Chapter 14

Non-Chordates

- Non-chordates **are** animals without notochord**.** Notochord **is an elastic skeletal rod lying lengthwise beneath the nerve cord and above the alimentary canal in the embryos or adults of all chordate animals.**
- Notochord is **found in both adult and larval lancelets** but in **adult vertebrates it is largely replaced by the vertebral column**.
- Hence **all the non-chordates are invertebrates whereas all the invertebrates are not non-chordates**. This means →
  Invertebrates – Protochordates = Non-chordates.
- Invertebrates are **essential for maintaining the functions of ecosystem** for many reasons. *For example* :
  - They form an integral part of the food web.
  - They recycle organic matter, feeding on faeces or dead plants and animals.
  - They make up the bulk of parasite species (along with micro-organisms such as bacteria that regulate animal and plant numbers).
- **Invertebrates** is a term coined by **Jean Baptiste Lamarck** to describe any **animal without a spinal (vertebral) column or backbone**.
- Lamarck **divided invertebrate into two groups**– the **insecta** and the **vermes**, but they are now classified into over 30 phyla, from simple organisms such as sponges and flatworms to complex animals such as arthropods and molluscs.
- All the phyla **which are non-chordates** (like **porifera, cnidarians, platyhelminthes, nematodes, annelida, arthropoda, mollusca & echinodermata**) are **invertebrates along with two** of the **three subphyla in phylum chordata**: **urochordata** and **cephalochordata**. These two, plus all the other known invertebrates, have only one cluster of Hox genes, while the vertebrates have duplicated their original cluster more than once.

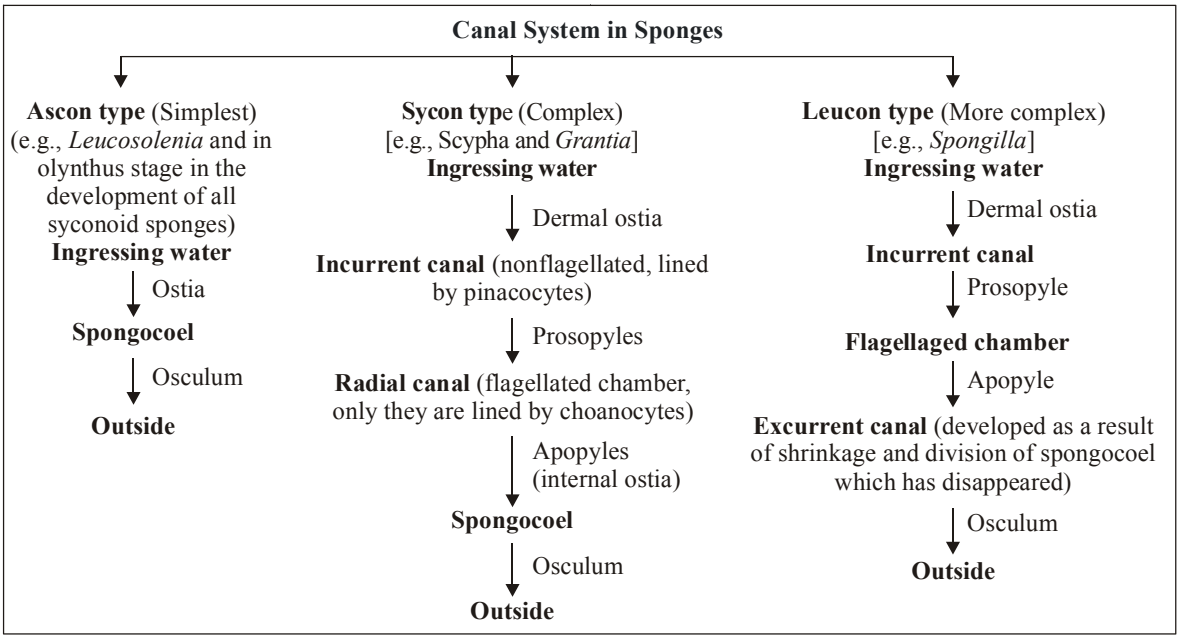
PORIFERA

- The phylum name porifera was coined by **Robert Grant**.
- The **sponges or poriferans** (from the Greek poros "*pore*" and Latin ferre "to *bear*") are **primitive, sessile** (attached), **aquatic (mostly marine** and few fresh water), **water dwelling filter feeders** that pump water through their bodies to filter out particles of food matter.
- The study of sponges is **parazoology**.
- Sponges are **asymmetrical** or **with radial symmetry** and **diploblastic** [ectoderm **(pinacoderm)** and **endoderm (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.** The beating of the choanocytes' flagella creates the sponge's water current.
  - **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. This is the **closest approach to true tissue in sponges**.
  - **Myocytes** : Modified pinacocytes which

control the size of the osculum and pore openings and thus the water flow.

- **Archaeocytes (or amoebocytes)** : 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**.

- With **no true tissues (parazoa),** sponges **lack muscles, nerves, and internal organs**. Their **similarity to colonial choanoflagellates shows the probable evolutionary jump from unicellular to multicellular organisms.**
- Sponges are **multicellular grade organisms** and **exhibit cellular level of organization**.
- Sponges usually have a **skeleton consisting of spicules** (may be either calcareous or silicious) **or spongin fibres**.
- The cavity common to all sponges is **spongocoel** or **paragastric cavity** lined with **flagellated choanocytes**.
- **Choanocytes (or collar cells)** are present only in sponges.
- Sponges have numerous mouthlets (**ostia**) and one exit (**osculum**).
- Sponges **have no real circulatory system**, however the water current is used for circulation. Dissolved gases are brought to cells and enter the cells *via* simple diffusion. Metabolic wastes are also transferred to the water through diffusion.
- Sponges **have no respiratory or excretory organs**; both functions occur by diffusion in individual cells.
- **Digestion** is **intracellular** like protozoan. Digestion of food takes place partially in choanocytes and partially in wandering amoebocytes.
- The food is constituted by protozoans, diatoms, bacteria, etc., coming in with water current.
- The chief **nitrogenous waste** of the sponge is **ammonia**.
- Contractile vacuoles are found in archaeocytes and choanocytes of freshwater sponges. The **only visible activities and responses in sponges**, other than propulsion of water, **are slight alterations in shape and closing and opening of incurrent and excurrent pores**, and these movements are very slow.
- 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 fresh water 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 derive 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**.
- The **free-swimming larvae**, known as **parenchymula** (*Leucosolenia* & *Clathrina*) and **amphiblastula** (sycon) serve as one of the **main form of dispersal for this largely sessile phylum**.
- **Vidabarine,** found in sponges, is a compound which may attack the AIDS virus directly.
- Sponges have **a canal system** and they need a continuous current of water flowing through their bodies **for respiration, excretion, nutrition and reproduction**.
- Sponges have **three types or canal systems**: **asconoid (simplest type)**, **syconoid** and **leuconoid**.
- **Asconoid sponges** are tubular with a central shaft called the **spongocoel** (or **paragastric cavity**, cavity common to all sponges). The beating of choanocyte flagella force water into the spongocoel through pores in the body wall. **Choanocytes line the spongocoel and filter nutrients out of the water**.
- **Syconoid sponges**, similar to asconoids, have a



tubular body with a single osculum, but the **body wall is thicker and more complex** than that of asconoids and **contains choanocyte-lined radial canals** that empty into the spongocoel.

- **Leuconoid sponges** lack a spongocoel and instead **have flagellated chambers**, containing choanocytes, which are led to and out of *via* canals.
- **Rhagon type** is found in few sponges **during larval stage**. This will be transformed to leuconoid type during adulthood.
- **Spongin fibres** are elongated protein fibres secreted by spongioblasts which form a fibrous network.
- **Spicules** are calcareous or siliceous hard spine – like structures.
- **Types of spicules** are – **monaxons** (straight or curved rods with a single axis), **triaxons** [with three axes crossing one another resulting in **hexactinal spicules** (in hexactinellida)]; **tetraxons** (spicules with four rays radiating from a central point. Its modifications include **diaene spicule** and triradiate/**triactinal spicule**); **polyaxons** (several rays radiating out from a central point).
- Skeleton of sponges is secreted by **scleroblasts**.
- **Three types of scleroblasts** are: **calcoblasts, silicoblasts** and **spongioblasts**.
- **Smallest sponge** is *Leucosolenia* and **tallest sponge** is *Poterionpatera*.
- *Chalina* is popularly known as '**the mermaids gloves**' or **'dead-man's fingers.'**
- *Proterospongia* with both amoeboid and collar cells acts as **connecting link between protozoa and porifera**.
- Sponges are **divided into 3 classes based on the type of spicules in their skeleton**.

Table : Classification of porifera

Calcarea	Hexactinellida	Demospoiangiate
Skeleton consist of calcareous spicules	6-rayed siliceous spicules	1 or 4 rayed siliceous spicules or spongin fibre or both.
Choanocytes relatively large	Choanocyte small	Choanocyte small
Marine and shallow water inhabitant	Marine and inhabit deep water	Show adaptation to fresh water, shallow and deep as well as in fresh water
Canal system is asconoid or leuconoid type.	Syconoid like type body	Leuconoid type canal system
E.g. *Leucosolenia*	E.g. *Euplectella*	E.g. *Spongilla*

Table : Some important examples

	Example	Important notes
		Class – Calcarea
1	*Scypha* [Urn or Crown sponge (sycon)]	• Vase shaped, radially symmetrical. • Resembles the **'olynthus stage'** (solitary hypothetical ancestral sponge) in the ontogeny. Shows protogyny • Have **stomoblastula** and **amphiblastula**.
2.	*Leucosolenia*	• Vase like colonical, marine and sessile sponge. • Has **radial symmetry** and **ascon type of canal system**. • Further development results in the formation of **stereogastrula or parenchymula larva**.
		Class – Hexactinellida
3.	*Euplectella* [Venus flower basket]	Exhibit commensalism with shrimps. Given as a wedding gift in Japan, symbolizing the idea "till death us do part".
4.	*Hyalonema* [Glass rope sponge]	Looks like a ball of glass wool with projecting tufts of glassy spicules.
		Class – Demospongiae
5.	*Cliona* [Boring sponge]	Its larvae bores into the shells of oyster. Hence harmful to oyster industry.
6.	*Spongilla*	Fresh water sponge. Canal system is essentially of rhagon type. Shows various shades of green colour due to presence of symbiotic algae (*Zoochlorella*).
7.	*Euspongia* [Bath sponge]	• Its skeleton is used for bathing found in warm shallow water of mediterrian sea. • Also called **horny sponge** due to consistence of their skeleton made of spongin fibres, forming a close-meshed reticulum • Skeleton is used for removing dirt from the body surface while bathing.

- The **three classes of sponges** are - **bony (calcarea or caliispongiae),** eg, *Scypha*; **glass (hexactinellida),** eg, *Euplectella*; and **spongin (demospongiae),** eg, *Euspongia.*

COELENTERATE

- Cnidaria or coelenterate is a phylum containing some 11000 species of relatively simple animals found **exclusively in aquatic, mostly marine environments.**
- **Leuckart** (1847) coined the term coelenterate.
- They are the **simplest metazoans**.
- Cnidarians get their name from **cnidocytes** (the **nettle cell**), which are **specialized cells that carry stinging organelles** (**nematocysts**).
- The **nematocysts** are the cnidarian's **main form of offence or defence** and **function by a chemical or physical trigger** that causes the specialized cell to eject a barbed and poisoned hook that can stick into, or entangle prey or predators, killing or at least paralysing its victim. It **also plays an important role in locomotion, food capture etc.**
- Out of 17, 4 **common types of nematocysts** are - **penetrant** or **stenotele** (**largest cnidoblast**, containing poisonous proteinaceous fluid called **hypnotoxin**), **volvent** or **desmoneme**, **streptoline glutinant** (large glutinant = holotrichous isorhizas) and **steroline glutinant** (small glutinant = atrichous isorhizas).
- Another important cell type is the **interstitial cell**, pluripotent cells that can transform into other cell types such as spermatozoa, adenocytes or nerve

cells, though not into epithelial or feeding muscle cells; the latter two can only be produced by cells of the same type. These **give many cnidaria an extraordinary capacity for regeneration. In particular the genus** *Hydra* **serves as a model for the research of pattern formation processes**.

- Nematocysts or cnidoblasts (**derived from interstitial cells of epidermis**) are **mainly present on tentacles**, a group of nematocyst is known as **cnidom**. They are **absent on basal disc**.
- **Nematocyst** is the **characteristic feature** of coelenterate.
- It contains a poisonous substance called **hypnotoxin**.
- **Sensory structure** of cnidoblast is **cnidocil**.
- Cnidocil is a **hair like structure at the opening of nematocyst**.
- **Contractile structure** of a nematoblast is **lasso**.
- Lasso is **contractile bundle of myonemes** which **prevents the nematocysts from collapse**.
- Cnidarians are **highly evident in the fossil records**, having **first appeared in the precambrian era**.
- The basic body shape of a cnidarian consists of a sac (*i.e* **blind sac body plan**) with a **gastrovascular cavity or coelenteron**, with a single opening.
- It is composed of **two layers of tissue**, known as the **ectoderm** and **endoderm (or gastroderm),** with a gelatinous non-cellular **mesoglea** in between them containing only scattered cells. Thus the organisms are considered to be **diploblastic**, though the mesoglea may be homologous with the mesoderm in other animals.
- The ectoderm surrounds the cnidarian's 'stomach', or **gastrovascular cavity** which **functions as both mouth and anus**.
- Ectoderm **also serves along with the mesogloea as a hydrostatic supporting skeleton**. Firm skeletons are only found among polyps, which produce lime for that purpose.
- **Gastrodermis** lines the coelenteron **has five types of cells - nutritive** (endothelio-muscular/gastrodermal) **cells, nerve cells, interstitial cells,** secretory **endothelio-glandular cells** and **sensory cells**.
- Nerve cells are **apolar**.
- **Epidermis** is made of epithelio-muscular cells, glandulo-muscular cells (adhesive material in pedal disc), interstitial cells, cnidoblasts, sensory cells, nerve cells and germ cells.
- Coelenterates **radially symmetrical animals** with **cell-tissue grade of body organisation**.
- **Radial symmetry**, means that whichever way it is cut along its central axis, the resulting halves would always be mirror images of each other.
- The animals have **blind sac body plan** *i.e.*, consists a single opening which serves both as mouth and anus.
- The distal end of body is produced into a conical elevation called **hypostome**.
- Mouth, surrounded by tentacles, is situated at the **apex of the hypostome**.
- The cnidarian **does not possess a true circulatory system**.
- **Respiratory** and **excretory organs** are **absent** as all the cells are in direct contact with water.
- **Respiration** takes place **through diffusion of oxygen directly through their tissues without specialised organs such as tracheae, gills or lungs**.
- The **gastrovascular system plays a role in the digestion and dispersion of food and the removal of metabolic waste**: it surrounds the gastrovascular cavity as well as its extensions in the tentacles of polyps. Thus the gastrovascular system serves two separate functions, digestion and transport.
- **Digestion** is both **intracellular** and **intercellular or extracellular.**
- Extracellular digestion occurs with the help of digestive enzymes poured into the gastrovascular cavity by secretory cells.
- Most cnidarians are **carnivores** and **mainly feed upon small crustaceans or zooplanktons**.
- Animals are **ammonotelic.**
- The **movement of cnidaria is controlled by a decentralised net of true nerve cells.**
- Nervous system is **primitive** and **diffuse type without brain** and is found in the form of an intra-epidermal nerve net.
- Sense organs are **statocyst**, **tentaculocyst** which occur in free swimming forms (medusa).
- Concentrations of nerve cells are **found in the mouth area of polyps (the hypostome), on the tentacles and stem (pedunculus),** and with jellies a ring of nerves is often found around the screen.
- Members of cnidaria have life-cycles that alternate between **asexual-polyps** and **sexual, free-swimming forms** called **medusae.** This phenomenon is called **metagenesis** or **alternation of generation** (e.g., *Obelia*).

- **Polyps** are anchored to the substrate by their basal discs, although a few species can move in curious slow-motion somersaults. By nature they display their tentacles upwards, away from the substrate. Polyps **often live in large colonies**.
- Polyp is **concerned with feeding and protection also**.
- **Medusae** have a hat or bell-shaped appearance and mostly swim passively with the current. Their tentacles hang freely below their bodies. However, they can actively swim by means of co-ordinated muscle contractions against the water contained in their gastrovascular cavity.
- Medusa stage is advanced to polyp because it has **great power of contractility**.
- In metagenesis, the **adult polyp forms male or female medusae (diploid) asexually**. There are three principal asexual events:
  - budding
  - **strobilation** occurs when a medusa forms on the higher (oral) end of the polyp, and is **common among scyphozoa**.
  - finally complete metamorphosis, from polyp to medusa form can also occur.
- **Asexual reproduction** *via* budding is **common** among cnidaria, particularly among the **hydrozoa class.**
- During their life cycle flagellated **planula larva** (*Obelia*) is formed which swims until it encounters a firm substrate on which it anchors itself and then passes through metamorphosis to the polyp stage.
- The life cycle also possesses a number of immature stages like **hydrula, hydratuba, scyphistoma** (= scyphula) and **ephyra** etc.

Some groups such as **coral** live symbiotically with algae, mostly dinoflagellata but sometimes chlorophyta. By absorbing the carbon dioxide produced by the cnidarian, utilising sunlight *via* photosynthesis and releasing the oxygen, the algae produce energy-rich carbohydrates which the cnidarian uses as its main source of food.

- **Planula** is the **larval form** of coelenterates.
- **Classification of cnidarians** is mainly **based on dominance of polyp and medusoid stage**.
- There are **three main classes** of cnidaria: **hydrozoa** (Portuguese Man o' War, *Obelia*, *Hydra* etc.) **scyphozoa** (jellyfish) and **anthozoa** (anemones, corals, etc.)

Hydrozoa

- In **hydrozoa**, **polyps is the dominant or only stage of the life cycle**, though it usually have both polyp and medusa stage. *Eg.*- *Hydra*, *Obelia*, *Physalia* etc.
- Food of *Hydra* is **water fleas** (*Daphnia* and cyclops).
- *Hydra* **does not have any free larval stage** in the development.
- Real discoverer of *Hydra* is **Abraham Trembley**.
- *Hydra* has **four type of nematocysts** serving different functions. These are **penetrants, volvents, stereoline glutinants** & **streptoline glutinants**.
- The nematocysts which are mainly used for offence and defence are known as **penetrants** or **stenoteles**.
- These are the **largest** and **most complex type** of nematocysts in *Hydra*. They are open and inject **hypnotoxin**.
- The movement of the prey is impeded by **volvents** or **desmonemes**.
- **Penetrants** and **volvents** are useful in **capturing the prey**.
- **Volvents** or **desmonemes** are **spineless** and closed. They **helps in capturing prey by coiling round them**.
- **Stereoline glutinants** are **thread like tubes without spines**.
- **Streptoline glutinants** are **used both in food capture and locomotion**.
- The action of nematocyst depends on enzymes, which bring about increased osmotic pressure inside the capsule of cnidoblast.
- Some *Hydras* have **green or brown colour due to presence of green algae** *Zoochlorellae* and **brown algae** *Zooxanthellae* in their nutritoepithelial cells.
- Gonads in *Hydra* are formed temporarily from **interstitial cells of epidermis**.
- *Hydra* is a **solitary polyp found in freshwater** (stagnant).
- *Hydra* is **diploblastic** and **radially symmetrical**.
- The **tentacles** of *Hydra* **help in locomotion and food capture**, so **analogous** (correspond functionally) **to pseudopodia of *Amoeba***.
- Myofibrils of *Hydra* are all smooth.
- Mesogloea of *Hydra*, secreted by both ectodermal and endodermal cells, is a thin, acellular consisting of a proteinaceous matrix and it can be crossed by interstitial cells.
- Body cavity of *Hydra*, called **coelenteron**, **serves**

the double purpose of digestion and circulation.

- **Various types of locomotion** in *Hydra* are **gliding, floating, walking** (erect movement with all tentacles directed downwards using them as legs), **looping** and **somersaulting**. etc
- Locomotion in *Hydra* is **not connected with mating**.
- *Hydra* is **carnivorous** feeding on small crustaceans.
- *Hydra* **engulfs only those animals which have glutathione in their body tissue fluid of the prey**.
- Digestion in *Hydra* is **first extracellular** (in gastrovascular cavity) and **then intracellular** (in endoderm cells).
- *Hydra* has **no enzymes to digest starch.**
- **Nitrogenous excretory product** in *Hydra* is **ammonia** and it is removed through general body surface.
- *Hydra* has a nervous system, but **no brain.**
- *Hydra* has nerve cells but no nerves.
- *Hydra* possesses a very **primitive nervous system** consisting of synaptic network of bipolar and multipolar nerve cells.
- *Hydra* is **negatively chemotropic**, it avoids chlorinated water.
- In *Hydra* reproduction is **both asexual and sexual**.
- *Hydra* reproduces asexually by **exogenous budding,** a type of vegetative propagation, and sexually by **formation of gametes.**
- *Hydra* is **monoecious** or **dioecious**. Most species (*e.g., Pelmatohydra oligactis*) are dioecious or unisexual.
- Fertilization **occurs externally on the body** by the entry of sperm into ovum.
- *Hydra* has **great regenerating capacities**. A piece of *Hydra* will regenerate into a full *Hydra* if it contains a part of epidermis and gastrodermis and size is not less than 1/6 mm in diameter.
- *Hydra* have **single ovary** in lower half and **few testes** in distal/upper half.
- *Hydra* **does not have any free larval stage** in the development.
- *Obelia* (**sea fur**) colony exhibits **trimorphism containing three types of individuals** namely **hydranth**, **blastostyle** and **medusae**.
- **Hydranth** is also known as **gastrozooid** and are **nutritive in function**.
- **Blastostyle** is **asexual reproductive zooids** with reduced gastrovascular cavity.
- **Medusae** is free swimming zooid with a mouth, large number of marginal tentacles, sense organs (statocyst), marginal nerve ring and four gonads for sexual reproduction.
- *Physalia* is also known as **Portuguese Man of War**.
- *Physalia* **has a bladder like pneumatophore** which contains a gas gland. The **gas secreted by the gas gland helps the animal to float over the water surface**.
- Secretion of nematoblasts in *Physalia* is **neurotoxin**.
- **Cormidia** is a group of zooids in *Physalia*.

Scyphozoa

- **Scyphozoa** are mostly marine, some are freshwater forms.
- **Medusa is dominant** in scyphozoa **with polyp either absent or ill developed**, *eg.*- *Aurelia* (jelly fish), *Cyanea* (sun jelly).
- **Nematoblast are present in both epidermis and gastrodermis** in class scyphozoa.
- **Ephyra** is the **larval form of** *Aurelia*.
- The sensory organs in *Aurelia* are the **rophalia**.
- *Aurelia aurita* is commonly known as **moonjelly**.

Anthozoa

- **Anthozoa** have only **polyp phase**. *eg.*- sea anemone (*Admasia*), corals animals.
- All anthozoa are **marine**.
- **No alternation of generation** occur in anthozoa.
- Sea anemone (*Metridium*) **shows commensalism with** *Euspagurus* (**hermit crab**).
- Sea anemone is also known as **sea flowers**.
- The gastrovascular cavity of sea anaemone is divided into chambers by endodermally formed mesenteries.
- **Cnidoblasts** and **germ cells** are **endodermal**.
- **Importal corals** are - *Tubipora* (organ pipe coral), *Fungia* (mushroom coral), *Madrepora* (stag horn coral), *Astraea* (star coral), *Favea* (stony coral), *Heliopora* (blue coral), *Corallium* (red coral) etc.
- **Coral reefs** may be defined as the extensive mass of coral colonies which grow continuously in size by budding of polyps. Eg. **fringing reef**, **atoll** and **barrier reef**.
- Coral animals **secrete external skeletons** of **calcium carbonate**.
- Coral is the rock-like external skeletons.
- **Corals** may be **solitary** or **colonial**.
- **Solitary coral** is *Fungia* (also called **mushroom coral**).
- **Colonial corals** are *Astraea* (star coral), madrepora (stag horn coral), *Pennatula*, *Gorgonia*.

- Pennatula is also known as **sea pen**.
- **Largest tentacle** is present in *Cyanea arctica* (about 1 m in length).
- **Important reef forming corals** are millepora, tubipora, heliopora etc.
- **Sea pancy** is the **common name** of *Ranilla*.

CTENOPHORA

- **Ctenophora** was **established by Hatscheck** (1839).
- Ctenophora is a **small phylum of marine coelenterates** like **free swimming** and **biradially symmetrical animals** having **8 meridional row of ciliary comb ribs**.
- They are **popularly called as comb jellies, seacombs** and **seagoose berries**.
- **Cnidoblast are absent** with the exception of *Euchlora rubra.*
- They possess **photocytes** or light producing structures, therefore are **luminescent**.
- Tentacles, when present, are solid and possess adhesive cells called **colloblasts** (= **lasso cells**).
- Ctenophores are **acoelomates**.
- Body plan is **intermediate between blind sac and tube within tube**.
- Animals are usually **monoecious**. An immature ciliated stage larva called **cydippid larva** is found in some forms.
- Ctenophora has **two classes – tenticulate** (with tentacles), eg. *Hormiphora* and **nuda** (without tentacles), e.g., *Beroe.*

PLATYHELMINTHES

- The term platyhelminthes (also called **flatworms**) was first proposed by **Gegenbaur**.
- The **platyhelminthes** (Greek "platy"': flat; "helminth": worm) are a phylum of relatively **simple soft-bodied invertebrate animals.**
- Flatworms are found in **marine, freshwater**, and even **damp terrestrial environments**. Most are **free-living forms**, but many are **parasitic on other animals**.
- Cephalization (**differentiation of head**) **begins in the flatworms.**
- The flatworm's cephalized soft body is **ribbon-shaped, flattened dorso-ventrally (from top to bottom), and bilaterally symmetric.**
- Flatworms are the **simplest triploblastic animals with organs**. This means their organ systems are formed out of **three germ layers**: an outer **ectoderm** and an inner **endoderm** with a **mesoderm** between them.
- There is also **no true body cavity (coelom)** except the gut and hence they are **acoelomates** which is filled with somewhat loosely spaced mesodermal tissue called **parenchyma tissue.**
- With about 25,000 known species they are the **largest phylum of acoelomates.**
- Animal possesses **tissue organ level of organization** and **blind sac body plan**.
- Extracellular body fluids (interstitial fluids) percolate between cells to help distribute nutrients, gses, and waste products.
- There is **no true circulatory**, **skeleton or respiratory system**, but like all other animals, flatworms do take in oxygen.
- Flatworms respire at their integument; gasses diffuse directly across their moist outer surface. This type of system is called **integumentary exchange**.
- Digestive system is **incomplete** due to possessing only one opening, **reduced or absent in parasitic form** (e.g., *Taenia*).
- **Excretion and osmoregulation** are brought about by **flame cells** or **solenocyte and protonephridia**.
- Flatworms possesses **high power of regeneration.**
- Flatworms do have a **bilateral nervous system**; they are the simplest animals to have one. Two cordlike nerves branch repeatedly in an array resembling a ladder (*i.e* **ladder like nervous sytem**). The head end of some species even has a collection of ganglia acting as a rudimentary brain to integrate signals from sensory organs such as eyespots.
- Sense organ are **better developed in free living forms** like *Planaria*.
- Flatworm reproduction is **hermaphroditic or monoecious**, meaning each individual produces eggs and sperm.
- **Fertilization** is **internal** and **cross fertilization is predominant.**
- They **usually do not fertilize their own eggs**.
- **Life cycle** is **indirect** or complicated with one or many larvae.
- **Classifications of flatworms**, primarily **based on differing degrees of parasitism**, is divided into three monophyletic classes – **turbellaria**, **trematoda** and **cestoda**.

Platyhelminthes

Divided into 3 classes

Turbellaria (Eddy worm)

- Freeliving in both fresh and marine water, but some are commensals & ectoparasites
- **Cilia on body surface**
- Epidermis is cellular, syncytial, characterised by presence of special hyaline rod shaped bodies called **rhabditis** producing chemical secretions
- Body is **unsegmented & leaf like**
- Suckers absent. Adhesive organs are glanduloepidermal & glandulomuscular
- Alimentary canal with 2 branches
- Simple life cycle. **Development** is usually direct **without any larval stages**.
- Eg. *Planaria, Bipalium, Thysanozoon* etc.

Trematoda

- Endoparasites or ectoparasites
- **Cuticle present**, no cilia
- **Unsegmented & leaf like body**
- Sucker and some times hooks present
- Alimentary canal with 2 branches
- Complicated life cycle with larval stages.
- **Development** is **direct in ectoparasites** & usually **indirect in endoparasites** with alternation of host.
- E.g. Liver fluke (*Fasciola*), *Schistostomata*, *Opisthorchis* etc.

Cestoda

- **Advanced class**
- Endoparasites in alimentary canal of vertebrates
- Cuticle presented, no cilia & epidermis
- Body is segmented & **ribbon like**
- **Every segment** is **hermaphrodite**
- Suckers, hooks (on scolex) present
- No alimentary canal
- Complicated life cycle with larval stages.
- E.g. Tapeworm (*Taenia*), *Echinococcus* etc.

- *Bipalium* is the **largest terrestrial turbellarian**.
- Trematodes with only oral suckers are called **monostomes**.
- The liver fluke has a dorsoventrally flat, unsegmented body with **two suckers**, **oral sucker** (anterior sucker) and **acetabulum** (ventral sucker).
- *Fasciolopsis* (= *Fasciola*) *buski*, is a fluke that lives in human **stomach** and **duodenum** in South-East Asia.
- *Opisthorchis sinensis* (Chinese/Oriental Liver Fluke) **causes jaundice and liver damage** in human beings in China, Japan and Vietnam. It has **two intermediate hosts - snail** and **fish**. Cats, dogs and pigs can also be infected.
- *Fasciola gigantica* (*F. indica*) is **liver fluke of cattle**.
- *Paragonimus westermani* is **lung fluke**.
- Body of *Taenia* is divided into three parts namely **scolex**, **neck** and **strobila**.
- **Scolex** has a rostellum bearing two circlets of chitinous hooks and four suckers or acetabula for holding onto the host.
- **Neck** is the unsegmented part, new segments are formed in this region.
- **Strobila** is the main body **made of proglottids**.
- Proglottids are of **three types** : young, mature and gravid.
- **Young or immature proglottids** are behind neck and are **without reproductive organs**.
- **Mature proglottids** are in the middle **having reproductive organs**, both male and female gonads.
- **Gravid proglottids** (rectangular in shape) are **with branched uterus containing fertilized eggs**.
- **Apolysis** is the process of separation of gravid proglottids.
- Body cavity is **absent** in tape worm, hence they are **acoelomate**.
- *Taenia* has **no digestive system**. It completely depends upon predigested nutrients absorbed from the host's gut through the cuticle.
- **Complete absence of an alimentary canal** is a **unique parasitic adaptation** in tapeworm.
- The **cuticle** protects the tape worm from the host's digestive enzymes.
- Main excretory products are **ammonia** and **fatty acids**.
- **All tapeworms** are **hermaphrodites**, and a complete reproductive system occurs in each mature proglottid.

Table : Some important examples

	Example	Important notes
		Class - Turbellaria
1.	*Dugesia* (*Planaria*)	• Has **great power of regeneration** • Carnivorous, omnivorous and hermaphrodite, Gregarious (live in groups) • Eggs are **ectolecithal** *i.e.,* yolk is deposited on the outside, direct development
	If *Planaria* is cut across into two, three or more parts, each part regenerates into a complete and normal individual. Regeneration, thus, involves two complementary processes, viz., *epimorphosis*, in which the missing parts are formed, and *morphollaxis,* in which the original parts are fit to function with regenerated parts in the new individual. A note-worthy observation is that a piece from the middle always regenerates a head towards its anterior side and tail towards its posterior side. In other words, each piece maintains its original *linear polarity.* This can be explained by the theory of metabolic or axial gradient by C.M Child .The theory holds that **metabolic activity is highest in head and gradually decreases towards the tail end**.	
		Class - Trematoda
2.	*Fasciola hepatica* (Sheep liver fluke)	• Digenetic endoparasite. Primary and secondary host are **sheep** and **snail** (*Limnaea* or *Planorbis*) respectively. • **Laurer's canal** is present and **acts as sperm duct**. During breeding season it serves as vagina during copulation (which take place in bile ducts of hosts) and receive the sperms. • Hermaphrodite, hence **cross fertilization is preferred** • **Correct sequence of various larva** : **miracidium** (ciliated, free swimming stage) → **sporocyst** (elongated sac like) → **redia** (elongated, cylindrical) → **paedogenesis** → **cercaria** (shows close resemblance with the adult fluke) → **metacercaria** (juvenile fluke, also called **marita**) • **Miracidium** is the stage when it infects the intermediate host and primary host is metacercaria. • Causes **liver rot or cirrhosis (fascioliasis)**
3.	*Schistosoma* (Blood fluke)	• It is dioecious with well defined sexual dimorphism • Lives in hepatic portal vein of human body vessels of urinary bladder • **Female** permanently **lodged in Gynaecophoric canal of male** • Life cycle involves single intermediate snail host • **Digenetic**, **primary host** is **man** and **secondary host** is **snail** • **Different larval stages - miracidium** → **sporocyst** → **cercaria** (no redia and metacercaria stage) • Infection causes **schistosomiasis** or **bilharziasis**, symptoms include skin rash bronchial cough, anaemia, abdominal pain, diarrhoea.
4.	*Elonorchis sinensis* (Chinese liver fluke)	Life cycle involves two intermediate hosts - a fresh water snail and a fresh water fish.
		Class - Cestoda
5.	*Taenia solium* (Pork tape worm)	• Endoparasite in small intestine of human beings. • Digenetic. **Primary host** is man and **secondary or intermediate host** is pig or cattle. • **Larval stages - oncosphere**, **hexacanth** (with six hooks) and **cysticercus** (bladder worm). • Secondary host **acquires infection** by ingesting oncospheres. • Cysticercus is the **infective stage to man**. • Causes **taeniasis disease**.

contd ...

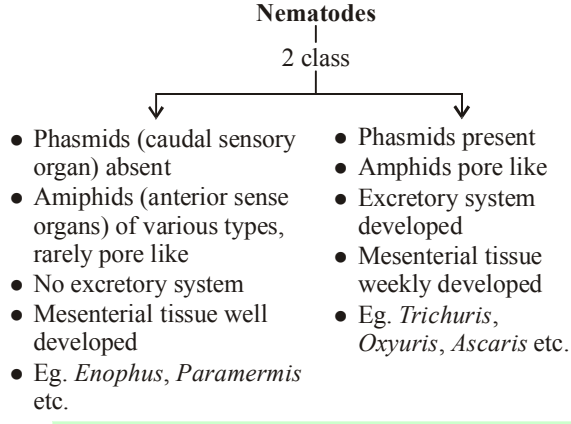
		• Human bladder worm infection is called **cysticercosis**, symptoms include necrosis of brain and epilepsy. Larvae settle in brain. It is caused because of auto infection by antiperistalsis & man is the accidental intermediate host. It is **more dangerous than taeniasis**. • Self fertilization occur in mature proglottids
6.	*Taenia saginata* (Beef tapeworm)	• Inhabits the beaf eating population • Longer than *T. solium* (12m) • Scolex **lack rostellum and chitinous hook** and uterine branches are absent, hence called **unarmed tape worm**. • **Digenetic**, man is **primary host** and **intermediate host** is cattle (sheep) and buffaloes
7.	*Echinococcus* (Hyadit worm or dog tapeworm)	• Endoparasite, primary host (dog, wolf, cat) and secondary host (cattle, sometimes man) • Causes **hydatid cyst** in liver, lungs and other parts
8.	*Hymenolepis nana* (dwarf tapeworm)	Smallest human tapeworm. 3 testes in each proglottids. No intermediate host.

NEMATODES

- Nematodes are commonly referred to as **non-segmented roundworms, threadworms or pinworms.**
- They constitute the **largest phylum of pseudocoelomates group** combined under the **superphylum aschelminthes**.
- The name aschelminthes was proposed by **Grobben** (1910) in place of the older name nemathelminthes.
- Phylum aschelminthes is **divided into 5 classes** : **rotifera, gastrotricha, kinorhyncha, nematomorpha** and **nematoda**.
- **Rotifera** are commonly called **wheel** (corona) **animalcules**.
- These are **microscopic animals** of ponds, lakes & streams, rarely in oceans.
- Body wall thickened into **plates or lorica** into which head may retreat.
- In class rotifera **males are smaller than females**, so, female reproduce parthenogenetically, eg. *Philodina*, *Rotaria*.
- **Gastrotricha** are microscopic & marine animals.
- Body wall have cuticle bearing short spines, eg.- *Chaetonotus*, *Lepidodermella & Macrodasys*.
- Body wall of **kinorhyncha** have spiny cuticle without cilia.
- These are **monoecious** and **gonads are present as paired tubular sacs**, eg.- *Echinoderes* & *Pycnophyes*.
- **Nematomorpha** are commonly called **hair worms**, found in springs, eg- *Paragordius* & *Nectonema*.
- Thick cuticle bearing small papillae is present in the body wall.
- **Digestive system** is **complete in larva** but **degenerate in non feeding adults**.
- **Nematodes** are commonly called as **round worms** which are **aquatic**, **terrestrial or parasitic**.
- Body wall have **cuticle**, **epidermis** & **longitudinal muscles**.
- **Examples of nematodes** are – *Ascaris, Wuchereria, Enterobius, Trichuris* etc.
- The nematodes were originally named nematoidea by **Rudolphi (1808).** They were renamed nematodes by **Burmeister (1837).**
- The **science dealing with the study of worms** especially parasitic flatworms and roundworms is called **helminthology.**
- Nematodes are **bilaterally symmetric, triploblastic protostomes** with a **tube-within-tube plan, organ system level of organization** and **a complete digestive system**.
- Roundworms **have no circulatory or respiratory systems** so they use diffusion to breath and for circulation of substances around their body.
- The **body cavity is a pseudocoel** or false coelom **(persistent blastula),** which lacks the muscles of coelomate animals used to force food down the digestive tract. Nematodes **thus depend on**

internal/external pressures and body movement to move food through their digestive tracts.

- Pseudocoelom contains **hydrolymph** and some cells called **pseudocoelomocytes**.
- The epidermis (may be **cellular** and **syncytial**) **secretes a layered cuticle made of keratin** that protects the body from drying out, from digestive juices, or from other harsh environments, as well as in some forms sporting projections such as cilia that aid in locomotion.
- There are **no circular muscles**, so the body can only undulate from side to side. **Muscles usually are present longitudinal**.
- Digestive system is **complete** with mouth and anus.
- Digestion is mainly **extracellular**, generally feeds on predigested food present in host's intestine.
- **Reserve food** is **in the form of glycogen stored in syncytial epidermis**.
- **Excretion** is brought about by **gland cells or H-shaped intracellular excretory tubes/canals** or both. Some forms have **protonephridia**.
- The animals **possess fixed number of cells & nuclei throughout life** (called **eutely**).
- Nematodes **have a simple nervous system**, with **circumpharyngeal nerve ring** and **six longitudinal nerve cords**. Sensory structures (which are **poorly developed**) at the anterior end are called **amphids,** while sensory structures at the posterior end are called **phasmids.**
- Sexual dimorphism is common.
- Reproduction is **usually sexual.** There is **no asexual reproduction**.
- Males are usually **smaller than females** (often very much smaller) and often **have a characteristically bent tail for holding the female for copulation**.
- During copulation, one or more chitinized spicules move out of the cloaca and are inserted into genital pore of the female. **Amoeboid sperm** crawl along the spicule into the female worm.
- **Eggs** may be **embryonated (infective second stage juvenile** in *Ascaris*) or **unembryonated** when passed by the female, meaning that their fertilized eggs may not yet be developed.
- In **free-living roundworms**, the eggs hatch into larva, which eventually grow into adults; **in parasitic roundworms**, the life cycle is often much more complicated.
- The **early larval stage of nematodes** is called **rhabditiform** or **rhabdioid larva**. It is **generally non-infective**.
- In free-living species, development usually consists of **four moults of the cuticle during growth**.
- Nematodes **commonly parasitic on humans include whipworms, hookworms, pinworms, ascarids**, and **filarids**.
- One form of nematode is **entirely dependent upon the wasps** which are the sole source of fig fertilization. They prey upon the wasps, riding them from the ripe fig of the wasp's birth to the fig flower of its death, where they kill the wasp, and their offspring await the birth of the next generation of wasps as the fig ripens.
- Nematodes are classified into two classes - **phasmida** (eg. *Ascaris, Dracunculus*) and **aphasmida** (eg., *Enoplus*, *Mermis* etc.) on the basis of presence or absence of phasmids (Chitwood 1933).



Plant parasitic nematodes

Plant parasitic nematodes include several groups causing severe crop losses. The most common genera are: *Aphelenchoides* (foliar nematodes), *Meloidogyne* (root-knot nematodes), *Heterodera*, *Globodera* (cyst nematodes) such as the potato root nematode, *Nacobbus*, *Pratylenchus* (lesion nematodes), *Ditylenchus*, *Xiphinema*, *Longidorus*, *Trichodorus*. Several phytoparasitic nematode species cause histological damages to roots, including the formation of visible galls (Meloidogyne) which are useful characters for their diagnosis in the field. Some nematode species transmit plant viruses through their feeding activity on roots. One of them is *Xiphinema index*, vector of GFLV (Grapevine Fanleaf Virus), an important disease of grapes.

Table : Some important examples

	Examples	Important notes
1.	*Enterobius vermicularis* [*Oxyuris* (Pin worm or seat worm)]	• Found in large intestine and appendix. **Monogenetic parasite**. • Causes **enterobiasis** or oxyurasis characterised by anal itching, appendicitis, nervous problem. • **No intermediate host**
2.	*Ascaris lumbricoides* [Roundworm] There are **three types of migration** by *Ascaris* larvae–*primary*, *secondary* and *aberrant migration*. **Primary migration** (from wall → hepatic → portal → liver → hepatic vein → heart → pulmonary artery → lungs) **Secondary migration** (from lungs back to intestine of the host *i.e.*, lungs → bronchi → trachea → pharynx → gullet → oesophagus → stomach → intestine) **Aberrant migration** (from lungs to brain, spinal cord, eyes etc.)	• Most common, monogenetic **intestinal parasite of humans**. • Have **telogonic gonads** which means only the anterior part of testis is functional. Female *Ascaris* is **didelphic** (has two ovaries) • Causes ascariasis, **characterised by** anaemia, diarrhoea, pneumonia and bronchitis, they are found world wide. • **Common in children**. • **Male is smaller** than female **with curved tail**, two pineal setae & cloaca. • Mouth is terminal in both & **triradiate** (surrounded by three denticulate lips, one median dorsal & two ventrolaterals) • **Embryonic development takes place in soil** (due to low temperature, more oxygen and suitable moisture) • Larva of first stage is not infective, **second stage larva** (rhabditiform) **is infective**. • **Transmission** of infective stage through embryonated egg takes place **by contaminated food and water**. • Life span in host is of **9 - 12 month**. • **Most pathogenic larva** is the **fourth stage in lungs**.
3.	*Ancylostoma duodenale* [Hookworm]	• Found in the human intestine. **Monogenetic**. • Causes itching and inflammation of skin, anaemia, retarded physical and mental growth. Migratory larva **causes pneumonia** because of foreign body larva reaction while it is in alveoli of lungs. • Their larvae enter the human body by boring the skin through feet. • Infective juvenile stage is **filariform larvae** (**non feeding**).
4.	*Dracunculus medinenis* [Guinea worm or madina worm of fiery serpent]	• Largest nematode parasite. Gravid female are **found in the subcutaneous tissues** of body and **form blisters**. • Female is **long** and **male is short**. • **Intermediate host** is *Cyclops* or water flea like *Mesocyclops* and *Themocyclops* and **primary host** is **man**. • Parasite causes itching, eosinophilia, nausea and vomiting.
5.	*Wuchereria bancrofti* [Filarial worm]	• **Found** in the **lymph vessels**. • Parasite is **digenetic** having secondary host - *Culex fatigens*, *Culex–pipens* and *Culex unique fasiatus*. • Causes **lymphatic filariasis** or **elephantiasis** by blocking lymphatic vessel and glands. Oedema typically begins in the ankle and progresses to foot and leg. • **Third stage juvenile** is **infectious stage**. • Larva is called **microfilariae** which **show day and night periodicity**. • By day they live in large deep seated blood vessels, but at night or during sleep they come into superficial or peripheral vessels in skin to be sucked by nocturnal mosquitoes.

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6.	*Loa loa* [The eye worm]	• Found in the subcutaneous tissues of eyes. Its **intermediate host** is *Chrysops*. • Causes **lymphatic conjunctivitis**.
7.	*Trichinella spirialis* [Trichina worm]	• **Intestinal endoparasite** of human. • Causes **trichnosis**, characterised by muscular pains and pneumonia or trichiniasis. • **Transmitted by eating infected pork**. **Intermediate host** is **pig or cattle**.
8.	*Trichuris trichura* [Whip worm]	• **Found** in the **caecum and appendix**. Monogenetic. • Causes **trichiurisis**, **characterized by** anaemia, bloody stools and pains.

ANNELIDA

- **Lamarck**, coined the term annelida for ringed animals.
- The annelida **comprising the metamerically segmented worms** including the well-known earthworms and leeches.
- **Metamerism** is the division of body into similar parts which is evident in the external feature of worms.
- Metamerism **increases the efficiency of body movement** by allowing the effect of muscle contraction to be extremely localized, and it makes possible the development of greater complexity in general body organization.
- Each segment is marked externally by one or more rings, called **annuli**. Each segment also has an outer layer of **circular muscle** underneath a thin cuticle and epidermis, and a system of **longitudinal muscles**.
- In **earthworms**, the **longitudinal muscles are strengthened by collagenous lamellae**; the **leeches have a double layer of muscles** between the outer circulars and inner longitudinals.
- Anterior to the true segments lies the **prostomium** and **peristomium**, **which carries the mouth**, and posterior to them lies the **pygidium, where the anus is located**.
- They are **found in most wet environments**, and **include many terrestrial**, **freshwater**, and **especially marine species** (such as the polychaetes), **as well as some which are parasitic or mutualistic**.
- Annelids are **triploblastic protostomes with a coelom** (**or coelomate**), **closed circulatory system** and **true segmentation**.
- Annelids are the **first animals to have a closed circulatory system**.
- Annelids **have organ system level of organisation.**
- During evolution, **true coelom appeared for the first time in annelids,** which is **formed by the splitting of mesoderm.** Therefore it is **schizocoel.**
- Oligochaetes and polychaetes typically have spacious coeloms; **in leeches, the coelom is largely filled in with tissue** and **reduced to a system of narrow canals**; **archiannelids may lack the coelom entirely**.
- The coelom is divided into a sequence of compartments by walls called **septa**. In the most general forms each compartment corresponds to a single segment of the body, which also includes a portion of the nervous and circulatory systems, allowing it to function relatively independently.
- **Respiration** is **cutaneous**, therefore annelids **must live in moist and aquatic environments**. Some times gases are exchanged through specialized gills or modified parapodia.
- There is a **tube within a tube plan** of the body because animals of this phylum have a wide, fluid filled body cavity containing other viscera that deals with internal functions between body wall & alimentary canal. Body wall (outer tube) and alimentary canal (inner tube) are specialised to their respective functions. Alimentary canal starts with mouth & ends with anus to ingest and egest food respectively. Whereas outer tube forms protective structures.
- The digestive system is a **complete tube with mouth & anus** at both ends.
- The **vascular system includes a dorsal vessel** conveying the blood toward the front of the worm,

and a **ventral longitudinal vessel** which conveys the blood in the opposite direction. The two systems are connected by a vascular sinus and by lateral vessels of various kinds, including in the true earthworms, capillaries on the body wall.

- Blood is **red due to presence of** respiratory pigment **haemoglobin or erythrocruorin** dissolved in plasma. **RBC's are absent**.
- Circulation (**open type**) is **caused by peristalsis or activity of heart**.
- **Excretory system** consists of metamerically disposed coiled tubes called **nephridia** (ectodermal in origin).
- All annelids **except leeches** also have **chitinous** hair-like structures, called **setae** (used to grip the ground during locomotion), projecting from their cuticle. Sometimes the **setae** are located on paddle-like appendages called **parapodia** (among polychaetes).
- **Hydrostatic pressure** is maintained across segments and **helps maintain body rigidity, allowing muscle contractions to bend the body without collapsing it**.
- The **nervous system** has a **solid, ventral nerve cord** from which lateral nerves arise in each segment.
- Annelids **may be monoecious or dioecious**. Larva may or may not be present, if present they are of the **trochophore type**.
- Annelids can reproduce **both sexually and asexually by fission**.
- Sexes separate, **trocophore** larva when present during development, undergoes, metamorphosis to reach the adult stage.
- Mostly **cross fertilization** takes place. They are **oviparous** and the eggs are laid in ootheca/cocoons/ egg case.
- **Clitellum** present in bisexual annelids is **useful in the formation of cocoon**.
- Fertilization is **external** except in *Hirudinaria*.
- **Classification of annelida is based on position & arrangement of setae** when present, **absence and presence of sense organs**.
- Annelida is divided into **four classes – archiannelida, polychaeta**, **oligochaeta** and **hirudinea**.
- Archiannelida are all **marine, small with internal segmentation & no parapodia & setae,** eg. *Dinophilus, Polygordius*.
- In the development of archiannelida, **lovens larva** is seen.
- **Polychaeta** is the **biggest class of phylum annelida**, eg *Nereis*, *Aphrodite* etc
- **Nectochaeta** is **free swimming larva** of some polychaetes which bears rings of cilia and 3 pairs of parapodia. Late trochophore larva of *Nereis* resembles nectochaeta.
- **Oligochaeta** are commonly called **earthworms**, mostly terrestrial, some in fresh water.
- *Pheretima* is the **biggest genus in the class oligochaeta**.
- **Hirudinae** are commonly called as **leeches**, eg *Hirudu* and *Hirudinaria*.
- These are **terrestrial**, **fresh water** and **marine ectoparasitic**, **blood sucking** or **carnivorous animals**.
- **Other examples of annelida** are *Drawida grandis* (longest earthworth of India); *Eunice* [pacific palolo worm (exhibit lunar periodicity)]; *Glycera* (smooth blood worm); *Sabella* (peacock worm); *Serpula* (fan worm); *Eutyphoeus* (earthworm of gangetic plains); *Ozobranchus* (leech with gills); *Haemadipsa* (land leech).

Table : Some important examples

	Example	Important notes
	Class - Polychaeta (Almost all marine, occur in greatest abundance near the seashore; locomotary structures and parapodia)	
1.	*Aphrodite* (Sea mouse)	During movement body colour changes from gold to peacock blue.
2.	*Polynoe* (Scaleworm)	• Close ally of *Aphrodite*. • Several species are bioluminescent, luminescent material is secreted by the gland cells located on surface of elytra.

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3.	*Chaetopterus* (Paddle worm)	• Lives in U-shaped parchement tubes. • Smallest oligochaetes.
4.	*Arenicola* (Lungworm or lobeworm)	• Lives in mud or sand in U or J-shaped burrows, lined by mucus. • Used as fish bait.
5.	*Neries* (Sandworm/ragworm/clamworm)	• Lives in U-shaped burrows in tidal areas of seashores. • Has chitinous jaw for capturing prey. • **Sexual stage of animal** is called **heteronereis** which develops in response to hormones and possesses enlarged eyes, swimming foliaceous parapodia and swollen gonad containing posterior half of body called epitoke (normal anterior part is called atoke). Trochophore larva.
	Class - Oligochaeta (Commonly called earthworms, mostly terrestrial, hermaphrodites, no larval stages and therefore no metamorphosis)	
6.	*Pheretima posthuma* (*Earthworm*) [For *more detail* refer *chapter Morphology and Anatomy of Animals*]	• Common earthworm of India, hermaphrodite. • **Ureotelic** under normal soil condition but urine contains small quantities of ammonia and creatine. They are **ammonotelic in water saturated soil**. • Lives in burrow in moist human rich soil. • Called **Nature's of ploughman**, cross fertilization.
7.	*Tubifex* [Blood worm (because of its bright red colour)]	• Reproduces only sexually. • Helps in purification of polluted fresh water. • It can carry on anaerobic respiration.
	Class - Hirudinea (Commonly called leeches; sanguivorous, botryoidal tissue present)	
8.	*Hirudinaria granulosa* (Cattle leech) The process of letting out blood by using leech is called **phlebotomy**.	• Sanguivorous (feeds on blood). Ectoparasite on cattle and humans. • Hermaphrodite. • Possess an anticoagulent - **hirudin or anticoagulin.** Hirudin is secreted by the salivary glands & prevents coagulation of blood of host thus ensuring a continous supply of blood. • Coelom is filled with **botryoidal tissue**. Botryoidal tissue is a pigmented and richly vascular masses of connective tissue & excretory in function.
11.	*Pontobdella* (Skate sucker or marine leech)	*P. muricata* **lays velvetty eggs in empty shells of molluscs** and mount to guard over them for more than 100 days till they hatch.

ARTHROPODA

- Phylum arthropoda (means jointed legs) is a **group of bilaterally symmetrical, triploblastic, tube-within-tube plan, organ system level of organisation, metamerically segmented** (with appendages on each segment) **animals**.
- Arthropods are the **largest phylum of animals** and **include the insects, arachnids**, **crustaceans**, and others.
- Arthropods are **common throughout marine, freshwater, terrestrial**, and **even aerial environments**, as well as including various symbiotic and parasitic forms.
- Body is often divided into **head, thorax** and **abdomen.**
- Head and thorax may be united to form **cephalothroax**.
- **Possess jointed appendages** which were **used for locomotion**, **feeding**, **defence** and **sensory purposes**.
- Appendages may be **uniramous** (have one single branch or ramus) or **biramous** (has two primary

rami) and may be secondarily lost or highly modified.

- Most **distinctive characteristic** of arthropod is their **exoskeleton** containing chitin, mucopolysaccharides and proteins, often strengthened by $CaCO_3$ (eg. many crustacea and millipedes).
- Exoskeleton is made up of a **non-living cuticle** (secreted by epidermis) which does not grow and must be shed at intervals (called **molting or ecdysis**) periodically and grows larger.
- Molting occurs 4-7 times before becoming an adult.
- Exoskeleton serves the purpose of forming an **armour against enemies**; a **protection against dessication** and a **framework for support** of the softer parts and for **muscular attachment**.

Cuticle

Formed of three layers

Innermost layer	Intermediate layer	External layer
Endocuticle	**Exocuticle**	**Epicuticle**
Flexible and composed of chitin.	Rigid and high in protein.	Thin, contains a waxy material and serves to prevent transmission of water and other substance; antibacterial.

Procuticle

- Muscles are **striated or striped** which are attached to special anchorages on the cuticle and are capable of rapid action (*i.e.* allows for faster contraction times). Muscles insert into the procuticle and are generally paired antagonistically as flexors and extensors.
- The **success of arthropods is related to their** hard exoskeleton, segmentation, and jointed appendages.
- **Respiratory system** is **well developed** and respiration **occurs through body surface, gills, trachea** or **book lungs**.
- **Aquatic arthropods use gills to exchange gases**. These gills have an extensive surface area in contact with the surrounding water.
- **Terrestrial arthropods** have **internal surfaces that are specialised for gas exchange**.
- Insects and most other terrestrial species have tracheal systems: air sacs leading into the body from pores called spiracles in the epidermis cuticle.
- Arthropods have **complete digestive system with mouth parts** modified and adapted for different methods of feeding.
- Arthropods have an **open or lacunar circulatory system**.

Arthropoda — 4 subphyla

Onychophora
- Worm like
- Primitive arthropoda
- Excretory organ nephridia.
- Eg. *Peripatus* (**connecting link** between annelida and arthropoda)

Trilobitomorpha
- Comprises a wholly extinct group of primitive marine arthropods
- Represent fossil arthropod
- Eg. *Triathrus*.

Chelicercata

Body is divided into cephalothorax and abdomen.

divided into 2 classes

Merostomata
- Aquatic, extinct
- Eg. *Eurypterus* and *Limulus* (**living fossil**)

Arachnida
- No antennae, lacking compound eye
- Most with a cephalothorax and abdomen. Some with a single body region.
- Most are terrestrial or aquatic.
- Most are predacious
- Air breather
- Eg. Spiders, ticks, mites, scorpions, horseshoe crabs.

Mandibulata

Crustacea
- Dominant arthropoda of sea
- Two pairs of antennae
- Two body regions (head and thorax combined into the cephalothorax)
- One pair of appendages per body segment. Appendages terminate in pinchers.
- Primarily an aquatic group, respiration is by gills even in terrestrial species.
- Excretion through green glands
- Some very unusual groups, for example, barnacles (*Sacculina*) and water fleas (*Daphnia*)
- Egs. Shrimp, lobsters, crabs and cyclops etc.

Myriapoda

divided into 3 classes

divided into 2 classes

Diplopoda
- Does not have poisonous claw.
- Single pair of antennae.
- Two body regions, head and body.
- Body segments fused in pairs, each apparent segment composed of two embryonic segments.
- Two pairs of appendages per apparent body segment, extending out from sides of body
- Usually herbivores or detritivore and slow moving.
- Eg. Millipedes (*Julus*)

Chilopoda
- Single pair of antennae
- Two body regions, head and body
- One pair of legs per body segment
- Appendages of first body segment modified into poisonous claws.
- Almost all predaceous and fast moving.
- Eg. Centipedes (*Scolopendra*)

Insecta (Largest class)
- Single pair of antenna
- Three body regions (head, thorax, and abdomen)
- Three pairs of legs (adult insect), one on each segment of thorax (hence called hexapoda)
- Most adult insects with wings.
- Respiration by trachae.
- Excretion by malpighian tubules.
- Development either hemimetabolous (incomplete metamorphosis, no pupal stage) or holometabolous (complete metamorphosis, pupal stage)
- Egs. Cockroach, *Apis*, *Bombyx* etc.

- The perivisceral body cavity is called **haemocoel** as it is full of **haemolymph** (blood). The **true coelom is restricted to the gonads**.
- Haemolymph containing **haemocyanin**, a copper-based oxygen-carrying protein, is propelled by a series of hearts into the body cavity where it comes in contact with the tissues.
- The heart is dorsal in position and bears, laterally paired openings called **ostia**. Blood capillaries are absent, blood flows through ill defined spaces (sinuses).
- The **blood is colourless** in insects.
- In crustacea the **blood is coloured blue** due to the presence of a respiratory pigment haemocyanin.
- Unlike vertebrates and some annelids, the **blood of an arthropod does not usually carry oxygen**.
- **Excretion** is brought about usually by **green glands in aquatic forms** and **malpighian tubules in terrestrial animals**. (Nephridia occur in onychophores).
- Excretory product is **ammonia/urea in aquatic forms** and **uric acid in terrestrial species**.
- **Nervous system** has **paired pre-oral ganglia** (cerebral and suboesophageal), **connectives, commissures** and a **double nerve cord** having segmented ganglia and nerves.
- **Various sense organs** found in arthropods include **antennae** (jointed feelers, perception of odour), **sensory hair** for touch, **chemoreceptors** (taste receptors located in feet in insects, labium and maxillary palps), **sound receptors** (chirping crickets and cicadas, anal circi in cockroach), **simple and compound eyes**, **statocysts** (for balancing), etc.
- **Antennae are absent in arachnids**.
- The animals are **unisexual/dioecious** and **exhibit the phenomenon of sexual dimorphism**.
- **Fertilization** is **internal in terrestrial forms** and **external in aquatic forms**. The animals are **oviparous**.
- Ovovivipary is occasional, *e.g.*, scorpion.
- **Eggs** are **macrolecithal, cleidoic** and **centrolecithal**.
- Most of the arthropods possess an **endocrine system** which consists of **neurosecretory cells in the brain, at the base of compound eyes** and **glands in the thorax**.
- Hormones **control reproduction, moulting** and **metamorphosis**.
- **Development** can be **direct (without larval stages) or indirect (with larval stages)**.
- **In direct development**, the **young resembles the adults** and occur in the same habitat. In **indirect development**, **independent larval stages occur** which often show different feeding habits, live in different habitats and **do not resemble the adults**. Metamorphosis occurs in such cases.
- Metamorphosis in insects is promoted by a hormone called **ecdysone hormone**.
- Parthenogenesis is also met in some insects like **honey bees**.
- Arthropoda is **divided into 4 subphyla** - onychophora, trilobitomorpha, chelicercata and mandibulata.

Table : Some important examples

	Examples	Important notes
	Class - Onychophora (Most primitive arthropods)	
1.	*Peripatus* (Walking worm)	Connecting link between annelida and arthropoda.
	Class - Arachnida	
2.	*Palamnaeus* (Indian scorpion)	• Body is divided into prosoma, mesosoma and metasoma. • **Venomous arthropod** and feeds on insects, worm, spider etc. Male is smaller than female. • Viviparous, respiration through book lungs. Shows courtship.
3.	*Aranea* (Spider)	• Chelicerae are **provided with poison gland and pedipalps in male functions as copulatory organ**. • Spinnerets (spinning organs) produce silken threads for construction of spider web to trap insects etc. • Male spider are commonly smaller. • **Common spiders are :** trapdoor spider (*Pachlomerus*); funnel web spiders (*Agelena*); wolf spider (*Lycosa*); oral web spiders (*Argiope*); black window spider (*Latrodectus*); venomous spider (*Lactodectus meactans*).

contd ...

4.	*Limulus* (King crab or Horse shoe crab)	It is a **living fossil** and large sized marine arthropod.
5.	*Ticks*	• Minute creature, but **larger than mites**. • **Ectoparasites** of vertebrates and provided with blood sucking mouth parts. • Common ectoparasite tick is cattle tick (*Boophilus micropus*). • Spread diseases like **Rocky mountain fever** besides causing irritation.
6.	*Sarcoptes scabie* (Human itch mite)	• Minute sac like animal without body division. • Free living as well as parasites on both vertebrates and invertebrates. • **Causes scabies** in human beings. • Dust mites (*Dermatofagodes farinea* and *D. pteronysiunus*) causes 45% of allergies. It feeds on dandruff, skin epidermis, hair etc.
	Class - Crustacea (Dominant arthropods of sea)	
7.	*Cyclops* (Water flea or cyclops)	• Possess **single median eye** (hence one eyed animals) • **Intermediate host of guinea worm and blood tape worm.**
8.	*Daphnia* (Water flea)	• Fresh water, laterally compressed. • Single compound eye and two nuchal (probably olfactory) organs are present. • Formed from fertilized eggs give to 4 - 6 generations of females parthenogenetically. • Cyclomorphosis (seasonal changes) occur.
9.	*Euspagurus* (Hermit crab)	• Lives inside molluscan shells. • Hermit crab and sea anemone often **forms a close association, termed commensalism**. Sea anemone protects the hermit crab by keeping its enemies away by its offensive odour and unpalable taste. In return hermit carb carries the sea anemone from place to place, providing varieties of food.
10.	*Palaemon* (Prawn)	Nocturnal, omnivorous, fresh water but bottom feeder. Abdomen ends in pointed telson. Indian marine or tiger prawn is *Penaeus*.
11.	*Astacus* (Cray fish)	• Resembles prawn. Secretive, noctural and carnivorous. • Greatly priced for their meat.
12.	*Sacculina* (Root headed barnacle)	Parasite on crab causing parasitic castration. Shows retrogressive metamorphosis.
	Class - Myriapoda	
13.	*Scolopendra* [Centipede (or hundred leggers)]	• Fast moving, carnivorous and nocturnal. • **First pair of legs** are **poison claws**.
14.	*Julus* [Millipede (or thousand leggers]	• Sluggish, timid and secretive. • When touched or lifted they curl up in flat spiral like a watch spring. • Mostly herbivorous or saprophytic. • **Stink or odoriferous gland is present**.
	Class - Insecta	
15.	*Periplaneta americana* (Cockroach) (*For more detail refer chapter Morphology of animals*)	Terrestrial arthropod, nocturnal (in activity), omnivorous, and shows cannabalism. Unisexual and shows sexual dimorphism. Undergoes paurometaboly (gradual metamorphosis) by 6-7 months. Indian cock-roach- *Blatta orientalis* is small sized and female *Blatta* has vestigial wings.
16.	*Lepisma saccharina* (Silver fish)	• Glistening silvery white, fish like body (wingless). Feeds on starchy substances. Chewing type mouth parts. • Nocturnal, commonly occurs amongst book, clothes, photoframes etc.

contd ...

17.	*Mantis religiosa* (Praying mantis)	• Carnivorous insects. Camouflaged in its green surroundings. • **Female eats up the male after copulation.**
18.	*Carausius* (Stick insect of tropical forest)	• Shows **mimicry**, mimics a twig to escape detection by enemies. • Also called **walking stick**, herbivorous. • Shows regeneration and parthenogenesis.
19.	*Phyllium scythe* (Leaf insect)	• Resembles a leaf. • Shows **mimicry with dicot leaf**.
20.	*Schistocerca gregaria* (Locust)	• Migratory allies of grass hopper. • Nymph are called **hoppers**. • **Swarming** occurs in them due to poor vegetation in their natural habitats.
21.	*Microtermes obesi* (Termites)	• Popularly called **white ants** but they are neither ants nor white in colour. • Cellulose is common food for which *Trichonympha* (a zooflagellate) helps in their digestion. • Built nest called **termitarium**. • Known to secrete special odour substances which serve as guide lines for their back journey into the nest.
22.	*Poecilocerus pictus* (Grass hopper)	• Short horned diurnal insect common on *Calotropis* plant. • Male grasshopper produces sound by rubbing edges of wings etc. • **Largest grass hopper** is *Silicofern grandis* (wings span 2.5).
23.	*Tachardia tacca* (Lac insect)	• **Scale insect with separate sexes. Produces lac**. • Lac, resin like substances, is **secreted by larvae and female lac insect** on a number of forest trees (called **stick lac**). • **India is biggest producer of lac**.
24.	*Bombyx mori* (Silk moth or silk worm moth) **Diseases of silkworm** • **Pebrine or pepper disease** - *Nosema bombycis* (protozoan parasite). • **Muscardine** - Fungal disease caused by *Isari farinosa, Spicaria pracina* etc. • **Flacherie** - *Bacillus bombycis* and *Streptococcus bombycis*. • **Grasserie** - Referred to silkworm jaundice, caused by *Borrelina* virus *bombycis*.	• Also called **mulberry silk moth**. Adult moth do not feed. Females are larger than male. Salivary gland (= labial gland) is **modified to form silk gland of larva**. • Male moth **dies soon after copulation**. • Larva is called **caterpiller or silkworm**. • **Life history** include **egg, larva, pupa and imago**. • **Produce silk** (a natural fibrous substance containing fibroin and sericin proteins) **from coccons** (pupa, chrysalis). • Silk is extracted by killing cocoon (called **sericulture**). Silk thread is formed of two proteins - **fibroin** and **sericin**. • **Different species producing silk** are – Mulberry silkworm – *Bombyx mori* Tasar silkworm – *Antheraea paphia* Muga silkworm – *Antheraea assama* Eli silkworm – *Attacus ricinii*
25.	*Musca domestica* (House fly)	• **Active in warm months** and **inactive during winter**. • Metathorax has **halteres for balancing**. Larva is called **maggot**. • **Transmit number of diseases** like conjunctivitis, trachoma, plague, leprosy, TB etc. • Show **complete metamorphosis** • **Stage in life history** : **Egg - Larva** (maggot) - **Pupa - Imago** (adult). • Maggot moults twice thus housefly has three larval instars. • **Myasis** is a **disease caused by maggots**.
26.	*Sympetrum hypomelas* (Dragon fly)	• Often known as **mosquito hawks** as mosquito form their main diet. • They are prehensile.

contd ...

<table>
<tr><td></td><td></td><td>• Copulation occurs in flight.
• Both the aquatic nymph (called naiads) and adult are predaceous.</td></tr>
<tr><td>27.</td><td>Apis dorsata
(Honey bee)</td><td>• Social insect lived in colony which contains workers (sterile diploids females), queen (fertile diploid females) and drones (fertiles haploid males).
• Queen develops from fertilized egg and a larva fed on royal jelly, drone develops parthenogenetically and worker bees develops from fertilized eggs and make and repair hive.
• Queens live for five years, drone have short life span and worker bees live for a few weeks only.
• Honey bee exhibit round and waggle dance to communicate for location of food.
• Queen mates only once in a life time and store sperm in her spermatheca. Drone and virgin queen takes part in nuptial flight.
• Royal jelly, given to queen, is produced from pharyngeal gland of workers.
• Workers have pollen collecting apparatus, honey storing mechanism and wax secreting glands (in abdomen).
• Collects honey, secrete bee-wax. Culturing honey bee is called apiculture.</td></tr>
<tr><td>28.</td><td>Mosquito
Table : Diseases caused by mosquitoes<table><tr><th>Disease</th><th>Mosquito</th></tr><tr><td>Malaria (Plasmodium)</td><td>Anopheles female</td></tr><tr><td>Filariasis (Wuchereria)</td><td>Culex female</td></tr><tr><td>Encephalitis (Virus)</td><td>Culex and Aedes female</td></tr><tr><td>Denuge fever (Virus)</td><td>Aedes female</td></tr><tr><td>Yellow fever (Virus)</td><td>Aedes female.</td></tr></table></td><td>• Small nocturnal two winged insects.
• Mandibles are absent in males, therefore, male mosquitoes, usually feed on flower sap on nectar while female feeds on blood of animals and human.
• Because of their blood sucking adaptation females are medically important as carrier of viral, bacterial and protozoan infections.
• Pedicel of antennae has Johnston's organ for percieving vibrations including those of sounds.
• Larva of mosquito is known as wriggler (3-4 days life span) & pupa is called tumbler (2-7 days life span).
• Sex of mosquitoes can be determined by the form of the antennae and maxillary palps.
• Common mosquitoes are Anopheles, Culex and Aedes. Anopheles and Culex can be easily identified by their sitting position. (Culex - body held parallel to surface while sitting, Aedes - body held parallel to surface while sitting with black and white striped body, Anopheles - body held at an angle to the surface, dark spotted wing.)</td></tr>
<tr><td>29.</td><td>Cimex lectularius
(Bed bug)</td><td>• Nocturnal ectoparasite.
• Hind wings are absent. Piercing and sucking mouth part.</td></tr>
<tr><td>30.</td><td>Pediculus humanus
(Human louse)</td><td>• Wingless flat insect. Ectoparasites. Eggs are called nits.
• Carry germs of typhus fever. Piercing and sucking mouth parts.</td></tr>
<tr><td>31.</td><td>Xenopsylla cheopis
(Rat flea)</td><td>• Ectoparasite of rats and humans.
• Transmit Pasteurella or Yersinia pestis or germs of bubonic plague from rats to humans.</td></tr>
<tr><td>32.</td><td>Aphis brassicae
(Cabbage aphid)</td><td>Plant pests. Secrete honey dew. Called 'ant cows'.</td></tr>
<tr><td>33.</td><td>Beetles</td><td>Occurs in almost all types of habitat. Hard bodies insects with heavy cuticle. Complete metamorphosis. Larva is called grubs. Eg. Lady bird beetle (Cocinella septupunctate) etc.</td></tr>
</table>

MOLLUSCA

- **Mollusca** is the **second largest phylum** after the arthropods & **includes predominantly marine species**.
- The molluscs includes a variety of familiar animals well-known for their decorative shells or as seafood. These range from tiny snails, clams, and abalone to squid, cuttlefish and the octopus (which is considered the most intelligent invertebrate).
- The **giant squid**, which until recently had not been observed alive in its adult form, **is the largest invertebrate**; although it is possible that the colossal squid is even larger.
- The scientific study of molluscs is called **malacology** and the study of shell of mollusca is called **conchology**.
- Molluscs are **triploblastic**, **bilaterally symmetrical, schizocoelic & unsegmented protostomes**.
- Mollusca **refers to the bivalve shell** and the **soft bodied animals within the shell**.
- The body is often divided into a **head** with **eyes or tentacles**, a **muscular foot** and a **visceral mass housing the organs** and **mantle**.
- Most molluscs have a **well-developed head**, containing high concentration of sensory and nervous functions.
- Some molluscs, like the cephalopods, have complex, sensitive eyes. Also located in the head is the **mouth region**, with the **radula** (a rasplike feeding organ present in many molluscs).
- Radulae are diverse within the mollusca, ranging from structures used to scrape algae off rocks, to the harpoon-like structures of cone snails.
- The **radula** is usually toothed, and is **adapted to a wide variety of feeding styles**, including scraping, stabbing, tearing and cutting, depending upon the species.
- Adjacent to the head is the large **muscular foot**, which is formed from the ventral body wall and is **used primarily for locomotion**, and is **often ciliated and covered with mucous glands**. Mucous reduces the friction and creates a surface for gliding and cilia aids in movement. This is **one of the reasons why some believe that molluscs evolved from flatworms** since arthropods completely lack external cilia and so do many annelids.
- The **visceral mass** is housed in the shell in most of the molluscs. It **holds most of the internal organs** and **houses the circulatory** and **digestive systems**.
- The **mantle or pallium** is a sheath of tissue formed from the dorsal body wall. It surrounds the mantle cavity, where the gills or lungs are often housed, and its surface can assist in gas exchange.
- The mantle **also secretes the calcium carbonate shell** in the molluscs that do have a shell. It may be **bivalve** or **univalve, spiral** or **cone like, internal** or **reduced** or **even absent**.
- Mantle **serves a protective function** and often has retractor muscles associated with it that allows the shell to be pulled down over the body.
- The principal body cavity is a blood-filled **haemocoel**.
- They have a **true coelom (eucoelom)**; any coelomic cavities have been reduced to vestiges around the hearts, gonads, and metanephridia (kidney-like organs).
- All species of the phylum mollusca **have a complete digestive tract** that starts from the mouth to the anus.
- **Circulatory system** is mainly of **open type**, but some reduced sinuses are present. Cephalopods **have closed circulatory system**, e.g., squid & octopus.
- **Blood** is **colourless** & **has amoebocytes** & often a respiratory pigment is copper containing **haemocyanin dissolved in plasma**.
- **Respiration** by **gills** (called the **ctenidia**), **lungs or both, sometimes direct**.
- **Excretory organ** is paired **metanephridia** (kidney, organ of bojanus). The excretory matter is **ammonia** or **uric acid**.
- Nervous system consists of **paired cerebral, pleural, pedal and visceral ganglia,** joined by longitudinal and cross connectives and nerves. Ganglia **usually form a circumcentric ring**.
- **Sense organs** include **eyes** and tentacles on head**, statocysts and osphradia** (a chemoreceptor to test chemical nature of water) near the base of gills.
- Osphradium (bipectinate means feather like) **serves as olfactory organ**, arises from the mantle, adjacent to the left nuchal lobe and **situated on the left side of the pulmonary chamber**.
- Osphradium **helps in testing the physical and chemical qualities of entering water** and also helps in the **selection of food material**.

If water is foul, then its (osphradium) entry into the mantle cavity is stopped by the closure of the left nuchal lobe. This sensory structure is **absent in terrestrial pulmonates - the land snails and slugs and nudibranches**. The gills have strong cilia that create the water current into the mantle cavity.

- **Reproduction** sexual, dioecious or monoecious.
- The sex organs of molluscs are housed in the visceral mass.
- The fertilized young develops into a ciliated larva called a **trochophore,** which, in the more advanced molluscs, develops into a **veliger** stage, which then develops into the adult organism.
- **Fertilization** is **generally external**, development is direct or through free larval forms like **trochophore**, **veliger**, **glochidium**, etc.
- **Radula**, **muscular foot**, **mantle** & **highly developed eye** are **unique features of molluscs** which are not found elsewhere.
- Mollusca is **divided into 6 classes - monoplacophora**, **amphineura** (polyplacophora), **scaphopoda**, **gastropoda**, **pelecypoda** (bivalve) and **cephalopods**.
- Species of **monoplacophora** are small, marine, with internal segmentation, possessing conical or cap-shaped shell, e.g. *Neopilina*. Larva is trochophore.
- **Amphineura** or **polyplacophora** have broad foot and a linear chain of eight serially overlapping dorsal shell plates, e.g. *Chiton* (coat of mail shells, sea mouse), *Chaetopleura*.
- **Scaphopoda** are elongated, cylindrical molluscs almost completely enclosed by the mantle, which secretes a single tubular, **calcareous shell** open at each end, **resembling the tusk of some mammals** (like elephant), e.g. *Dentalium* (tusk shell).
- **Gastropods** (stomach-footed mollusc) are **very large and diverse group** sharing the common feature that during the development the visceral hump is rotated through some 180° in an anticlockwise direction called **torsion** (*i.e.* bilateral symmetry in larval stage and asymmetry in adult form). E.g. *Pila* (apple snail), *Limax* (slug), *Helix* (land snail), *Aplysia* (sea hare) and *Cypraea* (cowrie).
- **Pelecypoda** (= lamellibranchia) are **bivalved molluscs**, most of which are **sedentary filter feeders** that depends on ciliary current produced by the gills to bring in food materials.
- **Examples of bivalves** are *Unio*, *Pinctada*, *Teredo*, *Solen* (rajor clam), *Pectan*, *Ostraea.*
- All bivalves are aquatic, with the majority living in shallow marine waters.
- The bivalve body consists mostly of a **muscular foot** in the anterior and a **series of gills** (ctenidia) and a **pair of siphons** (if present) in the centre and posterior part.
- Bivalves **secrete pearls**.
- Shell has three layers -
  - **Periostracum** - Outermost horny formed of chiton like organic substance, **conchiolin**. This layer is **responsible for exterior colouration of the shell and protects the underlying prismatic layer**.
  - **Ostracum (prismatic layer)** - Formed of prisms of $CaCO_3$.
  - **Nacreous or pearly layer** - Innermost layer, secreted by whole outer surface of mantle and formed of alternate transverse of $CaCO_3$ and conchiolin. Also known as **mother of pearl**.
- **Umbo** represents the **oldest part of shell** while **lines of growth** represent intervals between growth stages means indicate the age of individual.
- Unlike the gastropods, they **have no head, no radula** and **very little cephalization**.
- A pearl is **formed of a number of nacreous layers** secreted by nacre-secreting cells of mantle around a foreign body. Nacre is **pearly irridescent material**.
- The pearl of *Unio* is **not of commercial important**.
- **Most valuable pearl** is of *Pinctada margritifera*, commonly called **pearl oyster**.
- **Kokichi mikimota** is commonly called **"father of pearl industry"**.
- **Cephalopoda** (head foot molluscs) are the **most complex of the mollusca**, e.g. *Sepia* (cuttle fish), *Nautilus, Octopus, Loligo*.
- All cephalopoda or siphonopoda are **marine and all are predators**.
- Cephalopods have a **concentrated nervous system** and are among the **most intelligent of the invertebrates**.
- Locomotion is **either by jet propulsion** or **by swimming movements**.
- **Smallest molluscs** is *Ammonicera rota*.
- **Slowest molluscs** is *Helix aspera*/*garden slug*.
- **Largest shell** is *Tridaena derasa*/*giant marine clam*.
- **Largest snail is** *Tethys*.
- **Largest octopus is** *Octopus apollyon*.

In some gastropods and cephalopods, the symmetry is distributed during development and they become asymmetrical. **Asymmetry is there because** these molluscs undergo two processes–

(i) **Coiling -** Coiling in shells occurs in various ways and a portion of the body coils to accommodate within the shell. Often this results in a loss of one or more paired organs such as gills and kidneys. Coiling can be **dextral** (clockwise, towards right) or **sinistral** (anticlockwise toward left). e.g. *Pila*.

(ii) **Torsion -** Torsion or twisting involves a rearrangement of the internal organs from their traditional position by rotation of the digestive system and associated organs up to 180 degrees. **Actual site of torsion is neck tissues and structures within it**. It starts much before coiling.

Table : Some important examples

	Examples	**Important notes**
	Class - Monoplacophora [Only mollusca having segmentation (internal) or metamerism]	
1.	*Neopilina*	**Living fossil**. Only representative of palaeozoic group of molluscs. Also **connecting link between annelida and molluscs**.
	Class - Amphineura	
2.	*Chiton* (Coat of mail shell/sea mouse)	Nocturnal and herbivorous. Have multiple sense organs - osphradia, tactile receptors, taste receptors, otocysts, pit organs etc. A **trochophore larva is present**.
	Class - Scaphopoda	
3.	*Dentalium* (Elephant tusk shell)	• A marine mollusc, living at moderate depth in the sublittoral. • Filamentous captacula are found instead of true tentacles for assisting feeding function.
	Class - Gastropoda	
4.	*Pila* (Apple snail/pond snail)	• Lead amphibious life, **have pulmonary sac for aerial respiration and gill (ctenidium) for aquatic respiration**. • Osphradium of *Pila* is chemoreceptor • Eyes occur over ommatophores. • **Ammonotelic in water** and **ureotelic on land** • Has conispiral shell (coiled along an erect cone) which are either dextral or sinistral • Have **two type of sperm - eupyrene** (small & functional) and **oligopyrene** (large, non-functional)
5.	*Aplysia* (Sea-hare)	Secretes purple fluid when disturbed, which makes the animal invisible to its enemy.
6.	*Patella* (true limpet)	Marine gastropod. Has an aspidobranch gill (feather like 2 rows of gill lamellae.)
7.	*Doris* (Sea lemon)	Nudibranch and marine gastropod.
8.	*Limex* (Grey slug)	Terrestrial gastropod. It is a plant pest and damages seedlings, tender shoots and leaves.
9.	*Helix* (Sand snail)	Herbivorous, nocturnal terrestrial snail which is commonly found creeping over moist and shady place.
	Class - Pelecypoda or Lamellibranchia or Bivalvia	
10.	*Unio* (Fresh water mussel)	**Edible bivalve**. A **'glochidium larva'** (parasitic on fish) and keber's organ are present. Omnivorous and filter feeder. **Marsupium** is enlarged water tube and **act as brood pouch**.

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11.	*Teredo* (Ship worm)	Destructive to wood in sea-water.
12.	*Pinctada vulgaris* (Pearl oyster)	**Secretes precious pearls**. The pearl is **formed as a result of nacreous secretion from the mantle** around a sand particle. Pearl is **formed in about 7 years**.
13.	*Pectan* (Scallop)	Marine, free swimming and swims by clapping movements of shell valves.
14.	*Mytilus* (Sea mussel)	Marine bivalve. **Fixed to rocks** etc by a group of adhesive byssus threads. Development includes glochidium.
		Class - Cephalopoda
15.	*Sepia* (Cuttle fish)	• Shell internal, edible cephalopod of shallow warm sea, carnivorous. • Ink gland is present for escaping from enemy. Larval stage is absent.
16.	*Loligo* (Squid/sea arrow)	• Resembles *Sepia* in broad structures. Edible and fast swimmer in open waters of the sea. • Abundant in pelagic marine environment where they are voracious predators of many organism, especially fish. • Giant squid (*Architeuthis*) is the largest invertebrate.
17.	*Octopus* (Devil fish)	• Bottom dweller, nocturnal and large sized cephalopod. • Its poisonous saliva paralyse its prey. • One of the arms generally the right arms of male is spoon shaped and is called **hectocotylized arm** which is used to transfer sperms into the female mantle cavity.
18.	*Nautilus*	• A tetrabranch cephalopod, has an external coiled and chambered shell. • It floats by secreting gas in the chamber. Animals lives only in last chamber. Active at night and rest on bottom during day.

ECHINODERMATA

- The name echinodermata was coined by **Jacob Klein** in 1938.
- It **constitutes the only major group of deuterostome** (blastopore becomes anus) invertebrates.
- Echinoderms (**literally means spiny** or **prickly skinned**) are a phylum of marine animals found at all depths.
- This phylum **appeared in the early cambrian period** and contains about 7,000 living species and 13,000 extinct ones.
- Echinodermata is the **largest animal phylum to lack any freshwater or terrestrial representatives**.
- Echinoderm is **closely related to the chordates** because the coelom of the animal is made from the digestive tube, not from cell masses like the phyla mollusca, annelida etc.
- Echinoderms are **exclusively marine** and **largely bottom dwellers**, **enterocoelous**, **triploblastic animals**.
- They are **pentameral**, *i.e*, they have fivefold symmetry, with rays or arms in fives or multiples of five.
- Echinoderms possess an **endoskeleton of calcareous plates or spicules embedded in the skin**.
- Endoskeleton of echinoderms is unique in being a mesodermal structure instead of ectodermal, as in other invertebrates.
- Each skeletal element of an echinoderm is actually a single **crystal of calcium carbonate**, very finely branched and structured.

  Echinoderms have been **compared to living, moving castles**. Castles are made of interlocking blocks, with a single main entrance and numerous slit windows for air and for defence. Echinoderm skeletons are made up of interlocking calcium carbonate plates and spines with opening.
- In echinoderms, fine networks of calcium carbonate form a structure, known as **stereom**.
- Between the skeleton plates of echinoderm, a

number of special structure protrude, with which the echinoderm **breaths**, **moves** and **defends itself**. Typically these are **tube feet**, **pedicellaria** and **gills**.

- All echinoderms have a peculiar **hydraulic water-vascular system**, a modified coelom, which **help in locomotion**, **adhesion**, **respiration and food capturing**.
- A set of water filled canals branches from a **ring canal** (a canal encircling the gut).
- The canals lead to **podia**, or **tube feet**, which are sucker like appendages that the echinoderm can **use to move, grip the substrate, or manipulate objects**. **It also acts in capturing of food, respiration etc**.
- These **tube feet** are **external** and **retracted by hydraulic pressure in the water vascular system**.
- **Pedicellaria** are small, snapper-like skeletal elements.
- Pedicellaria **help in the capture and removal of debris and minute organisms** such as larvae. In some starfishes they **also helps in capturing of small prey for feeding purpose**.
- Echinoderms **have a spacious coelom** (an open, fluid - filled body cavity lined with tissues).
- Many starfish have the peculiar ability to feed by **turning the stomach inside out through the mouth**.
- Sea urchins scrape algae from rocks with five large teeth arranged in a structure known as **Aristotle's lantern**.

Aristotle's lantern - It is a characteristic of some members of class Echinoidea (*e.g.*, *Echinus*). In these members, five teeth surrounding the mouth are attached to a masticatory apparatus, called Aristotle's lantern, after its discoverer and because of its resemblance to an ancient Greek ship - lantern. It is situated within the test and projects slightly through the mouth. Sea urchin uses Aristotle's lantern for the **purpose of feeding**.

- Echinoderms (except holothurions) **generally lack respiratory systems**.
- The **circulatory system**, if present **consists of a haemal system** that is **derived from coelomic sinuses**.
- They also **possess an open and reduced circulatory system**, and **have a complete digestive tube (tubular gut)**.
- N**ervous and sensory system** are generally **poorly developed**.
- Poorly developed sense organs **include tactile organs**, **chemoreceptors**, **terminal tentacles**, **photoreceptors** and **statocysts**.
- They have a **simple radial nervous system** that **consists of a modified nerve net** (interconnected neurons with no central organs); **nerve rings with radiating nerves around the mouth extending into each arm**; the branches of these nerves coordinate the movements of the animal.
- No echinoderms has a brain, some however do have ganglia.
- The **sexes are usually separate**. Sexual reproduction typically consists of releasing eggs and sperm into the water, with **fertilization taking place externally**.
- Echinoderms are mostly **dioecious**, gonads large and single or multiple.
- Holothurians possess a **single gonad,** crinoids **lack distinct gonads** while asteroids and echinoids have **multiple gonads.**
- Development is **indirect** through free swimming larval forms.
- Echinoderms **possess remarkable power of autotomy** or **amputation** (breaking off the injured or unduly stimulated body parts) and **regeneration**.
- In class, asteroidea **metamorphosis is extremely rapid**, **taking place in about one hour**.
- Echinoderms can be **divided into five main classes** -
  - **Asteroidea** (e.g., *Asteropecten*, *Asterias* etc.)
  - **Ophiuroidea** (e.g., *Ophiura*, *Ophioderma*)
  - **Echinoidea** (e.g., *Echinus*, *Diadema*)
  - **Holothuroidea** (e.g., *Holothuria*, *Thyone* etc.)
  - **Crinoidea** (e.g., *Antedon*, *Neometra*).
- **Some species of asteroidea** (as for example sea stars) are **unique in their ability to regenerate an entire body from a single arm**.
- All **sea-star are voracious carnivores**, feeding mainly on crustaceans, polychaetes and molluscs and even other small fishes, and injured and dead animal.
- *Platasterias latiradiata* is the **only living species of somasteroidea** belonging to class **asteroidea**.
- **Bipinnaria larva** is the **characteristic of class asteroidea**.
- Bipinnaria larva **transforms into brachiolaria larva** before going to the adult stage.
- The members of class **ophiuroidea** are mostly **detritivores** consuming small bit of organic debris from the ocean floor.

- **Brittle stars** and **basket stars** make up the bulk of the members in the class **ophiuroidea**.
- **Ophiopluteus larva** is the free, swimming larva of brittle stars **belonging to the class ophiuroidea**.
- The members of the class **echinodea lack appendages** and includes **sea urchins** & **sand dollars.**
- **Echinopluteus larva** is the **characteristic of class echinoidea**.
- **Auricularia larva** is the **characteristic of class holothuroidea**.
- **Doliolaria larva** is the **characteristic of class crinoidea as well as holothuroidea**.
- **Sea lilies** (belong to **class crinoidea**) are the **most primitive of echinoderms**.

Table : Some important examples

	Examples	**Important Notes**
1.	*Asterias (Pentaceros)* (Star fish or sea pentagon)	• Has high power of regeneration, unisexual • Digestive glands or pyloric caeca contains four types of cells - **secretory or granular cells** (secrete proteolytic, amylolytic and lipolytic enzymes); **mucous cells** (secretes mucous); **storage cells** (store and reserve food as lipids, glycogen etc) and **current producing cells** (maintains a steady flow of enzymes). • Digestion is extracellular as well as intracellular. • Fertilization is external. • Feeds on molluscs and **destroys pearl oysters**. • Their dried skeletons are crushed and used as fertilizers. • **Largest starfish** is *Pyenopodia hellianthoides* (30 cm in diameter).
2.	*Ophiothrix* (Brittle star or spiny brittle star)	• Mouth is used for both ingestion and egestion. • Jointed parts of arms or ossicles are popularly called vertebrae.
3.	*Echinus* (Sea urchin)	• Live on ocean bottom. • Scrape algae to feed. • Long barbed spines make venom for protection. • **Aristotle's lantern** is present.
4.	*Echinoarachinus* (Sand dollar or sea dollar)	Flattened body. Live in sand along coastlines. Shallow burrowers. Aristotle's lantern is present.
5.	*Cucumaria* (Sea cucumber)	Bottom dweller. Has cloacal respiration and pair of respiratory trees in the coelom.
6.	*Antedon* (Sea lily/feather star)	Superficially resembles a herbaceous plant. Feeds on detritus and plankton.

End of the Chapter