ANIMAL KINGDOM

INTRODUCTION

- Animal kingdom comprises of multicellular eukaryotic animals and is one of the kingdoms amongst five kingdom scheme of classification (by Whittaker).
- Classification of the animal kingdom is based on different important characteristic features like habitat, level of organisation, symmetry etc.

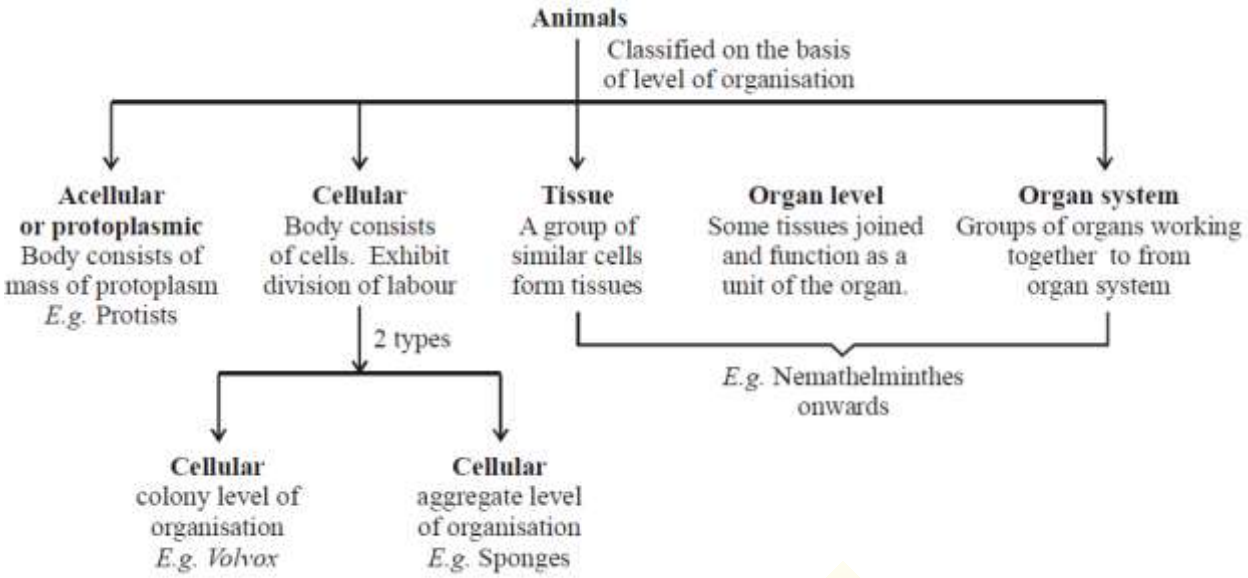
BASIS OF CLASSIFICATION

HABITAT

- Habitat is the place where an organism lives. On the basis of habitat, animals are divided into - aquatic and terrestrial.
- **Aquatic animals** live in water. Types of aquatic animals are **zooplankton**, **nekton** and **benthon**.
- Zooplanktons are passively floating or animals in water. E.g., protozoans, protists etc.
- Nekton are actively swimming aquatic organisms in water, able to move independently of water currents. E.g., Shark, Bony fishes.
- Benthon lives at bottom. It may be sedentary or motile. E.g., starfish, sponges, etc.
- Types of terrestrial animals are–
  - **Cursorial** (Runfast) – E.g., kangaroo, dog
  - **Fossorial** (lives in burrows/underground) – E.g., earthworm, rabbit.
  - **Arboreal** (lives on trees) E.g., bat, monkey
  - **Aerial/flying** (can fly) – E.g., birds, bats winged insects.

LEVEL OF ORGANISATION

- The cells in animal body are of several types and are organised into functional units of progressively increasing complexity.
- It is of five types – acellular, cellular, tissue, organ and organ system.



SYMMETRY

- Symmetry refers to the similarity in the arrangement of parts on opposite sides of the body.
- Three types of symmetry seen in the animals are **spherical symmetry**, **radial symmetry** and **bilateral symmetry**.
- In **spherical symmetry**, the body of the individual can be divided into similar halves by any plane passing through the centre. The animals showing spherical symmetry have spherical shape and the sides of the body are not distinguishable. E.g., Volvox, a colonial green alga.
- In **radial symmetry**, a number of similar parts radiate out from a central axis. The body of the individual can be divided into equal halves by any plane passing through the centre from top to bottom. E.g., sponges (Sycon), coelenterates (e.g., Hydra, jelly fish), echinoderms (e.g., star fish).

When the body can be divided into two similar halves by one or two vertical planes only, the radial symmetry is called **biradial symmetry**. It is present in sea-anemones.
Radial symmetry permits an animal to detect food or danger approaching from any side.

- In **bilateral symmetry**, the body can be divided into two equal halves by a single plane only because the important body organs are paired and occur on the two sides of a central axis.

Bilateral symmetry is found in many invertebrates and all vertebrates. In some higher animals like echinoderms (starfish), the adults are radially symmetrical, but even in them the larvae are bilaterally symmetrical.
Bilateral symmetry constitutes the second major evolutionary advance in the animal body plan.

GERM LAYERS

- Germ layers are ectoderm, mesoderm and endoderm which differentiate at the time of gastrulation in a developing embryo.
- **Diploblastic animals** are with two germ layers (ectoderm and endoderm) E.g., porifera & cnidaria.
- **Triploblastic animals** are with three germ layers (ectoderm, mesoderm and endoderm). E.g., platyhelminthes to chordates.

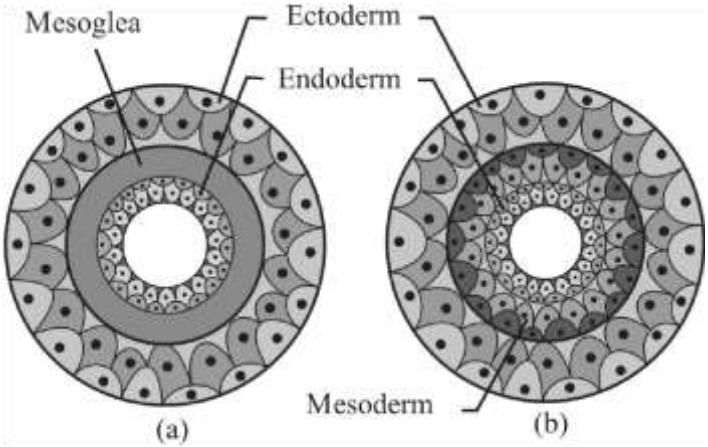


Fig. : Showing germinal layers :
(a) Diploblastic (b) Triploblastic

COELOM

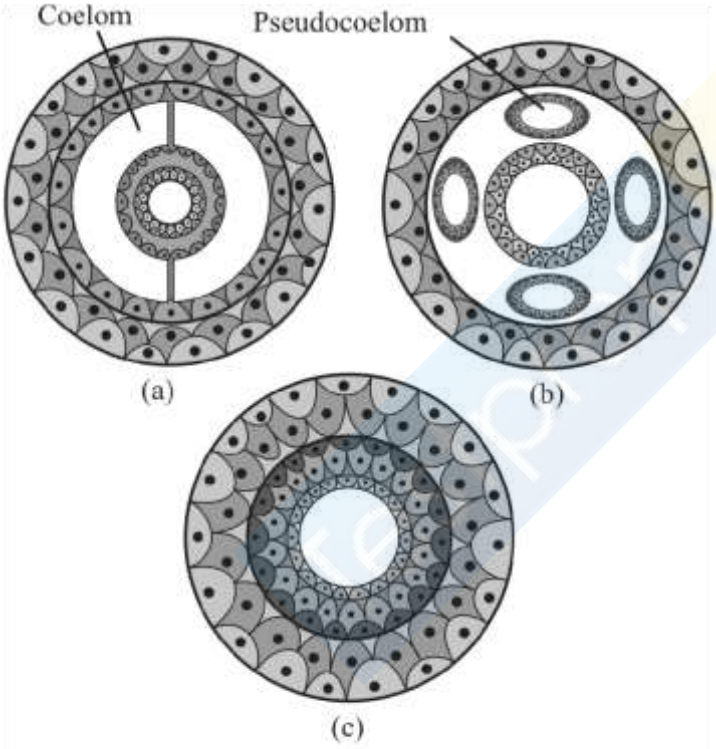


Fig. : Diagrammatic sectional view of :
(a) Coelomate (b) Pseudocoelomate (c) Acoelomate

- **Coelom** is the name given to the internal body cavity that separates the digestive tract from the outer body wall.
- It is filled with a fluid and lined by peritoneum derived from mesoderm.
- **Functions of body cavity** are
  - Cushions the organs thus, preventing injury.
  - Allows internal organs to grow and move independently of the outer body wall.
  - Serves as a hydrostatic skeleton in soft bodied coelomates, such as earthworms.
- Types of coelom are – acoelom, pseudocoelom and eucoelom.

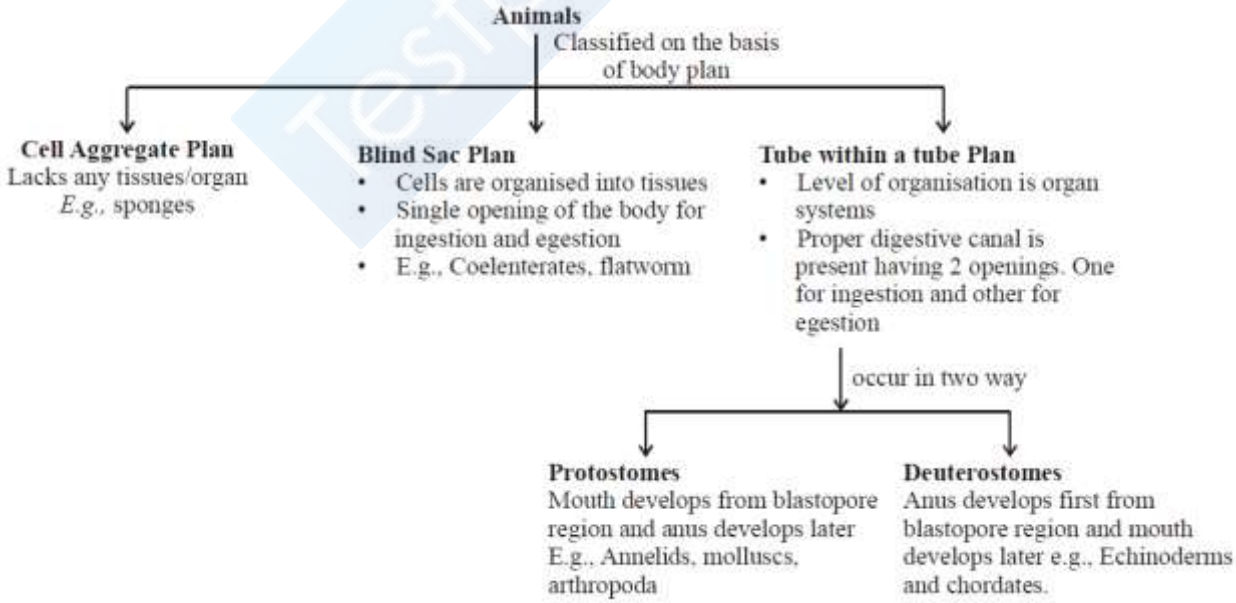
- **Acoelom** means without body cavity which is due to failure of mesoderm to cavitate during embryogeny, so no coelom, no peritoneum. The area between the digestive tract & outer wall is filled with cells, producing a solid body, e.g., porifera, coelenterata, platyhelminthes (flatworms).
- **Pseudocoelom** or false body cavity means presence of coelom (that develops from the blastocoel) but not lined by mesoderm, e.g., roundworms (nematodes), rotifers.
- **Eucoelom** or true coelom i.e., lined by mesoderm, resulting in tube-within-tube design, e.g., higher invertebrates (annelids, arthropods, molluscs echinoderms) and chordate.
- True coelom is of two types :
  - **Schizocoelom** (develop as a split in the mesoderm sheet), e.g., annelida, arthropod & molluscs.
  - **Enterocoelom** (mesoderm arises from the wall of embryonic gut or enteron as hollow outgrowths or enterocoelomic pouches), e.g., echinoderms, chordates.
- In arthropoda and molluscs, the actual or true coelom is reduced but spaces between viscera grow and form a large cavity filled with blood called **haemocoel** (=haemocoelom).

SEGMENTATION

- Metamerism is body structure having repeated segments. It helps develop specialization of organs. E.g., annelids.
- Metamerism results in the separation of mesoderm into segmented blocks of muscles.
- False segmentation or pseudometamerism occur through budding in tapeworm. In these, the body is divided into many segments known as proglottids.
- Arthropods shows only external segmentation.
- In chordates, only internal segmentation is present.

BODY PLAN

Animals have three types of body plans – **cell aggregate plan**, **blind sac plan** & **tube within a tube plan**.



CEPHALIZATION

- Differentiation of a definite head at the anterior end is formed as cephalization.
- It begins in platyhelminthes.

APPENDAGES

Appendages are projecting parts of the body used for specific functions like feeding, locomotion and sensation, etc.

Table : Types of appendages for locomotion, feeding and other purposes.

S. No.	Name of Appendages	Name of animals/ phylum/class
1.	Tentacles	*Hydra*, coelenterates
2.	Parapodia	*Nereis*/Annelids
3.	Foot (mascular)	*Pila*/Molluscs
4.	Antennae and legs	Cockroach/Arthropoda
5.	Tube feet	Starfish/Echinodermata
6.	Fins	Fishes/Pisces
7.	Limbs and wings	Amphibian, reptiles, birds and mammals

SKELETON

- **Skeleton** of animals provide shape, support, protection and help in locomotion.
- **Exoskeleton** is secreted by skin or ectoderm and made of non-living materials, e.g., calcareous shell of molluscs, chitinous cuticle of arthropods, hair, nail, scale, hoofs, horns, feathers.
- **Endoskeleton** is internal skeleton which is produced by mesoderm or occasionally endoderm, e.g., notochord, cranium, skeleton and cartilaginous tissue from most of the vertebrates. Endoskeleton consists of cartilages, bones and connective tissue of various types.

BODY TEMPERATURE

On the basis of body temperature, the animals are categorised into warm blooded and cold blooded animals.

WARM-BLOODED ANIMALS (OR HOMEOTHERMIC ANIMALS)

- Also known as endotherms.
- These have relatively constant body temperature and their body temperature is independent of that of their external environment.
- Body temperature of endotherms is derived from heat produced by their own oxidative metabolism and the presence of insulating hair, features and blubbers prevents this internally generated heat from freely diffusing to the external environment.
- E.g., Mammals and birds.

COLD-BLOODED ANIMALS (OR POIKILOTHERMIC ANIMALS)

- Also known as ectotherms.
- Their body temperature varies. These do not keep their body temperature constant so when their body temperature is high (on a hot summer day), these can be very active and when it is low (on a cold winter's night) and can produce energy only slowly.
- E.g., invertebrates, fish, amphibians and reptiles. These defend in two ways- hibernation and aestivation.

DEVELOPMENT

- Development is of two types- direct and indirect.

- In direct development, without any intermediate stage, the young ones resemble the adult in all respects. E.g., silverfish (Lepisma).
- In indirect development, young ones do not resemble the adults. The young ones pass through many intermediate stages before obtaining the shape of the adults. The phenomenon of passing through different juvenile stages during transition from larval to adult stage is called **metamorphosis**. Metamorphosis is found in many invertebrates, protochordates, some fishes & amphibians.

NOTOCHORD

- On the basis of notochord, animals are divided into non-chordates and chordates.
- Non-chordates does not possess notochord and chordate possess notochord atleast in some stage of their life.

CLASSIFICATION OF ANIMALS

- Animal kingdom is divided into two subkingdoms – protozoa and metazoa.
- **Protozoa** are the most abundant animals in the world (in number).
- **Metazoa** are multicellular eukaryotes which is divided into 3 branches - mesozoa, parazoa & eumetazoa.

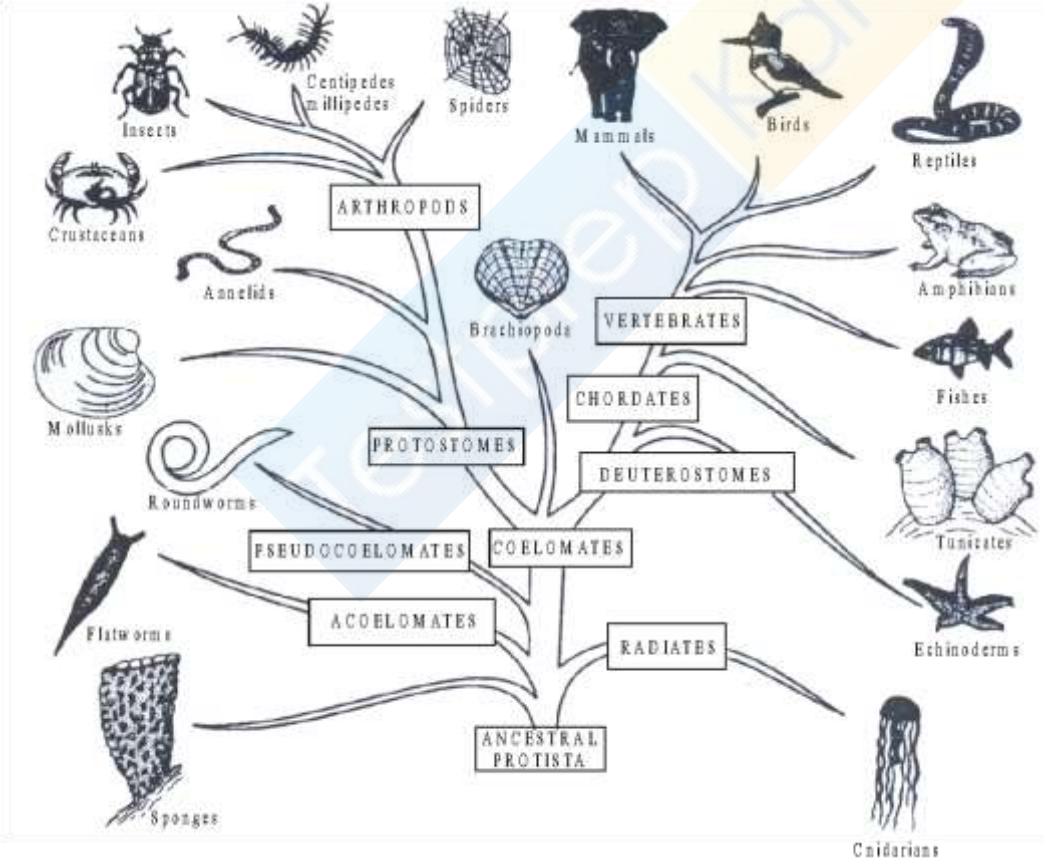
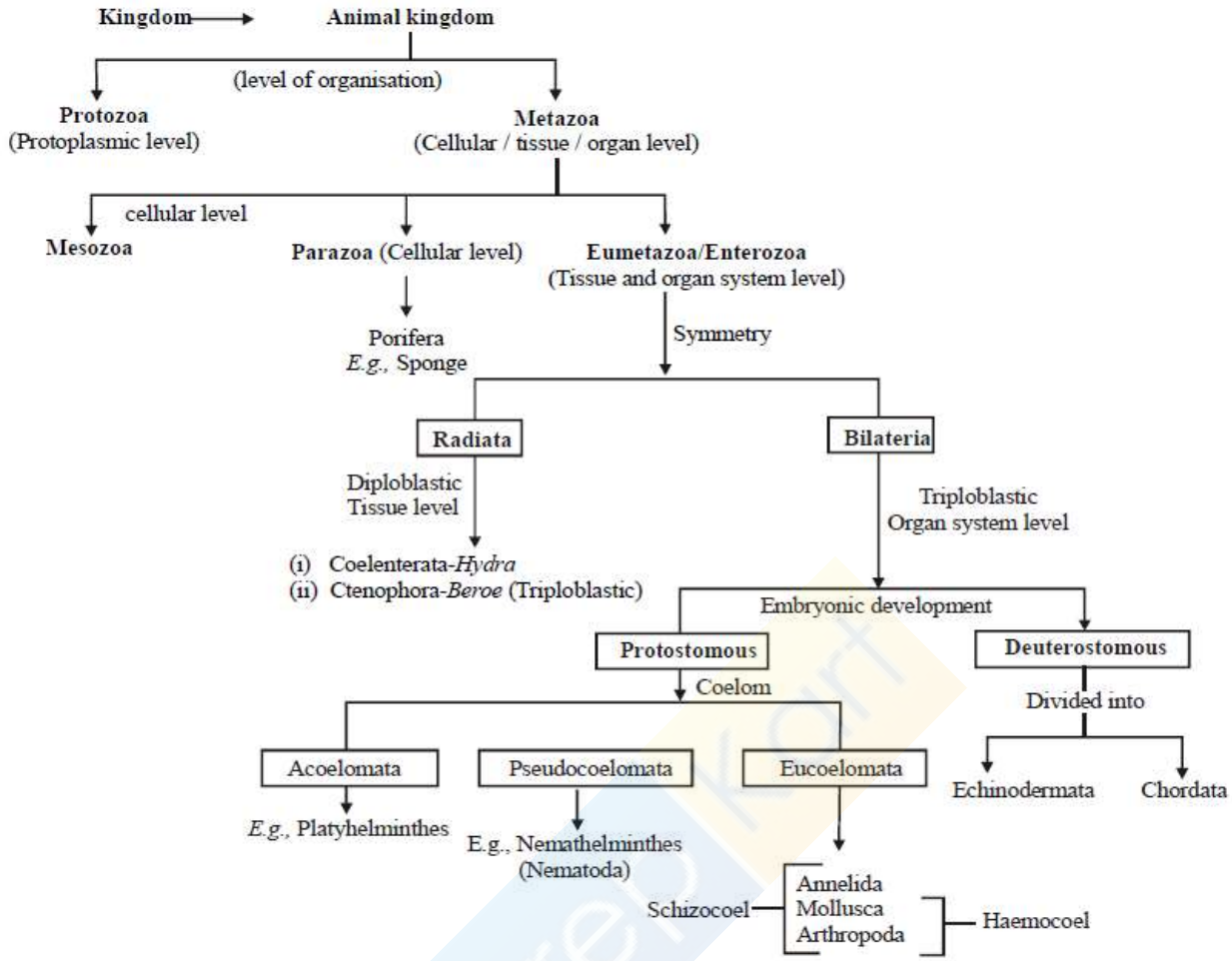


Fig. : The Phylogeny of the major groups of animals

- Outline classification of Animal Kingdom



PHYLUM - PORIFERA (COMMON NAME SPONGE)

- All are aquatic, mostly marine but few are found in fresh water also.

These are sessile, solitary or colonial. Entire body with pores i.e. numerous mouthlets (Ostia) and one opening for exit (Osculum).

- Sponges have various body form and shapes i.e. vase shape, cylindrical with radial symmetry (Leucosolenia), irregular shape (asymmetrical).
- Sponges have cellular level of organisation with two germ layer i.e. diploblastic and do not possess head and appendages.
- Body wall consists of two layers–outer epidermis/**pinacoderm** and inner **choanoderm**.
- Between pinacoderm and choanoderm lies the interconnecting gelatinous matrix, the **mesenchyme** or **mesohyl**.
- Mesenchyme consists of skeletal elements and free amoeboid cells.
- Sponges have several cell types–

○ **Choanocytes** (also known as "collar cells"): Flagellated cells which function as the sponge's digestive system are remarkably similar to the protistan choanoflagellates. The collars are composed of microvilli and are used to filter particles out of the water.

○ **Porocytes** : Tubular cells that make up the pores into the sponge body through the mesohyl. Special cells for passage of water.

○ **Pinacocytes** : Form the pinacoderm, the outer epidermal layer of cells.

○ **Myocytes** : Modified pinacocytes which control the size of the osculum and pore openings and thus, the water flow.

- **Archaeocytes (or amoebocytes)** : These are totipotent cells which can transform into sclerocytes, spongocytes or collencytes. They also have a role in nutrient transport and sexual reproduction.
- **Sclerocytes** : Secrete calcareous or siliceous spicules which reside in the mesohyl.
- **Spongocytes** : Secrete spongin, collagen-like fibres which make up the mesohyl.
- **Collencytes** : Secrete collagen.
- **Spicules** : Stiffened rods or spikes made of calcium carbonate or silica which are used for structure and defence.

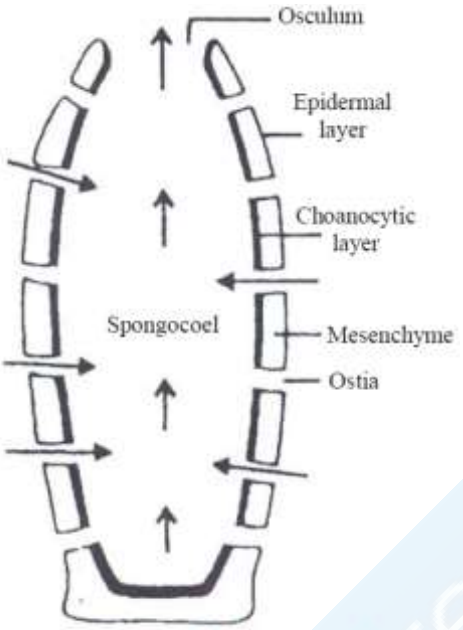


Fig. : Diagramatic presentation of body structure of sponges

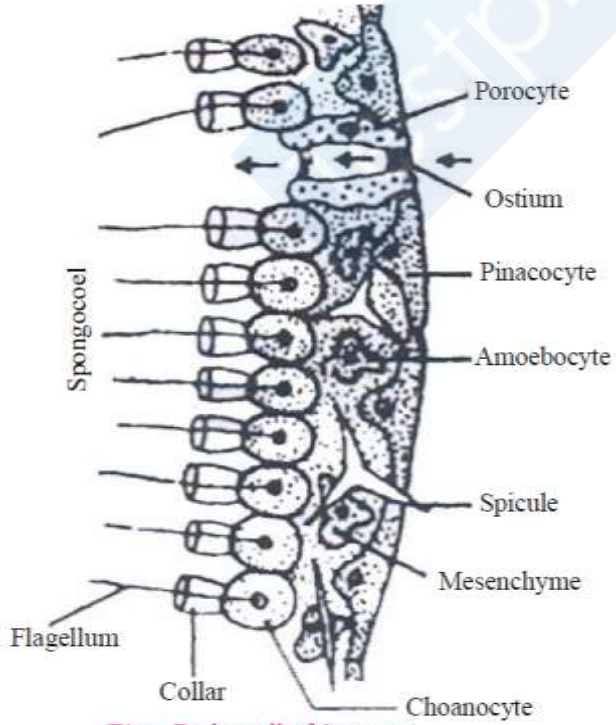


Fig. : Body wall of Sponges

- Body wall encloses a large cavity, the **spongocoel** or **paragastric cavity**. Choanocytes with flagella is lined in spongocoel and radial canal.

- **Canal system**: Canal system of porifera helps in nutrition, respiration & excretion. Canals are developed due to folding of inner wall. There are four types of canal systems:
  - *Asconoid* (Simplest canal), e.g., Leucosolenia, Olynthus
  - *Syconoid*, e.g., Scypha
  - *Leuconoid* (complex and most efficient canal system), e.g., Euspongia and Spongilla
  - *Rhagon*, e.g., Larva of Demospongia

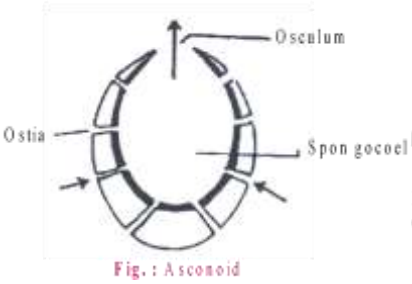


Fig. : Asconoid

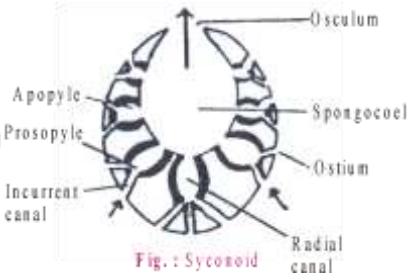


Fig. : Syconoid

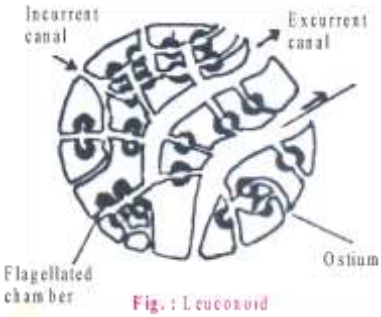
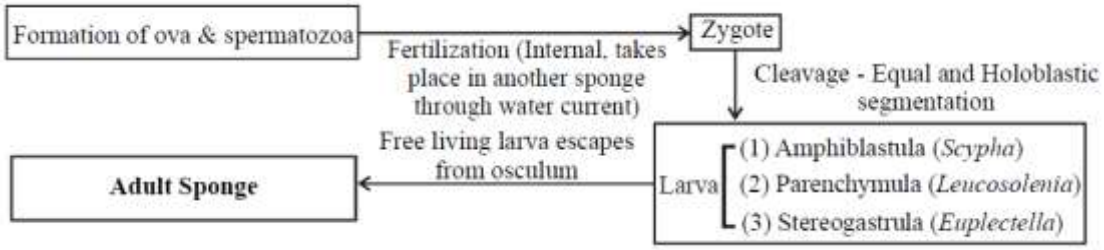


Fig. : Leuconoid

- **Skeleton** is internal, consisting of tiny calcareous calcoblast or siliceous spicules.
- **Scleroblast** secretes spicules and spongioblast secretes spongin fibre.
- Digestive cavity and mouth is absent. Nutrition is holozoic. Digestion is intracellular and occurs in food vacuoles of choanocytes. Food particles strained out by collar cell and pass them to amoebocytes.
- Food is stored in thesocytes.
- Distribution of food from ingestive cell to other is brought by the movable amoeboid cell.
- Respiration and excretion takes place by diffusion of gases through body surface. Excretory matter is ammonia.
- Sponges do not have nervous system.
- Sponges have great regenerating power due to archaeocytes which are totipotent cells.
- All sponges are hermaphrodites. Most sponges are monoecious i.e. male and female reproductive cells or gametes are formed in the same individual.
- Sponges are able to reproduce sexually (involving gamete formation and their fusion) or asexually (involving fragmentation, reduction bodies, external budding and gemmules).
- **Gemmules** (mostly found in freshwater sponge) are made up of amoebocytes surrounded by a layer of spicules and can survive conditions that would kill adult sponges. When the environment becomes less hostile, the gemmule resumes growing.
- Sex cells (sperm and ova) arise from undifferentiated archaeocytes.
- Sperm are formed from choanocytes; and oocytes derived from choanocytes in some sponges, and archaeocytes in others.
- Sperm are released into open water.
- Some sponges have **oviparous fertilization** where sperm and eggs meet in open water. In other species, sperm are taken into the bodies of other sponges and fertilized inside; this is known as **viviparous fertilization**.



- Largest sponge is Spheciospongia.

- Shrimps (Spongicola fish) is a crustacean, shows commensalism with Euplectella.

UNIQUE FEATURES

- Pores all over the body.
- Cellular level of body organisation.
- A canal system of intercommunicating cavities for the passage of a water current.
- Lack of mouth and digestive cavity.
- Choanocytes lining the main cavity (spongocoel) or certain canals (radial canals).
- Presence of spongin fibres.

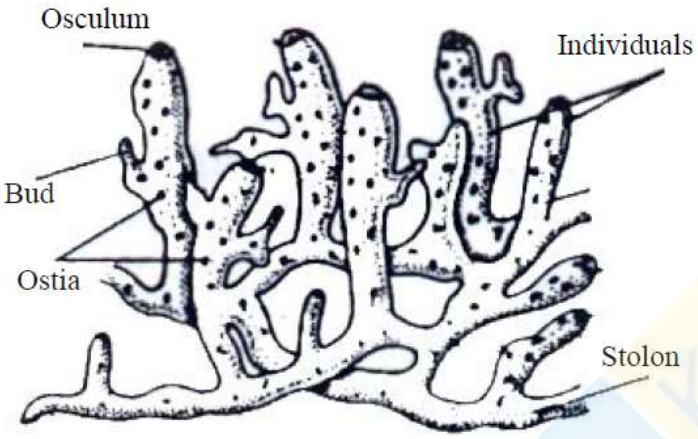


Fig. : A colony of *Leucosolenia*

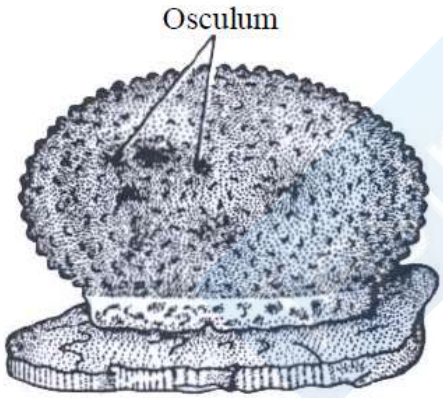
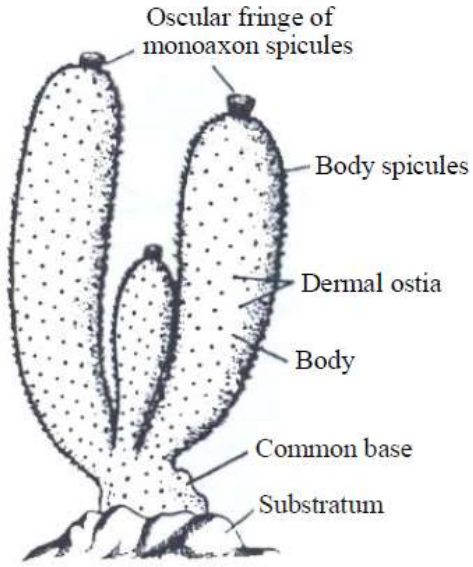


Fig. : *Euspongia*



Sycon (= Scypha)

Fig. : Common Sponges

PHYLUM - COELENTERATA

- These are mostly marine, few fresh-water (Hydra) carnivorous and some are fixed or free floating.
- Cnidarians get their name from cnidocytes, which are specialized cells that carry stinging organelles (nematocysts).
- Cnidoblasts or nematocysts are mainly present on tentacles. Nematocyst is the characteristic feature of coelenterates. It contains a poisonous substance called hypnotoxin.
- Sensory structure of cnidoblast is cnidocil.
- Coelenterates have two types of zooids (individual) – polyps and medusae.
- **Polyp**
  - Cylindrical in shape.
  - Mostly sessile, but sometimes motile.
  - May be solitary or often lives in large colonies.
- **Medusa**
  - Umbrella like
  - Free swimming
  - Always solitary
- If both are found in a species, two forms alternate in life cycle. (Alternation of generation or Metagenesis).
- Group of different types of zooids in polyp or medusa show polymorphism.
- Coelenterates are usually having radial symmetry, anthozoans have biradial symmetry.
- Coelenterates have tissue level of organisation.
- No head and appendages. The oral end (mouth) often bears slender, flexible hollow tentacles.
- **Body wall** is two layered i.e. outer epidermis & inner gastrodermis.
  - **Epidermis** consists of epitheliomuscular cells, cnidoblasts, interstitial cells, nerve cells, sensory cells.
  - **Gastrodermis** comprises of epitheliomuscular nutritive cells, gland cells, interstitial cells, nerve cells and sensory cells.

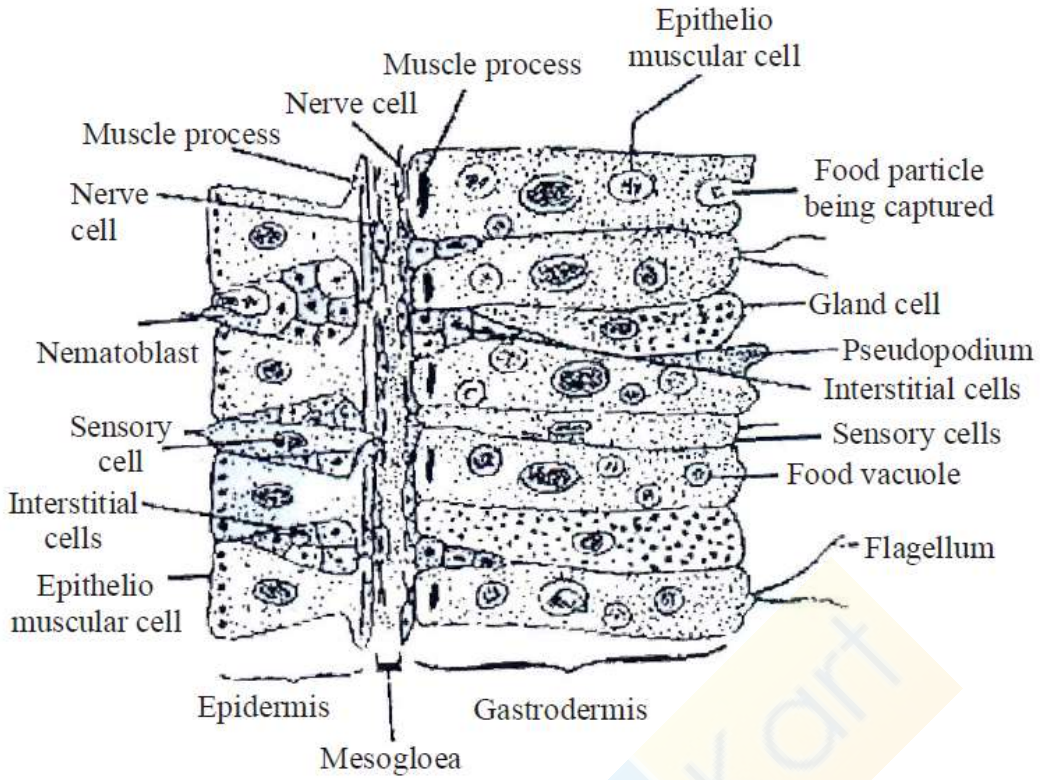


Fig. : Body wall of Coelenterate

- Body of coelenterates may be supported by horny or calcareous exoskeleton.
- Cavity of the coelenteron is having single aperture. Mouth serves both purpose i.e., has incomplete digestion tract (blind sac).
- **Digestion** is intercellular as well as intracellular i.e. takes place in coelenteron as well as in food vacuole.

Coelenteron is also responsible for distribution of food besides partly digesting it. This dual role named coelenteron as gastrovascular cavity.

- **Respiration and excretion** takes place by diffusion of gases through body surface.
- Excretory matter is ammonia.
- Nervous system is of diffused type. It is found in both polyp & medusa form. It is a loose network of nerve fibres from nerve cell on either side of mesogloea. Neurons are non-polar. Sensory cells are also present.
- Sexes may be separate or united. Coelenterates can reproduce asexually by budding (polyp) and by sexually (medusa).

Gonads have no duct. Fertilization may be external or internal, Cleavage is holoblastic. Development includes larva.

UNIQUE FEATURES

• Tissue level of organization of the body.
• Special stinging cells, the **cnidoblasts**, for defence and offence.
• Epitheliomuscular cells with a dual role of epithelium and musculature.
• Incomplete digestive tract bounded by body wall.
• A simple nervous system in the form of a network of nerve cells and fibres.
• Simple gonads without ducts.

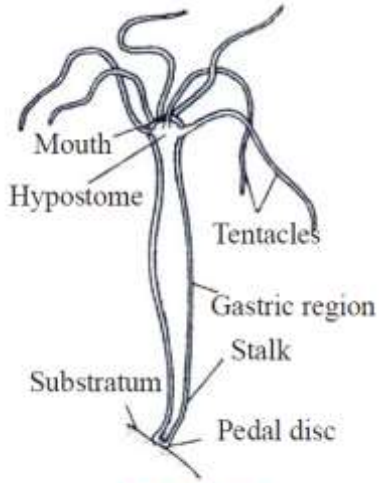


Fig. : *Hydra*

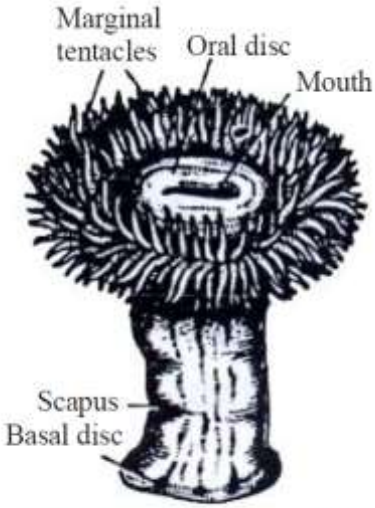


Fig. : Anthozoa (*Metridium*)

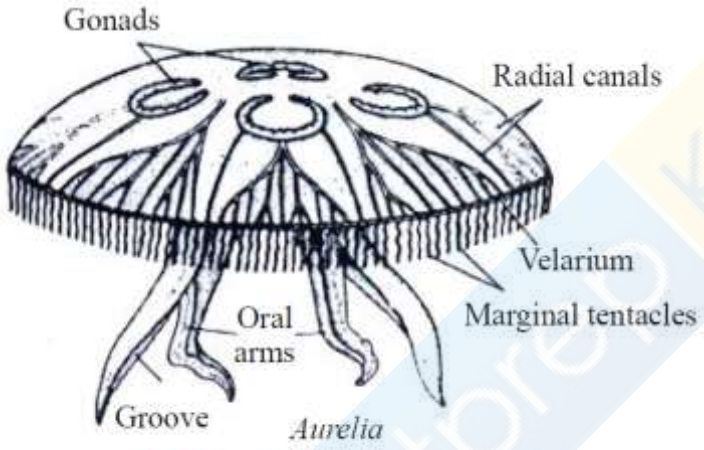


Fig. : Examples of Coelanterates

PHYLUM - CTENOPHORA

- Ctenophora name was given by Eschescholtz.
- These animals are known for their beauty and delicate nature. In sunlight, their comb-plate gives the effect of a rainbow.
- The animals of this phylum are known as, "**Sea-gooseberries**" or "**Comb-Jellies**" or "**Sea-walnuts**".
- Nematoblasts are absent, so they are also called "acnidaria".
- All animals are marine and pelagic (float on sea surface) and show bioluminescence.
- Body form may be spherical, cylindrical or pear-shaped. Body is soft, transparent, jelly like having biradial symmetry with tissue grade body organisation.
- Animals are triploblastic. Mesoglea contains amoeboid mesodermal cells called colloblast.
- Locomotion takes place by the presence of 8 ciliary comb plates on the body surface.
- Skeletal, excretory and respiratory systems are absent.
- Animals are carnivorous. These feed on the eggs and larvae of molluscs, fishes and crustaceans. A pair of long solid tentacles are present. In place of nematoblasts on the tentacles, a special type of cells are present (called lasso-cells) which help in catching the prey. Anus is absent.

- All animals are bisexual. Complex type of sexual reproduction is found. Metagenesis is absent. Regeneration is normally found.
- Development is of indirect type.
- Life cycle involves a free living Cydippid larval stage.
- Cleavage is holoblastic, determinate and unequal.
- Asexual reproduction is absent.
- Regeneration & paedogenesis is normally found.
- Ctenophora is divided into two classes on the basis of tentacles – tentaculata (with tentacles, e.g., Hormiphora) and nuda (without tentacles, e.g., Beroe).

PHYLUM - PLATYHELMINTHES

- Gegenbour suggested the name Platyhelminthes includes flatworms. It is the most primitive bilateral animals. These are free living, terrestrial, fresh water, marine or parasitic.
- Study of worms causing parasitic infestation in humans is helminthology. Most members of this phylum are the parasites of vertebrates. Some are found in aquatic habitats.
- Body organisation is of organ grade.
- Flatworms are triploblastic i.e. body is formed from three germinal layers (ectoderm, endoderm and mesoderm).
- Body is bilaterally symmetrical.
- Anterior and posterior parts are clear. Distinct head begins from this phylum (cephalization).
- Locomotory organs are absent in these animals but adhesive organs are present like suckers, hooks etc.
- Epidermis is syncytial and some times ciliated. On the body wall of parasitic animals, a thick cuticle is present i.e., tegument. Thick cuticle protects the parasite from the digestive-enzymes of the host. It is secreted by the epidermis.
- Muscles in the body wall are mesodermal. Below the epidermis, longitudinal, circular and oblique muscles are present.
- They are the largest phylum of **acoelomate**. In between various organs, a solid, loose mesodermal tissue called mesenchyma or parenchyma is present.
- Skeleton and circulatory systems are absent. Turgidity of the fluid in the parenchymal meshes maintains the form of the body (hydroskeleton)
- Animal respire through body surface. Anaerobic respiration is present in internal parasites like Taenia.
- Digestive system is incomplete due to the presence of only one opening. Reduced or absent in parasitic form (e.g., Taenia)
- Excretory organs are protonephridia or flame-cells. Flame-cells are also termed as the solenocytes. These also help in osmoregulation.
- Nervous system is ladder like having brain ring and two main longitudinal nerves connected at intervals by transverse commissures. Sense organs occur in free living form (e.g., Planaria) .
- All animals of this phylum are bisexual. Reproductive system is complex and well-developed.
- Fertilization may be self or cross and internal. Cleavage is spiral & determinate. Development may be direct or indirect. In indirect development, larva may be one or more types. In these animals, yolk/vitelline glands are present which provide nutrition to the eggs.

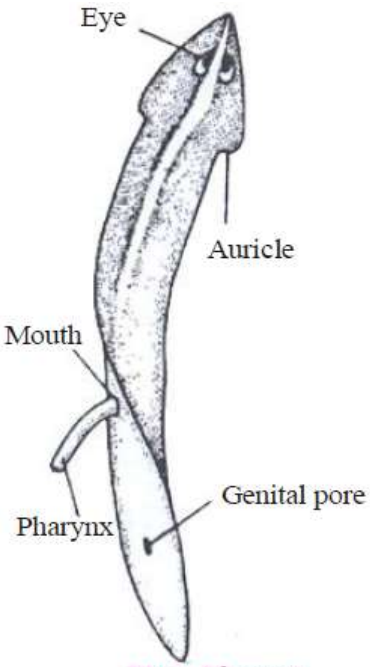


Fig. : *Planaria*

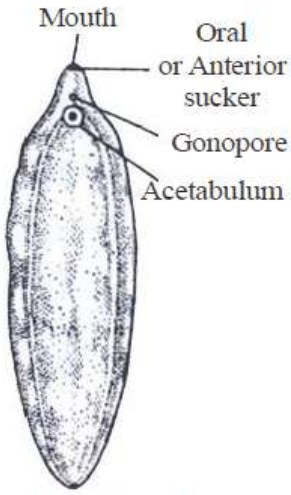


Fig. : *Fasciola*

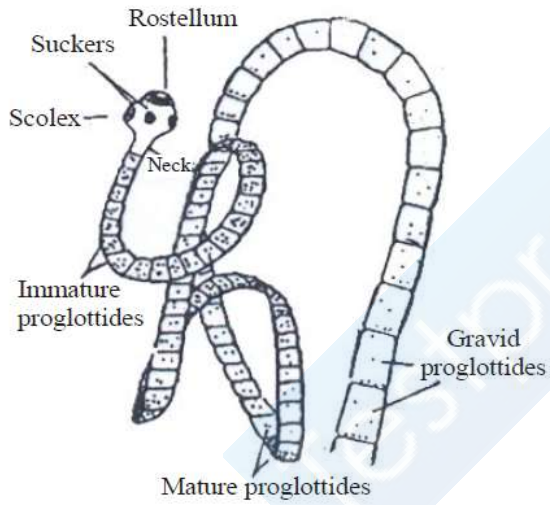


Fig. : *Taenia solium*

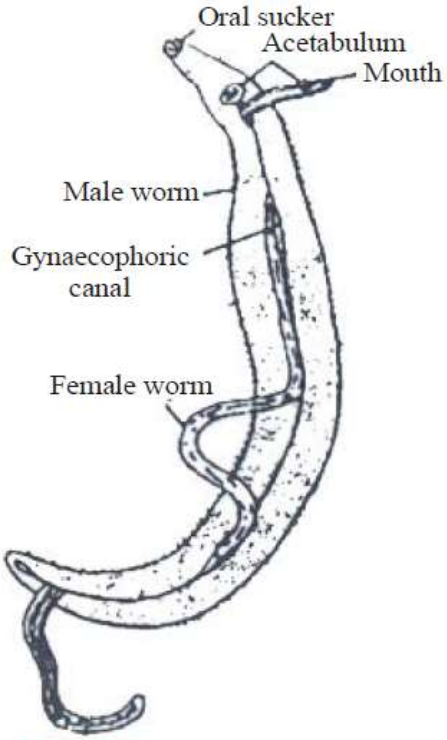


Fig. : *Schistosoma*

UNIQUE FEATURES

- Bilateral symmetry
- Organ-system level of organization
- Head with sense organs at the front end
- Three germ layers
- Brain ring and nerve cords
- Organised excretory system
- Ducts and copulatory organs are present

PHYLUM - ASCHELMINTHES (NEMATHELMINTHES OR NEMATODA)

- Also known as roundworms.
- Nematodes are found everywhere in freshwater, sea water, humus-rich soil. Many act as parasites and cause health problems.
- Animal of this phylum are cylindrical, tapering at both ends without segmentation.
- These are bilaterally symmetrical, triploblastic, having organ-system level and having tube within tube plan.
- Anterior end does not show distinct head.
- No appendage.
- Body wall consists of–
  - **Cuticle** - Firm, non living, resistant to digestive enzymes of host.
  - **Epidermis** - Without cilia. Syncytial i.e., a continuous layer of cytoplasm having scattered nuclei.
  - **Muscle layer** - Longitudinal fibre divided into four quadrants.

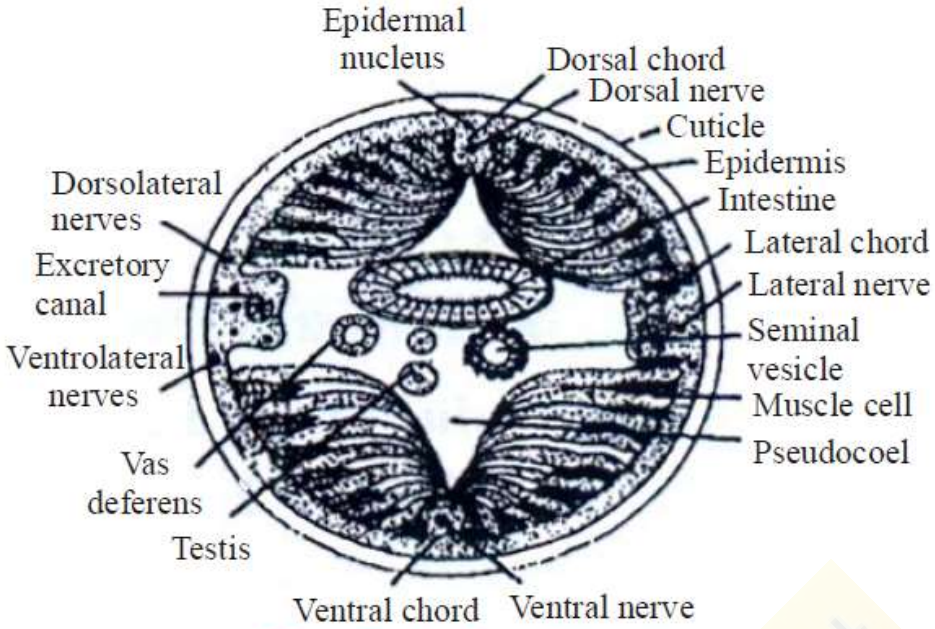


Fig. : Body plan of *Ascaris*

- Body cavity is present between body wall and digestive tract which is not lined by mesothelium i.e., pseudocoel (developed from blastocoel) and contains pseudocoelomic fluid.
- Skeleton is not mineralized. High fluid pressure in the pseudocoelom maintains the body shape. It is called hydroskeleton.
- Digestive tract is complete and differentiated into the mouth, pharynx, intestine & anus.
- Mouth is surrounded by 3 lips having sensory papillae and amphids.
- Pharynx is muscular. It is used to suck food. Intestine is non muscular.
- Respiration is through body surface by diffusion.
- Circulatory system is not developed
- Nervous system comprises of circumpharyngeal ring (brain), sense organs like papillae (tangoreceptors), amphids (chemoreceptor) are present on lip.

Paired unicellular phasmids (chemoreceptor) are found near hind end of body.

- Excretory system is H-shaped and consists of gland cells or intracellular canal or protonephridia - (renette cell). Excretory matter is ammonia.
- Reproduction system is developed and sexes are generally separate. Sexual dimorphism is present. Male is smaller than female and curved from its caudal end. Male has penial spicules for copulation. Genital tract joins digestive track to form cloaca. Female is larger than male and straight.
- Genital tract open independently. Female lays numerous eggs with chitinous shell.
- Fertilization is internal and development is mostly direct.
- Cleavage is holoblastic, spiral and determinate type.
- Number of cells are fixed from larva to adult development known as **Eutely.**

EXAMPLES

- ***Ascaris*** - Intestinal roundworm (in small intestine). Common in children. Embryonic development takes place in soil. Second stage larva (rhabditiform) is infective. Transmission of infective stage is through embryonated egg takes place by contaminated food and water. Most pathogenic larva is the fourth stage inhabited in human lungs.
- ***Enterobius*** - Pinworm or seat worm (in large intestine). No intermediate host causes enterobiasis.

- ***Ancylostoma*** - Hookworm (in small intestine) monogenetic. Infective juvenile stage is filariform larva (non feeding).
- ***Wuchereria*** - Filarial worm (in lymph vessels/gland) by female culex mosquito. Viviparous (Digenetic). Causes elephantiasis.
- ***Loa-loa*** - Eye worm. (African eye worm). Its intermediate host is Chrysops. Causes lymphatic conjunctivitis.
- ***Trichuris*** - Whipworm (in intestine)
- ***Rhabditis*** - Free living
- ***Trichinella*** - Present first in intestine then in striped muscle)
- ***Dracunculus*** - Guinea worm (madina worm) or fiery serpent (Digenetic - Cyclops as intermediate) (Oldest discovered Nematode)

UNIQUE FEATURES

- Syncytial epidermis
- Body wall musculature of longitudinal fibres only
- Pseudocoel, a body cavity without a lining of mesodermal coelomic epithelium
- Complete digestive tract
- Fluid-filled body cavity
- Separate sexes

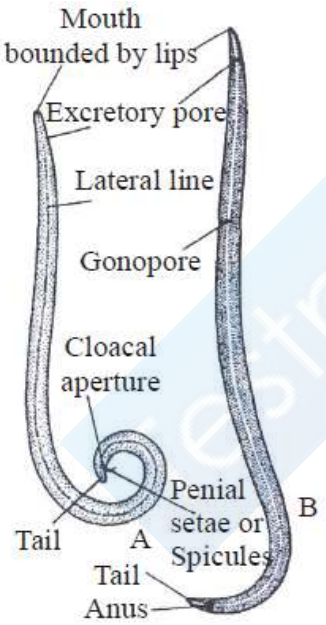


Fig. : Morphlogy of *Ascaris* : (A) Male, (B) Female

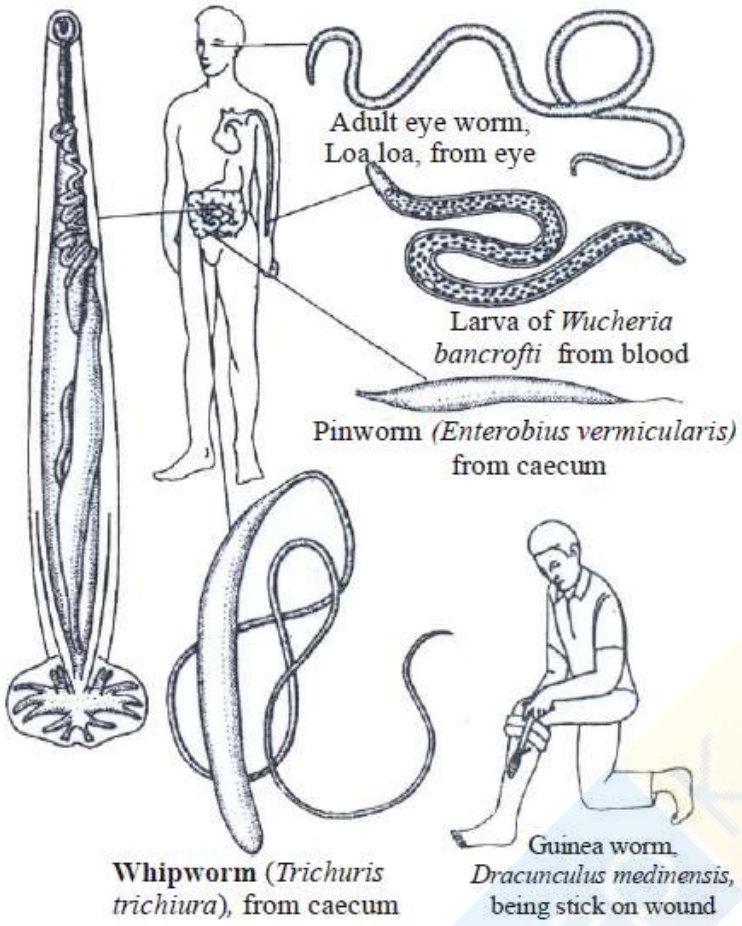


Fig. : Some roundworms that parasitize man

PHYLUM - ANNELIDA

- These are free living found in moist soil, fresh water, sea or few exist as parasites.
- Body is soft, elongated, cylindrical or flattened divided into segments or metameres by ring like, groves called annuli.
- Symmetry - Bilateral, Germ layer - Triploblastic, Level of organisation - Organ-system level having tube within tube plan.
- Anterior end forms a distinct head with sense organ in few annelids.
- Appendages are simple, unjointed, and locomotory having chitinous setae and parapodia.
- Body wall consists of
  - **Cuticle** - Thin moist albuminoid cuticle allowing free exchange of gas.
  - **Epidermis** - Single layered epidermis made up of supporting, sensory and glandular cell.
  - **Muscle layer** - (a) Circular layer, (b) Longitudinal layer.

Muscles are smooth/non striated.

- Body wall may have minute chitinous setae.
- Annelids are the first protostomi eucoelomate animals.
- Body cavity is true coelom lined by mesodermal coelomic epithelium (Schizocoel).
- It is divided by transverse septa into compartment. It is filled with coelomic fluid that contains cells.
- As such there is no skeleton, fluid filled coelom serves as a hydrostatic skeleton.

- Digestive tract is complete, straight and extends through the entire body. The gut has both circular and longitudinal muscles. Few annelids are sanguivorous. Digestive gland are developed for the first time in annelida.
- Respiration is through skin i.e. cutaneous respiration. Some have gills (bronchial respiration) also.
- Circulatory system is closed. Some blood vessels enlarge to act as pumping heart. (Heart appeared first time in annelids).

The blood is red with haemoglobin dissolved in plasma. It has amoeboid corpuscles only. Few annelids have chlorocruorin as a respiratory pigment also. Hirudinaria has circulatory system with haemocoelic system.

- Excretory organ is nephridia. Coiled tubules also helps in osmoregulation. Excretory matter is ammonia in aquatic form and urea in land form.
- Nervous system consists of – a circumenteric nerve ring , double, midventral , nerve cord with ganglia. Sense organs like chemoreceptor, photoreceptor & tentacle, palp, eyes may be present.
- Sexes may be separate or united. Asexual reproduction by budding or fission in some cases also.
- Cleavage is spiral and determinate, unequal and holoblastic.
- Regeneration is usually found. Life history includes a trochophore larva in few annelids.

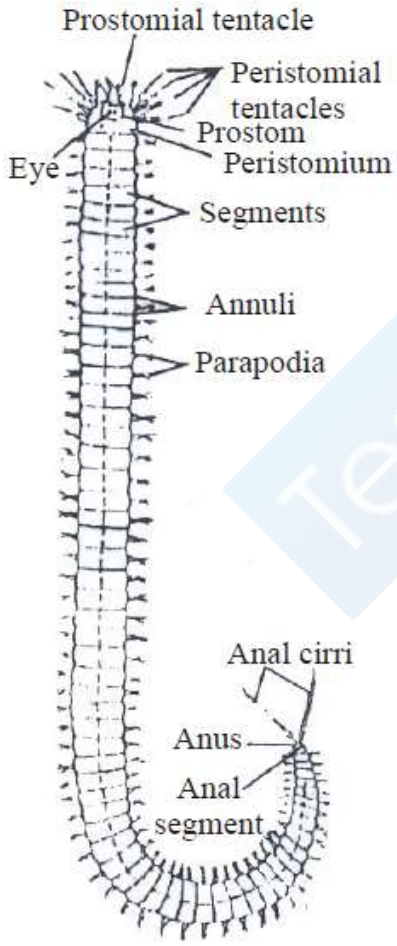


Fig. : *Nereis*

Fig. : *Heteronereis*

UNIQUE FEATURES

- Metameric segmentation.
- Nephridia for excretion and osmoregulation.
- Closed circulatory system with respiratory pigment dissolved in the plasma.

- Setae in the body wall in most forms.
- Head, appendages and respiratory organs in some cases.
- Circular and longitudinal muscles in both body wall and gut wall.

EXAMPLES

- ***Aphrodite* (Sea mouse)** : During movement, body colour changes from gold to peacock blue.
- ***Polynoe* (Scaleworm)** : Several species are bioluminescent. Luminescent material is secreted by the gland cells.
- ***Chaetopterus* (Paddle worm)** : Smallest oligochaetes lives in U-shaped parchment tubes. Strongly luminescent. Possess extraordinary power of regeneration.
- ***Arenicola* (Lugworm/lobe worm)** : Used as fish bait.
- ***Nereis*** : Inhabits in sea- shore between tide mark, burrows, nocturnal, carnivorous, gregarious, fertilization in sea.

Parapodia in each segment except first & last.
During breeding, body divides in two parts: anterior asexual part - atoke and posterior sexual portion epitoke. This change is known as epitoky.
Sexual stage is called heteronereis.

- ***Pheretima posthuma* (Earthworm)** : Ureotelic under normal soil condition and ammonotelic in water saturated soil called Natures' of plough man. Cutaneous respiration.
- ***Tubifex* (Blood worm)** : Fresh water, indicator of organic loading. Reproduces only sexually.
- ***Hirudinaria granulosa* (cattle leech)** : Feeds on blood, ectoparasite on cattle. Hermaphrodite. Possesses an anticoagulant hirudin.

Saw like chitinous teeth in buccal cavity. Circulation with haemocoelomic system.
Coelom is divided in tubes having coelomic fluid and haemoglobin. A special mesodermal tissue-botryoidal tissue made up of adipose tissue for fat storage is present.

PHYLUM - ARTHROPODA

- Arthropoda is the **biggest phylum**. About 9,00,000 species are there.
- Arthropods are found in water, land, sea, in plant and animal. These are colonial, gregarious, show parental care.
- Sometimes parthenogenesis phenomenon is also found i.e., development of an unfertilized egg into an offspring.
- Phylum includes crabs, prawns, insects, spiders, scorpions, ticks, mites, centipedes, millipedes.
- Fossil arthropods are called trilobites.
- Body is bilateral triploblastic with organ system level of organisation.
- Head is distinct (high degree of cephalization). It consists of many fused segments that bears well developed sense organs such as eyes, compound eyes, antennae.

Compound eye consists of many similar units, ommatidia each having lens and capable of forming image.

- Arthropoda have various shapes with externally segmented body. Segmentation is either
  - Two region with head, trunk or cephalothorax and abdomen.
  - Three region with head, thorax & abdomen.
- Some or all segments bear jointed appendages. Hence, name arthro - joints, poda - foot.
- No internal segmentation are present like annelida.
- Body wall consists of thick chitinous cuticle.

- Cuticle composed of protein & polysaccharide chitin which is further strengthened by deposition of mineral (calcium phosphate & carbonate).
- Cuticle restricts growth and periodically changes during growth known as moulting or ecdysis.
- Flexible part of cuticle is called suture.
- Wings of insects - chitinous.
- Chitinous plates which form exoskeletons are known as sclerites.
- Epidermis is single layered without cilia & flagella.
- Muscles are arranged in bundles.
- Muscles are striped/striated - Voluntary (first time developed in arthropods).
- Body cavity around viscera contains blood and is called the haemocoel. True coelom is reduced to cavities in reproductive organs (gonads) & excretory organs. Coelom of gonads is called gonocoel and of nephrons is called nephrocele.
- Digestive tract is complete. It is divided into three parts :
  - Stomodaeum (Anterior)
  - Mesenteron (Middle)
  - Proctodaeum (Posterior)

Striated muscles are found in the digestive tract.

- Mouthparts adapted for –
  - Biting and chewing type : Grasshopper, Cockroach, Termites, Caterpillars.
  - Piercing- Sucking type - Mosquitoes, Bugs, Fleas.
  - Chewing- lapping type - Bee
  - Sponging type - Housefly, fruit fly.
  - Siphoning type - Butterflies, moths
- Respiration is through body surface or special structures such as gills (e.g., Prawn), trachea (e.g., Insects), Book-lungs (e.g., Scorpion), Book-gills (e.g., King crabs) . Trachea carry oxygen directly to the cells.
- Circulatory system is open i.e., blood flows in haemocoel instead of blood vessels.
- Blood is called hemolymph. It is colourless and contain white corpuscles (e.g., Insect) and copper containing pigment haemocyanin (e.g., Prawn).
- Heart is a dorsal, tubular pulsating, one to many chambered tubular structure.
- Excretory organs are -
  - Antennary or green glands or maxillary gland (e.g. Crustaceans) opening directly to the exterior.
  - Coxal gland (e.g., Arachnids)
  - Malpighian tubules (e.g., Insects) opening into the gut.
- Excretory matter is ammonia in aquatic animal and uric acid in land animal.
- Nervous system comprises of a circumenteric ring and a double, solid mid ventral nerve cord bearing a pair of ganglia per segment or less due to fusion of adjacent ganglia.
- Insects communicate by releasing pheromones into the environment. Pheromones also acts on a sex attraction.

Sexes are separate. Fertilization internal but few aquatic forms have external fertilization. Gonads have ducts. Larva stage undergoes some degree of metamorphosis. Sexual dimorphism may be present. Mostly oviparous. Few viviparous.

- Animals of arthropoda are most successful invaders of terrestrial environment in invertebrates due to presence of cuticle, appendages are wings.

UNIQUE FEATURES

- Jointed appendages, modified for a variety of functions.

- Tough, jointed exoskeleton of chitinous plates.
- Tracheae for respiration in majority of cases.
- Compound eyes present.
- Malpighian tubules for excretion.
- Power of flight in most insects.
- Striped muscles arranged in bundles for moving particular parts

FEW ARTHROPODS

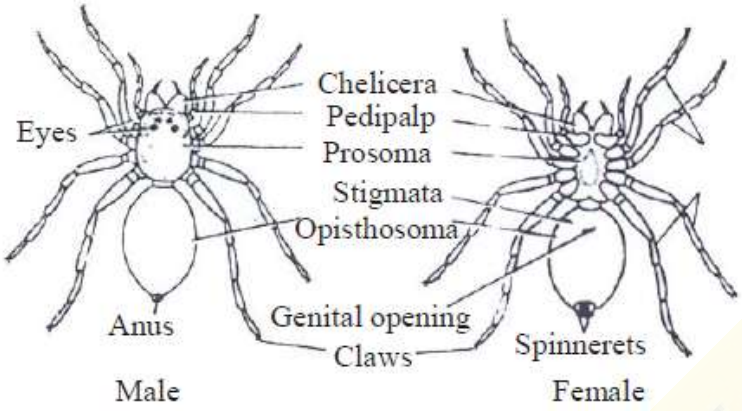


Fig. : Spider

Fig. : Testse fly (Diptera) vector of African sleeping sickness

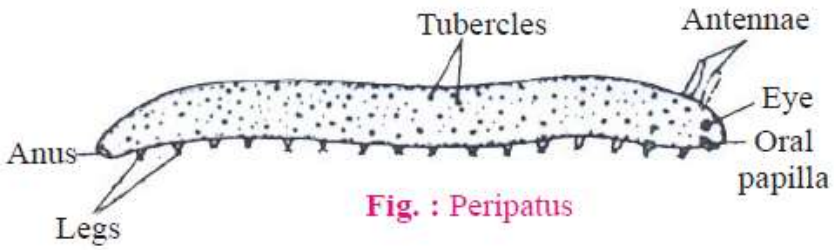


Fig. : Peripatus

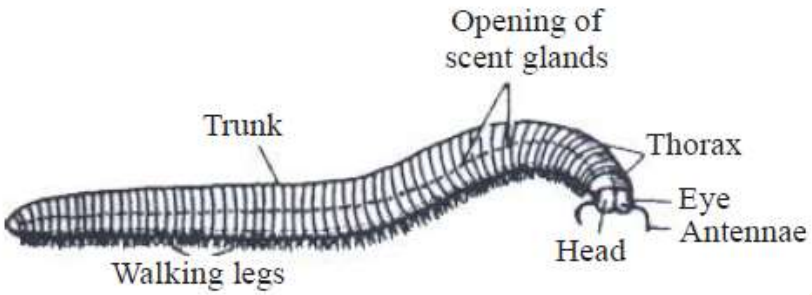


Fig. : Millipede

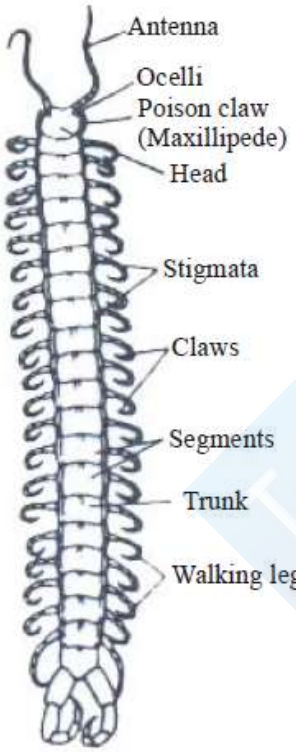


Fig. : A centipede

PHYLUM - MOLLUSCA

- It is the second largest phylum.
- Mollusca (soft bodied) are marine, some are also found in freshwater or on land.
- Study of this phylum is known as malacology & study of shells of molluscan is known as choncology.
- Body is unsegmented with variety of shapes. Neopilina is exceptionally segmented.

- Molluscs are usually bilateral. Few are secondarily asymmetrical (snail) due to twisting (torsion) during growth. These are triploblastic with organ system level.
- Body wall includes one layered epidermis (usually ciliated) with unstriped muscles found in bundles.
- Body parts consists of –
  - Head with sense organ. Head is absent in Pelecypoda & Scaphopoda.
  - Dorsal visceral mass containing organ system.
  - Ventral foot for locomotion.
  - Thin fleshy fold or outgrowth of dorsal body wall covers the body. This fold is called mantle or pallium. It encloses a space known as mantle or pallial cavity between itself and the body.
- The mantle usually secretes an external limy shell. Shell is made up of calcium carbonate and choncheolin protein. Shell may also be internal (Cuttlefish), reduced and even absent (Octopus).
- Coelom is greatly reduced. It is represented by cavities in the pericardium, kidneys and gonads. Space among the viscera contains blood and form haemocoel.
- Digestive tract is complete. Buccal cavity contains a rasping organ, the radula, with transverse row of teeth. Anus opens into the mantle cavity. Digestive glands are known as hepatopancreas.
- Respiration is usually by gills i.e., Ctenidia are in the mantle cavity but respiration may take place by body surface also.
- Dentalium respire by mantle. Pila respire by pulmonary sac on land and by gills in water.
- Circulatory system is open. It includes dorsal pulsatile heart and a few arteries that open into sinuses. Cephalopoda has closed type of circulatory system.

Blood has a copper containing, blue respiratory pigment, haemocyanin. Blood is colourless with amoebocytes.

- Excretory system includes 1 or 2 pairs of sac like kidneys, which open into the mantle cavity. Kidney of molluscans are metanephridia known as Keber's organs or Organ of Bojanus. Excretory matter is ammonia or uric acid.
- Nervous system comprises of three paired ganglia
  - Cerebral (above the mouth)
  - Pedal (in the foot)
  - Visceral (in visceral mass)
- Sense organs includes
  - Eye - Present over a stalk called ommatophore (Gastropoda).
  - Statocyst/Lithocyst - For equilibrium in foot
  - Osphradia - Chemoreceptor/Olfactory as well as for testing chemical & physical nature of water.
- Sexes usually separate (snail has ovotestis). Gonads have ducts. Fertilization may be external or internal. Cleavage is spiral, determinate, unequal and holoblastic.

Development is direct or indirect. Trochophore is very common larva of phylum mollusca.
Larva : Glochidium (Freshwater mussel) and Veliger (Pila)

UNIQUE FEATURES

- Three body regions: head, visceral mass and foot.
- A glandular fold, the mantle, over the body.
- Mantle cavity with anal, excretory and genital apertures in it.
- Calcareous shell around the body in most cases.
- A rasping organ, the radula, in the buccal cavity.
- Much better sense organs, such as eyes, statocysts, osphradia, etc.

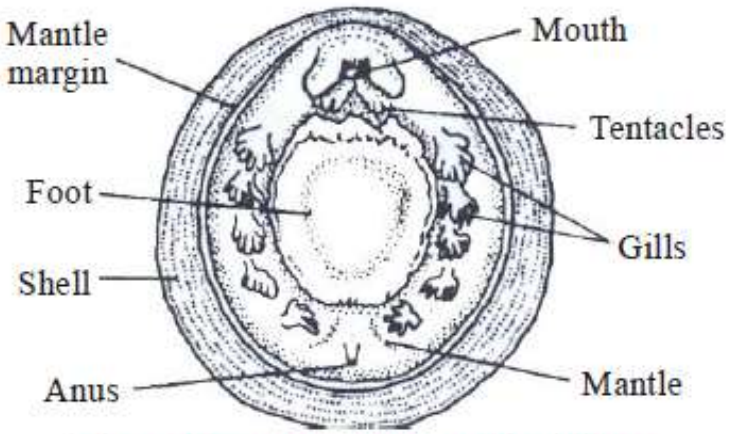


Fig. : Monoplacophora (*Neopilina*)

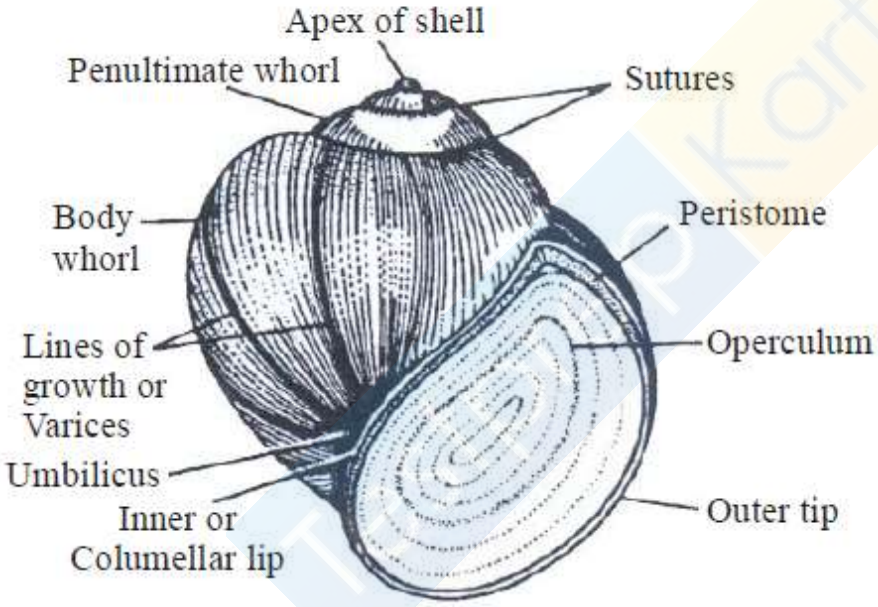


Fig. : Gastropoda (*Pila*)

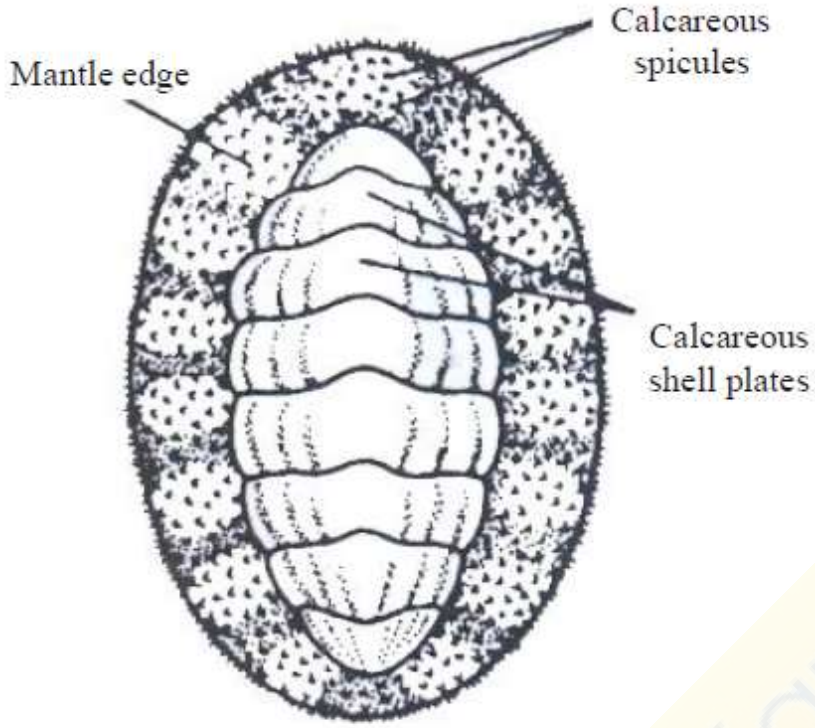


Fig. : Polyplacophora (*Chiton*)

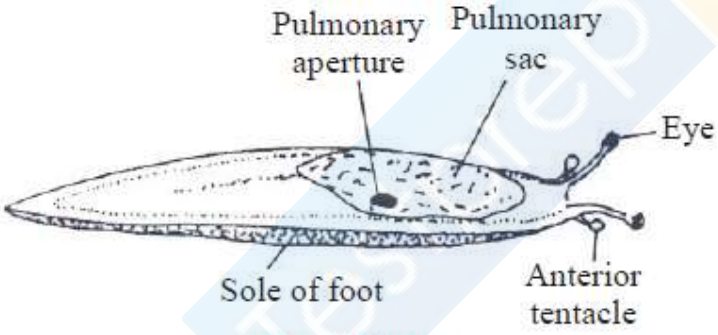


Fig. : *Limax*

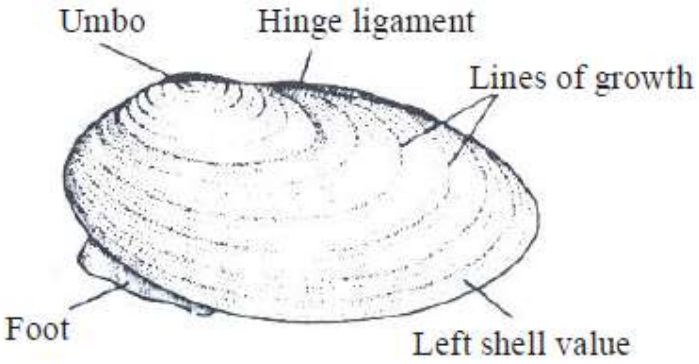


Fig. : Pelecypoda (*Unio*)

PHYLUM - ECHINODERMATA

- All are marine except Synapta similis.
- Generally live at bottom and slow moving.
- Body shape is star like, cylindrical like, melon-like, disc-like, flower like.
- Body is unsegmented with bilateral symmetry in larva and radial pentamerous (arranged in five or multiple) in adults.
- Echinoderms are triploblastic with organ - system level of organisation.
- Echinoderms do not have head.
- Tube feet (podia) which comes out through radial area i.e. ambulacral used for locomotion. These are extended and retracted by variation in hydraulic pressure of fluid in them and by the contraction of their muscles.
- Body wall of echinoderms consists of–
  - **Epidermis** - Single layered & ciliated.
  - **Dermis** - Below the epidermis, thick dermis having mesodermal endoskeleton of calcareous plate (Ossicles) is present. It has spines.
  - **Muscles** - Smooth and lie below the dermis.

Minute structure pedicellariae comes out through skin. These keep body surface clear of debris by opening & closing.

- Echinoderms have true coelom lined by ciliated mesothelium. Enterocoelous contains fluids with free amoeboid cells called coelomocytes.
- Coelom is divided into many tubes and sinuses, which together form 3 systems –
  - A unique water filled **ambulacral** or **water vascular system** with tube feet to help in locomotion. A perforated plate, madreporite permits entry of water into ambulacral system which also help in food and gas transport system.
  - **Haemal** system.
  - **Perihaemal** system.

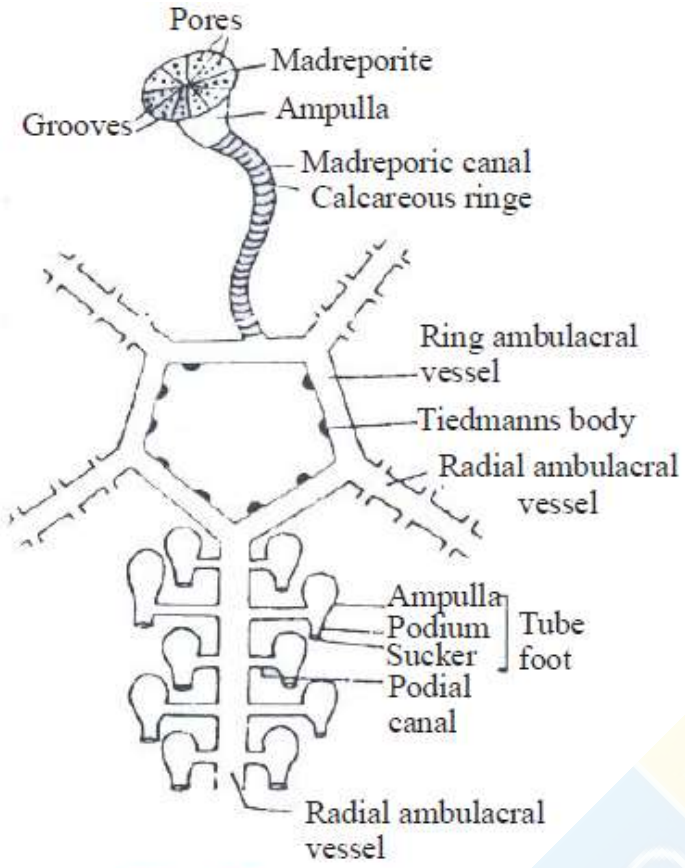


Fig. : Water vascular system

- Respiration takes place by gills (called dermal branchiae or papulae) in most of echinoderms like starfish, by genital bursae in Brittle star, by cloacal respiratory trees in sea - cucumber, by Peristomial gills in sea urchin by Tube - feet in few echinoderms.
- Digestive tract is complete (incomplete - brittle star).
- Circulation system is reduced and open type called haemal system/ Perihaemal system. No heart or pumping vessel.
- There is no excretory organ system. Nitrogenous waste (ammonia) diffuses out via gills, bursae, respiratory trees and tube feet. Amoeboid cells in coelomic fluid also perform excretory function by absorbing excretory matter.
- Nervous system is simple and primitive type. It includes a nerve ring and radial nerve cord with simple sense organ (No brain).
- Echinoderms resemble chordates in early embryonic development.
- Echinoderms have separate sexes.
- Fertilization is external (no copulation). Life history includes ciliated, bilaterally symmetrical larva that undergoes metamorphosis and changes into an adult (Deuterostome).
- Larvas are
  - Star fish → Bipinnaria
  - Brittle star → Ophiopluteus
  - Sea urchin → Echinopluteus
  - Sea cucumber → Auricularia
  - Feather star → Doliolaria
- Few echinoderms (star fish) have great power of regeneration. These break off their arms for defence purposes. This phenomenon is known as **autotomy**.

UNIQUE FEATURES

- Bilateral symmetry in the larva and radial symmetry in the adult.
- Mesodermal endoskeleton of calcareous plates, usually with spines.
- Modification of a part of the coelom into a water vascular system for aid in locomotion.
- Characteristic tube feet for locomotion.
- Peculiar pedicellariae for cleaning the body surface.

PHYLUM - CHORDATA

- Chordates were evolved during ordovician period of the palaeozoic era.
- The term chordata is originated by the two words of Greek language the ‘Chorda’ and the 'Ata'. Meaning of 'Chorda' is 'a thick string' and meaning of 'ata' is 'to have' and overall meaning of chordata is animals having a notochord.
- Notochord supports the body of these animals. So, chordates are the animals in which notochord is present in any stage of their life – span. Animals, which do not have notochord, are called non-chordates.
- According to taxonomists, 90-95% animals are non-chordates of the total animals present on earth, and the rest of the 3-5% animals are chordates.
- In chordates, species of maximum live animals is Pisces group and minimum live animals is amphibia group.

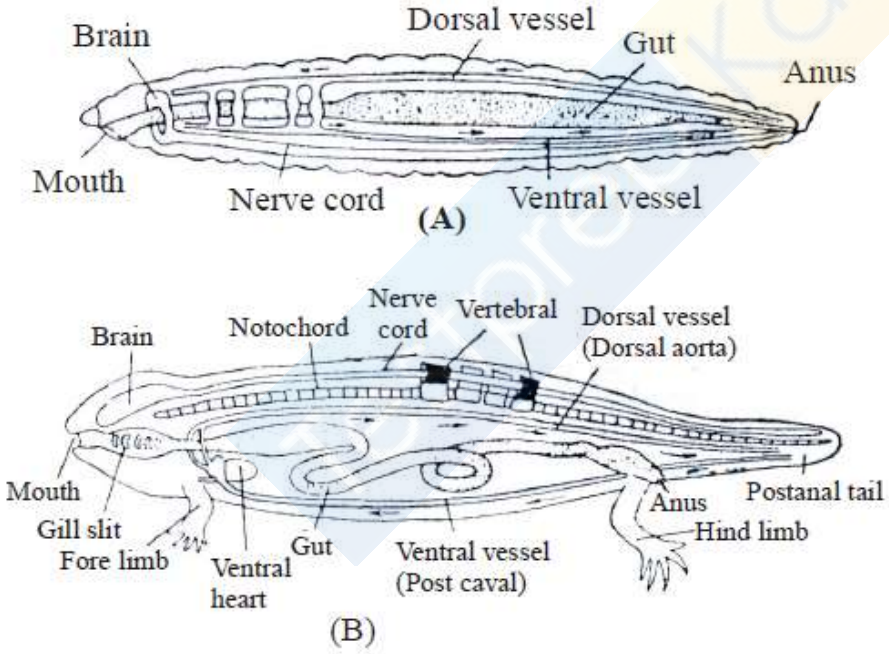


Fig. : Showing fundamental difference between (A) Non chordate and (B) Chordate

FUNDAMENTAL CHARACTERS OF CHORDATES

- In all chordate animals, there are some specific characters at any stage of their life span, these are called fundamental chordate characters.
- These are notochord, dorsal tubular nerve cord, pharyngeal gill slits and tail.

PRESENCE OF NOTOCHORD/CHORDA DORSALIS

- In the embryonic stage of chordate animals, there is a solid stick like structure (just below the central nervous system and above the alimentary canal), this is called notochord.

- Notochord is extended from anterior end to the posterior end of the body at the dorsal surface.
- Notochord is mesodermal in origin. It forms a primary endoskeleton which gives support to the central nervous system and muscles.
- In protochordata group, notochord is present throughout the lifespan but in vertebrata it is modified into backbone or vertebral column in adults.
- Notochord is replaced by vertebral column around the spinal cord and cranium around the brain.

PRESENCE OF DORSAL TUBULAR NERVE CORD

- In chordate animals, the nervous system is situated at the dorsal surface of the body.
- In these animals, a hollow, tubular structure is present which is situated just beneath the body wall and just above the notochord.
- Nerve cord is ectodermal in origin i.e. it is formed by the ectoderm of embryo.
- In non-chordates, nerve cord is solid and double and is situated at mid ventral side of the body, e.g., in annelids and arthropods.
- Ganglia are absent in the nerve cord of chordates.

PRESENCE OF PHARYNGEAL GILL-SLITS

- In each chordate animal, there are paired, lateral gill slits in the walls of pharynx for respiration at any stage of its life span.
- In higher chordate animals, pharyngeal gill slits are found only in embryonic stages, these are absent in adults.
- In aquatic chordates (pisces) and lower chordates, pharyngeal gill clefts are present throughout their life span for respiration.
- In terrestrial chordates, gill clefts are absent in adults because the main respiratory organ is lung for adults.
- Above three fundamental characters are necessarily found in primary embryonic stages of chordates, but in the adult stage, these are either absent or modified into other structures.

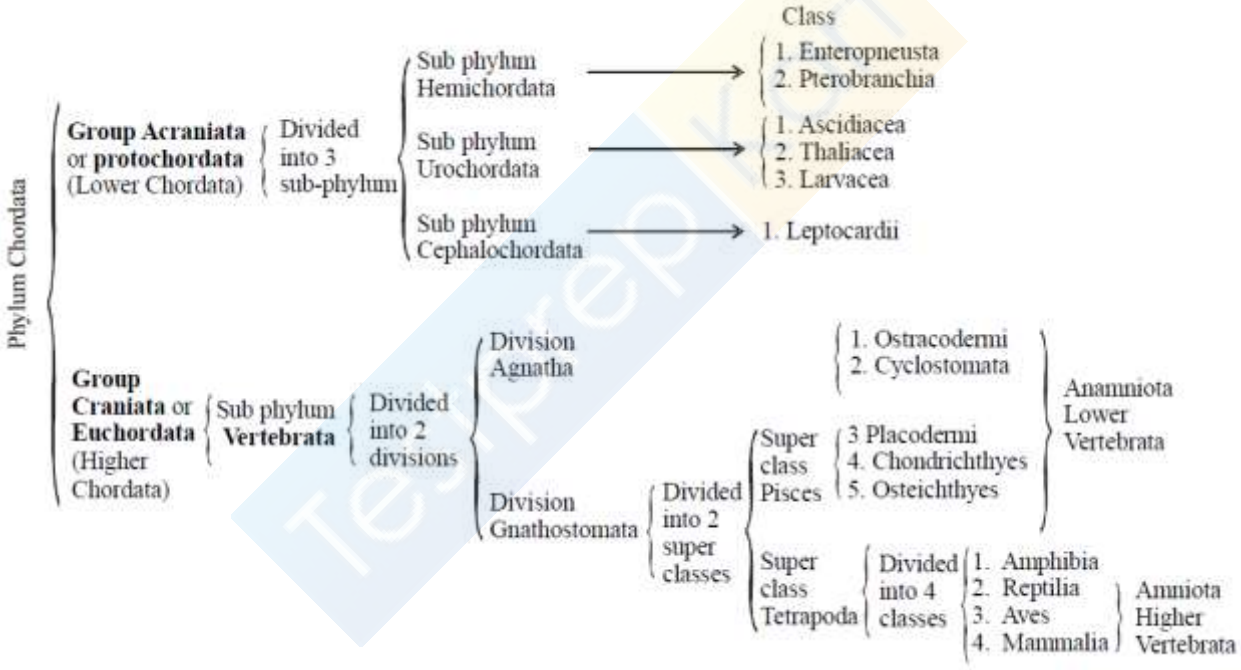
PRESENCE OF TAIL

- It is the post anal part of the body.
- Tail is reduced or absent in many adult chordates.
- It is considered as the fourth character of chordates.

GENERAL CHARACTERS OF CHORDATA

- Chordates are aquatic, terrestrial or aerial, free living.
- Body is bilaterally symmetrical.
- Body wall triploblastic, in which all the three germinal layers ectoderm, mesoderm and endoderm are present.
- Metamerism is found in the arrangement of muscles in embryonic stages and in adults, metamerism is found in arrangement of vertebrae and ribs.
- True coelom is found in them which is enterocoelous type. (Deuterostomes animals)
- Alimentary canal and digestive system is complete, digestive glands are present and digestion is extracellular.
- In these animals, heart is situated at the ventral side of the body, just beneath the alimentary canal, and blood flows from anterior to posterior side in dorsal blood vessel.
- In chordate animals, blood vascular system is of closed type.
- Respiratory pigment is haemoglobin that is present in RBC.

- Hepatic portal system is found in all chordates but renal portal system is also present in chordates except birds and mammals.
- Normally exoskeleton is present which is highly developed in most vertebrates.
- In chordates, endoskeleton is found which is made up of cartilage and bones.
- In embryonic stages of chordates, a muscular tail is found that is known as post anal tail. In some chordates, this tail is reduced, e.g. man, apes.
- Proto, meso and metanephric kidneys are found in the form of excretory organs.
- Sexual reproduction is dominant.
- These have less regenerative ability.
- Males and females are separate. Metamorphosis or development of embryo is direct i.e. without any larval stage (few exceptions)
- Chordates may be cold blooded (Poikilothermous), e.g., amphibians, reptiles and fishes or warm blooded (Homeothermous), e.g., birds and mammals.
- Phylum chordata is divided into two groups on the basis of cranium, vertebral column and paired appendages –
  - Acraniata or Protochordata
  - Craniata or Euchordata



Flow chart : 4.1 Outline Classification of Phylum Chordata

ACRANIATA OR PROTOCHORDATA

- All the members of this group are small & found in sea water i.e. these are all marine.
- Respiration is by gills.
- Pharyngeal gill clefts are found in embryonic and adult stages.
- Notochord persists throughout life, but skull, brain and vertebral column is absent in them.
- Notochord is not replaced by the vertebral column.
- Exoskeleton, head and paired appendages are also absent.
- These are unisexual or bisexual animals. Reproduction is asexual as well as sexual.
- Larval stage is present
- Acraniata group is divided into three sub phylums–

- Hemichordata
- Urochordata
- Cephalochordata

HEMICHORDATA

- Animals of this subphylum are all fossorial, and their tunnels are 'U' - shaped.
- Body is warm like, brittle and soft and divided into three parts – proboscis, collar and trunk
- Body wall has single layered epidermis. No dermis
- Body cavity is enterocoelous, that is divided into protocoel, mesocoel and metacoel.
- Mostly ciliary feeders. Complete alimentary canal is present in the digestive system. This is straight or 'U' - shaped.
- Respiratory pigment, vanadium is present in their blood. These respire by gill slits or body surface.
- Circulatory system is of open type. Blood is colourless with amoeboid corpuscles. Heart is situated dorsally.
- Skeleton tissue is absent and bones are also absent.
- True notochord is absent. A notochord like structure is found in their buccal cavity, that is called "**Buccal diverticulum**" or "**Stomochord**" (outgrowth structure of gut).
- Post anal tail is absent.
- Metamorphosis is direct or indirect because some animals have tornaria larva just like bipinnaria larva of echinodermata in their developmental stages.
- Hemichordata is divided into two classes–
  - **Enteropneusta** e.g., Balanoglossus (Tongue worm or Acorn worm), Saccoglossus, Palatoglossus
  - **Pterobranchia** e.g, Rhabdopleura, Cephalodiscus
- Modern taxonomist do not include hemichordata in chordata phylum. Hyman (1959) kept in separate phylum Hemichordata in invertebrates.
- Hemichordata is the **connecting link between non-chordata & chordata**.

UROCHORDATA OR TUNICATA

- All the members of this subphylum are marine, free swimming or attached with rocks.
- Adults are normally fixed and larva is free swimming.
- All the adult members have test all over their body, made up of tunicin just like cellulose [tunicine = $C_6H_{10}O_5$], so these animals are also called tunicata. The test is secreted by specific cells of mesoderm.
- Metameric segmentation is absent and coelom is also absent.
- Method of food intake is ciliary.
- A ciliary glandular slit is present at the ventral surface of pharynx, it is called endostyle. It absorbs iodine from marine water.
- Endostyle is homologous to thyroid gland of mammals.
- Normally, atrial apertures and branchial apertures are found.
- Blood vascular system is open type. Heart is situated at ventral surface of body, it is tubular and neurogenic in nature. Direction of blood flow is changing every time.
- Respiratory pigment is Vanadium in blood which is stored in purple blood corpuscles known as vanadocytes.

- Notochord is found only in tail of tadpole larva. Tail is lost during metamorphosis. Chordate characters are found only in the tail region of tadpole larva, so the name urochordata was given to this subphylum.
- Excretion is by supra neural gland, pyloric gland and nephrocytes.
- Dorsal tubular nerve cord is found in nervous system which is present only in larval stage. In adult stage, nerve cord is modified into a neural ganglion.
- Most of the animals are bisexual. Asexual reproduction is normally by budding. Each gonad contains testis and ovary portion in it.
- Fertilization is external and mostly cross-fertilization.
- A free swimming larval stage is found in this group, just like tadpole of frog, it is also called tadpole larva.
- All the members of this subphylum show “Retrogressive metamorphosis”. During this metamorphosis, a well developed free swimming larva is changed into ill developed, fixed adult. In these animals, larval stage is more developed.
- Only one chordate character is found in adults i.e. pharyngeal gill clefts are found in adults.
- Dorsal tubular nerve cord is found in central nervous system which is present only in larval stage. In adult, nerve cord is converted into nerve ganglion.
- Subphylum urochordata is divided into three classes on the basis of atrial cavity, gill apertures and conditions of life-cycle. These are **Larvacea**, **ascidiacea** and **thaliacea**.

○ **LARVACEA**

In these animals some times, larval stage is permanent stage i.e. larva does not metamorphose into adult, but attains sexual maturity and reproduces like an adult. This condition is called neoteny or Paedogenesis.
Examples
(i) Oikopleura - Shows pseudomorphism - A gelatinous sheet envelops the animal, which has emergency back door to escape.
(ii) Appendicularia

○ **ASCIDIACEA**

These are sessile marine invertebrates occurring usually in shallow waters and attached to hard surfaces.
Examples
(i) Herdmania - Sea potato or sea squirts.
(ii) Ascidia
(iii) Ciona
(iv) Molgula
(v) Botryllus

○ **THALIACEA**

The pelagic tunicates known as salps float singly or in cylindrical or chain like colonies.
Examples
(i) Pyrosoma - Biofluorescence is found (strongest light among marine organism)
(ii) Doliolum - Barrel shaped.
(iii) Salpa

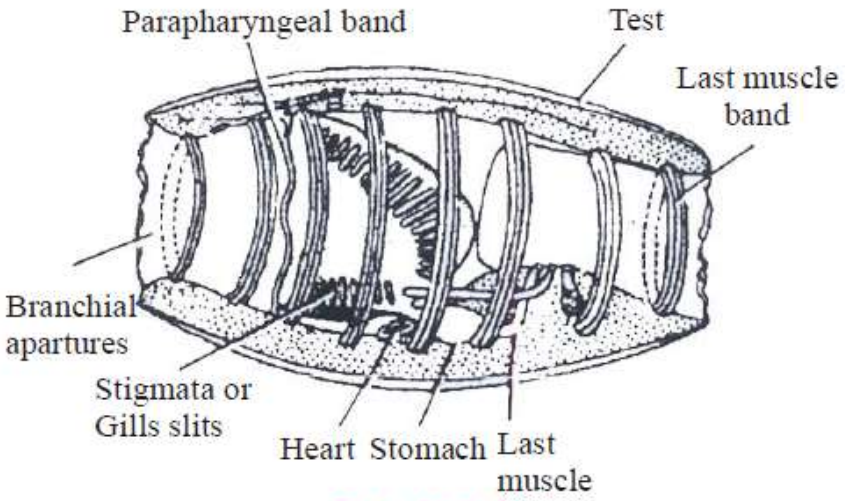


Fig. : *Doliolum*

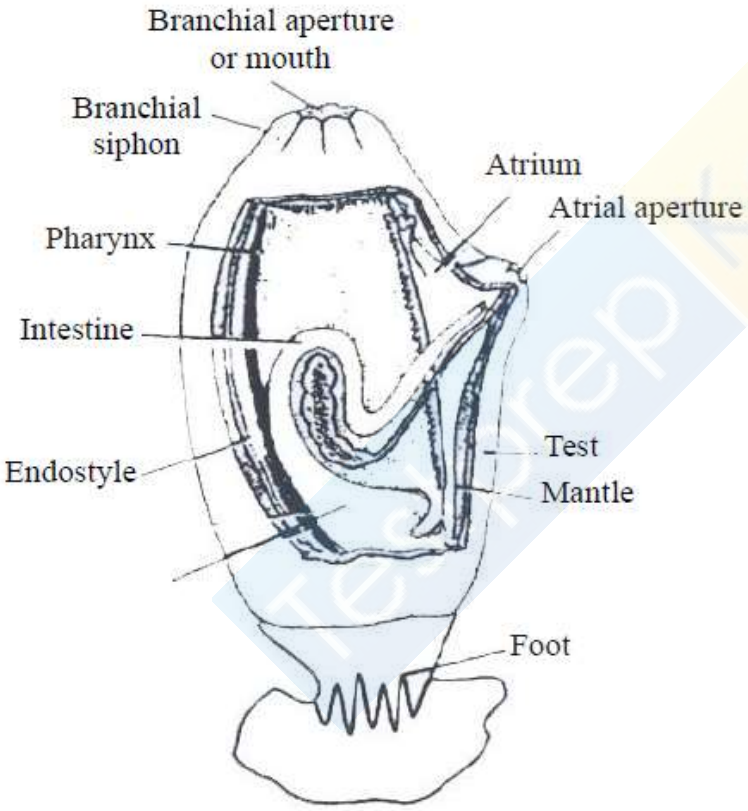


Fig. : *Ascidia*

CEPHALOCHORDATA

- Members of this subphylum are found in shallow sea water.
- Animals form burrows in sand and are nocturnal.
- Body is laterally compressed like fish and is segmented.
- Head is absent, the body is divided into trunk and tail.
- Paired appendages absent but middle layer fins are present.
- Alimentary canal complete. Buccal opening is covered by oral hood from all four sides. Just beneath it, "Wheel organ" or "Ciliated organ of Mullar" is present. This organ helps in the ingestion of food by producing circular currents in water.

- Hatchecks pit is found on the wall of oral hood which secretes mucus.
- These are ciliary feeders which feed on diatoms and microbes. Oral cirri and velum is present.
- Blood vascular system is closed type and respiratory pigment is absent.
- Hepatic portal system is present.
- For excretion, protonephridia are present in the form of flame cells or solenocytes. Hatchecks nephridium (single) present on the floor of velum helps in excretion.
- Nervous system is in the form of dorsal, tubular hollow nerve cord.
- Notochord and nerve cord remain extended from one end of the body to the other end.
- Fundamental chordate characters remain throughout life. Larva and adult both show chordate characters.
- These are unisexual animals.
- Fertilisation is external. Development is indirect i.e. larval stage is found.
- Members of this group are the first complete chordate animals.
- It has only one class - Leptocardii

Examples :
(1) Branchiostoma or Amphioxus (Lancelet). Also called a typical chordate.
(2) Asymmetron

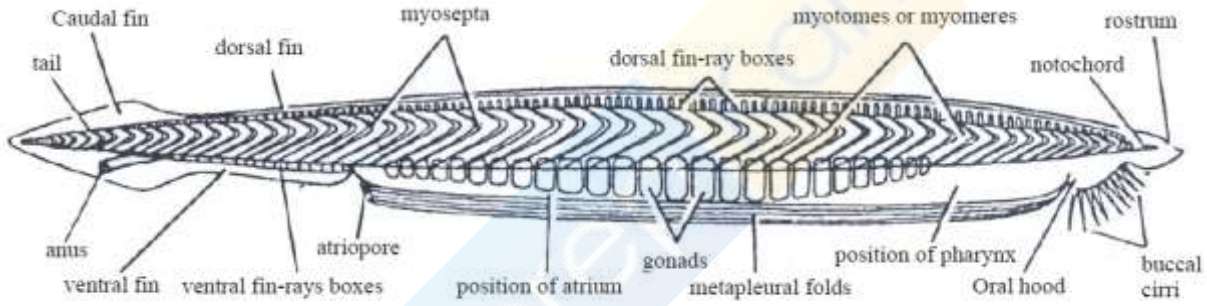


Fig. : *Branchiostoma* : Entire animal in right side view

CRANIATA OR EUCHORDATA

- These animals are known as higher chordates due to the presence of highly developed/advanced characters.
- These characters include prominent head, vertebral column, jaws and cranium.
- Only one subphylum - **Vertebrata** is included in this phylum chordata.

VERTEBRATA

- In these animals, notochord is completely or partially replaced by the vertebral column. Vertebral column is made up of so many vertebrae.
- Brain is covered by a protective covering. It is made up of bones or cartilage, it is called cranium.
- There is a prominent head and a well developed brain. Nerve cord remains enclosed within the vertebral column.
- Animals containing vertebral column are included in subphylum vertebrata.
- Different types of exoskeletons are found on the body of these animals, e.g., scales, wings, feathers, hair etc.
- Animals are unisexual.
- Vertebrata is further divided into two divisions – **agnatha**, **gnathostomata**

AGNATHA

- Jaws are absent in these animals (lowest grade vertebrates).
- Notochord persistent. All developed vertebrae are found at notochord.
- Mouth at the anterior end of the body is round, funnel shaped and suctorial.
- Paired fins are absent
- Genital ducts are absent.
- Two semi - circular canals are found in internal ear.
- One median pineal eye is found along with two lateral eyes on head.
- Group Agnatha is divided into two classes – ostracoderm and cyclostomata.

CLASS A : OSTRACODERM

- All the members of this class are extinct.
- Two semicircular canals are present in internal ear.
- Their body was covered by a protective covering made up of hard scales.

E.g., Cephalaspis (Primitive vertebrate of Ordovician period)

CLASS B : CYCLOSTOMATA

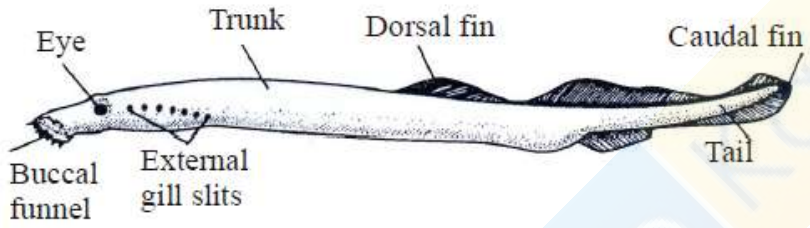


Fig. : *Petromyzon*

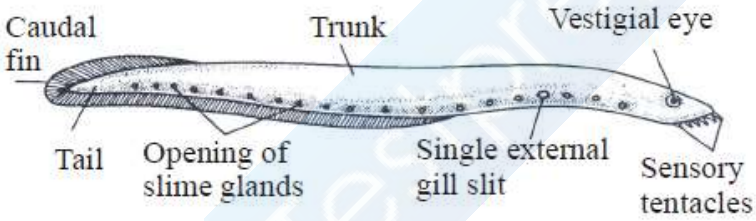


Fig. : *Myxine*

- Most of the members of this class are marine, except some freshwater species.
- These fishes are parasite as well as scavenger.
- This class includes Jawless fishes (false - fishes).
- Body is long, thin, tubular. Tail is flat.
- Skin soft, smooth and scaleless.
- Mouth is rounded, sucker like and biting - eating type.
- Three eyes are found on the head–one median pineal eye and two lateral eyes.
- Only one nostril (monorhynus) is present
- Internal ear contains one or two semicircular canals. Internal ear works as statoreceptor only. i.e. organ of balance.
- Gill clefts are 5 to 16 pairs.
- Digestive system is without stomach. Intestine has spiral typhlosole.
- Notochord and vertebral column are present in adults. Vertebral column is made up of cartilage. Bones are absent.

- Heart is two - chambered. It is called venous - heart.
- Kidneys are protonephric or mesonephric type.
- Paired fins are absent. Dorsal median and tail fin is present.
- Tail is protocercal type. In this type of tail, notochord is extended at the last end of tail and tail fin is divided into two equal dorsal and ventral lobes.
- Animals are unisexual, fertilization is external, larval stage absent. Except Ammocoete, larva is found during development of Petromyzon.

Examples–

- Petromyzon or Lamprey : It is a living fossil. It is an ectoparasite (Sanguivorous) on true fishes. Many teeth are found in mouth and it shows anadromous migration.

Larva Ammocoete is considered as connecting link between cephalochordata and cyclostomata.

- Myxine or Hagfish (slime eel) : It has wrinkled lips just like an old woman. It usually remains attached with the gills of host. It has archinephric kidney in young ones
- Bdellostoma
- Ichthyomyzon

GNATHOSTOMATA

- Mouth is encircled by true jaws.These are developed vertebrates.
- Vertebral column are well developed.
- Mouth is not rounded. Pineal eye is absent.
- Movement by paired fins or legs.
- Gonads are paired, genital ducts are present.
- 3 semicircular canals are found in internal ear.
- Animals are unisexual.
- Gills or lungs are meant for respiration.
- Gnathostomata is classified into two super classes on the basis of locomotory organs, respiratory organs, heart and blood vascular system– **pisces** and **tetrapoda**

SUPER CLASS - PISCES

- “Devonian period” is called “Golden period of fishes”
- Study of fishes is Ichthyology.
- This super class includes true fishes.
- Pisces is the first true jawed vertebrate groups.
- Animals are aquatic, may be freshwater or marine.
- Body is long, boat shaped and streamlined, which is divided into head, trunk and tail. Neck is absent. Slime glands are present on the skin.
- Body is covered by dermal scales. But catfish, Torpedo & Wallagonia fish are scaleless. Colour in fish is produced by iridocytes present in the dermis.
- Paired fins are present for swimming, e.g., Pectoral and pelvic fins are paired. Along with these unpaired fins are also found on the body, e.g., mid dorsal fin and caudal fin.
- External nares are one pair. This condition is known as dirhynous condition.
- External and middle ears are absent (No ossicle or tympanum). Only internal ear is present in which three semicircular canals are present, which works as statoreceptor. Eyes are without lids.
- Respiration by gills, gills are 4 to 7 pairs and naked or covered by operculum.
- "Air bladder" helps in respiration in lung-fishes (Group-Dipnoi)

- Heart is two chambered and known as "Venous heart" , because it contains only impure blood, which goes to the gills for purification from heart, pure blood is then distributed to all parts of the body directly from gills. i.e. circulation of blood is unicircuit.
- RBC (present in blood) are nucleated. **Sinus venosus**, **renal** and **hepatic** portal systems are found in the circulatory system.
- Endoskeleton is made up of cartilage or bones.
- Vertebrae in fishes are amphicoelous in which centrum is concave at both the surfaces.
- In the skull of fishes, only one occipital condyle is present, so their skull is called **monocondylar type**.
- Cranial nerves are 10 pairs.
- **Lateral line receptor system** is present in the body of fishes, which includes many receptor organs which can detect vibrations (rheoreceptor) and electric field.
- Kidneys in fishes are **mesonephric type**.
- Cartilaginous fish excrete urea, marine bony fish excrete trimethylamine oxide (TMO) and freshwater fish excrete ammonia. Urinary bladder is absent.
- Fishes are unisexual.
- Fertilization is internal or external.
- Eggs are mesolecithal or megalecithal type.
- Extraembryonic membranes are absent in fishes so all the fishes are placed under group anamniota.
- Metamorphosis is direct i.e. larval stage is lacking during development.
- These are cold blooded, poikilothermic animals (Exception - Tuna fish and Swordfish are endothermic).
- Small fishes (baby fishes) are called Fry or Hatchling.
- Fishes show a seasonal migration in a particular season.
  - **Catadromous migration** : Migration of fishes from fresh water to marine water, e.g. Anguilla
  - **Anadromous migration** : Migration of fishes from marine water to freshwater, e.g. (1) Salmon (2) Sturgeon (3) Hilsa
- Fish which can tolerate a narrow range of salinity in water is stenohaline.
- Fish which can tolerate a wide range of salinity in water is called euryhaline.

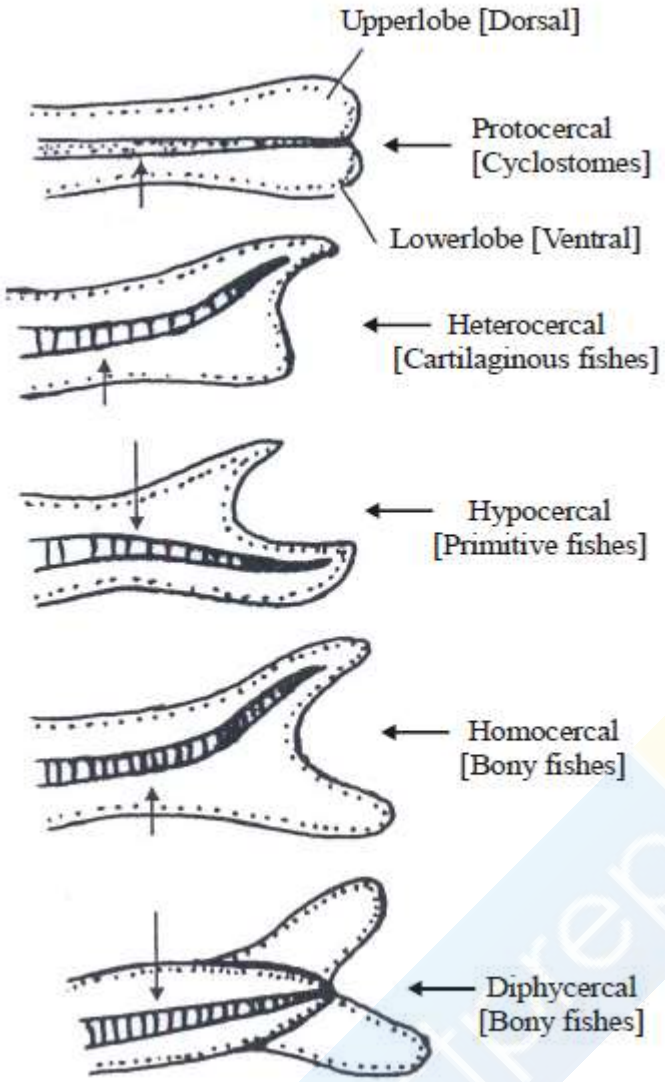


Fig. : Types of Tails of fishes

- Pisces is divided into three classes – **placodermi**, **chondrichthyes** and **osteichthyes**.

CLASS - PLACODERMI

- In this class, extinct fishes (fossil fish) are included, which used to live from devonian era to permian era. So, these were the first fresh water true fishes.
- Their body was covered by bony plates, so these are called "armoured fishes"
- E.g., : Climatius - First jawed fish - Dinichthyes

Fig. : Dinichthyes

CLASS - CHONDRICHTHYES OR ELASMOBRANCHI

- This class includes cartilaginous fishes.
- These are normally marine and a few inhabit tropical rivers.
- Endoskeleton is made up of cartilage.

- Exoskeleton over the skin is made up of placoid scales. These scales are like denticle and are originated by dermis of skin.
- In these fishes, 5-7 pairs of gills are present, which open directly outside the body by gill slits. Operculum is normally absent in these fishes.
- Mouth is present at the ventral surface of head. Jaws and teeth are present. Suspensorium of jaws is hyalostylic type.
- Air - bladder or lungs are absent.
- 5 pairs of spiracles are present.
- A spiral valve or scroll valve (to increase surface area) is found in intestine.
- Cloacal aperture is present. Genital ducts open into cloacal aperture.
- There is a special structure at the dorsal surface of head in these fishes, which is called "Ampulla of Lorenzini", that works as thermoreceptor.
- Liver is bilobed.
- Tail is heterocercal type.
- Fertilization is internal. Male fishes have "Claspers" as copulatory organs which are developed by the inner edges of pelvic fins.
- Fishes are **oviparous** or **viviparous** (few have yolk sac placenta).
- Operculum present. Cartilage fish with operculum is placed under holocephali group.

Examples
- Scoliodon (Dog fish) - Dog like sense of smell. It is also known as Indian shark. Viviparous
- Sphyrna - Hammer headed shark
- Stegostoma - Tiger Fish/Zebra shark
- Carcharodon - Great white shark (Man eater shark)
- Rhinobatos - Guitar Fish
- Pristis - Saw fish
- Trygon (Stingray) - Its dorsal fin has poisonous spines.
- Torpedo (Electric ray) - In this fish, an electric organ is found which is a modified muscle. It can give shock of about 100 volts. It is exoskeleton less.
- Rhincodon (Whale shark) - It is the largest true fish. Its length is 13-14 meters.
- Chimaera (“Rat fish” or “King of herrings” or Ghost fish) – Connecting link between bony & cartilaginous fish.

CLASS : OSTEICHTHYES OR TELEOSTOMI
- This class includes bony fish.
- These are found in fresh water as well as marine water.
- Endoskeleton of these fishes is made up of bones, so these fishes are called "bony - fishes"
- Their exoskeleton is made up of scales, which may be cycloid or ctenoid or ganoid type. Placoid scales are absent.
- Respiration by 4-pairs of gills. These gills are covered by operculum at each side of the body.
- Mouth is normally terminal or subterminal, teeth are found in jaws.
- Helping respiratory organs, that is, "air bladders" are present. Lung fishes respire through air bladders. In other fishes, these air bladders are hydrostatic i.e. help in maintaining balance of body.
- Spiracle is absent.
- Scroll valve in intestine is absent.

- Cloaca absent, in place of cloacal aperture, anus is present.
- No Ampulla of Lorenzini.
- Liver is trilobed.
- Tail is normally homocercal type but sometimes it may be diphycercal type.
- These are unisexual genital ducts that open outside the body through separate apertures.
- Fertilization is external, claspers are absent in male fishes.
- Fishes are oviparous but may be ovoviviparous or viviparous.

Examples

- Labeo : (Rohu"or "Indian carp)- It is a fresh water fish. Carnivorous when young but becomes herbivorous when adult.
- Clarias - "Cat fish" or magur
- Wallagonia : Lachi (scale less)
- Catla : Catla (Fresh water)
- Heteropneustis : Singhi
- Channa : Lata Fish
- Lophius : Angler Fish
- Hippocampus - ("Sea - horse" or "Pregnant male")–

It swims in water in its vertical position. A pouch like structure is present at the abdomen of male, fishes known as “Brood-pouch”. In this pouch, male collects the eggs. Secondary vivipary and parental care is found in hippocampus.

- Anabas - Climbing perch. Unable to climb trees
- Sardinella - Salmon
- Acipensor - Sturgeon - Endoskeleton is cartilaginous
- Pterophyllum - Angel Fish
- Exocoetus (flying fish) - Its dorsal fin is long, it can fly (glide) over 400 metre with the help of this fin.
- Anguillaa (Eel) - Snake like migrate to sea for spawning. Young eel (Elver) migrate back to fresh water.
- Fistularia - Rute fish
- Harpodon - Bombay Duck
- Amia - Bow fish
- Echeneis - Remora Sucker fish shows commensalism with shark and whales. Dorsal fin modified into sucker.
- Latimaria or coelacanth - Living fossil fish - It is the oldest living vertebrate known till now. It belongs to group Crossopterygii.
- Chenocephalus - Ice fish. Only vertebrate without haemoglobin.
- Opsanus - Toad fish
- Synanceja horrida (Stone fish) - It is the most poisonous fish.
- Gambusia (Top minnow) - Larvivorous fish.

Facts :

– Shagreen is dried skin of Cartilaginous fish.
– Cod liver oil is rich in Vitamin D.
– Shark liver oil is rich in Vitamin A.
– Maltase cross is found in vertebra of shark for supporting vertebrae.
– Mermaid’s purse refers to egg capsule of shark.

– Isinglass is a gelatinous product from air bladder of certain fish for making cement, jelly and for clarification of wine & beer.
Smallest fish Mystichthyes - Goby fish - Pandaka
(8-10 mm)

CLASS : DIPNOI GROUP

- Fishes of dipnoi group are called Lung-fishes because their air bladder helps in respiration.
- Three chambered heart.
- Both external and internal nares are present.
- Their tail is heterocercal type. Scale is placoid type.
- These are freshwater fishes.

Examples

- Protopterus : African lungfish : It is living fossil fish.
- Lepidosiren : South American lungfish.
- Neoceratodus : Australian lungfish.

SUPERCLASS - TETRAPODA

- Members of this superclass are found in water and on land.
- Locomotion by 2 pairs of pentadactylous limbs.
- Gills are present only in embryonic stages. Main respiratory organ in adults is lung.
- Exoskeleton is made up of scales, feathers or hair and endoskeleton is made up of bones.
- Heart is three or four chambered and double circulation is found in them.
- Kidneys are mesonephric or metanephric type.
- Middle ear is present. Birds and mammals have external ears also.
- Tetrapoda is divided into four classes–
  - **Amphibia**
  - **Reptilia**
  - **Aves**
  - **Mammalia**

CLASS - AMPHIBIA

- Amphibians originated in the devonian period. Carboniferous is the age of amphibians.
- Class amphibia includes amphibious animals which can live on both the places at ease i.e. underwater and on land.
- These are the **first chordate animals** which come out of water but these are not able to live on land permanently, these depend on water for their reproduction. Their eggs do not have protective covering to check evaporation.
- Class amphibia represents dual mode of life.
- Body is divided into head, trunk and tail. Some amphibians lack tail, e.g., frog, toad, etc.
- Skin is smooth and mostly scale less, but whenever scales are present these are embedded in the skin e.g., Ichthyophis.
- Numerous mucous glands are found in skin which help in moistening the skin, so these animals respire through moist skin. Some poisonous glands are also found in the skin of some animals, e.g., Bufo.

Pigment cells are also found as chromatophore for colouration. Few amphibians have the ability to change colour by expansion and contraction of pigment cells. This phenomenon is known as **metachrosis**.

- Two pairs of limbs help in swimming in water or moving on land. Forelimbs have four fingers and hindlimbs have five fingers. Their digits do not have nails or claws at all.
- Mouth is bigger in size. Upper or both the jaws have alike teeth. These are pleurodont, homodont and polyphyodont.
- A well developed and complete alimentary canal along with digestive glands are present in the digestive system (**salivary glands are absent in frog**).
- Alimentary canal, urinary bladder and genital ducts open into cloaca.
- Respiration by gills, skin (approx 8%), lungs or buccopharyngeal cavity.
- Two nostrils are found, this condition is called dirrhynous.
- Heart is three chambered– 2 auricles and 1 ventricle (arteriovenous). Sinus venosus and Truncus arteriosus is well developed.
- R.B.Cs are biconvex, oval and nucleated.
- In these animals, renal portal system and hepatic portal system are found.
- Endoskeleton is made up of bones, but cranium is cartilaginous.
- Skull has two occipital condyles, with the help of these two condyles, skull is connected by first vertebra of vertebral column i.e. atlas, this type of skull is called **dicondylic skull**.
- Ribs absent, but may be present in some animals, but ribs are not attached with sternum.
- Vertebrae, in these animals are procoelous type, in which centrum is concave from anterior side and convex from posterior side.
- External ear absent, only one ear ossicle columella (stapes) is present in middle ear.
- Cranial nerves are 10 pairs.
- Lateral line sensory system is necessarily found at any stage of development. In frog, it is found only in larval stage.
- 1 pair of kidneys work as excretory organs. These kidneys are mesonephric or opisthonephric type. These animals are ureotelic. But tailed animals & larvas are ammonotelic.
- These are cold blooded or poikilothermic animals.
- These animals undergo hibernation or aestivation to prevent themselves from extreme cold and heat and to overcome unfavourable conditions.
- These are unisexual animals, males have copulatory organs sometimes. These animals return to water from land for their reproduction.
- Fertilization is external and inside the water, but some animals show internal fertilization.
- These are oviparous, which lay their eggs in water. Eggs are mesolecithal. Extra-embryonic membranes are absent, so these are placed under amniota group.
- Cleavage in eggs is holoblastic and unequal.
- Development is indirect type i.e. tadpole larva in frog, Axolotl larva in Salamander
- Amphibia is divided into three orders :
  - Gymnophiona or Apoda
  - Caudata or Urodela
  - Anura or Salientia

CLASS - REPTILIA

- Reptilia were originated during the carboniferous period of the palaeozoic era. Mesozoic era is known as "Golden age of Reptiles".
- The branch of biology which deals with the study of reptiles is known as "Herpetology".
- Class Reptilia’s animals are the first successful terrestrial animals.

- These are normally terrestrial animals, but some animals are aquatic in nature also.
- Body is divided into head, neck, trunk and tail.
- Their skin is dry, cornified, rough, non-glandular (femoral gland in male lizard).
- In these animals, each limb has five digits. Each digit has incurved nails.
- Some lizards and snakes do not have limbs, e.g., Ophisaurus lizard is a limbless lizard. Their exoskeleton is made up of horny epidermal scales or bony scales or bony plates. A complete alimentary canal is found in these animals which opens into the cloaca.
- Teeth are acrodont and thecodont, pleurodont type. Tongue is protrusible.
- Respiration is by lungs, throughout life, but members of order Chelonia can respire through their cloaca (known as "Cloacal respiration")
- Heart is incompletely four chambered with 2 complete auricles and two incomplete ventricles. Right and left both systemic arches are present.
- Ventricle of animals of order crocodilia is completely divided into two, i.e. heart is four chambered in crocodiles.
- Sinus venosus is ill - developed and truncus arteriosus is absent. RBCs are oval and nucleated.
- Endoskeleton of these animals is made up of bones.
- Only one occipital condyle is present in skull, this type of skull is called monocondylic skull. Ribs are present in neck and thorax. Ribs of thoracic region make true sternum.
- Centrum of vertebrae are procoelous type. Sternum is well developed. Sternal ribs are found in reptiles.
- A chevron bone is found in caudal vertebrae of these animals.
- One pair of metanephric kidneys help in excretion.
- These animals are uricotelic for water conservation.
- There are 12 pairs of cranial nerves. Brain is well developed.
- Lateral line system is absent. At the roof/ceiling of buccal cavity Jacobson's organ (olfactory) is present.
- Genital aperture is not separate from anus. Ureters, genital ducts and alimentary canal open into a single cloacal aperture.
- These are unisexual animals. Fertilization is internal. One or two penis (hemipenis) is found in male animals as copulatory organ.
- These are mostly oviparous, but some animals are viviparous also. Amount of yolk is very much in their eggs, i.e. eggs are polylecithal & telolecithal.
- Eggs are cleidoic, i.e. eggs are covered by a shell made up of $CaCO_3$. Cleidoic eggs is an adaptation for terrestrial habitat. Eggs are leathery .
- All the three embryonic membranes amnion, chorion and allantois are present in the embryo. Yolk sac is also attached with embryo. So this class is grouped under amniota group.
- Cleavage is discoidal, meroblastic.
- Development is direct i.e. larva stage is absent.
- Parental care is often marked.
- These are cold blooded, poikilothermic animals. Their body temperature varies according to climate.
- Class reptilia is classified into 5 subclasses on the basis of presence or absence of temporal fossae in the temporal region of the skull and on their number.

CLASS - AVES

- Birds are originated at the end of the Jurassic period of the mesozoic era & modernisation in cretaceous era.
- Study of birds is known as "Ornithology".

- Dr. Salim Ali was the great ornithologist of India and known as "Birdman of India"
- Study of bird’s egg is known as Oology.
- Study of bird’s nest is known as Nidology.
- 'Birds are glorified reptiles' stated by Huxley.
- Arrangement of wings on the body of the bird is known as pterylosis.
- All types of birds are included in this class.
- Body is boat shaped. It is divided into head, neck, trunk and tail. Neck is long and flexible.
- A cover of soft feathers (derivative of stratum corneum) is present all over the body of all the birds, that is called "plumage".
- Scales are found only on hind limbs.
- Skin is dry and without glands. But oil glands or Preen glands are found on tail or Uropygium. These glands secrete oil which softens and makes greasy to the feathers.
- Two pairs of limbs are present. Forelimbs (with three digits) are modified into wings, which help in flying and in conserving heat. Four clawed digits are found on hind limbs.
- A three chambered cloaca is present in the birds.
- Jaws are modified into horny beak. Beak is toothless. An epidermal horny sheath is present on beak which is called Ramphotheca.
- Spongy lungs are present for respiration. Air sacs are also found, these help in flying.
- Sound producing organ is present at the junction of trachea and bronchi of birds is called syrinx.
- Heart is four chambered.
- Hepatic portal system is well developed in birds, but renal portal system is ill developed. Sinus venosus is absent. Only right aortic arch persists.
- R.B.Cs are nucleated.
- Endoskeleton is bony. These bones are hollow, in which air is filled (called pneumatic bones). These make the body light in weight and help in flying. Exoskeleton is in the form of soft feathers all over the body (except hind limbs).
- A single occipital condyle is found in skull i.e. birds are monocondylic.
- Centrum of the vertebra is heterocoelous.
- Some vertebrae of the posterior body portion join together to form synsacrum.
- Last four caudal vertebrae fuse to form pygostyle.
- Sternum is large. Swollen basal part of sternum is called "Keel" which offers a joint plane for flight muscles.
- Keel is highly developed in flying birds.
- Ribs of birds are bifid and uncinate processes and are present in ribs.
- Foramen of triosseus is found in their pectoral girdle.
- Two bones, clavicle and interclavicle fuse to form V - shaped furcula.
- Furcula is also known as Wish bone or Merrythought bone, which acts as a spring between two girdles.
- Furcula is absent in flightless birds.
- Kidneys are metanephric (Trilobed). Ureters open into cloaca. These are uricotelic and excrete uric acid as a semisolid substance. Excreta of marine birds is known as guano.
- Most of the birds do not have urinary bladder and copulatory organ.
- Brain is large, smooth, highly developed. Cerebellum is well developed for aerial mode of life. Cranial nerves are 12 pairs.
- The skin around the nostrils in birds is called “Cere”.

- Eyes are large and well developed which are surrounded by rings made up of bony plates known as sclerotic ossicles. Nictitating membrane is present in eye. Vision is unilocular.
- A specific comb like structure pectin is found in the eyes of all birds except kiwi's eyes. Pecten helps in accommodation of eye and provides nutrition to eyeballs. It also controls the pressure of liquid present in eye vision and telescopic vision of birds is due to pectin.
- External ears are present but ear pinnae are absent. Columella bone (Stapes, ear ossicle) is found in middle ear. Cochlea (not coiled) is present in internal ear.
- Olfactory organs are less - developed.
- Birds are monodelphic i.e. only left ovary and left oviduct is functional in females. Birds are oviparous vertebrates.
- Birds are unisexual. Sexual dimorphism is well marked. Copulatory organ is absent in males. Fertilization is internal.

Eggs are large, megalecithal, telolecithal and cleidoic. Shell is perforated. Cleavage is discoidal meroblastic.

- Embryonic development is direct. Embryonic membranes are present, so birds are included under group amniota.
- All the birds form nests. Parental care is well marked. Young one without feather is known as nidiculous and with feather is known as nidifugous.
- Birds are warm blooded or homeothermic or endothermic animals i.e., body temperature remains almost constant, what ever may be the temperature of the atmosphere around these birds.

CLASS - MAMMALIA

- Mammals were evolved in the triassic period of the Mesozoic era. Coenozoic era is known as "golden era of mammals".
- The members of this class are cosmopolitan. These are highly developed animals.
- Body is divided into head, neck, trunk and tail.
- A horizontal, diaphragm is present in the body cavity of all the members of this class without any exception. This diaphragm is present in between thorax and abdomen. Diaphragm helps in respiration, defaecation, micturition and parturition.
- Body is covered by a coat of hair (made of a keratin) called pelage.
- Skin of mammals is thick, water proof, glandular. So many types of glands are present in the skin as sweat glands, oil glands or sebaceous glands and mammary glands.
- Mammary glands (modified sweat glands) are found in females for baby feeding, so on the basis of this, the class mammalia was so named.
- Mostly horns are present at head, nails at digits, claws or hoof are found, which provide protection.
- Two pairs of limbs are present in trunk. Limbs are pentadactyl which help in swimming, walking, running etc. Hind limbs are absent in Cetacea and Sirenia.
- Alimentary canal is complete, its proximal end is called mouth and distal end is called anus. Anus and urogenital apertures are separate. Cloaca is absent (Exception-members of Prototheria have cloaca).
- Teeth are fixed in sockets in the buccal cavity, so teeth are called thecodont.
- Teeth are of four types i.e. such type of teeth are called heterodont teeth.
- Teeth come out two times in a life span in most of the animals so these are also called diphyodont teeth.
- Suspensorium of their jaws is craniostylic type.
- Lower jaw is made up of dentary bone.
- Respiration is by one pair of lungs (enclosed in pleural cavity).
- Larynx or sound organ is found in the neck region for the production of sound.

- Heart is four chambered. Double circulatory system is present. No sinus venosus. Only left aortic (systemic) arch is present.
- RBCs are small, circular and non-nucleated except, family camelidae (Lama) and Camel which has nucleated RBCs.
- Endoskeleton is bony, skull is dicondylic.
- Vertebrae are acoelous or amphiplatyan type i.e. centrum is flat at both sides. Cartilaginous pads are found at the edges of centrum, that are called epiphysis.
- Neck is having 7 cervical vertebrae except: Bradypus/sloth has 9 or 10 cervical vertebrae and Sea - cow/manatees has 6 cervical vertebrae.
- Ribs are bifid.
- One pair of metanephric kidneys are situated in abdominal cavity. These animals are ureotelic.
- Brain is comparatively large and highly developed.
- Cerebrum and cerebellum are very complex in structure and highly developed.
- A special structure is present for the connection of both the cerebral hemispheres of the brain that is called corpus - callosum.
- Optic lobes are four in number and are solid. All the 4 optic lobes collectively known as corpora quadrigemina.
- Cranial nerves are 12 pairs
- External ear is present in the form of ear pinna.
- Malleus, incus and stapes are the three ear ossicles in middle ear.
- Cochlea of internal ear is highly coiled spirally.
- Mammals are unisexual animals. Testes of males are situated (outside the body) in the scrotal sacs. A distinct penis is present in males for copulation.
- Ovaries and a reduced penis clitoris is found in females.
- Fertilization is internal and it takes place in fallopian tubes.
- Eggs are developed in uterus. Embryonic membranes - amnion, chorion, allantois and yolk sac are found in embryo so these are grouped under group amniota.
- Eggs are alecithal or microlecithal & homolecithal but eggs of prototherians are megalecithal.
- Embryo is attached through the uterus of mother by placenta, so these animals are also called placental animals. Placenta helps in the nutrition, respiration and excretion of embryo.
- Mostly mammals are viviparous, which give birth to their young ones. Some mammals are oviparous (prototherians) and some mammals are ovoviviparous (metatherians).
- Parental care is well marked in mammals. Mother feeds the child by milk secreted by her mammary glands and looks after her child.
- Mammals are warm blooded and homeothermic or endothermic animals.

CLASSIFICATION OF MAMMALS

Livings mammals are classified into two subclasses – Prototheria and theria.

PROTOTHERIA

- In this subclass, primitive egg laying mammals are included.
- Eggs are large, yolky and shelled (megalecithal).
- Mammary glands are without nipples.
- Gynaecomastism is found in these animals i.e. male and female both feed their child. Mammary glands are functional in males and females both.
- Cloaca is present.
- Testes in males are situated inside the body (abdominal cavity).

- Pinnae are absent and cochlea is less coiled.
- Corpus - callosum is absent in brain.
- A toothless horny beak is found in adult animals, but teeth are present in childhood.
- These are partially homeothermic animals.
- Members of this subclass are found in Australia, New Guinea and Tasmania.
- Only one order monotremata is included in this subclass. It forms a connective link between reptiles and mammals.
- Example–
  - Ornithorhynchus or Duck billed platypus - Poison glands are found in male platypus.
  - Tachyglossus or Echidna or spiny anteater.

THERIA

- These are viviparous animals.
- Embryo is attached with uterus of mother by placenta.
- Mammary glands with nipple are present.
- Cloaca is absent
- Testes are situated in scrotal sacs.
- Pinnae are present and cochlea is much coiled
- Corpus callosum is present
- Teeth are present. These are found in adults and children both.