Animal Diversity of Non– Chordates

Paper– I

2025

Dr. V. Uday Kiran

ANIMAL DIVERSITY BIOLOGY OF NON CHORDATES - PAPER – I

Study Material

Edited By

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LOYOLA DEGREE COLLEGE (YSRR), PULIVENDULA – 516 390.

SEMESTER-I

COURSE 1: ANIMAL DIVERSITY-I BIOLOGY OF NON-CHORDATES

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVES:

- To understand the taxonomic position of protozoa to helminthes.
- To understand the general characteristics of animals belonging to Protozoa to Hemichordate.
- To understand the structural organization of animals phylum from protozoa to Hemi Chordata.
- To understand the origin and evolutionary relationship of different phyla from Protozoa to Hemi Chordata.
- To understand the origin and evolutionary relationship of different phylum from annelids to hemichordates.

LEARNING OUTCOMES:

By the completion of the course student will able to –

- Describe concept of animal kingdom classification and general characters of Protozoa
- Classify Porifera and Coelenterata with taxonomic keys
- Classify Phylum Platy & Nemathelminthes using examples, parasitic adaptation
- Describe Phylum Annelida & Arthropoda using examples and economic importance of vermicomposting & economic importance of insects.
- Describe Mollusca, Echinodermata & Hemichordata with suitable examples in relation to the phylogeny

SYLLABUS:

UNIT-I

1.1 Whittakers five kingdom concept and classification of Animal Kingdom.
1.2 Protozoa General Characters and classification up to classes with suitable examples
1.3 Protozoa Locomotion & nutrition
1.4 Protozoa reproduction

Activity: Assignment /Seminar on the above
Evaluation: Marks to be awarded for written and oral presentations

UNIT –II

2.1 Porifera General characters and classification up to classes with suitable examples
2.2 Canal system in sponges
2.3 Coelenterata General characters and classification up to classes with suitable examples
2.4 Polymorphism in coelenterates & Corals and coral reefs

Activity: Assignment /Seminar /Quiz/Project on the above
Evaluation: Evaluation of Written part Evaluation of oral Presentation, Assessment of students in Quiz participation and Ranking - Evaluation of Project Report and oral presentation

UNIT – III

3.1 Platyhelminthes General characters and classification up to classes with suitable examples

3.2 Parasitic Adaptations in helminths

3.3 Nemathelminthes General characters and classification up to classes with suitable examples

3.4 Life cycle and pathogenicity of *Ascaris lumbricoides*

Activity: Assignment /Seminar /Quiz/Project/Peer teaching on the above

Evaluation: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity

UNIT – IV

4.1 Annelida General characters and classification up to classes with suitable examples

4.2 Vermiculture - Scope, significance, earthworm species, processing, Vermicompost, economic importance of vermicompost

4.3 Arthropoda General characters and classification up to classes with suitable examples

4.4 *Peripatus* - Structure and affinities

Activity: Assignment /Seminar /Quiz/Project/Peer teaching on the above

Evaluation: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity

UNIT – V

5.1 Mollusca General characters and classification up to classes with suitable examples

5.2 Pearl formation in Pelecypoda

5.3 Echinodermata General characters and classification up to classes with suitable examples Water vascular system in star fish

5.4 Hemichordata General characters and classification up to classes with suitable examples *Balanoglossus* - Structure and affinities

Activity: Assignment /Seminar /Quiz/Project/Peer teaching on the above

Evaluation: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity

CO-CURRICULAR ACTIVITIES:

- Preparation of chart/model of phylogenic tree of life, 5-kingdom classification
- Visit to Zoology Museum or Coral Island as part of Zoological tour
- Charts on polymorphism
- Clay models of canal system in sponges
- Plaster-of-paris model of *Peripatus*
- Construction of a vermicompost in each college, manufacture of manure by students and donating to local farmers
- Chart on pearl forming layers using clay
- Visit to a pearl culture rearing industry/institute
- Live model of water vascular system
- Observation of Balanoglossus for its tubicolous habit

REFERENCE BOOKS:

- L.H. Hyman „*The Invertebrates' Vol I, II and V*. – M.C. Graw Hill Company Ltd.
- Kotpal, R.L. 1988 - 1992 Protozoa, Porifera, Coelenterata, Helminthes, Arthropoda, Mollusca, Echinodermata. Rastogi Publications, Meerut.
- E.L. Jordan and P.S. Verma „*Invertebrate Zoology'* S. Chand and Company.

Unit-1

1.1.Whitakers five kingdom concept and classification of Animal kingdom.

The Five Kingdom System of Classification

Scientists classify living things into categories based on their physical and genetic similarities. In the 1969s, American biologist Robert Whittaker proposed a classification system based on five kingdoms: Monera (prokaryotes), Protista (chiefly protozoa and algae), Fungi (molds, yeasts, and mushrooms), Plantae (plants), and Animalia (animals). Whittaker's system was widely accepted until the 1970s, when further studies led to the division of Monera into two kingdoms—Bacteria and Archaea.

Features of Five Kingdom System of Classification

- Whitaker proposed that organisms should be broadly divided into kingdoms, based on certain characters like the structure of the cell, mode of nutrition, the source of nutrition, interrelationship, body organization, and reproduction.
- The kingdoms include:
- Bacteria and archaea are in the **Kingdom Monera::**
- Algae and protozoa are in the **Kingdom Protista** (organisms in this kingdom are referred to as protists)
- Fungi are in the **Kingdom Fungi**
- Plants are in the **Kingdom Plantae**
- Animals are in the **Kingdom Animalia**

Kingdom Monera::

- These organisms are prokaryotic and unicellular.
- They do not have a well-defined nucleus and also lack cell organelles.
- Some organisms show the presence of cell wall while there are others without a cell wall. Consequently, some organisms are autotrophic and others are heterotrophic.
- Examples include Bacteria, Cyanobacteria, and Mycoplasma.

Kingdom Protista::

- Organisms grouped under Kingdom Protista are all unicellular, but eukaryotic organisms.
- These are the simplest forms of eukaryotes that exhibit either autotrophic or heterotrophic mode of nutrition.
- Some organisms have appendages such as cilia or flagella or pseudopodia to move around.
- Some examples are Diatoms, Protozoans like Amoeba, Paramecium

Kingdom Fungi::

- Heterotrophic, Multicellular and Eukaryotic organisms are grouped under Kingdom Fungi.

- Their mode of nutrition is saprophytic as they use decaying organic matter as food.
- They have cell walls, which are made up of a substance called Chitin.
- Fungi also form a symbiotic association with some blue-green algae.
- Yeast, Mushroom, Aspergillus are examples of Fungi.

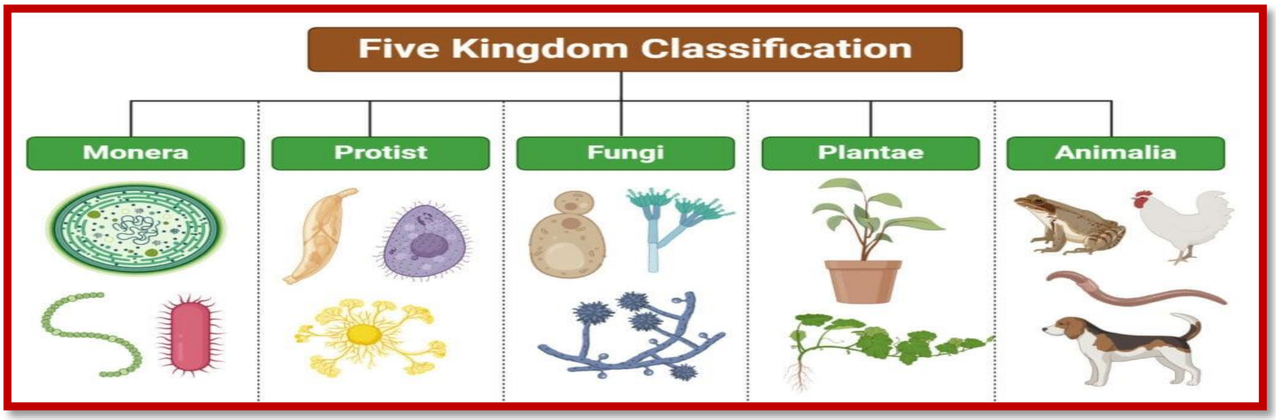
Kingdom Plantae::

- These are Eukaryotic, Multicellular organisms with a cell wall that is made up of cellulose.
- They are autotrophs and synthesize their own food through the process of photosynthesis. This kingdom includes all plants.

- Based on the body differentiation and presence or absence of specialized vascular tissue, Kingdom Plantae is divided into different divisions, namely Thallophyta, Bryophyta, Pteridophyta, Gymnosperms, and Angiosperms.
- Examples are Spirogyra, Ferns, Pines, and Mango Plant etc.

Kingdom Animalia::

- **Kingdom Animalia** includes **multicellular, eukaryotic organisms** that **do not have a cell wall** and are **heterotrophic** in nutrition.
- Animals show **wide diversity**, from simple to highly complex forms with tissues and organs.
- The animal kingdom is divided into **different phyla** like **Porifera, Coelenterata, Arthropoda, Echinodermata, and Chordata** (e.g., Hydra, Starfish, Earthworm, Monkey, Bird).
- **Viruses are not included** in the Five-Kingdom System because they are **acellular and non-living** outside a host.
- Though **Whittaker's Five-Kingdom System** is widely used, **some scientists prefer other classification systems** for better accuracy.



1.2. Protozoa general characters' and classification up to classes with suitable examples.

Introduction

The animals included in phylum Protozoa can be defined as microscopic and acellular animalcules without tissues and organs. They have one or more nuclei. Protozoa exist either singly or in colonies. Almost about 50,000 species are known till date.

Anton Van Leeuwenhoek was the first to observe protozoa (Vorticella convellaria) under a microscope. He called them animalcules. **Gold fuss** coined the term Protozoa which in Greek means first animals (Proto= first; zoans=animals). **Hyman** and other zoologists preferred to call them as acellular animals.

The body of protozoans is **unicellular**. They are generally referred to as acellular rather than unicellular as the so called single cell performs all the life activities. Though it is structurally equivalent to a single cell of the metazoan body, it is functionally equivalent to the whole metazoan animals.

General Characters of Phylum Protozoa

1. Protozoan animals exhibit protoplasmic grade of organization. There is division of labor among various organelles of the cell.
2. These are solitary (*Euglena*), or colonial (*Proteospongia*)
3. They may be free living (*Amoeba*) or symbiotic (Parasitic, mutualistic or commensalistic)
4. Body symmetry is symmetrical (Actinopodeans) or radial (sessile forms) or bilateral (*Giardia*) or absent (*Amoeba*)
5. Locomotion is brought about by pseudopodia or flagella or cilia or myonemes.
6. Nutrition is holozoic or holophytic or osmotrophic (Saprophytic or parasitic). Digestion is intracellular. Some forms like Euglena are mixotrophic (perform more than one type of nutrition)
7. Exchange of respiratory gases takes place by diffusion through the general body surface. Respiration is anaerobic in some parasitic forms.
8. Excretion occurs by diffusion across general body surface or by contractile vacuoles. Contractile vacuoles serve

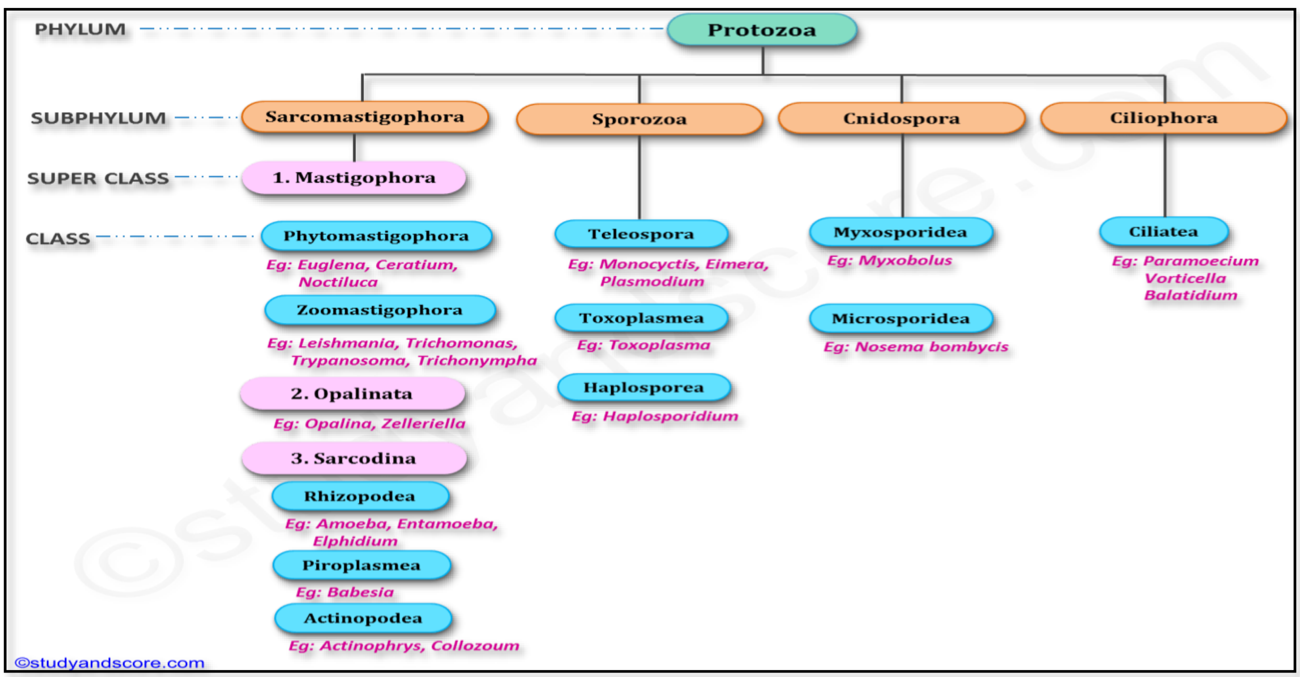
mainly for Osmoregulation and are common in freshwater forms.

9. Asexual reproduction takes place by binary fission or multiple fission or plasmotomy or budding.
10. Sexual reproduction takes place by syngamy or conjugation
11. Many forms undergo encyctment to tide over unfavorable conditions
12. Somotoplasm and germplasm are not differentiated. Hence they are immortal (exempt from natural death).

Classification of Phylum Protozoa

Phylum Protozoa is a large and varied group. This phylum has a number of problems in its classification. As per one of the classification given out by Hyman, Hickman and Storer, this phylum is divided into two subphyla on the basis of organs of locomotion. These two subphyla are further divided into 5 classes.

Most accepted classification of protozoa is given by BM Honigberg and others based on the scheme given by the committee on Taxonomy and Taxonomic problems of the society of Protozoologists divides this phyla into 4 subphyla.



The following is the classification as proposed by Honigberg and his group.

SUBPHYLUM I: SARCOMASTIGOPHORA (Gr.

Sarcodes=fleshy; mastix=whip; phoros=bearing)

The locomotion in this subphylum is brought about by flagella or pseudopodia or both. Other important feature of this subphylum is the presence of monomorphic nuclei. This subphylum is further divided in to 3 super classes:

Superclass 1: Mastigophora (Gr. Mastix=whip; phoros=bearing)

The body of the animals belonging to this super class is covered by pellicle. The locomotory organelles are flagella. In this super class the asexual reproduction occurs by longitudinal binary fission. This super class includes 2 classes:

Class 1: Phytomastigophora (Gr. Phyton=plant; Mastix=whip; phoros=bearing)

They have chromatophores with chlorophyll. The nutrition in these organisms is mainly holophytic which takes place by phototrophy. These are free living organisms. The reserve food in these organisms is starch or paramylon. These organisms may have 1 or 2 flagella.

Ex: *Euglena, Ceratium, Noctiluca*

Class 2: Zoomastigophora (Gr. Zoon=animal; Mastix=whip; phoros=bearing)

These organisms do not have chlorophyll bearing chromatophores. These are mostly parasitic. The nutrition in these organisms is holozoic or saprozoic. The reserved food is glycogen. They may have one to many flagella.

Ex: *Leishmania, Trypanosoma, Trichomonas, Trichonympha*

Superclass 2: Opalinata

The organisms belonging to this super class live as commensals or parasites in the gut of anurans. Their body is covered by oblique rows of cilia-like flagella. These organisms may have 2 or many nuclei also the nuclei are monomorphic. They undergo asexual reproduction by binary fission or by syngamy. Sexual reproduction takes place by anisogamy.

Ex: *Opalina, Zelleriella*

Superclass 3: Sarcodina (Gr. Sarcode=fleshy)

The locomotion in the organism belonging to this superclass is brought about by pseudopodia. Their body is amoeboid without definite pellicle. The nutrition is holozoic or saprozoic. This super class is further divided into 3 classes:

Class 1: Rhizopodea (Gr. Zoon=animal; Mastix=whip; phoros=bearing)

The pseudopodia of the animals in this class are in the form of lobopodia, filopodia or reticulopodia without axial filaments. This class includes amoebas, foraminiferans and mycetozoans. These animals are mostly free living and a few are also parasitic. In amoebas, the body is naked; in foraminiferans the body is covered by porous calcareous shell.

Ex: *Amoeba, Entamoeba, Elphidium*

Class 2: Piroplasmea

The animals belonging to this class are parasitic. Locomotory structures are absent in this class. Spores are also absent. These are the small parasites in the red blood cells of vertebrates.

Ex: *Babesia*

Class 3: Actinopodea (Gr. Actis=ray; podos=foot)

The pseudopodia of the animals belonging to this class are in the form of axopodia with axial filaments, radiating from the spherical body. These are planktonic. This class includes Heliozoans, Radiolarians and acanthareans. Radiolarians and acanthareans are marine forms whereas heliozoans are both marine and fresh water forms. Skeletons of radiolarians have siliceous shells. The shells of dead radiolarians accumulate on the ocean floor to form radiolarian ooze.

Ex: *Collozoum, Actinophrys, Acanthometra*

SUBPHYLUM II: SPOROZOA (Gr. Actis=ray; podos=foot)

The animals belonging to this subphylum are exclusively endoparasites. Special locomotory organelles are absent in these animals. Sometimes pseudopodia are present which are useful only for ingestion of food. Sporozoites are merozoites bear anterior apical complex that helps penetrate host cells. This subphylum includes 3 classes:

Class 1: Telosporea

The Sporozoites are long in these animals. Reproduction is both asexual and sexual. They are blood and gut parasites of vertebrates. Sexual reproduction is by isogamy or anisogamy.

Ex: *Monocyctis, Eimera, Plasmodium*

Class 2: Toxoplasmea

In this class reproduction is only asexual type which takes place by internal budding where two daughter cells are produced within the mother cell and the mother cell is finally destroyed in the process of reproduction. Spores are absent.

Ex: *Toxoplasma*

Class 3: Haplosporea

The spores in this class are amoeboid. Also reproduction is only asexual type taking place through multiple fissions.

Ex: *Haplosporidium, Ichthyosporidium*

SUBPHYLUM III: CNIDOSPORA (Gr. Knide=nettle; spora=seed)

The animals belonging to this subphylum are parasitic. Special kind of locomotory organelles are absent in these animals. Spores are present with one or more polar filaments. Polar filaments are special and unique features of these animals. When these spores infect a host, the polar filament is discharged and it gets attached to the host tissue. This subphylum includes 2 classes:

Class 1: Myxosporidea

The spores of the animals of this class are large and develop from several nuclei. These are generally extracellular parasites. The spores of this class have two polar filaments and have two to three valves

Ex: *Myxobolus*

Class 2: Microsporidea

The spores of the animals of this class are small and are developed from only one nucleus. These spores have single valve. These are generally intracellular parasites. Many of the animals of this class have a single polar filament.

Ex: *Nosema bombycis*

SUBPHYLUM IV: CILIOPHORA (La. Cilium=eye lid with lashes; phoros=bearing)

Ciliophorans are complex of all the protozoans. The locomotory organelle of all the animals of this subphylum is cilia. These cilia also help in feeding at some stage of the life cycle of the animals. The nuclei of these organisms are dimorphic. Macronucleus is vegetative and polyploid. Micronucleus is reproductive and diploid. Asexual reproduction takes place by binary fission. Sexual reproduction takes place by conjugation. Only one class is included in this subphylum:

Class 1: Ciliatea

The locomotory organelles of these animals are numerous hair-like cilia. One or more contractile vacuoles are present in these forms. The nucleus is dimorphic including both macro nucleus and micronucleus.

Ex: *Paramoecium, Vorticella, Balatidium*

1.3. Protozoa locomotion and Nutrition

Introduction

Protozoa are single-celled, eukaryotic organisms that belong to the kingdom **Protista**. They are considered the simplest and most primitive forms of animal life, as they exhibit animal-like features such as **movement** and **heterotrophic nutrition**. These microscopic organisms possess a well-defined nucleus and perform all vital life functions within a single cell. Most protozoans are **free-living** and thrive in aquatic environments such as freshwater and marine habitats or moist soil. However, some species are **parasitic**, living inside the bodies of plants or animals and often causing diseases. Owing to their structural simplicity and functional complexity, protozoa serve as important models for studying basic biological processes.

1. LOCOMOTION IN PROTOZOA

Locomotion in protozoa is essential for movement, capturing food, and escaping from predators. It enables them to interact effectively with their environment and obtain nutrients for survival. The movement is brought about by specialized structures called **locomotory organelles**. The main types of these organelles are **pseudopodia, flagella, and cilia**, each functioning in a distinct manner.

- Cellular extensions like **Pseudopodia** (Eg: Amoeba)
- Pellicular contractile structures like **Myonemes** (Eg: Euglena and Sporozoans)
- Locomotory organelles like **Flagella** (Eg: Paramecium) and **Cilia** (Eg: Euglena)

PSEUDOPODIA (CELLULAR EXTENSION):

Pseudopodia, also known as **false feet**, are temporary cytoplasmic outgrowths formed on the cell surface by the movement of cytoplasm. They help in **locomotion** and **capturing food** in many protozoans.

Depending on the number of pseudopodia formed on the surface:

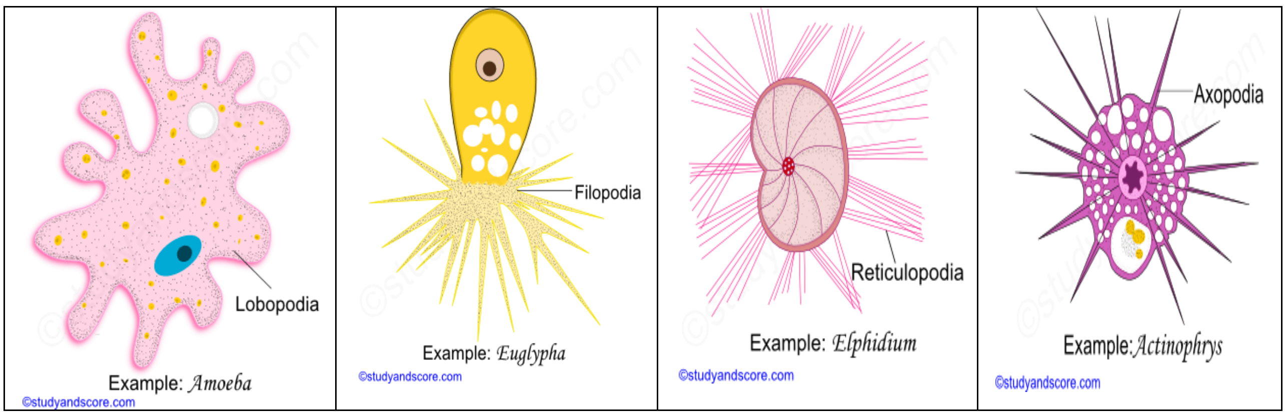
- **Polypodia:** Several pseudopodia are formed on the surface of the body.
  Eg: *Amoeba proteus*
- **Monopodia:** Only a single pseudopodium is formed on the surface of the body.
  Eg: *Entamoeba histolytica*

Depending on the structure of the pseudopodia:

- **Lobopodia:** These are lobe-like, blunt structures with broad ends composed of endoplasm and ectoplasm, helping in movement by a pressure flow mechanism.

Eg: *Amoeba proteus*, *Entamoeba histolytica*

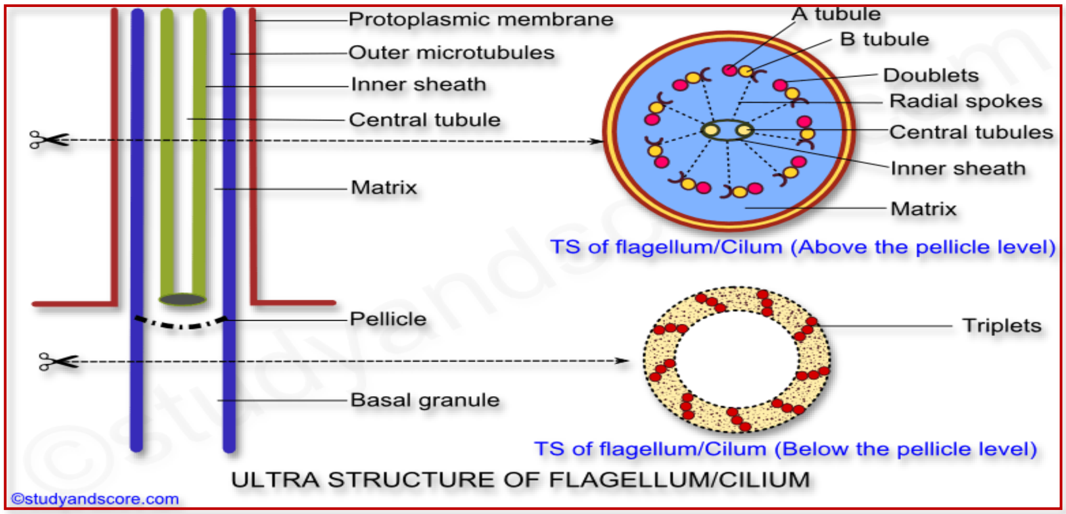
- **Filopodia:** These are slender, tapering pseudopodia made of ectoplasm that may branch but never form a network, aiding in food capture. **Eg:** *Euglypha*, *Lecithium*
- **Reticulopodia:** Also called rhizopodia, these are branched, interconnected pseudopodia forming a network used mainly for food ingestion and movement. **Eg:** *Elphidium*, *Globigerina*
- **Axopodia:** Fine, needle-like pseudopodia with a central axial rod, covered by adhesive cytoplasm, primarily used for food collection. **Eg:** *Actinosphaerium*, *Actinophrys*, *Collozoum*



MYONEMES (PELLICULAR CONTRACTILE EXTENSIONS): Many protozoans possess contractile structures within the **pellicle or ectoplasm** known as *myonemes*. These structures help in maintaining body shape and enabling slight contractions or movements. They may occur in different forms such as:

- **Ridges or grooves** – *Euglena*
- **Contractile myofibrils** – larger ciliates
- **Microtubules** – *Trypanosoma*

FLAGELLUM (LOCOMOTORY ORGANELLE): Flagella are **thread-like locomotory organelles** found in flagellate protozoans (Mastigophora). Each flagellum consists of a long, stiff **axial filament or axoneme** surrounded by an outer sheath. The axoneme arises from a **basal granule (blepharoplast or kinetosome)**, which originates from the **centriole** and lies just below the cell surface in the ectoplasm. The area around the blepharoplast, known as the **microtubule-organizing center**, regulates the formation and arrangement of microtubules essential for flagellar movement.

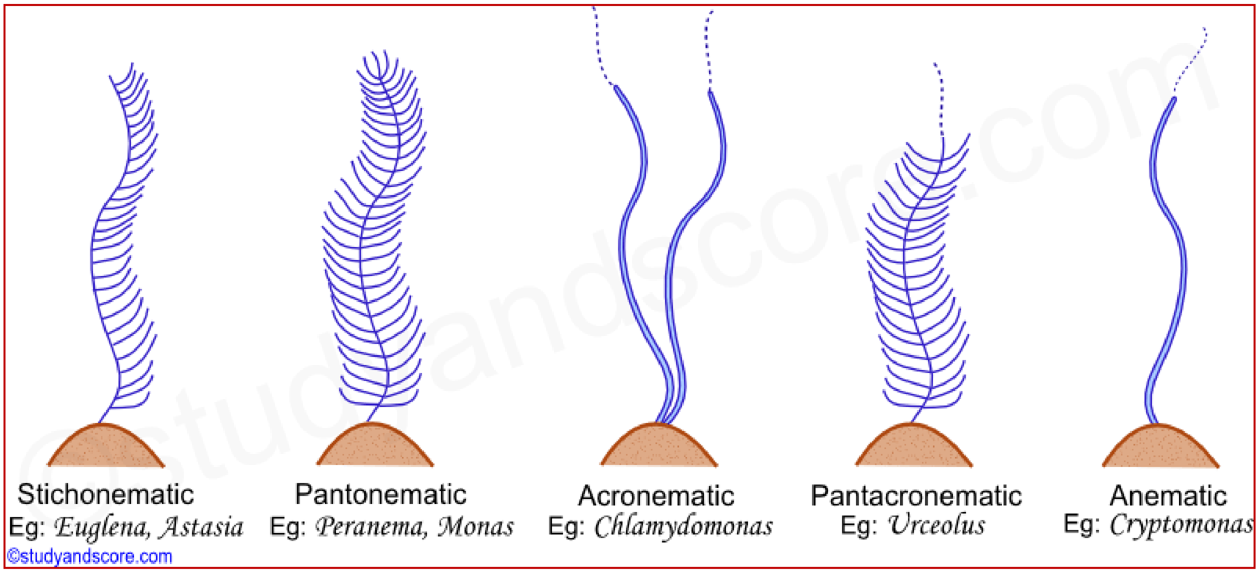


Under an electron microscope, the flagellum shows a **9 + 2 arrangement** of microtubules, with two central fibers surrounded by nine peripheral doublets. Each doublet bears **dynein arms** that generate the sliding force responsible for movement. The entire structure is enclosed by a **protoplasmic sheath**, and some flagella possess fine lateral appendages called **flimmers or mastigonemes**.

Types of Flagella

The number and arrangement of flagella in Mastigophora vary widely, and their classification depends on the **flagellar arrangement, lateral appendages,** and **axial filament structure**.

- **Stichonematic**: Only one row of lateral appendages occurs on the axoneme up to tip. Eg: *Euglena, Astasia*
- **Pantonematic**: Two or more rows of lateral appendages occur on the axoneme Eg: *Peranema, Monas*
- **Acronematic**: Lateral appendages are absent and axoneme ends as a terminal 'naked' axial filament Eg: *Chlamydomonas, Polytoma*
- **Pantacronematic**: Flagellum is provided with two or more rows of lateral appendages and the axoneme ends in a terminal naked axial filament. Eg: *Urceolus*
- **Anematic**: In some cases the flagella is simple without any lateral appendages and a terminal naked filament. Eg: *Chilomonas, Cryptomonas*



CILIA (LOCOMOTORY ORGANELLES)

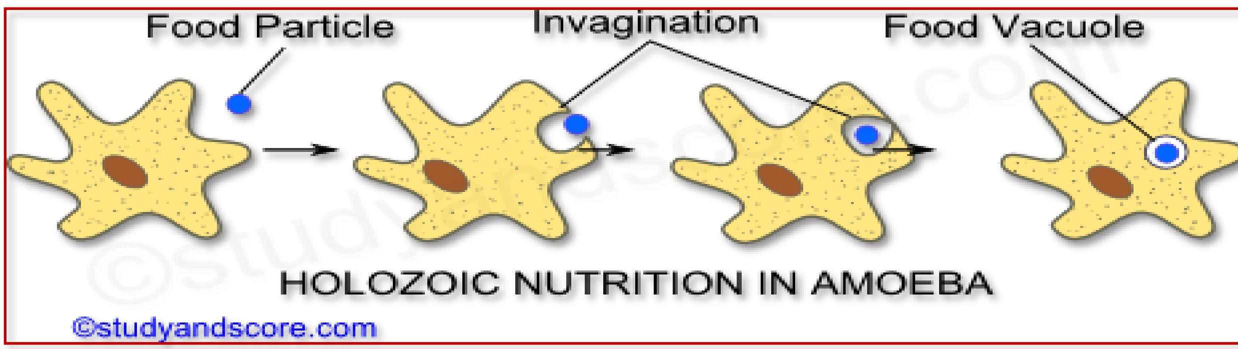
Cilia are short, hair-like projections covering the body surface or specific regions of ciliate protozoans, aiding in **locomotion and food collection**. Structurally, they resemble flagella but are shorter and arise from **kinetosomes**, each containing a **9 + 2 axonemal arrangement** with dynein arms enclosed by a protoplasmic sheath. Beneath the pellicle lies the **infraciliary system**, composed of kinetosomes, kinetodesmal fibrils, and kinetodesmata arranged into units called **kineties**. These kineties connect to the **motorium**, forming a **neuromotor system** that regulates and coordinates ciliary movement.

Types of cilia

- In some primitive forms like holotrichs (Eg: *Paramecium*) cilia are present all over the body
- In some forms like peritrichs (Eg: *Vorticella*) cilia are present only in the peristomial region
- In Suctorians (Eg: *Acineta*) cilia are present in only in the young ones which are later replaced by sucking tentacles in the adults

NUTRITION IN PROTOZOA

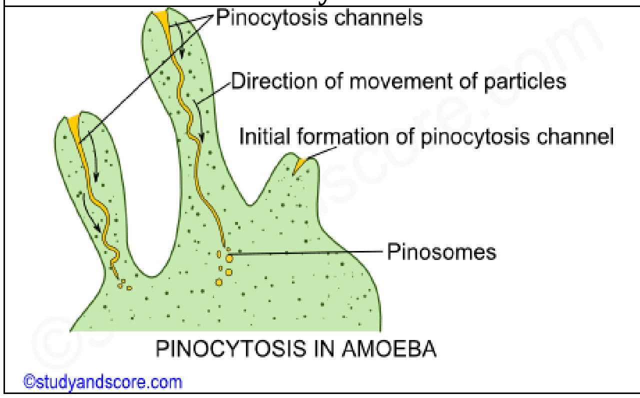
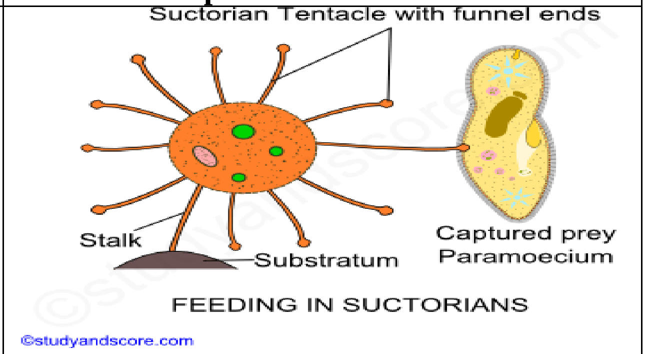
Protozoa exhibit diverse nutritional modes — some synthesize their own food, others depend on symbiotic algae, while many capture or absorb nutrients from their surroundings. A few species are **parasitic**, living in or on hosts, sometimes causing serious diseases. They show all types of nutrition such as **holophytic, holozoic, saprozoic, mixotrophic,** and **parasitic**. **Holophytic nutrition:** Seen in phytoflagellates that possess **chloroplasts and chromatophores** to perform photosynthesis using sunlight, carbon dioxide, and water. The carbohydrate **paramylon** formed during this process is characteristic of **Euglenoid flagellates**. **Holozoic nutrition:** Most protozoa feed by **ingesting other organisms**, involving steps like food capture, ingestion, digestion, assimilation, and egestion, with the help of **flagella, pseudopodia,** or **trichites**.



Some protozoa use **axopodia, reticulopodia,** or **tentacles** to draw nearby prey toward their body, while in ciliates, a well-developed **ciliary oral apparatus** helps capture food and direct it into the **cytostome** and **cytopharynx**.

- ✓ **Pinocytosis:** Also known as *cell drinking*, this process involves the ingestion of **liquid food** through invaginations on the cell surface. These invaginations form **pinocytotic channels** that enclose surrounding fluid and pinch off as **food vacuoles** into the endoplasm. It is typically induced by certain active substances in the medium, allowing the absorption of **high molecular weight compounds** from the external environment.
- ✓ **Saprozoic Nutrition:** In this mode, protozoa absorb dissolved nutrients directly through their body surface by **osmosis**, mainly from **dead and decaying organic matter** decomposed by bacteria. It is common in **Mastigamoeba** and some **colorless flagellates**.

- ✓ **Suctorians:** These protozoa feed on other ciliates using **tentacles with funnel-shaped ends** that paralyze the prey with toxins and then **suck out their body fluids** through central tubular structures.

Pinocytosis:	Saprozoic nutrition:
 PINOCYTOSIS IN AMOEBA	 FEEDING IN SUCTORIANS

Myxotrophic Nutrition: This mode combines photosynthesis with osmotrophy or phagocytosis, seen in flagellates like **Euglena** and **Peranema**.

Nutrition of Parasitic Protozoa: Parasitic protozoa feed through **phagotrophy or osmotrophy**, depending on their habitat, with intestinal and blood forms absorbing nutrients directly from the host.

1.4. Protozoa Reproduction

REPRODUCTION INTRODUCTION

Paramecium reproduces both asexually and sexually. It also undergoes several kinds of nuclear organizations. It can also multiply during nuclear organizations. Various processes of reproduction in Paramecium are listed below:

VARIOUS PROCESSES OF REPRODUCTION IN PARAMECIUM

Nuclear organization and its importance

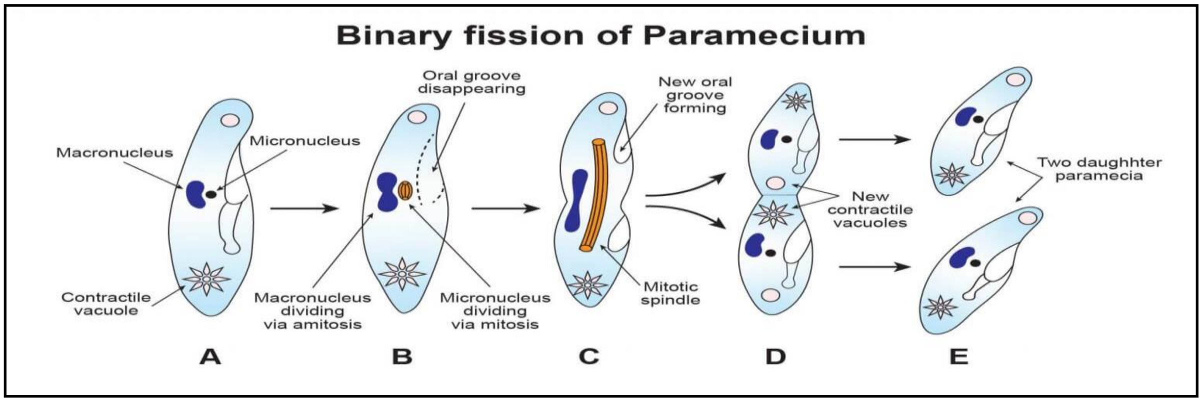
In *Paramecium*, the degeneration of the old macronucleus and formation of a new one from the fusion of micronuclei is called **nuclear reorganization**. During binary fission, the macronucleus divides by **amitosis**, causing random distribution of genetic material. Repeated fissions disturb the **genic balance**, reducing vitality and slowing division. Some species can undergo only about **320–350 continuous binary fissions** before death if nuclear reorganization fails. Therefore, replacing the old, imbalanced macronucleus with a new one has a **rejuvenating effect** on the clone and restores its vigor. **The following processes are:**

1. Conjugation
2. Autogamy
3. Endomixis
4. Cytogamy

Whereas, binary fission is an asexual reproduction process in which nuclear organization does not occur.

ASEXUAL REPRODUCTION: BINARY FISSION

In *Paramecium*, binary fission is the common method of asexual reproduction that occurs under favorable conditions. The division is **transverse**, taking place at a right angle to the body's longitudinal axis. Before fission, *Paramecium* stops feeding and its **oral groove disappears**. The **macronucleus divides amitotically**, while the **micronucleus divides mitotically**, and both move to opposite ends. A constriction forms in the middle, splitting the cytoplasm into two equal parts. This results in two daughter individuals — the **protor** (from the anterior end) and the **opisthe** (from the posterior end) — each with a full set of organelles. New oral grooves, cytopharynx, and contractile vacuoles are formed. The entire process takes about **two hours** and may occur **one to four times a day**.



SEXUAL REPRODUCTION: CONJUGATION

In *Paramecium*, **conjugation** is a type of sexual reproduction. It is a **temporary union** between two individuals of the same species to **exchange genetic material**. This process helps in **rejuvenation and survival** of the species after many binary fissions.

Conjugation inducing factors:

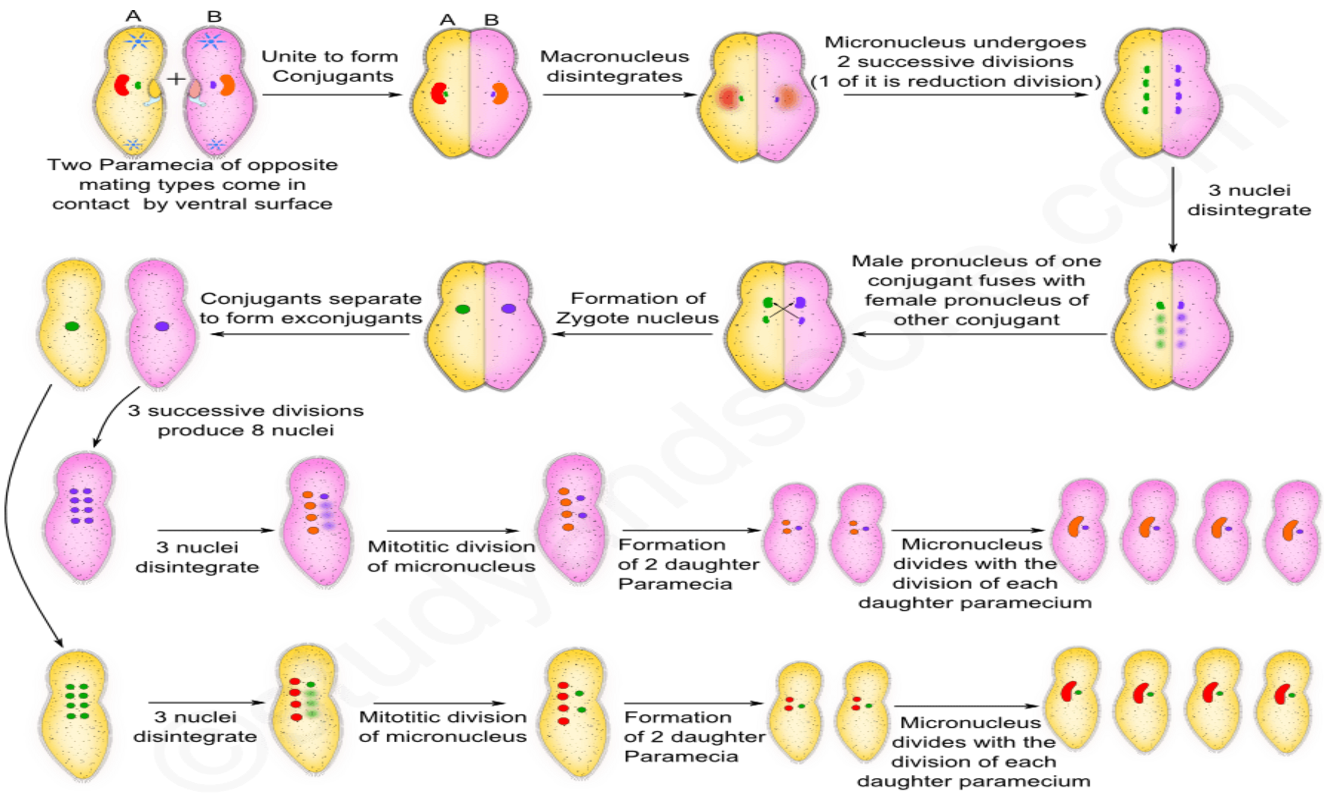
- It occurs under **unfavorable conditions** such as lack of food, starvation, changes in light, temperature, or presence of certain chemicals.
- It also happens **after many asexual divisions** to restore vitality.

Mating types:

Each species of *Paramecium* has **two mating types** that differ in their surface chemistry. Conjugation happens **only between opposite mating types** of the same variety.

Process of conjugation:

Two *Paramecia* of opposite mating types **come in contact at their ventral surfaces** and attach through their **oral groove regions**. Their **cilia, trichocysts, and feeding structures degenerate**, and a **cytoplasmic (conjugation) bridge** forms between them. These united individuals are called **conjugants**.



STEP WISE REPRESENTATION OF CONJUGATION PROCESS IN PARAMECIUM

During conjugation in *Paramecium*, the two conjugants remain attached for several hours. During this time, they exchange and reorganize their nuclear material as follows:

1. Changes in macronucleus: The **old macronucleus breaks into pieces** and these fragments are **absorbed into the cytoplasm**.

2. Changes in micronucleus:

- The **diploid micronucleus** in each conjugant **enlarges and divides by meiosis**, forming **four haploid nuclei**.
- **Three** of these haploid nuclei **degenerate**, leaving **one**.
- The remaining nucleus **divides by mitosis** into **two pronuclei** — a **small migratory nucleus** (active) and a **large stationary nucleus** (passive).
- The **migratory nucleus** from one conjugant moves through the **cytoplasmic bridge** into the other and **fuses** with the stationary nucleus of that conjugant.
- This **fusion forms a diploid zygote nucleus** called the **synkaryon**, and this process is known as **amphimixis**.

3. After separation:

- Once the zygote nucleus is formed, the two conjugants **separate** and are now called **ex-conjugants**.
- In each ex-conjugant, the **zygote nucleus divides three times** by mitosis, producing **eight nuclei**.
- **Four** become **macronuclei**, and the other **four remain as micronuclei**.
- Of these micronuclei, **three degenerate**, and the **remaining one divides** again as the ex-conjugant **divides into two daughter cells**.
- Each daughter *Paramecium* has **two macronuclei and one micronucleus**.
- Later, the **micronucleus divides again** along with the cytoplasm, forming **four new *Paramecia*** — each with **one macronucleus and one micronucleus**.

Final Result: From one conjugation process, a total of **eight new *Paramecia*** are formed — **four from each original conjugant**.

Significance of Conjugation in *Paramecium*

1. **Nuclear Reorganization:**
   Conjugation forms a **new, active macronucleus** through the reorganization of micronuclear material, ensuring proper cell functioning.
2. **Rejuvenation:**
   The **old and weak macronucleus** is replaced by a **new one**, which restores normal metabolism, growth, and vitality. This process **rejuvenates** the *Paramecium*, making it healthy and active again.
3. **Genetic Variation:**
   During conjugation, **exchange of genetic material** occurs between two *Paramecia* of opposite mating types, leading to **genetic recombination** and **variation** in the offspring.

A. Syngamy (Gametic Fusion)

- Two gametes (sexual cells) fuse completely to form a **zygote**.
- The gametes may be **morphologically similar (isogametes)** or **different (anisogametes)**.
- The zygote develops into a new individual after meiosis.
- **Examples:** *Plasmodium, Monocystis*.

B. Autogamy

- It occurs within a **single individual** without pairing.
- The micronucleus divides meiotically, and two haploid nuclei fuse to form a **diploid nucleus**.
- This restores the vitality of the organism.
- **Example:** *Paramecium aurelia*.

C. Cytogamy

- Two individuals come together and exchange nuclear material, but **no fusion of cytoplasm** occurs.
- Found in *Paramecium caudatum*.

D. Endomixis

- Similar to autogamy but without nuclear exchange or pairing.
- Nuclear reorganization occurs **within the same cell**, leading to rejuvenation.

- **Example:** *Paramecium aurelia*.

E. Sporogony

- A special form of multiple fission following zygote formation.
- The zygote divides several times to form numerous **sporozoites**, each developing into a new organism.
- **Example:** *Plasmodium*, *Eimeria*.

Unit-II

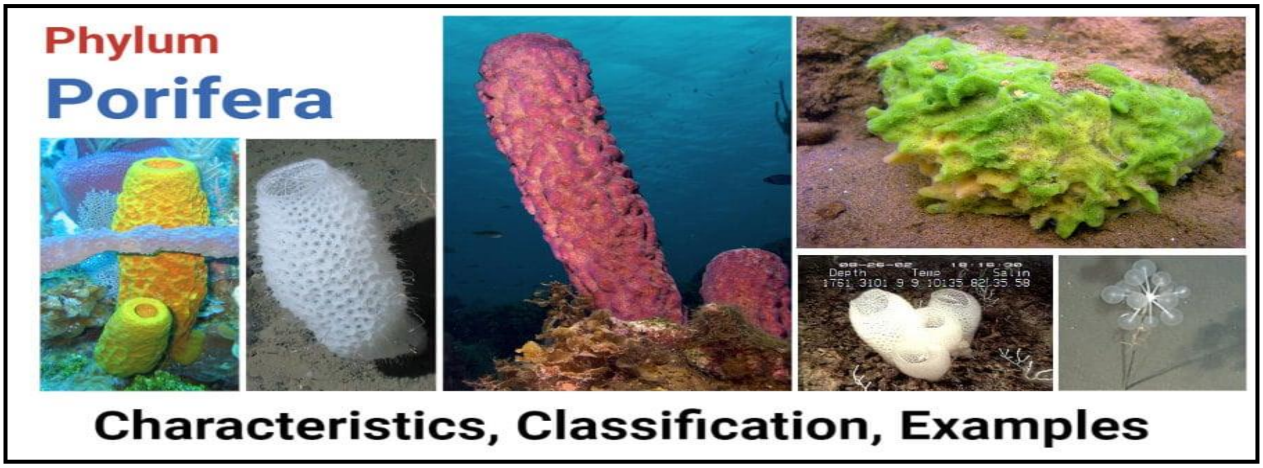
2.1 .Porifera General characters and classification up to classes with suitable examples.

Porifera, or sponges, are simple multicellular animals with porous bodies that lack true tissues and organs. Their general characteristics include being sessile, aquatic (mostly marine), and having a skeleton of spicules or spongin. They are classified into three classes based on their skeleton: **Calcarea** (calcareous spicules), **Hexactinellida** (six-rayed siliceous spicules), and **Demospongiae** (spongin or siliceous spicules, or both).

General characters of Porifera

1. Porifera are all aquatic, mostly marine except one family Spongillidae which lives in freshwater.
2. They are sessile and sedentary and grow like plants.
3. The body shape is vase or cylinder-like, asymmetrical, or radially symmetrical.
4. The body surface is perforated by numerous pores, the Ostia through which water enters the body and one or more large openings, the oscula by which the water exists.
5. The multicellular organism with the cellular level of body organization. No distinct tissues or organs.
6. They consist of outer ectoderm and inner endoderm with an intermediate layer of mesenchyme, therefore, diploblastic
7. The interior space of the body is either hollow or permeated by numerous canals lined with choanocytes. The interior space of the sponge body is called spongocoel.
8. Characteristic skeleton consisting of either fine flexible spongin fibers, siliceous spicules, or calcareous spicules.
9. Mouth absent, digestion intracellular.
10. Excretory and respiratory organs are absent.
11. Contractile vacuoles are present in some freshwater forms.
12. The nervous and sensory cells are probably not differentiated.
13. The primitive nervous system of neurons arranged in a definite network of bipolar or multipolar cells in some, but is of doubtful status.
14. The sponges are monoecious.
15. Reproduction occurs by both sexual and asexual methods.
16. Asexual reproduction occurs by buds and gemmules.
17. The sponge possesses a high power of regeneration.
18. Sexual reproduction occurs via ova and sperms.

19. All sponges are hermaphrodite.
20. Fertilization is internal but cross-fertilization can occur.
21. Cleavage holoblastic.
22. Development is indirect through a free-swimming ciliated larva called amphiblastula or parenchymula.
23. The organization of sponges are grouped into three types which are ascon type, sycon type, and leuconoid type, due to simple and complex forms.
24. **Examples:** *Clathrina, Sycon, Grantia, Euplectella, Hyalonema, Oscarella, Plakina, Thenea, Cliona, Halichondria, Cladorhiza, Spongilla, Euspondia*, etc.



Classification::

The phylum includes about 5,000 species of sponges, grouped into 3 classes depending mainly upon the types of skeleton found in them. The classification here is based on **Storer** and **Usinger** (1971) which appears to be a modification from **Hyman's** classification**.**

Class 1. Calcarea (L., calx=lime) or Calcispongiae (L., *calcis*= lime+ *spongia*= sponge)

- Small-sized **calcareous sponges**, below 10 cm in height.
- Solitary or conical; body shape vase-like or cylindrical.
- They may show asconoid, Syconoid, or leuconoid structures.
- A skeleton of separate one or three or four-rayed calcareous spicules.
- Exclusively marine.

Order 1. Homocoela (=Asconosa)

- Asconoid sponges with cylindrical and radially symmetrical bodies.
- Body wall thin, not folded. Choanocytes line the Spongocoel.
- Often conical.
- Examples: *Leucosolenia*, *Clathrina*.

Order 2. Heterocoela (=Syconosa)

- Syconoid and leuconoid sponges having a vase-like body.

- The body wall is thick, folded. Choanocytes line the flagellated chambers (radial canals) only.
- Spongocoel is a line by flattened endoderm cells.
- Solitary or conical
- Examples: *Sycon* or *Scypha*, *Grantia*.

Class 2. Hexactinellida (Gr., *hex*=six + *actin*=ray) or Hyalospongiae (Gr., *hyalos*=glass+ *spongos*= sponge)

- Moderate -sized. Some reach 1 meter in length.
- Called glass sponges.
- Body shape cup, urn, or vase-like.
- Skeleton is of siliceous spicules which are triaxon with 6 rays. In some, the spicules are fused to form a lattice-like skeleton.
- No epidermal epithelium.
- Choanocytes line finger-shaped chambers.
- Cylindrical or funnel-shaped
- Found in deep tropical seas.

Order 1. Hexasterophora

- Spicules are hexasters i.e. star-like in shape with axes branching into rays at their ends.
- Flagellated chambers regularly and radially arranged.
- Usually attached to substratum directly.
- Examples: *Euplectella* (Venus' flower basket), *Farnera.*

Order 2. Amphidiscophora

- Spicules are amphidiscs i.e. with a convex disc, bearing backwardly directed marginal teeth at both ends.
- Flagellated chambers are slightly different from the typical type.
- Attached to the substratum by root tufts.
- Examples: *Hyalonema*, *Pheronema*.

Class 3. Demospongiae (Gr., *dermos*= frame+ *spongos*= sponge)

- Contains the largest number of sponge species.
- Small to large-sized.
- Conical or solitary.
- The body shape is a vase, cup, or cushion.
- Skeleton of siliceous spicules or spongin fibers, or both, or absent.
- Spicules are never 6-rayed, they are monaxon or tetraxon and are differentiated into large megascleres and small microscleres.
- The body canal system is leucon type.
- Choanocytes restricted to small rounded chambers.
- Generally marine, few freshwater forms.

Subclass I. Tetractinellida

- Sponges are mostly solid and simple rounded cushion-like flattened in shape usually without branches. Dull to brightly colored.
    - Skeleton comprised mainly of tetraxon siliceous spicules but absent in order Myxospongida.
    - The Canal system is a leuconoid type.

- Mostly in shallow water.

Order 1. Myxospongida

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

Order 2. Carnosa

- Structure simple.
- Spicules are not differentiated into megascleres and microscleres.
- Asters may be present.
- Examples: *Plakina*, *Chondrilla*.

Order 3. Choristida

- Both large and small spicules present.
- Examples: *Geodia*, *Thenea*.

Subclass II. Monaxonida

- Occurs in a variety of shapes from rounded mass to branching types or elongated or stalked with funnel or fan-shaped.
- Spicules monaxon. Spongin present or absent.
- Spicules are distinguished into megascleres and microscleres.
- Found abundant throughout the world.
- Mostly in shallow waters, some in the deep sea, some in freshwater.

Order 1. Hadromerina

- Monaxon megascleres in the form of tylostyles.
- Microscleres when present in the form of asters.
- Spongia absent.
- Examples: *Cliona*, *Tethya*.

Order 2. Halichondrina

- Monaxon megascleres are often of 2 types i.e. monactines and diactines.
- Microscleres are absent.
- Spongia present and scanty.
- Example: Halichondria (crumb-of-bread sponge).

Order 3. Poecilosclerina

- Monaxon megascleres are of 2 types, one type in the ectoderm and another type in the choanocyte layer.
- Microscleres are typically chelas, sigmas, and toxas.
- Example: Cladorhiza.

Order 4. Haplosclerida

- Monaxon megascleres are of only one type i.e. diactinal.
- No microscleres.
- Spongia fibers are generally present.
- Examples: *Chalina*, *Pachychalina*, *Spongilla*.

Subclass III. Keratosa

- The body is rounded and massive with a number of conspicuous oscula.
- Horny sponges with the skeleton of spongin fibers.
- No spicules.
- Found in shallow and warm waters of tropical and subtropical regions.
- Examples: *Euspongia*, *Hippospongia*.

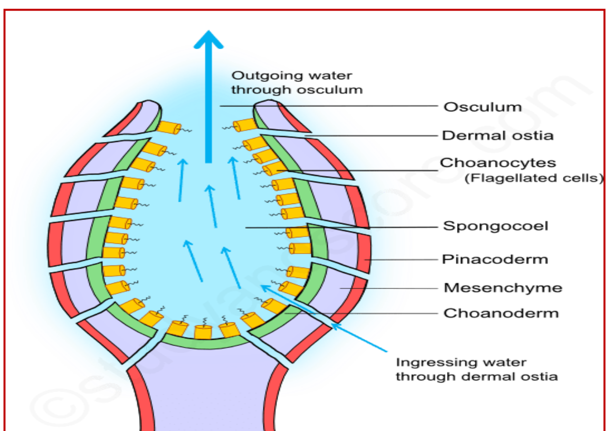
2.1. Canal system in sponges

The **canal system** in sponges refers to the network of body cavities through which water flows, bringing food and oxygen while removing waste. Water enters the sponge through **pores (ostia)** and exits through a large opening called the **osculum**. This system allows the sponge to perform vital life processes such as **nutrition, respiration, excretion, and reproduction**.

The canal system shows progressive complexity in different types of sponges, beginning with the simplest form in *Olynthus* and becoming more advanced in other species where the **collar cells (choanocytes)** are restricted to specific regions. The three main types of canal systems, in increasing order of complexity, are: **Asconoid, Syconoid, and Leuconoid**.

1. Asconoid Canal System

This is the **simplest type** of canal system, found in small, vase-shaped sponges such as *Leucosolenia*.



Ascon type canal system (Ex: Leucosolenia)

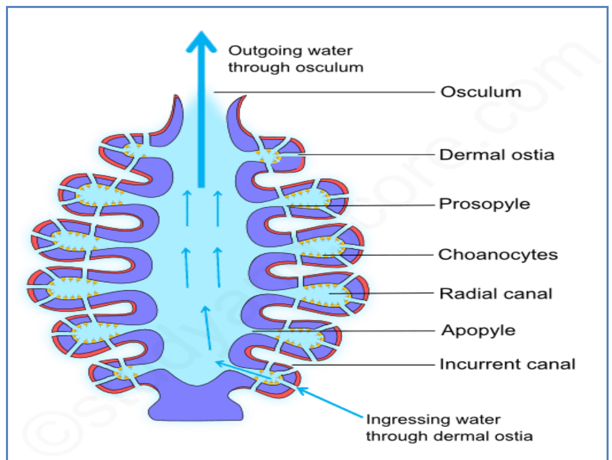
Main features:

- The **body wall** is thin, unfolded, and has a poorly developed **mesenchyme**.
- Numerous **ostia (incurrent pores)** pass directly through **porocytes** into the **spongocoel**.
- The **spongocoel**, which opens to the outside through a single **osculum**, is lined with **choanocytes**.

Water flow: Ostia → Spongocoel → Osculum-Out side

2. Syconoid Canal System

The **syconoid type** is more advanced and complex than the asconoid type. It is found in sponges such as *Sycon*, *Sycetta*, and *Grantia*.



Sycon type canal system (Ex: Scypha)

Main features:

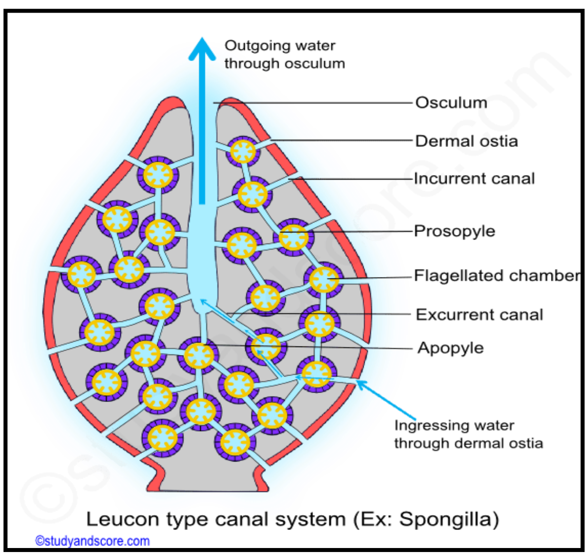
- The **body wall** is thicker and folded, with a well-developed **mesenchyme**.
- The folds form **radial canals**, which are lined with **choanocytes** and hence called **flagellated canals**.

- The spaces between the radial canals are **incurrent canals** lined by epidermis.
- **Incurrent canals** open to the exterior through **dermal ostia** and connect to radial canals through **prosopyles**.
- The **radial canals** open into the **spongocoel** via **internal ostia**.

Water flow: Dermal Ostia → Incurrent Canals → Prosopyles → Radial Canals → Internal Ostia → Spongocoel → Osculum.

3. Leuconoid Canal System

The **leuconoid type** is the most **complex** canal system and represents the highest level of organization in sponges. It is seen in *Leucilla*, *Geodia*, *Oscarella*, *Spongilla*, etc.



Leucon type canal system (Ex: Spongilla)

Main features:

- The **mesenchyme** is thick, forming an extensive **dermal and gastral cortex**, which increases wall thickness.
- The **ostia** open into **irregular and branched incurrent canals**.
- The **spongocoel** is either very narrow or completely absent.
- The **radial canals** are folded and modified into **flagellated chambers**, each lined with choanocytes.
- The **flagellated chambers** connect to **excurrent canals**, which open either into the spongocoel or directly to the exterior through the **osculum**.
- Variations of the leuconoid type include **Eurypylous, Prosodal, Aphodal, and Diplodal** forms.

Water flow: Ingressing water - dermal ostia – incurrent canal - Prosopyles - Flagellated chambers - Apopyles - excurrent canals - Osculum - Outside

4. Rhagon Canal System (in Demospongiae)

In **Demospongiae**, the leuconoid canal system is derived from a simpler structure found in the **rhagon larva**, hence known as the **rhagon canal system**.

Main features:

- The sponge body is **conical** in shape.
- The **basal region (hypophare)** lacks flagellated chambers, while the **upper region (spongophare)** contains them.
- The **mesenchyme** is thick and traversed by **incurrent canals** and **subdermal spaces**.

- The **incurrent canals** open into small **flagellated chambers**, which in turn connect to the **spongocoel** through **excurrent canals**.
- The **spongocoel** opens to the exterior via the **osculum**.

Functions of the Canal System

The canal system plays a vital role in maintaining the life processes of sponges. It helps in:

- **Nutrition** – by bringing in water containing food particles.
- **Respiration** – by allowing exchange of oxygen and carbon dioxide.
- **Excretion** – by removing metabolic wastes.
- **Reproduction** – by aiding the distribution of reproductive cells and gametes.

This organized version keeps the original meaning intact while presenting the information clearly, logically, and in a form suitable for study or report writing.

2.3. Coelenterata General characters and classification up to classes with suitable examples

Phylum: Coelenterata (Cnidaria)

General Characters:

1. **Habitat:**
   Mostly **aquatic** and **marine**, a few (like *Hydra*) are **freshwater**.
2. **Body Organization:**
   - Shows **tissue-level organization**.
   - The body is **diploblastic**, made up of **ectoderm** and **endoderm**, with a jelly-like **mesoglea** in between.
3. **Symmetry:**
   Radially symmetrical, allowing interaction with the environment from all directions.
4. **Body Form:**
   - The body has a **gastrovascular cavity** (coelenteron) with a **single opening** (mouth) used for both ingestion and egestion.
   - No anus.

5. **Tentacles:**

   Surround the mouth and bear special stinging cells called **cnidocytes** or **nematocysts**, used for **defense and capturing prey**.

6. **Body Forms / Polymorphism:** Occur in two basic forms:
   - **Polyp:** Cylindrical, sessile (attached) form — e.g., *Hydra*.
   - **Medusa:** Umbrella-shaped, free-swimming form — e.g., *Aurelia*. Some species show both forms in their life cycle (metagenesis).

7. **Digestion:**

   Both **extracellular** (in gastrovascular cavity) and **intracellular** (in cells).

8. **Nervous System:** Diffused **nerve net** type, without brain or central nervous system.
9. **Skeletal Structures:** May have **calcareous** or **horny skeletons** (e.g., *Corals*).
10. **Reproduction:**
    - **Asexual reproduction** by budding (common in polyps).
    - **Sexual reproduction** by gametes (usually in medusa).
    - **Alternation of generations (metagenesis)** may occur between polyp and medusa forms.
11. **Development:** Fertilization leads to a **planula larva**, which develops into the adult.
12. **Examples:** *Hydra*, *Aurelia* (jellyfish), *Obelia*, *Physalia* (Portuguese man of war), *Corallium* (red coral).

Classification of Coelenterata (Cnidaria)

The phylum Coelenterata is divided into the following **three main classes** based on dominant life form, type of polyp-medusa relationship, and colony structure:

1. Class Hydrozoa

Characteristics:

- Both **polyp and medusa** forms are present; polyp usually dominant.
- Mostly **colonial**, though some are solitary (*Hydra*).
- **Medusa** is usually small and has a **velum** (a shelf-like membrane on the bell margin).
- **Asexual reproduction** by budding; **sexual** by gametes.
- **Exhibit alternation of generations** (e.g., *Obelia*).

Examples:

Hydra, *Obelia*, *Tubularia*, *Physalia* (Portuguese man of war), *Velella*, *Porpita*.

2. Class Scyphozoa

Characteristics:

- Commonly called **true jellyfish**.
- **Medusa form dominant**; polyp stage is small or reduced.
- Medusa **lacks velum**.
- Body is soft, gelatinous, and often large in size.
- **Marine** and free-swimming.
- **Reproduction** involves alternation of generations.

Examples:

Aurelia (Moon jellyfish), *Cyanea*, *Rhizostoma*, *Pelagia*.

3. Class Anthozoa

Characteristics:

- Only **polyp form present**; **medusa stage absent**.
- **Solitary or colonial** forms; all are **marine**.
- Body is **flower-like** with numerous tentacles.
- The **gastrovascular cavity** is divided by **mesenteries** (septa).
- Many secrete **calcareous skeletons**, forming **coral reefs**.

Examples:

Adamsia (sea anemone), *Corallium* (red coral), *Metridium*, *Gorgonia* (sea fan), *Madrepora* (stony coral).

2.4 Polymorphism in coelenterates & Corals and coral reefs

Polymorphism in Coelenterates

Polymorphism is the occurrence of **different forms within the same species** that perform **different functions**. The word comes from Greek — *polys* meaning “many” and *morphe* meaning “form.” In coelenterates, polymorphism helps in **division of labor** among individuals. These different forms live together in a **colony**, making the group more efficient. The **class Hydrozoa** shows the best example of polymorphism.

Main Forms of Polymorphism

1. **Polyp:**
    - Tubular in shape.
    - Mouth is surrounded by tentacles at one end.
    - The other end is fixed to a surface by a **pedal disc**.
    - Usually **sessile** (non-moving).
    - Responsible for feeding and asexual reproduction.
2. **Medusa:**
    - **Umbrella or bell-shaped** form.
    - Has **tentacles at the margins** and a **mouth in the center** of the lower side.
    - Usually **free-swimming (motile)**.
    - Involved in **sexual reproduction**.

Although they look different, both forms have the same basic body plan and are considered **homologous**.

Patterns of Polymorphism in Hydrozoa

Different hydrozoan colonies show different degrees of polymorphism. Based on the number and function of zooids, three main patterns are observed:

1. Dimorphic

- This is the simplest and most common type of polymorphism.
- Colonies have **two kinds of zooids**:
    - **Gastrozooids (Hydranths):** Used for feeding.
    - **Gonozooids (Blastostyles):** Help in asexual reproduction.
- Examples: *Obelia*, *Tubularia.*

2. Trimorphic

- Colonies have **three types of zooids**:
    - **Gastrozooids:** For feeding.
    - **Gonozooids:** For reproduction.
    - **Dactylozooids:** Defensive zooids containing nematocysts.
- Example: Seen in some advanced hydrozoans.

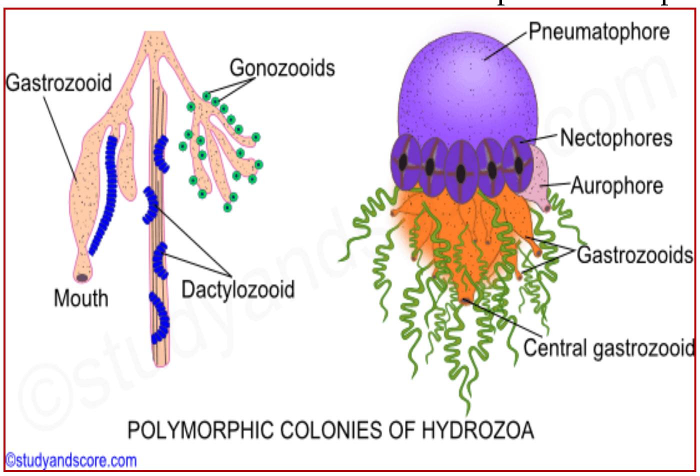
3. Polymorphic

- Colonies have **more than three types of zooids**, each performing specialized functions.

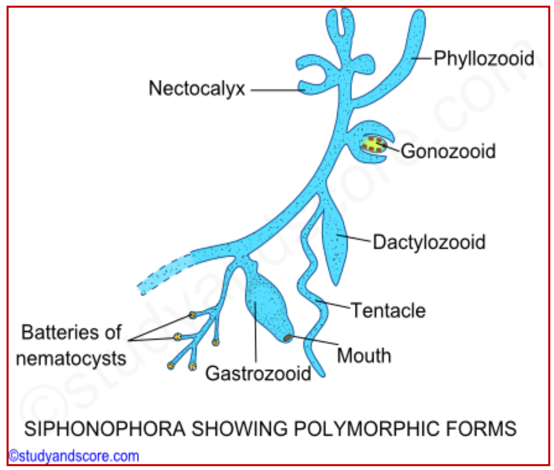
- Example: *Hydractinia* colony has five types:
  - **Gastrozooids:** Feeding
  - **Dactylozooids:** Protection
  - **Tentaculozooids:** Sensory function
  - **Skeletozooids:** Form chitinous spines for support
  - **Gonozooids:** Reproduction

Modifications of Polyp forms

- Gastrozooids also called as feeding polyps. They have a mouth and long a long tentacle
- Dactylozooid also called as protective polyp. They have no mouth but have a basal long tentacle
- Gonozooid also called as reproductive polyp. It produces sexual medusa form.



POLYMORPHIC COLONIES OF HYDROZOA



SIPHONOPHORA SHOWING POLYMORPHIC FORMS

Modifications of Medusa forms

- Nectophore also called as swimming zooid. They have muscular bell without tentacles
- Pneumatophore also called as float bladder-like medusa. They are filled with secreted gas.
- Phyllozooid also called as bract. They are studded with nematocysts and help in protection.
- Gonophore also called as gonad zooid. They may be either male or female.

Importance of polymorphism

Polymorphism is the phenomenon mainly associated with the division of labor. Different functions are assigned to different individuals rather than different parts or organs of the body of the same individual. Polyp forms are associated with the feeding, protection and asexual reproduction while medusa forms are concerned mainly with sexual reproduction.

2.4 .Coral reefs introduction

Coral Reefs

Introduction

Corals are fascinating marine animals that usually live together in colonies. They mostly belong to the class **Anthozoa**, though a few come from **Hydrozoa**. Each tiny coral polyp secretes a hard **calcium carbonate skeleton**, which forms the beautiful structures we simply call **coral**. These skeletons can be solid, massive, or delicately branched. The living coral polyps look like miniature **sea anemones**, and over time, their colonies grow and join together to form vast **coral reefs**. Corals flourish in **warm, clear, shallow tropical waters** where temperatures stay above **20°C**, and they are mainly found in the **Indo-Pacific, Central-Western Pacific, and Caribbean regions**.

Formation of Coral Reefs

- Coral reefs are formed by the continuous growth and **budding of coral polyps** that secrete calcium carbonate.
- The skeletons of dead corals accumulate, and new corals grow over them, forming **massive limestone structures**.
- The main builders of reefs are **stony corals (Scleractinia)**, while **coralline algae** and **foraminiferans** also contribute.

Types of Coral Reefs

1. Fringing Reefs

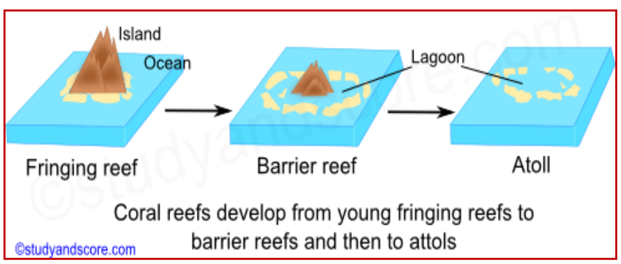
Fringing reefs are the **simplest and most common type** of coral reefs. They grow **directly along the shoreline** of islands or continents and are separated from the shore by a **narrow, shallow water channel** known as the **reef flat**. The reef flat is often exposed during low tide and contains living as well as dead coral colonies, sand, and other marine life. The **seaward edge** of the reef, called the **reef front**, is the most active zone of coral growth because it receives plenty of sunlight and oxygenated water. **Example: Fringing reefs of the Gulf of Mannar (India)** and **Red Sea coast**.

2. Barrier Reefs

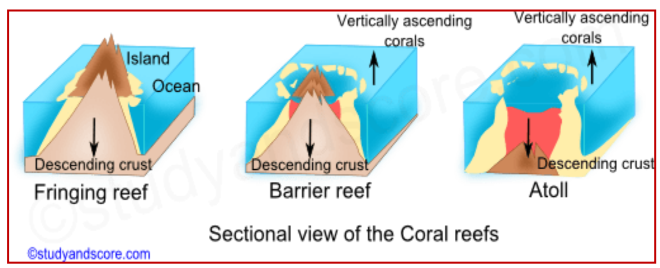
Barrier reefs are **more advanced and larger** than fringing reefs. They form **parallel to the coastline** but are located **farther offshore**, separated from the land by a **deep, wide lagoon** that can range from half a mile to over 10 miles in width. The lagoon provides calm waters suitable for navigation and supports rich biodiversity. Barrier reefs act as **natural barriers**, protecting the shorelines from strong waves and storms. **Example:** The **Great Barrier Reef** in **Australia—the largest and most famous coral reef system in the world, stretching over 2,300 kilometers—is a classic example of this type.**

3. Atolls (Coral Islands)

Atolls are **ring-shaped or horseshoe-shaped reefs** that enclose a **central lagoon**. They usually occur **in the open ocean** and are formed over **submerged volcanic islands**. As the volcanic island gradually sinks or subsides, the corals continue to grow upward, maintaining their position near the sea surface, eventually forming a circular reef around the lagoon. Atolls often have **small islets (cays)** made of coral sand and debris, some of which are inhabited. **Example:** The **Lakshadweep Islands (India)** and **Bikini Atoll (Pacific Ocean) are well-known examples.**



Coral reefs develop from young fringing reefs to barrier reefs and then to attols



Sectional view of the Coral reefs

Importance of Coral Reefs

- **Biodiversity Hotspots:** Called the **"rainforests of the sea"**, coral reefs support a vast variety of marine organisms like fishes, mollusks, echinoderms, and algae.
- **Coastal Protection:** Act as **natural barriers** against waves, storms, tsunamis, and sea erosion.
- **Economic Value:** Provide resources for **fisheries, tourism, and ornament trade** (e.g., red coral used as jewelry).
- **Medicinal Value:** Source of compounds used in **treatments for cancer, HIV, and other diseases**.

- **Petroleum and Construction:** Coral deposits serve as sites for **oil accumulation** and provide **building materials** like lime and cement.
- **Ecological Role:** Maintain **marine balance**, support **nutrient cycling**, and act as **nursery grounds for fishes**.

Unit-III

3.1 Platyhelminthes General characters and classification up to classes with suitable examples

Phylum: Platyhelminthes (Flatworms)

General Characters:

1. **Body Form:**
   The body is **dorsoventrally flattened**, soft, and bilaterally symmetrical. Hence, they are called **flatworms**.
2. **Germ Layers:**
   They are **triploblastic** animals, meaning their body develops from three germ layers – ectoderm, mesoderm, and endoderm.
3. **Body Cavity:**
   They are **acoelomates**, i.e., there is **no true body cavity (coelom)** between the body wall and the gut.
4. **Body Organization:**
   They exhibit the **organ-system level** of body organization.
5. **Digestive System:**
   The digestive system is **incomplete** (only one opening – the mouth; no anus) or **absent** in some parasitic forms.
6. **Circulatory and Respiratory Systems:**
   Both are **absent**; exchange of gases and nutrients occurs by **diffusion**.
7. **Nervous System:**
   Consists of **a pair of cerebral ganglia** (brain-like structures) and **two main nerve cords** running along the body.
8. **Excretory System:**
   Excretion and osmoregulation occur through **flame cells** (also called protonephridia).

9. **Reproduction:**

   Mostly **hermaphroditic** (both sexes in the same individual). Reproduction may be **sexual or asexual**. Fertilization is usually **internal**.

10. **Mode of Life:**

    They may be **free-living** (mostly aquatic) or **parasitic** in animals, including humans.

Classification of Phylum Platyhelminthes

Phylum Platyhelminthes is divided into **three main classes:**

1. Class: Turbellaria (Free-living Flatworms)

- Mostly **free-living** and aquatic (marine or freshwater).
- Body is **soft, ciliated**, and without suckers.
- Possess a **simple digestive system** with a mouth and pharynx.
- **Example:** *Planaria (Dugesia), Bipalium*.

2. Class: Trematoda (Flukes)

- **All are parasitic**, mainly **endoparasites** in the liver, lungs, or blood of vertebrates.
- Body is **leaf-shaped**, **unsegmented**, and **non-ciliated**.
- Possess **suckers** for attachment to the host.
- Have a **complex life cycle** involving **one or more intermediate hosts** (often a snail).
- **Example:** *Fasciola hepatica* (Liver fluke), *Schistosoma* (Blood fluke).

3. Class: Cestoda (Tapeworms)

- **Exclusively parasitic** in the intestine of vertebrates.
- Body is **long, ribbon-like**, and **segmented** into **proglottids**.
- **No digestive system** – absorb nutrients directly through the body surface.
- Have a **scolex (head)** with suckers and sometimes hooks for attachment.
- **Example:** *Taenia solium* (Pork tapeworm), *Echinococcus granulosus* (Dog tapeworm).

3.2. Parasitic Adaptations in helminthes

Helminths are parasitic worms that live inside or outside the body of a host organism and derive nutrition from it. They include both **flatworms (Platyhelminthes)** and **roundworms**

(Nemathelminthes). To survive and reproduce successfully within their hosts, these parasites have developed several **morphological, physiological, and reproductive adaptations**.

1. Morphological Adaptations

1. **Protective Body Covering:** The body of parasitic helminths is covered by a **thick cuticle** or **tegument**, which protects them from the host's digestive enzymes and immune reactions. *Example: Fasciola hepatica* has a resistant tegument.
2. **Attachment Organs:** They possess **suckers, hooks, or adhesive glands** to attach firmly to the host tissues and resist peristaltic movement. *Examples:*
    - *Fasciola hepatica* – oral and ventral suckers.
    - *Taenia solium* – scolex with hooks and suckers.
3. **Reduction of Sense Organs:** Since parasites live in a dark and constant environment, their **sense organs are poorly developed or absent.**
4. **Body Shape:** The body is **flattened or elongated** to fit within the host's organs such as the intestine or liver.
5. **Absence of Locomotory Organs:** Parasitic helminths are **non-motile** and depend on their host; hence, cilia or flagella are absent.

2. Physiological and Functional Adaptations

1. **Anaerobic Respiration:** Most internal parasites live in oxygen-poor environments and thus perform **anaerobic respiration**.
2. **Absorption of Nutrients:** Parasitic worms, especially tapeworms, **absorb pre-digested food** directly from the host's intestine through their body surface (tegument).
3. **Efficient Excretory and Osmoregulatory Systems:** They possess **flame cells or excretory canals** to remove wastes and maintain internal balance.
4. **Tolerance to Host Environment:** Parasites can **resist host enzymes, pH, and immune defenses** through chemical secretions and resistant body coverings.

3. Reproductive Adaptations

1. **High Reproductive Capacity:** Parasites produce **a large number of eggs** to ensure survival, as many get destroyed in the environment or fail to reach a suitable host. *Example: Ascaris lumbricoides* produces over 200,000 eggs per day.
2. **Hermaphroditism:**

    Many helminths (like *Taenia* and *Fasciola*) are **hermaphrodites**, having both male and female reproductive organs in the same individual, ensuring reproduction even when isolated.

3. **Complex Life Cycle:** Most parasitic helminths have **complex life cycles** involving **intermediate hosts**, which helps in wide dispersal and survival. *Example:*
   - *Fasciola hepatica* – sheep (definitive host) and snail (intermediate host).
   - *Taenia solium* – human (definitive) and pig (intermediate).
4. **Protective Egg Shells and Larval Stages:** Eggs have **thick shells** to withstand harsh external conditions. Larvae are well-adapted for infecting new hosts.

4. Behavioral and Life Cycle Adaptations

- **Host Recognition:** Larvae can recognize and infect suitable hosts.
- **Encystment:** Some larvae form **cysts** in host tissues to protect themselves until conditions are favorable.
- **Transmission Strategies:** Many helminths spread through **contaminated food, water, soil, or intermediate hosts.**

Parasitic helminths exhibit a wide range of **structural, physiological, and reproductive adaptations** that enable them to **survive, reproduce, and spread** effectively within their hosts. These adaptations make them **highly specialized organisms** perfectly suited for parasitic life.

3.3. Nemathelminthes General characters and classification up to classes with suitable examples

General Characters

1. **Body Form:**
   - Worm-like, elongated, **cylindrical and unsegmented** body.
   - Both ends of the body are **tapering** (pointed).
2. **Body Covering:**
   - Body is covered by a **tough, flexible, non-cellular cuticle** made of collagen which protects against digestive enzymes and host defense.
3. **Symmetry:**
   - **Bilateral symmetry** – the body can be divided into two equal halves by a single plane.

4. **Germ Layers:**
   - **Triploblastic**, i.e., body wall has three layers – ectoderm, mesoderm, and endoderm.
5. **Body Cavity:**
   - They are **pseudocoelomates** – body cavity (pseudocoel) is not lined completely by mesoderm.
6. **Digestive System:**
   - **Complete** digestive tract with mouth and anus.
   - Mouth is at the anterior end, often with **lips or teeth-like structures**; anus at the posterior end.
7. **Circulatory and Respiratory Systems:**
   - **Absent.** Exchange of gases and transport of nutrients occur through diffusion.
8. **Nervous System:**
   - **Simple**, consisting of a nerve ring around the pharynx and longitudinal nerve cords.
9. **Excretory System:**
   - Excretion occurs through **renette cells** or **excretory canals**.
10. **Sexes:**
    - Mostly **dioecious (sexes separate)**; males are smaller than females and often have copulatory spicules.
11. **Reproduction:**
    - **Sexual reproduction**; fertilization is **internal**.
    - Development is usually **direct or indirect** with larval stages.
12. **Mode of Life:**
    - Many are **free-living** in soil or aquatic habitats; others are **parasitic** in animals and humans.

The phylum **Nemathelminthes**, also known as **Aschelminthes**, includes elongated, cylindrical, and unsegmented worms commonly called **roundworms**. They may be free-living or parasitic in plants and animals. Based on structural and physiological features, the phylum is divided into two main classes: **Aphasmidia (Adenophorea)** and **Phasmidia (Secernentea)**.

Class 1: Aphasmidia (Adenophorea): Members of this class are mostly free-living and occur in marine or freshwater habitats, although some are parasitic. The amphids (chemosensory organs) are located behind the lips and are not pocket-like. They lack phasmids, and the excretory system is either simple or absent. Common examples include *Enoplus*, *Trichuris trichiura* (whipworm), and *Trichinella spiralis*, which causes trichinosis in mammals.

Class 2: Phasmidia (Secernentea): This class mainly consists of parasitic nematodes that live inside the bodies of animals and humans. Amphids are pocket-like and well-developed, and phasmids (posterior sensory glands) are present. The excretory system is well-developed with lateral excretory canals. Examples include *Ascaris lumbricoides* (roundworm), *Enterobius vermicularis* (pinworm), *Ancylostoma duodenale* (hookworm), and *Wuchereria bancrofti* (filarial worm).

Examples and Importance:

Phylum **Nemathelminthes** includes simple, cylindrical, unsegmented worms that are mostly parasitic. They possess a **complete digestive system**, a **pseudocoel**, and show **sexual dimorphism**. Their parasitic members are of great medical importance as they cause several diseases in humans and animals.

3.4 . Life cycle and pathogenicity of *Ascaris lumbricoides*

Ascaris lumbricoides **(Intestinal Nematode) "Roundworm"**

Geographic Distribution:

Ascaris lumbricoides can be found throughout the world but is more commonly found in moist temperate and tropical regions. *Ascaris* is increasingly prevalent where poor sanitation exists. In cultures where human excrement (night soil) is used as fertilizer, infection may again be greater.

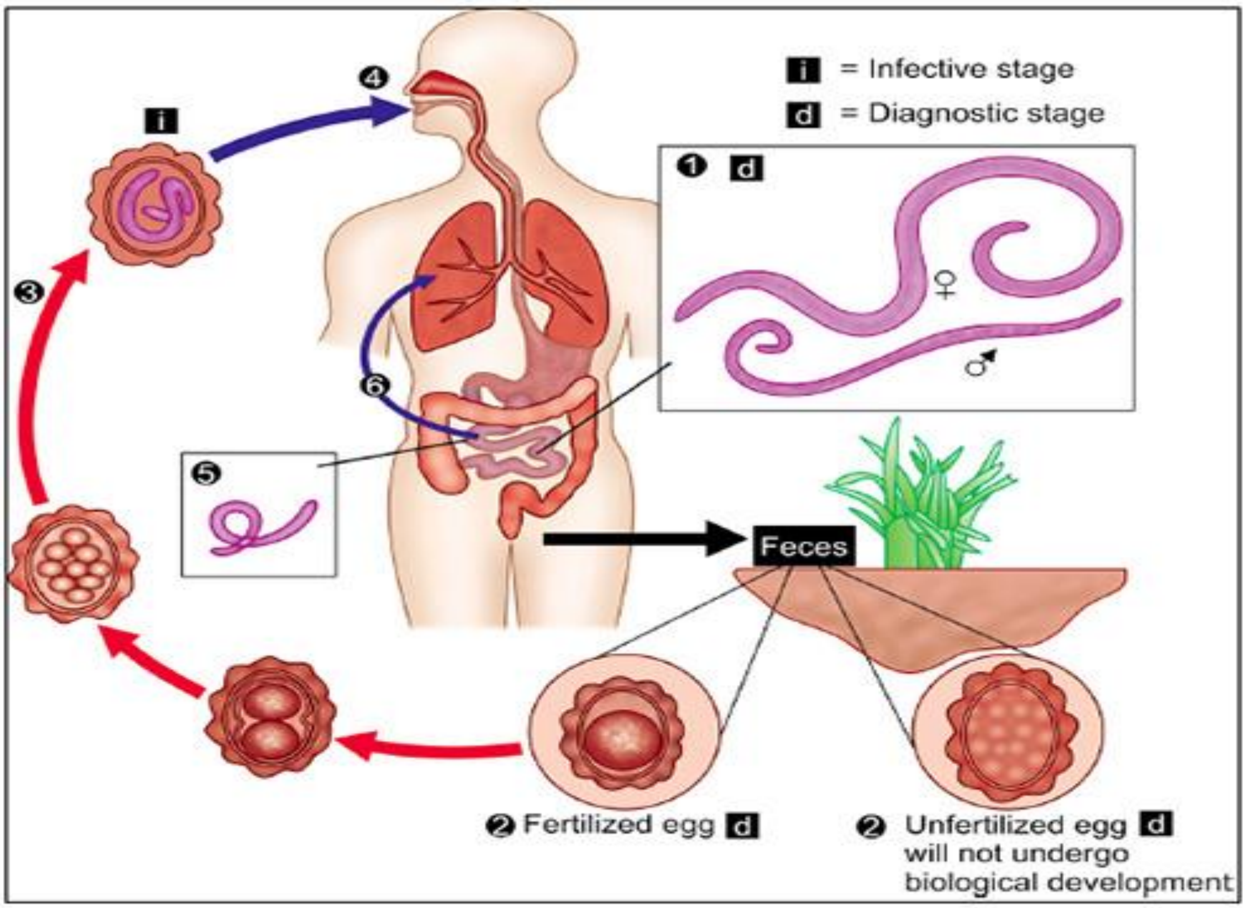
Pathogenicity:

Ascariasis occurs when fully embryonated eggs of *Ascaris lumbricoides* are ingested. It is one of the most widespread parasitic infections globally. Mild infections may cause no symptoms, but heavy infestations can lead to **respiratory problems** such as cough, wheezing, and shortness of breath due to **Ascaris pneumonitis (Loeffler's syndrome)**. Severe intestinal infections, especially in children, can cause **bowel obstruction**, **fever**, **abdominal distension**, **pain**, and **vomiting**.

Life Cycle of *Ascaris lumbricoides*

1. **Ingestion of Infective Eggs:** Humans become infected when they accidentally ingest embryonated (infective) eggs from contaminated food, water, or soil. These eggs contain larvae ready to hatch once inside the body.
2. **Larval Hatching and Migration:** In the **duodenum** (the first part of the small intestine), the eggs hatch and release larvae. The larvae then penetrate the intestinal wall and enter the **bloodstream or lymphatic system**.

3. **Migration to Liver and Lungs:** The larvae are carried through the **liver** and **heart**, eventually reaching the **lungs** via pulmonary circulation. In the lungs, they break out of the tiny blood vessels and move into the **alveoli** (air sacs), where they grow for about **2–3 weeks**.
4. **Return to Intestine:** As the larvae mature, they travel up the **respiratory tract**—from the alveoli to the bronchi, trachea, and throat. They are then **swallowed** again and return to the **small intestine**.



5. **Maturation into Adult Worms:**
   Back in the small intestine, the larvae develop into adult worms. Within **2–3 months** after infection, the female worms start producing **around 200,000 eggs per day**.
6. **Eggs Released in Feces:**
   The fertilized eggs are passed out in feces. In the external environment, they need **2–3 weeks** in warm, moist soil to become **embryonated** and infective again. Unfertilized eggs do not develop further.

7. **Environmental Survival:**

   Although the eggs are sensitive to heat and drying, they can survive in **moist soil for long periods**, maintaining their ability to infect others and thus completing the cycle.

Key notes

- **Infective stage:** Embryonated (fertilized, larvated) egg.
- **Diagnostic stage:** Fertilized eggs passed in feces.
- **Mode of infection:** Ingestion of infective eggs through contaminated food or water.
- **Habitat of adult worm:** Small intestine of humans.
- **Disease:** *Ascariasis* — may cause abdominal pain, intestinal blockage, coughing (during lung migration), and malnutrition.

Unit-IV

4.1. Annelida General characters and classification up to classes with suitable examples

Phylum: Annelida

General Characters

1. **Body organization** – Triploblastic, bilaterally symmetrical, and **segmented (metameric)** body.
2. **Habitat** – Mostly **aquatic (marine or freshwater)**, some are **terrestrial** and a few are **parasitic**.
3. **Body wall** – Consists of a thin, moist **cuticle**, circular and longitudinal **muscles**, and **chitinous setae** (for locomotion).
4. **Segmentation** – Body divided into **repeating segments (metameres)** separated by **septa**.
5. **Coelom** – **True coelomates (schizocoelous)**; coelom acts as a **hydrostatic skeleton**.
6. **Digestive system** – Complete, with **mouth and anus**; regionally specialized (pharynx, gizzard, intestine).
7. **Circulatory system** – **Closed type** with blood vessels and capillaries; **haemoglobin** present in plasma.
8. **Respiration** – Through **body surface**, **gills**, or **parapodia** (in some marine forms).
9. **Excretion** – By **nephridia** (segmentally arranged).
10. **Nervous system** – Well-developed; consists of a **cerebral ganglion** (brain) and a **ventral nerve cord**.
11. **Reproduction** – Mostly **sexual**; some are **hermaphrodites** (e.g., earthworm) while others are **dioecious**; development may be **direct or indirect (with trochophore larva)**.

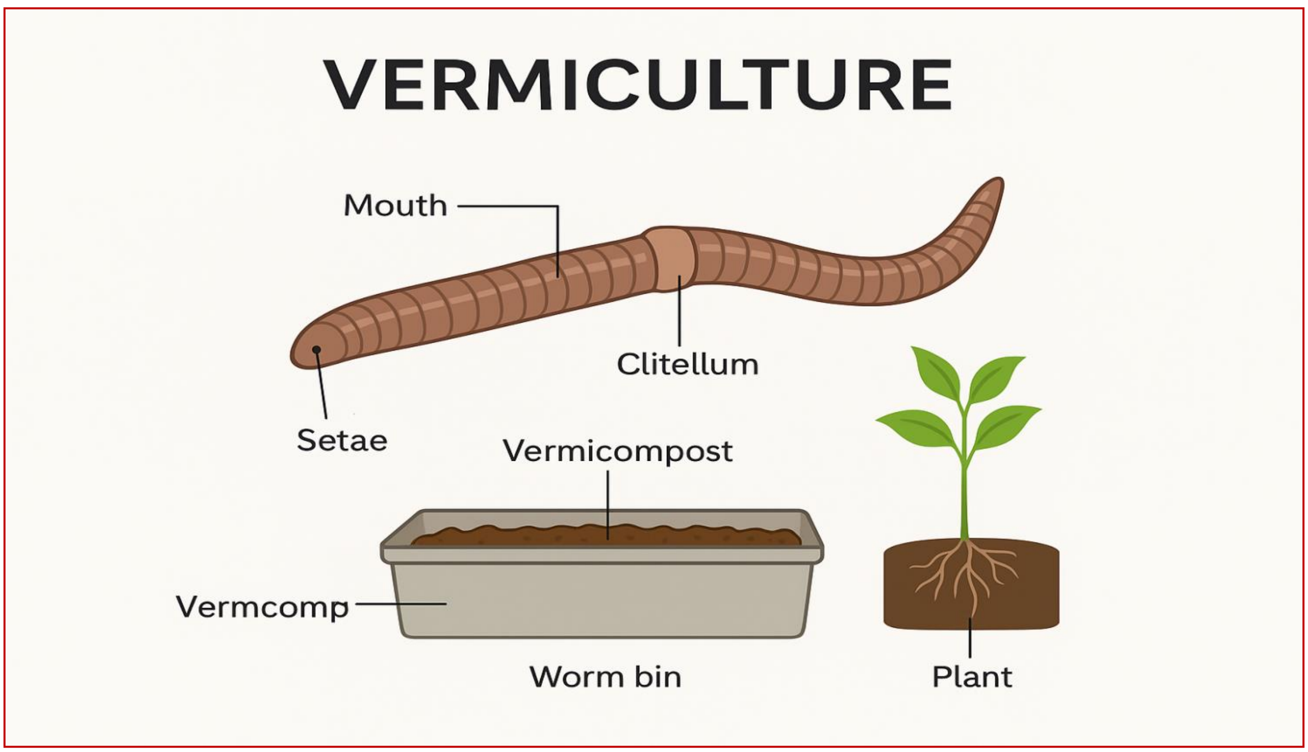
Classification up to Classes with Examples

Phylum Annelida is divided into the following major classes:

1. **Class Polychaeta** – These are mostly **marine annelids** having **parapodia** with numerous **setae**. The head is distinct and bears sensory organs such as eyes and tentacles. The sexes are separate, and development occurs through a **trochophore larva**. **Examples:** *Nereis*, *Arenicola*, *Aphrodite*.

2. **Class Oligochaeta** – These are mostly **terrestrial or freshwater worms** such as the earthworm. They have **no parapodia** and **few setae** on each segment. They are **hermaphrodites**, and development is **direct** without a larval stage. They are important decomposers and improve soil fertility. **Examples:** *Pheretima posthuma* (Earthworm), *Lumbricus*, *Tubifex*.
3. **Class Hirudinea** – These include **leeches**, which are mainly **freshwater or parasitic**. They lack both parapodia and setae. The body has a fixed number of segments, and each end bears a **sucker** for attachment. They are **hermaphroditic**, and development is **direct**. **Examples:** *Hirudo medicinalis* (Medicinal leech), *Haemopis*.
4. **Class Archiannelida** – These are **primitive marine annelids**, often unsegmented or slightly segmented. They lack parapodia and retain many larval features throughout life, showing their primitive nature. **Examples:** *Polygordius*, *Protodrilus*.

4.2. Vermiculture - Scope, significance, earthworm species, processing, Vermicompost, economic importance of vermicompost.



Vermiculture: Scope, Significance, and Economic Importance

Introduction:

Vermiculture is the scientific method of breeding and raising earthworms to convert organic waste into nutrient-rich compost called **vermicompost**. It is an eco-friendly and sustainable technique for managing biodegradable waste. This process improves soil fertility and structure by enhancing its nutrient and microbial content. Vermiculture helps reduce environmental pollution caused by improper waste disposal. It also supports organic farming by providing a natural alternative to chemical fertilizers. Overall, vermiculture plays a vital role in promoting sustainable agriculture and environmental conservation..

Scope of Vermiculture:

Vermiculture has gained importance in agriculture, horticulture, and waste management.

- Converts kitchen waste, agricultural residues, and farmyard manure into valuable compost.
- Improves soil structure and fertility naturally, reducing dependency on chemical fertilizers.
- Serves as a tool for solid waste management in rural and urban areas.
- Helps in sustainable farming and organic food production.
- Generates employment opportunities in rural communities.

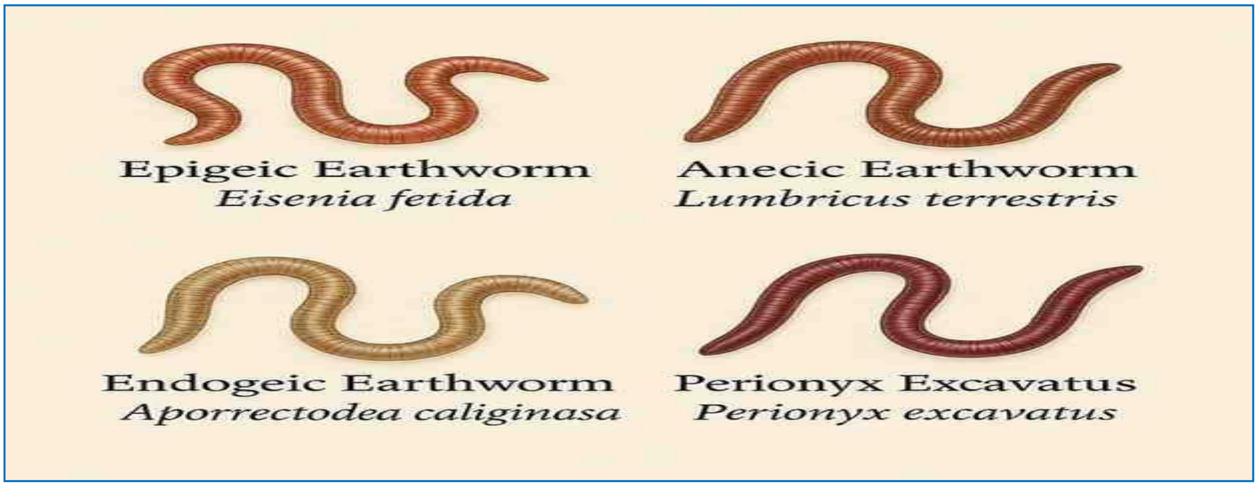
Significance of Vermiculture:

1. **Environmental Benefits:** Vermiculture helps reduce land pollution by turning organic waste like food scraps, leaves, and farm residues into useful compost instead of letting them rot in landfills. This process also prevents the foul odor that usually comes from decaying waste and keeps the surroundings clean and healthy.
2. **Soil Enrichment:** The vermicompost produced by earthworms improves soil health by increasing microbial activity. It makes the soil more porous, allowing air and water to move easily through it. It also helps the soil hold moisture for a longer time, which is beneficial for plant growth.
3. **Nutrient Recycling:** Through vermiculture, organic waste is converted into humus that is rich in essential nutrients such as nitrogen, phosphorus, potassium, calcium, and other micronutrients. These nutrients are slowly released into the soil, providing continuous nourishment to plants.

4. **Eco-friendly Farming:**
Vermiculture supports sustainable and organic farming by reducing the need for chemical fertilizers and pesticides. It helps in growing healthier crops naturally and maintains the ecological balance, making it safe for both humans and the environment.

Common Earthworm Species Used:

1. **Eisenia fetida** – (Red wigglers): Fast breeders, commonly used for composting household and farm waste.
2. **Eudrilus eugeniae** – (African nightcrawler): Highly efficient in tropical regions.
3. **Perionyx excavatus** – (Indian blue worm): Native species suitable for Indian climatic conditions.
4. **Lumbricus rubellus** – Used widely for organic waste decomposition in temperate zones.



Processing and Production of Vermicompost:

1. **Collection of Raw Material:** Organic wastes such as agricultural residues, vegetable peels, dry leaves, and cow dung are collected as the main raw materials for composting. These provide food for the earthworms and serve as the base for compost formation.
2. **Pre-decomposition:** The collected waste is left to partially decompose for about 15–20 days. This step helps to remove excess heat generated by microbial activity, making the material safe and suitable for earthworms.
3. **Bed Preparation:** Composting beds are prepared in pits, tanks, or wooden boxes about 1 to 1.5 feet deep. Layers of partially decomposed organic waste are spread evenly to create a soft bed for the worms to thrive.

4. **Introduction of Worms:** Healthy and active earthworms (such as *Eisenia foetida* or *Eudrilus eugeniae*) are released onto the surface of the bed. These worms gradually move through the waste, consuming and converting it into fine compost.
5. **Moisture Maintenance:** The compost bed must be kept moist, around 40–50%, by sprinkling water regularly. Proper moisture and shade are necessary for the survival and activity of the earthworms.
6. **Harvesting:** After about 45–60 days, the organic waste is converted into dark, crumbly, and odor-free compost. The compost is then separated from the worms, dried, and sieved before being used as nutrient-rich **vermicompost** for plants.

Vermicompost:

Vermicompost is the final product obtained from the decomposition of organic matter by earthworms.

- **Color:** Dark brown or black
- **Texture:** Fine and granular
- **Composition:** Rich in humus, nitrogen, phosphorus, potassium, calcium, and beneficial microbes.

Economic Importance of Vermicompost:

- **Soil Fertility:** Increases productivity by improving soil structure and nutrient content.
- **Crop Yield:** Enhances germination, growth, and yield of crops.
- **Cost-effective:** Reduces expenditure on chemical fertilizers.
- **Waste Utilization:** Converts farm and kitchen waste into valuable fertilizer.
- **Employment:** Provides livelihood through small-scale vermicomposting units.
- **Sustainable Agriculture:** Promotes eco-friendly and organic farming practices.

Vermiculture is an effective and sustainable method for recycling organic waste, improving soil health, and supporting eco-friendly agriculture. It combines environmental conservation with economic benefits, making it an essential component of modern sustainable farming systems.

4.3.Arthropoda General characters and classification up to classes with suitable examples.

Phylum: Arthropoda

General Characters:

1. Arthropoda is the largest phylum in the animal kingdom, including insects, crabs, spiders, and centipedes.
2. They are **bilaterally symmetrical**, **triploblastic**, and **coelomate** animals.
3. The body is **segmented** and divided into **head, thorax, and abdomen** (or cephalothorax and abdomen in some).
4. They possess a **chitinous exoskeleton** made of a tough, non-cellular cuticle, which is periodically shed during **molting or ecdysis**.
5. They have **jointed appendages** (legs, antennae, mouthparts) used for various functions like movement, feeding, and sensing.
6. The body cavity is a **hemocoel**, and blood circulation is **open type**, where blood (hemolymph) bathes the organs directly.
7. **Respiration** occurs through **gills, tracheae, or book lungs**, depending on the group.
8. **Excretion** takes place by **Malpighian tubules**, **green glands**, or **coxal glands**.
9. The **nervous system** consists of a dorsal brain and a ventral double nerve cord.
10. **Sexes are separate (dioecious)**, and reproduction is generally **sexual** with development either direct or indirect (through larval stages).

Classification of Arthropoda (up to Classes)

1. **Class Crustacea**
    - Mostly aquatic, with gills for respiration.
    - Body divided into **cephalothorax and abdomen**.
    - Two pairs of antennae and biramous (branched) appendages present.
    - **Examples:** *Palaemon* (Prawn), *Cancer* (Crab), *Astacus* (Crayfish), *Daphnia*, *Cyclops*.
2. **Class Arachnida**
    - Mostly terrestrial, body divided into **cephalothorax and abdomen**.
    - Four pairs of walking legs, no antennae.
    - Respiration through **book lungs or tracheae**.

- **Examples:** *Aranea* (Spider), *Scorpio* (Scorpion), *Tick*, *Mite*.

3. **Class Chilopoda**
   - Terrestrial, elongated body with many segments.
   - Each segment bears one pair of legs.
   - Carnivorous with poison claws near the head.
   - **Examples:** *Scolopendra* (Centipede).
4. **Class Diplopoda**
   - Terrestrial, body elongated and cylindrical.
   - Each segment (after the fourth) bears **two pairs of legs**.
   - Herbivorous or detritivorous.
   - **Examples:** *Julus* (Millipede).
5. **Class Insecta**
   - Largest and most diverse class.
   - Body divided into **head, thorax, and abdomen**.
   - Three pairs of legs, usually two pairs of wings.
   - Respiration through **tracheae**.
   - **Examples:** *Musca domestica* (Housefly), *Apis* (Honeybee), *Anopheles* (Mosquito), *Periplaneta americana* (Cockroach).
6. **Class Merostomata**
   - Marine arthropods with a hard carapace and long telson (tail spine).
   - Respiration by book gills.
   - **Example:** *Limulus* (King Crab or Horseshoe Crab).

4.4. Peripatus - Structure and affinities

Peripatus – Structure and Affinities

Scientific Classification		
Phylum	❖	Onychophora
Genus	❖	*Peripatus*
Common name	❖	Velvet worm

Introduction:

Peripatus is a small, soft-bodied, worm-like invertebrate that exhibits features of both **Annelida** (segmented worms) and **Arthropoda** (jointed-legged animals). Because of these mixed characteristics, it is often regarded as a **connecting link between Annelids and Arthropods**, providing important evolutionary evidence of the transition from segmented worms to arthropods.

Habitat and Distribution:

Peripatus is a terrestrial animal that lives in moist, dark environments like under logs, stones, and leaf litter. It is found in tropical and subtropical regions such as **Australia, New Zealand, South Africa, and South America**.

External Structure (Morphology):

1. **Body Shape:**

- Elongated, cylindrical, and soft; worm-like body covered with **velvety skin** (hence called "velvet worm").
- Body length ranges from 1 to 8 cm.

2. **Segmentation:**

   - Body appears superficially segmented, but internal segmentation is not distinct.

3. **Appendages:**

   - Possesses **14 to 43 pairs of unjointed, stumpy legs** called **lobopodia**, each ending in claws.
   - The legs help in slow creeping movement.

4. **Head:**

   - Bears a pair of **antennae**, a pair of **simple eyes**, and **oral papillae** that open into **slime glands** (used for defense and capturing prey).

5. **Mouth:**

   - Ventral and surrounded by a pair of jaws derived from appendages.

Internal Structure:

1. **Body Wall:**

   - Thin, flexible cuticle without calcification; does not undergo molting like arthropods.

2. **Digestive System:**

- Straight alimentary canal with distinct mouth, pharynx, esophagus, stomach, intestine, and anus.
- Carnivorous — feeds on small insects and other invertebrates.

3. **Respiratory System:**

   - Respiration through **tracheae**, with small **spiracles** distributed all over the body (similar to arthropods).

4. **Circulatory System:**

   - **Open type**, with a tubular heart lying dorsally and several pairs of ostia.

5. **Excretory System:**

   - **Segmentally arranged nephridia** in each leg-bearing segment (similar to annelids).

6. **Nervous System:**

   - Ladder-like, with a pair of cerebral ganglia connected to two ventral nerve cords.

7. **Reproductive System:**

   - Sexes are separate (dioecious).
   - Fertilization is **internal**.
   - In many species, development is **viviparous** (young ones born alive).

Affinities of *Peripatus*

1. Resemblances with Annelida:

- Soft, worm-like, unsegmented body.
- Presence of nephridia for excretion.
- Body wall musculature similar to annelids.
- Straight alimentary canal.

2. Resemblances with Arthropoda:

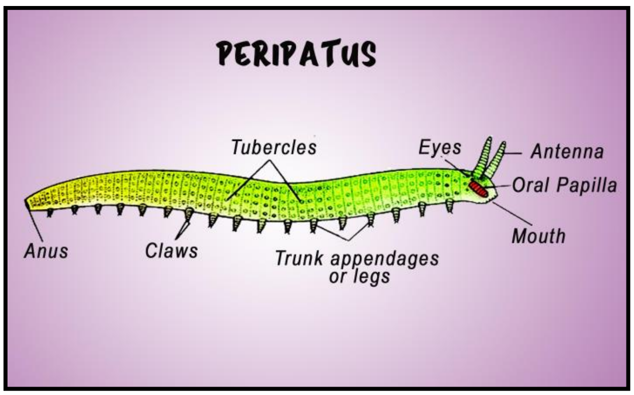
- Presence of chitinous cuticle.
- Tracheal respiration and open circulatory system.
- Appendages are paired and lateral.
- Clawed feet, jaws, and antennae.
- Hemocoelic body cavity.

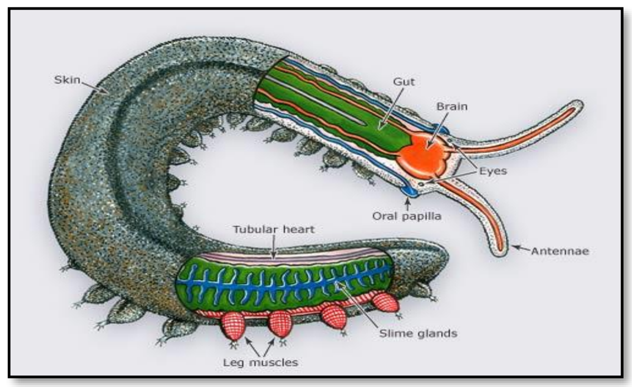
3. Resemblances with Mollusca:

- Slime glands resemble mucous glands of molluscs.

4. Unique or Distinctive Characters (Onychophoran Features):

- Unjointed lobopodia (legs).
- Slime glands for prey capture and defense.
- Tracheae with non-closable spiracles.
- Combination of annelidan and arthropodan features makes it a unique phylum (*Onychophora*).





Evolutionary Significance:

Peripatus is considered a **living fossil** and represents an **evolutionary link** between the segmented worms (Annelida) and arthropods. It provides insight into how early arthropods might have evolved from annelid-like ancestors. *Peripatus* is an important evolutionary form that bridges the gap between worms and arthropods. With its annelid-like nephridia and arthropod-like tracheae, it demonstrates a perfect blend of primitive and advanced features, justifying its placement in the separate phylum **Onychophora**.

Unit-V

5.1. Mollusca General characters and classification up to classes with suitable examples

Phylum: Mollusca

General Characters

1. **Body organization:**
   Molluscs are **bilaterally symmetrical**, **triploblastic**, and **coelomate** animals with a **soft, unsegmented body**.
2. **Body divisions:**
   The body is divided into **head, visceral mass, and foot**.
   - The **head** bears sensory organs and mouth.
   - The **visceral mass** contains the internal organs.
   - The **foot** is a muscular organ used for locomotion and attachment.
3. **Body covering:**
   The body is covered by a **soft mantle** that secretes a **calcareous shell**, which may be **external** (as in snails) or **internal** (as in squids).
4. **Body cavity and skeleton:**
   They possess a **true coelom** and often a **hydrostatic skeleton**.
5. **Digestive system:**
   The alimentary canal is **complete**, and the mouth often bears a **radula**—a rasping tongue-like organ used for scraping food.
6. **Circulatory system:**
   - **Open type** in most molluscs (e.g., snails).
   - **Closed type** in cephalopods (e.g., squids and octopuses).
7. **Respiration:**
   Respiration occurs through **gills (ctenidia)**, the **mantle surface**, or **body wall**.
8. **Excretion:**
   Excretory organs are **nephridia** or **kidney-like structures**.
9. **Nervous system:**
   Well-developed, with paired **ganglia and nerve cords**. Cephalopods have a **highly developed brain**.
10. **Reproduction:**
    Reproduction is **sexual**, mostly **dioecious** (separate sexes), and fertilization may be **internal or external**. The development may include **larval stages** like *trochophore* or *veliger*.

Classification of Mollusca (Up to Classes)

1. **Class 1: Monoplacophora**

- Body with a single, cap-like shell.
- Shows primitive segmentation.
- **Example:** *Neopilina*.

2. **Class 2: Polyplacophora (Chitons)**
- Body flattened, with **eight dorsal plates**.
- Found clinging to rocks in marine areas.
- **Example:** *Chiton*.

3. **Class 3: Scaphopoda (Tusk Shells)**
- Tubular shell open at both ends.
- Marine, burrowing forms.
- **Example:** *Dentalium*.

4. **Class 4: Gastropoda (Snails and Slugs)**
- Asymmetrical body due to **torsion**.
- Shell usually coiled.
- Mostly terrestrial or aquatic.
  - **Examples:** *Pila*, *Helix*, *Achatina*, *Limnaea*.

5. **Class 5: Pelecypoda (Bivalvia or Lamellibranchia)**
- Body enclosed in a **two-valved shell**.
- Head absent; gills are large and plate-like.
- Mostly sedentary filter feeders.
- **Examples:** *Unio*, *Mytilus*, *Ostrea* (oyster).

6. **Class 6: Cephalopoda (Squids, Octopus, Cuttlefish)**
- Marine, highly active animals.
- Shell may be reduced or internal (*Sepia*, *Loligo*).
- **Tentacles** with suckers for capturing prey.
- **Examples:** *Octopus*, *Loligo*, *Sepia*, *Nautilus*.

5.2 Pearl formation in Pelecypoda

Pearl Culture

Pearl is a smooth, shining white globular structure formed inside the shell of an oyster. Pearl oysters are sedentary and were first cultured in India in 1973 at Thoothukudi. They are mainly found along the Kanyakumari coast and the Gulf of Kutch. High-quality pearls come from the genus *Pinctada*, cultured in 30 ppt salinity using rack, raft, or long-line methods. Freshwater bivalves like *Lamellidens* are also used for artificial culture. These oysters usually live on rocky or coral ridges forming pearl banks that yield superior “Lingha Pearls.”

Pearl Formation

When a foreign particle enters between the mantle and shell of an oyster, it gets covered by the mantle tissue, which secretes continuous layers of nacre around it as a defense mechanism. Over time, these calcium carbonate layers form a hard, shiny pearl. When the pearl becomes large, the oyster eventually dies, and the pearls are then collected and graded manually.

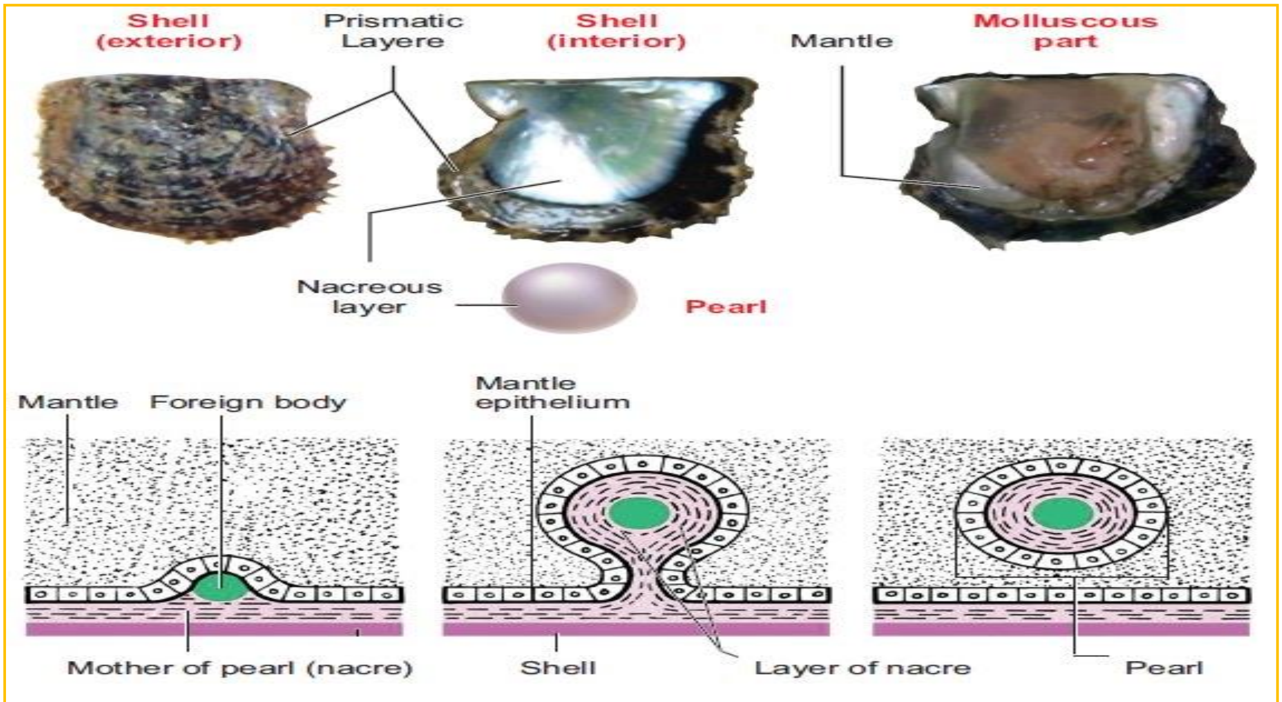


Figure 13. 12 Pearl and Pearl Formation

Process of Pearl Formation

1. **Entry of Foreign Particle:** A small particle (like sand or parasite) enters between the **mantle** and the **shell** of the oyster.
2. **Irritation and Response:** This particle causes **irritation** to the delicate mantle epithelium.
3. **Secretion of Nacre:** To protect itself, the **mantle** secretes a smooth, shiny substance called **nacre** (or *mother of pearl*), made of **calcium carbonate** and **conchiolin**.
4. **Layer Formation:** The nacre is deposited **in concentric layers** around the foreign particle over time.
5. **Pearl Development:** Gradually, the particle becomes completely covered by nacre, forming a **pearl sac** and later a **solid pearl**.
6. **Time Taken:** Pearl formation usually takes **3–4 years**, depending on the species and environmental conditions.

Structure of a Pearl

- A pearl is made up of **many concentric layers** of **nacre**.
- **Chemical composition:**
  - Calcium carbonate ($CaCO_3$): ~90%
  - Organic matter (conchiolin): ~5%
  - Water: ~2–4%

Layers of Shell in Pelecypoda

1. **Periostracum** – Outer organic layer made of *conchiolin*.
2. **Ostracum** – Middle calcareous layer composed of *calcium carbonate*.
3. **Nacreous Layer** – Innermost layer made of *calcium carbonate and conchiolin*, secreted by the entire mantle surface and responsible for *pearl formation*.

Types of Pearls

1. **Natural Pearls:** Formed naturally without human interference.
2. **Cultured (Artificial) Pearls:** Formed when humans insert a nucleus or tissue piece into the oyster to stimulate nacre secretion.
3. **Imitation Pearls:** Artificially made from glass or plastic, coated with fish scales or chemicals to mimic natural pearls.

5.3. A. Echinodermata General characters and classification up to classes with suitable examples .

Phylum: Echinodermata

General Characters:

1. Echinoderms are exclusively **marine animals**, mostly free-living and found on the sea floor.
2. The body is **radially symmetrical** in adults (usually pentamerous), but **bilaterally symmetrical** in larvae.
3. They have a **calcareous endoskeleton** made up of **ossicles or spicules** embedded in the body wall.
4. The body has **oral (mouth) and aboral (opposite) surfaces**, but no head or segmentation.
5. **Water vascular system** (ambulacral system) is present, used for locomotion, respiration, and food capture.
6. They have **no excretory organs**, and respiration occurs through tube feet, papulae, or respiratory trees.
7. The **circulatory system** is open and poorly developed.
8. **Sexes are separate**, and fertilization is external. Development includes a **bilateral larval stage** (e.g., bipinnaria, auricularia).
9. They have great **regenerative power**, especially in starfish and brittle stars.

Classification of Echinodermata (Up to Classes):

1. Class: Asteroidea (Starfishes)

- Body star-shaped with five or more arms radiating from a central disc.
- Tube feet with suckers present on the oral surface.

- Mouth on the lower (oral) side, anus on the upper (aboral) side.
- **Example:** *Asterias*, *Luidia*, *Linckia*, *Pentaceros*.

2. Class: Ophiuroidea (Brittle Stars)

- Body with a distinct central disc and long, slender, flexible arms.
- Tube feet without suckers; locomotion mainly by arm movement.
- No anus; digestion incomplete.
- **Example:** *Ophiura*, *Ophiolepis*, *Astrophyton*.

3. Class: Echinoidea (Sea Urchins and Sand Dollars)

- Body globular or disc-like, without arms.
- Covered by a rigid shell (test) made of fused calcareous plates.
- Movable spines and tube feet present.
- **Example:** *Echinus*, *Arbacia*, *Clypeaster*, *Echinarachnius*.

4. Class: Holothuroidea (Sea Cucumbers)

- Body elongated, soft, and cylindrical.
- Skeleton reduced; body wall leathery.
- Tube feet modified for crawling and burrowing.
- **Example:** *Holothuria*, *Cucumaria*, *Synapta*.

5. Class: Crinoidea (Sea Lilies and Feather Stars)

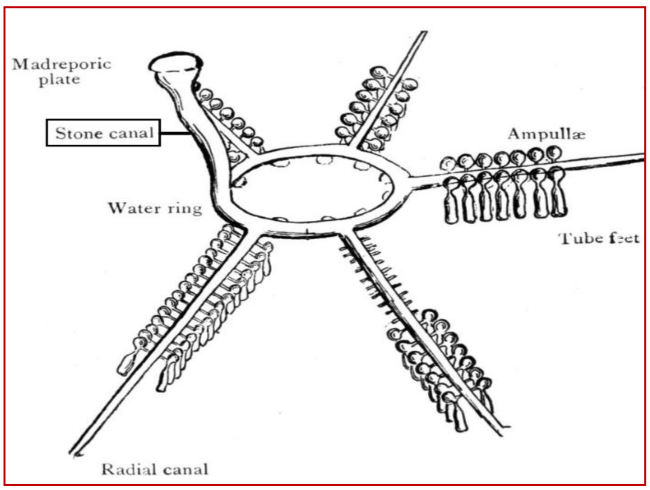
- Body cup-shaped with five or more arms bearing pinnules (feather-like structures).
- Mouth directed upward; attached to substrate by a stalk (in sea lilies).
- Most primitive echinoderms.
- **Example:** *Antedon*, *Metacrinus*, *Rhizocrinus*.

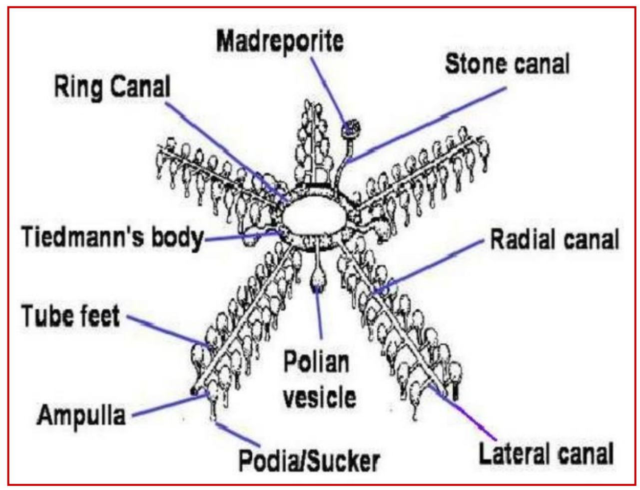
B. Water vascular system in star fish.

In Echinoderms a peculiar system is met with. It is filled with sea water, it is called water vascular system or Ambulacral system. The entire system is lined with ciliated epithelium. This system is well developed in Asteroidea. It contains Madreporite, stone canal, ring canal, 5 radial canals, Tiedemann's bodies, lateral canals and tube feet.

Madreporite: A calcareous plate like structure is present on the aboral surface of the central disc of star fish. It is placed near to two arms and these two arms are called 'Biviurrr.' On surface of the madreporite grooves of furrows are present. Each furrow contains a number of pores. Hence it is called serve plate. These pores led into small canal which open into a stone canal.

Stone Canal: It is a 'S' shaped canal, it is called Madreporic canal. It travels towards the oral side on unite with ring canal at one of inter radius. The walls of stone canal are strengthened by calcarious rings. The inner surface of stone canal is lined with flagellated cells. The movement of flagelia will draw water currents into the stone canal. The wall of the stone canal shows a ridge on one side called 'Lamellated ridge.





Ring Canal: It is penta - radial and is present arround the mouth, on the oral side. At each inner radius, it shows poiian vesicles and Tiedemann's bodies.

Pollan vesicle : In the Asteroidea groups, four muscular like poiian vesicles are present at the 4 inter radi. Some scientists believe that they store water and are considered as reservoirs. Some scientists consider that they produce amoebocytes.

Tiedmann's bodies : Usually in Asterias 9 Tiedeman's bodies are present. On either side of the poiian vesicle two Tiedemann bodies are present. At the stone canal union with ring panal only one Tiedmann body is present. They are lymphoid sac like structures. They are believed to produce amoeboytes.

Radial canals From the ring canal five radial canals arise and run throughout the entire length of the arm. Each radial canal lies below the ambulacra! groove of the oral surface of the arm. Each radial canal ends at the tip of the arm as a tentacle. It is olfactory in function.

Lateral canals From the radial canal of each arm pairs of lateral canals will arise and they end with tube feet.

Tube feet: The basal part of the tube feet is bulged and is called ampulla. It continues as a long tube feet which ends with a 'Sucker'. The ampulla contains circular and longitudinal muscles. The long tube feet like structure contain only longitudinal muscles. Lateral canal will open into ampulla and is guarded by a valve.

Functions of Water Vascular System (in Starfish)

The water vascular system mainly helps in **locomotion** (movement) and **food collection**.

1. Locomotion:

- The ampulla squeezes water into the tube feet, making them stretch out.
- The tube feet stick to the surface using suckers.
- When the tube feet pull back, the starfish moves forward, and water goes back into the ampulla.
- By repeating this stretching and pulling, the starfish moves slowly.
- Usually, it moves using the tube feet of one or two arms at a time.

2. Food Collection:

- The starfish uses its strong **tube feet** to open the shells of molluscs like clams or oysters.
- Once the shell is opened, it pushes out its **stomach** to feed on the **soft body parts** of the prey.

5.4 .A. Hemichordata General characters and classification up to classes with suitable examples

Hemichordata

General Characters:

1. **Body Structure:**
   - Bilaterally symmetrical, triploblastic, and coelomate animals.
   - Body divided into three parts: **Proboscis (or prosome), Collar (or mesosoma), and Trunk (or metasoma).**
2. **Coelom:**
   - True coelom present, divided into three parts corresponding to body divisions.
3. **Nervous System:**
   - Dorsal nerve cord present but not well developed.
   - No true brain; nerve ring present around the collar.
4. **Digestive System:**
   - Complete alimentary canal with mouth, pharynx, stomach, intestine, and anus.
   - Pharynx with gill slits (similar to chordates).
5. **Circulatory System:**
   - Open circulatory system.
   - Heart or pulsating vesicle present.
6. **Respiration:**
   - Pharyngeal gill slits function in respiration.
7. **Excretion:**
   - Excretory organs are absent or represented by glomerulus.
8. **Reproduction:**
   - Dioecious (separate sexes).
   - External fertilization; development usually indirect with a tornaria larva.
9. **Habitat:**
   - Mostly marine, live in burrows or tubes in mud or sand.
10. **Other Features:**
    - They have a stomochord (a structure once thought homologous to the notochord).
    - No true notochord but hemichordates show some chordate affinities.

Classification of Hemichordata:

Phylum Hemichordata is divided into three classes based on their morphology and lifestyle:

1. **Class Enteropneusta:** These are commonly called acorn worms. They have a worm-like body that is distinctly divided into three parts: proboscis, collar, and trunk. Enteropneusts are mostly burrowing marine animals that possess gill slits and a stomochord. They exhibit indirect development with a tornaria larva. A well-known example is *Balanoglossus*.
2. **Class Pterobranchia:** Pterobranchs are small, colonial hemichordates. Their body is also divided into three parts, but the trunk is modified to bear tentacles used for filter feeding. They live inside secreted tubes and usually lack gill slits or have them highly reduced. Asexual reproduction is common in this class. Examples include *Rhabdopleura* and *Cephalodiscus*.
3. **Class Planctosphaeroidea:** This is a rare and primitive group of hemichordates with a small, spherical, planktonic body. Very little is known about their biology. An example genus is *Planctosphaera*.

B . *Balanoglossus* - Structure and affinities.

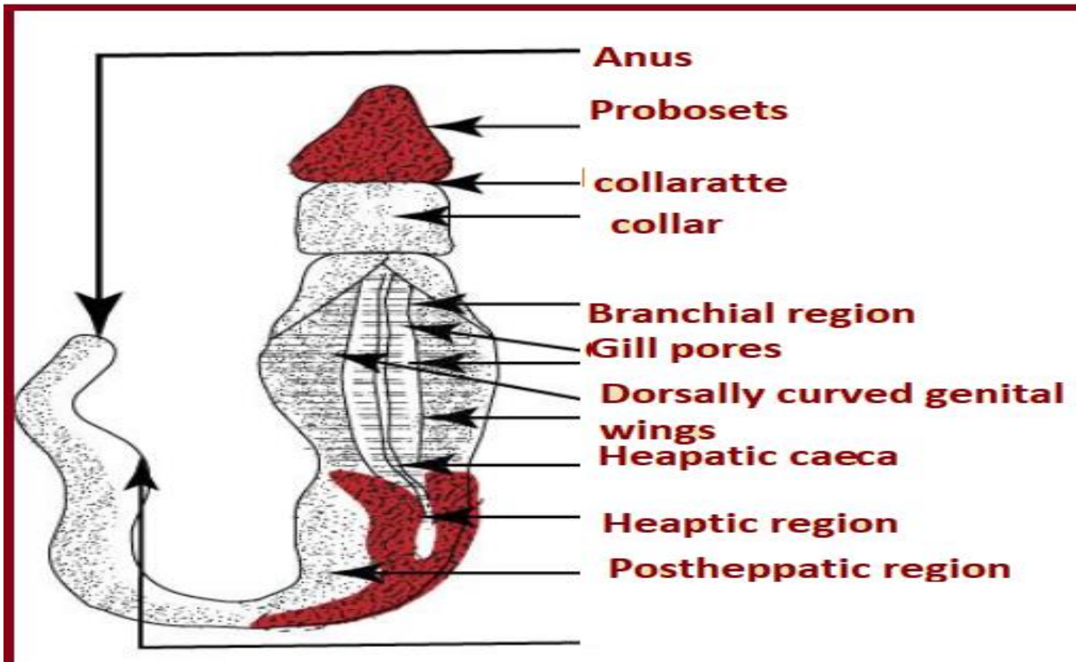


Fig: Balanoglossus

It is a **marine water-dwelling acorn worm** (Enteropneusta). Blanoglossus cannot survive in freshwater. It belongs to **hemichordates.** it is an **"evolutionary link" between invertebrates and vertebrates.**

- Discovered by **J.F. Eschscholtz in 1825** in Mashail Island. He described it as a worm-like holothurian. **Kowalewski (1865)** discovered the gill – slits in Blanoglossus, led to the creation of a special class Enteropneusta by Gegenbaur (1870).
- **Bateson (1885)** included them in Phylum Chordata. Hyman (1959), however, placed them near Echinodermata and gave Hemichordata a status of an independent phylum.

Structure of Balanoglossus:

1. **Body Division:**

   The body is elongated and divided into three distinct regions:

   - **Proboscis (or prosome):** The anterior part, muscular and cylindrical, used for burrowing and food collection. It contains the stomochord, a dorsal tubular extension.
   - **Collar (or mesosoma):** The middle region, short and cylindrical, bears the mouth on its ventral side at the posterior end.
   - **Trunk (or metasoma):** The largest posterior part, responsible for digestion and reproduction. It contains the pharynx with numerous gill slits for respiration.

2. **Coelom:**

   The coelom is well-developed and divided into three parts corresponding to the three body regions (protocoel, mesocoel, and metacoel).
3. **Digestive System:** Complete digestive tract with mouth (on collar), pharynx (with gill slits), esophagus, stomach, intestine, and anus.
4. **Circulatory System:** Open circulatory system with a dorsal and ventral blood vessel connected by a contractile vesicle (heart-like structure) in the proboscis.
5. **Nervous System:** A simple dorsal nerve cord and a ventral nerve cord, with a nerve ring around the collar. No brain.
6. **Respiratory System:** Pharyngeal gill slits in the trunk for filter feeding and gas exchange.
7. **Excretory System:** Protonephridia or glomerulus-like structures present for excretion.
8. **Reproduction:** Dioecious; external fertilization; development indirect with tornaria larva.

9. **Locomotion and Habitat:** Burrowing marine animal living in U-shaped burrows in sandy or muddy sea beds.

Affinities of Balanoglossus:

1. **Chordate Affinities:**
   - Presence of pharyngeal gill slits used in respiration.
   - Dorsal tubular nerve cord (though not well developed).
   - Stomochord, a structure once thought to be homologous to the notochord.
   - Endostyle-like structure present.
   - Bilateral symmetry and triploblastic coelomate body.
2. **Annelid Affinities:**
   - Body is elongated and worm-like, similar to annelids.
   - Presence of a segmented body (though segmentation is not very obvious).
   - Closed circulatory system and presence of a dorsal blood vessel.
   - Excretory system resembles nephridia in annelids.
3. **Distinctive Features:** Despite some similarities, Balanoglossus differs from both chordates and annelids by having unique features such as the stomochord and the arrangement of body coeloms.

All the best

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