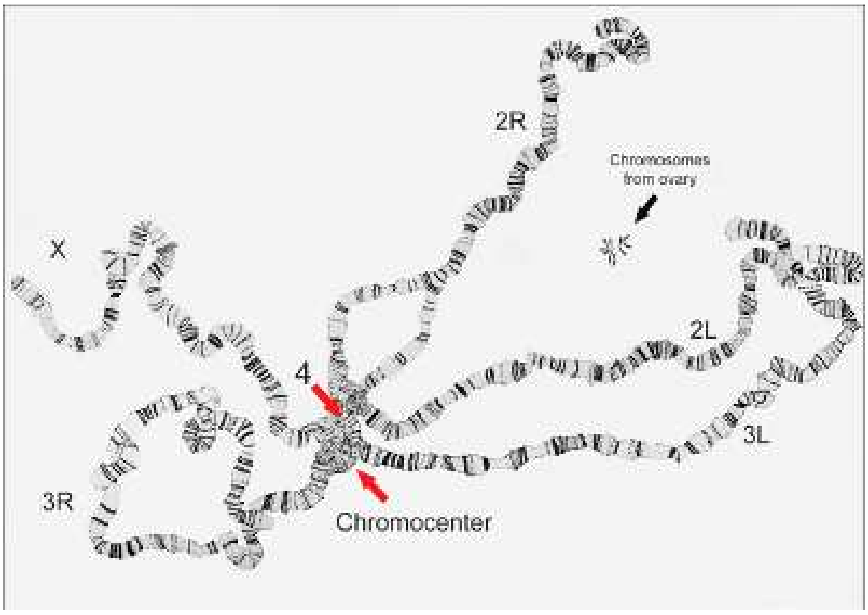


Fig.12.10 Polytene chromosome in the salivary gland of Drosophila

Dissection of 3rd instar larvae for salivary gland: -

- Take a few drop of saline on a clean slide and put the 3rd instlar larvae in it.
- Locate the junction of thorax and abdomen.
- Take two needles, one in each hand. Press the first needle firmly on the posterior end of thorax and other needle at the junction of thorax and abdomen.
- Pull the second needle so that abdomen is separated from head and thorax.
- Then press the thorax with a needle and observe that the salivary glands are seen floating in the saline water on the slide.

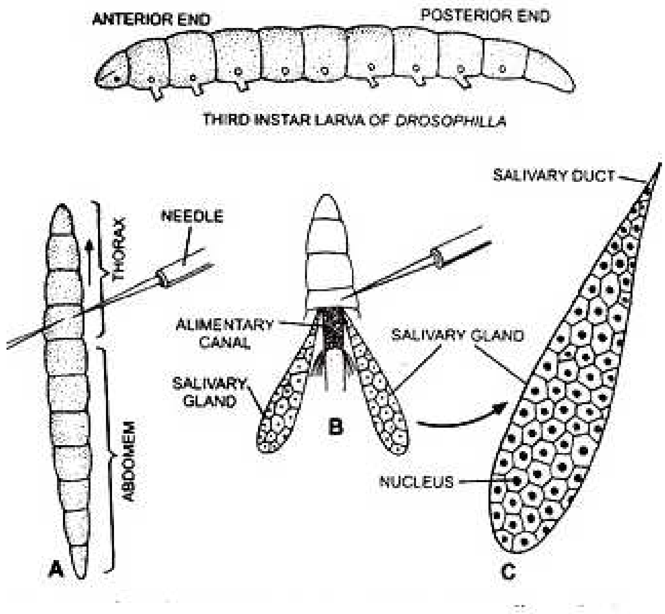


Fig 12.11 Dissection of 3 rd instar Drosophila larva for salivary gland

Preparation of Slide: -

- Take a clean slide; put a drop of acetocarmine on it.
- Transfer the salivary glands in acetocarmine on slide and cover it with a cover slip.
- Leave it for 10 minutes and then warm it gently and then put a blotting paper over it press it smoothly by your thumb.
- Observe the slide under microscope and for details observe under high power of microscope.

Comments:-

1. These are large-sized, hence, called giant chromosomes.
2. These chromosomes present alternate pattern of dark bands and light inter-bands.
3. The dark bands contain rich amount of DNA and RNA, and composed of much coiled chromonemal thread.
4. The light bands contain rich amount of proteins and little amount of DNA and RNA.
5. A polytene chromosomal is multistranded; it is formed of large number of chromosomal thread or strands.

6. A polytene chromosomes exhibits puffs and Balbiani rings at certain points.

7. The puffs are made of lateral extension of bands of chromosomal starands into side loops.

8. The puffs and Balbiani rings are related with the metabolic activities of the chromosomes.

9. These Chromosomes help in the synthesis of proteins, nucleic acids and formation of nuclear material.

10. These were discovered by Balbiani in 1881.

12.4.3- Study of permanent Slide showing stage of Mitochondria:-

The main components of a typical animal cell are as follows:-

1. Nucleolus
2. Nucleus
3. Ribosome
4. Vesicle
5. Rough endoplasmic reticulum
6. Golgi apparatus (or "Golgi body")
7. Cytoskeleton
8. Smooth endoplasmic reticulum
9. **Mitochondrion**
10. Vacuole
11. Cytosol (fluid that contains organelles, comprising the cytoplasm)
12. Lysosome
13. Centrosome.
14. Cell membrane

The **mitochondrion** (plural **mitochondria**) is a double membrane-bound organelle found in all eukaryotic organisms, although some cells in some organisms may lack them (e.g. Red blood cells). A number of organisms have reduced or transformed their mitochondria into other structures. To date, only one eukaryote is known to have completely lost its **mitochondria**.

The word mitochondrion comes from the Greek, *mitos*, i.e. "thread", and, *chondrion*, i.e. "granule" or "grain-like". Mitochondria have been described as "the powerhouse of the cell" because they generate most of the cell's supply of adenosine tri-phosphate (ATP), used as a source of chemical energy.

Mitochondria are commonly between 0.75 and 3µm in diameter but vary considerably in size and structure. Unless specifically stained, they are not visible.

In addition to supplying cellular energy, mitochondria are involved in other tasks, such as signaling, cellular differentiation, and cell death, as well as maintaining control of the cell cycle and cell growth. Mitochondrial biogenesis is in turn temporally coordinated with these cellular processes. Mitochondria have been implicated in several human diseases, including mitochondrial disorders, cardiac dysfunction, heart failure and autism.

The number of mitochondria in a cell can vary widely by organism, tissue, and cell type. For instance, red blood cells have no mitochondria, whereas liver cells can have more than 2000. The organelle is composed of compartments that carry out specialized functions.

These compartments or regions include the outer membrane, the inter membrane space, the inner membrane, and the cristae and matrix. Mitochondrial proteins vary depending on the tissue and the species. In humans, 615 distinct types of protein have been identified from cardiac mitochondria, whereas in rats, 940 proteins have been reported. The mitochondrial proteome is thought to be dynamically regulated. Although most of a cell's DNA is contained in the cell nucleus, the mitochondrion has its own independent genome that shows substantial similarity to bacterial genomes.

History:-

The first observations of intracellular structures that probably represented mitochondria were published in the 1840s. Richard Altman, in 1894, established them as cell organelles and called them "bioblasts". The term **"mitochondria"** was **coined by Carl Benda in 1898.**

Leonor Michaelis discovered that Janus green can be used as a supravital stain for mitochondria in 1900. In 1904, Friedrich Meves, made the first recorded observation of mitochondria in plants in cells of the white waterlily, *Nymphaea Alba* and in 1908, along with Claudius Regaud, suggested that they contain proteins and lipids.

Benjamin F. Kingsbury, in 1912, first related them with cell respiration, but almost exclusively based on morphological observations. In 1913, particles from extracts of guinea-pig liver were linked to respiration by Otto Heinrich Warburg, which he called "grana".

Warburg and Heinrich Otto Wieland, who had also postulated a similar particle mechanism, disagreed on the chemical nature of the respiration. It was not until 1925, when David Keilin discovered cytochromes, that the respiratory chain was described.

In 1939, experiments using minced muscle cells demonstrated that cellular respiration using one oxygen atom can form two adenosine triphosphate (ATP) molecules, and, in 1941, the concept of the phosphate bonds of ATP being a form of energy in cellular metabolism was developed by Fritz Albert Lipmann. In the following years, the mechanism behind cellular respiration was further elaborated, although its link to the mitochondria was not known.

The introduction of tissue fractionation by Albert Claude allowed mitochondria to be isolated from other cell fractions and biochemical analysis to be conducted on them alone. In 1946, he concluded that cytochrome oxidase and other enzymes responsible for the respiratory chain were isolated to the mitchondria.

Eugene Kennedy and Albert Lehninger discovered in 1948 that mitochondria are the site of oxidative phosphorylation in eukaryotes. Over time, the fractionation method was further developed, improving the quality of the mitochondria isolated and other elements of cell respiration were determined to occur in the mitochondria.

The first high-resolution electron micrographs appeared in 1952, replacing the Janus Green stains as the preferred way of visualizing the mitochondria. This led to a more detailed analysis of the structure of the mitochondria, including confirmation that they were surrounded by a membrane.

It also showed a second membrane inside the mitochondria that folded up in ridges dividing up the inner chamber and that the size and shape of the mitochondria varied from cell to cell. The popular term **"powerhouse of the cell"** was coined by **Philip Siekevitz in 1957**.

In 1967, it was discovered that mitochondria contained ribosomes. In 1968, methods were developed for mapping the mitochondrial genes, with the genetic and physical map of yeast mitochondrial DNA being completed in 1976.

Origin and evolution:-

There are two hypotheses about the origin of mitochondria, **endosymbiotic and autogenous**. The endosymbiotic hypothesis suggests that mitochondria were **originally prokaryotic** cells, capable of implementing oxidative mechanisms that were not possible for eukaryotic cells; they became endosymbionts living inside the eukaryote.

In the autogenous hypothesis, mitochondria were born by splitting off a portion of DNA from the nucleus of the eukaryotic cell at the time of divergence with the prokaryotes; this DNA portion would have been enclosed by membranes, which could not be crossed by proteins. Since mitochondria have many features in common with bacteria, the most accredited theory at present is endosymbiosis.

A mitochondrion contains DNA, which is organized as several copies of a single, circular chromosome. This mitochondrial chromosome contains genes for redox proteins, such as those of the respiratory chain.

The CoRR hypothesis:

CoRR is short form of co-location for redox regulation. CoRR hypothesis proposes that this co-location is required for redox regulation. The mitochondrial genome codes for some RNAs of ribosomes, and the 22 t-RNAs necessary for the translation of messenger RNAs into protein. The circular structure is also found in prokaryotes. The proto-mitochondrion was probably closely related to the Rickettsia.

However, the exact relationship of the ancestor of mitochondria to the alphaproteobacteria and whether the mitochondrion was formed at the same time or after the nucleus remain controversial.

The ribosome's coded for by the mitochondrial DNA are similar to those from bacteria in size and structure. They closely resemble the bacterial 70S ribosome and not the 80S cytoplasmic ribosomes, which are coded for by nuclear DNA.

The endosymbiotic relationship of mitochondria with their host cells was popularized by Lynn Margulis. The endosymbiotic hypothesis suggests that mitochondria descended from bacteria that somehow survived endocytosis by another cell, and became incorporated into the cytoplasm.

The ability of these bacteria to conduct respiration in host cells that had relied on glycolysis and fermentation would have provided a considerable evolutionary advantage. This symbiotic relationship probably developed 1.7 to 2 billion years ago.

A few groups of unicellular eukaryotes have only vestigial mitochondria or derived structures: the microsporidians, metamonads, and archamoebae. These groups appear as the most primitive eukaryotes on phylogenetic trees constructed using r-RNA information, which once suggested that they appeared before the origin of mitochondria.

However, this is now known to be an artifact of long-branch attraction—they are derived groups and retain genes or organelles derived from mitochondria (e.g., mitosomes and hydrogenosomes).

Structure:-

A mitochondrion has a double membrane; the inner one contains its chemiosmotic apparatus and has deep grooves which increase its surface area. While commonly depicted as an "orange sausage with a blob inside of it" (like it is here), mitochondria can take many shapes and their inter-membrane space is quite thin.

A mitochondrion contains outer and inner membranes composed of phospholipid bilayers and proteins. The two membranes have different properties. Because of this double-membraned organization, there are five distinct parts to a mitochondrion. They are:

1. The outer mitochondrial membrane.
2. The intermembrane space (the space between the outer and inner membranes),
3. The inner mitochondrial membrane,
4. The cristae space (formed by in-folding of the inner membrane), and
5. The matrix (space within the inner membrane).

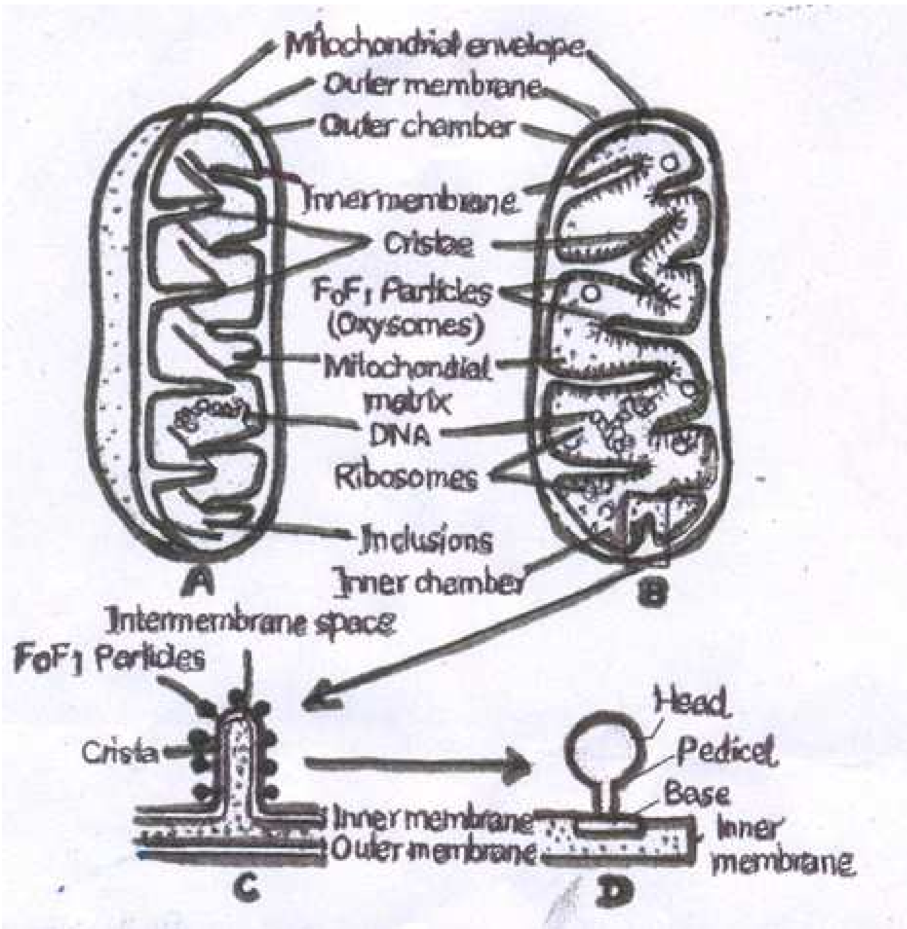


Fig.12.12 Section of Mitochondria showing membrane Chamber and cristae

Mitochondria stripped of their outer membrane are called mitoplasts.

Outer membrane:-

The **outer mitochondrial membrane**, which encloses the entire organelle, is 60 to 75 angstroms (Å) thick.

It has a protein-to-phospholipid ratio similar to that of the eukaryotic plasma membrane (about 1:1 by weight). It contains large numbers of integral membrane proteins called porins. These porins form channels that allow molecules of 5000 daltons or less in molecular weight to freely diffuse from one side of the membrane to the other.

Larger proteins can enter the mitochondrion if a signaling sequence at their N-terminus binds to a large multisubunit protein called translocase of the outer membrane, which then actively moves them across the membrane.

Mitochondrial pro-proteins are imported through specialised translocation complexes. The outer membrane also contains enzymes involved in such diverse activities as the elongation of fatty acids, oxidation of epinephrine, and the degradation of tryptophan.

These enzymes include monoamine oxidase, rotenone-insensitive NADH-cytochrome c-reductase, kynurenine hydroxylase and fatty acid Co-A ligase. Disruption of the outer membrane permits proteins in the intermembrane space to leak into the cytosol, leading to certain cell death. The mitochondrial outer membrane can associate with the endoplasmic reticulum (ER) membrane, in a structure called MAM (mitochondria-associated ER-membrane).

This is important in the ER-mitochondria calcium signaling and is involved in the transfer of lipids between the ER and mitochondria. Outside the outer membrane there are small (diameter: 60Å) particles named sub-units of Parson.

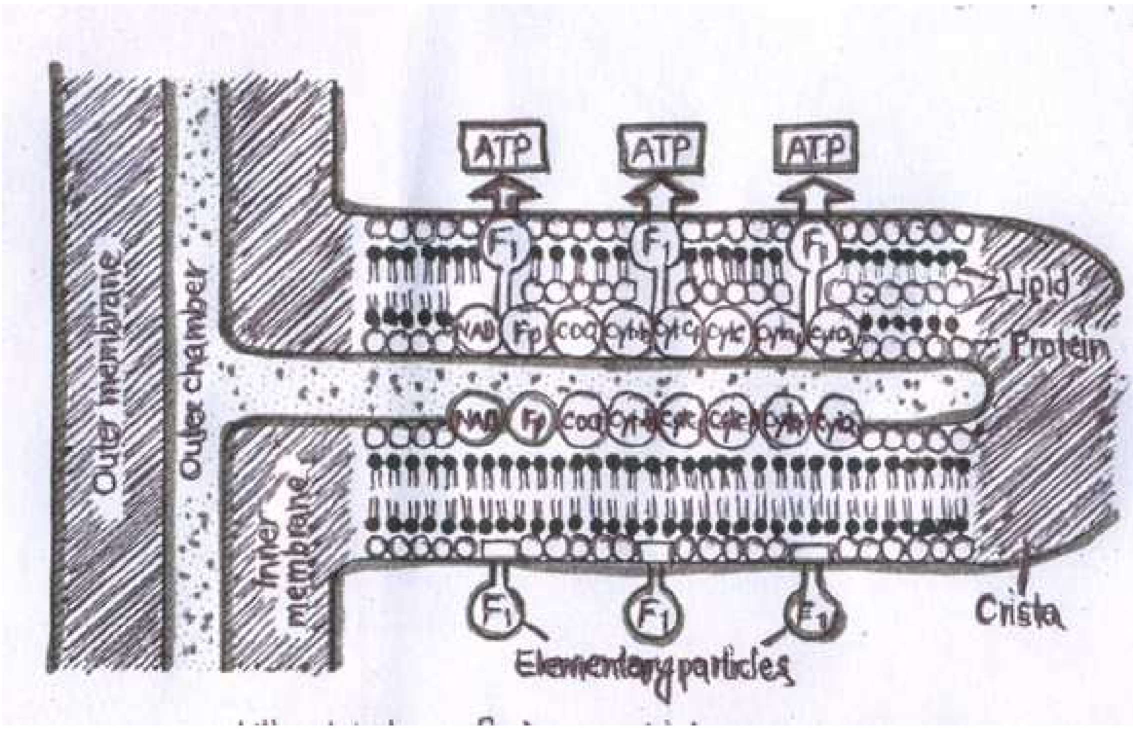


Fig.12.13 Ultra structure of mitochondrial crest showing F1 particles

Intermembrane space:-

The intermembrane space is the space between the outer membrane and the inner membrane. It is also known as perimitochondrial space. Because the outer membrane is freely permeable to small molecules, the concentrations of small molecules, such as ions and sugars, in the intermembrane space is the same as in the cytosol.

However, large proteins must have a specific signaling sequence to be transported across the outer membrane, so the protein composition of this space is different from the protein composition of the cytosol. One protein that is localized to the intermembrane space in this way is cytochrome c.

Inner membrane:-

The inner mitochondrial membrane contains proteins with five types of functions:

1. Those that perform the redox reactions of oxidative phosphorylation
2. ATP synthase, which generates ATP in the matrix
3. Specific transport proteins that regulate metabolite passage into and out of the matrix
4. Protein import machinery
5. Mitochondrial fusion and fission protein

It contains more than 151 different polypeptides, and has a very high protein-to-phospholipid ratio (more than 3:1 by weight, which is about 1 protein for 15 phospholipids). The inner membrane is home to around 1/5 of the total protein in a mitochondrion. In addition, the inner membrane is rich in an unusual phospholipid, cardiolipin.

This phospholipid was originally discovered in cow hearts in 1942, and is usually characteristic of mitochondrial and bacterial plasma membranes. Cardiolipin contains four fatty acids rather than two, and may help to make the inner membrane impermeable. Unlike the outer membrane, the inner membrane doesn't contain porins, and is highly impermeable to all molecules. Almost all ions and molecules require special membrane transporters to enter or exit the matrix.

Proteins are ferried into the matrix via the translocase of the inner membrane (TIM) complex or via Oxa1. In addition, there is a membrane potential across the inner membrane, formed by the action of the enzymes of the electron transport chain.

Cristae:-

The inner mitochondrial membrane is compartmentalized into numerous cristae, which expand the surface area of the inner mitochondrial membrane, enhancing its ability to produce ATP. For typical liver mitochondria, the area of the inner membrane is about five times as large as the outer membrane.

This ratio is variable and mitochondria from cells that have a greater demand for ATP, such as muscle cells, contain even more cristae. These folds are studded with small round bodies known as F_1 particles or oxysomes. These are not simple random folds but rather invaginations of the inner membrane, which can affect overall chemiosmotic function.

One recent mathematical modeling study has suggested that the optical properties of the cristae in filamentous mitochondria may affect the generation and propagation of light within the tissue.

Matrix:-

The matrix is the space enclosed by the inner membrane. It contains about 2/3 of the total protein in a mitochondrion. The matrix is important in the production of ATP with the aid of the ATP synthase contained in the inner membrane.

The matrix contains a highly concentrated mixture of hundreds of enzymes, special mitochondrial ribosome's, t-RNA, and several copies of the mitochondrial DNA genome. Of the enzymes, the major functions include oxidation of pyruvate and fatty acids, and the citric acid cycle.

Mitochondria have their own genetic material, and the machinery to manufacture their own RNAs and proteins. A published human mitochondrial DNA sequence revealed 16,569 base pairs encoding 37 genes: 22 t-RNA, 2 r-RNA, and 13 peptide genes.

The 13 mitochondrial peptides in humans are integrated into the inner mitochondrial membrane, along with proteins encoded by genes that reside in the host cell's nucleus.

Mitochondria-associated ER membrane:-

The mitochondria-associated ER membrane (MAM) is another structural element that is increasingly recognized for its critical role in cellular physiology and homeostasis. Once considered a technical snag in cell fractionation techniques, the alleged ER vesicle contaminants that invariably appeared in the mitochondrial fraction have been re-identified as membranous structures derived from the MAM—the interface between mitochondria and the ER. Physical coupling between these two organelles had previously been observed in electron micrographs and has more recently been probed with fluorescence microscopy.

Such studies estimate that at the MAM, which may comprise up to 20% of the mitochondrial outer membrane, the ER and mitochondria are separated by a mere 10–25 nm and held together by protein tethering complexes.

Purified MAM from sub cellular fractionation has been shown to be enriched in enzymes involved in phospholipids exchange, in addition to channels associated with Ca^{2+} signaling. These hints of a prominent role for the MAM in the regulation of cellular lipid stores and signal transduction have been borne out, with significant implications for mitochondrial-associated cellular phenomena, as discussed below.

Not only has the MAM provided insight into the mechanistic basis underlying such physiological processes as intrinsic apoptosis and the propagation of calcium signaling, but it also favors a more refined view of the mitochondria.

Though often seen as static, isolated 'powerhouses' hijacked for cellular metabolism through an ancient endosymbiotic event, the evolution of the MAM underscores the extent to which mitochondria have been integrated into overall cellular physiology, with intimate physical and functional coupling to the endomembrane system.

Phospholipids transfer:-

The MAM is enriched in enzymes involved in lipid biosynthesis, such as phosphatidylserine synthase on the ER face and phosphatidylserine decarboxylase on the mitochondrial face. Because mitochondria are dynamic organelles constantly undergoing fission and fusion events, they require a constant and well-regulated supply of phospholipids for membrane integrity.

But mitochondria are not only a destination for the phospholipids they finish synthesis of; rather, this organelle also plays a role in inter-organelle trafficking of the intermediates and products of phospholipids biosynthetic pathways, ceramide and cholesterol metabolism, and glycosphingolipid anabolism.

Such trafficking capacity depends on the MAM, which has been shown to facilitate transfer of lipid intermediates between organelles. In contrast to the standard vesicular mechanism of lipid transfer, evidence indicates that the physical proximity of the ER and mitochondrial membranes at the MAM allows for lipid flipping between opposed bilayers.

Despite this unusual and seemingly energetically unfavorable mechanism, such transport does not require ATP. Instead, in yeast, it has been shown to be dependent on a multiprotein tethering structure termed the ER-mitochondria encounter structure, or ERMES, although it remains unclear whether this structure directly mediates lipid transfer or is required to keep the membranes in sufficiently close proximity to lower the energy barrier for lipid flipping.

The MAM may also be part of the secretory pathway, in addition to its role in intracellular lipid trafficking. In particular, the MAM appears to be an intermediate destination between the rough ER and the Golgi in the pathway that leads to very-low-density lipoprotein, or VLDL, assembly and secretion. The MAM thus serves as a critical metabolic and trafficking hub in lipid metabolism.

Calcium signaling:-

A critical role for the ER in calcium signaling was acknowledged before such a role for the mitochondria was widely accepted, in part because the low affinity of Ca^{2+} channels localized to the outer mitochondrial membrane seemed to fly in the face of this organelle's purported responsiveness to changes in intracellular Ca^{2+} flux.

But the presence of the MAM resolves this apparent contradiction: the close physical association between the two organelles results in Ca^{2+} microdomains at contact points that facilitate efficient Ca^{2+} transmission from the ER to the mitochondria. Transmission occurs in response to so-called "Ca^{2+} puffs" generated by spontaneous clustering and activation of IP3R, a canonical ER membrane Ca^{2+} channel.

The fate of these puffs—in particular, whether they remain restricted to isolated locales or integrated into Ca^{2+} waves for propagation throughout the cell—is determined in large part by MAM dynamics. Although reuptake of Ca^{2+} by the ER (concomitant with its release) modulates the intensity of the puffs, thus insulating mitochondria to a certain degree from high Ca^{2+} exposure, the MAM often serves as a firewall that essentially buffers Ca^{2+} puffs by acting as a sink into which free ions released into the cytosol can be funneled. This Ca^{2+} tunneling occurs through the low-affinity Ca^{2+} receptor VDAC1, which recently has been shown to be physically tethered to the IP3R clusters on the ER membrane and enriched at the MAM. The ability of mitochondria to serve as a Ca^{2+} sink is a result of the electrochemical gradient generated during oxidative phosphorylation, which makes tunneling of the cation an exergonic process.

Normally, mild calcium influx from cytosol into the mitochondrial matrix causes transient depolarization that is corrected by pumping out protons.

But transmission of Ca^{2+} is not unidirectional; rather, it is a two-way street. The properties of the Ca^{2+} pump SERCA and the channel IP3R present on the ER membrane facilitate feedback regulation coordinated by MAM function. In particular, the clearance of Ca^{2+} by the MAM allows for spatio-temporal patterning of Ca^{2+} signaling because Ca^{2+} alters IP3R activity in a biphasic manner.

SERCA is likewise affected by mitochondrial feedback: uptake of Ca^{2+} by the MAM stimulates ATP production, thus providing energy that enables SERCA to reload the ER with Ca^{2+} for continued Ca^{2+} efflux at the MAM. Thus, the MAM is not a passive buffer for Ca^{2+} puffs; rather it helps modulate further Ca^{2+} signaling through feedback loops that affect ER dynamics.

Regulating ER release of Ca^{2+} at the MAM is especially critical because only a certain window of Ca^{2+} uptake sustains the mitochondria, and consequently the cell, at homeostasis. Sufficient intraorganelle

Ca^{2+} signaling is required to stimulate metabolism by activating dehydrogenase enzymes critical to flux through the citric acid cycle. However, once Ca^{2+} signaling in the mitochondria passes a certain threshold, it stimulates the intrinsic pathway of apoptosis in part by collapsing the mitochondrial membrane potential required for metabolism.

Studies examining the role of pro- and anti-apoptotic factors support this model; for example, the anti-apoptotic factor Bcl-2 has been shown to interact with IP3Rs to reduce Ca^{2+} filling of the ER, leading to reduced efflux at the MAM and preventing collapse of the mitochondrial membrane potential post-apoptotic stimuli. Given the need for such fine regulation of Ca^{2+} signaling, it is perhaps unsurprising that disregulated mitochondrial Ca^{2+} has been implicated in several neurodegenerative diseases, while the catalogue of tumor suppressors includes a few that are enriched at the MAM.

Molecular basis for tethering:-

Recent advances in the identification of the tethers between the mitochondrial and ER membranes suggest that the scaffolding function of the molecular elements involved is secondary to other, non-structural functions. In yeast, ERMES, a multiprotein complex of interacting ER- and mitochondrial-resident membrane proteins, is required for lipid transfer at the MAM and exemplifies this principle.

One of its components, for example, is also a constituent of the protein complex required for insertion of transmembrane beta-barrel proteins into the lipid bilayer. However, a homologue of the ERMES complex has not yet been identified in mammalian cells.

Other proteins implicated in scaffolding likewise have functions independent of structural tethering at the MAM; for example, ER-resident and mitochondrial-resident mitofusins form heterocomplexes that regulate the number of inter-organelle contact sites, although mitofusins were first identified for their role in fission and fusion events between individual mitochondria.

Glucose-related protein 75 (grp75) is another dual-function protein. In addition to the matrix pool of grp75, a portion serves as a chaperone that physically links the mitochondrial and ER Ca^{2+} channels VDAC and IP3R for efficient Ca^{2+} transmission at the MAM. Another potential tether is Sigma-1R, a non-opioid receptor whose stabilization of ER-resident IP3R may preserve communication at the MAM during the metabolic stress response.

Function:-

The most prominent roles of mitochondria are to produce the energy currency of the cell, ATP (i.e., phosphorylation of ADP), through respiration, and to regulate cellular metabolism.

The central sets of reactions involved in ATP production are collectively known as the citric acid cycle, or the Krebs cycle. However, the mitochondrion has many other functions in addition to the production of ATP.

Energy conversion:-

A dominant role for the mitochondria is the production of ATP, as reflected by the large number of proteins in the inner membrane for this task. This is done by oxidizing the major products of glucose: pyruvate, and NADH, which are produced in the cytosol.

This type of cellular respiration known as aerobic respiration, is dependent on the presence of oxygen. When oxygen is limited, the glycolytic products will be metabolized by anaerobic fermentation, a process that is independent of the mitochondria.

The production of ATP from glucose has an approximately 13-times higher yield during aerobic respiration compared to fermentation. Recently it has been shown that plant mitochondria can produce a limited amount of ATP without oxygen by using the alternate substrate nitrite.

ATP crosses out through the inner membrane with the help of a specific protein, and across the outer membrane via porins. ADP returns via the same route.

Additional functions:-

Mitochondria play a central role in many other metabolic tasks, such as:

- Signaling through mitochondrial reactive oxygen species
- Regulation of the membrane potential
- Apoptosis-programmed cell death
- Calcium signaling (including calcium-evoked apoptosis)
- Regulation of cellular metabolism
- Certain heme synthesis reactions Steroid synthesis.
- Hormonal signaling

Mitochondria are sensitive and responsive to hormones, in part by the action of mitochondrial estrogen receptors (mtERs). These receptors have been found in various tissues and cell types, including brain and heart

Some mitochondrial functions are performed only in specific types of cells. For example, mitochondria in liver cells contain enzymes that allow them to detoxify ammonia, a waste product of protein metabolism. A mutation in the genes regulating any of these functions can result in mitochondrial diseases.

Mitochondrial diseases:-

Damage and subsequent dysfunction in mitochondria is an important factor in a range of human diseases due to their influence in cell metabolism. Mitochondrial disorders often present themselves as neurological disorders, including autism.

They can also manifest as myopathy, diabetes, multiple endocrinopathy, and a variety of other systemic disorders. Diseases caused by mutation in the mtDNA include Kearns-Sayre syndrome, MELAS syndrome and Leber's hereditary optic neuropathy.

In the vast majority of cases, these diseases are transmitted by a female to her children, as the zygote derives its mitochondria and hence its mtDNA from the ovum. Diseases such as Kearns-Sayre syndrome, Pearson syndrome, and progressive external ophthalmoplegia are thought to be due to large-scale mtDNA rearrangements, whereas other diseases such as MELAS syndrome, Leber's hereditary optic neuropathy, myoclonic epilepsy with ragged red fibers (MERRF), and others are due to point mutations in mtDNA.

In other diseases, defects in nuclear genes lead to dysfunction of mitochondrial proteins. This is the case in Friedreich's ataxia, hereditary spastic paraplegia, and Wilson's disease.

These diseases are inherited in a dominance relationship, as applies to most other genetic diseases. A variety of disorders can be caused by nuclear mutations of oxidative phosphorylation enzymes, such as coenzyme Q10 deficiency and Barth syndrome. Environmental influences may interact with hereditary predispositions and cause mitochondrial disease.

For example, there may be a link between pesticide exposure and the later onset of Parkinson's disease. Other pathologies with etiology involving mitochondrial dysfunction include schizophrenia, bipolar disorder, dementia, Alzheimer's disease, Parkinson's disease, epilepsy, stroke, cardiovascular disease, chronic fatigue syndrome, retinitis pigmentosa, and diabetes mellitus.

Mitochondria-mediated oxidative stress plays a role in cardiomyopathy in Type 2 diabetics. Increased fatty acid delivery to the heart increases fatty acid uptake by cardiomyocytes, resulting in increased fatty acid oxidation in these cells. This process increases the reducing equivalents available to the electron transport chain of the mitochondria, ultimately increasing reactive oxygen species (ROS) production. ROS increases uncoupling proteins (UCPs) and potentiate proton leakage through the adenine nucleotide translocator (ANT), the combination of which uncouples the mitochondria.

Uncoupling then increases oxygen consumption by the mitochondria, compounding the increase in fatty acid oxidation. This creates a vicious cycle of uncoupling; furthermore, even though oxygen consumption increases, ATP synthesis does not increase proportionally because the mitochondrion is uncoupled.

Less ATP availability ultimately results in an energy deficit presenting as reduced cardiac efficiency and contractile dysfunction. To compound the problem, impaired sarcoplasmic reticulum calcium release and reduced mitochondrial reuptake limits peak cytosolic levels of the important signaling ion during muscle contraction.

The decreased intra-mitochondrial calcium concentration increases dehydrogenase activation and ATP synthesis. So in addition to lower ATP synthesis due to fatty acid oxidation, ATP synthesis is impaired by poor calcium signaling as well, causing cardiac problems for diabetics.

12.4.4- Study of permanent Slide showing stage of Golgi body:-

The **Golgi body** also known as the **Golgi complex**, **Golgi apparatus**, or simply the **Golgi**, is an organelle found in most eukaryotic cells. It was identified in 1897 by the Italian scientist Camillo Golgi and named after him in 1898.

Part of the cellular endomembrane system, the Golgi apparatus packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination. The Golgi apparatus resides at the intersection of the secretory, lysosomal, and endocytic pathways.

It is of particular importance in processing proteins for secretion, containing a set of glycosylation enzymes that attach various sugar monomers to proteins as the proteins move through the apparatus.

Owing to its large size and distinctive structure, the Golgi apparatus was one of the first organelles to be discovered and observed in detail. It was discovered in 1898 by Italian physician Camillo Golgi during an investigation of the nervous system. After first observing it under his microscope, he termed the structure the internal reticular apparatus. Some doubted the discovery at first, arguing that the appearance of the structure was merely an optical illusion created by the observation technique used by Golgi.

With the development of modern microscopes in the 20th century, the discovery was confirmed. Early references to the Golgi referred to it by various names including the "Golgi–Holmgren apparatus", "Golgi–Holmgren ducts", and "Golgi–Kopsch apparatus". The term "Golgi apparatus" was used in 1910 and first appeared in the scientific literature in 1913.

Among eukaryotes, the sub cellular localization of the Golgi apparatus differs. In mammals, a single Golgi apparatus complex is usually located near the cell nucleus, close to the centrosome. Tubular connections are responsible for linking the stacks together. Localization and tubular connections of the Golgi apparatus are dependent on microtubules. If microtubules are experimentally depolymerized, then the Golgi apparatus loses connections and becomes individual stacks throughout the cytoplasm. In yeast, multiple Golgi apparatuses are scattered throughout the cytoplasm.

In plants, Golgi stacks are not concentrated at the centrosomal region and do not form Golgi ribbons. Organization of the plant Golgi depends on actin cables and not microtubules. The common feature among Golgi is that they are adjacent to endoplasmic reticulum (ER) exit sites.

Structure:-

In most eukaryotes, the Golgi apparatus is made up of a series of compartments consisting of two main networks: the cis Golgi network (CGN) and the Trans Golgi network (TGN). The CGN is a collection of fused, flattened membrane-enclosed disks known as cisternae, originating from vesicular clusters that bud off the endoplasmic reticulum.

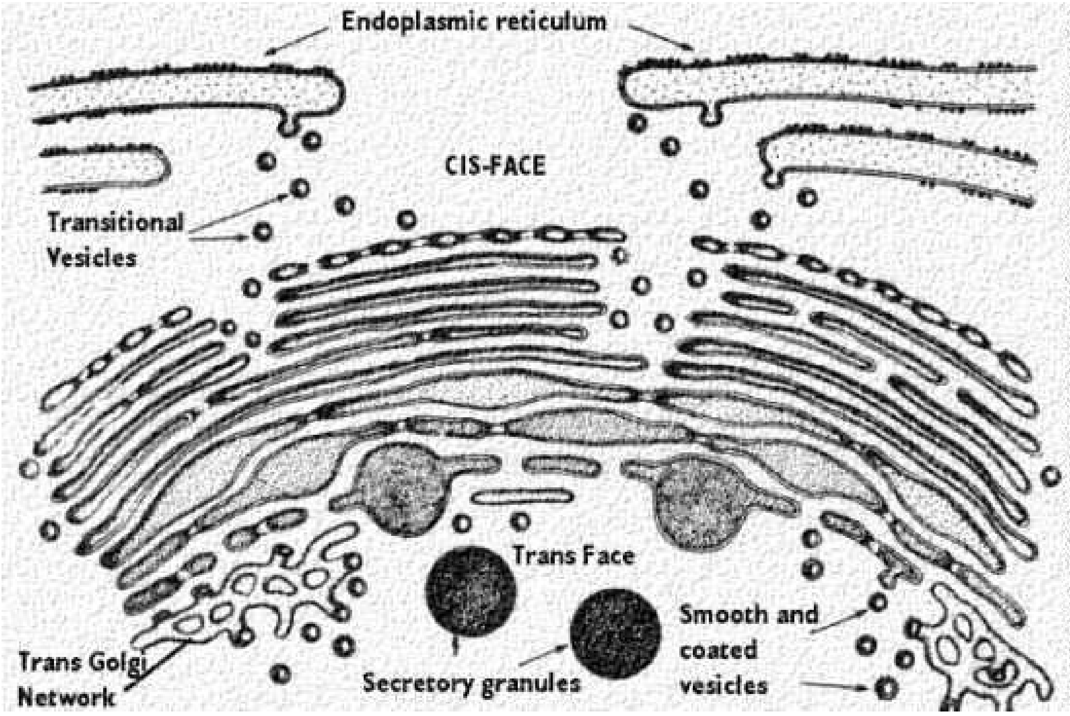


Fig.12.14 Relation between different component of Golgi body & their relation with secretion

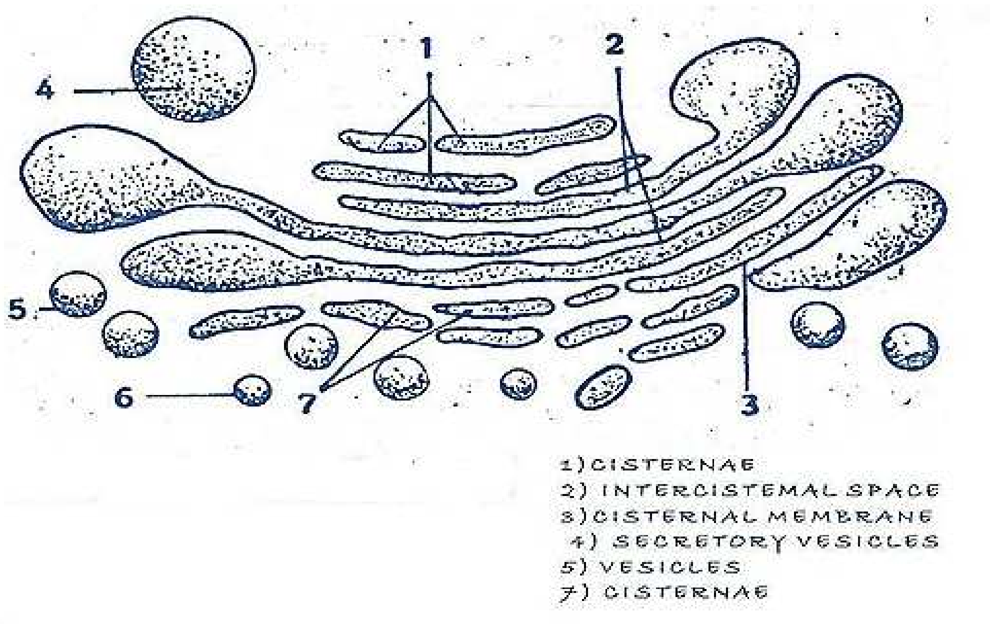


Fig.12.15 Ultrastructure of Golgi complex

A mammalian cell typically contains 40 to 100 stacks. Between four and eight cisternae are usually present in a stack; however, in some protists as many as sixty cisternae have been observed. This collection of cisternae is broken down into cis, medial, and Trans compartments.

The TGN is the final cisternal structure, from which proteins are packaged into vesicles destined to lysosomes, secretory vesicles, or the cell surface. The TGN is usually positioned adjacent to the stacks of the Golgi apparatus, but can also be separate from the stacks. The TGN may act as an early endosome in yeast and plants.

There are structural and organizational differences in the Golgi apparatus among eukaryotes. In some yeasts, Golgi stacking is not observed. Pichia pastoris does have stacked Golgi, while Saccharomyces cerevisiae does not. In plants, the individual stacks of the Golgi apparatus seem to operate independently.

The Golgi apparatus tends to be larger and more numerous in cells that synthesize and secrete large amounts of substances; for example, the antibody-secreting plasma B cells of the immune system have prominent Golgi complexes.

In all eukaryotes, each cisternal stack has a cis entry face and a trans exit face. These faces are characterized by unique morphology and biochemistry. Within individual stacks are assortments of enzymes responsible for selectively modifying protein cargo.

These modifications influence the fate of the protein. The compartmentalization of the Golgi apparatus is advantageous for separating enzymes, thereby maintaining consecutive and selective processing steps: enzymes catalyzing early modifications are gathered in the cis face cisternae, and enzymes catalyzing later modifications are found in Trans face cisternae of the Golgi stacks.

Function:-

The Golgi apparatus is a major collection and dispatch station of protein products received from the endoplasmic reticulum (ER). Proteins synthesized in the ER are packaged into vesicles, which then fuse with the Golgi apparatus.

These cargo proteins are modified and destined for secretion via exocytosis or for use in the cell. In this respect, the Golgi can be thought of as similar to a post office: it packages and labels items which it then sends to different parts of the cell or to the extracellular space. The Golgi apparatus is also involved in lipid transport and lysosome formation.

The structure and function of the Golgi apparatus are intimately linked. Individual stacks have different assortments of enzymes, allowing for progressive processing of cargo proteins as they travel from the cis to the trans Golgi face. Enzymatic reactions within the Golgi stacks occur exclusively near its membrane surfaces, where enzymes are anchored.

This feature is in contrast to the ER, which has soluble proteins and enzymes in its lumen. Much of the enzymatic processing is post-translational modification of proteins. For example, phosphorylation of oligosaccharides on lysosomal proteins occurs in the early CGN. Cis cisterna is associated with the removal of mannose residues. Removal of mannose residues and addition of N-acetylglucosamine occur in medial cisternae.

Addition of galactose and sialic acid occurs in the trans cisternae. Sulfation of tyrosines and carbohydrates occurs within the TGN. Other general post-translational modifications of proteins include the addition of carbohydrates (glycosylation) and phosphates (phosphorylation). Protein modifications may form a signal sequence that determines the final destination of the protein. For example, the Golgi apparatus adds a mannose-6-phosphate label to proteins destined for lysosomes.

Another important function of the Golgi apparatus is in the formation of proteoglycans. Enzymes in the Golgi append proteins to glycosaminoglycans, thus creating proteoglycans. Glycosaminoglycans are long unbranched polysaccharide molecules present in the extracellular matrix of animals.

Vesicular transport:-

The vesicles that leave the rough endoplasmic reticulum are transported to the cis face of the Golgi apparatus, where they fuse with the Golgi membrane and empty their contents into the lumen. Once inside the lumen, the molecules are modified, and then sorted for transport to their next destinations.

Those proteins destined for areas of the cell other than either the endoplasmic reticulum or the Golgi apparatus are moved through the Golgi cisternae towards the trans face, to a complex network of membranes and associated vesicles known as the trans-Golgi network (TGN). This area of the Golgi is the point at which proteins are sorted and shipped to their intended destinations by their placement into one of at least three different types of vesicles, depending upon the signal sequence they carry.

Current models of vesicular transport and trafficking:-

Model 1: Anterograde vesicular transport between stable compartments:-

- In this model, the Golgi is viewed as a set of stable compartments that work together. Each compartment has a unique collection of enzymes that work to modify protein cargo. Proteins are delivered from the ER to the cis face using COPII-coated vesicles. Cargo then progress toward the trans face in COPI-coated vesicles. This model proposes that COPI vesicles move in two directions: anterograde vesicles carry secretory proteins, while retrograde vesicles recycle Golgi-specific trafficking proteins.

  Strengths: The model explains observations of compartments, polarized distribution of enzymes, and waves of moving vesicles. It also attempts to explain how Golgi-specific enzymes are recycled.

Weaknesses: Since the amount of COPI vesicles varies drastically among types of cells, this model cannot easily explain high trafficking activity within the Golgi for both small and large cargoes. Additionally, there is no convincing evidence that COPI vesicles move in both the anterograde and retrograde directions.

- This model was widely accepted from the early 1980s until the late 1990s.

Model 2: Cisternal progression/maturation:-

In this model, the fusion of COPII vesicles from the ER begins the formation of the first cis-cisterna of the Golgi stack, which progresses later to become mature TGN cisternae. Once matured, the TGN cisternae dissolve to become secretory vesicles. While this progression occurs, COPI vesicles continually recycle Golgi-specific proteins by delivery from older to younger cisternae. Different recycling patterns may account for the differing biochemistry throughout the Golgi stack. Thus, the compartments within the Golgi are seen as discrete kinetic stages of the maturing Golgi apparatus.

Strengths:

The model addresses the existence of Golgi compartments, as well as differing biochemistry within the cisternae, transport of large proteins, transient formation and disintegration of the cisternae, and retrograde mobility of native Golgi proteins, and it can account for the variability seen in the structures of the Golgi.

Weaknesses:

This model cannot easily explain the observation of fused Golgi networks, tubular connections among cisternae, and differing kinetics of secretory cargo exit.

Model 3: Cisternal progression/maturation with heterotypic tubular transport:-

This model is an extension of the cisternal progression/maturation model. It incorporates the existence of tubular connections among the cisternae that form the Golgi ribbon, in which cisternae within a stack are linked. This model posits that the tubules are important for bidirectional traffic in the ER-Golgi system: they allow for fast anterograde traffic of small cargo and/or the retrograde traffic of native Golgi proteins.

Strengths: This model encompasses the strengths of the cisternal progression/maturation model that also explains rapid trafficking of cargo, and how native Golgi proteins can recycle independently of COPI vesicles.

Weaknesses: This model cannot explain the transport kinetics of large protein cargo, such as collagen. Additionally, tubular connections are not prevalent in plant cells. The roles that these connections have can be attributed to a cell-specific specialization rather than a universal trait. If the membranes are continuous, that suggests the existence of mechanisms that preserve the unique biochemical gradients observed throughout the Golgi apparatus.

Model 4: Rapid partitioning in a mixed Golgi:-

This rapid partitioning model is the most drastic alteration of the traditional vesicular trafficking point of view. Proponents of this model hypothesize that the Golgi works as a single unit, containing domains that function separately in the processing and export of protein cargo. Cargo from the ER moves between these two domains, and randomly exits from any level of the Golgi to their final location. This model is supported by the observation that cargo exits the Golgi in a pattern best described by exponential kinetics. The existence of domains is supported by fluorescence microscopy data.

Strengths: Notably, this model explains the exponential kinetics of cargo exit of both large and small proteins whereas other models cannot.

Weaknesses: This model cannot explain the transport kinetics of large protein cargo, such as collagen. This model falls short on explaining the observation of discrete compartments and polarized biochemistry of the Golgi cisternae. It also does not explain formation and disintegration of the Golgi network, nor the role of COPI vesicles.

Model 5: Stable compartments as cisternal model progenitors:-

This is the most recent model. In this model, the Golgi is seen as a collection of stable compartments defined by Rab (G-protein) GTPases.

Strengths: This model is consistent with numerous observations and encompasses some of the strengths of the cisternal progression/maturation model. Additionally, what is known of the Rab GTPase roles in mammalian endosomes can help predict putative roles within the Golgi. This model is unique in that it can explain the observation of "megavesicle" transport intermediates.

Weaknesses: This model does not explain morphological variations in the Golgi apparatus, nor define a role for COPI vesicles. This model does not apply well for plants, algae, and fungi in which individual Golgi stacks are observed (transfer of domains between stacks is not likely). Additionally, megavesicles are not established to be intra-Golgi transporters.

Though there are multiple models that attempt to explain vesicular traffic throughout the Golgi, no individual model can independently explain all observations of the Golgi apparatus. Currently, the cisternal progression/maturation model is the most accepted among scientists, accommodating many observations across eukaryotes. The other models are still important in framing questions and guiding future experimentation. Among the fundamental unanswered questions are the directionality of COPI vesicles and role of Rab GTPases in modulating protein cargo traffic.

12.6- Summary:-

Cytology, branch of biology concerned with the study of the structure and function of cells as individual units, supplementing histology, which deals with cells as components of tissues. Cytology is concerned with the structure and activities of the various parts of the cell and cell membrane; the mechanism of cell division; the development of sex cells, fertilization, and the formation of the embryo; cell derangements, such as those occurring in cancer; cellular immunity; and the problems of heredity.

Until modern times, cytology was concerned primarily with the microscopic observation of stained dead cells and the correlation of such observations with known physiological phenomena. Recently, new procedures have been introduced by which the living cell can be observed and studied. The phase-contrast microscope provides a means of studying the living cell in action without the use of dyes. Micro dissection, microinjection, and microchemistry furnish methods for drawing off minute amounts of living protoplasm through tubes a half micron in diameter, and subjecting them to analysis.

Cytology is important in modern medicine, especially in the diagnosis of diseases by examination of the cells occurring in the various body fluids. The determination of the number and proportion of the different types of cells in the blood, by a blood count, is important in diagnosing acute infections and other diseases. Variations in the size and shape of the red blood cell indicate the presence of: sickle-cell anemia if the cell is half-moon shaped; pernicious anemia if it is very large; or iron-deficiency anemia if it is very small. The type of disease may also be determined through cytology, as, for example, in distinguishing the various types of meningitis by examination of the cells present in the cerebrospinal fluid.

12.7 –Glossary:-

Active Transport: The movements or ions or molecules of a substance through the plasma membrane from a solution of low concentration to a solution of high concentration i.e. against electro-chemical gradient. The process needs energy.

Amino Acid Organic compounds with acidic (-COOH) and amino (-NH2), groups; 20 of which, different in organic chain attached to carbon atom, are the structural units of protein macromolecules.

Amitosis	Director division of nucleus into two, without differentiation of chromosomes and formation of spindle etc.
Anaphase	A stage in nuclear division immediately after metaphase and is followed by telophase. It is characterized by the movement of sets of daughter chromosomes from the equatorial plate towards the opposite poles of the spindle.
Aneuploids	The organism having chromosomes of a set parent in different numbers
Autolysis	Disintegration of cells by the action of their own enzymes
Budding	A mode of asexual reproduction in which new organism develops from the parent body in the form of an outgrowth or projection.
Catalase	An enzyme which facilitates conversion of hydrogen peroxide to water and oxygen
Cell division	The process of division of pre-existing (parental) cell into two new daughter cells.
Chromatin	Deeply stained part of of the nuclear reticulum mostly of DNA, which condenses into chromosomes during cell division.
Chromomere	Irregular masses of heterochromatin
Coenzyme	Organic compound which activates the enzyme.
Colloid	Substances having particles which range from 1mμ to 100 mμ in size
Conjugation	Temporary association between the organisms of two different strains so as to facilitate nuclear exchange
Cytolysis	Dissolution or disintegration of a cell
Deletion	Loss of segment from a chromosome
Diplotene	A stage in the first prophase of meiosis, in which each of the synaptic chromosomes get doubled by splitting. It comes after pachytene and is followed by diakinesis
Germ cell	As gamete
Gonad	Gamete producing organ
Haploid	Having half the number of chromosomes that are present in the diploid organism. Usually the gametes..
Heterogamy	Darkely stained part of the chromatin in the interphase nucleus which represents the condenced chromatin and results due to failure of its conversion into a nuclear reticulum.

Matrix	Intercellular substances in which animal cells are embedded
Micron	A unit of measurement: 1/1000 mm usually designated by the Greek letter μ.
Operon	A group of genes that are transcribed into a single length messenger RNA for a single character
Osmosis	The passage of a fluid through a semi-permiable membrane due to osmotic pressure
Pachytene	Midprophase stage of first reduction division (or meiosis) in which the chromosomes are visible as long paired threads
Polar body	Bodies extruded out during oogenesis one after each maturation division
Promotor	A site on a chromosome where RNA-polymerase binds and initiates RNA synthesis
Recombination	The appearance in an individual of alleles for different characters that were not present together in either parent
Spindle	The chromatic figure formed during cell division by the differentiation of cytoplasm into radiating fibres which are diposed in such a manner that these form a spindle figure. The equator of spindle provides surface for the orientation of chromosomes
Tetrad	The group of four chromatids resulting from the pairing of homologous chromosomes and their splitting during 1st prophase of meiosis
Triploids	Organism having three haploid sets of chromosomes i.e.3n
Unit membrane	The membrane formed of two layers of lipid molecules sandwiched between the two layers of protein molecules. It forms the outer boundary of almost all the cell organelles.

12.8: Self assessment Questions

1. Who proposed the cell theory?
2. Mitochondria are generally called the power houses of cell. Why?
3. What are the special types of chromosomes?
4. What are the difference between mitosis and meiosis?
5. What do you understand by meiotic division?

12.9: References:-

Cell and Molecular Biology by Karp 5th ED., ISBN 0-471-46580-1

Lodish, Harvey (2013). Molecular Cell Biology. W.H. Freeman and Company. ISBN 978-1-4292-3413-9.

De Robertes & Robertis: Cell & Molecular Biology, 1987, Lee & Fibiger Philadelplna.

Swanson, C.P.T. Merz and W.J. Young (1982), Cytogenetic, 2nd Edition, Prentice Hall, Englewood Cliffs.

Afzelius Bjorn, Anatomy of cell.

Brachet.j. and e. Mirsky (1959). The living Cell, Sci.Am. 205, (3) 50.

Freeman, J.A., (1954), Cellular Fine Structure, McGraw-Hill Book Company, New York.

Landley, L.L. (1968). Cell Function, 2nd ed. Van Nostrand Reinhold Company, New York.

12.10: Suggested Readings:-

Cell Biology-Harvey Lodish,

Dr. S.P. Singh, Cytology – Prof. P.K.Gupta

12.11: Terminal Questions:-

1. Describe the structure and function of Mitochondria.
2. What are Lampbrush Chromosomes? Mention its structure and significance.
3. What is cell theory? Give an illustrated account of the structure and function of golgi body.
4. Discuss the methods of preparation and dissection of 3rd instar larvae for salivary gland.
5. Write short notes any two of the following.

(a) Polytene Chromosome (b) Cristae © Karyokinesis

UNIT 13: GENETICAL EXPERIMENT

Contents

13.1- Objectives:

We will develop the practical understanding on Mendelian and non-Mendelian hereditary experiments. Genetics, scientific study of how physical, biochemical, and behavioral traits are transmitted from parents to their offspring's. The word genetics was coined in 1906 by the British biologist William Bateson.

13.2 Introductions:-

Genetics deals with the mechanism of heredity and causes of variations in living beings. The heredity or inheritance, in turn, deals with the process of transmission of characters from one generation to another. Several interesting experiments based on the principles and laws of heredity can be conducted in our biological laboratories. However, the exercises of genetics have been planned in the following ways to illustrate some basic principles of heredity. Geneticists determine the mechanisms of inheritance whereby the offspring of sexually reproducing organisms do not exactly resemble their parents, and the differences and similarities between parents and offspring recur from generation to generation in repeated patterns. The investigation of these patterns has led to some of the most exciting discoveries in modern biology.The science of genetics began in 1900, when several plant breeders independently discovered the work of the Austrian monk Gregor Johann Mendel. He published his work in 1866. His work remained unnoticed for decades and gained posthumous recognition as father of modern genetics. Working with garden peas, Mendel described the patterns of inheritance in terms of seven pairs of contrasting traits that appeared in different pea-plant varieties. He observed that the traits were inherited as separate units, each of which was inherited independently of the others. He suggested that each parent has pairs of units but contributes only one unit from each pair to its offspring. The units that Mendel described were later given the name genes. Soon after Mendel's work was rediscovered, scientists realized that the patterns of inheritance he had described paralleled the action of chromosomes in dividing cells, and they proposed that the Mendelian units of inheritance, the genes, are carried by the chromosomes. This led to intensive study of cell division. Every cell comes from the division of a pre-existing cell. All the cells that make up a human being, for example, are derived from the successive divisions of a single cell, the zygote, which is formed by the union of an egg and a sperm.

The great majority of the cells produced by the division of the zygote are, in the composition of their hereditary material, identical to one another and to the zygote itself. Each cell of a higher organism is composed of a jellylike layer of material, the cytoplasm, which contains many small structures. This cytoplasm material surrounds a prominent body called the nucleus. Every nucleus contains a number of minute, threadlike chromosomes. Some relatively simple organisms such as cyan bacteria and bacteria, have no distinct nucleus but do have cytoplasm, which contains one or more chromosomes Chromosomes vary in size and shape and usually occur in pairs. The members of each pair, called homologues, closely resemble each other. Most cells in the human body contain 23 pairs of chromosomes, whereas most cells of the fruit fly *Drosophila* contain four pairs, and the bacterium *Escherichia coli* has a single chromosome in the form of a ring. Every chromosome in a cell is now known to contain many genes, and each gene is located at a particular site, or locus, on the chromosome. The process of cell division by which a new cell comes to have an identical number of chromosomes as the parent cell is called mitosis. In mitotic division each chromosome divides into two equal parts, and the two parts travel to opposite ends of the cell. After the cell divides, each of the two resulting cells has the same number of chromosomes and genes as the original cell. Every cell formed in this process thus has the same genetic material. Simple one-celled organisms and some multicellular forms reproduce by mitosis; it is also the process by which complex organisms achieve growth and replace worn-out tissue. Higher organisms that reproduce sexually are formed from the union of two special sex cells known as gametes. Gametes are produced by meiosis, the process by which germ cells divide. It differs from mitosis in one important way: in meiosis a single chromosome from each pair of chromosomes is transmitted from the original cell to each of the new cells.

Thus, each gamete contains half the number of chromosomes that are found in the other body cells. When two gametes unite in fertilization, the resulting cell, called the zygote, contains the full, double set of chromosomes. Half of these chromosomes normally come from one parent and half from the other.

13.3- Experimentation on Mendelian Inheritance

Mendelian inheritance is inheritance of biological features that follows the laws proposed by Gregor Johann Mendel in 1865 and 1866 and re-discovered in 1900.

It was initially very controversial. When Mendel's theories were integrated with the Boveri–Sutton chromosome theory of inheritance by **Thomas Hunt Morgan in 1915**, they became the core of classical genetics while Ronald Fisher combined them with the theory of natural selection in his 1930 book

The Genetical Theory of Natural Selection, putting evolution onto a mathematical footing and forming the basis for Population genetics and the modern evolutionary synthesis.

The laws of inheritance were derived by Gregor Mendel, a nineteenth-century Austrian monk, and later Prälet, conducting hybridization experiments in garden peas ***(Pisum sativum)*** he planted in the backyard of the church. Between 1856 and 1863, he cultivated and tested some 5,000 pea plants.

From these experiments, he induced two generalizations which later became known as Mendel's Principles of Heredity or **Mendelian inheritance**.

He described these principles in a two-part paper, *Versuche über Pflanzen-Hybriden*, that he read to the Natural History Society of Brno (Brunn) on 8 February and 8 March 1865, and which was published in 1866.

Mendel's conclusions were largely ignored. Although they were not completely unknown to biologists of the time, they were not seen as generally applicable, even by Mendel himself, who thought they only applied to certain categories of species or traits.

A major block to understanding their significance was the importance attached by 19th-century biologists to the apparent blending of inherited traits in the overall appearance of the progeny, now known to be due to multigame interactions, in contrast to the organ-specific binary characters studied by Mendel.

In 1900, however, his work was "re-discovered" by three European scientists, Hugo de Vries, Carl Correns, and Erich von Tschermak.

The exact nature of the "re-discovery" has been somewhat debated: De Vries published first on the subject, mentioning Mendel in a footnote, while Correns pointed out Mendel's priority after having read De Vries' paper and realizing that he himself did not have priority.

De Vries may not have acknowledged truthfully how much of his knowledge of the laws came from his own work, or came only after reading Mendel's paper.

Later scholars have accused Von Tschermak of not truly understanding the results at all.

Regardless, the **"re-discovery"** made Mendelism an important but controversial theory. Its most vigorous promoter in Europe was William Bateson, who coined the terms "genetics" and "allele" to describe many of its tenets.

The model of heredity was highly contested by other biologists because it implied that heredity was discontinuous, in opposition to the apparently continuous variation observable for many traits.

Many biologists also dismissed the theory because they were not sure it would apply to all species.

However, later work by biologists and statisticians such as Ronald Fisher showed that if multiple Mendelian factors were involved in the expression of an individual trait, they could produce the diverse results observed, and thus showed that Mendelian genetics is compatible with natural selection.

Thomas Hunt Morgan and his assistants later integrated the theoretical model of Mendel with the chromosome theory of inheritance, in which the chromosomes of cells were thought to hold the actual hereditary material, and created what is now known as classical genetics, which was extremely successful and cemented Mendel's place in history.

Mendel's findings allowed scientists such as Fisher and J.B.S. Haldane to predict the expression of traits on the basis of mathematical probabilities.

A large contribution to Mendel's success can be traced to his decision to start his crosses only with plants he demonstrated were true-breeding. He also only measured absolute (binary) characteristics, such as colour, shape, and position of the offspring, rather than quantitative characteristics. He expressed his results numerically and subjected them to statistical analysis.

His method of data analysis and his large sample size gave credibility to his data. He also had the foresight to follow several successive generations (f2, f3) of pea plants and record their variations.

Finally, he performed "test crosses" (back-crossing descendants of the initial hybridization to the initial true-breeding lines) to reveal the presence and proportion of recessive characters.

Mendel observed seven traits that are easily recognized and apparently only occur in one of two forms:

1. Flower colour is purple or white
2. Seed colour is yellow or green
3. Flower position is axial or terminal
4. Pod shape is inflated or constricted
5. Stem length is long or short
6. Pod colour is yellow or green
7. Seed shape is round or wrinkled

Mendel's laws:-

Mendel discovered that, when he crossed purebred white flower and purple flower pea plants (the parental or P generation), the result was not a blend. Rather than being a mix of the two, the offspring (known as the F_1 generation) was purple-flowered.

When Mendel self-fertilized the F_1 generation pea plants, he obtained a purple flower to white flower ratio in the F_2 generation of 3 to 1. The results of this cross are tabulated in the Punnett square to the right.

He then conceived the idea of heredity units, which he called **"factors"**. Mendel found that there are alternative forms of factors—now called genes—that account for variations in inherited characteristics. For example, the gene for flower colour in pea plants exists in two forms, one for purple and the other for white.

The alternatives “forms” are now called alleles. For each biological trait, an organism inherits two alleles, one from each parent. These alleles may be the same or different.

An organism that has two identical alleles for a gene is said to be homozygous for that gene (and is called a homozygote). An organism that has two different alleles for a gene is said by **heterozygous** for that gene (and is called a **heterozygote**).

Mendel also hypothesized that allele pairs separate randomly, or segregate, from each other during the production of gametes: egg and sperm.

Because allele pairs separate during gamete production, a sperm or egg carries only one allele for each inherited trait. When sperm and egg unite at fertilization, each contributes its allele, restoring the paired condition in the offspring.

Independent assortment: -

The genotype of an individual is made up of the many alleles it possesses. An individual's physical appearance, or phenotype, is determined by its alleles as well as by its environment. The presence of an allele does not mean that the trait will be expressed in the individual that possesses it.

If the two alleles of an inherited pair differ (the heterozygous condition), then one determines the organism’s appearance and is called the dominant allele; the other has no noticeable effect on the organism’s appearance and is called the recessive allele.

Thus, in the example above dominant purple flower allele will hide the phenotypic effects of the recessive white flower allele.

This is known as the Law of Dominance but it is not a transmission law, dominance has to do with the expression of the genotype and not its transmission. The upper case letters are used to represent dominant alleles whereas the lowercase letters are used to represent recessive alleles.

Mendel's laws of inheritance:-

1. **Law of dominance:**

   Some alleles are dominant while others are recessive; an organism with at least one dominant allele will display the effect of the dominant allele.

2. **Law of segregation**:

   During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene.

3. **Law of independent assortment:**

   Genes for different traits can segregate independently during the formation of gametes.

   In the pea plant example above, the capital "P" represents the dominant allele for purple flowers and lowercase "p" represents the recessive allele for white flowers.

Both parental plants were true-breeding, and one parental variety had two alleles for purple flowers (*PP*) while the other had two alleles for white flowers (*pp*). As a result of fertilization, the F_1 hybrids each inherited one allele for purple flowers and one for white.

All the F_1 hybrids (*Pp*) had purple flowers, because the dominant *P* allele has its full effect in the heterozygote, while the recessive *p* allele has no effect on flower color.

For the F_2 plants, the ratio of plants with purple flowers to those with white flowers (3:1) is called the phenotypic ratio. The genotypic ratio, as seen in the Punnett square, is 1 *PP*: 2 *Pp*: 1 *pp*.

Law of dominance:-

Mendel's Law of Dominance states that recessive alleles will always be masked by dominant alleles.

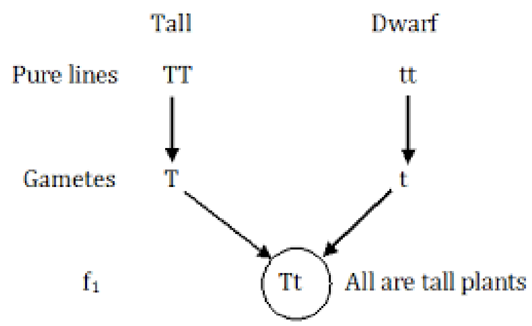
Therefore, a cross between a homozygous dominant and a homozygous recessive will always express the dominant phenotype, while still having a heterozygous genotype.

Law of Dominance can be explained easily with the help of a mono hybrid cross experiment:- In a cross between two organisms pure for any pair (or pairs) of contrasting traits (characters), the character that appears in the F1 generation is called "dominant" and the one which is suppressed (not expressed) is called "recessive." Each character is controlled by a pair of dissimilar factors.

Only one of the characters expresses. The one which expresses in the F1 generation is called Dominant. It is important to note however, that the law of dominance is significant and true but is not universally applicable.

According to the latest revisions, only two of these rules are considered to be laws. The third one is considered as a basic principle but not a genetic law of Mendel.

Example:



Mendelian Trait:-

A Mendelian trait is one that is controlled by a single locus in an inheritance pattern. In such cases, a mutation in a single gene can cause a disease that is inherited according to Mendel's laws.

Examples include sickle-cell anemia, Tay-Sachs disease, cystic fibrosis and xeroderma pigmentosa.

A disease controlled by a single gene contrasts with a multi-factorial disease, like arthritis, which is affected by several loci (and the environment) as well as those diseases inherited in a non-Mendelian fashion.

Law of Segregation of genes:-

The Law of Segregation states that every individual organism contains two alleles for each trait, and that these alleles segregate (separate) during meiosis such that each gamete contains only one of the alleles.

An offspring thus receives a pair of alleles for a trait by inheriting homologous chromosomes from the parent organisms: one allele for each trait from each parent.

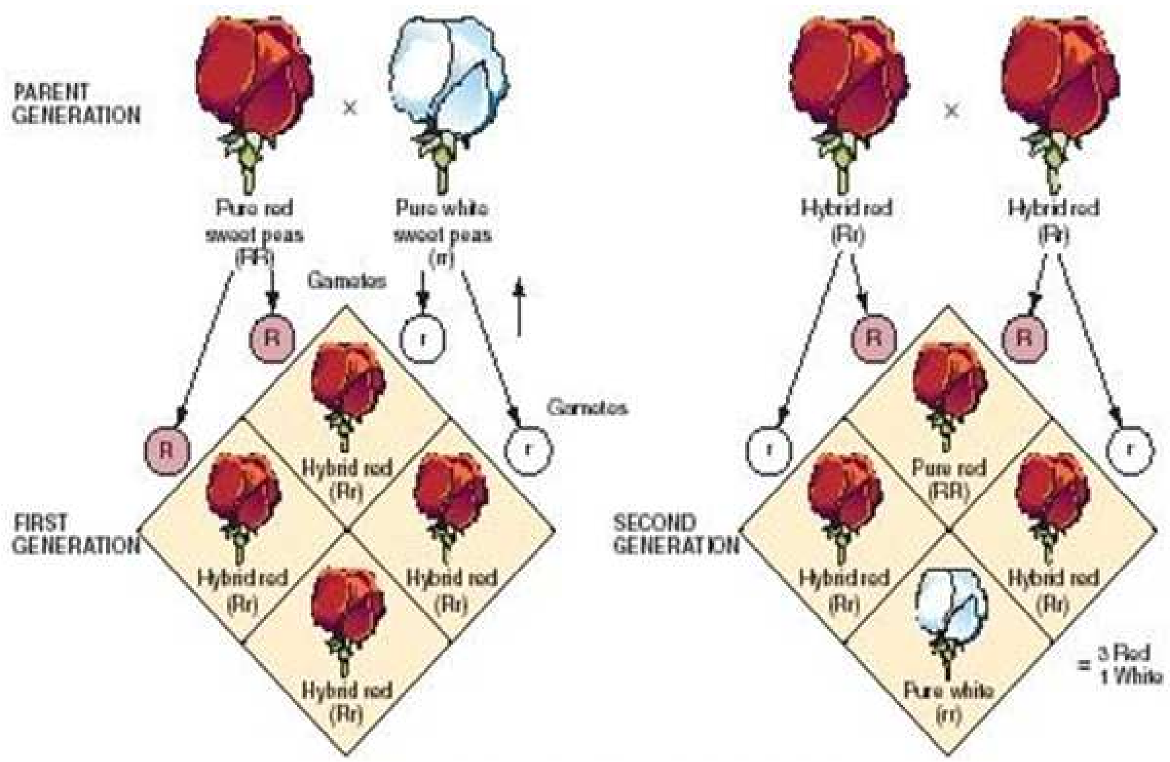


Fig.13.1 Mendel first law: Law of segregation

Molecular proof of this principle was subsequently found through observation of meiosis by two scientists independently, the German botanist Oscar Hertwig in 1876, and the Belgian zoologist Edouard Van Beneden in 1883.

Paternal and maternal chromosomes get separated in meiosis and the alleles with the traits of a character are segregated into two different gametes.

Each parent contributes a single gamete, and thus a single, randomly successful allele copy to their offspring and fertilization.

Explanation:-

Mendel's law of segregation describes what happens to the alleles that make up a gene during formation of gametes.

For example, suppose that a pea plant contains a gene for flower color in which both alleles code for red.

One way to represent that condition is to write RR, which indicates that both alleles (R and R) code for the color red. Another gene might have a different combination of alleles, as in Rr. In this case, the symbol R stands for red color and the r for "not red" or, in this case, white.

Mendel's law of segregation says that the alleles that make up a gene separate from each other, or segregate, during the formation of gametes. That fact can be represented by simple equations, such as:

RR → R + R or Rr → R + r

Mendel's second law is called the law of independent assortment. That law refers to the fact that any plant contains many different kinds of genes.

One gene determines flower color, a second gene determines length of stem, and a third gene determines shape of pea pods, and so on.

Mendel discovered that the way in which alleles from different genes separate and then recombine is unconnected to other genes.

That is, suppose that a plant contains genes for color (RR) and for shape of pod (TT). Then Mendel's second law says that the two genes will segregate independently, as:

RR → R + R and TT → T + T

Mendel's third law deals with the matter of dominance. Suppose that a gene contains an allele for red color (R) and an allele for white color (r).

What will be the color of the flowers produced on this plant? Mendel's answer was that in every pair of alleles, one is more likely to be expressed than the other. In other words, one allele is dominant and the other allele is recessive.

In the example of an Rr gene, the flowers produced will be red because the allele R is dominant over the allele r.

Law of Independent Assortment:-

The Law of Independent Assortment states that alleles for separate traits are passed independently of one another from parents to offspring.

That is, the biological selection of an allele for one trait has nothing to do with the selection of an allele for any other trait. Mendel found support for this law in his dihybrid cross experiments.

In his monohybrid crosses, an idealized 3:1 ratio between dominant and recessive phenotypes resulted. In dihybrid crosses, however, he found a 9:3:3:1 ratios.

This shows that each of the two alleles is inherited independently from the other, with a 3:1 phenotypic ratio for each.

Independent assortment occurs in eukaryotic organisms during meiotic prophase I, and produces a gamete with a mixture of the organism's chromosomes.

The physical basis of the independent assortment of chromosomes is the random orientation of each bivalent chromosome along the metaphase plate with respect to the other bivalent chromosomes.

Along with crossing over, independent assortment increases genetic diversity by producing novel genetic combinations.

There are many violations of independent assortment due to genetic linkage. Of the 46 chromosomes in a normal diploid human cell, half are maternally derived (from the mother's egg) and half are paternally derived (from the father's sperm).

This occurs as sexual reproduction involves the fusion of two haploid gametes (the egg and sperm) to produce a new organism having the full complement of chromosomes.

During gametogenesis-the production of new gametes by an adult—the normal complement of 46 chromosomes needs to be halved to 23 to ensure that the resulting haploid gamete can join with another gamete to produce a diploid organism.

An error in the number of chromosomes, such as those caused by a diploid gamete joining with a haploid gamete, is termed aneuploidy.

In independent assortment, the chromosomes that result are randomly sorted from all possible maternal and paternal chromosomes.

Because zygotes end up with a random mix instead of a pre-defined "set" from either parent, chromosomes are therefore considered assorted independently.

As such, the zygote can end up with any combination of paternal or maternal chromosomes. Any of the possible variants of a zygote formed from maternal and paternal chromosomes will occur with equal frequency.

For human zygotes, with 23 pairs of chromosomes, the number of possibilities is 223 or 8,388,608 possible combinations.

The zygote will normally end up with 23 chromosomes pairs, but the origin of any particular chromosome will be randomly selected from paternal or maternal chromosomes.

This contributes to the genetic variability of progeny.

To this point we have followed the expression of only one gene. Mendel also performed crosses in which he followed the segregation of two genes.

These experiments formed the basis of his discovery of his second law, the law of independent assortment. First, a few terms are presented.

Dihybrid Cross: -

A cross between two parents that differ by two pairs of alleles (AABB x aabb)

Dihybrid: -

An individual heterozygous for two pairs of alleles (AaBb), again a dihybrid cross is not a cross between two dihybrids. At a dihybrid cross that Mendel performed.

Parental Cross:-

Yellow, Round Seed x Green, Wrinkled Seed

F1 Generation:-

All yellow, rounds

F2 Generation:-

9 Yellow, Round, 3 Yellow, Wrinkled, 3 Green, Round, 1 Green, Wrinkled

Symbol
Seed Color:

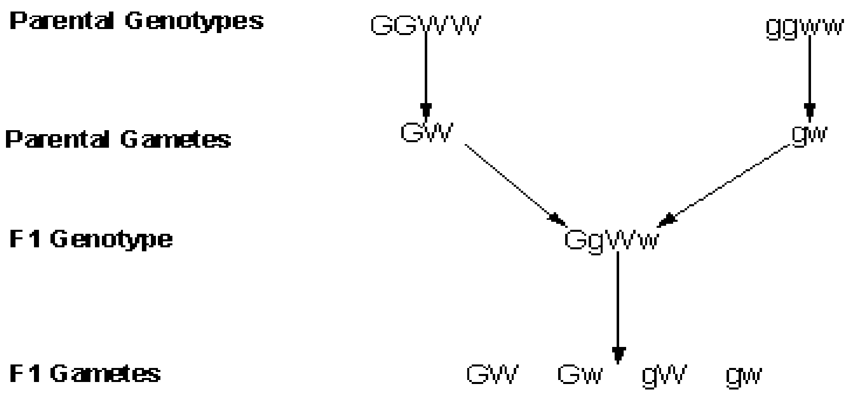
Yellow = *G*; Green = *g*

Seed Shape: -

Round = *W*; Wrinkled = *w*

The dominance relationship between alleles for each trait was already known to Mendel when he made this cross.

The purpose of the dihybrid cross was to determine if any relationship existed between different allelic pairs.



The Punnett Square for the F_2 cross.

		Female Gametes			
		GW	**Gw**	**gW**	**gw**
Male Gametes	**GW**	**GGWW** (Yellow, round)	**GGWw** (Yellow, round)	**GgWW** (Yellow, round)	**GgWw** (Yellow, round)
	Gw	**GGWw** (Yellow, round)	**GGww** (Yellow, wrinkled)	**GgWw** (Yellow, round)	**Ggww** (Yellow, wrinkled)
	gW	**GgWW** (Yellow, round)	**GgWw** (Yellow, round)	**ggWW** (Green, round)	**ggWw** (Green,round)
	gw	**GgWw** (Yellow, round)	**Ggww** (Yellow, wrinkled)	**ggWw** (Green, round)	**ggww** (Green, wrinkled)

The phenotypes and general genotypes from this cross can be represented in the following manner:

Phenotype	General Genotype
9 Yellow, Round Seed	G_W_
3 Yellow, Wrinkled Seed	G_ww
3 Green, Round Seed	ggW_
1 Green, Wrinkled Seed	ggww

The phenotypes and general genotypes from this cross can be represented in the following manner: The results of this experiment led Mendel to formulate his second law.

13.4- Experimentation on Non Mendelian Inheritance

Non-Mendelian inheritance is a general term that refers to any pattern of inheritance in which traits do not segregate in accordance with Mendel's laws.

These laws describe the inheritance of traits linked to single genes on chromosomes in the nucleus.

In Mendelian inheritance, each parent contributes one of two possible alleles for a trait. If the genotypes of both parents in a genetic cross are known, Mendel's laws can be used to determine the distribution of phenotypes expected for the population of offspring.

There are several situations in which the proportions of phenotypes observed in the progeny do not match the predicted values.

Although inheritance of traits in fungi, viruses, and bacteria are all non-Mendelian, the phrase "non-Mendelian inheritance" is usually only used to describe the exceptions which occur in eukaryotic reproduction. Non-Mendelian inheritance plays a role in several disease processes.

The F1 offspring of Mendel's pea crosses always looked like one of the two parental varieties.

In this situation of "complete dominance," the dominant allele had the same phenotypic effect whether present in one or two copies. But for some characteristics, the F1 hybrids have an appearance in between the phenotypes of the two parental varieties.

A cross between two four o'clock (***Mirabilis Jalapa***) plants shows this common exception to Mendel's principles.

Some alleles are neither dominant nor recessive. The F1 generation produced by a cross between red-flowered (RR) and white flowered (WW) *Mirabilis jalapa* plant consists of pink-colored flowers (RW). Which allele is dominant in this case? Neither one.

This third phenotype results from flowers of the heterzygote having less red pigment than the red homozygotes. Cases in which one allele is not completely dominant over another are called incomplete dominance. In incomplete dominance, the heterozygous phenotype lies somewhere between the two homozygous phenotypes.

A similar situation arises from co-dominance, in which the phenotypes produced by both alleles are clearly expressed.

For example, in certain varieties of chicken, the allele for black feathers is codominant with the allele for white feathers. Heterozygous chickens have a color described as "erminette," speckled with black and white feathers.

Unlike the blending of red and white colors in heterozygous four o'clock, black and white colours appear separately in chickens. Many human genes, including one for a protein that controls cholesterol levels in the blood, show co-dominance, too.

People with the heterozygous form of this gene produce two different forms of the protein, each with a different effect on cholesterol levels.

In Mendelian inheritance, genes have only two alleles, such as a and A. In nature, such genes exist in several different forms and are therefore said to have multiple alleles. A gene with more than two alleles is said to have multiple alleles.

An individual, of course, usually has only two copies of each gene, but many different alleles are often found within a population.

One of the best-known examples is coat colour in rabbits. A rabbit's coat colour is determined by a single gene that has at least four different alleles.

The four known alleles display a pattern of simple dominance that can produce four coat colours. Many other genes have multiple alleles, including the human genes for ABO blood type.

Furthermore, many traits are produced by the interaction of several genes. Traits controlled by two or more genes are said to be polygenic traits. Polygenic means "many genes."

For example, at least three genes are involved in making the reddish-brown pigment in the eyes of fruit flies. Polygenic traits often show a wide range of phenotypes.

The variety of skin colour in humans comes about partly because more than four different genes probably control this trait.

Extra-nuclear inheritance:-

Extranuclear inheritance (also known as cytoplasmic inheritance) is a form of non-Mendelian inheritance first discovered by Carl Correns in 1908.

While working with ***Mirabilis Jalapa*** Correns observed that leaf colour was dependent only on the genotype of the maternal parent. Based on these data, he determined that the trait was transmitted through a character present in the cytoplasm of the ovule.

Later research by Ruth Sager and others identified DNA present in chloroplasts as being responsible for the unusual inheritance pattern observed.

Work on the poky strain of the mold ***Neurospora crassa*** begun by Mary and Hershel Mitchell ultimately led to the discovery of genetic material in mitochondria as well.

According to the endosymbiont theory, mitochondria and chloroplasts were once free living organisms that were each taken up by a eukaryotic cell. Over time, mitochondria and chloroplasts formed a symbiotic relationship with their eukaryotic hosts.

Although the transfer of a number of genes from these organelles to the nucleus prevents them from living independently, each still possesses genetic material in the form of double stranded DNA.

It is the transmission of this organellar DNA that is responsible for the phenomenon of extranuclear inheritance. Both chloroplasts and mitochondria are present in the cytoplasm of maternal gametes only.

Paternal gametes (sperm for example) do not have cytoplasmic mitochondria. Thus, the phenotype of traits linked to genes found in either chloroplasts or mitochondria are determined exclusively by the maternal parent.

In humans, mitochondrial diseases are a class of diseases, many of which affect the muscles and the eye.

Gene conversion:-

Gene conversion can be one of the major forms of non-Mendelian inheritance. Gene conversion is a reparation process in DNA recombination, by which a piece of DNA sequence information is transferred from one DNA helix (which remains unchanged) to another DNA helix, whose sequence is altered.

This may occur as a mismatch repair between the strands of DNA which are derived from different parents.

Thus the mismatch repair can convert one allele into the other. This phenomenon can be detected through the offspring non-Mendelian ratios, and is frequently observed, e.g., in fungal crosses.

Infectious heredity:-

Another form of non-Mendelian inheritance is known as infectious heredity. Infectious particles such as viruses may infect host cells and continue to reside in the cytoplasm of these cells.

If the presence of these particles results in an altered phenotype, then this phenotype may be subsequently transmitted to progeny.

Because this phenotype is dependent only on the presence of the invader in the host cell's cytoplasm, inheritance will be determined only by the infected status of the maternal parent.

This will result in a uniparental transmission of the trait, just as in extranuclear inheritance.

One of the most well studied examples of infectious heredity is the killer phenomenon exhibited in yeast. Two double-stranded RNA viruses, designated L and M, are responsible for this phenotype.

The L virus codes for the capsid proteins of both viruses, as well as an RNA polymerase. Thus the M virus can only infect cells already harboring L virus particles.

The M viral RNA encodes a toxin which is secreted from the host cell.

It kills susceptible cells growing in close proximity to the host. The M viral RNA also renders the host cell immune to the lethal effects of the toxin.

For a cell to be susceptible it must therefore be either uninfected, or harbor only the L virus.

The L and M viruses are not capable of exiting their host cell through conventional means. They can only transfer from cell to cell when their host undergoes mating.

All progeny of a mating involving a doubly infected yeast cell will also be infected with the L and M viruses. Therefore, the killer phenotype will be passed down to all progeny.

Heritable traits that result from infection with foreign particles have also been identified in *Drosophila*. Wild type flies normally full recover after being anesthetized with carbon dioxide.

Certain lines of flies have been identified that die off after exposure to the compound. This carbon dioxide sensitivity is passed down from mothers to their progeny. This sensitivity is due to infection with σ (Sigma) virus, a rhabdovirus only capable of infecting Drosophila.

Although this process is usually associated with viruses, recent research has shown that the ***Wolbachia bacterium*** is also capable of inserting its genome into that of its host.

Genomic imprinting:-

Genomic imprinting represents yet another example of non-Mendelian inheritance. Just as in conventional inheritance, genes for a given trait are passed down to progeny from both parents.

However, these genes are epigenetically marked before transmission, altering their levels of expression.

These imprints are created before gamete formation and are erased during the creation of germ line cells. Therefore, a new pattern of imprinting can be made with each generation.

Genes are imprinted differently depending on the parental origin of the chromosome that contains them. In mice, the insulin-like growth factor 2 gene undergoes imprinting.

The protein encoded by this gene helps to regulate body size. Mice that possess two functional copies of this gene are larger than those with two mutant copies.

The size of mice that are heterozygous at this locus depends on the parent from which the wild type allele came.

If the functional allele originated from the mother, the offspring will exhibit dwarfism, whereas a paternal allele will generate a normal sized mouse.

This is because the maternal Igf2 gene is imprinted. Imprinting results in the inactivation of the Igf2 gene on the chromosome passed down by the mother.

Imprints are formed due to the differential methylation of paternal and maternal alleles. This results in differing expression between alleles from the two parents. Sites with significant methylation are associated with low levels of gene expression.

Higher gene expression is found at unmethylated sites. In this mode of inheritance, phenotype is determined not only by the specific allele transmitted to the offspring, but also by the sex of the parent that transmitted it.

Mosaicism:-

Individuals who possess cells with genetic differences from the other cells in their body are termed mosaics. These differences can result from mutations that occur in different tissues and at different periods of development.

If a mutation happens in the non-gamete forming tissues, it is characterized as somatic. Germline mutations occur in the egg or sperm cells and can be passed on to offspring.

Mutations that occur early on in development will affect a greater number of cells and can result in an individual that can be identified as a mosaic strictly based on phenotype.

Mosaicism also results from a phenomenon known as X-inactivation. All female mammals have two X chromosomes. To prevent lethal gene dosage problems, one of these chromosomes is inactivated following fertilization.

This process occurs randomly for all of the cells in the organism's body. Because a given female's two X chromosomes will almost certainly differ in their specific pattern of alleles, this will result in differing cell phenotypes depending on which chromosome is silenced.

Calico cats, which are almost all female, demonstrate one of the most commonly observed manifestations of this process.

Trinucleotide repeat disorders:-

Trinucleotide repeat disorders also follow a non-Mendelian pattern of inheritance.

These diseases are all caused by the expansion of microsatellite tandem repeats consisting of a stretch of three nucleotides.

Typically in individuals, the number of repeated units is relatively low. With each successive generation, there is a chance that the number of repeats will expand.

As this occurs, progeny can progress to premutation and ultimately affected status.

Individuals with a number of repeats that falls in the premutation range have a good chance of having affected children.

Those who progress to affected status will exhibit symptoms of their particular disease.

Prominent trinucleotide repeat disorders include Fragile X syndrome and Huntington's disease.

In the case of Fragile X syndrome it is thought that the symptoms result from the increased methylation and accompanying reduced expression of the fragile X mental retardation gene in individuals with a sufficient number of repeats.

13.5 – Study of Mutant Drosophila through Chart and Photographs

Drosophila melanogaster is a species of fly (the taxonomic order Diptera) in the family Drosophilidae. The species is known generally as the **common fruit fly** or **vinegar fly**.

Starting with Charles W. Woodworth's proposal of the use of this species as a model organism, *D. melanogaster* continues to be widely used for biological research in studies of genetics, physiology, microbial pathogenesis, and life history evolution.

It is typically used because it is an animal species that is easy to care for, has four pairs of chromosomes, breeds quickly, and lays many eggs. *D. melanogaster* is a common pest in homes, restaurants, and other occupied places where food is served.

Flies belonging to the family Tephritidae are also called "fruit flies". This can cause confusion, especially in Australia and South Africa, where the Mediterranean fruit fly *Ceratitis capitata* is an economic pest.

Physical appearance:-

Wildtype fruit flies are yellow-brown, with brick-red eyes and transverse black rings across the abdomen.

They exhibit sexual dimorphism: females are about 2.5 millimeters (0.098 in) long; males are slightly smaller with darker backs.

Males are easily distinguished from females based on colour differences, with a distinct black patch at the abdomen, less noticeable in recently emerged flies, and the sex combs (a row of dark bristles on the tarsus of the first leg).

Furthermore, males have a cluster of spiky hairs (claspers) surrounding the reproducing parts used to attach to the female during mating.

Lifecycle and reproduction:-

The *D. melanogaster* lifespan is about 30 days at 29 °C (84 °F). It had been recorded that their lifespan can be increased to 3 months.The developmental period for *D. melanogaster* varies with temperature, as with many ectothermic species. The shortest development time (egg to adult), 7 days, is achieved at 28 °C (82 °F). Development times increase at higher temperatures (11 days at 30 °C or 86 °F) due to heat stress. Under ideal conditions, the development time at 25 °C (77 °F) is 8.5 days, at 18 °C (64 °F) it takes 19 days and at 12 °C (54 °F) it takes over 50 days. Under crowded conditions, development time increases, while the emerging flies are smaller.

Females lay some 400 eggs (embryos), about five at a time, into rotting fruit or other suitable material such as decaying mushrooms and sap fluxes. The eggs, which are about 0.5 mm long, hatch after 12–15 hours (at 25 °C or 77 °F). The resulting larvae grow for about 4 days (at 25 °C) while molting twice (into second- and third-instar larvae), at about 24 and 48 h after hatching. During this time, they feed on the microorganisms that decompose the fruit, as well as on the sugar of the fruit itself. The mother puts feces on the egg sacs to establish the same microbial composition in the larvae's guts which has worked positively for her. Then the larvae encapsulate in the puparium and undergo a four-day-long metamorphosis (at 25 °C), after which the adults enclose (emerge).

Females become receptive to courting males at about 8–12 hours after emergence. Specific neuron groups in females have been found to affect copulation behavior and mate choice. One such group in the abdominal nerve cord allows the female fly to pause her body movements to copulate. Activation of these neurons induces the female to cease movement and orient herself towards the male to allow for mounting. If the group is inactivated, the female remains in motion and does not copulate. Various chemical signals such as male pheromones often are able to activate the group.

The female fruit fly prefers a shorter duration when it comes to sex. Males, on the other hand, prefer it to last longer.

Males perform a sequence of five behavioral patterns to court females. First, males orient themselves while playing a courtship song by horizontally extending and vibrating their wings. Soon after, the male positions itself at the rear of the female's abdomen in a low posture to tap and lick the female genitalia.

Finally, the male curls its abdomen and attempts copulation. Females can reject males by moving away, kicking, and extruding their ovipositor. Copulation lasts around 15–20 minutes, during which males transfer a few hundred, very long (1.76 mm) sperm cells in seminal fluid to the female.

Females store the sperm in a tubular receptacle and in two mushroom-shaped spermathecae; sperm from multiple matings compete for fertilization. A last male precedence is believed to exist in which the last male to mate with a female sires about 80% of her offspring. This precedence was found to occur through both displacement and incapacitation.The displacement is attributed to sperm handling by the female fly as multiple matings are conducted and is most significant during the first 1–2 days after copulation. Displacement from the seminal receptacle is more significant than displacement from the spermathecae. Incapacitation of first male sperm by second male sperm becomes significant 2–7 days after copulation.

The seminal fluid of the second male is believed to be responsible for this incapacitation mechanism (without removal of first male sperm) which takes effect before fertilization occurs. The delay in effectiveness of the incapacitation mechanism is believed to be a protective mechanism that prevents a male fly from incapacitating its own sperm should it mate with the same female fly repetitively.

Sensory neurons in the uterus of female *D. melanogaster* respond to a male protein, sex peptide, which is found in sperm. This protein makes the female reluctant to copulate for about 10 days after insemination. The signal pathway leading to this change in behavior has been determined. The signal is sent to a brain region that is a homolog of the hypothalamus and the hypothalamus then controls sexual behavior and desire

D. melanogaster is often used for life extension studies, such as to identify genes purported to increase lifespan when mutated.

Genetic markers:-

Genetic markers are commonly used in *Drosophila* research, for example within balancer chromosomes or P-element inserts, and most phenotypes are easily identifiable either with the naked eye or under a microscope.

In the list of example common markers below, the allele symbol is followed by the name of the gene affected and a description of its phenotype. (Recessive alleles are in lower case, while dominant alleles are capitalized.)

- Cy^1: Curly; the wings curve away from the body, flight may be somewhat impaired.
- e^1: ebony; black body and wings (heterozygotes are also visibly darker than wild type).
- Sb^1: stubble; bristles are shorter and thicker than wild type.
- w^1: white; eyes lack pigmentation and appear white.
- y^1: yellow; body pigmentation and wings appear yellow. This is the fly analog of albinism.

Drosophila genes are traditionally named after the phenotype they cause when mutated. For example, the absence of a particular gene in *Drosophila* will result in a mutant embryo that does not develop a heart.

Scientists have thus called this gene *tinman*, named after the Oz character of the same name. This system of nomenclature results in a wider range of gene names than in other organisms.

Similarity to humans:-

Study by National Human Genome Research Institute comparing the fruit fly and human genome estimated that about 60% of genes are conserved between the two species. About 75% of known human disease genes have a recognizable match in the genome of fruit flies, and 50% of fly protein sequences have mammalian homologs. An online database called Haemophila is available to search for human disease gene homologues in flies and vice versa. *Drosophila* is being used as a genetic model for several human diseases including the neurodegenerative disorders Parkinson's, Huntington's, spinocerebellar ataxia and Alzheimer's disease.

The fly is also being used to study mechanisms underlying aging and oxidative stress, immunity, diabetes, and cancer, as well as drug abuse.

Sex determination:-

Drosophila flies have both X and Y chromosomes, as well as autosomes. Unlike humans, the Y chromosome does not confer maleness; rather, it encodes genes necessary for making sperm. Sex is instead determined by the ratio of X chromosomes to autosomes. Furthermore, each cell "decides" whether to be male or female independently of the rest of the organism, resulting in the occasional occurrence of gynandromorphs

X Chromosomes Autosomes Ratio of X: A Sex:-

XXXX	AAAA	1	Normal Male
XXX	AAA	1	Normal Female
XXY	AA	1	Normal Female
XXYY	AA	1	Normal Female
XX	AA	1	Normal Female
XY	AA	0.50	Normal Male
X	AA	0.50	Normal Male (STERILE)
XXX	AA	1.50	Meta Female
XXXX	AAA	1.33	Meta Female
XX	AAA	0.66	Intersex
X	AAA	0.33	Meta Male

Three major genes are involved in determination of *Drosophila* sex. These are sex-lethal, sisterless, and deadpan.

Deadpan is an autosomal gene which inhibits sex-lethal, while sisterless is carried on the X chromosome and inhibits the action of *deadpan*.

An AAX cell has twice as much deadpan as sister less, so sex-lethal will be inhibited, creating a male.

However, an AAXX cell will produce enough sister less to inhibit the action of deadpan, allowing the sex-lethal gene to be transcribed to create a female.

Later, control by deadpan and sister less disappears and what becomes important is the form of the sex-lethal gene.

A secondary promoter causes transcription in both males and females. Analysis of the c-DNA has shown that different forms are expressed in males and females.

Sex-lethal has been shown to affect the splicing of its own mRNA.

In males, the third exon is included which encodes a stop codon, causing a truncated form to be produced.

In the female version, the presence of sex-lethal causes this exon to be missed out; the other seven amino acids are produced as a full peptide chain, again giving a difference between males and females.

Presence or absence of functional sex-lethal proteins now goes on to affect the transcription of another protein known as double sex.

In the absence of sex-lethal, double sex will have the fourth exon removed and be translated up to and including exon 6 (DSX-M[ale]), while in its presence the fourth exon which encodes a stop codon will produce a truncated version of the protein (DSX-Female]).

DSX-F causes transcription of Yolk proteins 1 and 2 in somatic cells, which will be pumped into the oocyte on its production.

Study Of Mutants Of Drosophila:-

Introduction:-

The fruit flies in this exhibit show just a few of the mutations that occur in natural fruit fly populations.

The genetic instructions to build a fruit fly-or any other organism-are imprinted in its DNA, a long, threadlike molecule packaged in bundles called chromosomes.

Like a phone book made up of different names and addresses, each chromosome consists of many individual sections called genes.

Each gene carries some of the instructions for building one particular characteristic of an organism.

Structure:-

To build a complete organism, many genes must work precisely together. A defect in a gene can cause a change in the building plan for one particular body part-or for the entire organism.

Mutations are neither good nor bad: some may be beneficial for an organism; others may be lethal.

By creating new gene versions, mutations are a driving force for changes in evolution, sometimes leading to new species.

Biologists learn about the proper function of any gene by studying mutations. If a defective gene causes short wings, for instance, scientists know that the healthy version of the gene is responsible for correct wing formation.

Altered wings Structure:-

Normal Fruits Flies: These are normal fruit flies, or "wildtypes." Notice the shape and length of their wings. Now compare them with the other fruit flies here.

Short-Winged Flies: Notice the shortened wings of these flies. Flies with vestigial wings cannot fly: they have a defect in their "vestigial gene," on the second chromosome.

These flies have a recessive mutation. Of the pair of vestigial genes carried by each fly (one from each parent), both have to be altered to produce the abnormal wing shape.

If only one is mutated, the healthy version can override the defect

Curly-Winged Flies:-

Notice the curled wings of these flies. They have a defect in their "curly gene," which is on the second chromosome.

Having curled wings is a dominant mutation, which means that only one copy of the gene has to be altered to produce the defect. In fact, if both copies are mutated, the flies do not survive.

Normal Fruit Flies:-

These normal fruit flies, or "wild types," have black-and-tan striped bodies. Compare them with the other fruit flies here.

Yellow Flies:-

Notice that these flies are yellower than normal flies. They have a defect in their "yellow gene," which is on the X chromosome.

Since the yellow gene is needed for producing a fly's normal black pigment, yellow mutant flies cannot produce this pigment.

Ebony Flies:-

Notice that these flies have a dark, almost black, body. They carry a defect in their "ebony gene," on the third chromosome.

Normally, the ebony gene is responsible for building up the tan-colored pigments in the normal fruit fly. If the ebony gene is defective, the black pigments accumulate all over the body.

Animal Models for the Study of Learning and Memory:-

Four animal models have proved particularly useful. The first is perhaps the most surprising: the fruit fly Drosophila, long the subject of study by geneticists for the speed with which it breeds and the ease with which mutants could be generated.

Fruit flies will spontaneously fly towards particular odors, but if they receive an electric shock as they approach they can learn to avoid that particular odor.

A series of mutants have been generated that either could not learn to respond by avoidance, or forgot after varying periods of time.

Each class of mutants had a specific biochemical abnormality—the loss of activity of a particular enzyme or of one of the factors required for the synthesis of specific proteins.

Hence it is argued that the missing enzyme or factor is also necessary for learning and memory to occur.

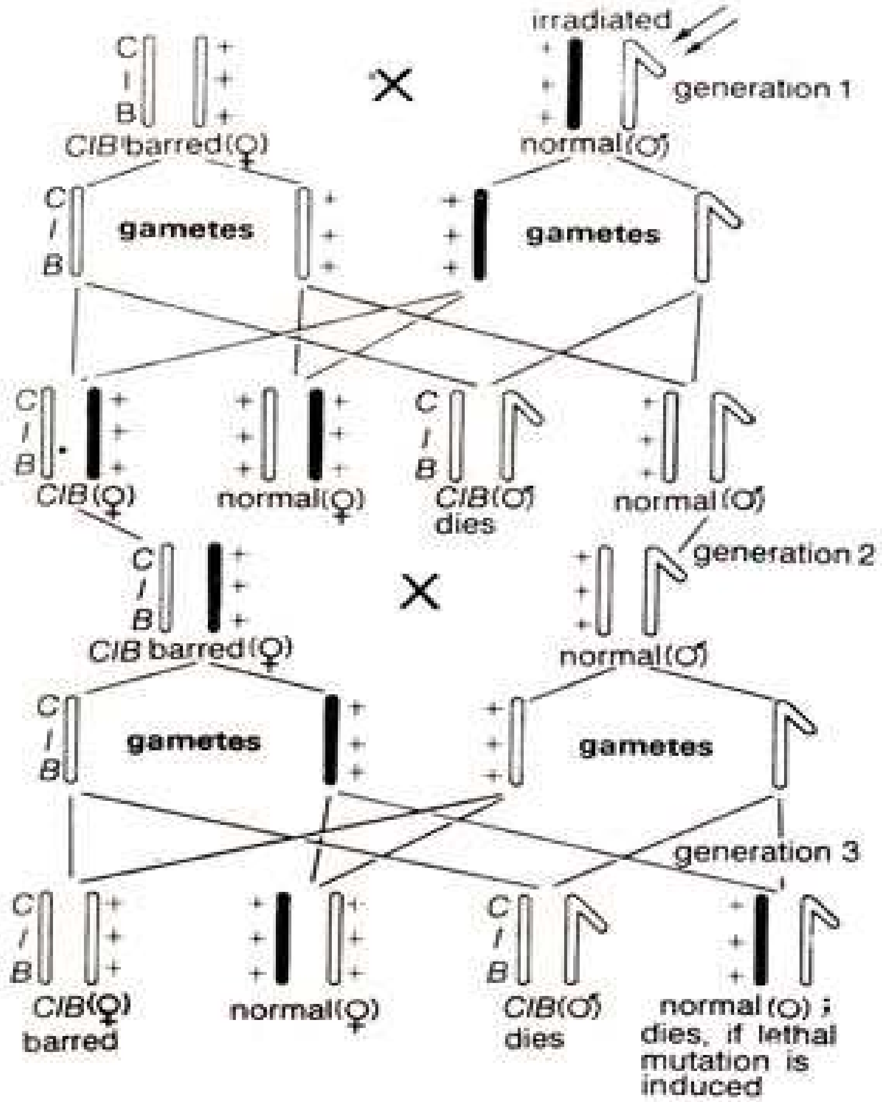


Fig.13.2 Muller's CIB method for detection of sex linked lethal mutations in Drosophila.

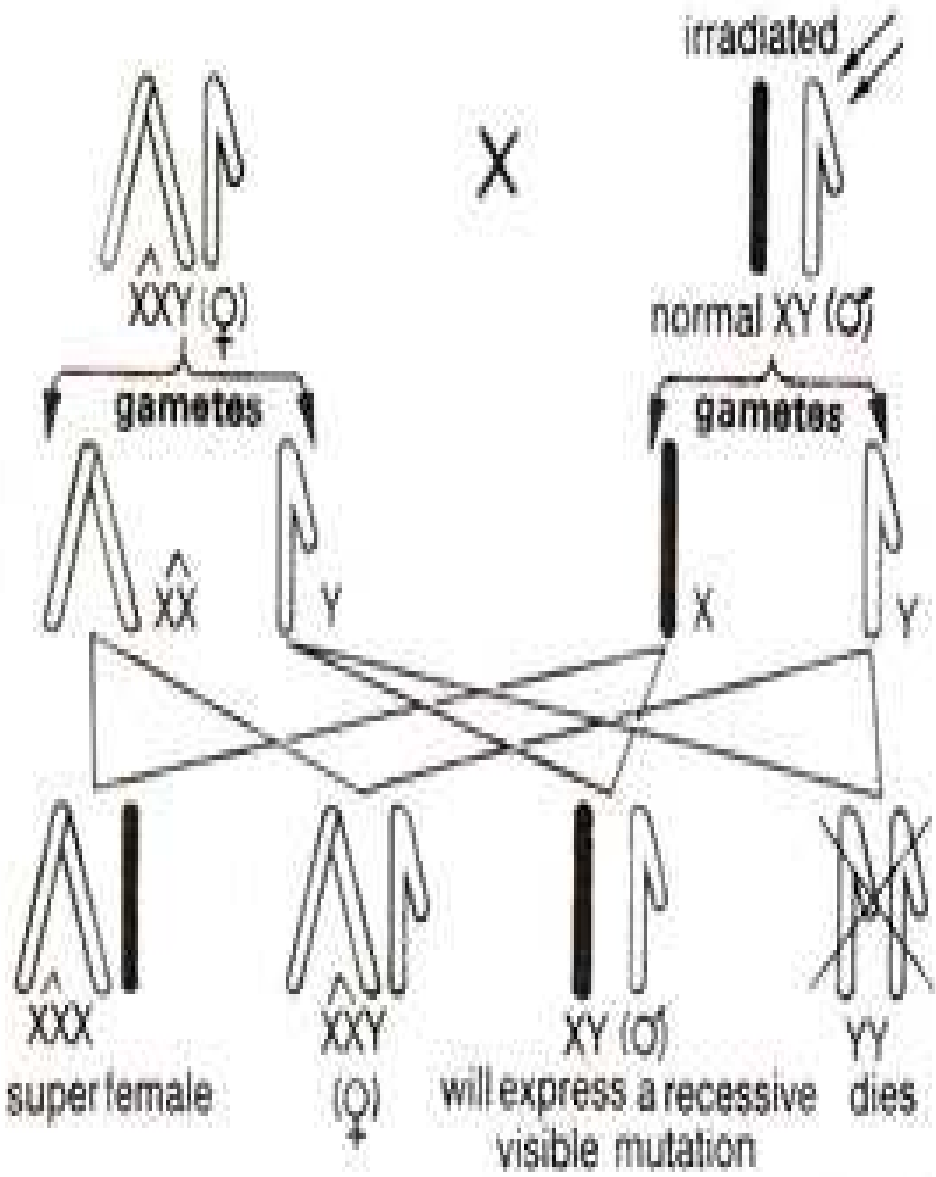


Fig.13.3 Attached X-method for detection of sex linked visible mutations.

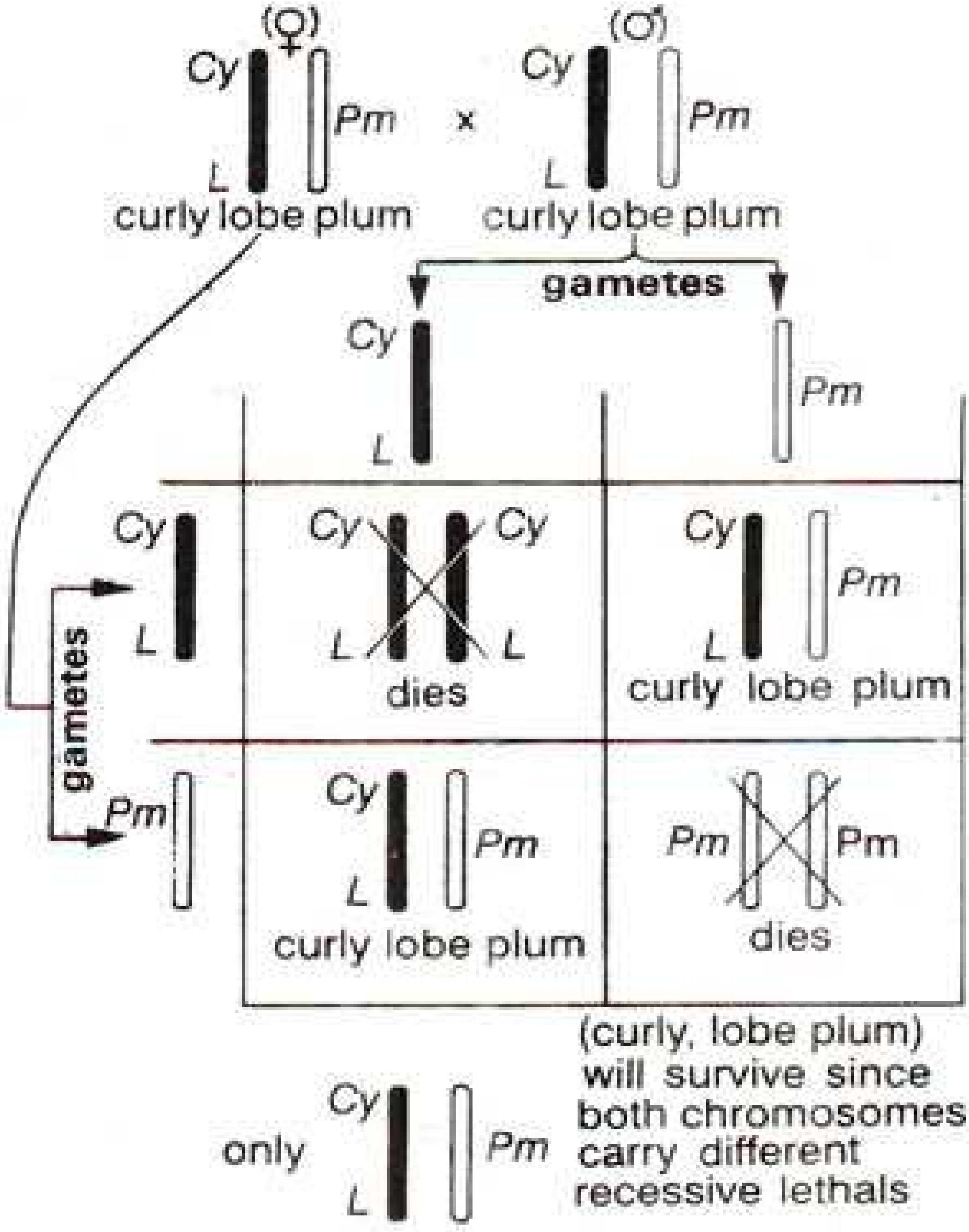


Fig.13.4 Balanced lethal system in Cy LIPm Drosophila

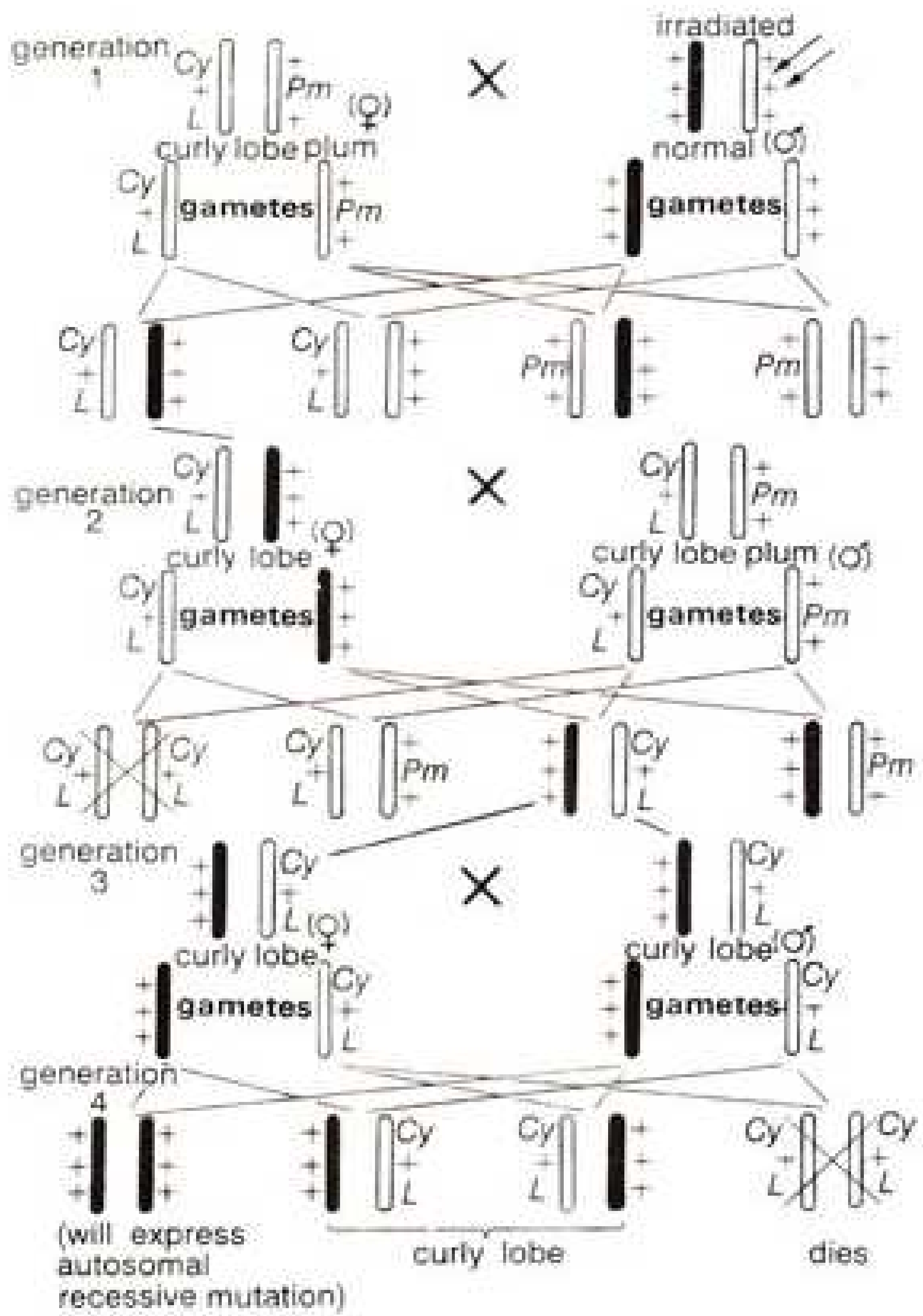


Fig.13.5 Detection of autosomal mutations in Drosophila

13.6- Genetical Exercise

Exercise No 1: -

Objective:

Two grey Drosophila flies on breeding produce 152 grey and 49 black off-springs. Give the genotypes of the parents and justify your answer giving reasons. (Given grey is dominant over black.

Observation:

The ratio of the dominant and recessive off-springs in the given problem 152:49 comes to be approximately 3:1.

Hence, the parents of these off-springs will be heterozygous for grey and black traits having genotypes Gg and Gg**.**

Explanation:-

In case of a monohybrid cross when heterozygous individuals are crossed among themselves, they produce off-springs with dominant and recessive characters in a ratio of 3:1.

Grey	*	**Grey**
Gg	↓	**Gg**
↓	↓	↓
Gametes		**Gametes**

Gametes	**G**	**g**
G	**Gg** **Grey**	**Gg** **Grey**
g	**gg** **Black**	**gg** **Black**

Conclusions: -

The genotypes of the parents will be Gg and Gg. It is a case of simple Mendelian Inheritance showing the phenomenon of dominance and recessive.

Exercise No2: -

Objective: -

Both the parents of a blue-eyed child are brown-eyed. Find out the genotypes of the parents if brown eyes (B) are dominant over blue (b) which is recessive.

Observation: -Since recessive character is only expressed in homozygous condition, hence, the genotype of the child will be **bb.**

The child receives characters from both the parents in equal amount. Therefore, its one **b** has come from one parent and the other b from other parents causing his eyes blue.

But in the given problem both the parents are brown-eyed. Therefore, they must have been heterozygous with genotype **Bb** and **Bb.**

Explanation: -

When heterozygous brown-eyed parents cross, they produce brown-eyed and blue-eyed off-springs in a ratio of **3:1.**

The brown-eyed off-springs having genotype **BB** and **Bb,** while blue-eyed with **bb**

Brown Eyed father * **Brown Eyed father**

Bb ↓ **Bb**

↓ ↓ ↓

Gametes **Gametes**

B **b**

Gametes	**B**	**b**
B	**Gg** **Grey**	**Gg** **Grey**
b	**gg** **Black**	**gg** **Black**

Conclusion:

The genotype of the parents of a blue-eyed child will be **Bb**. It is a case of simple Mendelian Monohybrid Inheritance showing the phenomena of **dominance, recessive** and **segregation**.

Exercise No 3:-

Objective:

In garden pea, tall **(T)** is dominant over dwarf **(t)** and red flower colour **(R)** to white **(r**) If pure red tall is crossed with a dwarf white, what will be

- **(i)** P1 genotypes,
- **(ii)** the gametes of **P1,**
- **(iii)** the F1 phenotype and genotype,
- **(iv)** the gametes of **F1**, and **(V) F2 p**henotypic ratio.

Point out the genetic principles involved.

Observation:

It appears from the object that it is a case of di-hybrid cross and based on the cross as suggested of Mendelian Inheritance.

Explanation:-

To find out the solution of the questions asked in the object, work out the cross as suggested as pure red tall means homozygous tall plants with red flowers, genotype will be **TTRR.**

Dwarf white means homozygous dwarf plants with white flowers, genotype will be **ttrr.**

It will be homozygous because recessive are expressed only when they are in homozygous condition.

	Phenotype	**Tall red**	×	**Dwarf white**
(P1)	**Genotype**	**TT RR**	↓	**tt rr**
	Gametes	**TR, TR**	↓	**tr, tr**
(F1)	**Genotype**	**TR tr**	↓	**TR tr**
	Phenotype	**Tall red**	↓	**Tall red**
	Gametes	**TR, Tr, tR, tr**	×	**TR, Tr, tR, tr**
			↓	

♂ / ♀	TR	Tr	tR	tr
TR	TRTR Tall Red	TRTr Tall red	TRtR Tall red	TRtr Tall red
Tr	TrTR Tall red	TrTr Tall white	TrtR Tall red	Trtr Tall white
tR	tRTR Tall red	tRTr Tall red	tRtR Dwarf red	tRtr Dwarf red
tr	trTR Tall red	trTr Tall white	trtR Dwarf red	trtr Dwarf white

Phenotypic ratio: 9 Tall red: 3 Tall white: 3 Dwarf red: 1 Dwarf white

Conclusion: (i) P1 genotype are TTRR and ttrr

(ii) The gametes of P1 are TR and tr types

(iii) F1 phenotype is Tall red and genotype is TRtr for all possible offsprings

(iv) The gametes of F1 are TR, Tr and tr, and

(v) The F2 phenotype ratio is 9:3:3:1

The genetic principles involved are the phenomena of dominance and recessive, law of segregations and the Law of Independent Assortment.

Based on Incomplete Dominance:-

Objective:

Explain giving reasons for the occurrence of modified **3:1** phenotypic ratio **1:2:1** in a monohybrid cross.

Observation:

According to the phenomenon of dominance, a monohybrid cross should always result into **F2** off-springs in a phenotypic ratio of **3:1** and their genotypic ratio being **1:2:1.** But sometimes, due to incomplete dominance, **3:1** phenotypic ratio comes to be **1:2:1.** It means that the phenomenon of dominance shows exceptions.

Explanation:

Let us consider an example to illustrate the modified **1:2:1** phenotypic ratio.An Andalusian fowl a cross between its homozygous black and white varieties results in blue hybrids. These blue hybrids when crossed among themselves, the **F2** generation off-springs are **1 black : 2 blue : 1 white.**

The colour of **F1** hybrid blue is a blended character, i.e., a colour midway between the two parents. It means that none of the colour of the parents are either fully dominant or recessive. Therefore, both the factor expresses them partially resulting into a blending of parental characters. Such factors are usually referred to as intermediate factors or genes.

♂ / ♀	b	b
B	Bb Blue	Bb Blue
B	Bb Blue	Bb Blue

Blue Fowl * **White Fowl**

Bb ↓ **bb**

↓ ↓ ↓

All Blue Fowls …….F1

↓

Cross- fertilization

♂ / ♀	B	b
B	BB Black	Bb Blue
b	Bb Blue	bb White

Phenotypic ratio = 1 Black: 2 Blue: 1 White

Conclusions: The modified phenotypic **1:2:1** ratio is due to the phenomenon of incomplete dominance. As referred to, it is due to intermediate genes, hence, called intermediate inheritance.

13.6: Summery:-

Genetics, scientific study of how physical, biochemical, and behavioral traits are transmitted from parents to their offspring.

Geneticists determine the mechanisms of inheritance whereby the offspring of sexually reproducing organisms do not exactly resemble their parents, and the differences and similarities between parents and offspring recur from generation to generation in repeated patterns.

The investigation of these patterns has led to some of the most exciting discoveries in modern biology.Most physical characteristics of humans are influenced by multiple genetic variables as well as by the environment. Some characteristics, such as height, have a relatively large genetic component. Others, such as body weight, have a relatively large environmental component.

Still other characteristics, such as the blood groups and the antigens involved in the rejection of transplanted organs, appear to involve entirely genetic components; no environmental condition is known to change these characteristics.The transplantation antigens have recently been extensively studied because of their medical interest. The most important ones are produced by a group of linked genes known as the HLA complex.

This group of genes not only determines whether transplanted organs will be accepted or rejected, it is also involved in the body's resistance to various diseases (including allergies, diabetes, and arthritis).The identification and study of genes are of great interest to biologists, and are also of medical importance when a particular gene is involved in disease.

The human genome contains approximately 30,000 genes, of which about 4,000 may be associated with disease. A globally coordinated effort, called the Human Genome Project, was started in 1990 to characterize the entire human genome.

By 2003 a complete sequence map of the human genome had been produced. Its primary goals had been to determine the complete sequence of the 3 billion DNA subunits (bases), generate various genome maps, including the entire nucleotide sequence of the human genome, and identify all human genes, making them accessible for further biological study.

The project was greatly assisted by the ability to clone large fragments of DNA into yeast artificial chromosome vectors for further analysis, the automation of many techniques such as DNA sequencing, and the use of supercomputers in whole-genome shotgun sequencing, for example.

13.7: Glossary:-

Alleles	A pair of gene located at corresponding position on a pair of homologous chromosomes.
Aneuploidy	The action or loss of individual chromosomes leading to abnormal chromosomes constitution
Anticodon	A sequence of three nucleotides on one of the loops of tRNA which is complementary to a codon of mRNA
Bacteriophase	Virus which parasitizes bacteria

Cistron	The smallest unit of DNA that codes for one polypeptide chain. Is synonymous with structural gene
Codon	A sequence of three nucleotides on the mRNA which codes for a particular amino acid
Down's syndrome	Mutant condition resulting from chromosomal trisomy or translocation, characterized by severe mental retardation, also known in the past as mongoloid idiocy
Euchromatin	Lightly stained portions of chromosomes
Genetic Drift	A random change in gene frequency from one generation to another in a population
Genome	The total genetic constitution of an organism
Haploid	The number of chromosomes found in mature gametes of sexually reproducing organism; one half of the species number of chromosomes; referred to as the n-number of chromosomes
Induced mutation	Mutation as a result of manmade factors
Karyotype	A composite picture of an individual‘s chromosomes, made by taking a photomicrograph of specially prepared cells and then cutting out the chromosomes and matching them
Monosomy	Presence of a single copy of a chromosome in cells which are genetically diploid organism
Muton	The small genetic unit that can mutate
Operator gene	In bacteria, the gene that controls transcription of structural gene
Pleitrophy	The occurrence of a syndrome of diverse effects, resulting from the mutation of a single genetically determined
Polygeny	The determination of a trait by several pairs of genes with additive effects on the phenotype
Polyploidy	Presence of extra sets of chromosomes
Polysome	Cluster of ribosome formed during protein synthesis
Regulator gene	In bacteria, the gene which produces a repressor substance that binds to the operator gene
Somatic	Pertaining to body cells other than gametes. A somatic mutation is one occurring in a body cell rather than a sex cell
Structural gene	In bacteria, the gene that contains the coding for a specific polypeptide.

Tetrad	A cluster of four chromatids formed by duplicated homologous lying parallel to one another following synapses.
Tolerance	An immunological phenomenon in which an organism does not react to the presence of antigen.
Transcription	The synthesis of new RNA molecules using DNA as a template
Trisomy	Presence of three copies of a chromosome in cells of a normally diploid organism
X-linkage	Linkage of genes on the X-chromosome

13.8: Self Assessment Questions:-

1. Which plant was used by Mendel in his experiment?
2. Who proposed the Law of Dominance?
3. Who proposed the hypothesis of one gene one enzyme?
4. Give an example of Incomplete Dominance.
5. What is the ration of Dihybrid cross in F2 generation?

Terminal Question:-

1. What do you understand by spontaneous mutations and induced mutations? Discuss variation in mutation rates and frequencies at different loci within an organism.

2. Discuss Mendel's laws of inheritance. Which law do you think is most important and why?

3. Discuss the pre- Mendelian ideas about the mechanism of inheritance of traits. Why workers before Mendel did not succeed in formulating laws of inheritance?

4. Discuss sex determination with the help of suitable examples.

5. Write short notes any two of the following-

(a) Dihybrid crosses

(b) Allele or allelomorph

(c) Pure line

13.9: References:-

Altenberg, E. (1957), Genetics, 2nd Edn. Holt, Rinehart and Winston, New York. (Indian Edition 1970).

Beadle, G.W (1945), Genetics and metabolism on Neurospora, Physical, Rev.25: 643-663.

Crick, F.H.C. (1966). Codon-anticodon pairing: The wobble hypothesis. J.Mol.Bio.19: 548-555.

Gilham N.W. (1978). Organellar Heredity. Revan Press, New York.

Gowen, J.W. (Ed.) (1952). Heterosis. Lowa State Coll. Press, Ames.

Hodking, J. (1990). Sex determination compared in Drosophila and Coenorhabditis. Nature 344: 721-728.

Shapeio, J.A. (Ed.) (1983). Mobile Genetic Elements, Academic Press, New York.

Yamamoto, T. et.al. (1992). A bipartite DNA binding domain composed of direct repeats in the TATA box binding factor TFID. Proc. Natl. Acad. Sci., USA 89: 2844-2848.