Animal Diversity: Invertebrates (Zoo 201)

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Lesson 01

INTRODUCTION TO ANIMAL SYSTEMATICS

Topic- 001: Patterns of organization:

Asymmetry: Absence of a central point or axis around which body parts are equally distributed e.g Protists and many sponges.

Symmetry: It describes how parts of an animal are arranged around a point or an axis.

Two types 1. Radial symmetry 2. Bilateral symmetry

Other patterns of Organization:

1. Unicellular organization
2. Diploblastic organization (a. two germ layered gastrula)
3. Triploblastic organization (b. three germ layered gastrula)

I. The Triploblastic Acoelomate Pattern

II. The Triploblastic Pseudocoelomate

III. The Triploblastic Coelomate

Topic- 002: Invertebrate Taxonomy:

Taxonomy helps us categorize organisms so we can more easily communicate biological information. In this lecture, the following topics of animal systematics are discussed:

- What is binomial nomenclature?
- Rules for writing scientific name.
- Robert H. Whittaker's system of classification
- Evolutionary conservation

Studies of ribosomal RNA have led systematics to the conclusions that all life shares a common ancestor and that there are three major evolutionary lineages.

Archaea: The Archaea are prokaryotic microbes that live in extreme environments

Eubacteria: True bacteria, prokaryotic microorganisms.

Eukarya: The Eukarya include all eukaryotic organisms.

Topic – 003: Animal Systematics:

Animal systematics is the comparative analysis of living and fossil species, including their discovery, description, evolutionary relationships to other species and patterns of geographic distribution. Following groups are used in animal classification:

-**Monophyletic Group:**

-Polyphyletic Group:

- ❖ Three contemporary schools of systematics exist:

1. **EVOLUTIONARY SYSTEMATICS:**

   The systematic in which evolutionary relationships are developed by study of fossils of ancestors of closely related animals is called evolutionary systematics.

2. **NUMERICAL TAXONOMY:**

   -Numerical taxonomists use mathematical models and computer-aided techniques.

   -Numerical taxonomists do not distinguish between homologies and analogies.

3. **PHYLOGENETIC SYSTEMATICS (CLADISTICS)**

The cladistics study two types of characters:

a) **Symplesiomorphies (basic characters):** The characters that all members of a group share are called symplesiomorphies.
b) **Synapomorphies (derived characters):** Characters that have arisen since common ancestry with the out-group are called derived characters or Synapomorphies.

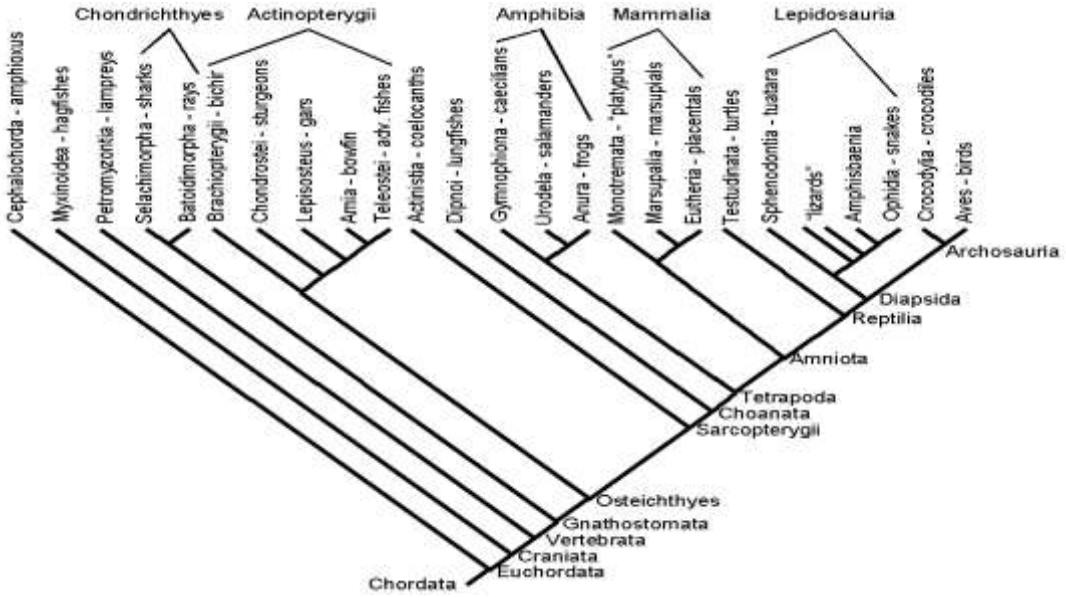
Topic – 004: Phylogeny:

"A phylogeny is a hypothetical relationship between groups of organisms being compared."

Phylogenetic tree, also called **Dendrogram**, a diagram showing the evolutionary interrelations of a group of organisms derived from a common ancestral form.

- The ancestor is in the tree "trunk"; organisms that have arisen from it are placed at the ends of tree "branches."
- The distance of one group from the other groups indicates the degree of relationship; *i.e.,* closely related groups are located on branches close to one another.
- Evolutionary trees often imply a **ladder-like progression of increasing complexity**. This is misleading, because evolution has often resulted in reduced complexity.

Contemporary Paleontologist **Stephan J. Gould** uses the term contingency to refer to rapid evolutionary explosion followed by a high likelihood of extinction.



Lesson 02

PATTERNS OF ORGANIZATION

Topic – 005: Patterns of Unicellular Organization:

SYMMETRY: The concept of symmetry is fundamental to understand animal organization.

1. **ASYMMETRICAL SYMMETRY:**

In some animals there is no plane of symmetry, hence are asymmetrical e.g. sponges.

2. **RADIAL SYMMETRY:**

-In radial symmetry the body can be divided into two roughly equal halves by any one of many vertical planes passing through the central oral-aboral axis.

-The radial symmetry is seen among sedentary animals such as in anthozoans and sea stars.

3. **BILATERAL SYMMETRY**

-Bilateral Symmetry is the arrangement of body parts such that a single plane passing between longitudinal axis of an animal divides the animal into right and left mirror images.

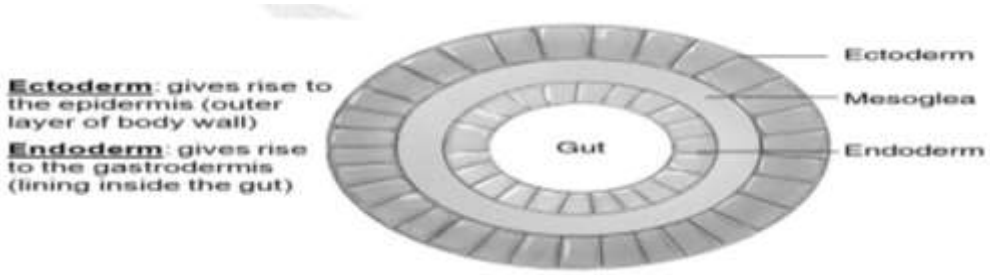
-Bilateral Symmetry is characteristic of active animals such as in mammals.

Unicellular level of organization:

- Organisms whose body consists of **single cells or cellular aggregates** display the unicellular level of organization.
- Unicellular body plans are the characteristic of the **Protista.**
- Inspite of absence of interdependence, colonial organisms show some **division of labor**.

Topic – 006: Diploblastic Organization:

- Diploblastic organization is the simplest tissue-level organization. Body parts of these animals are organized in two layers i.e. ectoderm and endoderm.
- Radially symmetric animals are diploblastic.
- **Mesoglea:** A non-cellular layer between the epidermis and the gastrodermis is called mesoglea.
- The feeding movements of Hydra or the swimming movements of jellyfish are only possible when groups of cells cooperate, showing tissue level organization.



Topic – 007: Triploblastic Patterns of Organization

Triploblastic Organization

- These animals are usually bilaterally symmetrical animals.
- Their tissues are derived from three embryological layers i.e ectoderm, mesoderm and endoderm.
- Ectoderm: Give rise to epidermis, outer layer of the body wall
- Mesoderm: It forms skeletal muscle, bone, connective tissue, the heart, and the urogenital system.
- Endoderm: Give rise to gatsrodermis, the tissues that line gut **cavity**

Topic – 008: Advantages of coelom:

The coelom is the main body cavity in most animals. A body cavity is a fluid filled space in which internal organs can be suspended and separated from the body wall.

Body cavities are advantageous because they;

- Provide room for organ development.
- Provide more area for diffusion of gases, nutrients and wastes into and out of organs.
- Provide an area for storage.
- Often act as hydrostatic skeleton.
- Provide a vehicle for eliminating wastes and reproductive products from the body.
- Facilitate increased body size.

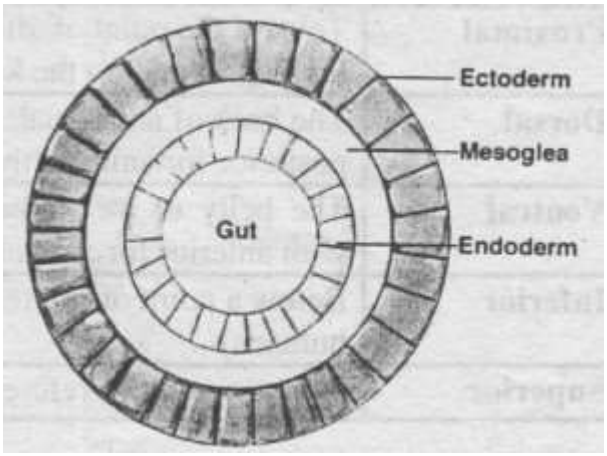
Topic – 009: Triploblastic Acoelomate Pattern:

Triploblastic animals whose **mesodermally** derived tissues form a relatively solid mass of cells between ectodermally and mesodermally derived tissue are called acoelomate

Some cells between the ectoderm and endoderm of acoelomate animals are loosely organized cells called parenchyma. Parenchymal cells are not specialized for a particular function. The acoelomate is represented by phyla **Platyhelminthes** (ribbon worms) and **Gastrotricha**.

Important Characteristics:

- Bilateral symmetry.
- Mesoderms have muscles and other organs.
- They have nervous system- brain and spinal cord.
- Most triploblastic animals have an organ system level of organization. Tissues are organized to form excretory, circulatory and other systems.

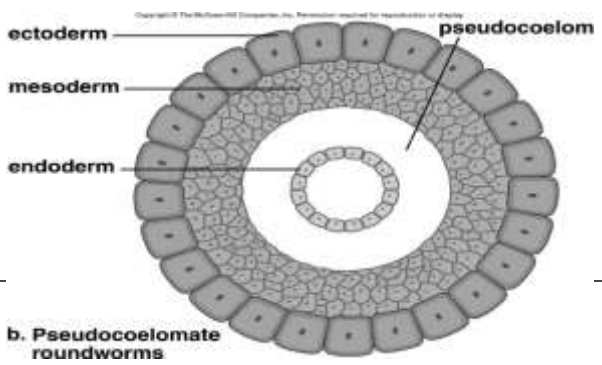


Topic – 010: Triploblastic Acoelomate Pattern:

- A pseudocoelom **(Gr**. **Pseudes**, **false**) is a body cavity not entirely lined by mesoderm. It is remnant of blastocoel.
- All pseudocoelomates are protostomes.
- An example of a Pseudocoelomate is the roundworm.
- Pseudocoelomate animals are also referred to as **Blastocoelomate**.

Important Characteristics:

- Lack a circulatory system. The hydrostatic pressure of the pseudocoelom gives the body a supportive framework that acts as a skeleton.
- Often syncytial covered by secreted cuticle.
- Loss of larval stages and possibly show pedomorphism.



Topic – 011: Triploblastic Coelomate Pattern:

A coelom is a body cavity entirely surrounded by mesoderm.

Peritoneum:

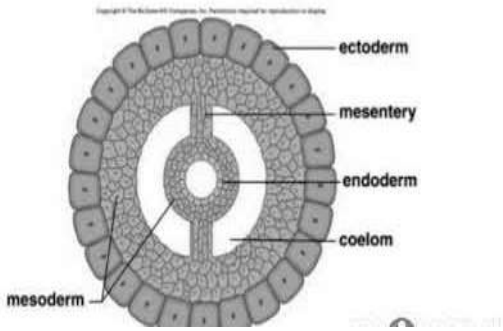
A thin mesodermal sheet lines the inner body wall and is continuous with the serosa, which lines the outside of visceral organs. The peritoneum and serosa are continuous and suspend visceral structures in the body cavity.

Mesenteries:

The suspended sheets are called mesenteries.

Important Characteristics:

- Having mesodermally derived tissues, such as muscle and connective tissue, associated with internal organs enhances the function of virtually all internal body systems.
- It provides space of the enlargement and development of internal organs.
- It may act as a circulatory medium for transport of materials or storage area.
- Fluid in the peritoneum cushions and protects them from shocks.



Topic – 012: Major Subdivisins of Animal Kingdom:

Kingdom Animalia is divided into two major groups.

Invertebrates:

An invertebrate is an animal **without a backbone**. About 98 % of all the animals are invertebrate. Invertebrates include phylum cnidarian, nematode, mollusk, annelid and echiderms.

Vertebrates:

A vertebrate is an animal **with backbone**. About 2% of all animals are vertebrate which belong to the phylum chordate. Vertebrates include fish, amphibians, reptiles, birds, mammals.

Traditional groupings based on embryological and anatomical characters.

- **BRANCH A (Mesozoa):** Phylum mesozoa, the mesozoa.
- **BRANCH B (Parazoa):** Phylum porifera, the sponge and phylum placozoa.

- **BRANCH C (Eumatazoa):** All other phyla

Lesson 03

GENERAL FEATURES OF PROTOSOMES AND DEUTEROSTOMES

Topic – 013: Comparative Embryology:

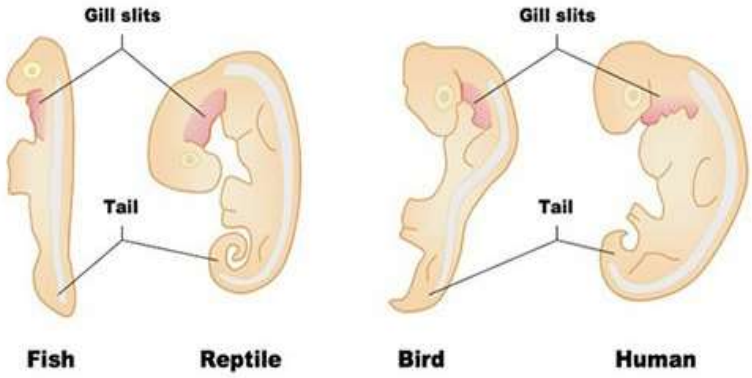
Embryology: It is the study of the development of embryos from fertilization until they become fetuses, or the point at which you can distinguish the species.

Comparative embryology: It refers to the study of similarities and differences in early or embryonic developments of animals.

Recapitulation Theory*:*

- German biologist Ernst Haeckel proposed in 1866 that "ontogeny recapitulates phylogeny". It means that the development of the embryo follows the evolutionary history of the species.

- Vertebrate embryos, no matter the species, share features such as gill slits, but mammal embryos do not become fish before they become mammals. Instead, the slits are a remnant from a distant shared ancestor and develop into complex features of the head.

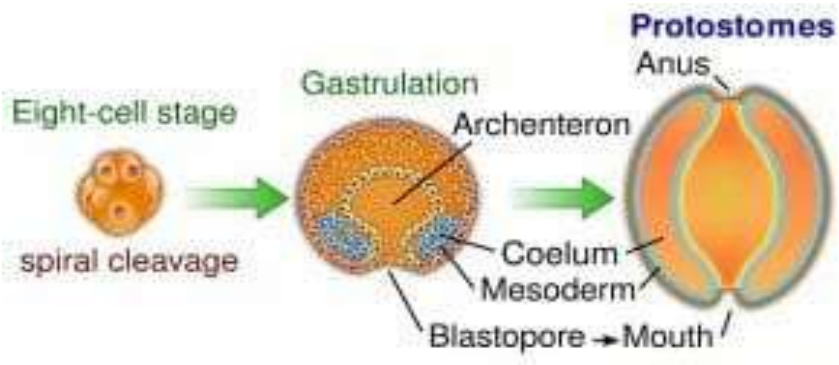


Topic – 014: General Features of Protostomes:

Protostomes constitute clade of multicellular organisms in which the mouth develop from the primary embryonic opening.

- The coelom forms from a split in the embryonic mesoderm.

- Cell **fates become fixed** at the first cleavage of the early embryo.
- Larval forms, if present, are called **trochophores.**
- The Protostomes include animals in the phyla Platyhelminthes, Nematoda, Mollusca, Annelida, Arthropoda and others.



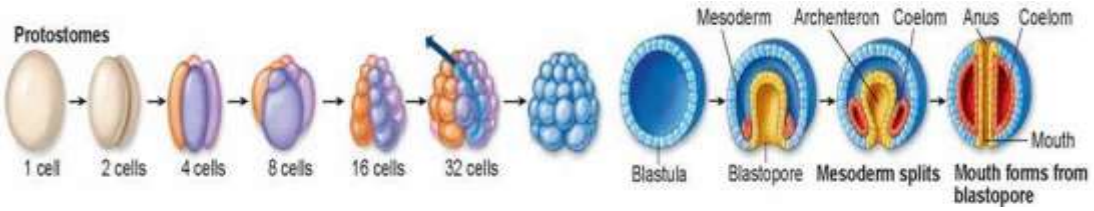
Topic – 015: Spiral and Determinate cleavage in Protostomes:

Cleavage is a process of rapid mitotic cell divisions of the zygote to form number of cells for building up the offspring's body.

Spiral cleavage:

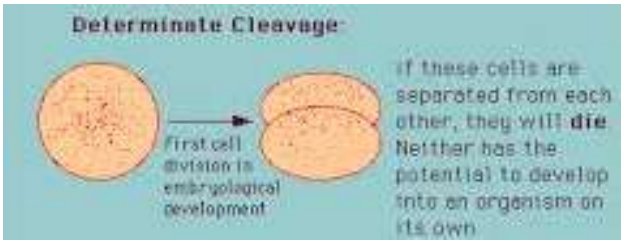
Spiral cleavage is a holoblastic cleavage that is typical of protostomes and that is characterized by arrangement of the blastomere of each upper tier over the cell junctions of the next lower tier so that the blastomere spiral around the pole to pole axis of the embryo.

Mechanism of Spiral cleavage:



Determinate cleavage:

It results in developmental fate of cells being set early in embryo development.



Topic – 016: Schizocoelous Coelom Formation in Potostomes:

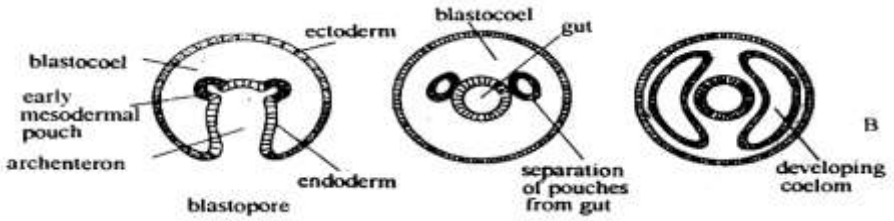
A number of hypothesis focuses on the origin of coelom.

Shizocoelus coelom:

Coelom formation occurs by the splitting of mesodermal layer.

The animals which develop by means of shizocoely are known as shizocoelomates.

Shizocoelus Coelom Hypothesis: The shizocoelus hypothesis is patterned in which all mesoderm is derived from a particular ectodermal cell of the blastula. Mesoderm derived from this cell fills the area between ectoderm and endoderm. The coelom arises from a splitting of this mesoderm.



Topic – 017: General Features of Deuterostomes:

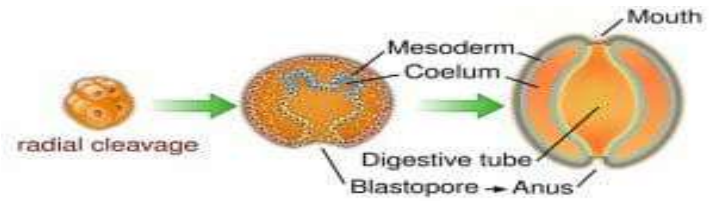
Deuterostome originates from the Greek word meaning "mouth second". In deuterostomes, the anus develops first and the mouth develops later.

Important Characteristics:

1. **Enterocoely:** In deuterostomes, the mesoderm forms as invaginations of the developed gut that pinch off, forming the coelom. This is called the enterocoely.
2. **Some major clades:** There are three major clades of deuterostomes i.e., Chordata (vertebrates and their kin), Echinodermata (starfish, sea urchins, sea cucumbers, etc.) and Hemichordata (acorn worms).
3. **Bilateral symmetry**
4. **Radial and Indeterminate cleavages:**
5. **Larval type:** Some deuterostomes possess a kidney-shaped larva called a dipleurula.

Topic – 018: Radial and Indeterminate Cleavage in Deuterostomes:

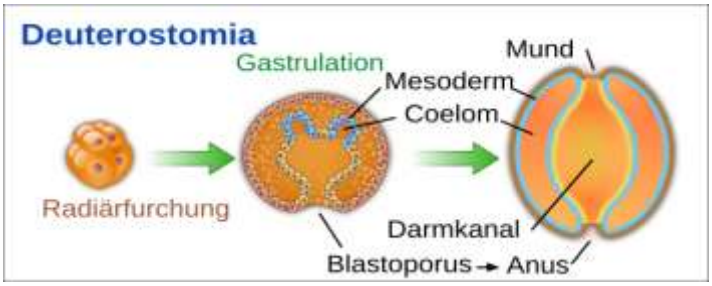
- Radial cleavage occurs when the mitotic spindle is **oriented perpendicular** to the axis of zygote and results in embryonic cells directly over one another.
- In that the developmental **fate of the cells** in the developing embryo are not determined by the identity of the parent cell.
- With indeterminate cleavage each cell in the early stages of cleavage retains the capacity to develop into a complete embryo.
- Indeterminate cleavage makes possible identical twins and embryonic stem cells.



Topic – 019: Deuterostomes:

They are a sister-clade of the Protostomes, and the two together with the Xenacoelomorpha form the major group of animals called the Bilateria—a major group animal which display bilateral symmetry and are mostly triploblastic.

Enterocoelous development is the stage of embryological development of deuterostomes in which the coelom forms. The stage starts with the gastrula; as the archenteron forms, pockets of migrating cells also form, creating another layer between the endoderm and ectoderm, the mesoderm. These pockets gradually expand to form the coelom.



Lesson 04

KINGDOM PROTOZOA

Topic – 020: Life Within a Single Plasma Membrane:

Introduction:

Microscopic and acellular animalcules without tissues and organs. They have one or more nuclei. Protozoa exist either singly or in colonies.

Nutrition:

A. Holozoic **B.** Holotrophic **C.** Saprozoic or Saprophytic nutrition **D.** Parasitic nutrition

Habitat of Protozoa:

Adaptation of Protozoa is extended to all environments open to microorganism.

Cell Structure:

The typical protozoan cell is bounded by a trilaminar unit membrane, supported by a sheet of contractile fibrils which enable the cell to change its shape and to move. The cytoplasm can often be differentiated into an outer rim of relatively homogeneous ectoplasm and a more granular inner endoplasm..

Locomotion:

1. Pseudopodial **2.** Flagellate **3.** Ciliary **4**. Peristaltic

Respiration in Protozoa:

Protozoa do not have any organelle for the process of respiration. The limiting permeable membrane acts as a respiratory surface.

Excretion in Protozoa:

Waste materials are passed out of the body by diffusion or by the contractile vacuoles.

Reproduction:

1. Asexual reproduction. **2.** Sexual reproduction.

Topic – 021: Symbiotic Life Style:

Symbiosis is an intimate association between two organisms. There are following types of symbiosis in protozoans:

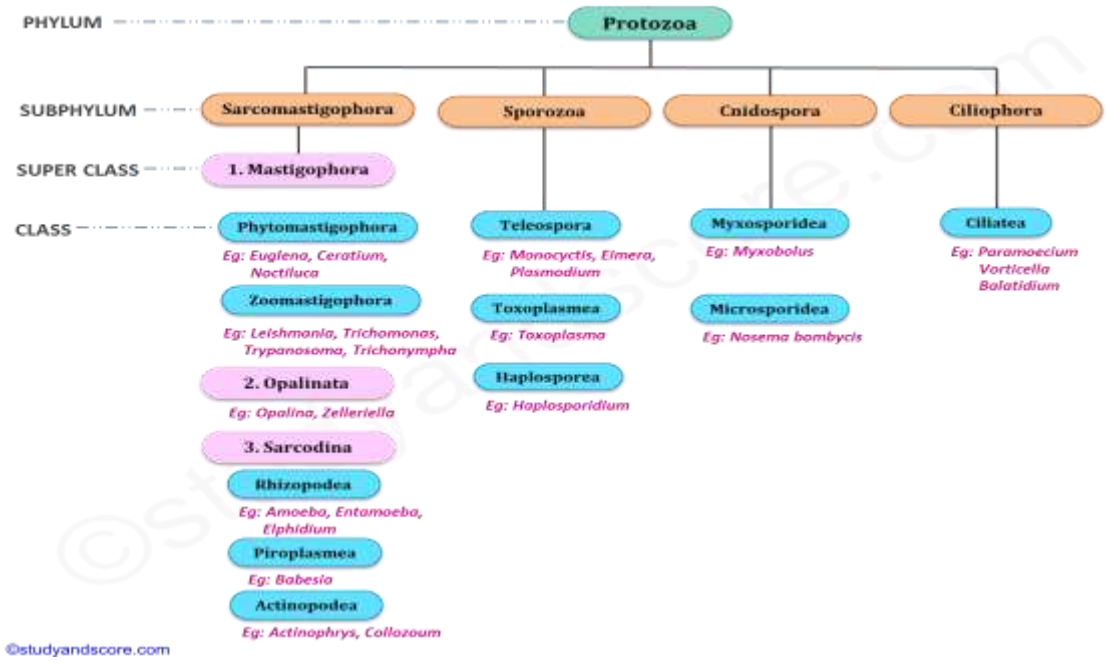
1. **Parasitism:** An association in which one organism lives in or on a second organism, host and causes disease in the host is called parasitism.

2. **Commensalisms:** The symbiotic relationship in which one member of the relationship benefits and the second member are neither benefited nor harmed is called commensalism.

3. **Mutualism:** The symbiotic relationship in which both species get benefit is called mutualism.

Topic – 022: Protozoan Taxonomy:

Zoologists who specialize in the study of protozoa are called **protozoologists.** Classification of protozoans into phyla is based primarily on types of nuclei, mode of reproduction, and mechanism of locomotion.



Topic – 023: Phylum Sarcomastigophora:

It is the largest protozoan phylum and has the following characteristics:

- Unicellular or colonial
- Locomotion by flagella, pseudopodia, or both
- Autotrophic (self-nourishing), saprozoic (living in decaying organic matter), or heterotrophic (obtains energy from organic compounds)
- Single type of nucleus
- Sexual reproduction (usually)

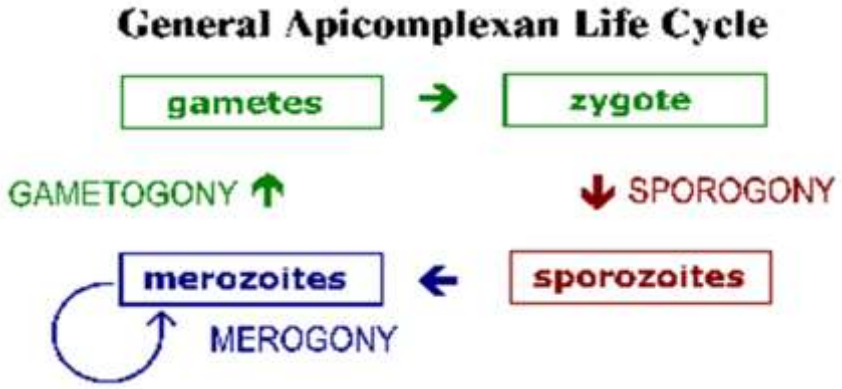
Topic – 024: Phylum Apicomplexa:

The Apicomplexa are a monophyletic group composed almost entirely of parasitic.

Characteristics of the phylum include:

- Apical complex for penetrating the host cells.
- Single type of nucleus.

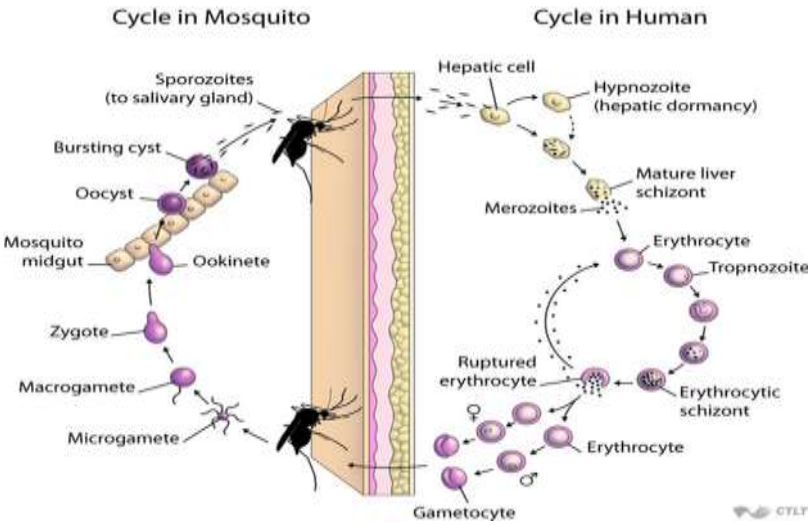
- No cilia and flagella, except in some reproductive stages.
- Life cycles that typically include asexual (schizogony, Sporogony) and sexual (gametogony) phases.



Topic – 025: Life Cycle of Malarial Parasite, The *Plasmodium*:

- One sporozoean genus, *Plasmodium*, causes malaria and has a long history. Over 100 million humans are estimated to annually contract the disease.

- ***Plasmodium***, which infects red blood cells in mammals (including humans), birds, and reptiles, occurs worldwide. The organism is transmitted by the bite of the **female Anopheles mosquito**. The plasmodium life cycle involves vertebrate and mosquito hosts.



Topic – 026: Pseudopodia and Amoeboid Locomotion:

In Amoeba movement of the animal is made by the throwing of pseudopodium called **amoeboid movement**. This is the most primitive kind of movement which is caused by contractility.

Members of the **subphylum Sarcodina** when feeding and moving, they form temporary cell extensions called **pseudopodia**.

Kinds of pseudopodia

Four types are following:

- Lobopodium
- Filopodium
- Reticulpodium or Rhizopodium
- Axopodium or Actinopodium

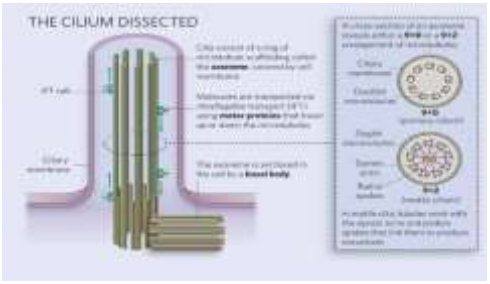
Topic – 027: Cilia and Other Pellicular Structures:

Cilia are tiny, hair like projections covering the entire animal body. Cilia are generally similar to flagella, except that they are much shorter, more numerous, and widely distributed over the surface of the protozoan.

Size: Cilium size ranges measuring approximately 10-12 micrometer in length and about 0.27 micrometer in diameter.

Structure of cilia: They arise by penetrating the pellicle from basal bodies located within the ectoplasm of the cell. Cilium has an axoneme consisting of 9 doublet microtubules with dynein arms around the periphery.

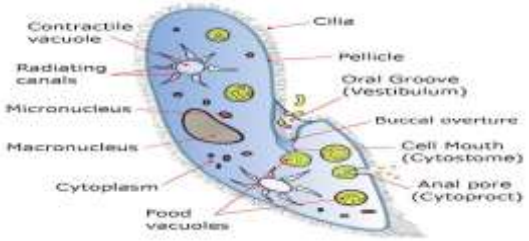
Function of cilia: The function of cilia is food capture and locomotion.



Pellicle structures:

- Trichocysts are pellicular structures primarily used for protection. They are rodlike or oval organelles oriented perpendicular to the plasma membrane.

- In Paramecium, they have a "golf tee" appearance. The pellicle can discharge trichocysts, which then remain connected to the body by a sticky thread.



Topic – 028: Genetic Control And Reproduction in Ciliates:

Nuclei: Ciliates have two kinds of nuclei. A large, polyploid **macronucleus** regulates daily metabolic activities. One or more smaller **micronuclei** are the genetic reserve of the cell.

Asexually Reproduction: Cilia reproduce asexually by transverse binary fission and, occasionally, by budding.

Sexual Reproduction: Ciliates reproduce sexually by conjugation.The partners involved are called conjugant.

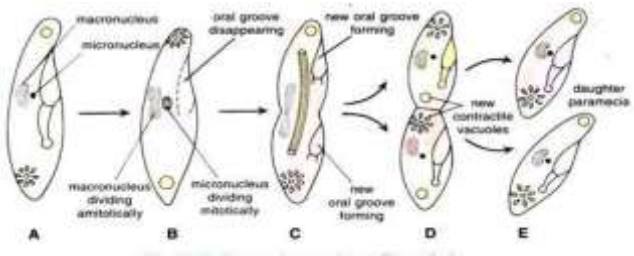
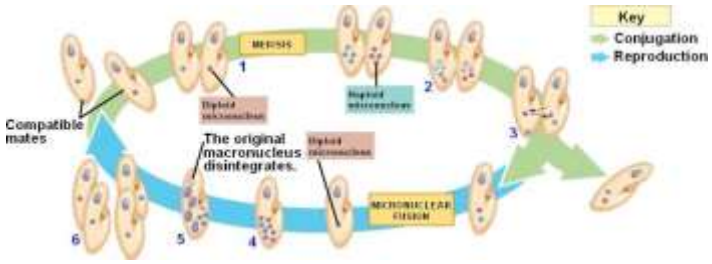


Figure: Steps in Binary Fission



Symbiotic Ciliates:

- Most ciliates are free living; however, some are **commensalistic or mutualistic**, and a few are **parasitic**.

- ***Balantidium coli*** is an important parasitic ciliate that lives in the large intestines of humans, pigs, and other mammals.
- It produces proteolytic enzymes that digest host epithelium, causing a flask-shaped ulcer.

Topic – 029: Further Phylogenetic Considerations:

History:

Protozoa probably originated about **1.5 billion years** ago. Although known fossil species exceed 30,000, they are of little use in investigations of the origin and evolution of the various protozoan groups. Many characters for phylogenetic analyses come from structural features of protozoan organelles.

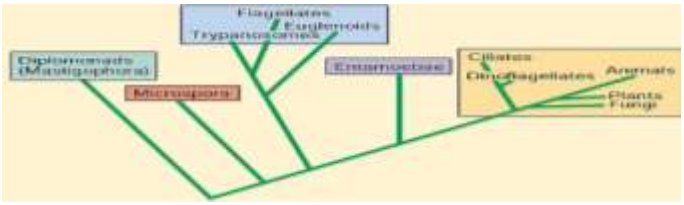


Figure: Cladogram showing evolutionary relationship of protozoa

Lesson 05

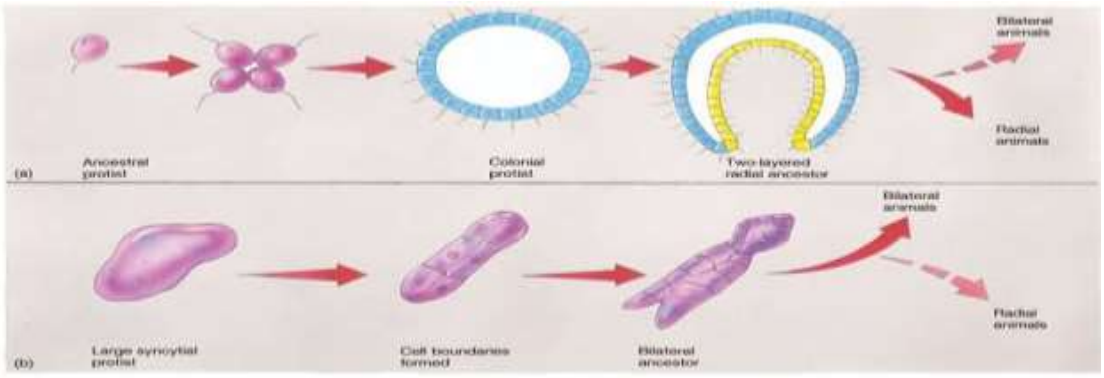
MULTICELLULAR ORGANIZATION: PHYLUM PORIFERA

Topic – 030: Origins of Multicellularity:

Multicellular life has been a part of earth's history for approximately 550 million years.

Colonial hypothesis: Many zoologists believe that multicellularity could have arisen as dividing cells remained together, in the fashion of many colonial protists.

Syncytial hypothesis: A second proposed mechanism is called the syncytial hypothesis. A syncytium is a large, multinucleate cell. The formation of plasma membranes in the cytoplasm of a syncytial protists could have produced a small, multicellular organism.



Two hypotheses regarding the origin of Multicellularity

Topic – 031: Phylum Porifera (Cell types, Body wall and Skelet0n):

The Porifera or sponges, are primarily marine consisting of loosely organized cells.

Cell Types:

- Thin flat cells, called pinacocytes, line the outer surface of a sponge. Pinacocytes may be mildlycontractile, and their contraction may change the shape of some sponges.
- Mesenchymal cells are present next to pinacocytes and have amoeboid functions
- Choanocytes (Gr. choane, funnel + cyte, cell) are flagellated cells that have a collar like ring of microvilli surrounding a flagellum. The flagellum creates a water current through the sponge, and the collar filters microscopic food particles from the water.
- The presence of choanocyte in sponges suggests an evolutionary link between the sponges and a group of protists called **choanoflagellates.**

Skeleton:

Sponges are supported by a **skeleton** that may consist of microscopic needlelike spikes called spicules. Spicules are formed by amoeboid cells, are made of calcium carbonate, silica or sponging. The nature of the skeleton is an important characteristic in sponge taxonomy.

Topic – 032: Phylum Porifera (Classification):

Class Calcarea:

Spicules composed of calcium carbonate; spicules are needle shaped or have three or four rays; ascon, leucon, or sycon body forms; all marine. Calcareous sponges.

Class Hexactinellida:

Spicules composed of silica and are six rayed; spicules often fused into an intricate lattice; sycon or leucon body form, found at 450 or 900 m depth in tropical west Indies and eastern pacific. Glass sponges, Euplectella.

Class Demospongea:

Demosponges are brilliantly colored sponges with needle-shaped four-rayed siliceous spicules or spongin or both; leucon body form. Includes one family of freshwater sponges. Spongillidae, and the bath sponges, cliona, spongilla.

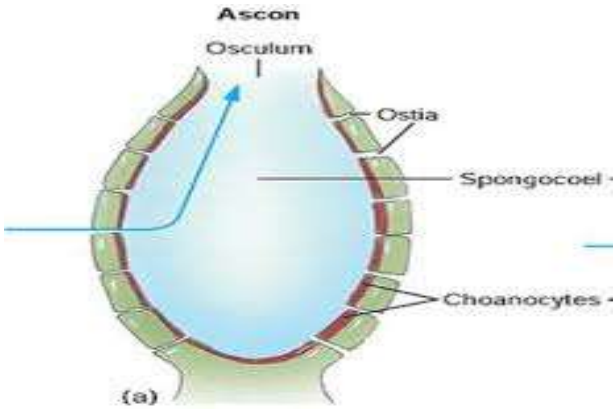
Topic – 033: Phylum Porifera (Ascon Body Form):

Water current:

Methods of food filtration and circulation reflects the body forms in the phylum porifera. Zoologists have described three sponge body forms.

Ascon body form:

The simplest and least common sponge body form is the ascon. Ascon sponges are **vase like**. Ostia are the outer openings of porocytes and lead directly to a chamber called the spongocoel. Choanocytes line the spongocoel, and their flagellar movements draw water into the spongocoel through the ostia. Water exist the sponge through the **osculum**, which is a single large opening at the top of the sponge.

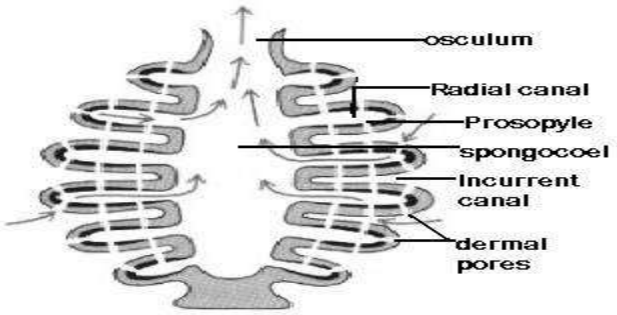


Topic – 034: Phylum Porifera (Sycon Body Form):

The sponge wall is folded in the sycon body form. Water enters a sycon sponge through openings called **dermal pores**. Dermal pores are the openings of invaginations of the body wall, called **incurrent canals**. Pores in the body wall connect incurrent canals to radial canals, and the radial canals lead to the spongocoel.

Choanocytes:

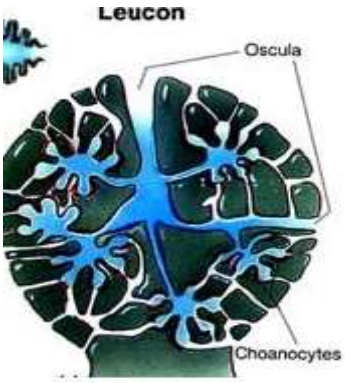
Choanocytes line radial canals (rather than the spongocoel), and the beating of choanocyte flagella move water from the ostia, through incurrent and radial canal, to the spongocoel, and out the osculum.



Topic – 035: Phylum Porifera (Leucon Body Form):

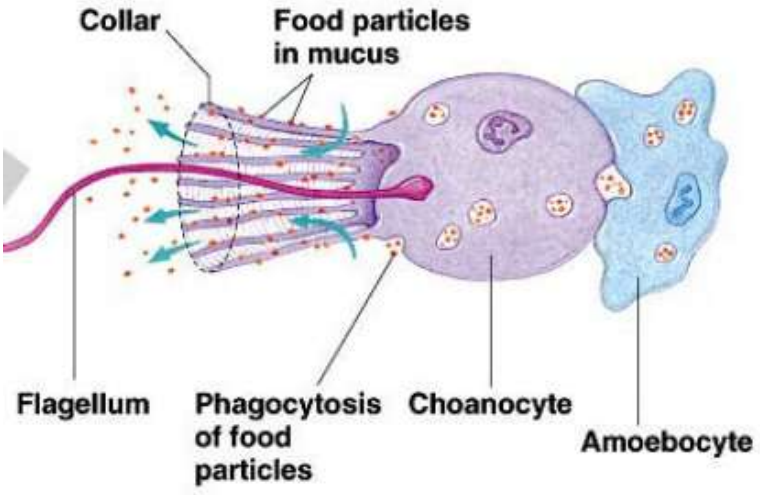
- Leucon sponges have an **extensively branched canal** system.
- Water enters the sponges through ostia and moves through branched incurrent canals, which leads to choanocytes lined chambers.
- Canals leading away from the chambers are called as **excurrent canals**.

- Proliferation of chambers and canals has resulted in the absence of a spongocoel, and often, multiple exist points (oscula) for water leaving the sponges.



Topic – 036: Phylum Porifera (Maintenance Functions):

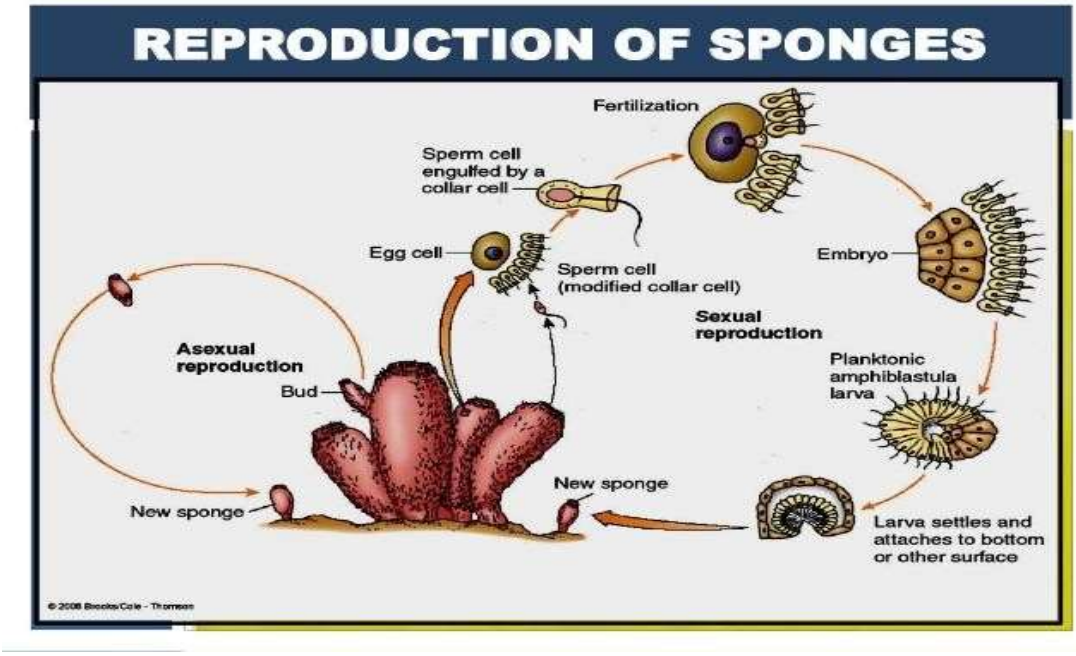
- Sponges feed on particles that range in size from 0.1 to 50 micrometer. Large populations of sponges play an important role in reducing turbidity of coastal waters. Choanocytes filter small, suspended food particles. Partially digested food is passed to amoeboid cells, which distribute it to other cells.



- Pinacocytes lining in current canals may phagocytize larger food particles.
- Nitrogenous waste (principally ammonia) removal and gas exchange occur by diffusion.
- Sponges do not have nerve cells to coordinate body functions. Most reactions result from individual cells responding to stimulus.

Topic – 037: Phylum Porifera (Reproduction):

Most sponges are monoecious (both sexes occur in the same individual) but do not usually self-fertilize because individual sponges produce eggs and sperm at different times. **Asexual reproduction** of freshwater and some marine sponges involve the formation of resistance capsules, called gemules, containing masses of amoeboid cells. When the parent sponge dies in the winter, it releases gemmules, which can survive both freezing and drying. When favourable conditions return in the spring, amoeboid cells stream out of a tiny openings, called the micropyle, and organize in



Lesson 06

PHYLUM CNIDARIA: THE COELENTERATES

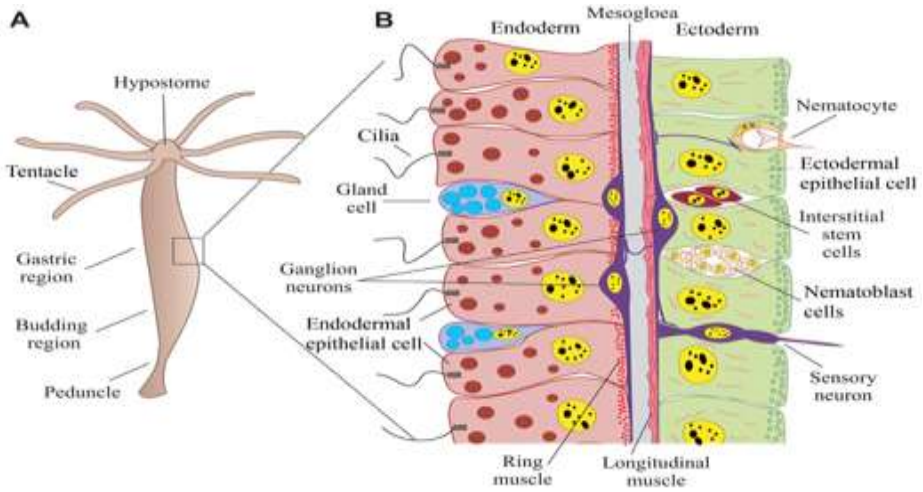
Topic – 038: General Charcteristics:

- Radial or biradial symmetry.
- They have body walls of ectoderm and endoderm separated only by mesogloea; a single body cavity (enteron) with a mouth but no separate anus;
- a simple nerve net;
- No separate excretory or circulatory systems.
- Nematocysts are present.
- Solitary or colonial, and they are often polymorphic with alternate polyps and medusa.

Topic – 039: The Body Wall and Nematocyst:

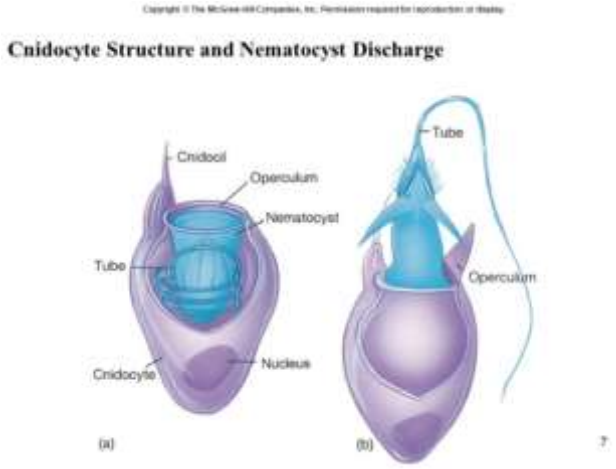
Cnidarians possess diploblastic, tissue-level organization.

Mesoglea: Between the epidermis and endodermis is a jelly-like layer called **mesoglea**.



Nematocyst

A **nematocyst** is a fluid-filled, intracellular capsule closing a coiled hollow tube. Nematocyst gather food and help to defend the organism.

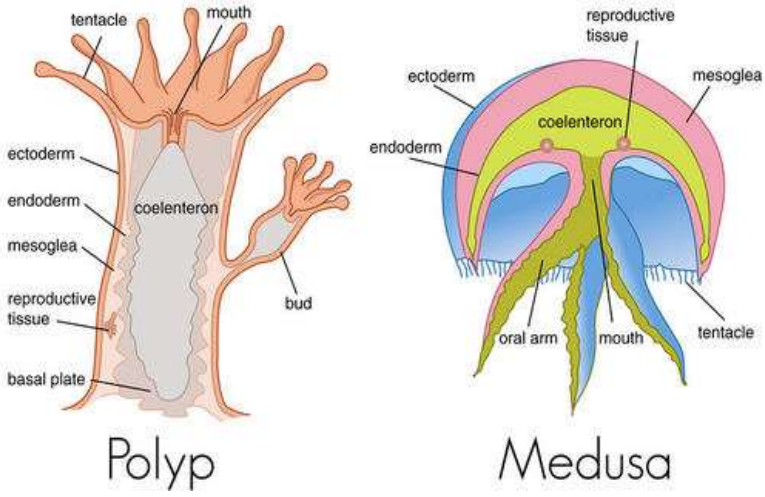


Topic – 040: Alteration of Generation in Cnidaria

Most of the interesting and sometimes puzzling aspects of this phylum is the **dimorphism.**

Alternation of polyp and medusa:

The two forms, **polyp** and **medusa** alternate successively where the polyp reproduce asexually to form a large number of medusa, each medusa reproduce sexually by a union of eggs and sperms to form zygote. The zygote grows into a larva, which fix itself to a substrate and finally form a new polyp.



Topic – 041: Maintenance Functions in Cnidaria:

1. Gastrovascular cavity: The gastrodermis of all cnidarians lines a blind-ending **gastrovascular cavity**. This cavity performs the function of digestion, exchange of gases, removal of metabolic wastes and the discharge of gametes.

2. Ingestion of food: Nematocysts **entangle** and paralyze prey. **Tentacles** draw food towards the mouth. Food enters the gastrovascular cavity.

3. Digestion of food: Nutritive- muscular cells are present among the gastro dermal cells for digestion

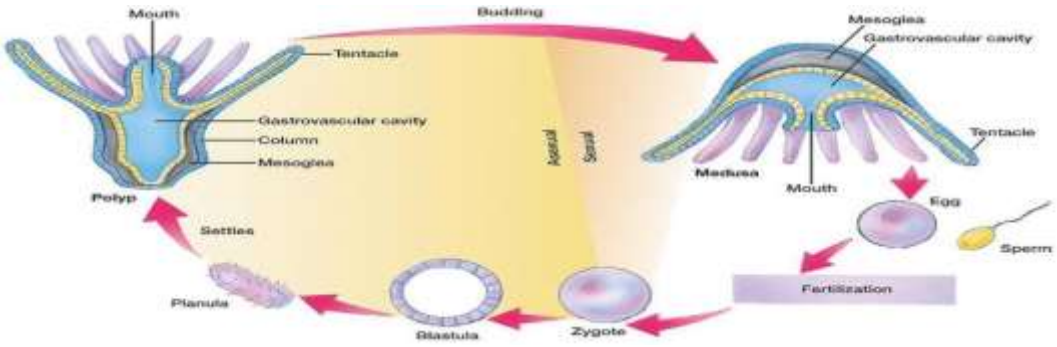
4. Support and movement: Cnidarians have **hydrostatic skeleton** that is composed of water or body fluids in a cavity of the body. The contractile elements of body wall act against the hydrostatic skeleton.

5. Types of movements: Swimming and floating.

6. Nervous and Sensory functions: The cnidarians nerve cells are most primitive nervous elements in the animal kingdom. Sensory structures of cnidarians are distributed throughout body.

Topic – 042: Reproduction in Phylum Cnidaria

- Asexual reproduction by budding.
- Sexual reproduction by production of male and female gametes



Generalized Life Cycle of a Cnidarian

Topic – 043: Phylum Cnidaria (Class Hydrozoea)

Hydrozoans are small, relatively common cnidarians. They are mostly marine, but this is the one cnidarian class with freshwater representatives.

Three features distinguish hydrozoans from other cnidarians:

- Nematocysts are only in the epidermis;
- Gametes are epidermal and released to outside of the body rather than into the gastrovascular cavity; and
- The mesoglea never contains amoeboid mesenchyme cells.
- Obelia and Hydra

Topic – 044: Phylum Cnidaria (Class Scyphozoa)

Scyphozoans have the following main characteristics:

- Members of the class Scyphozoa are all **marine.**
- They are **"true jellyfish"** because the dominant stage in their life history is the medusa.
- Unlike hydrozoan medusae, scyphozoan **medusae lack a velum.**
- The mesoglea contains **amoeboid mesenchyme cells.**

- **Cnidocytes** occur in the gastrodermis as well as the epidermis.
- **Gametes are gastrodermal** in origin. Aurelia has eight notches. Each notch has a sense organ called rhopalium which is the main character of this group.

Topic – 045: Phylum Cnidaria (Class Anthozoa):

Anthozoans have the following important characteristics:

- Anthozoans are commonly called as **Flower animals**.
- They are **all polyp forms.**
- Many are supported by **Skeleton.**
- Members of the class Anthozoa are **colonial or solitary, and lack medusae.**
- They include **anemonesand stony and soft corals.**
- Anthozoans are all **marine** and are found at all depths.

Lesson 07

PHYLUM CTENOPHORA

Topic – 046: General Characteristics:

Ctenophorans have the following common features:

- **Diploblastic**, tissue-level organization, Biradial symmetry.
- Nervous system in the form of a nerve net
- Adhesive structures called **Colloblasts**
- Eight rows of ciliary bands, called **comb rows**, for locomotion
- Animals in the phylum Ctenophora are called **sea walnuts or comb jellies**.
- They **don't have nematocyst** except in one species (Haeckelia rubra).
- Main Feature is that they **emit light.**
- **Pleurobranchia** is the representative of this class.

Topic – 047: Further Phylogenetic Considerations:

Debate is still going on the position of these phyla.

Origin of Cnidaria and Ctenophora: There are two interpretations about the origin of cnidaria and Ctenophora:

1. **Radial ancestor:** One interpretation is that the ancestral animal was derived from a radially ancestor. This ancestor itself is derived from a colonial flagellate. Therefore, radiate phyla (Cnidaria and Ctenophora) are closely related to that ancestral group.

2. **Bilateral ancestor:** Other zoologists believe that the bilateral ancestor gave rise to both the radiate phyla and bilateral phyla. Therefore, the radiate phyla are removed from the base of the evolutionary tree.

- **Origin of Cnidaria**: The classical interpretation is that primitive Hydrozoa were the ancestral radial animals.
- **Affinities of Ctenophora:** The Ctenophora and Cnidaria have following important common characteristics:

1. Radial (biradial) symmetry 2. Diploblastic organization
3. Nerve nets 4. Gastrovascular cavities.

Lesson 08

TRIPLOBLASTIC ACOELOMATE ORGANIZATION: THE FLAT WORMS

Topic – 048: Evolutionary Perspective:

Evolutionary Perspective:

Members of the phyla Platyhelminthes, Nemertea and Gastrotricha show **triploblastic acoelomate organization.**

There are three views about this evolution:

- **First View:** Evolution from radial diploblastic animals
- **Second view:** Evolution from bilateral ancestor
- **Third view:** Acoelomate derived from coelomate
-

Topic – 049: General Characterisics of platyhelmenthes:

1. Grade of organization: Organ- system grade of organization
2. Symmetry: Bilateral symmetry and Body is dorso-ventrally flattened
3. Germ layer: Triploblastic.
4. Coelom: Absent (acoelomate).
5. Digestive system: incomplete or absent
6. In tapeworms, Direct absorption of soluble nutrients by cells and tissues.
7. Excretory system: Protonephridia with Flame cell
8. Respiration: by simple diffusion of gases through body surface
9. Circulatory system: Absent
10. Life cycle is complex involving one or more hosts.
11. Reproduction:

    Sexual: by gametic fusion in hermaphrodite species

    Asexual: by regeneration and fission

    Fertilization: Fertilization is internal.

The Phylum is divided into four classes:

1.Class Turbellaria 2.Class Monogenea 3.Class Trematoda 4.Class Cestoidea

Topic – 050: Platyhelminthes (Classification)

1. Class Turbellaria: mostly free-living worms.

2. Class Monogenea:

- The class monogenea is distinguished by most of its members being ectoparasite
- **Opisthaptor** as attachment organ
- Monogeneans have an indirect life-cycle.

3. Class Trematoda:

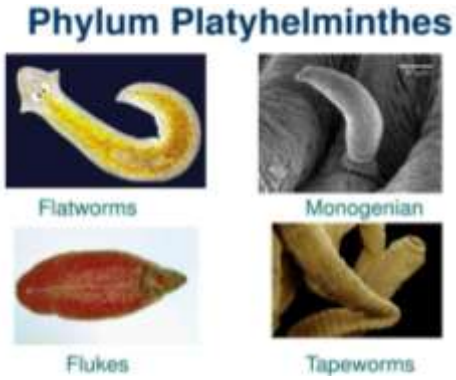
- . Generally, trematodes are endoparasites of molluscs and vertebrates.
- They are digenetic flukes.
- **Tegument**- the outer layer of the epidermis which forms a syncytium and is highly effective at providing protection and absorbing nutrients.

4. Class Cestoidea:

It is the most highly specialized class of flatworms. The members of cestoidea are commonly called tapeworms. All are endoparasites.

Two unique parasitic adaptations in tapeworms;

- Digestive system is absent in tape worms. They absorb nutrients directly from the host.
- Most adult tapeworms consist of **proglottids.**



Lesson 09

CLASS TURBELLARIA: FREE LIVING FLATWORMS

Topic – 051: General Features and Maintenance Functions:

Turbellarians are their name for the **turbellance** that their beating cilia create in water.

Body wall:

A basement membrane that separates the epidermis from **mesodermally** derived tissues. An outer layer of circular muscles and inner layer of longitudinal muscle lie beneath the basement membrane. The innermost layer is **endodermis** that comprises the digestive cavity. **Rhabdites** a protective mucus sheath around the body possibly in response to attempted predation or desiccation. **Adhesive glands** attract part of turbellaria to the substrate. **Releaser glands** release the enzyme that dissolved the attachment.

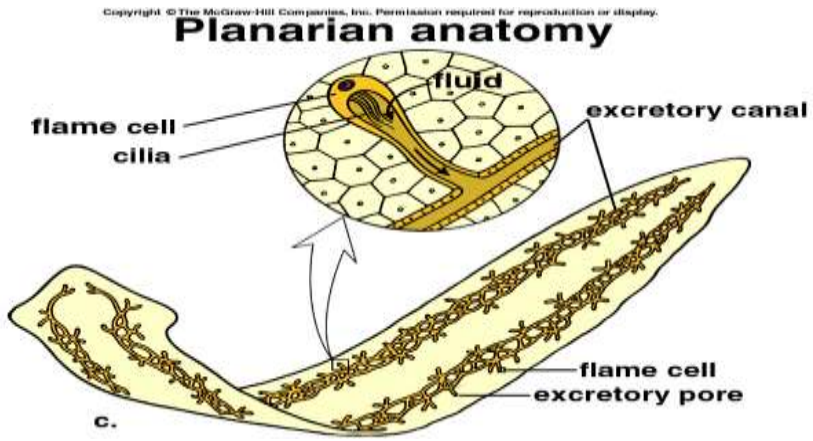
Locomotion: They move **using cilia using muscular undulation**.

Digestion and Nutrition: Most turbellarians are **carnivores, some are herbivores**. Food digestion is extra cellular and **intra-cellular.**

Topic – 052: Exchange with Environment, Nervous and Sensory Functions:

The turbellarians **don't have respiratory organs**, for gaseous exchange, respiratory gases are exchanged by diffusion.

Protonephridia are network of fine tubules that run the length of the turbellarian, along each of its sides. Numerous fine side branches of tubules originate in the parenchyma as tiny enlargement called **flame cells**.



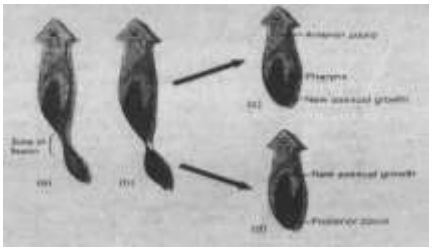
Nervous system and sensory organs:

- Cerebral ganglia control the nervous system of turbellarian.
- The head region also has specialized sensory organs i.e. eye spots, **tactile** and chemical sensory organs that help turbellarians to find food.

Topic – 053: Reproduction and Development:

Many turbellarians reproduce asexually by transverse fission. Turbellarians are monoecious and reproductive system arises from the mesodermal tissues in the parenchyma.

Asexual Reproduction: Two or more animals formed as a result of fission are called Zooids.



Planaria- Asexual Reproduction

Sexual reproduction:

- **Male reproductive organs:** Numerous paired testes lie along each side of the worm. Sperm ducts (vas deferens) open into seminal vesicle. Seminal vesicle is a sperm storage organ. A protrusible penis is present.

- **Female reproductive system:** female system has one to many pairs of ovaries. Oviducts start from ovaries and open into the genital chamber. Genital pores open outside through genital pore.
- **Fertilization:** Cross-fertilization produces greater genetic vesicle diversity.

  -Development: Eggs are laid with or without a gel-like mass. Two kinds of capsules:

(a) Summer capsules hatch in two to three weeks

(b) Autumn capsules have thick walls to resist freezing and drying.

A few turbellarians produce a free-swimming **Muller's larva.**

Lesson 10

CLASS TREMATODA: THE FLUKES

Topic – 054: General Features of Fluke:

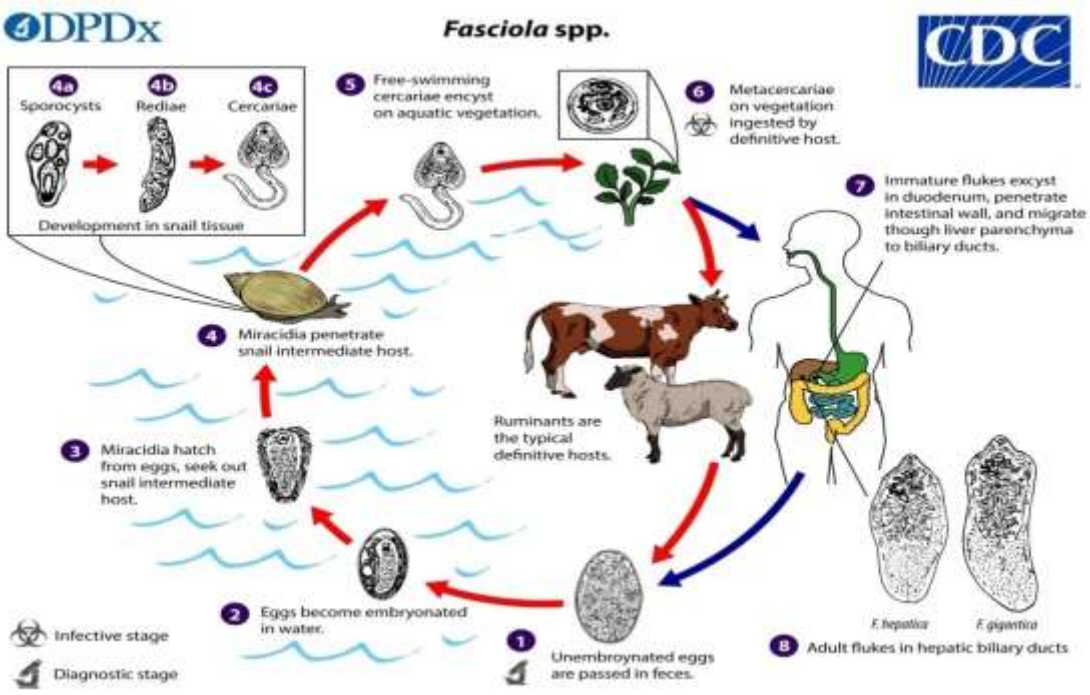
Body wall:

Body wall structure is similar to all flukes and represents an evolutionary adaptation to the **parasitic** way of life. The epidermis consists of an outer layer called the tegument which forms a syncytium. The outer zone of tegument consists of an organic layer of proteins and carbohydrates called the **glycocalyx.** The glycocalyx aids in the transport of nutrients, wastes, and gases across the body wall, and protect the fluke against enzymes and host immune system.

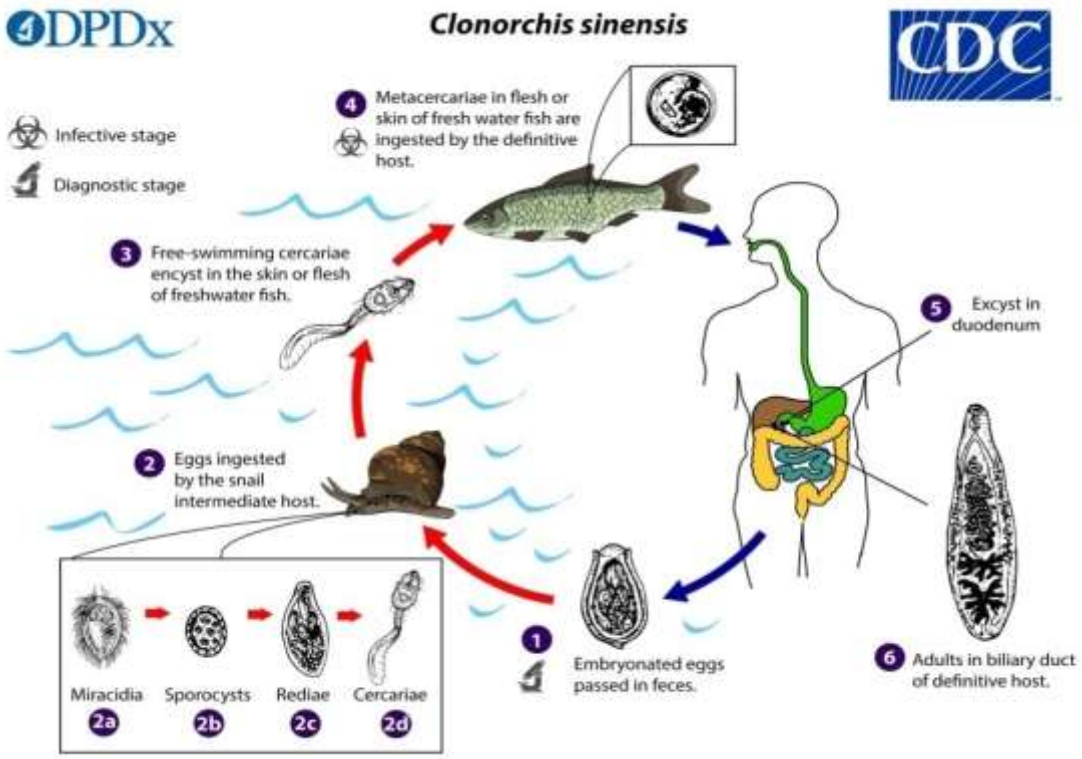
Also found in this zone are structures that facilitate nutrient exchange. Cytoplasmic bodies that contain the nuclei and most of the organelle lie below the basement membrane.

Topic – 055: Important Trematode Parasites:

***Fasciola hepatica* (Liver fluke):**

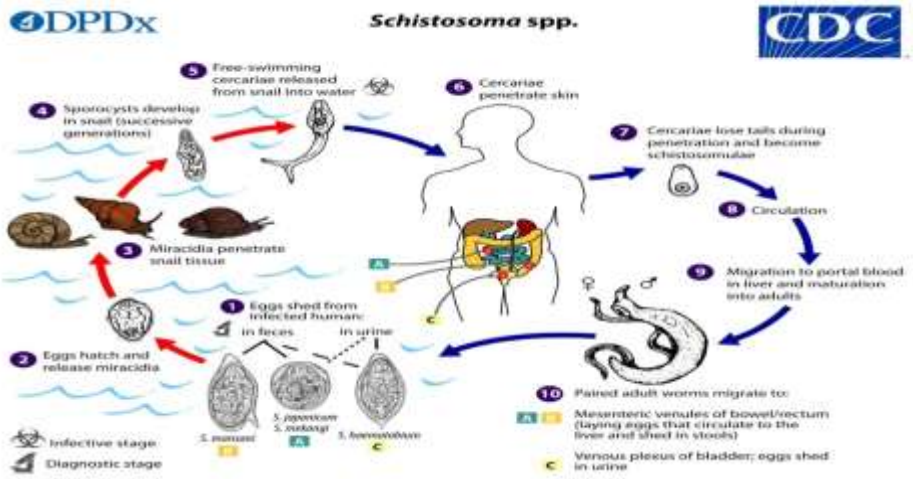


Topic – 056: Chinese Liver Fluke:



Life cycle of Chinese Liver Fluke

Topic – 057: Schistosome Fluke:



Life cycle of Schistosoma Fluke

Lesson 11

CLASS CESTOIDEA: THE TAPEWORMS

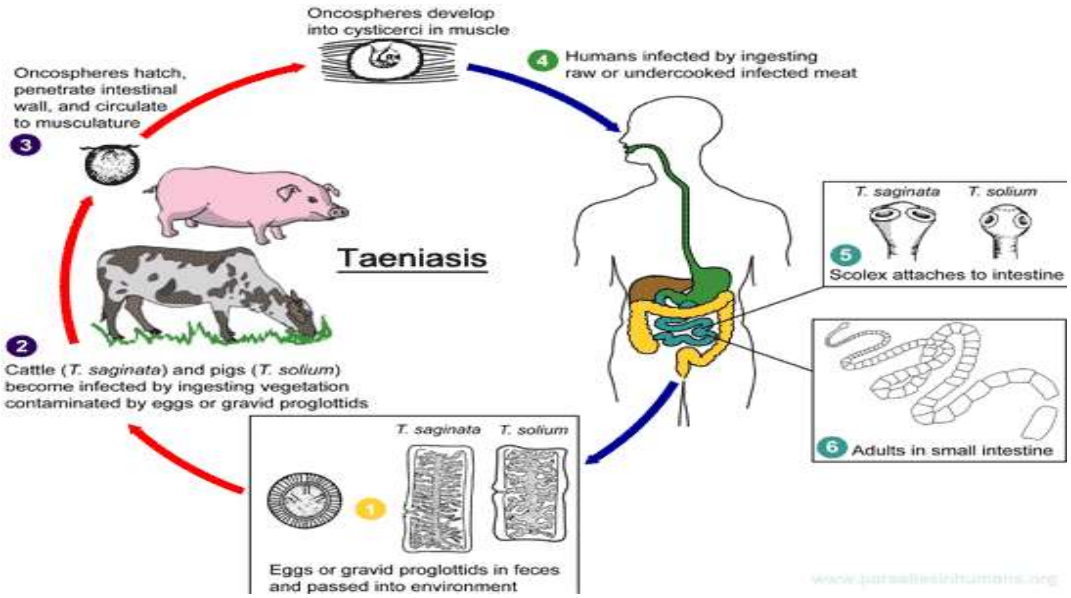
Topic – 058: General Features:

Cestoda is a class of parasitic worms in the flatworm phylum (Platyhelminthes); they are **ribbon-like** worms as adults, known as tapeworms. Their bodies consist of many similar units, known as proglottids. Species of the other subclass, Cestodaria, are mainly **fish parasites**.

Cestodes have no gut or mouth and absorb nutrients from the host's alimentary tract by their **tegument,** through which gas exchange also takes place. The tegument also protects the parasite from the host's digestive enzymes and allows it to transfer molecules back to the host.

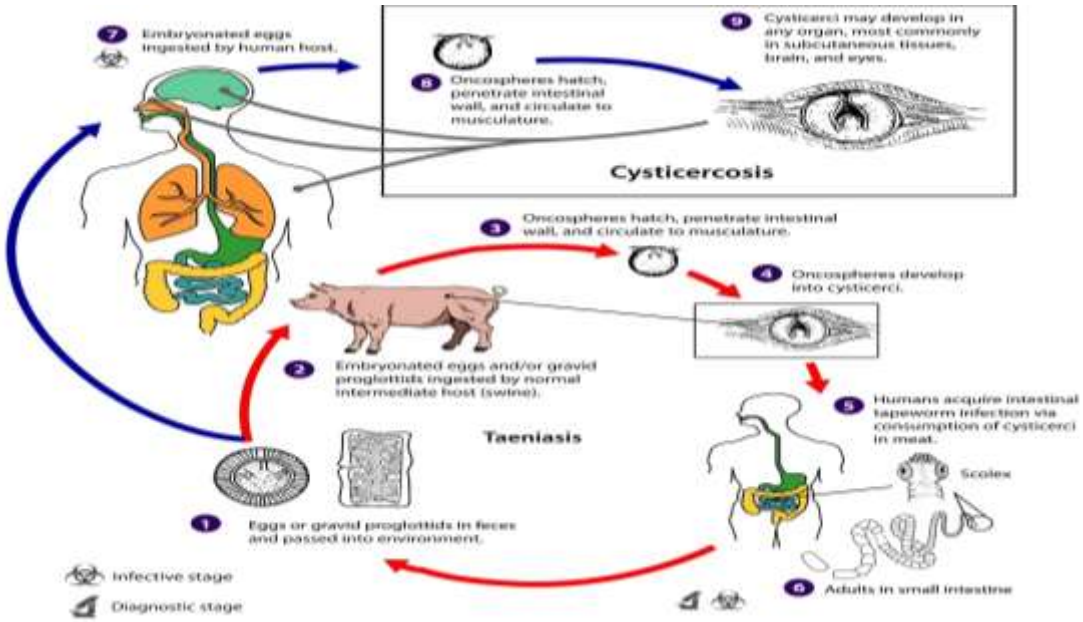
Reproduction: Cestodes are exclusively hermaphrodites, **cross-fertilization** is the norm. During copulation, the cirri of one individual connect with those of the other through the **genital pore** and then **spermatozoa** are exchanged.

Topic – 059: *Taeniarynchus saginatus* (Beef tapeworm):



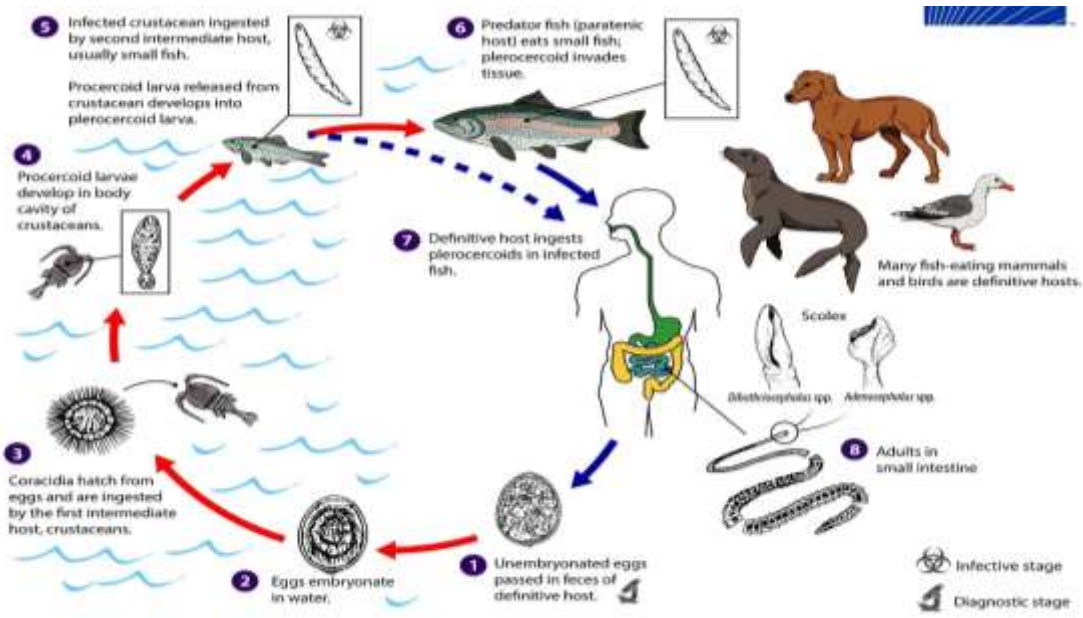
Life Cycle of *Taenia saginatus*

Topic – 060: *Taenia solium* (pork tapeworm):



Life Cycle of *Taenia solium*

Topic – 061: *Diphyllobothrium latum* (Broad Fish Tapeworm)



Life cycle of *Diphyllobothrium latum*

Lesson 12

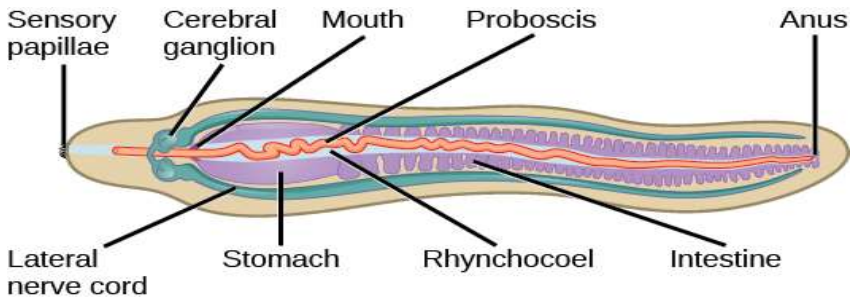
PHYLUM NEMERTEA AND GASTROTRICHA WITH EVOLUTIONARY PERSPECTIVE

Topic-062: Phylum Nemertea:

- The Nemertea are colloquially known as ribbon worms.
- They show bilateral symmetry and remarkable contractile properties. Animals in phylum Nemertea show a flattened morphology.
- Presence of a proboscis enclosed in a rhynchocoel**.**

Nervous system:

Fused ganglia and longitudinal nerves connected by a network of nerve fibers. Ocelli, tactile papillae, sensory pits and grooves as sense organs.



Circulatory system: The circulatory system is derived from the coelomic cavity of the embryo. Blood is propelled by the muscular walls of the blood vessels and by bodily movements.

Locomotion: Well-developed musculature and cilia.

Digestive System: The digestive system is complete and extends straight through the length of the body to the terminal anus, lying ventral to the proboscis sheath.

Topic 063: Phylum Gastrotricha:

They have following **characteristics:**

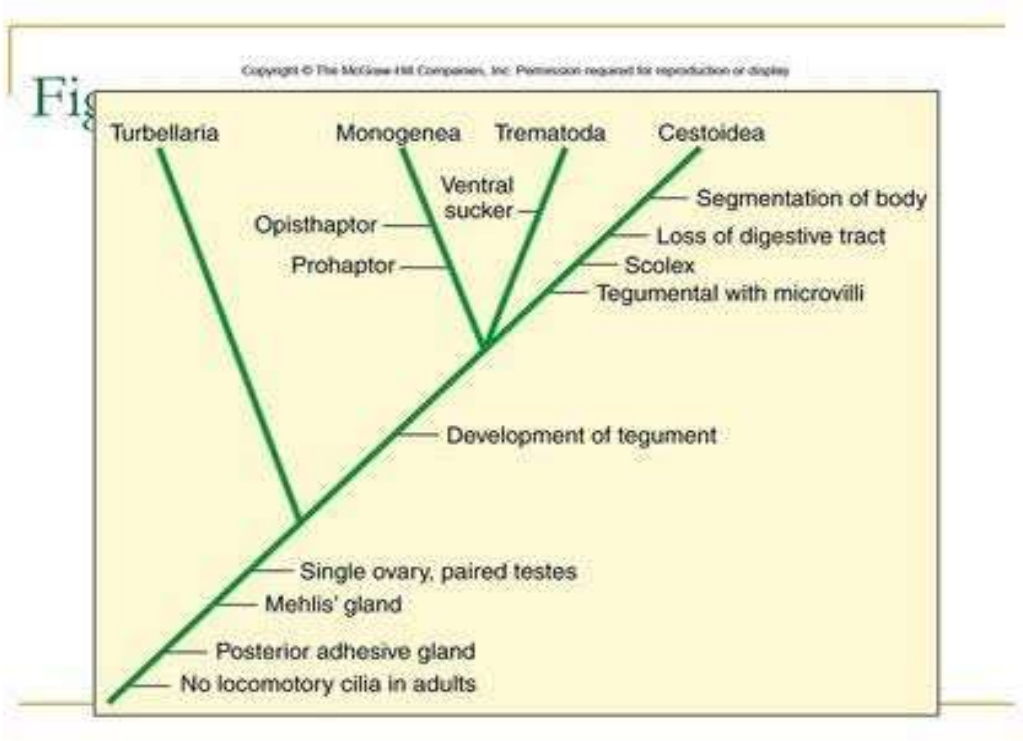
- They are usually bristly or scaly in appearance,
- The body cavity is indistinct, and if present is without epithelioid lining.
- A forked tail is often present.
- A syncytial epidermis is present beneath the cuticle.
- The muscular system is highly developed, have specialized muscular bands
- They feed on bacteria, diatoms and small protozoa.

- The **Nervous System** includes a brain and a pair of lateral nerve trunks.
- The **Digestive System** is a straight tube.
- They are **Hermaphroditic**. Most of the freshwater species reproduce asexually by Parthenogenesis.

Topic-064: Further Phylogenetic Considerations:

There are different views about the evolution of platyhelminthes. Zoologist believes that the platyhelminths body form is central to animal evolution an ancestral flatworm similar to a **turbellarian**. The uniqueness of the tegument as a synapomorphy (a shared, evolutionary derived character used to describe common descent among two or more species) uniting the **Monogenea, Termatoda**, and **Cestoidea.**

Cladogram for platyhelminthes



Lesson 13

PSEUDOCOELOMATE ORGANIZATION

Topic 065: Pseudocoelomate Body Plan

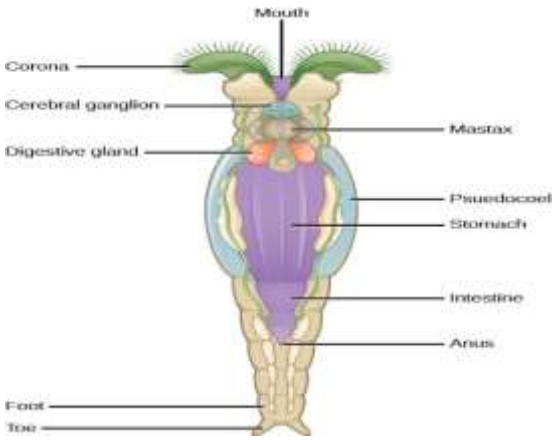
A pseudocoelomate is an organism with body cavity that is not derived from the mesoderm, as in a true coelom, or body cavity.

Aschelminths: General Characteristics

- They are marine or fresh water animal.
- They are first invertebrates which possess body cavity.
- But they lack peritoneal linings and mesenteries.
- The pseudocoelom is often fluid filled or may contain a gelatinous substance with mesenchyme cells, serves as a cavity for circulation, aids in digestion, and acts as an internal hydrostatic skeleton that functions in locomotion.
- Most Aschelminths have a complete tubular digestive tract that extends from an anterior mouth to a posterior anus.
- This complete digestive tract was first encountered in the nemerteans and is characteristic of almost all other higher animals.

Topic 066: Phylum Rotifera

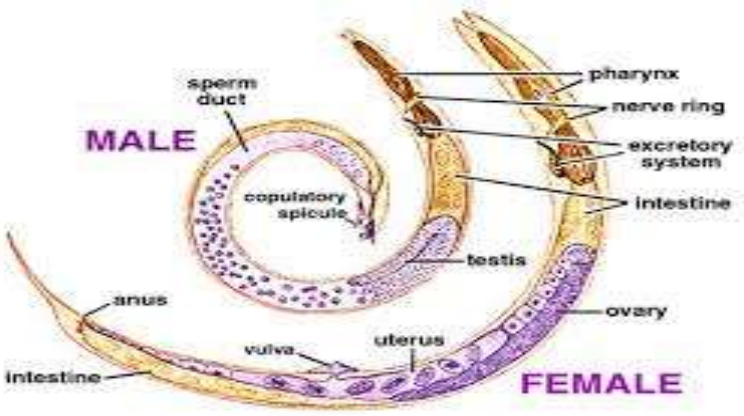
- Phylum Rotifera (derived their name from the characteristic ciliated organ, the corona.
- Corona is present around lobes on the head. The cilia of the corona do not beat synchrony; instead, each ciliam is at a slightly earlier stage in the beat cycle than the next ciliam in the sequence.
- They are abundant in most fresh water habitats. A few species (less than 10%) are marine.
- Some have beautiful colors, although most are transparent, and some have odd and bizarre shapes.
- They are triploblastic, bilateral, unsegmented, and pseudocoelomate.
- They have complete digestive system with specialized organs.
- Well-developed cuticle is present. Rotifers have a pair of protonephridial tubes with flame cells which eventually drain into a cloacal bladder.



Topic 067: External Features of Phylum Nematoda

Characteristics:

- Many nematodes are parasites of plants or animals; most other are free living in marine fresh water or soil habitats.
- Some nematodes play an important role in recycling nutrients in soils and bottom sediments.
- Body of Phylum Nematoda is un-segmented, bilaterally symmetrical, elongated and tapering at both ends.
- Only longitudinal body-wall muscles are present instead of circular body-wall muscles.
- Excretory system is without nephridia and flame cells.
- Alimentary canal provided with distinct mouth and anus (complete digestive tract).



- Extracellular digestion takes place.
- Sexes of Sexes of Phylum Nematoda are separate (gonochoristic). Phylum Nematoda are separate (gonochoristic).

Topic 068: Feeding and Digestive System

Its digestive system is not fully developed and has a one-way digestive system from the mouth to the anus. They also have a cavity between their digestive tract and their body wall which is called pseudocoel. The digestive system of a nematode is made up of three main parts: the stomodeum, the intestine, and the protoderm.

- The stomodeum is the beginning of the digestive tract where we find the mouth opening, esophagus (also called the pharynx), and the buccal cavity (the area inside the mouth).
- On the other end of the worm is the protoderm, which is where waste is expelled after the food is processed and moved through the digestive tract.
- In between these two openings, and much like in our own digestive system, we find the intestine.
- Nematodes do not have an independent **circulatory system or cardiovascular system** as do humans.
- Gases and nutrients are exchanged with the external environment through diffusion across the surface of the animal's body.

Lesson 14

PHYLUM NEMATODA

Topic 069: Feeding and Digestive System, other Organsof Phylum Rotifera

This current brings food particles into the mouth. Digestive system is composed of:

Pharynx: Pharynx contains a structure called the mastax (jaws). The mastax is a muscular organ. It grinds food. The inner walls of the mastax contain several sets of jaws called trophi. The trophi have different structures.

Intestine and cloacal bladder: In some species, ciliated intestine forms cloacal bladder. It receives water from the Protonephridia and eggs from the ovaries.

Nervous System: The brain consists of a single, dorsal, bilobed supra-pharyngeal ganglion situated above mastax in head.

Sense Organs: They include stiff bristles (styles), ciliated pits, antennae and eyespots. Stiff bristle occurs along anterior edge of the body.

Excretory system: It consists of a pair of coiled, syncytial protonephridia tubules. Fine capillary tubules terminate in flame bulbs. Sometimes a transverse tubule called Huxley's anastomose connects the two main tubules.

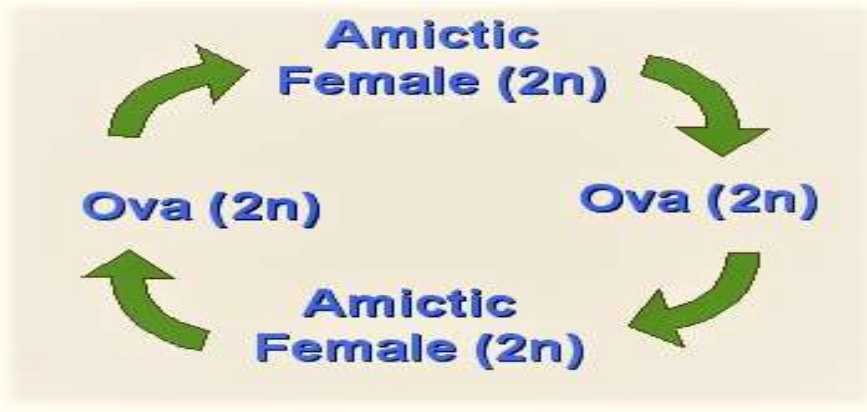
Reproductive system: Dioecious, sexes separate with sexual dimorphism. Most rotifers are females and all bdelloids are females producing only parthenogenetic ova**.**

Body Wall: It consists of cuticle, epidermis and subepidermal muscles. Cuticle is made up of scleroprotein. It covers the body surface forming lorica, spines and other surface structures. The epidermis is syncytial containing a constant number of nuclei.

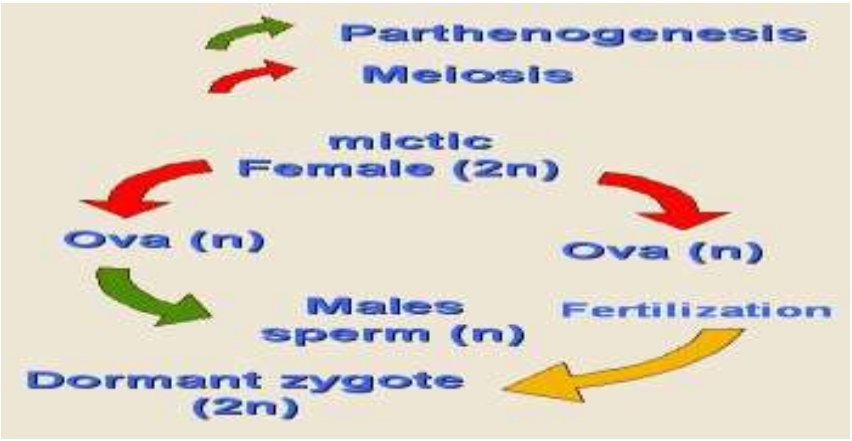
Topic 070: Reproduction and Development of Phylum Rotifera

- In one class (Seisonidea), the female produce haploid eggs. This egg is fertilized to develop into males or females.
- In another class (Bdelloidea), all female is parthenogenetic. They produce diploid egg these eggs hatch into diploid females.
- The third class (Monogononta) produces two different types of eggs: amictic and mictic cycle.

Amictic cycle:

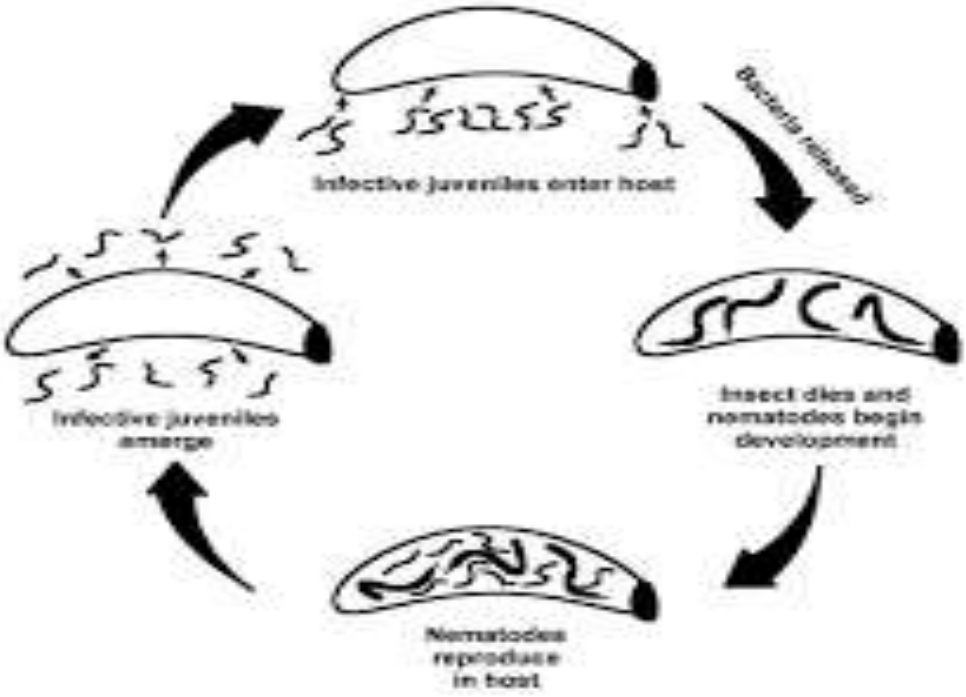


Mictic cycle:



Topic 071: Phylum Nematoda: Reproduction and Development

- Most **nematode**s are dioecious and dimorphic, with the males being smaller than the females.
- The long, coiled gonads lie free in the pseudocoelom.
- Some nematodes bear live young, the eggs having matured in the female **reproductive tract**; but most release eggs, which develop into larvae that molt one or more times before reaching maturity.



Topic 072: Phylum Kinorhyncha

- **Kinorhyncha** is a phylum of small marine invertebrates that are widespread in mud or sand at all depths as part of the meiobenthos. They are also called mud dragons.
- The phylum kinorhyncha contain about 150 known species.
- Body short (less than 1 mm in length), grub-like and **bilaterally symmetrical**.
- Body more than two cell layer thick, with tissues and organs.
- The body surface of kinorhyncha is devoid of cilia and is composed of 13 or 14 definite unit which is called **zonites.**
- Kinorhynchs are segmented, limbless animals, with a body consisting of a head, neck, and a trunk of eleven segments.
- They live in the marine mud or in the interstitial spaces of marine sand. They are found in the intertidal zone to the depths of several thousand metres.

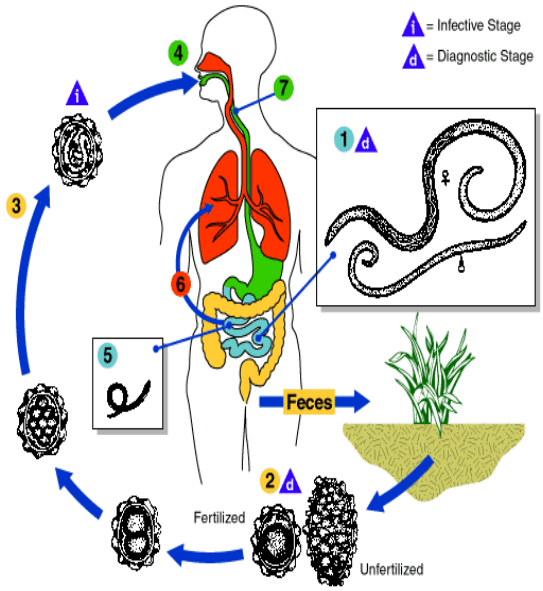
Lesson 15

SOME IMPORTANT NEMATODE PARASITES OF HUMANS

Topic 073: *Ascaris lumbricoides*

Ascaris lumbricoides is the "large roundworm" of humans, growing to a length of up to 35 cm. It is one of several species of Ascaris. Anascarid nematode of the phylum Nematoda, it is the most common parasitic worm in humans.

Adult worms live in the lumen of the small intestine. A female may produce up to 240,000 eggs per day, which are passed with the feces.



The signs and symptoms of the nematode infection by Ascaris lumbricoides may include the following:

- Abdominal discomfort.
- Abdominal cramping.
- Abdominal swelling (especially in children)
- Fever.
- Coughing and/or wheezing.
- Nausea.
- Vomiting.
- Passing roundworms and their eggs in the stool.

Topic 074: *Enterobius vermicularis*

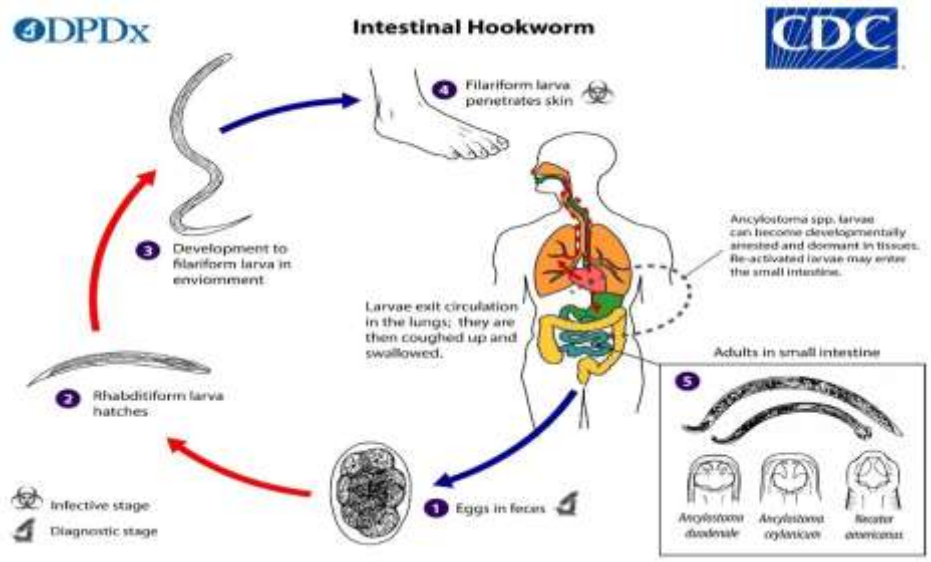
The human pinworm is an organism that primarily lives in ileum and cecum.
They have high reproductive potential.
Their life cycle increases the likelihood of **transmission** from one host to another host.
They develop an **enzymes** resistant cuticle, resistant eggs and encysted larvae.
Transmission: *Enterobiasis* may also be acquired through surfaces in the environment that are contaminated with pinworm

Symptoms of pinworm infection may include:

- Itching of the anal or vaginal area.
- Insomnia, irritability and restlessness.
- Intermittent abdominal pain and nausea. strong itching of the anal area.

Topic 075 :*Necatar amaricanus*

Habitat: The new world **hookworm**, is found in Southern United States. The adults live in small intestine, where they hold onto intestinal wall with teeth and feed on blood and tissue fluids.

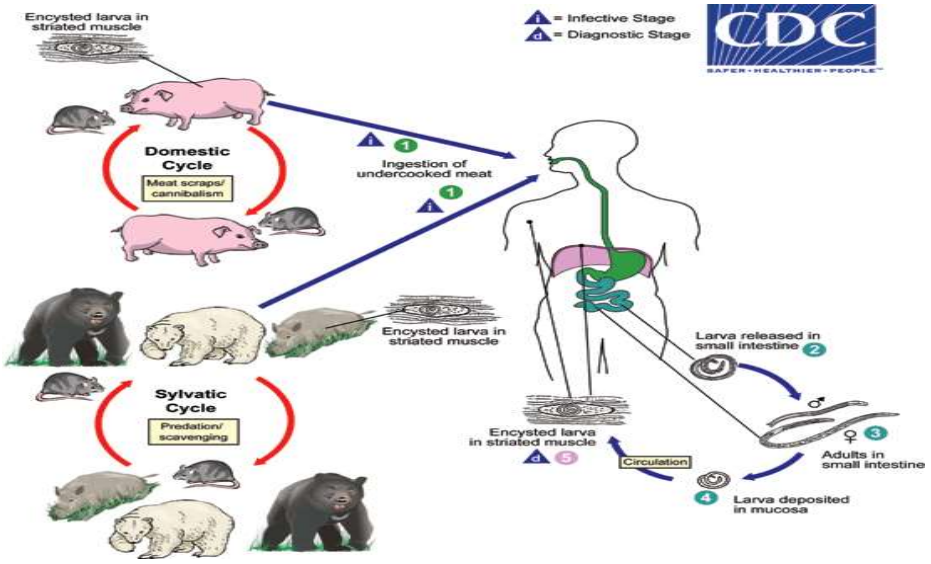


Topic 076: *Trichinella spirallis*: The pork worm

Trichinosis:

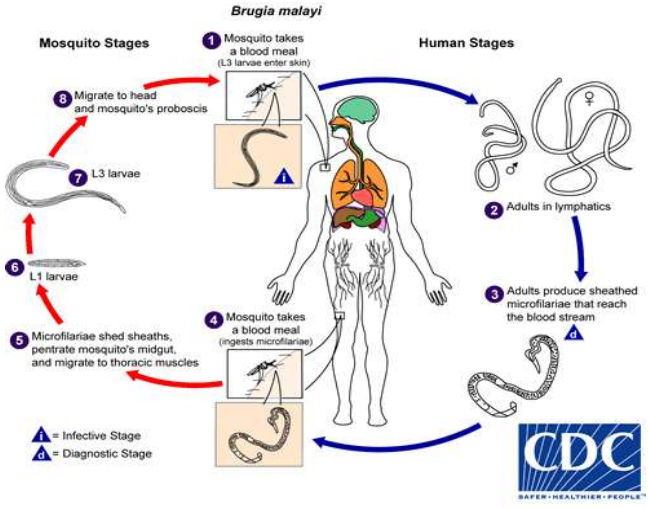
- Adult Trichinella (Gr. Trichinos, hair) spiralis live in mucosa of the small intestine of humans and other omnivores (e.g. the pig).
- In the intestine, adult females give birth to the young larvae that than enter the circulatory system and are carried to the skeletal (striated) muscles of the same host.
- The young larvae encyst in the skeletal muscles and remain infective for many years. The disease this nematode is called **trichinosis**.

Life cycle:



Topic 077: *Wuchereia spp.* The Filarial worms

- Dramatic manifestations of elephantiasis are occasionally produced after a long and repeated exposure to the worms.
- The condition is marked by excessive growth of connective tissue and enormous swelling of affected parts, such as the scrotum, legs, arms and more rarely, the vulva and beasts.
- Another filarial worm causes liver blindness and is carried by blackflies.
- It infects more than 30 million people in parts of Africa, Arabia and Central America.



Lesson 16

MOLLUSCAN SUCCESS

Topic- 078: Relationship to the other animals

Molluscs have great similarity with other protostomes like annelids. These similarities are**:**

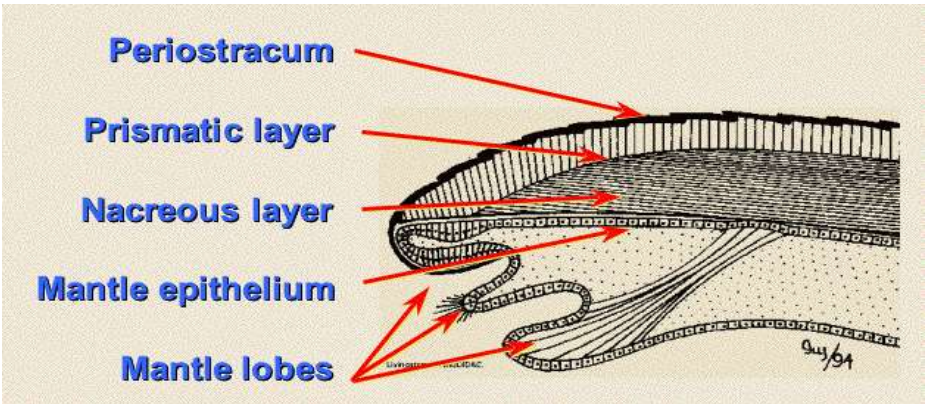
- Both have similar trochophore larvae.
- Certain adult structures are similar e.g., the excretory organs and their duct systems.

Origin of coelom:

- **Schizocoel hypothesis:** Coelom is formed by the splitting of mesoderm i.e. protostomes. It suggests that a triploblastic acoelomate (flatworm) body form is the ancestor of the coelomate.
- **Enterocoel hypothesis:** Coelom has arisen as out pocketing of a primitive gut i.e. in deuterostomes. Therefore, acoelomate body form was secondarily derived from the coelomate.

Topic – 079: Molluscan characteristics

- Bilateral symmetry and trochophore larvae.
- Secreted by mantle and has three layers i.e. Periostracum Prismatic and Nacreous.
- Body plan consists of head-foot, visceral mass,mantle and mantle cavity.
- Size varies from Microscopic snail *Angustopila dominikae* to the giant squid *Architeuthis*.
- Radula is used for feeding.
- Open circulatory system of heart (closed in cephalopods) is present.



Structure of shell

Lesson 17

CLASS GASTROPODA

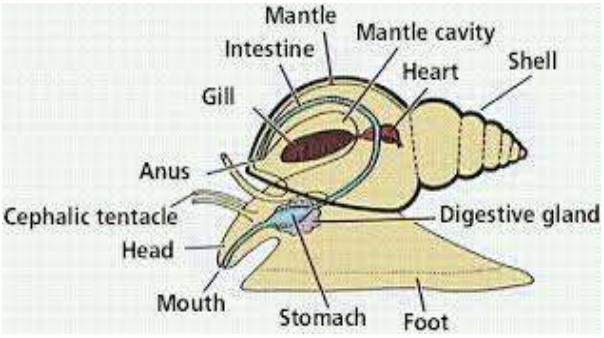
Topic- 080: The characteristics of shell and associated structures

- Largest containing 35,000 living species.
- Snails, limpets, slugs, whelks, sea slugs, sea hares and sea butterflies.
- habitats is sea water, freshwater, on land and polar regions.
- Torsion-modification body form
- Operculum enhances protection.
- Earliest fossil gastropods shell coiled in one plane.
- Modern shells are asymmetrically coiled with successive coils or whorls.
- Pulmonate and prosobranch snails are medically important Trematodes.

Topic- 081: Feeding, Digestion, Gas Exchange, Locomotion

Feeding and digestion:

- Most gastropods are herbivorous, scavengers and some are planktonic feeders.
- Extracellular and intracellular digestion



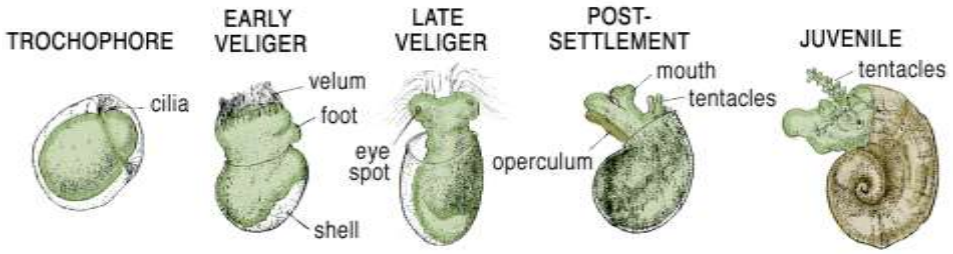
Digestive system of Gatropoda

Respiration:

- Respiration by **gills** and most aquatic forms lack gills and depend on the mantle and skin.
- Pulmonates lack gills and have **lung** which open to the outside by a **pneumostome**.
- Some gastropods have **siphon** that serves as an inhalant tube.

Topic- 082: Reproduction and Development

- Molluscs are dioecious and the reproductive organs lie in spirals of the visceral mass.
- Internal and external fertilization is performed.
- Metamorphosis is also present.



Development of Gastropoda

Topic- 083: Other Maintenance Functions

- Gastropods have an open circulatory system.
- A distinct heart, consisting of single muscular ventricle and two auricles.
- Hydraulic skeleton for support and extention of body structures.
- Eyes, lens and cornea.
- Statocysts are in the foot.
- Osphradia are chemoreceptors and help detect prey.
- Molluscs, with the exception of cephalopods, have no brain.
- Six ganglia in the head-foot and visceral mass.
- Nephridium for excretion.

Topic- 084: Gastropod Diversity

- Largest containing about 40,000 living and 15,000 fossil species.
- Subclass Opisthobranchia are mostly marine.
- Shell, mantle cavity,gills are reduced and acquire nematocysts.
- Members include sea hares, sea slugs, and their relatives.
- Subclass Pulmonata are freshwater or terrestrial species.
- Mantlecavity is highlyvascular and serves as a lung.
- Ciliary feeders.

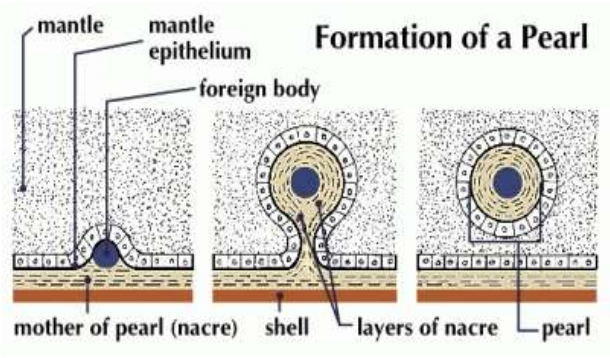
Subclass Opisthobranchia

Subclass Pulmonata

CLASS BIVALVIA

Topic- 085: The shell and Associated Structures

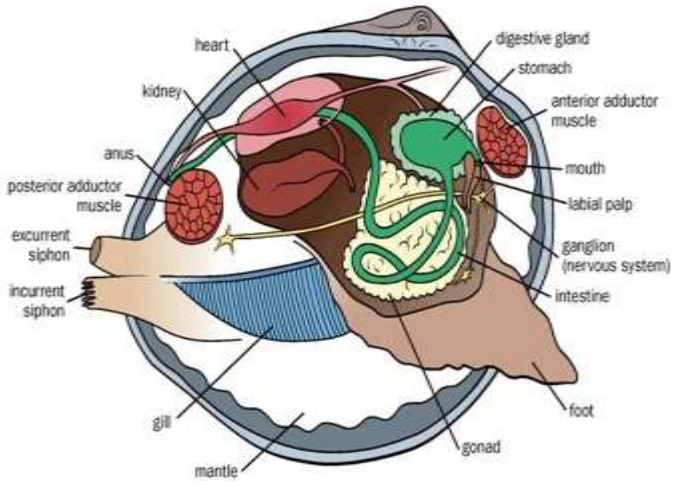
- More than 30,000 species including clams, scallops, mussels and oysters.
- Laterally compressed.
- Two shells (valves) are held together by a hinge ligament.
- Two equal adductor muscles for protection and locomotion.
- Pearl formation.



Pearl Formation

Topic- 086: Feeding, Digestion, Gas Exchange, Locomotion

- Suspension feeders.
- Gaseous exchange is by diffusion.
- Heart has 3 chambers with two auricles.
- Hemolymph
- Glandcells and crystalline style help in digestion.
- Intracellular and extracellular digestion.



Structure of Bivalvia

Topic- 087: Reproduction and Development

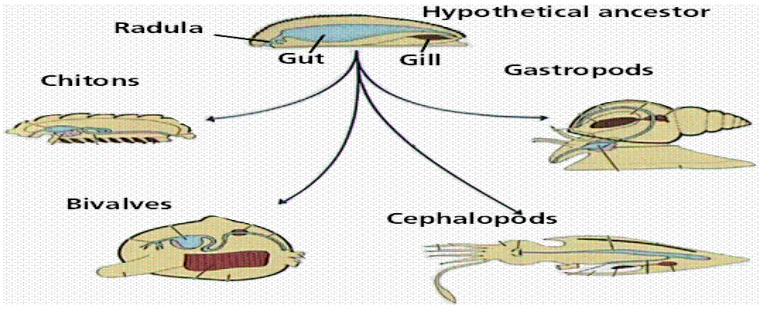
- Dioecious, monoecious and protandrous.
- Gonads are in the visceral mass and open to the mantle cavity.
- External fertilization.
- Trochophore and veliger stages.

Topic- 088: Other Maintenance and Functions

- Three-chambered heart has two atria and a ventricle.
- Beats slowly from 0.2 to 30 times per minute.
- A pair of U-shaped kidneys (nephridial tubules
- Three pairs of widely separated ganglia.
- Pair of statocysts
- Pair of osphradia.
- Tactile and chemoreceptor cells

Topic- 089: Diversity in Bivalves

- Found on freshwater, marine and land.



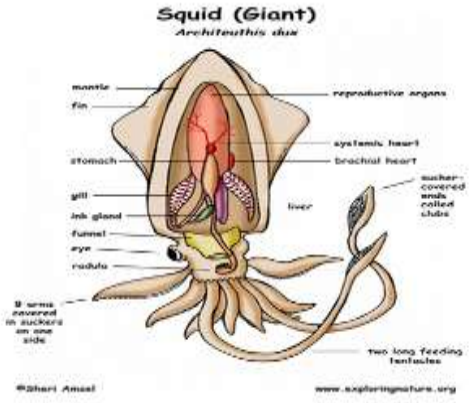
Diversity in Bivalves

Lesson 19

CLASS CEPHALOPODA

Topic- 090: The Shell and Associated Structures

- Shell of nautillus is coiled, reduced or absent.
- Buoyancy by a series of gas chambers.
- Siphuncle.
- Prpteinaceous pen.



Structure of Cephalopoda

Topic- 091: Feeding and Digestion

- Locate prey by sight and capture with tentacles.
- Jaws and radula.
- Nocturnal hunters.
- Salivary glands inject venom.
- Muscular digestive tract.
- Extracellular.

Gas Exchange and Locomotion:

- Pair of gills.
- Jet propulsion.
- Gas filled chambers keep the shell upright.

Topic- 092: Reproduction &Development

- Dioecious.
- Testes and spermatophores.
- Large, yolky eggs.
- Glands secrete gel-like cases around eggs.

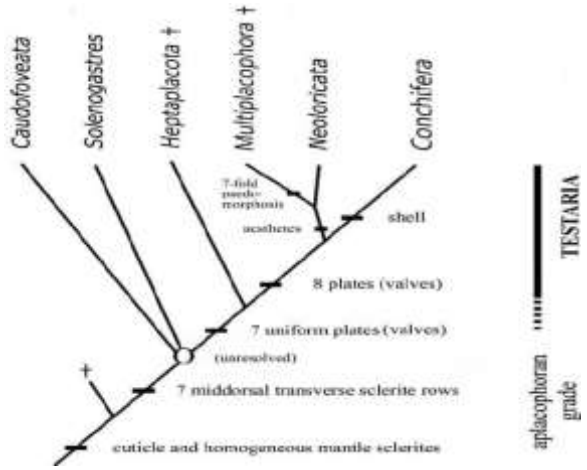
- Develop in the egg membranes and hatch similar to adults.
- Young are not cared after hatching.

Topic- 093: Other maintenance functions

- Closed circulatory system.
- Capillaries connect arteries and veins.
- Branchial heart consists of two auricles and one ventricle.
- High metabolic rates.
- Association of blood vessels with nephridia.
- Large brain formed by a fusion of ganglia.
- Eye is similar to the structure of vertebrate eyes.
- Cephalopods locus by moving the lens back and forth.
- Form images of different shapes and differentiate between some color
- Osphradia

Topic- 094: Further phylogenetic considerations

- 500 million years old according to the fossil record.
- Protostome ancestry.
- Origin form triploblastic stock.
- Segmentation different from annelids and arthropods.
- Tied to the annelid-arthropod line.
- Adaptive radiation.



Phylogenetic Considerations

Lesson 20

ANNELIDS: THE SEGMENTED WORMS

Topic- 095: Annelids relationship to other animals

- Protostomes.
- **Schizocoelous origin:** means that annelids evolved from ancient flatworm stock.
- **Enterocoelous origin:** means that the ancient diploblastic animals.

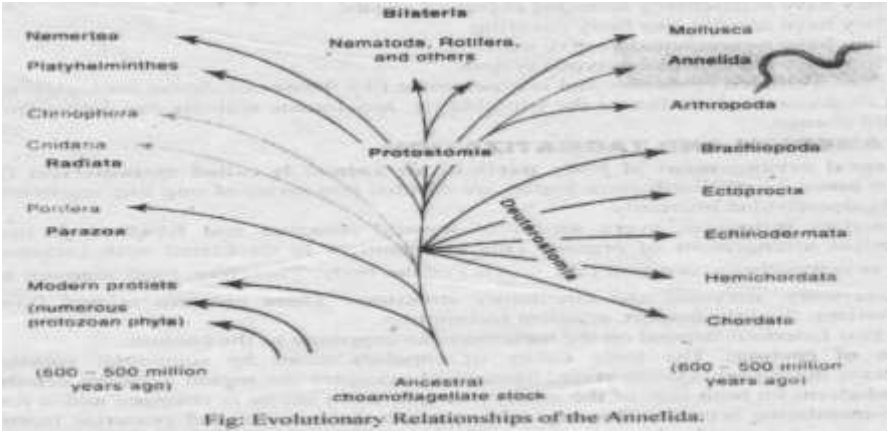


Fig: Evolutionary Relationships of the Annelida.

Annelids relationship to other animals

Topic- 096: General characteristics

- Less than 1mm in length to more than 3m.
- Coelom is present and used as storage for gametes and hydrostatic skeleton for locomotion.
- A closed circulatory system absent in some.
- Protostome characteristics.
- Metanephridia (usually) or protonephridia.
- Brain or cerebral ganglion.
- Ventral nerve cord.

Topic- 097: Metameric body form

- Segmental arrangement of body parts.
- Flexible support and efficient locomotion.
- Origin of coelom: Formed by the splitting of mesoderm during embryonic stage.
- Origion of muscles: Develop from mesodermal layer.
- Tagmatization

Lesson 21

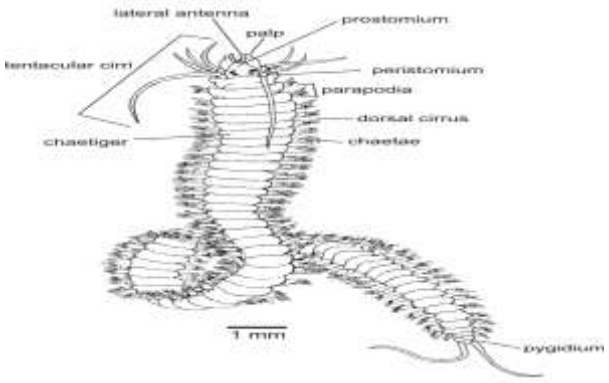
CLASS POLYCHAETA

Topic- 098: External structure and locomotion

- Parapodia and setae.
- Prostomium.
- Walk, fast crawl or swim.
- Undulatory waves.
- Burrowing by contractions of the body wall.

Topic- 099: Class Polychaeta Feeding and the Digestive System

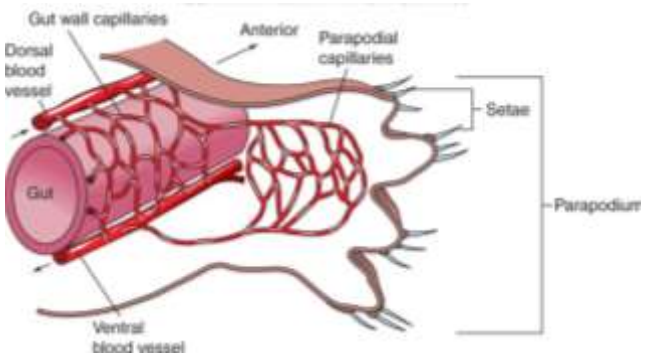
- Herbivores and scavengers.
- Digestive track is a straight tube
- Proboscis retractor muscles
- Paired jars for capturing prey.
- Poison glands at the base of the jaw.
- Filter feeders.



Digestive System of Polychaeta

Topic- 100: Gas Exchange and Circulation

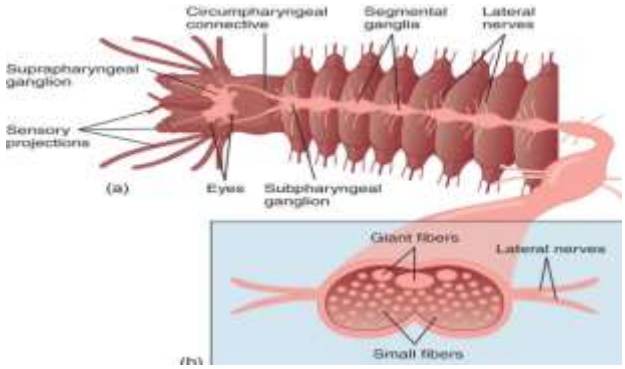
- Diffusion.
- Parapodia increase the surface area for gases exchange.
- Closed circulatory system.
- Oxygen is carried by respiratory pigments dissolved in the plasma.
- Blood is colorless, green or red, depending on the respiratory pigment.
- Consist of dorsal aorta, ventral aorta, segmental vessels and capillaries



Gas Exchange and Circulatory system of Polychaeta

Topic- 101: Nervous and Sensory Functions

- Pair of suprapharyngeal ganglia.
- It is connected to a part of subpharyngeal ganglia by circumpharyngeal connectives. These connectives run dorsoventrally along both side of the pharynx.
- Ventral nerve cord has a paired segmental ganglion
- Lateral nerves
- Two to four pairs of eyes
- Nuchal organs
- Statocysts.
- Ciliated tubercles. Ridges, and bands for tactile senses.



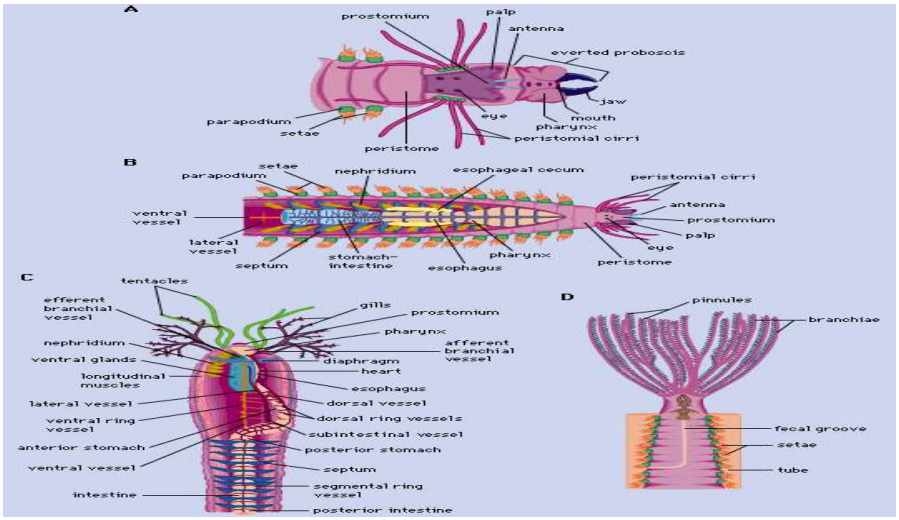
Nervous System of Polychaeta

Topic- 102: Excretion

- Ammonia.
- Ammonia diffuses readily into the water and occurs through the body wall.
- Protonephridium and Metanephridium.
- Efficient osmoregulatory abilities.

Topic- 103: Regeneration, Reproduction And Development

- Dioecious
- Sexual reproduction.
- Asexual reproduction by regeneration budding and transverse fission.
- Gonads project from the coelomic peritoneum limited is specific segments.
- Few have separate gonoducts.
- External Fertilization and Trochophore larva
- Epitoky. and atoke.



Reproductive system of Polychaeta

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Lesson 22

CLASS OLIGOCHAETA

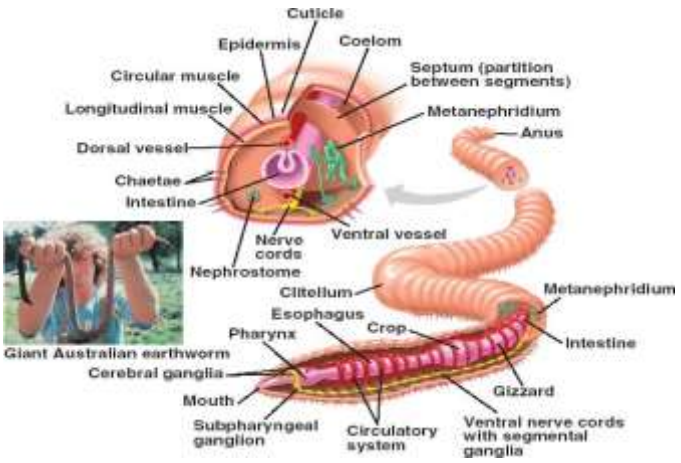
The class Oligochaeta has **over three thousand species**. They are found throughout the world in freshwater and terrestrial habitats. A few oligochaetes are estuarine, some are marine.

In this lecture, the following topics of class Oligochaeta are discussed:

- External structure and Locomotion
- Digestive system
- Gas Exchange and Circulation
- Nervous and Sensory function
- Excretion in Oligochaeta
- Regeneration, Reproduction and Development

Topic- 104: External Structure and Locomotion:

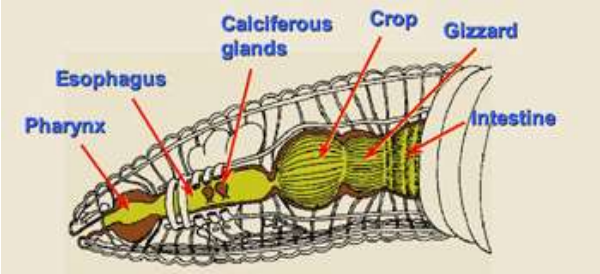
- Oligochaetes have lesser number setae than Polychaetas.
- The Parapodia and long setae interfere with their bumming lifestyles.
- The prostomium lacks sensory appendages.
- A series of special segments are present at the anterior half and these segments swell to form a girdle like structure called the clitellum.
- The longitudinal muscles contract and segments bulge and setae protrude out.
- The coelomic hydrostatic pressure helps in burrowing.
- Terrestrial oligochaetes, are scavengers and feed upon decaying organic material.



External Structure of Oligochaetes

Topic –105: Digestive System:

- Terrestrial oligochaetes tunnel through the ground, swallowing soil.
- Typically has a thin-walled storage area, or **crop, and a muscular gizzard** for grinding.
- Specialized **calciferous glands** remove excess calcium, magnesium, strontium, and phosphate and regulate the level of these ions in the blood.



Digestive System of Oligochaetes

Topic –106: Gas Exchange and Circulation:

- **Gaseous exchang**e normally occurs over the whole of the animal's body.
- Secrete moisture in the form of coelomic fluid from the dorsal pores.
- The parapodia increase the surface area for gases exchange.
- There is no well-developed respiratory system in the majority of oligochaetes.
- Body wall is the main organ of gas exchange. **Cuticle** is kept damp by the excretion of nephridia and the cutaneous mucus.

Circulation

- Hearts the main propulsive structures are the dorsal and ventral vessels.
- Have a closed circulatory system.
- Oxygen is carried by respiratory pigments that are dissolved in the plasma.
- Blood is colorless, green or red, depending on the respiratory pigment.

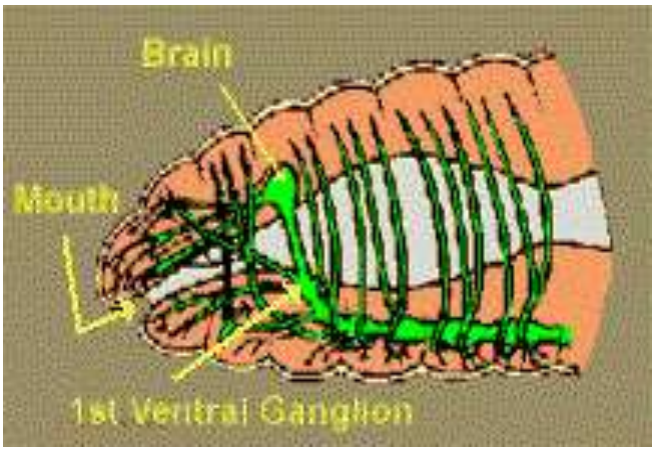
Topic –107: Nervous and Sensory Function:

- **The nervous system** of the earthworm is "segmented" and well developed.

- The CNS consists of a bilobed brain, sub-pharyngeal ganglia, circum-pharyngeal connectives and a ventral nerve cord.
- The "brain" is located above the pharynx and is connected to the first ventral ganglion.
- The ventral nerve cord and all ganglia have undergone a high degree of fusion.

Sensory Functions

- Do not have discrete sensory organs.
- Skin particularly in the anterior region, has cells with sensory functions some are light-sensitive and some are chemosensory.
- Oligochaetes lack the well develop eyes.
- Sensitive to a wide variety of chemical and mechanical stimuli.



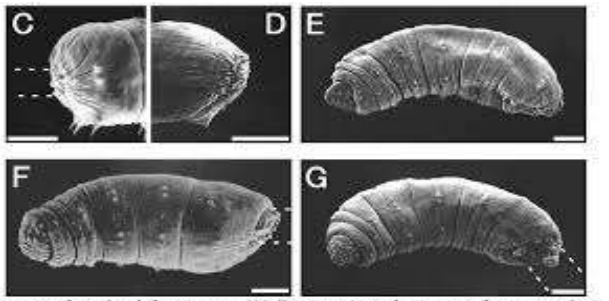
Nervous system of Oligochaetes

Topic –108: Excretion in Oligochaetes:

- Excretion is through small ducts known as metanephridia.
- Terrestrial oligochaetes secrete urea, but the aquatic forms typically secrete ammonia.
- Oligochaetes secrete the copious amount of the water and they retain the essential ions which is an important part of the organism.
- Oligochaetes possess the Chloragogen tissue that surround the dorsal blood vessels that act as vertebrate liver.
- Classified into holonephridia and meronephridia.
- Role of the nephridia in osmotic regulation has been determined by measurement of the depression of freezing point of blood, coelomic fluid and urine.

Topic –109: Regeneration, Reproduction and Development:

- **Annelids** have the general reputation of having extensive regeneration capabilities.
- ***Enchytraeus japonensis*** is a small terrestrial oligochaete which primarily reproduces asexually by fragmentation and regeneration.
- The red wiggler, or compost worm, might regenerate a new head or a new tail.
- The worm might grow a new head if cut behind the 13th segment, but it can't replace sexual organs.
- The head of the worm may survive and regenerate its tail if the animal is cut behind the **clitellum**.
- Original tail of the worm will not be able to grow a new head.



generation from head fragments. (A) Regeneration of autotomy fragments obtain

Development

- The eggs of polychaetas are deposited in the sea where they develop into trochophore larvae.
- The **yolky eggs** of oligochaetes do not have a larval stage and develop directly into juvenile worms in the cocoon.

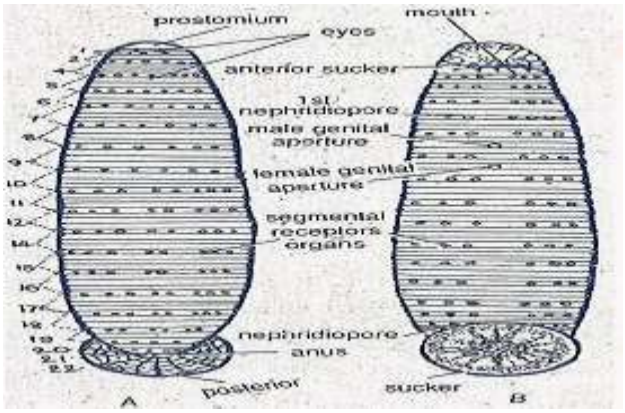
Regeneration of Oligochaetes

Lesson 23

CLASS HIRUDINEA

Topic – 110: External Structure and Locomotion:

- Leeches lack **parapodia** and head appendages.
- **Setae** are absent in most of leeches and if present occur in anterior segments.
- Leeches are dorsoventrally anteriorly and have **34 segments**.
- The **musculature** of leeches is more complex than annelids.
- A layer of oblique muscles is present between the circular and longitudinal muscles and responsible for the flattening of leech.
- The leech has a single **hydrostatic cavity**. It uses a looping type of locomotion.



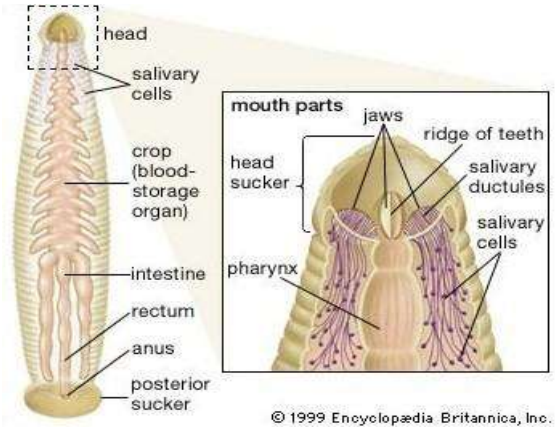
External structure of Hirudinea

Topic – 111: Feeding and the Digestive System:

- Many leeches feed on **body fluids**. They may eat the bodies of other invertebrates. Some feed on the **blood** of vertebrates, including human blood.
- Leeches are parasites. Leeches are not specie specific.
- **The mouth** of a leech opens in the middle of the anterior sucker.
- In some leeches, the anterior digestive tract is modified into a **protrusible proboscis.**
- **Salivary glands** secrete an anticoagulant called hirudin. **Hirudin** prevents blood from clotting.

Digestive System:

- The leech starts its **digestive system** with the jaws, three blades set
- In feeding they slice their way through the skin of the host, leaving a **Y-shaped incision**.
- In the crop, some blood-sucking species can store up to five times the body mass of blood.



Digestive system of Hirudinea

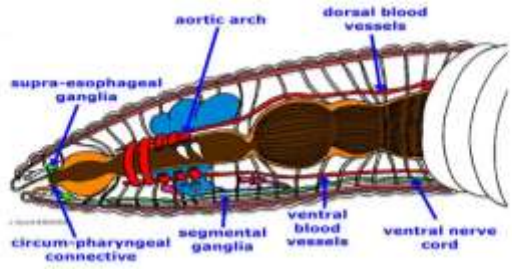
Topic – 112: Gas Exchange and Circulation:

Respiration

- Leeches do not maintain any specific respiratory organ.
- Leeches obtain oxygen and carbon dioxide in a gas exchange through the epidermis.
- Once oxygen makes it into the blood, it is carried throughout the body by the pigment hemoglobin, this pigment is specifically designed for respiration.

Circulatory system

- In ***Hirudo medicinalis***, the circulatory system is composed of **4 blood vessels.**
- A ventral vessel attached to the nervous system, a dorsal vessel and **2 contractile lateral vessels** joined by a network of fine capillaries.
- This system is devoid of a heart.



Gas Exchange and Circulatory system of Hirudinea

Topic – 113: Excretory System of Leech:

Excretory system consists of **17 pairs** of small coiled tubes, the **nephridia**, arranged segmentally, one pair in each segment from **6th to 22nd**.

Nephridia are of two types:

i) Testicular

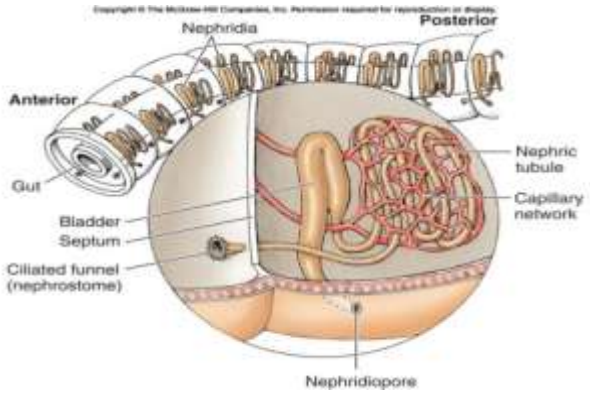
ii) Pre-testicular

i) **Testicular nephridia**

- Posterior 11 pairs of nephridia lying one pair in each segment from 12 to 22nd, are termed testicular nephridia.
- A typical testicular nephridium is a horseshoe-shaped structure traversed by a complicated system of canals.

It consists of 6 parts:

1) Main lobe
2) Vesicle and vesicle duct
3) Apical lobe
4) Inner lobe
5) Initial lobe
6) Ciliated organ



Excretory system of Hirudinea

Topic – 114: Nervous System:

- The main nerve center consists of the cerebral ganglion above the gut and another ganglion beneath it, with connecting nerves forming a ring around the pharynx.

- A nerve cord runs backwards from this in the ventral coelomic channel, with **21 pairs** of ganglia in segments **6 to 26**.
- In segments **27 to 33,** other paired ganglia fuse to form the caudal ganglion.

Sensory Cells:

- Leeches have between two and ten pigment spot ocelli, arranged in pairs towards the front of the body.
- There are also sensory papillae arranged in a lateral row in one annulation of each segment.
- Some rhynchobdellids have the ability to change color dramatically by moving pigment in chromatophore cells.

Topic – 115: Regeneration:

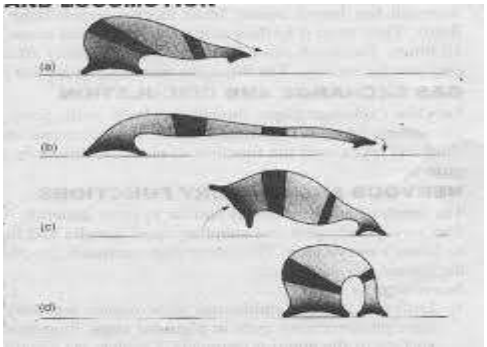
Leeches can't regenerate a part of their body that has been severed. During the juvenile stage, leeches demonstrate two types of growth depending on their type.

Reproduction and development:

- Although oligochaetes and Hirudinea are hermaphrodites, they are not able to use their own sperm to self-fertilize their eggs.
- The hermaphrodites must fertilize each other's eggs through mating.
- Leeches are cross-fertilized during copulation.
- After copulation their clitellum secretes a cocoon that receives eggs and sperms.

Copulation:

- Leeches are hermaphrodites, with the male reproductive organs, the testes, maturing first and the ovaries later.
- The penis passes a spermatophore into the **female gonopore** and sperm is transferred, and probably stored in, the vagina.



Regenration of Hirudinea

Topic – 116:Further Phylogenetic Considerations

The oligochaetes and leeches from a single clade, and share important characteristics including the presence of a clitellum.

1. Traditional interpretation:

- It suggests that the ancestral polychaetes gave rise to modern polychaetes through adaptive radiation.
- A group of annelids adapted in freshwater.
- The fresh water developed the ability to regulate the salt and water content of body fluids.

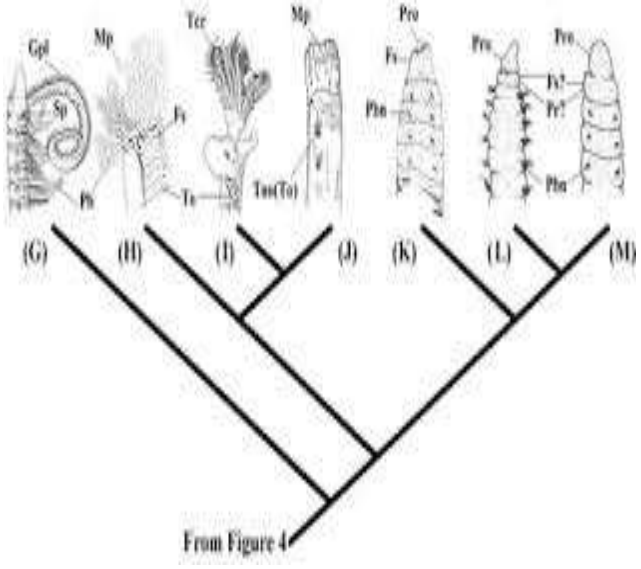
2. Cladistic analysis:

Cladistics analysis suggests that the phylum Annelida is not a monophyletic suggests that:

(a) Evolution of polychaetes: The Polychaetes arose from a metameric ancestor. It has independently of the Oligochaetes and leeches.

(b) Evolution of Oligochoetes and leeches: The oligochoetes and leeches have many common important characteristics.

- A clitellum is present in groups.
- No unique synapomorphies (derived characteristics) are present in the oligochaetes.



Phylogenetic Considerations

Lesson 24

ARTHROPODS: BLUEPRINT FOR SUCCESS

Topic – 117: Characteristics of Phylum Arthropoda

Characteristics of the phylum Arthropoda include:

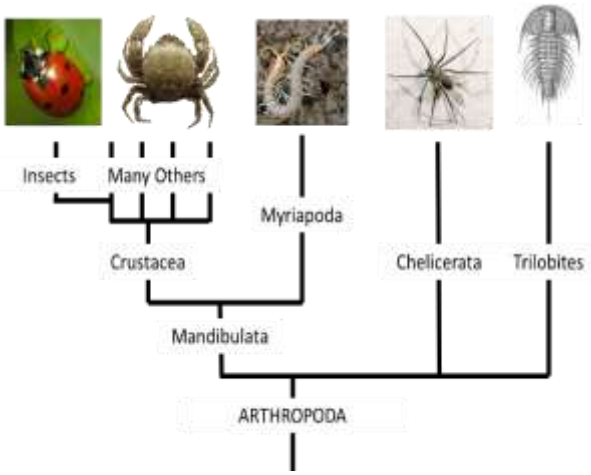
- They show metamerism. Metamerism is modified by the specialization of body regions for specific functions.
- Chitinous exoskeleton provides support and protection. It is modified to form sensory structures.
- They have paired jointed appendages.
- Ecdysis or molting takes place during growth.
- They have ventral nervous system.
- Coelom reduced to cavities. These cavities are reduced to gonads and sometimes excretory organs.
- They have open circulatory system. Blood is released into tissue spaces (haemocoel) derived from the blastocoel.
- They have complete digestive tract.
- Metamorphosis is often present. It reduces competition between immature and adult stages

Topic – 118: Phylum Arthropoda Relationship to Other Animals:

Relationship with annelids:

The **arthropods** share many features with phylum **Annelida**.

- Both arthropods and annelids are segmented and members of the annelids class polychaeta have a pair of appendages on each segment.
- The plan of the nervous system in arthropods is very similar to that of annelids and the basic plan in both groups shows a tubular dorsal heart which is lost or modified in some.
- Annelids possess a coelom in which arthropods are present only in the embryo.



Arthropoda Relationship to Other Animals

Topic – 119: Metamerism and Tagmatization:

Three characteristics have contributed in the success of arthropods. One of is **metamerism.**

Metamerism is the phenomenon of having a linear series of body segments fundamentally similar in structure, though not all such structures are entirely alike in any single life form because some of them perform special functions.

- In animals, metameric segments are referred to as somites or metameres**.**
- Metamerism of arthropods is apparent externally.
- The arthropod body is composed of a similar segments. Each segment bears a pair of appendages.
- Similarly most organ systems are not metamerically arranged.

Tagmatization:

Metamerism produces specialization in regions of the body for specific functions. The regional specialization is called tagmatization.

- In arthropods body regions are called tagmata. Tagmata are specialized for feeding and sensors perception, locomotion and visceral functions.
- The development of distinct tagmata is believed to be a feature of the evolution of segmented animals, especially arthropods.
- In the ancestral arthropod, the body was made up of repeated segments, each with similar internal organs and appendages.

- One evolutionary trend is the grouping together of some segments into larger units, the tagmata. The evolutionary process of grouping is called tagmosis.

Metamerism and Tagmatization of arthropods

Lesson 25

GENERAL CHARACTERISTICS AND EXTERNAL FEATURES OF ARTHROPODS

Topic – 120: General Characteristics Of Arthropods:

The members of phylum Arthropoda exhibit the following general characteristics.

Tagma: Their segmented body is divided into tagmata (specialized body regions).

Coelom: The coelom is reduced to portions of the reproductive and excretory systems. Most of the body cavity consists of hemocoel (sinuses or spaces within the tissues) filled with blood.

Exoskeleton: They possess auricular exoskeleton composed of chitin, protein, and lipids.

Muscle system: They possess a complex muscle system attached to the exoskeleton for support and leverage. Functional cilia are absent.

Digestive system: They possess a complete digestive system with mouthparts modified from ancestral appendages into structures adapted for different methods of feeding.

Circulatory system: Their circulatory system is open with a dorsal heart, arteries and hemocoel containing hemolymph (blood).

Excretory system: Coaxial glands or malpighian tubules serve as an excretory system. Coaxial glands are paired, thin walled spherical sacs bathed in the blood of body sinuses.

Gaseous exchange: Gas exchange occur through the body surface, gills, trachea or lungs. Trachea are a series of branched chitin lined tubules that conduct gases to and from body tissues.

Nervous system: Their nervous system is much like the annelids. It includes a dorsal brain made up of a ring around the gullet that attaches to a double nerve cord of ventral ganglia.

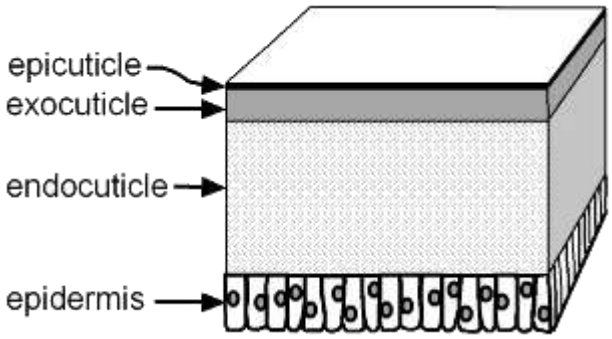
Reproductive system: Their sexes are usually separate, with paired reproductive organs and ducts and internal fertilization the norm; some types are capable of parthenogenesis.

Arthropods

Topic – 121: Phylum Arthropoda: The Exoskeleton

- The body wall is composed of complex, layered cuticle or **exoskeleton** secreted by the underlying hypodermis.

- The nonliving exoskeleton covers all the body surfaces and supports a variety of functions: protection from injury and predators, preventing water loss, offering structural support, and providing a system of levers for muscle attachment.



Exoskeleton of Arthropods

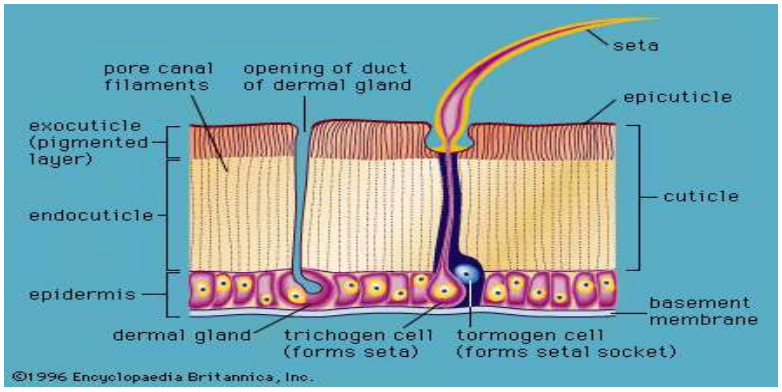
Topic – 122: Phylum Arthropoda : Composition of Exoskeleton:

The exoskeleton of an arthropod is their tough, hard outer layer.

CONSTITUENTS:

It constitutes of outermost **epicuticle**, **exocuticle**, **procanal**, **endocuticle**, **Schmidt'slayer**, **epidermis** and **basal lamella**.

- Epidermis is the outer layer of the insect and is mostly single layered. The density and shape of epidermal cells change substantially during development.
- The apical plasma membrane of epidermal cells form short microvilli.
- All epidermal cells are glandular as they secrete cuticle components and enzymes involved in cuticle modification and digestion at the time of molting.



Composition of Exoskeleton of Arthropods

Topic – 123: Phylum Arthropoda: Modifications In Exoskeleton:

- Hardening in the procuticle provides armour like protection for arthropods, but it also necessitates a variety of adaptations to allow arthropods to live and grow within their confines.
- Exoskeleton is made up of many plates (sclerites) that may be fused or joined together with flexible membrane.
- Exoskeleton may project outward and produce various structures, such as spines, protective shields or prominent horns.
- The cuticle of arthropods, pierced by ducts of dermal glands that pour out secretions over the surface, is a living structure.
- Invaginations of exoskeleton form firm ridges and bars for muscle attachment.
- Another modification of exoskeleton is formation of joints.
- The uncalcified integument, permitting movement of the shell, as between segments of a periopod, or between abdominal somites called articular membrane.

Topic – 124: Phylum Arthropoda: Advantages of Exoskeleton:

Armor or Protection: One advantage of exoskeleton provides is a strong outer layer that act as an armor against predators and environmental hazards.it provides protection.

Cuticle:

- The cuticular lining of fore and hindgut also protects the epidermis by the food from **abrasion**.
- The cuticle also plays a major role in success of insects in terrestrial environments by reducing **water loss**.

- It also serves as a **protective water barrier** and it imparts advantages related to structure and mobility.

Support and Structure:

- Like endoskeletons exoskeletons also provide structure and support to animal body.
- It plays an important role in supporting the insect, an essential requirement in terrestrial environment.

Locomotion:Muscles used for locomotion attach directly to the exoskeleton giving the animal better leverage for rapid movement.

Anti-drying: One of the most important function of an exoskeleton is to protect land-dwelling species from drying out.

Topic – 125: Phylum Arthropod: What is Ecdysis?

Growth And Molting:

The growth of an arthropod would be impossible unless the exoskeleton is not periodically shed, such as in molting process called **ecdysis**.

Enzyme Control:

Growth is periodic and concentrated into a period of time when the exoskeleton is shed, called molting or ecdysis, which is under the control of a hormone called **ecdysone**.

Significance:

- Molting is a complex process that is invariably dangerous for the arthropod involved.
- Ecdysis is the molting of the cuticle in many invertebrates of clade **Ecdysozoa**
- Before the old exoskeleton is shed, the cuticle separates from the epidermis through a process called **apolysis**.
- **Sclerotization** or **hardening** occurs just after the shedding of old cuticle and expansion of the new cuticle. After sclerotization the insect is able to **move** or **fly**.

Topic – 126: Phylum Arthropod: How Ecdysis Occurs?

The growth of an arthropod would be virtually impossible unless the exoskeleton is periodically shed, such as in the molting process called ecdysis.

STAGES:

Ecdysis is divided into four stages:

- Enzymes, secreted from hypodermal gland, begin digesting the old procuticle to separate the hypodermis and exoskeleton.
- New procuticle and epicuticle are secreted.
- The old exoskeleton splits open along predetermined ecdysal lines when the animal stretches by the air or water intake; pores in the procuticle secrete additional epicuticle.
- Finally, calcium carbonate deposits or sclerotization harden the new exoskeleton.

Topic – 127: Importance of Ecdysis:

Necessary Evil:

- Molting is a critical but vulnerable time for arthropods.
- The animal then extracts itself from the old skin and inflates its new skin.
- Once the new exoskeleton has dried and hardened the animal can move again.

Metamorphosis: The new exoskeleton is initially soft but hardens after the molting of the old exoskeleton. The old exoskeleton is called an **exuviae**.

Continuity: Arthropod growth is limited to molting, so growth happens in steps rather than continuously. The stages between moltings are called instars.

Factors: Warmer temperatures and more food and water can shorten the instar length and make the individual bigger. Other cues, such as the length of the day, are used to determine the timing of molting.

Maturation: Most insects have a specific end point to their growth, and after their final molt they are sexually mature adults.

Topic – 128: Phylum Arthropoda: Metamorphosis

DEFINITION:

"Metamorphosis is the process of development of an organism that involves distinct stages with an abrupt change between them".

- Metamorphosis is a remarkable process of differentiation.
- The speed and extent of cell growth and is astonishing.

- In most species, such rapid growth and such sweeping changes to cell type only happen during embryonic development.

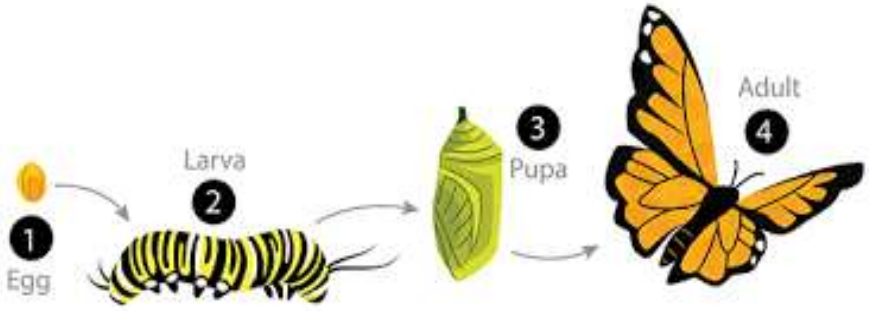
Role of Hormones in Metamorphosis:

- The changes leading to metamorphosis are triggered by hormones, which the animal's body releases as the right conditions for metamorphosis approach.
- In some animals a hormone cascade follows, with the trigger hormone causing the release of several other hormones that act on different parts of the animal's body.
- The hormones cause drastic changes to the functioning of cells, and even behavioral changes such as the caterpillar spinning its cocoon.
- The effects of hormones on metamorphosis can be studied by **artificially administering** these hormones to pre-metamorphic animals.

Topic – 129: Explanation of Metamorphosis with Examples:

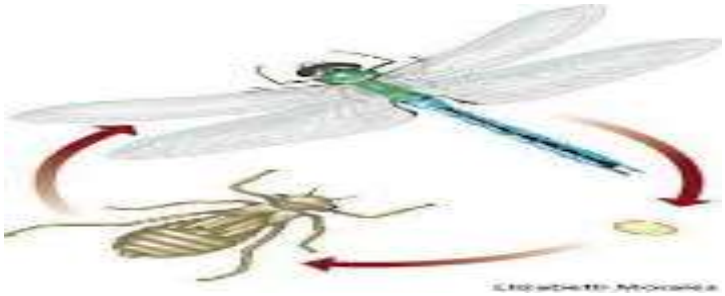
Types of Metamorphosis

Complete Metamorphosis: In complete metamorphosis, a larva completely changes its body plan to become an adult.



Stages of complete metamorphosis

Incomplete Metamorphosis: In incomplete metamorphosis, only some parts of the animal's body change during metamorphosis. Animals that only partially change their bodies as they mature are called **"hemimetabolous**" .

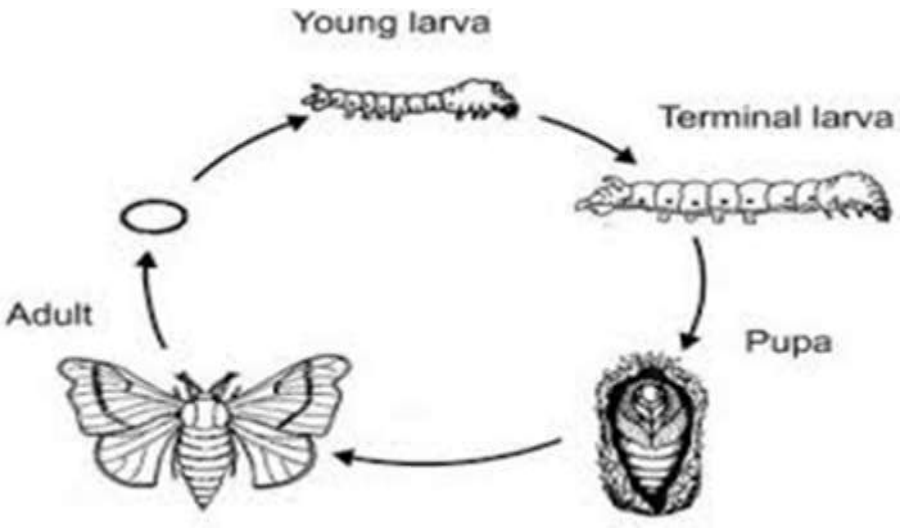


Stages of Incomplete Metamorphosis

Examples of Metamorphosis

Butterflies

The idea of a worm-like caterpillar wrapping itself in a cocoon for weeks and then emerging as a beautiful butterfly is certainly strange.



Examples of metamorphosis of butterfly

Topic – 130: Subphylum Trilobitomorpha: Members of the subphylum Trilobitomorpha were a dominant form of life in the oceans from the Cambrian period (600 million years ago) to the Carboniferous period (345 million years ago).
They crawled along the substrate feeding on annelids, molluscs, and decaying organic matter.
The trilobite body was oval, flattened, and divided into three longitudinal regions.
All body segments articulated so that the trilobite could roll into a ball to protect its soft ventral surface.

Lesson 26

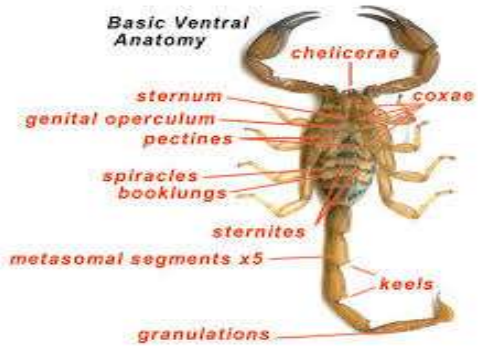
SUB PHYLUM TRILOBITOMORPH AND CHELICERATA

Topic – 131: General Features and Characteristics

- **Symmetry**: Bilateral; segmented body regions organized into cephalon (head), thorax and pygidium.
- **Body Cavity**: Presumably, they were like other arthropods and had a true coelom that was reduced and absent in adults. Haemocoel the only body cavity.
- **Body Covering**: Covered by chitinous exoskeleton, reinforced by calcium carbonate.
- **Support**: Hardened exoskeleton.
- **Digestive System**: Food tube simple. Mouth at anterioventral end.
- **Circulatory System**: Likely, they had an open system. Haemocoel of blood sinuses with a dorsal circulatory vessel (heart).
- **Locomotion**: A pair of biramous walking legs per thoracic segment.
- **Excretory System**: Not known.
- **Nervous System**: Probably with circumesophagial ring and ventral cords ganglionated at each segment. The cephalon had a pair of sensory antennae.
- **Respiratory System**: The exopodites of the biramous walking leg likely functioned as gills
- **Reproductive System**: Likely they were oviparous.

Topic – 132: Subphylum Chelicerata (General Features and Characteristics)

Chelicerates (Chelicerata) are a group of arthropods that includes harvestmen, scorpions, mites, spiders, horseshoe crabs, sea spiders, and ticks.



Evolution of Chelicerata: The Chelicerata originated as marine animals in the Middle Cambrian period; the first confirmed chelicerate fossils, belonging to *Sanctuaries*, date from **508 million years ago.**

Nutrition and Feeding

- Chelicerates were originally predators,
- The group has diversified to use all the major feeding strategies: predation, parasitism, herbivory, scavenging and eating decaying organic matter.

Topic – 133: Phylum Arthropoda: Class Merostomata

Characteristics:

Marine creatures distinguished by a large, hard exoskeleton that includes an arched, horseshoe-shaped shield in front (prosoma), a middle portion (opisthosoma), and a thin tail (telson); they are among the oldest living organisms.

Merostomata: The subclass Merostomata is one of three branches of the chelicerate line of arthropods; the other two branches include sea spiders and terrestrial spiders.

Body surface:

The body of a horseshoe crab is covered by a smooth greenish to dark brown exoskeleton.

Habitat: Horseshoe crabs inhabit saline portions of estuaries or near-shore coastal areas.

Behavior: As larvae, horseshoe crabs swim vigorously for hours, but they adopt diurnal activity patterns as juveniles and adults.

Lesson 27

CLASS ARACHNIDA

Topic – 134: Characteristics

Arachnids are classified in the Phylum Arthropoda, which also consists of crustaceans, insects, centipedes, and millipedes. This phylum is defined by the following key characteristics:

- Body segmentation - usually consisting of a head, thorax, and abdomen
- Jointed appendages
- A firm but flexible exoskeleton
- An open circulatory system - blood is free-flowing in the body, not contained in vessels
- Specialized appendages - including claws (crustaceans) or wings (insects)
- No antennae, claws, or wings, but instead have mandibles structures for biting and chewing prey
- Eight appendages
- A fused head and thorax, called a cephalothorax

Topic –135: Class Arachnida: Diet and feeding:

- Arachnids are mostly carnivorous, feeding on the pre-digested bodies of insects and other small animals.
- Only in the harvestmen and among mites, such as the house dust mite, is there ingestion of solid food particles, and thus exposure to internal parasites, although it is not unusual for spiders to eat their own silk.
- Several groups secrete venom from specialized glands to kill prey or enemies. Several mites and ticks are parasites, some of which are carriers of disease.

Digestive juices:

- Arachnids produce digestive juices in their stomachs and use their pedipalps and chelicerae to pour them over their dead prey.
- The digestive juices rapidly turn the prey into a broth of nutrients, which the arachnid sucks into a pre-buccal cavity located immediately in front of the mouth.

Stomach:

- The stomach is tubular in shape, with multiple diverticula
- The stomach and its diverticula both produce digestive enzymes and absorb nutrients from the food.

Topic – 136:Class Arachnida: Excretion

Crustaceans and arachnids possess paired excretory organs (maxillary, antennal, or coxal glands) that open at the bases of certain appendages.

Myriapods, insects, and some arachnids, such as spiders and mites, possess another type of excretory organ, Malpighian tubules, which open into the intestine.

Water loss:

Both arachnids and insects possess waxy compounds in the epicuticle, the outer layer of the exoskeleton, which greatly reduce evaporative water loss.

Waxes:

Arthropods that lack a waxy epicuticle, such as the pill bugs, and very small arthropods, such as mites, pseudo scorpions, and collembolans, live in leaf mold and soil, beneath logs, under stones, and in other areas where the danger of desiccation is reduced.

Waste products:

- Both insects and spiders eliminate their nitrogenous wastes as compounds insoluble in water (uric acid, guanine), thereby not requiring that water be excreted.
- Insects share with birds and mammals the ability to produce a urine that is saltier than the blood, which is of great value in conserving water because it permits the production of a concentrated urine.

Topic – 137: Importance of Malpighian Tubules:

- Arachnids have a unique excretory system of Malpighian tubules which work in conjunction with specialized rectal glands .
- Some arachnids are adapted to dry environment so they possess Malpighian tubules of excretion. Malpighian tubules are blind tubules that connect to the gut near the union of the midgut and the hindgut.

Structure of tubules:

- Malpighian tubules of the arachnids are not homologous to those of hexapods.
- The malpighian tubules arise from midgut in arachnid while from hindgut in hexapods.
- Coxal glands are considered to be ancestral while Malpighian tubules are derived.

Functions:

- Potassium and other solutes are secreted into the tubules which drain the fluid or urine into the intestine.
- Rectal glands reabsorb most of the potassium and water leaving behind such wastes as uric acid.
- The primary excretion of arachnids is guanine. It is insoluble in water and non-toxic.
- It can be excreted with little associated water loss.

Topic – 138: Gaseous Exchange (Book Lungs):

A book lung is a type of respiration organ used for atmospheric gas exchange that is found in many arachnids, such as scorpions and spiders.

Function of book lungs:

- Book lungs are not related to the lungs of modern land-dwelling vertebrates.
- Stacks of alternating air pockets and tissue filled with hemolymph give them an appearance similar to a "folded" book.
- The folds maximize the surface exposed to air, and thereby maximize the amount of gas exchanged with the environment.
- In most species, no motion of the plates is required to facilitate this kind of respiration.

Trachea:

Sometimes, book lungs can be absent, and gas exchange is performed by the thin walls inside the cavity instead, with their surface area increased by branching into the body as thin tubes called tracheae.

Topic – 139: Tracheal System (Structure and Function):

Spiracles: Air enters the respiratory systems of insects through spiracles. These external openings, which act as muscular valves in some insects, lead to the tubes called tracheae.

- It is responsible for delivering sufficient oxygen (O2) to all cells of the body and for removing carbon dioxide (CO2) that is produced as a waste product of cellular respiration.
- The respiratory system of insects (and many other arthropods) is separate from the circulatory system.

Development of tracheal tube:

- Each tracheal tube develops as an **invagination of the ectoderm** during embryonic development.
- In dry terrestrial environments, this temporary air supply allows an insect to conserve water by closing its spiracles during periods of high evaporative stress.
- Aquatic insects consume the stored air while under water or use it to regulate buoyancy.

Topic – 140: Circulatory System:

Closed circulatory system:

The circulatory system of arachnids like that of most arthropods is an open system in which a dorsal contractile vessel pumps blood into tissue spaces.

Open circulatory system:

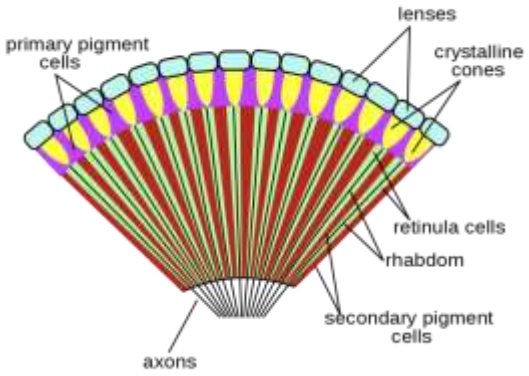
Open circulatory system requires less energy, it doesn't provide the animals with a fast delivery of oxygen and nutrients. For larger animals, like you, the open system would not provide enough oxygen or nutrients to maintain your organs. But for the little guys, like a scorpion, it works just fine.

Topic – 141: Nervous System:

- The arthropod nervous system consists of a dorsal brain and a ventral, ganglionated longitudinal nerve cord (primitively paired) from which lateral nerves extend in each segment.
- The system is similar to that of annelid worms, from which arthropods may have evolved.
- The neuromuscular organization of arthropods is quite different from that of vertebrates, in which one neuron supplies a number of muscle cells, together forming a functional motor unit. The small size of the muscles prohibits such an organization in arthropods.
- Instead, the state of contraction of an arthropod muscle is determined by which of several different types of neurons supplying one muscle cell are fired.

Topic – 142: Sensory Structure-Sensilla:

- The sense organs (sensilla) on the body surface involve some specialization of the exoskeleton barrier.
- The sensory nerve endings are lodged in cutecular hairs (setae), peglike projections, cones, pits, or slits, which may occur in large numbers on antennae, mouthparts, joints, and leg tips.
- Changes in the tension of the surrounding cuticle stimulate the nerve endings.
- **Chemoreceptive sensilla** (taste and smell) have holes in cuticle permitting the chemical substances being monitored to enter.



Topic – 143: Setae in Arachnida:

Setae

- A stiff hair, bristle, or bristle like process or part on an organism.
- Setae on the bodies of spiders are used as sensory organs.
- Setae on the bodies of many polychaete worms, such as earthworms, are used for locomotion. Microscopic setae on the feet of geckos allow adhesion to vertical surfaces.

Bristle generator: Setae on the integument of insects are unicellular, meaning that each is formed from a single epidermal cell of a type called a trichogen, literally meaning "bristle generator".

Tormogen: They are at first hollow and in most forms remain hollow after they have hardened. They grow through and project through a secondary or accessory cell of a type called a tormogen.

Functions:

In Arachnida species the role of the setae has evolved from simple **mechanoreception** to various other functions, including

- Defense
- Locomotion
- Prey capture
- Pheromone dispersal
- Sexual display
- Screening, and Camouflage

Topic – 144: Reproduction and Development:

- Arachnid reproduction is quite varied, depending upon the species.
- For example, the blue-faced peacock spider gets dancing about and sticking his legs in the air, all to impress the ladies.
- The reproductive organs for the male and the female are located in their back ends.
- Spiders make their egg sacs with silken threads shaped like a ball.
- The eggs of many crustaceans hatch into larvae which have fewer segments than the adult. The earliest larval hatching stage is a minute nullius larva, which possesses only the first three pairs of appendages.
- In most chelicerae's and insects, almost all of the segments are present at hatching, although in insects the body form may differ from that of the adult. Primitive insects, such as collembolans, have the adult form on hatching.
- Many insects, such as grasshoppers, crickets, and true bugs, hatch as nymphs, which superficially resemble the adult but lack wings.

Lesson 28

THE CRUSTACEANS

Topic- 145

- An exoskeleton that is more pronounced and generally thicker and heavier than other taxa of arthropods.
- Two or three tag Mata cephalic thorax with shield like carapace and abdomen or head thorax and abdomen.
- Biramous branching appendages. Head appendages consist of two pairs of Antennae, a pair of mandibles, two pairs of maxillae, and one pair of compound eyes.
- Gas exchange is typically across gills.
- Excretion by true nephridial structures.

Reproduction and Sexuality

- Crustaceans follow **sexual reproduction**, wherein the males and females mate to produce offspring through eggs (oviparous).
- The eggs are usually carried by the female under her abdomen till they hatch. There they undergo a series of metamorphoses.

Topic-146: General Characteristics of Class Malacostraca

Malacostraca are among one of the most **species-rich classes** in nature.

Size: The crustaceans in this class differ widely **in size**from a few millimeters to almost one meter in length

Segmented exoskeleton: The crustacean body is segmented and covered with an exoskeleton that often takes the form of a calcified chitin carapace.

Coloration: Many species are beautifully and brightly colored. The colors and patterns depending on the substrate against which the animal is seen.

Habitat: They can be found in all types of water bodies, both marine and fresh water. They also occur on the muddy and sandy bottoms of water bodies

Symbiosis: Some species pairs have symbiotic relationships, while others are commensals, that is, they rely on food supplied by another species.

Adaptive behavior: It is not surprising that these animals make use of information acquired through experience to constantly adapt their behavior.

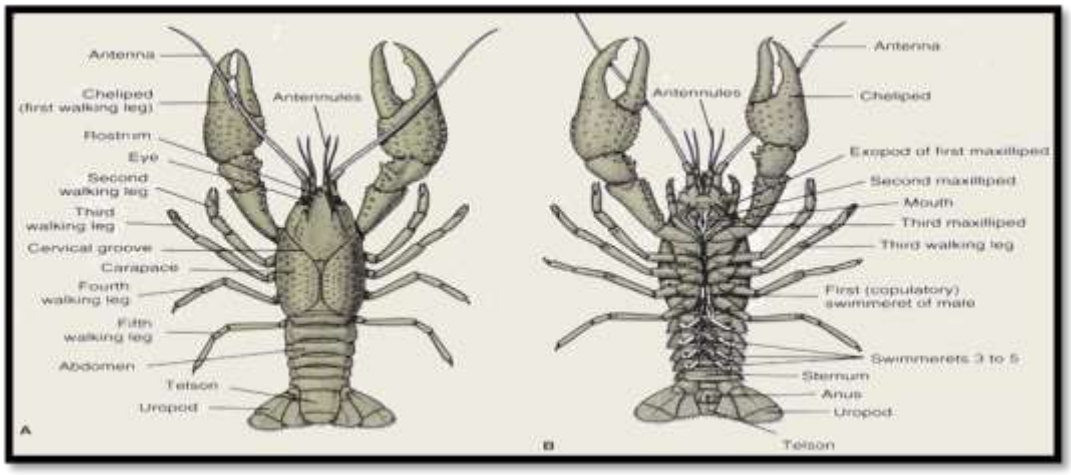
Reproduction: The sexes are normally, but not always, separate in crustaceans. Most individual barnacles have both male and female reproductive organs.

Topic-147: External Anatomy of Crustaceans

Body form: Body of crustaceans is covered with a secreted cuticle composed of chitin, protein and calcareous material.

Cray fish (general amphibian structure): Crayfish illustrate general crustacean structure and function. They are convenient to study because of their relative abundance and large size.

Paired appendages: Paired appendages are present in both body regions. **The first two** pair of cephalothoracic appendages is the first and second antennae. The **third through fifth** pair of appendages are associated with the mouth.



Topic-148: Feeding and Digestion

Feeding habitat:

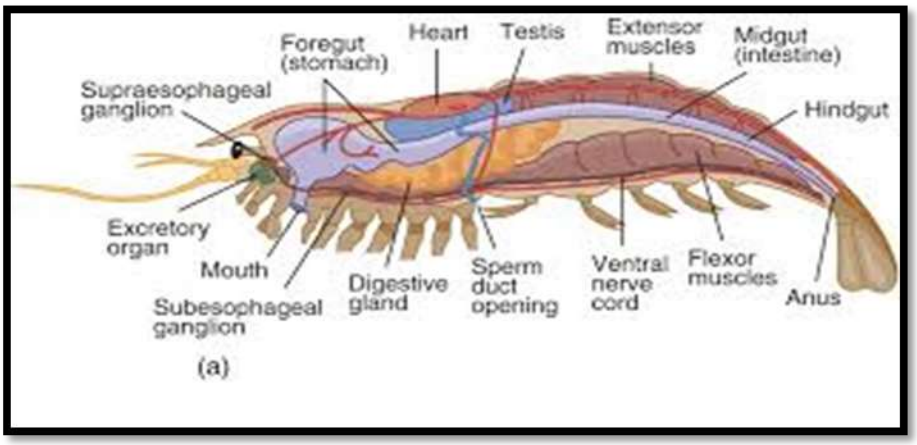
Feeding habitat and adaptation for feeding vary greatly among crustaceans. Many forms can shift from one type of feeding to another depending upon environment and food availability but mostly same set of mouth part is used by all.

Predators: Many crustaceans both large and small are **predatory** and some have interesting adaptation for killing prey.

Suspension feeders: Suspension feeders such as shrimps and water fleas use their legs, which bears a thick fringe of setae, to create water currents that sweep food particles through setae.

Digestion:

Digestive system is responsible for breakdown of food into energy and nutrients that the body can use, passing waste products along to the excretory system.



Topic- 149: Gaseous Exchange

Respiration:

- The goal of respiration is to bring oxygen into the body and expel waste gases out of the body.
- Gases exchange in smaller crustaceans occurs across thin areas of cuticle or the entire body and specialized organs for gas exchange may be absent.
- Very small aquatic crustaceans exchange gases through the process of diffusion directly across the body surface called the integument.
- Diffusion is passive movement of molecules down to their concentration gradient, driven by random molecular motion.
- Larger aquatic crustaceans primarily use gills for respiration.

Haemoglobin and Haemocyanin

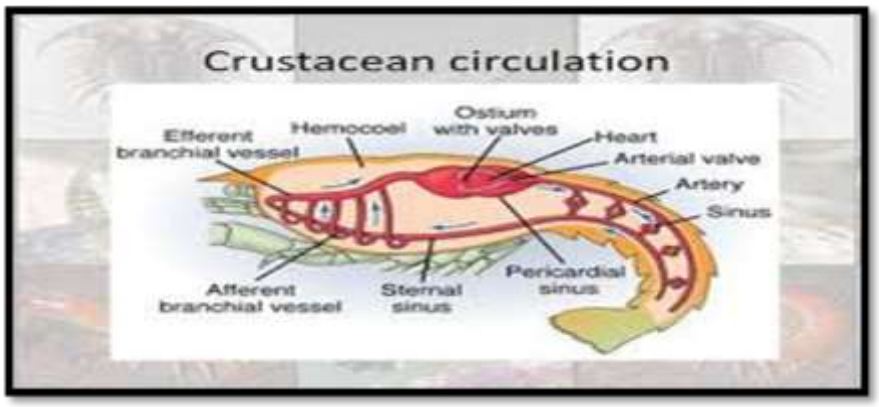
Like humans, some crustaceans have the **respiratory pigment hemoglobin** in the blood to bind to oxygen, giving the blood a red color.

Some members of the Malacostraca crustaceans have **haemocyanin** to bind to oxygen.

Topic- 150: Circulation

Open circulatory system:

- Circulation in crustaceans is similar to that of most arthropods.
- Crustaceans have an open circulatory system consisting of a heart either compact or tubular, and arteries which transport blood to different areas of the haemocoel.
- Some smaller crustaceans lack a heart.
- Cirripedes and many ostracods and copepods have no heart, the blood being kept in motion by either a blood pump or rhythmic movements of the body, gut, or appendages.



Topic-151: Nervous System

Structure:

The crustacean nervous system consists basically of a brain, or supraesophagealganglion, connected to a ventral nerve cord of ganglia, or nerve centers.

Function: The first ventral nerve center under the esophagus (sub esophageal ganglion) is usually formed by the fusion of the ganglia from the mandibular, maxillulary, and **maxillary segments**, but other ganglia may be incorporated.

Cray fish nervous system: Crustacean nervous systems show trends similar to those in annelids and arachnids. Primitively, the central nervous system is ladder like.

Topic- 152: Sensory Structures

Statocyst: The statocyst is a balance sensory receptor present in some aquatic invertebrates, including Molluscs, Cnidarians, Ctenophorans, Echinoderms, Cephalopods, and Crustaceans.

Function:

- Mechanosensory hairs are aligned in a crescent shape on the statocyst floor.

- Statocysts were identified to be either tonic- or phasic type according to their response patterns to the hair deflection performed by water jet stimulation.

Depolarizing:

Constant depolarizing current applied intracellularly evoked long lasting spike discharge in the tonic type neurons and transient discharge in the phasic type- neurons.

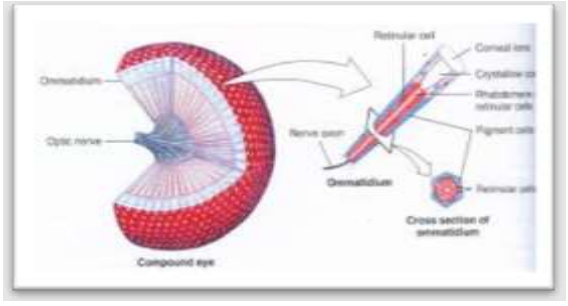
Topic-153: Compound Eyes and Ocelli

Structure:

- Sensory organs are **well developed**.
- There are two types of eyes –a median, or **nauplius,** eye and compound eyes.
- The simple eyes, called ocelli, allow larval crustaceans to orient toward or away from the light, but do not form images.
- Most crustaceans have compound eyes similar to insect eyes. In crabs and crayfishes, they are on the ends of moveable eyestalks.

Function:

- Larval crustaceans have a single, median photoreceptor consisting of a few sensilla.
- **Compound eyes** are precise instruments, different from vertebrate eyes, yet especially adopt at detecting motion, they can analyze polarized light.
- The convex corneal surface gives a wide visual field, particularly in stalked eyes where the surface may cover an arc of **200 degrees** or more.



Topic-154: Role of Endocrine System in Ecdysis Of Crustacean

Endocrine Function:

- In crustaceans, endocrine functions are closely tied to nervous functions.
- **Molting** occurs most frequently during larval stages and less often as the animal reaches adulthood.

Premolt period: Premolt period the old cuticle becomes thinner as inorganic salts are withdrawn from it and stored in the tissues.

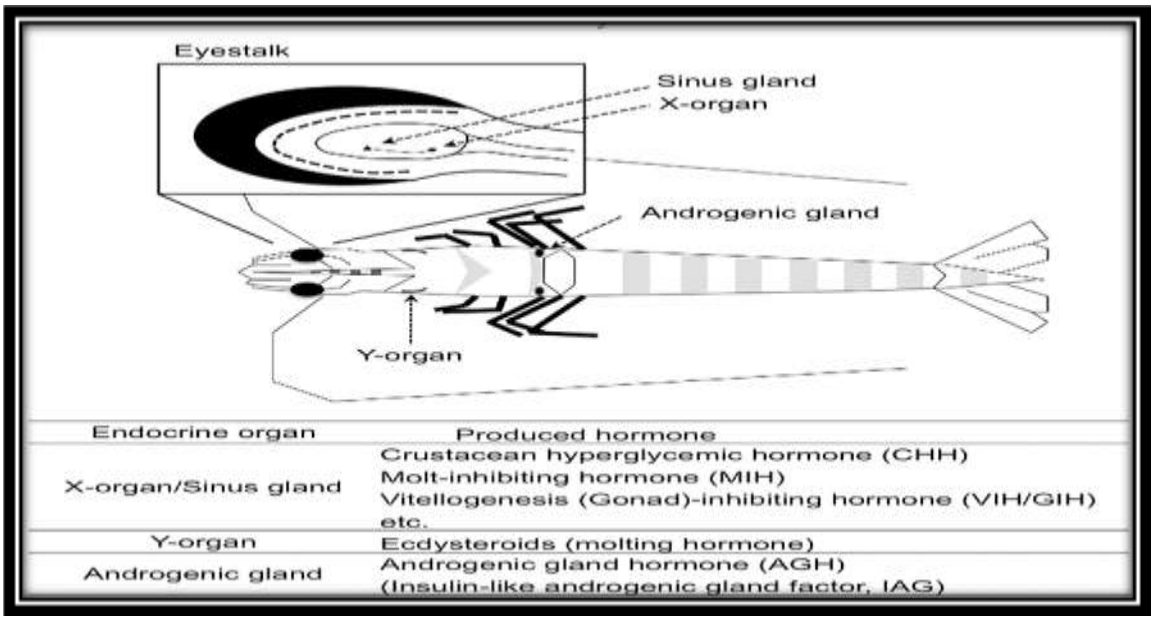
Ecdysis: The ecdysis is under the hormonal control as demonstrated in both crustaceans and insects, but the process is often initiated by a stimulus perceived by the central nervous system.

Chromatophores: Body colour of crustaceans is largely a result of pigments in special branched cells (chromatophores) in the epidermis.

Topic- 155: Androgenic Glands

In male: Androgenic glands, which are neurosecretory**,** occur in male malacostracans, and their secretion stimulates expression of male sexual characteristics.

In female: Femalepossess rudiments of theses glands during development, but the glands never mature. The androgenic gland is thought to be the exclusive source of hormone responsible for sex differentiation and sexual characteristics in crustaceans.



Endocrine organ	Produced hormone
X-organ/Sinus gland	Crustacean hyperglycemic hormone (CHH) Molt-inhibiting hormone (MIH) Vitellogenesis (Gonad)-inhibiting hormone (VIH/GIH) etc.
Y-organ	Ecdysteroids (molting hormone)
Androgenic gland	Androgenic gland hormone (AGH) (Insulin-like androgenic gland factor, IAG)

Topic- 156: Excretory Organs

Antennal glands/Maxillary glands:

Location:

Excretory and osmoregulatory organs in crustaceans are paired glands located in the head, with excretory pores opening at the base of either the antennae or the maxillae, thus antennal glands or maxillary glands, respectively.

Structure:

- The antennal glands of decapods are also called green glands.
- They resemble the coxal glands of the chelicerates.
- The waste product is mostly ammonia with some urea and uric acid. Some waste diffuse through the gills as well through the excretory glands.
- Antennal or maxillary glands are located in the head, and empty at the base of the second antenna or first maxilla.

Topic-157: Reproduction And Development

- Most crustacean are **dioecious**, (they have separate sexes), and numerous specialization for copulation occur among the different groups.
- Barnacles are monoecious but generally practice cross-fertilization.
- Most crustaceans brood their eggs in some manner-branchiopods and barnacles have special brood chambers, copepods have egg sacs attached to the sides of the abdomen, and malacostracans usually carry eggs and young attached to their appendages.
- Gonads are present in the dorsal portion of the thorax.
- The development of Crustacean\ embryos is direct.
- The young hatches as miniature adults. Many other crustaceans develop a planktonic free-swimming larva. It is called a **nauplius** and it is the primitive larvae.

Lesson 29

LESSER KNOWN CLASSES OF SUB PHYLUM CHELICERATA AND CRUSTACEANS

Topic-158: Class Branchiopod

- Members of the class Branchiopoda live in freshwater.
- Branchiopods have reduced first antennae and second maxillae.
- They possess flattened leaf like flattened appendages **(phyllopodia)** and are the chief respiratory organs (hence, the name branchiopods).
- The legs are also used in filter feeding and locomotion.

Fairy shrimp and brine shrimp:

- Fairy shrimp and brine shrimp belong to order **Anostraea**.
- Fairy shrimp live in temporary ponds formed from rains.
- **Eggs** are brooded, and when the female dies and the temporary pond becomes dry.
- The embryos become dormant in a resistant capsule.
- These are slowing swimming and defenseless crustaceans.

Topic -159: Class Copepod

- Copepods have a cylindrical body and a median ocellus. Ocellus develops in the naupilus stage and persists into the adult stage.
- The first antennae are modified for swimming.
- The abdomen is free of appendages.
- Most copepods are planktonic. A few copepods live on the substrate. A few are predatory. Others are commensals or parasites of marine invertebrates. Fishes, or marine mammals.
- They use their second maxillae or filter feeding.
- Copepods are typically very small, 1–2 mm long and their exoskeleton is typically transparent.

The copepods are the most abundant and species-rich group of crustaceans and are found worldwide including in the polar regions.

Topic-160: Class Cirripedia

- Members of the class Cirripedia are the barnacles, enclosed in a shell of calcareous plates.
- They are highly sessile as adults and attach to their substrate by a stalk or directly.
- They are exclusively marine.
- They include about one thousand species.

The subclass Cirripedia is divided into two superorders, Acrothoracica and Thoracica.

Life cycle:

- Most barnacles are monoecious.
- The planktonic nauplius of barnacles is changed into planktonic larval stage called cypris larva. It has a bivalved carapace.
- Barnacles attach to a variety of substrates.
- These are rock outcroppings, ship bottoms, whales and other animals.

Topic-161: Sub-Phylum Chelicerata

Class Pycnogonida:

- Members of the class Pycnogonida are the sea spiders.
- All are marine.
- They are most common in cold waters.
- Pycnogonida live on the ocean floor.
- They feed on cnidarian poi is and ectoprocts. Some sea spiders feed by sticking prey tissues through a proboscis.

Reproduction:

- Pycnogonids are dioecious.
- Gonads are U-shaped. branches of the gonads extend into each leg.
- Gonophores are present on one of the pairs of legs.

Topic-162: Further Phylogenetic Consideration

1. **Polyphyletic lineage:**

Many zoologists believe that the living arthropods should be divided into three separate phyla: C'helicerata, Crustacea and Uniramia.

2. Monophyletic origin:

All four subphyla are present in the fossil record from the early Paleozoic era. There are currently no known fossils of arthropods from Precambrian times.

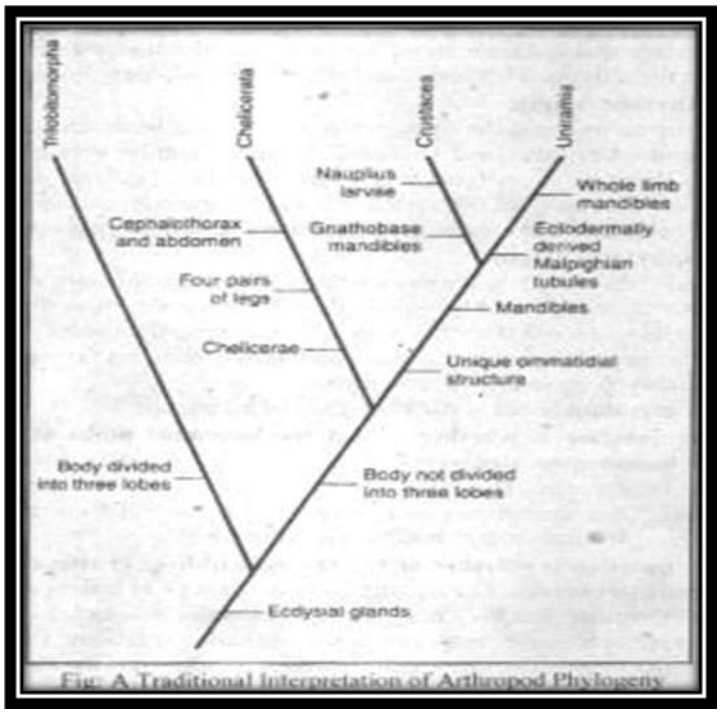


Fig. Further phylogenetic considerations

Lesson 30

THE MYRIAPODS

Topic-163: Millipedes

- Members of the class diplopoda are Millipedes.
- Ancestors of this group appeared on land during Devonian period and were among the first terrestrial animals.
- Millipedes have segmented body.
- They move in a wave like fashion with each leg moving a little later than the one in front of it.

Structure:

The structure of millipedes is as follows:

- The head of a millipede is typically rounded above and flattened below and bears a pair of large mandibles in front of a plate-like structure called a gnathochilarium.
- Many orders also possess a pair of sensory organs known as the Tömösváry organs.
- Millipedes breathe through two pairs of spiracles located ventrally on each segment near the base of the legs.

Topic-164: Class Chilopoda

- Members of the class chilopoda are called Centipedes.
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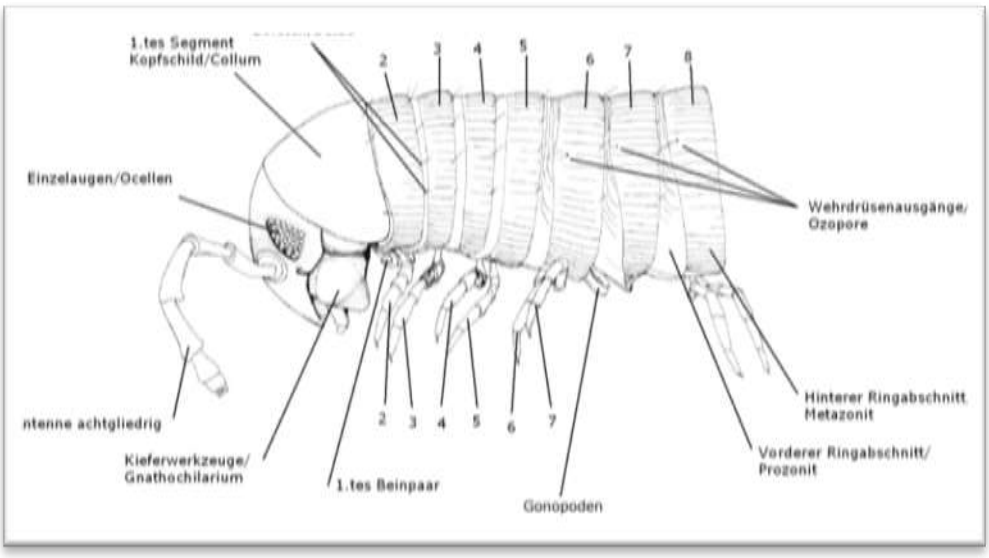


an range from a few millimetres in the smaller lithobiomorphs and geophilomorphs to about 30 cm (12 in) in the largest scolopendromorphs.

- Centipedes can be found in a wide variety of environments. They are found in an array of terrestrial habitats from tropical rainforests to deserts.
- Centipedes are among the largest terrestrial invertebrate predators, and often contribute significantly to the invertebrate predatory biomass in terrestrial ecosystems.

Structure:

- Most centipedes are generally **venomous** and could inflict a painful bite, injecting their venom through pincer-like appendage known as **forcipules.**
- **Forcipules** are a unique feature found only in centipedes and in no other arthropods.
- Despite the name, centipedes can have a varying number of legs, ranging from **30 to 354**.
- Similar to spiders and scorpions, centipedes are predominantly **carnivorous.**
- They have a rounded or flattened **head**, bearing a pair of antennae at the forward margin. They have a pair of elongated mandibles, and two pairs of maxillae.

Topic-165: Class Pouropoda And Symphyla

Structure:

- They have neither eyes nor hearts, although they do have **sensory organs** which can detect light.
- The body segments have ventral **tracheal pouches** forming apodemes similar to those in millipedes and Symphyla, although the trachea usually connected to these structures are absent in most species.
- There are long **sensory hairs** located throughout the body segments.
- Pauropods can usually be identified because of their **distinctive anal plate**, which is unique to pauropods.
- The **antennae** are branching, biramous, and segmented, which is distinctive for the group. Pauropods are usually either white or brown.

\Lesson 31

CLASS HEXAPODA: EXTERNAL STRUCTURES AND LOCOMOTION

Topic-166: Insect Flight

The **major characteristics** that make flight possible in the insecta are following:

- Abundance of striated muscles specialized for rapid, strong contractions.
- Muscles antagonism by means of a lightweight, jointed skeleton, permitting a great amount of movement to be generated from relatively short changes in muscle length.
- Small body size
- Water-impermeable outer body covering preventing dehydration.
- Efficient system for gas exchange, nutrient storage and distribution of nutrients to the musculature.
- Highly developed nervous system and sensory system for steering, navigating and sensing wind direction.

Topic- 167: Synchronous Flight

- Direct or synchronous flight is a mode of transportation that is fueled by wing muscles that insert directly into the wing base.
- The insertion point of the wing is hinged which enables the muscles downward movements to lift the wing portion upward and upward movements pull the wing portion downward.
- One drawback to direct flight is that these insects cannot hover in mid-air unless they use wind currents. This does not mean the primitive mechanism is neither obsolete nor hindered.

Topic-168: Asynchronous Flight

Indirect flight muscles attach to the thorax and deform it for flight. This is possible because the wings are a part of the thoracic exoskeleton, therefore when the flight muscles deform the thorax, the wings move.

Longitudinal muscles deform the thorax from front to back causing the thorax to move upward and wings to move downward.

(a**) Upward thrust**: Dorsoventral muscles pull the dorsal exoskeleton (tergum) downward. It produces the upward wing thrust.

b**) Downward thrust**: Then. the longitudinal muscles contract. It pulls the exoskeleton upward. Therefore, the exoskeleton forms an arch. It produces downward thrust of wing.

Topic-169: Other Forms of Locomotion

Running cockroach: Reaches speeds of about 5 km/hour.

Jumping Insects: A grasshopper can high-jump vertically upwards 45 cm (10 times its body length) and long-jump 90 cm horizontally (20 times its body length). Grasshoppers are jumping insects. They have long metathoracic legs. These legs have larger muscles. These muscles produce large propulsive forces.

Walking insects: When walking most insects use a triangle of legs involving the first and last leg of one side together with the middle leg of opposite side.

Lesson 32

GASEOUS EXCHANGE, NUTRITION AND CIRCULATION IN INSECTS

Topic- 170: Gaseous Exchange

- Terrestrial animals require different respiratory systems that permit rapid oxygen and carbon dioxide but at the same restrict water loss.
- In insects, it is the function of **tracheal system**, an extensive connection of thin walled tubes that branch into every part of the body.
- The tracheal system of insects involved independently of that of other arthropodan such as spiders.
- The tracheal trunk opens to the outside by **spiracles,** usually two pairs on the thorax and seven or eight pairs on the abdomen.

Topic-171: Nutrition and Digestive System and Circulation in Insects

Nutrition System and Digestive system:

- The diversity of insect feeding habits parallels the diversity of insects themselves.
- The **maxillae** often have entire surfaces and bear a sensory pulp. The **labium** is a lower sensory lip. All of these are in food handling.
- An insect uses its digestive system to extract nutrients and other substances from the food it consumes.
- Most of this food is ingested in the form of macromolecules and other complex substances which must be broken down by **catabolic reactions** before being used by cells of the body for energy, growth, or reproduction.

Circulatory system:

The main function of insect blood, **hemolymph**, is that of transport and it bathes the insect's body organs.

Topic-172: Ventilating Mechanism in Insects

- Insects do not breathe through their mouths as we do.
- The do not have lungs and their blood, which is a watery, yellowish liquid, does not carry oxygen and carbon dioxide around their bodies.
- Insects have a system of tubes, called **tracheae**, instead of lungs.

- These tracheae penetrate right through the insect's body.
- Air enters the tracheae by pores called **spiracles.**
- These spiracles are found on each side of the insect's abdomen. Each segment of the abdomen has a pair of spiracles.

Lesson 33

THERMOREGULATION IN INSECTS

Topic-173: Shivering Thermogenesis

- **Insect thermoregulation** is the process whereby insects maintain body temperatures within certain boundaries.
- Insects have traditionally been considered as poikilotherms (animals in which body temperature is variable and dependent on ambient temperature) as opposed to being homotherms (animals which maintain a stable internal body temperature regardless of external influences).

Topic-174: ECTOTHERM AND ENDOTHERM

- An **ectotherm** is an organism in which internal physiological sources of heat are of relatively small or quite negligible importance in controlling body temperature.
- Some of these animals live in environments where temperatures are practically constant, as is typical of regions of the abyssal ocean and hence can be regarded as homeothermic ectotherms.
- In contrast to ectotherms, endotherms rely largely, even predominantly, on heat from internal metabolic processes, and mesotherms use an intermediate strategy.
- Normally their range of ambient environmental temperatures is relatively constant, and there are few in number that attempt to maintain a higher internal temperature due to the high associated costs.
- Many flying insects, such as honey bees and bumble bees, also raise their internal temperatures endothermally prior to flight, by vibrating their flight muscles without violent movement of the wings.

Topic-175: Behavioral Adaptations to Regulate Temperature

Many animals regulate their body temperature through behavior, such as seeking sun or shade or huddling together for warmth.

Countercurrent heat exchanger

- is an arrangement of blood vessels in which heat flows from warmer to cooler blood, usually reducing heat loss?
- Some animals use body insulation and evaporative mechanisms, such as sweating and panting, in body temperature regulation.

NonShivering thermogenesis: Provides another mechanism for heat production. This mechanism depends on specialized fat tissue known as **brown fat**, or brown adipose tissue.

Vasoconstriction and vasodilation

- In endotherms, warm blood from the body's core typically loses heat to the environment as it passes near the skin. Shrinking the diameter of blood vessels that supply the skin, a process known as **vasoconstriction**, reduces blood flow and helps retain heat.
- On the other hand, when an endotherm needs to get rid of heat, after running hard to escape a predatorthese blood vessels get wider, or dilate. This process is called **vasodilation**. Vasodilation increases blood flow to the skin and helps the animal lose some of its extra heat to the environment.

Lesson 34

NERVOUS AND SENSORY FUNCTIONS IN INSECTS

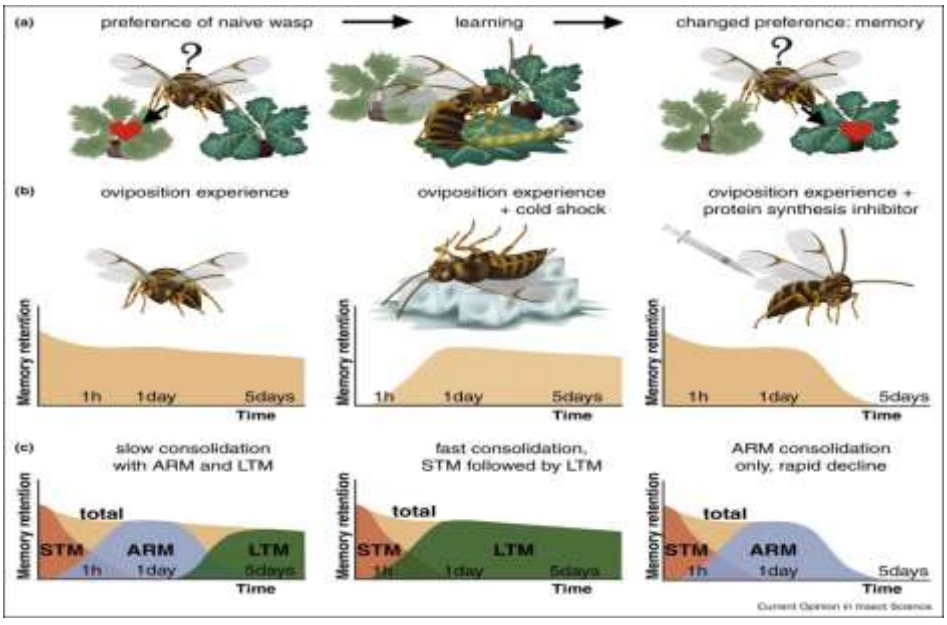
Topic 176: Nervous System of Insects

- The central nervous system consists of a series of ganglia that supply nerves to successive segments of the body.
- The three main ganglia in the head (protocerebrum, deutocerebrum, and tritocerebrum) commonly are fused to form the brain.
- The rest of the ganglionic chain lies below the alimentary canal against the ventral body surface.
- In most insects the number of separate ganglia has been reduced by fusion. The last abdominal ganglion always serves several segments.
- In homopterans and heteropterans all the abdominal ganglia usually fuse with mesothoracic and metathoracic ganglia

Topic 177: Learning and Memory of Insects

Habitat: The one habitat the hexapods do not inhabit are subtidal marine areas

Diet: Many hexapods are herbivorous, but some are also carnivores, parasites or parasitoids.



Topic 178: Sense Organs

Sense cells: All insects have sense organs that allow them to see, smell taste bear and touch their environment.

Sensory receptors are derived from embryonic ectoderm and are integral parts of the insect's exoskeleton. Sensory organs (sensilla, singular: sensillum) protrude from the cuticle, or sometimes lie within or beneath it.

Occurrence of Sense Organs:

Although these small sense organs occur all over the body, they are particularly abundant in antennae, palps, and cerci.

Sensilla: The sensilla are usually small hairs modified for **perception** of specific stimuli each sensillum consists of one sense cell and one nerve fiber.

All sense organs (receptors) act as transducers:Converting light energy, chemical energy, or mechanical energy from the environment into electrical energy of nerve impulses in sensory neurons.

Mechanoreceptors of Insects: Detect movements, vibrations, or other mechanical disturbances. Insect mechanoreceptors can be found almost anywhere on the surface of an insect's body

Topic 179: Hearing (Johnston's Organs)

All insects can respond to pressure waves with generally distributed setae; others have specialized receptors. These waves are in the range of sounds that the wings of females produce.

Interpretation of Sounds: Insect sense and interpret sounds in order to communicate with other insects and to navigate their environments.

Johnston's Organ: A sense organ in the second antennal segment of insects that responds:

- To movements of the antennal flagellum
- Serves as a flight-speed indicator

In fruit flies, the organ is used to sense the wing-beat frequencies of mates, and in hawk moths, it is thought to assist with stable flight.

In honeybees, Johnston's organ assists in the location of food sources. Johnston's organs are in the base of the antennae of most insects, including mosquitoes and midges (order Diptera).

Setae: Long setae that vibrate when certain frequencies of sound strike them cover the antennae of these insects. Vibrating setae move the antenna in its socket, stimulating sensory cells.

Topic 180: Tympanic Organs

Tympanal Membrane: The tympanal membrane (eardrum) is a **thinned** region of exoskeleton, typically supported by a **chitinous** and stretched across an **air-filled cavity.**

Insect's Tympanal Organ: Many hearing insects have a pair of tympanal organs that vibrate when they catch sound waves in the air. As the name hints, these organs catch the sound and vibrate in much the way that tympani.

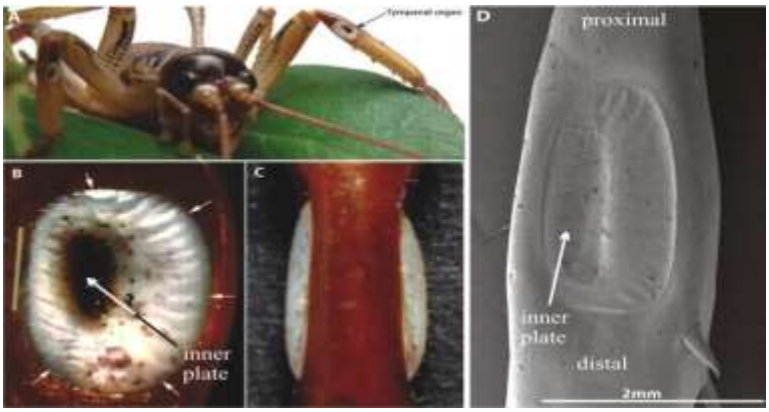


Fig. Insect's Tympanal Organ

Topic 181: Chemoreception

Chemical senses: The chemical senses may be **divided** into taste, for detection of aqueous chemicals, and smell, for air- borne ones but the distinction is relative. Alternative terms are contact (taste, gustatory) and distant (smell, olfactory) chemoreception.

Insect chemoreception: is mediated by a large and diverse super family of seven trans membrane domain receptors. These receptors were first identified in Drosophila, but have since been found in other insects, including mosquitoes and moths.

Expression and functional analysis of these receptors have been used to identify receptor ligands and to map receptors to functional classes of neurons. Many receptors detect general odorants or tastants, whereas some detect pheromones.

Chemosensory trap chemical molecules, which are transferred to a site for recognition, where they specifically depolarize a membrane and stimulate a nerve impulse.

Topic 182: Structure and Function of Compound Eyes

Compound eye: The most sophisticated insect visual organ is the compound eye.

Ommatidia: The compound eye is based on repetition of many individual units called ommatidia. Each ommatidium resembles a simple stemma: it has a cuticular lens overlying a crystalline cone, which focuses light onto eight (or maybe 6–10) elongate retinula cells

Optical superposition eyes: The light sensitivity of apposition eyes is limited severely by the small diameter of facet lenses.

Blurring Problem: Because the light arriving at a **rhabdom** has passed through many facet lenses, blurring is a problem in optical superposition eyes and resolution generally is not as good as in apposition eyes.

In comparison with a vertebrate eye, the resolving power of insect compound eyes is rather unimpressive.

Topic183: Structure and Function of Ocelli in Insects

Ocelli are concerned in some way with flight, and insects which are good at flying tend to have well developed ocelli.

- Ocelli consist of 500 to1,000 receptor cells beneath a single cuticular lens.
- Ocelli are sensitive to changes in light intensity.
- Important in the regulation of daily rhythms.
- Ocelli are simple photoreceptors.
- They consist of a single lens and several sensory cells.

Individual groups of retinular cells that contribute to one rhabdom or the complete retina are surrounded by pigment cells or by a reflective layer.

Topic 184: Excretion

Excretion is the process whereby an organism eliminates metabolic wastes and unwanted chemicals from its system.

Metabolism is the sum total of all the chemical reactions occurring in the cells and body.

TheMalpighiantubulesof insects:

- The main excretory organ of the insect is the Malpighian tubule.
- Malpighian tubules are tubular outgrowths of the gut.

- They typically develop as pouches emerging from the junction between the midgut and the hindgut,
- The primary urine, together with soluble products ofdigestionand insoluble indigestible matter from the midgut, then passes to the rectum.
- Water is then reabsorbed together with the soluble products of digestion and other useful substances, including the bulk of the ions that entered the primary urine
- The activity of the excretory system in insects is under hormonal control.

Topic 185: Chemical Regulation

Neurosecretory cell a type of neuron, or nerve cell, whose function is to translate neural signals into chemical stimuli. Insects secrete hormones from neurosecretory cells and also from endocrine glands.

There are two main classes of hormones in Insects:

1) True Hormones produced by epithelial glands and belonging to the ecdysteroids or juvenile hormones.
2) The Neuropeptide hormones produced by neurosecretory cells.

Neurohormones: One of the brain hormones is thoracotropic hormone.This is released from nerve endings located in a neurohemal organ called the corpus cardiacum. The thoractropic hormone is transferred in the blood to the thoracic glands in the body region called the thorax.

Topic 186: Control of Ecdysis in Neuroendocrine System

Ecdysis: The one class of hormone in insects is involved in Ecdysis.

It describes the process by which arthropods and insects shed their outer cuticle (exoskeleton).

The Ecdysis Process: Ecdysis in arthropods occurs after a series of steps that are mediated by a hormone called **ecdysone** that is secreted from glands behind the brain. This hormone has three functions:

- Causes the cuticle to separate from the skin underneath,
- Causes the secretion of new cuticle material in the skin
- And it starts the breakdown of the old cuticle.

Topic-187: Role of Juvenile Hormone in Metamorphosis

The **juvenile hormone,** keeps tissue in a juvenile or larval form. This hormone is released by the corpora allata, another pair of non-neural endocrine glands, **located** behind the corpora cardiaca.

In immature insects, juvenile hormone is secreted by the corpora allata prior to each molt.This hormone inhibits the genes that promote development of adult characteristics (e.g. wings, reproductive organs,and external genitalia), causing the insect to remain "immature" (nymph or larva).

At the approach of sexual maturity in the adult stage, brain neurosecretory cells release a brain hormone that "reactivates" the corpora allata, stimulating renewed production of juvenile hormone.

Lesson 35

TYPES OF PHEROMONES

Topic – 188: Pheromones

The subphylum Hexapoda includes animals whose bodies are divided into three tagmata, have five pairs of head appendages, and three pairs of legs on the thorax.

The subphylum is divided into two classes

Entognatha Members of this class have mouthparts that are hidden inside the head capsule,

Insecta They are all characterized by mouthparts that project from the head capsule.

FUNCTIONS OF INSECT PHEROMONES

- **Sex pheromones:**Excite or attract members of the opposite sex; accelerate or retard sexual maturation.
- **Caste-regulating pheromones:**Used by social insects to control the development of individuals in a colony.
- **Aggregation pheromones:**Produced to attract individuals to feeding or mating sites.
- **Alarm pheromones:**Released to warn other individuals of danger; may cause orientation toward the pheromone source and elicit a subsequent attack or flight from the source.
- **Trailing pheromones:**Laid down by foraging insects to help other members of a colony identify the location and quantity of food found by one member of the colony.

Topic-189: Sex Pheromones

Types of alarms in honey bees and their function:

1. Alarm pheromone

Two main alarm pheromones have been identified in honeybee workers. One is released by the Koschevnikov gland, near the sting shaft, and consists of more than 40 chemical compounds,

2. Brood recognition pheromone

Another pheromone is responsible for preventing worker bees from bearing offspring in a colony that still has developing young. Both larvae and pupae emit a "brood recognition" pheromone.

3. Drone pheromone

Drones produce a pheromone that attracts other flying drones to promote drone aggregations at sites suitable for mating with virgin queens.

4. DuFour's gland pheromone

Dufour's secretions allow worker bees to distinguish between eggs laid by the queen, which are attractive, and those laid by workers.

Topic 190: Caste Regulating Pheromone

Royal jelly:

Royal jelly is a honey bee secretion that is used in the **nutrition of larvae**, as well as adult queens. It is secreted from the glands in the hypopharynx of **nurse bees,** and fed to all larvae in the colony, regardless of sex or caste.

Topic 191:Aggregation Pheromones

What are aggregation pheromones?

Aggregation pheromones are **chemical signals** from one organism that stimulate a response in another organism of the same species. Generally, this behavior is either attraction to the opposite sex or part of **courtship interaction** and are referred as sex **attractants pheromones**.

Topic 192: Alarm Pheromones

Alarm pheromones are defined as chemical substances, produced and released by an organism, that warn or alertanother of the same species of impending danger.

Functions of alarm pheromone:

Alarm signals

visual or auditory

How alarm pheromone acts?

Defensive response;

Facilitate localization

Volatile pheromones

Three responses to sting alarm pheromone: sting alarm pheromone usually shows three responses;

1. Recruitment
2. Locomotion
3. localization.

Topic 193: Trailing Pheromones

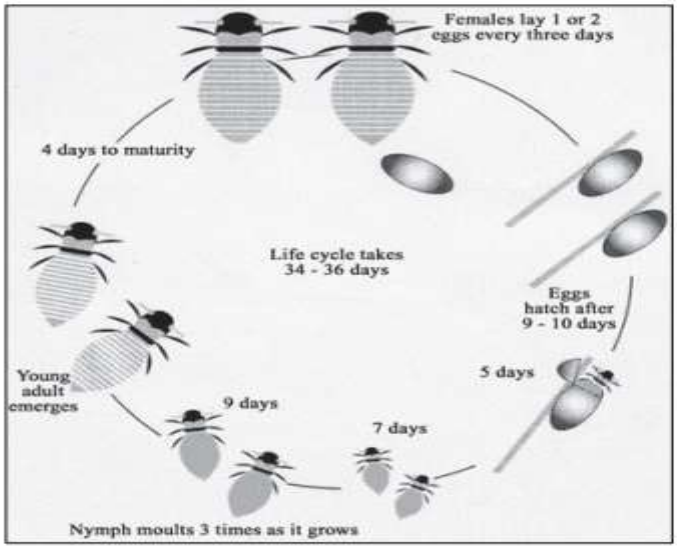
Trail pheromones are semi chemicals secreted from the body of an individual to impact the behavior of another individual receiving it. Bees mark the nest entrance with products from the Nasonov gland that induce workers to enter.

Lesson 36

REPRODUCTION AND DEVELOPMENT IN INSECTS

Topic 194: Reproductive Potential in Insects

The culmination of insect reproduction is typically the oviposition of mature, fertilized eggs in an environment that will support their development. Accessory glands produce secretions used to protect eggs. Females often have a structure called an **ovipositor**.



Topic 195: Sexual Maturity of Insect by Internal Factors

Ecdysone hormone:

Composition of ecdysone hormone:

Ecdysone is a steroid compound derived from cholesterol.

Two forms are found in insects

1. α-ecdysone
2. β-ecdysone

Role of juvenile hormone:

The hormone controls the appearance of juvenile characters in larval stages, presumably by suppressing the activity of genes concerned with the expression of adult characters; reduction in the amount of or **absence of the hormone** at later molts results in the appearance of mature characters.

Factor affecting molting process:

- **Diapause**

Topic 196: Sexual Maturity of Insects By External Factors

- Complex interactions between internal and external environmental factors regulate sexual maturity.
- Internal regulation includes interactions between endocrine glands and reproductive organs.
- External regulating factors may include the quantity and quality of food.

Topic 197: Role of Spermatophores In Insect Fertilization

Formation of spermatophore:

How spermatophore transfers to female during copulation:

- The male accessory glands of insects secrete a viscous substance that surrounds the spermatozoids and solidifies on them to form the spermatophore.
- This spermatophore is then transferred to the female during copulation, thereby ensuring that the spermatozoids are transported. The spermathecae are blind-ended tubes coming off of the common oviduct that receive and store the sperm until the eggs are fertilized.
- The development of a more spacious spermatheca and an expanded vagina can be adapted to receive nutrients secreted and also allow a prolonged stock sperm.
- The females of many species digest, eat, or remove the spermatophore after it has been transferred.

Topic 198: Mating Behavior in Insects

Mating behavior: Mating behavior is typically viewed as comprising all events from pair formation through courtship to the final breakup of the mating pair..

Locating and recognizing mates:

- Chemical attractants
- Humming sound
- Courtship ritual

Mating:Internal fertilization by insertion of the male intromittent organ into the female genital tract for deposition of sperm is the usual method of **copulation**.

Topic 199: Insect Development

Ametabolous development: The developmental patterns of insects reflect degrees of divergence between immatures and adults and are classified into three (or sometimes four) categories.

Paurometabolous metamorphosis: Paurometabolous (Gr. pauros, small) metamorphosis involves a species-specific number of molts between egg and adult stages, during which immatures gradually take on the adult form. metamorphosis.

Hemimetabolous metamorphosis: Some zoologists use an additional classification for insects that have a series of gradual changes in their development, but whose immature form is much different from the adult form usually due to the presence of gills.

Holometabolous development: In holometabolous (Gr. holo, whole) metamorphosis, immatures are called larvae because they are very different from the adult in body form, behavior, and habitat.

Topic 200: Ametabolous Metamorphosis

Ametabolous type of development is called when the insects undergo little or no metamorphosis. Here the young emerge from the eggs resemble the adults in all respects except in size and sexual structures.

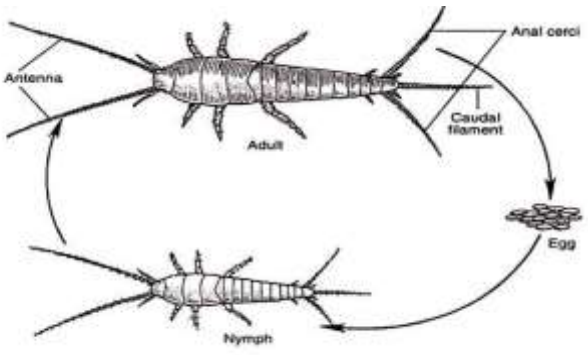
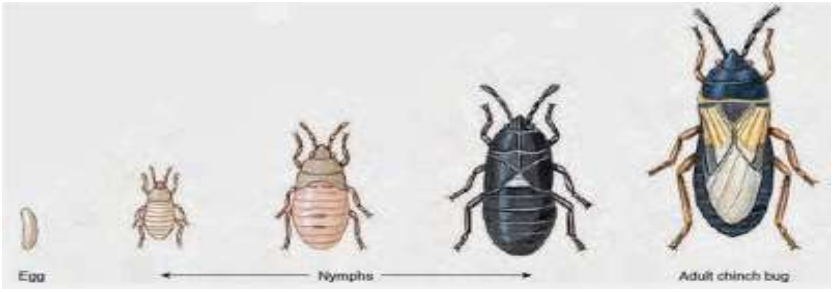


Fig. 18.134: Ametabolous development in *Lepisma*.

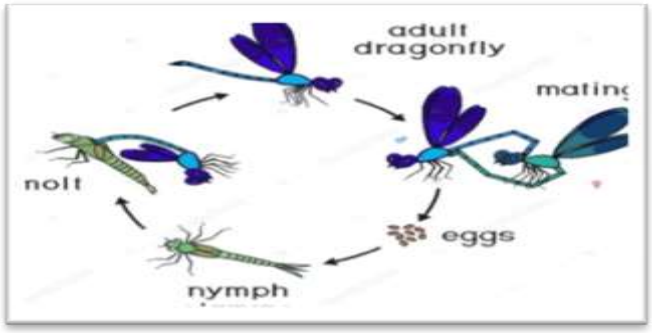
Topic 201: Paurometabolous Metamorphosis

Paurometabolous metamorphosis involves a species- specific number of molts between **egg** and adult stages, during which immatures gradually on the adult form..

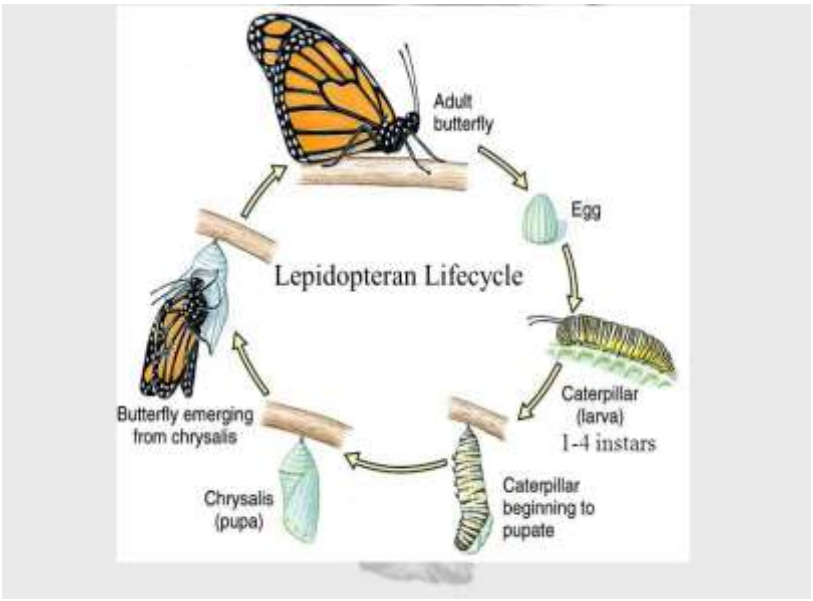


Topic 202: Hemimetabolous Metamorphosis

Some insects undergo a hemimetabolous (Gr. hemi, half, + metabole, change) , or gradual (incomplete) , metamorphosis.



Topic 203: Holometabolous Metamorphosis



Lesson 37

INSECT BEHAVIOR AND SOCIAL INSECTS

Topic 204: Innate Behavior Of Insects

Behavior:

Behavior is defined as the way that organisms respond to their environment and to internal signals.it has two types: innate behavior and learned behavior**.**

Innate behavior:

It occurs naturally in all animals of a given species. An innate behavior is also called an **instinct**.

Topic 205: Social Insects

Social behavior has evolved in many insects and is particularly evident in those insects that live in the colonies.

Complex organizations of honey bees:

Honey bees have one of the most complex organizations in the insect world.

- A single sexually mature female, or **queen;**
- A few hundred **drones**, which are sexually mature males;
- The rest are **workers**, which are sexually inactive females

Caste are determine partly by fertilization and partly by what is feed to larvae

Pheromones in the "queen substance," which is produced by a queen's mandibular gland, prevent female workers from maturing sexually workers produce royal jelly only when the level of "queen substance" pheromone in colony drops, most typically due to overcrowding

Topic 206: The Caste System Of The Honey Bee

Sex differentiation in bees:

Queen and worker develop from fertilized egg while drone develops from unfertilized egg. Further differentiation of queen and worker depends on the quality and quantity of food that is fed to the queen or worker larvae.

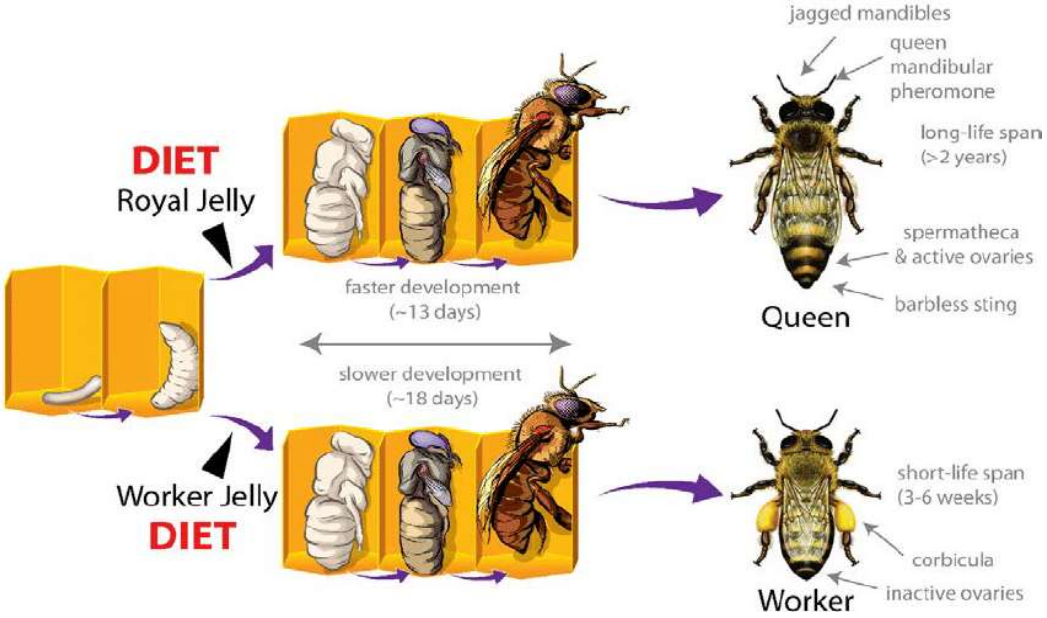
Fig. Sex differentiation in bees

Topic 207: Control Of Honey

BEE CASTE SYSTEM

Role of pheromones

- Control the honey bee caste system.
- This pheromone inhabits the workers from rearing other queens.
- As the pheromone decreases, workers begin to feed the food for queens **(royal jelly)** to Several female larvae developing in the hive.



Lesson 38

ECONOMIC IMPORTANCE OF INSECTS

Topic 208: Role of Insects in Pollination

They carry or move the pollen grains from the anther of one flower to the receptive part of the carpel or pistil (stigma) of another.

Pollinator decline:

- Loss of pollinators, also known as Pollinator decline has been noticed in recent years.
- These caused a disturbance in early plant regeneration processes.
- Pollination by animals' aids in the genetic variability and diversity within plants.
- Loss of pollinators is especially devastating because there are so many plant species rely on them.

Crops production and commercial purposes:

- Pollination of food crops has become an environmental issue, due to two trends.
- The other trend is the decline of pollinator populations, due to pesticide misuse and overuse, new diseases and parasites of bees, clear cut logging, decline of beekeeping, suburban development, removal of hedges and other habitat from farms, and public concern about bees.

Topic 209: Biological Control by Insects

Insects are agents of biological control:

- The classic example of insect regulating another is vedalia lady bird beetles control of cottony cushion scale.
- A second biological control, the parasitic fly Cryptochetum iceryae has also been introduced to California as an additional control vector.

Advantages of biological control:

- Biological Pest control is a very specific strategy, whatever the predator is introduced will only control the population of the pest they are meant to target, making it a green alternative to the chemical or the mechanical control methods
- The great benefit of this method is its selectivity, there is a restricted danger of damage to non-target plant species.
- Another benefit of the biological control method is the environmental safety of BCAs

Topic 210: Importance of Soil Dwelling Insects

Weed Killers: So many insects feed upon unwanted weeds just the same manner they do with the cultivated crops.

Scavengers: Insects which feed on dead and decaying matter of plants and animals are called as scavengers.

Aeration and turnover of the soil: As decomposers, insects help create top soil, the nutrient-rich layer of soil that helps plants grow.

Promotion of decay process: In many ecosystems millipedes (Diplopoda) have special importance as decomposers.

Role in food chain: Food for other animals: Many insects live on grass and plants for food. food insects but in-turn they become prey to many birds, amphibians, fishes, lizards, and other animals.

Topic 211: Insects as Parasites and Vector Of Diseases

Effects caused by insect parasites:

- Insect parasites can significantly
- Reduce growth and Survival,
- Reproduction and movement of their hosts.

Vector: Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are bloodsucking insects.

Some commonly occurring diseases:

Mosquitoes are the best known disease vector. Others include ticks, flies, sandflies, fleas, triatomine bugs and some freshwater aquatic snails.

Vector-borne diseases:

Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by mosquitoes, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, snails and lice.

Topic 212: Role Of Insects as a Pest

- Insects are the pest of domestic animals and the plants.
- These insects reduce the health of domestic animals and the quality of animal products. Harmful insects include those which eat and destroy plants and fruits such as grasshoppers, chinch bug,
- Practically every cultivated crop has several insects' pests. These pests destroy crops in the field through their biting, chewing, boring, sucking, and defoliation activities.
- The biting and chewing insects possess strong mandible and maxillae which enable them to bite, sucking insects' pests possess proboscis which enable them to pierce through plants and suck liquid materials from plant tissues
- First is direct injury done to the plant by the feeding insect, which eats leaves or burrows in stems, fruit.
- The second type is indirect damage in which the insect itself does little or no harm but transmits a bacterial, viral, or fungal infection into a crop.

Topic 213 :Furthur Phylogenetic Considerations

Phylum Arthropoda itself is monophyletic has also been controversial.

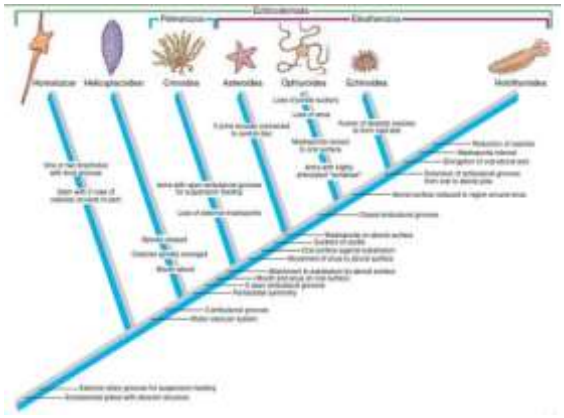
:

Lesson 39

ECHINODERMS: RELATONSHIP TO THE OTHER ANIMALS

Topic- 214: Relatonship to the other animals

- Fossils record indicates 12 to 18 classes of echinoderms have become extinct.
- Share a common ancestor with the hemichordates and chordates.
- Deuterostome characteristics.



Relatonship to the other animals

Topic 215: General characteristics

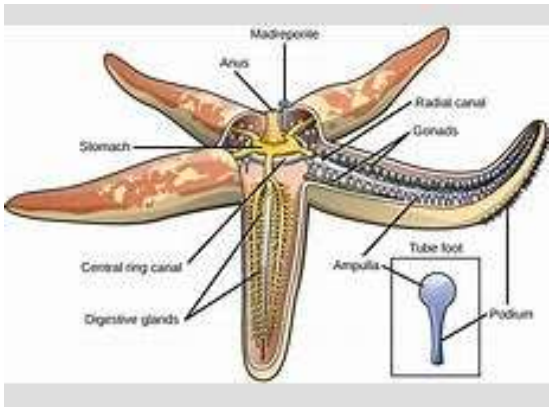
- Marine, radially symmetrical.and filter feeders
- Calcareous endoskeleton
- Hydraulic system to operate their limbs.
- Water vascular system
- Nervous system consisting of a nerve net, nerve ring, and radial nerves.
- Tentacle-like structures called tube feet.

Topic 216: Echinoderm Skeleton

- Calcium carbonates plates called ossicles derived from a mesoderm.
- Modified into the fixed or articulated spine

Topic 217: Pentaradial form of Echinoderms

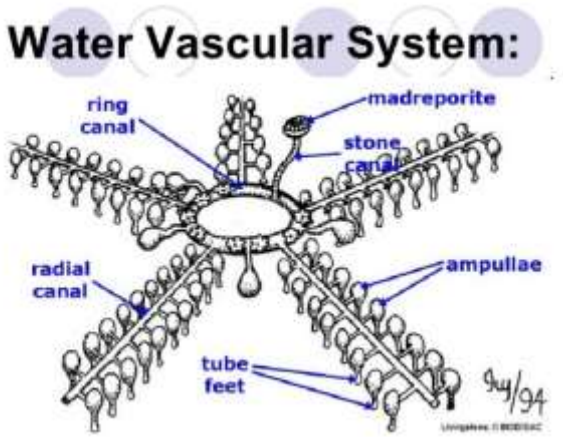
- Evolution of the skeleton may be responsible for the pentaradial body form.
- Basic five point radial symmetry and lack cephalization.
- Radial symmetry is adaptive for sedentary or slowly moving animals
- Series of calcium carbonates plates called ossicles



Pentaradial form of Echinoderms

Topic 218: Water Vascular System

- Water filled canals and their extensions are called tube feet.
- Fluid filled canals derived from one of three pairs of coelomic compartments
- Hydraulic system for locomotion, food and waste transportation, and respiration.
- Podia, or tube feet.



Water Vascular System

Topic 219: Structure and Function of the Tube Feet

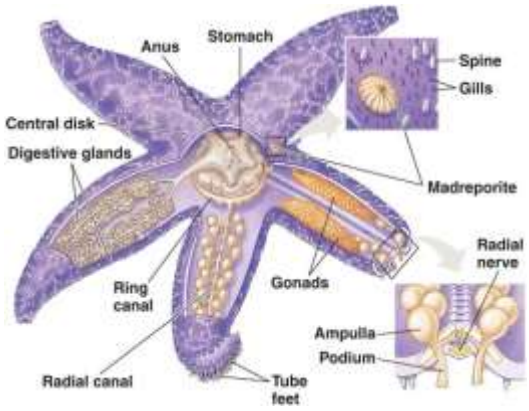
- Tube feet are **extensions of the canal system**.
- **Ampulla:** A rounded sac like structure situated above the ambulacral ossicles.
- **Podium:** It is the middle tubular portion.
- **Sucker:** The lower end of the podium is flattened forming a cup like structure.

Topic 220: Functions of Water Vascular System

- Locomotion.
- Feeding mechanism
- Diffusion of the respiratory gasses and nitrogenous wastes.
- Circulation of nutrients
- "Ambulacralsystem" and "aquiferous system"

Topic 221: Hemal System

- Peculiar system of tissues and organs consists of strands of tissues.
- Spongy axial organ.
- Axial sinus, and connects to two hemal rings, one oral and the other aboral.
- Transports nutrients from the coelomic fluid to the gonads.
- Likened to a vestigial circulatory system.
- Circulation in cushion star.



Hemal System

Lesson 40

CLASS ASTEROIDEA

Topic 222: Class Asteroidea

- 1,900 species and second largest group in the Echinodermata.
- They often live on hard substrates in marine environments.
- Thin folds of the body wall, called dermal branchiae.
- Pincher-like structures called pedicellariae.
- Ambulacral groove and paired rows of tube feet.
- Suction disks sensory receptors are distributed over the surface of the body and tube feet.
- Sea stars are dioecious, and external fertilization is the rule.
- Bipinnaria larva

Asteroidea

Topic 223: Dermal Branchiae

- External gill-like structures are scattered across their body surface.
- Gas exchange.
- Papulae.
- Cilia beat and ventilate the respiratory surface.

- Outer ectodermal epithelium, gland cells and a small basiepithelial nerve plexus.
- Papulae function as a simple site of respiratory exchange.

Dermal Branchiae

Topic 224: Pedicellariae

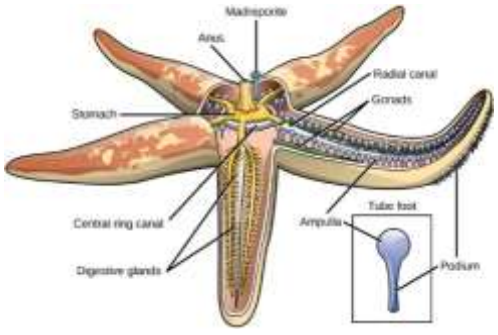
- Small peculiar appendages
- On aboral surface and has a head and a stalk.
- Protective functions.
- Straight pedicellariae and crossed pedicellariae.

Topic 225: Ambulacral Groove

- Series of ossicles in their arm form an ambulacral groove.
- Two rows of calcareous ambulacral spines.
- Ambulacral areas exists in five or multiples of five.
- Ambulacrum.
- Open ambulacral grooves.
- Sea urchins lack ambulacral grooves.

Topic 226: Locomotion in Star Fish

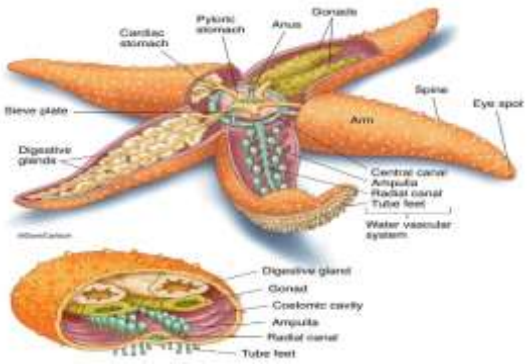
- Water vascular system.
- Muscular pressure to coelomic fluid to stiffen them for walking.
- Valves prevent backflow of fluid
- Coordinated action of all or many of the tube feet is sufficient to draw the animal up a vertical surface or over rocks.



Locomotion in Star Fish

Topic 227: Feeding and Digestion in Star Fish

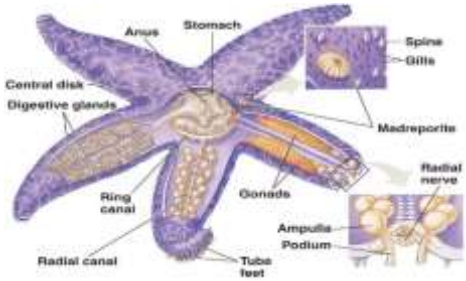
- Carnivorous and predator.
- Cardiac stomach and the pyloric stomach.
- Pyloric cecae are secretory and absorptive structures.
- Extracellular digestion.



Digestive system in star fish

Topic 228: Gaseous Exchange in Star Fish

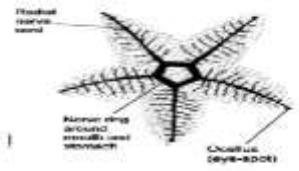
- Gases, nutrients and metabolic wastes are transported in the coelom.
- Ammonia
- Diffusion across dermal branchiae, tube feet and other membranous structures.
- Respiration through the thin skin and the dermal gills or papulae.
- Endosmosis of oxygen and exosmosis of carbon dioxide.



Gaseous Exchange in Star Fish

Topic 229: Nervous System of Starfish

- No brain
- Nervous system looks like a ring with 5 antenna
- Circumoral nerve and radial nerve.
- Amine-containing neurones involved in tube-foot coordination.



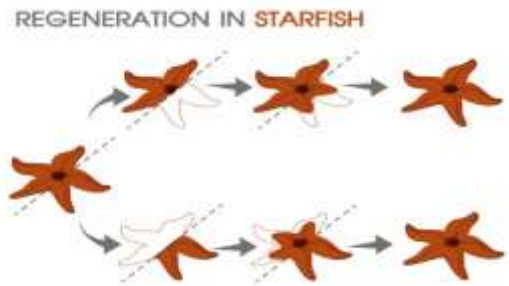
Nervous System of Starfish

Topic 230: Sensory Functions of Starfish

- Motor nervous system lodged within the mesothelial linings of the coelomic body cavities.
- Bilateral and metameric groups of central distributory motor neurons are present.
- Pre-ganglionic fibres.
- Lateral, the other (bilobed) medial neurons.
- Most of their senses poorly organized
- Chemoreception, mechanoreception and photoreception

Topic 231: Regeneration in Star Fish

- Ability to regenerate amputated limbs.
- Ability to regenerate lost arms
- Regrow an entire new limb given time.
- Catch connective tissue.



Regeneration in Star Fish

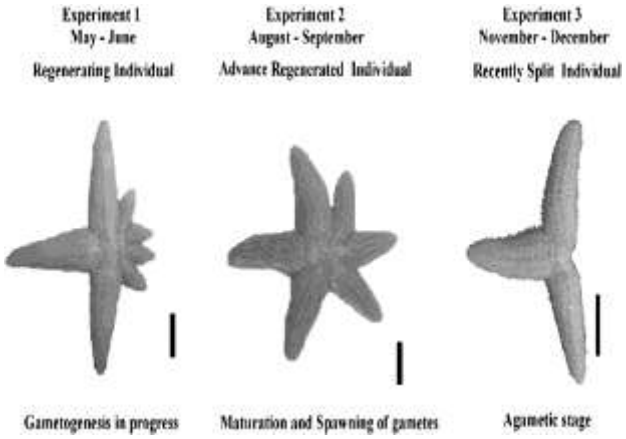
Topic 232: Sexual Reproductive Structures

- Gonochoric.
- Hermaphrodites and ovotestis.
- Free spawning.
- Brooding.
- Lecithotrophic and "planktotrophic".
- Asexually by fission of their central discs.
- Comet forms.

Sexual Reproductive Structures

Topic 233: Role of Photoperiod and Pheromones in Spawning

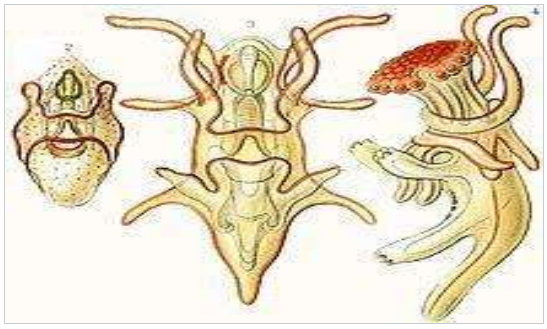
- Anticipatory cue to time seasonal events in their life histories.
- Photoperiod and temperature are environmental factors to coordinate sexual activity.
- Sexually by spawning.
- Gonads, in each arm.
- Larval stage is a miniscule, jelly-like blob.
- Benthic (surface-dwelling) existence.



Role of Photoperiod and Pheromones in Spawning

Topic 234: Development in Sea Star

- Short bipinnari arms by holoblastic, radial cleavage.
- Three kinds of bilaterally symmetricallarvae.
- 18 days after insemination, the juvenile completes metamorphosis.
- Juvenile is 600 um in diameter.
- Aboral skeletal system of the juvenile composed of one central.
- Lack of a brachiolaria stage.



Development in Sea Star

Lesson 41

CLASS OPHIUROIDEA

Topic 235: General Features

- Long slender flexible arms
- Common name "brittle star"
- Locomotion involves the entire arm.
- Movement is made possible by an internal skeleton that supports the arm.
- Scales.
- Mouth is framed by five jaws bearing spinel like teeth and papillae.
- These slits are openings for the respiratory bursae.
- Sexes are separate.
- Ophiopluteus

Ophiuroidea

Topic 236: Brittle Stars and Basket Stars

- Central disc separated from slender arms.
- Temperate and tropical

- Others hide in crevices in the reef.
- Shy away from light and seen at night.
- The arms lined with numerous spines arranged in rows.
- Suspension feeders and predators.

Topic 237: Difference between Sea Star and Brittle Star

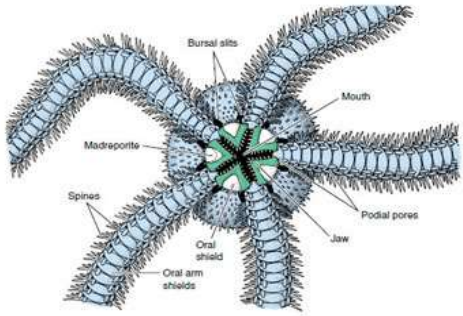
SEA STAR	BRITTLE STAR
- Class Asteroidea	- Class Ophiuroidea
- Set of calcareous plates embedded.	- Five radiating slender fixed arms.
- Move its sack-like stomach	- Move by sinuous flexing arms
- Complete digestive system	- Incomplete digestive system.
- Feed on crabs, bottom dwelling fish and sea gull.	- Scavengers or predators.
- Cardiac stomach performs external digestion whereas pyloric stomach performs the internal digestion.	- Break up very easily upon injury but also regenerates fast.
- Well-developed water vascular system.	- Do not have water vascular system.

Sea Star

Brittle Star

Topic 238: Locomotion in Ophiuroids

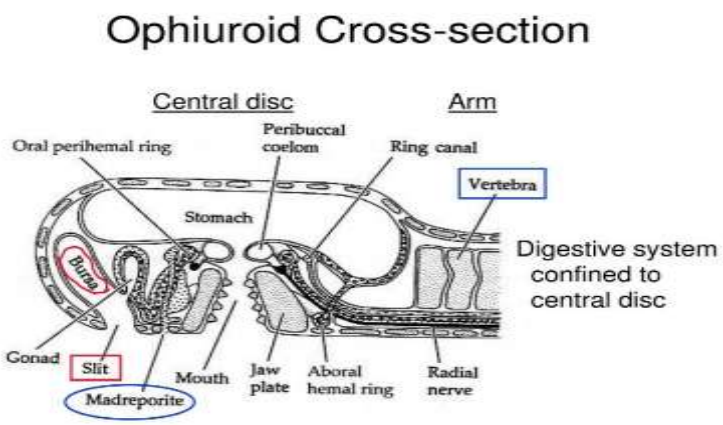
- Arms and tube feetfor locomotion.
- Move rapidly by wriggling their arms
- Movement has similarities with bilateral symmetrical animals.
- Lack suckers and ampullae.
- The water vascular system.



Locomotion in Ophiuroids

Topic 239: Feeding and Digestion in Ophiuroids

- Carnivores, filter feeders, and scavengers.
- Digestion occurs within folds of the stomach.
- Glandular hepatic cells.



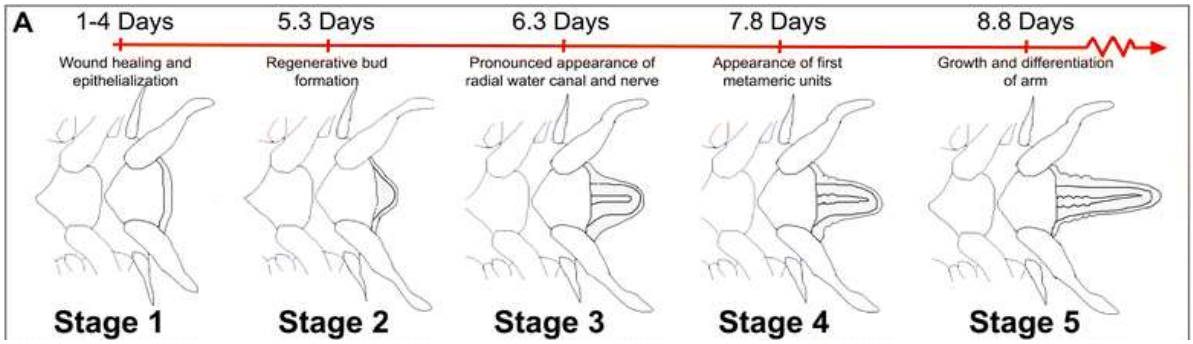
Digestive system in Ophiuroids

Topic 240: Gaseous Exchange in Ophiuroids

- Ten bursae on thebottom of the central body disk.
- Cilia within the sacs direct water flow so that oxygen can be absorbed from the water
- Water flows through cilia or muscular contraction.
- Oxygen is transported by the hemal system.

Topic 241: Escaping from Predators

- Shed the distal part of their tails to confuse pursuers.
- Autotomy
- metameric units.
- Regeneration



Steps of regeneration

Topic 242: Reproduction in Ophiuroids

- Dioecious
- Males are smaller than females.

- The gametes are released into the bursa.
- Ophiopluteus.
- Many species are truly viviparous.
- 1-2 gonads per bursa.

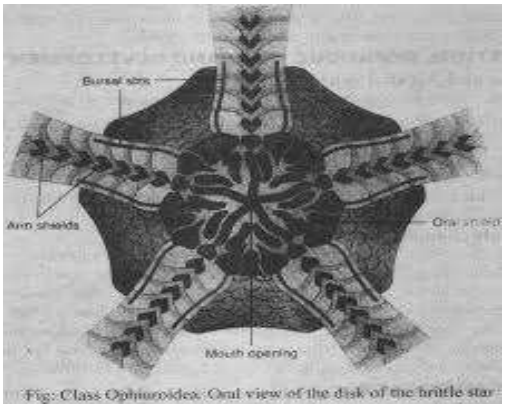
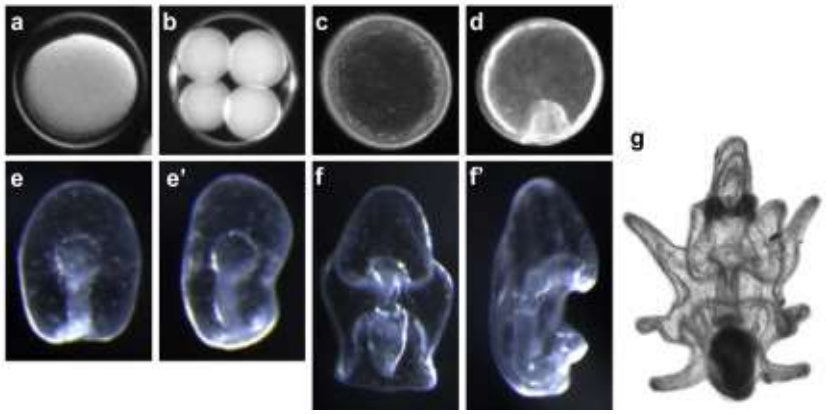


Fig: Class Ophiuroidea: Oral view of the disk of the brittle star

Reproduction in Ophiuroids

Topic 243: Development in Ophiuroids

- Development may be direct or indirect.
- Three primary larval types: ophiopluteus, vitellaria, and doliolaria.
- Four general patterns of larval development.
- Germinal vesicle breakdown (GVBD).
- External fertilization.
- Species with direct development exhibit both external and internal brooding.



Development in Ophiuroids

Lesson 42

CLASS ECHINOIDEA

Module 244: Class Echinoidea: General Features

- Regular is the sea urchins; Irregular is the sand dollars.
- Pentamerous radial symmetry and spiny skin.
- Moveable spines
- Water vascular system.
- Well-developed digestive system.
- Regular urchins have five pairs of gonads, irregular urchins have between two and five.
- External fertilization and echinopluteus larva.
- Grazer and scavengers.

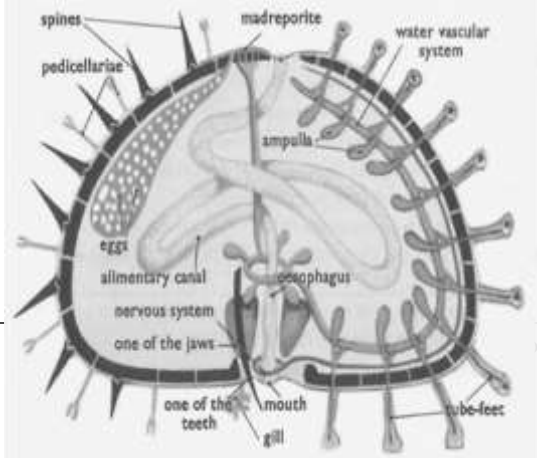
Echinoidea

Topic 245: Skeleton of Sea Urchins

- Test is the name of a sea urchin skeleton.
- No shells.
- Five rows of ambulacral plates and five interambulacral plates.
- Socket to which the spines are attached by ball and socket joints.
- Primary (long) and secondary (short) spines.
- Some spines contain venom dangerous to swimmers.

Topic 246: Role of Pedicilleria in Sea Urchins

- Small wrench- or claw-shaped appendage with movable jaws called valves.
- Four main forms: tridactylous, ophicephalous, triphyllous and globiferous.
- Intradermal ossicles.
- Grooved or hollow to inject venom.
- An effector organ with neuropils and sensory receptors.
- Protection against sedimental particles.



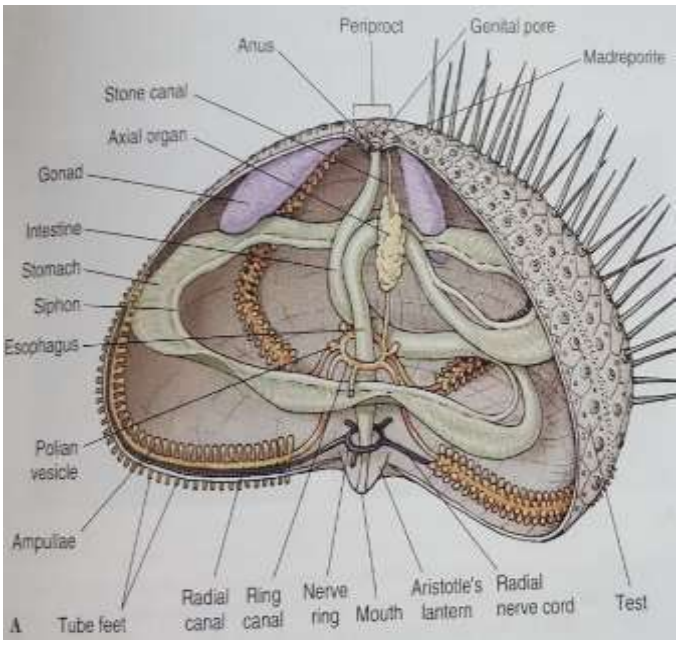
Pedicilleria in Sea Urchins

Topic 247: Water Vascular System of Sea Urchin

- Similar to other echinoderms.
- Radial canal runs between the oral and aboral poles.
- Ampillae and suction.
- Madreporite located within one of the plates surrounding the anus.
- Number of polianvesicles
- Small water-filled tentacle.

Topic 248: Locomotion in Echinoids

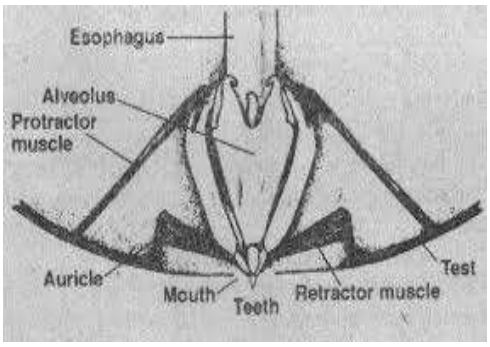
- No arms and move using tube feet for pulling.
- Spines.
- Suctions naps and adhesion.



Locomotion in Echinoids

Topic 249: Aristotle's Lantern in Echinoids

- Conical shaped chewing apparatus projecting from mouth.
- Complex arrangement of muscles and calcareous teeth constituting about 35 ossicles.
- Teeth are extruded to scrape algae and other food from rocks.
- Five strong teeth, 40 skeletal ossicles and 60 muscles.
- Masticating the food.
- Feed on algae, bryozoans, coral polyps, and dead animal remnants.



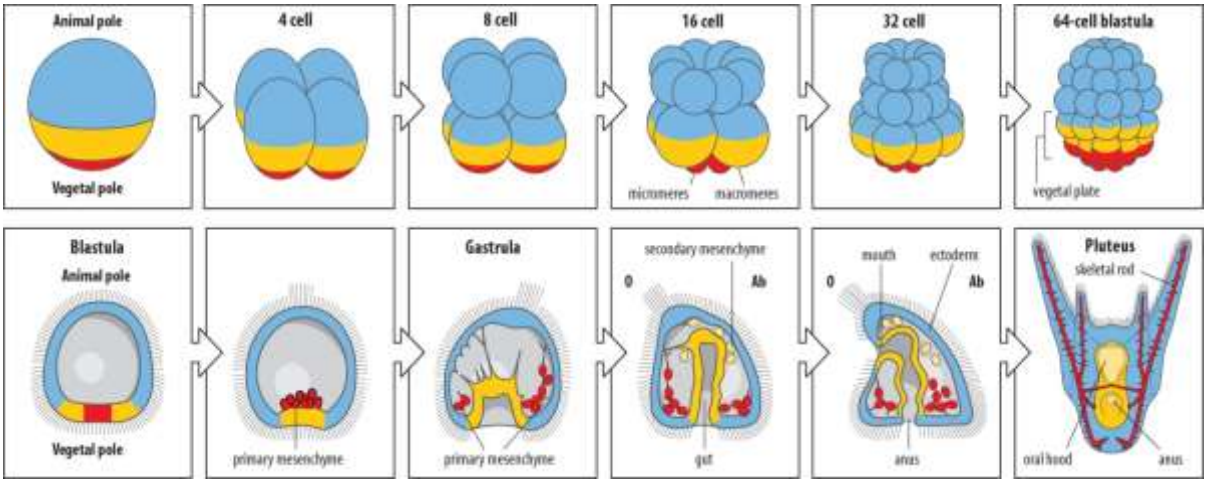
Aristotle's Lantern in Echinoids

Topic 250: Maintenance Functions

- Gas exchange and excretion occurs through skin gills & diffusion into the tube feet.
- Ciliary currents and aristotle's lantern move coelomic fluids into and out of gills.
- No circulatory system.
- Coelomic fluid distributes food and oxygen.
- No head or brain. Eyespots on the tips of each arm detect light.
- Tube feet respond to touch.
- Nerve ring that encircles the mouth and radial nerves that extend into each arm.
- Radial nerves lie within the ambulacral groove and the radial strands of the hemal system.
- Radial nerves coordinate the functions of tube feet.

Module 251: Reproduction and Development

- Dioecious but sexes are indistinguishable externally.
- Two gonads are present in each arm and enlarge during the reproductive periods.
- Gonopores open between the bases of each arm.
- External fertilization.
- Spawning.
- Lay many eggs thus there is an increased of survival in the marine environment.
- After fertilization the egg hatches into larvae.
- Larvae develop quickly and metamorphose into bigger juveniles.



Development in Echinoids

Lesson 43

CLASS HOLOTHUROIDEA

Topic- 252: Class Holothuroidea

- Soft and cylindrical body.
- More or less elongated limbs and without solid appendages.
- Body´s diameter varies between 24 and 25 centimeters.
- Circle of five to twenty tentacles around the mouth.
- Water-circulating system is made up of a ring canal and long canals.
- Endoskeleton
- Microscopic ossicles (or sclerietas) joined by connective tissue.
- Skeleton made up of bonelike parts that look like rods, roses, buttons, etc.

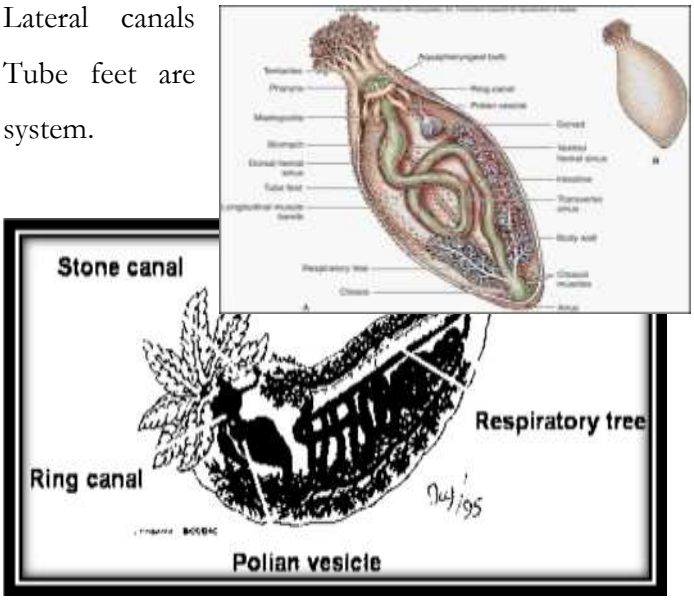
Topic- 253: Body Wall of Sea Cucumber

- Thick and muscular body wall and lacks pedicellariae.
- Beneath the dermis is a layer of circular muscles overlying longitudinal muscles.
- Ossicles are microscopic and do not function in determining body shape.
- Trepang.

Body Wall of Sea Cucumber

Topic- 254: Phylum Echinoderamata: Water Vascular System of Sea Cucumber

- Series of water-tilled canals.
- Originates in embryo as a modification of the coelom.
- Ring canal and madreporite.
- Polian vesicles store fluid .
- Five (or a multiple of five) radial canals arises from the ring canal.
- Lateral canals arise from radial canal.
- Tube feet are extensions of the canal system.

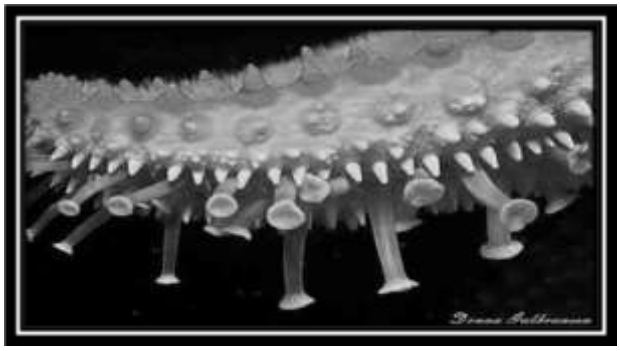


Water Vascular System of Sea Cucumber

Topic- 255: Locomotion in Sea Cucumber

- Sluggish burrowers and creepers.
- Spines and tube feet in locomotion.

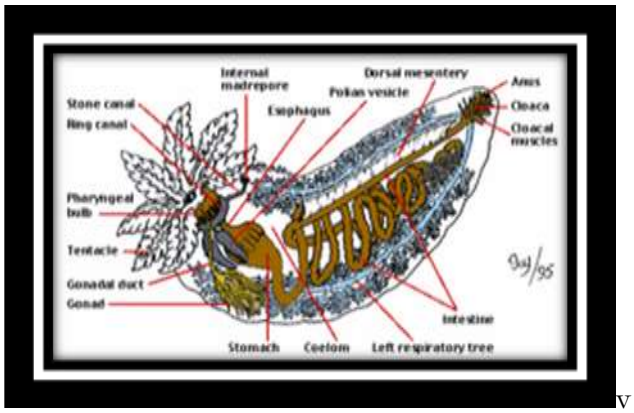
- Move by thrashing the arms including a rowing motion.
- The tube feet and contraction and expansion of the body.
- Swimming is known to occur in crinoids, ophiuroids, and holothurians.



Locomotion in Sea Cucumber

Topic- 256: Feeding and Digestion in Sea Cucumber

- Deposit and suspension feeding and ingest plastic fragments.
- Hemal system is well developed and is food distribution.
- Ingest particulate organic matter using their tentacles.
- A pharynx is surrounded by a ring of ten calcareousplates.
- Esophagus and stomach present and in some the pharynx opens directly into intestine.
- Coelomocytes secrete enzymes to aid in digestion, engulf and distribute the products.
- Spectacular defensive system.



Digestive system in Sea Cucumber

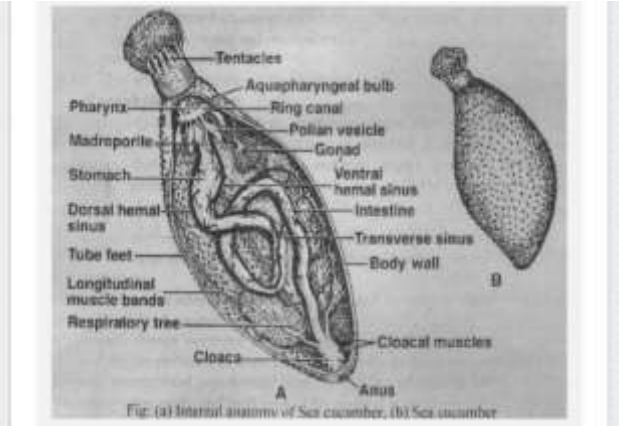
Topic- 257: Respiratory Tree

- Breathe by throwing water in through the anus and then expelling it.
- Respiratory gases and wastes move between coelom and seawater across the tubules.
- Skin usually has water projections or spines, or both.

- Muscular water filled bulb ampulla.
- Move by alternately, extending and retracting groups of tube feet.
- Very thin walled tube feet for the diffusion of oxygen into the body cavity and outward of carbon dioxide and wastes.

Topic- 258: Nervous and Sensory Functions in Sea Cucumber

- Statocysts and photoreceptors.
- No true brain.
- No distinct sense organs
- Nerve endings scattered through the skin
- Small eye spots near the bases of their tentacles.



Nervous and Sensory systems in Sea Cucumber

Topic- 259: Defense in Sea Cucumber

- Toxins in their body walls.
- Cuverian tubules through the anus.
- Evisceration.
- Regeneration.

Defense system in Sea Cucumber

Topic- 260: Regeneration, Reproduction and Development in Sea Cucumber

- Releasing sperm and ova into the ocean water.
- Dioecious
- 30 species fertilize eggs internally then pick up the fertilized zygote with feeding tentacles.
- On the adult's body it develops and hatches as a juvenile.
- Free-swimming larva after three days of development.
- The first stage of larval development is auricularia.
- Larva grows and transforms into the doliolaria.

Lesson 44

CLASS CRINOIDEA AND CONCENTROCYCLOIDEA

Topic- 261: Class Crinoidea: General Features

- Stem and a crown consisting of a cup-like central body known as the theca.
- Five rays or arms.
- Mouth surrounded by feeding arms and is linked to a u-shaped gut.
- Passive suspension feeders.
- Dioecious
- Gonads are located in the pinnules but few in the arms.

Crinoidea

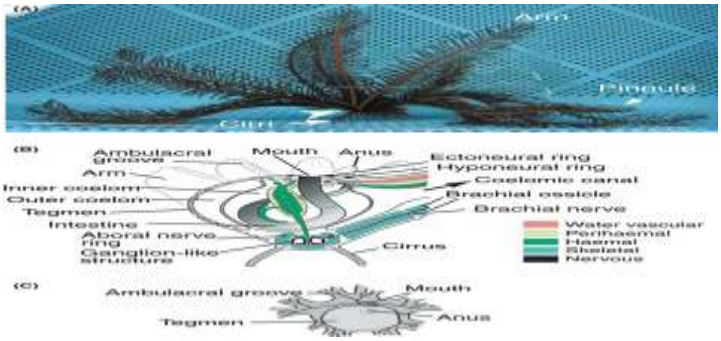
Topic- 262: Sea Lilies and Feather Stars

- Sea animals with five arms and a mouth that faces up.
- Crown holds the mouth, digestive tract, and anus.
- Live in deep water and feather stars live on coral reefs.
- Eat plankton and waste.
- Regrow lost body parts.
- Separate sexes.

Sea Lilies and Feather Stars

Topic- 263: Class Crinoidea: Maintenance Functions, Regeneration, Reproduction and Development

- Calyx and the tegmen holds the visceral mass.
- Coelomic canal system, muscles and ligaments.
- Circulation, gas exchange and excretion similar to other echinoderms.
- Outstretched arms for suspension feeding.
- Lack the nerve ring. A cup shape nerve mass is below the calyx.
- Regeneration.
- Dioecious and gametes arc formed by germinal epithelium in the coelom.



Maintenance of Crinoidea

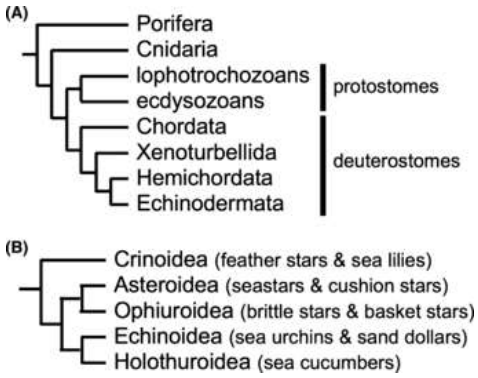
Topic- 264: Class Concentricycloidea

- Sea daisies less than 1 centimeter in diameter.
- Water vascular system includes two concentric ring canals.
- Outer ring may represent radial canals.
- Polian vesicles attached.
- No digestive tract or has a shallow, saclike stomach but no intestine or anus.
- Series of overlapping skeletal plates known as ossicles.

Concentricycloidea

Topic- 265: Further Phylogenetic Considerations

- Most extinct by the end of the Paleozoic and only five classes survive today.
- Based on bilateral larvae, ancestors must be bilateral and coelom had three pairs of spaces.
- traditional view is that the first were sessile became radial as an adaptation to that existence.
- Extinct carpoids had stereom ossicles but were not radially symmetrical.
- Fossil helicoplacoids show three true ambulacral grooves and mouth on the side of body.
- Free moving ancestors applying oral surface to the substratum would rise to Eleutherozoa.



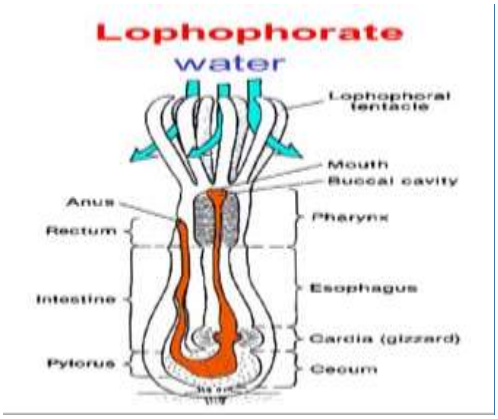
Phylogenetic Considerations

Lesson 45

LESSER INVERTEBRATES

Topic- 266: The Laphophorates

- Aquatic possessing a lophophore, a fan of ciliated tentacles around the mouth.
- Moss animals, lamp shells and phoronid worms.
- Brachiopoda are enclosed in a bilaterally symmetrical bivalve shell of oval form.
- An open circulatory system with a dorsal contractile vesicle.
- One or two pairs of metanephridia.
- Found in all seas at different depths between tide marks to 2900 fathoms.
- Body wall has three layers; an outer epidermis, middle layer of connective tissue and a layer of ciliated coelomic epithelium lining the body-cavity.
- Sexes are separate and two pairs of gonads are present.



Structure of Lophophorate

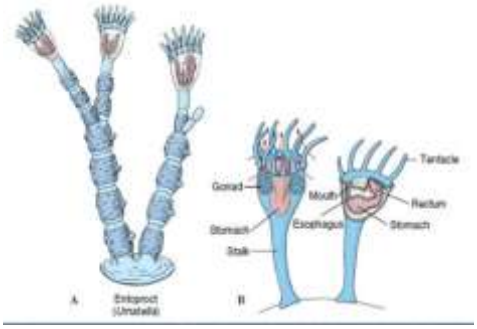
Topic- 267: The Phoronids

- Elongated and worm- shaped.
- Gut loops and ends close to the mouth instead of passing straight through the body.
- "horseshoe worms" abundant in shallow marine sediments.
- Mouth is surrounded by a lophophore.
- Short oesophagus, a spherical stomach, intestines and anus.
- Single descending artery and ascending vein linked by a network of fine capillaries.
- Tentacles act as organs of gaseous exchange and feeding.
- Pair of tubular metanephridia .
- Hermaphroditic and internal fertilization.

The Phoronids

Topic- 268: The Entoprocta

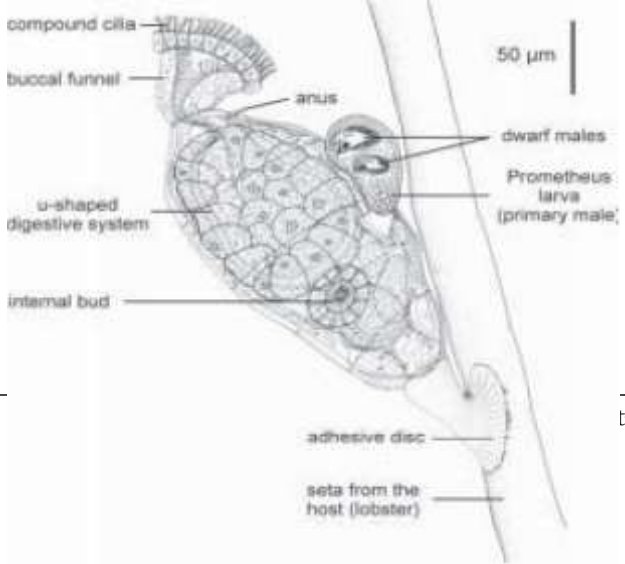
- Marine habitats; singly or in colonies
- Stalk (peduncle) attaches to shells, to seaweed, or to other animals, e.g. Sponges etc.
- Globular head (calyx) that houses a u-shaped gut and the nervous, excretory, and reproductive systems
- Crown of ciliated tentacles
- Anus lies within this tentacular ring
- Hermaphrodites
- Trochophore larva



The Entoprocta

Topic- 269: The Cycliophora

- Microscopic animals
- Live on the mouthparts of langoustines and lobsters.
- 6 forms in cycliophores: 1) the fixed form 2) pandora larva 3) chordoid larva 4) larva prometheus 5) dwarf male 6) the female.
- Sexual via a chordoid larva and asexual mode of reproduction via a pandora larva.



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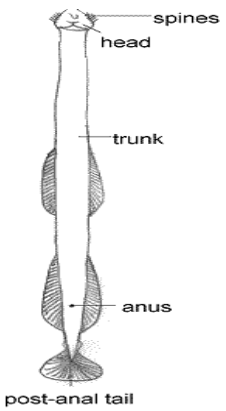
Topic- 270: Entoprocts

The entoprocts (Gr. *entos,* within and *proktos,* anus) comprise a small phylum of about one hundred species of sedentary marine filter feeders.
They are either solitary or colonial, and live in coastal waters.
One group is commensalistic on the body surface of various invertebrates.
Most entoprocts are microscopic.
Entoprocts may form large, matlike colonies on rocks.
An individual entoproct consists of a muscular stalk bearing a cup-shaped calyx with a crown of ciliated tentacles.
Entoprocts stalk is surrounded by a chitinous cuticle and may bear an attachment disk with adhesive glands.
Entoprocts have a small body cavity that most zoologists consider a pseudocoelom.
Loose connective tissue, however, fills this body cavity.

Topic- 271: The Chaetognaths

- Small, bilaterally symmetrical soft-bodied.
- Arrow worms generally less than an inch (2.5 centimeters) in size.
- Strictly marine, with a cosmopolitan distribution throughout the oceans.
- Characterized by a largely transparent body, fins on tail and body.
- Grasping bristles or hooks on each side of the mouth used to capture prey.
- Two orders, phragmorphora and aphragmorphora.
- Alimentary system comprises the mouth, esophagus, gut, and anus.
- Superficial cerebral ganglion and no respiratory or circulatory systems.
- Excretion is done through the skin and anus.
- Hermaphroditic and fertilization is internal.



The Chaetognaths