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COURS « ZOOLOGY »

(2nd YEAR BIOLOGY LICENSE LMD)

(BASIC STUDIES)

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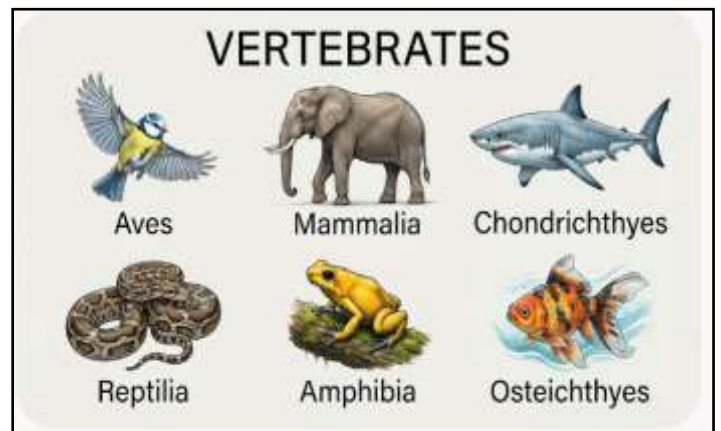
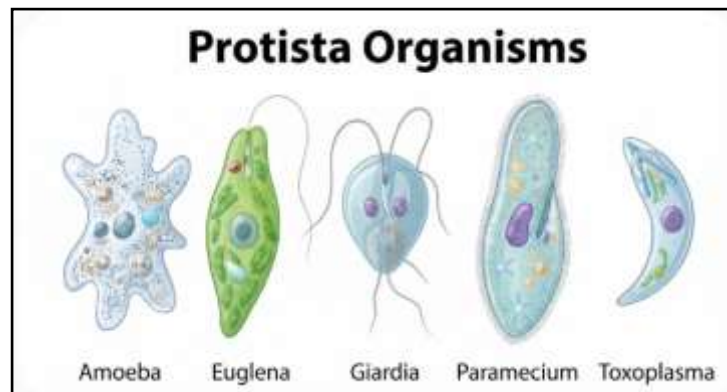


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Introduction

Once upon a time, all living organisms were grouped into two kingdoms: plants and animals. Animals included every living thing that moved, ate and grew to a certain size before stopping. Plants included all organisms that did not move or eat, and continued to grow throughout their lives. A living being is a highly complex organism that goes through biological cycles it is born, grows, can reproduce, and eventually dies. Living beings differ from one another in their levels of organization and methods of nutrition, resulting in a wide diversity. To better study this diversity, scientists classify all living organisms into broad groups called kingdoms, based on shared characteristics. Five kingdom being the most common which was developed in 1969 by the American ecologist **Robert Harding Whittaker** (1920-1980) (**Figure 1**).

- 1- Monera (Bacteria)
- 2- Protozoa (Protista)
- 3- Fungi
- 4- Plantae
- 5- Animalia.

Whittaker's classification scheme was based on the following criteria::

1. Structure of Cell
2. Body organisation
3. Mode of nutrition
4. Reproduction
5. Phylogenetic relationships

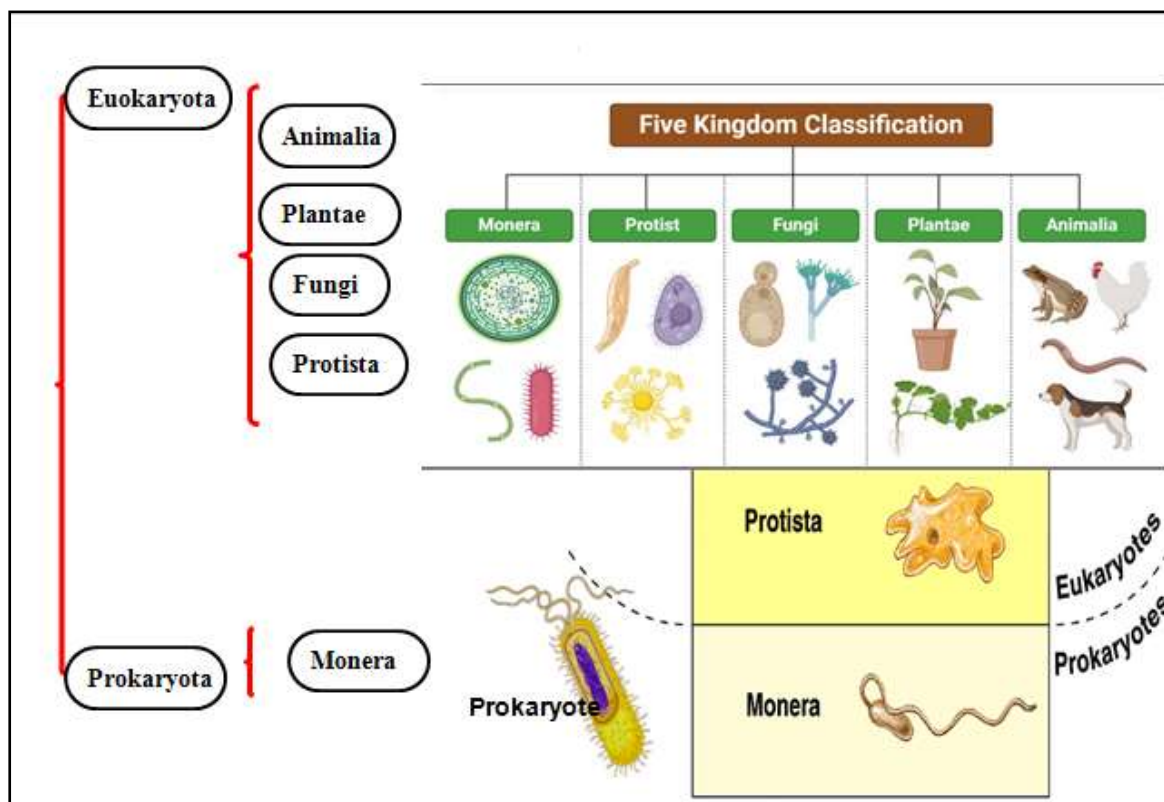


Figure 1. Five kingdom classification.

The table 1 show the characteristics of the five kingdoms.

Table 1. Characteristics of the five kingdoms.

Kingdom	Characteristics
Monera	Cell structure : unicellular prokaryotes (no nucleus or organelles) Nutrition : Absorptive or Photosynthetic. Mouvement : Flagella (Tubulin). Reproductive : Asexual.
Protista	Cell structure : Unicelled Eukaryotes (nucleus and organelles present). Nutrition : Absorptive or Photosynthetic. Mouvement : Flagella, cilia, pseudopods (streaming) Reproductive : Both asexual and sexual.
Fungi	Multicellular, Eukaryotes Structure of Cell : Cell wall composed of chitin. Mode of nutrition : Heterotrophic, Absorptive, Saprobiic Mouvement : Not motile Reproductive : Both asexual and sexual
Plantae	Multicellular, Eukaryotes, structure of cell : The presence of a cellulosic cell wall and of plastids. Nutrition : Autotrophic organism

	Mouvement : Non motile Reproductive : Both asexual and sexual
Animalia	Multicellular, Eukaryotes Structure of cell: Cell wall and plastids are absent. Nutrition : Heterotrophic Mouvement : It is highly motile. Reproductive : Asexual and sexual reproduction are both possible.

I.1. Animal kingdom

The diversity of animals is incredible in size, animal can vary from 0,1 mm to a few tens of meters. Some only live a few days, others more than century. Animals are found in all habitats ranging from abyssal trenches to the peaks of the highest high mountains. Despite their many differences, all of these organisms have several things in common, they probably come from the same ancestor have fundamentally the same needs and the same constraints imposed by the environment in which they live.

I.2. Definition

Zoology is the scientific study of animals. It encompasses the study of their structure, embryology, behaviour, anatomy, classification, ecology, distribution and interactions with their ecosystems, both in living and extinct animals. Zoology is one of the primary branches of biology. The term is derived from the ancient Greek words *zōion* ('animal') and *lógos* ('knowledge', 'study').

I.3. Animal diversity

Zoologists group multicellular animals into 32 phyla. Each branching is characterized by a particular architecture and a series of biological properties which distinguishes it from all others. The number of species in each of these groups gives an idea of their current importance. The Arthropods are currently the most successful group, with many species thriving in their respective environments and this success is explained by that of Insects. Some other phyla dominate: Molluscs (mussels, snails and octopus), Nematodes and Chordates (**table 2**).

1.4. Numerical importance of the animal kingdom

Table 2. Number of living species in the main phyla.

Phyla (phylum)	Number of species
Arthropoda	1, 200,000
Mollusca	110,000
Nematoda	90,000
Chordata	47, 200
Apicomplexa	20,000
Platyhelminthes	15,000
Annelida	15,000
Ciliophora	7,500
Echinodermata	6000
Sarcomastigophora	4,500
Porifera	4,300

I.5. History

The presence of a very high number of living beings has pushed the zoologiste to look for method to disting them for each other. The branch of zoology that deals with the identification, description, nomenclature and classification of animals is known as systematic zoology, or animal taxonomy. At present, more then one million species of animals are known. They present an intersesting diversity of stucture, function, habits and mode of life. It is evident that some system is required for accurately naming and grouping such a large number of animals in order to facilitate their objective study and also to show the relationship between the various groups.

The Greek philisopher **Aristotle (322-384 B.C)** was among the earliest scientists who attempted classifying living organisms. He proposed classifying animals according to whether or not they had 'red blood' in two groups : **Enaima** and **Anaima**, with and without blood respectively. It was also once suggested that animals may be classified according to the type of environment they live in as terrestrial, aquatic or aerial, or according to the type of food they use into flesh-eaters (carnivorous) and plant-eaters (herbivorous).

Gradually, however, emerged the idea of classifying animals according to the morphological similarities between them. This idea was formulated clearly in the 17th century by the English naturalist **John Ray (1627-1705)** whose system can be considered as first scientific approach to animal classification. Moreover, he was the first to give a precise definition of the **species**, the basic unit for classification of living organism. He defined species as 'an assemblage or grouping of morphologically similar animals that interbreed freely with one another, but not with other species'.

If they do, they produce infertile (sterile) hybrids. Later came the Swedish naturalist **Carl Linnaeus (1707-1778)** who laid down the basic of the system of classification we use nowadays. He classified living organisms according to the morphological and anatomical similarities between them. He also devised the system of « Binomial nomenclature, by which each type of organism is given a name composed of two words: the first is the genus name and the second is the species name. Both are in Latin and are written in italics or underlined. The genus name starts with a capital letter, and the species name starts with a lowercase letter. The scientific name for humans, for example, is *Homo sapiens*.

I.6. Systematic or taxonomy

Taxonomy is the theory and practice of classifying organisms. It is the science of naming and classifying them. Taxonomists are scientists who specialize in identifying, classifying and naming organisms on our planet. So far, they have named approximately 1.7 million species. Around 13,000 new species are added to the list of known organisms each year. The term 'taxonomy' was coined by the Swiss naturalist De Candolle in 1813. It is derived from the Greek words *taxis*, meaning 'arrangement', and *nomos*, meaning 'law'. Taxonomie means the law governing the classification/arrangement of organisme into taxa.

Taxon pleural « **taxa** » is any taxonomic groupings or a group of organisms in a classification system, such as species, a genus, a family

Taxonomy (from the Greek words for 'arrange' and 'law') is the systematic arrangement of organisms into orderly groups based on their similarities. It is also known as classification. It is the branch of biology that deals with the identification, classification and naming of organisms. Biologists use a classification system to name and group organisms in a logical manner, and taxonomy uses the binomial system developed by Linnaeus. Taxonomy defines a species based on reproductive isolation.

Nowadays, animals are classified not only based on morphological and anatomical characteristics, but also on biochemical, genetic, embryological and physiological features.

Species that share many features are placed in the same genus. Similarly, related genera are grouped into families, families with certain common characteristics constitute orders, and orders in turn are grouped into classes. These classes form the higher taxonomic grouping known as phyla or phylum.

1.7. Taxonomists

1.7.1. Two thousand years ago, **Aristotle (384–322 BC)** was the first taxonomist to divide organisms into plants and animals. He then subdivided these groups according to their habitat: land, sea or air. He divided the animal kingdom into two groups:

1) Animals without red blood cells (Anaima): This group included animals without red blood cells. Examples: **Sponges, arthropods** and **molluscs**.

2) Enaima: Animals with red blood cells. Example: **Chordates**.

Early scientists used common names to identify organisms. Examples of common names include: seahorse, starfish, sea lion and jellyfish.

1.7.2. Linnaeus (1707–1778): He classified organisms by their structure and created the naming system we use today. He devised a naming system based on physical characteristics.

1.8. Basic of taxonomy and zoological nomenclature

1.8.1. Notion of species

The term 'species' was coined by John Ray. In his 1693 book *Historia generalis plantarum*, he described species as groups of morphologically similar organisms that arose from a common ancestor. In his book *Systema Naturae*, Carolus Linnaeus considered species to be the basic unit of classification. A species can be defined as a group of organisms that have similar morphology and physiology, and that can interbreed to produce fertile offspring.

1.8.2. Binomial nomenclature

Carl Linnaeus (1707-1778) who laid down the basic of the formal system of naming species. A two name system for writing scientific name: (Bi = two, nomial = names 'Nominal' means 'naming'. 'Nomenclature' means 'the system of naming'. These are two definitions to know:

Genus: a group of closely related species.

Species: A group of similar organisms that can breed and produce fertile offspring. Binomial nomenclature is the system by which each type of organism is given a name composed of two words; the first word names the genus and the second word names the species. Both are in **Latin** and are written in **italics** or **underlined**. The name of the genus starts with a capital letter, and the name of the species starts with a lowercase (small) letter.

The scientific name of man, for example, is *Homo sapiens* (Linnaeus, 1758), and it can be written : *H. sapiens* (L, 1758). If the genus is known but the species is unknown, the genus is written followed by "sp." (sp. = specimen) for an unidentified species. Example: *Taenia sp.*

1.8.3. Hierarchical classification

Species are grouped hierarchically into genera, genera into families, families into orders, orders into classes, classes into phyla, and phyla into kingdoms. An other intermediate categories such as subkingdom, grade, division, subdivision, **subphylum**, **superclass**, **subclass**, **superorder**, suborder, superfamily, subfamily and subspecies.

Example for classification from *Homo sapiens*

Kingdom : Animalia

Phylum : Chordata

Subphylum : Vertebrata

Super class : Tetrapoda

Class : Mammalia

Order : Primates

Family : Hominidae

Genus : Homo

Species : *Homo sapiens*.

The nomenclature of the classical classification established a codified terminology which allows, given the sole ending (or **suffix**) of any taxon (table 3).

Table 3. Suffixes indicating taxonomic rank

Taxonomic rank	Suffixe	Taxonomic rank	Suffixe
Phyla (phylum)	//	Order	idea, ida
Sub-phyla	//	Suborder	//
Class	//	Infra-order	//
Sub-class	//	Super-family	-oidea
Superorder	//	Family	-idae

I.9. Organizational plan of the animal kingdom

Animals show huge diversity in both number and type, from single-celled forms to complex multicellular ones. They live every where from the deepest seas to snowy mountains, and from the poles to the equator. Although their structures and shapes vary, animals share core features such as cell arrangement, body plan, symmetry, segmentation, a coelom and germ layers, as well as the ability to regulate their body temperature, skeletal elements (including the notochord), and the ways their digestive, respiratory, circulatory, excretory, and

reproductive systems are organized. Classifying organisms helps simplify study and uncovers how different groups are related

According to the organizational plan, the main criteria for studying animals taken into consideration are:

- The number of cells (protozoa (unicellular) or metazoa (pluricellular))
- The number of embryonic layers (Diploblastica or Triploblastica)
- The presence or absence of a coelomic cavity (Acoelomata, pseudocoelomata and coelomata)
- The fate of the blastopore (protostomia, deterostomia)
- The position of the nerve cord (hyponeuria, epineuria, epithelioneuria)

I.9.1. Number of cell

The animal kingdom is divided into two subkingdoms according to the number of cells: subkingdoms of Protozoa and subkingdoms of Metazoa.

The metazoa are multicellular animals. The cells are arranged in embryonic layers, with each layer representing a specific tissues and organs. The Embryonic development begins with the segmentation phase (**figure 2. B, C, D, E**) at during which the egg divides into smaller and smaller cells. Cells resulting from the division of the egg cell are blastomeres.

At the end of segmentation, the embryo reaches the blastula stage (**figure 2. F**). Most often he it is a hollow sphere, the blastomeres are located on the periphery and surround a cavity filled with liquid called blastocoels.

Then the embryo undergoes gastrulation and reaches the gastrula stage. In the simplest case (**figure 2 G, H, I**), the cells located at the lower pole of the sphere invaginate inside, thus forming a primitive intestine, the archenteron, which remains in communication with the outside through an orifice, the blastopore. Layer of cells located on the outer side of the gastrula constitutes the ectoblast and the leaflet located on the internal side and which forms the archenteron constitutes the endoblast.

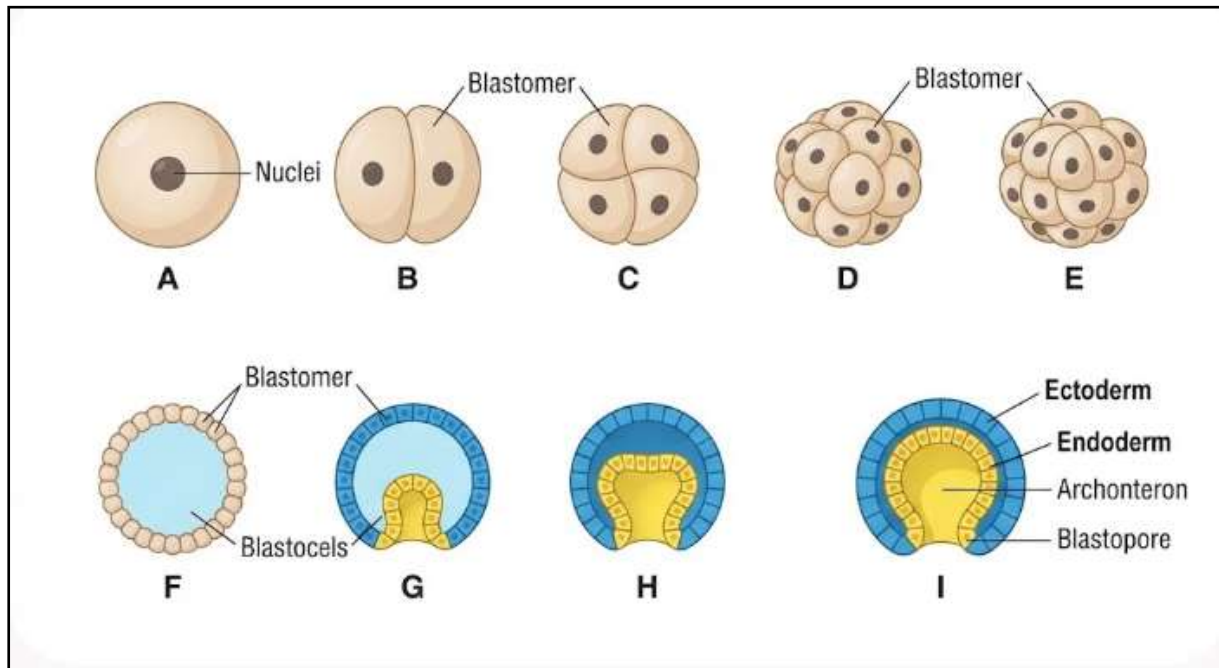


Figure 2. Developmental phases of metazoa.

The cells that constitute an animal organism can combine two different ways:

- Or in relatively loose ways. Cellular junctions are sparse. These metazoans do not have **real tissues**, they are also called **Parazoa**.
- Either in a much more solid way, thanks to the presence of numerous cell junctions and the establishment of a basal lamina at the base of epithelia. These animals have **real tissues**, they are Eumetazoa.

1.9.2. Number of germ layers

1.9.2.1. Metazoa Diploblastica

The diploblastics bring together all the metazoans which have at the embryonic level of two layers ectoderm and inner endoderm (**Figure 3**).

- Diploblasts include: **sponges (Porifera)**, cnidarians and ctenaries.

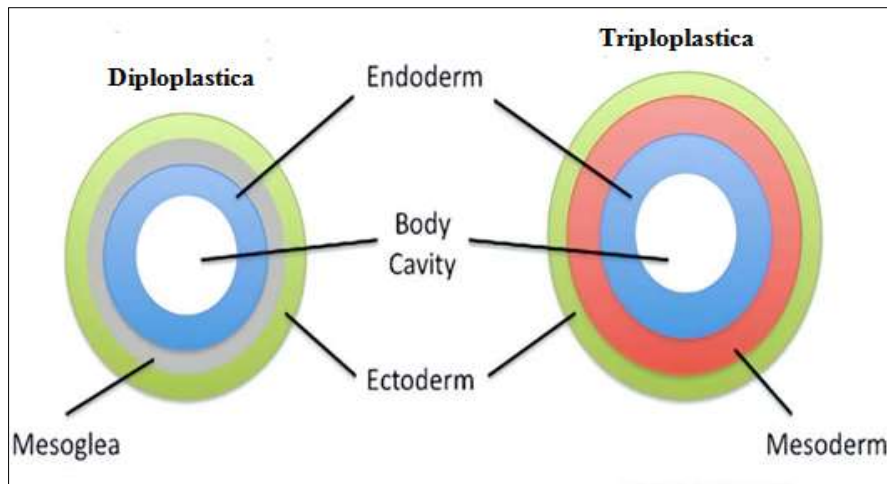


Figure 3. Presentation of Diploblastic and Triploblastic metazoa.

I.9.2.2. Metazoa Triploblastica

When a middle layer or **mesoderm** is formed in between the ectoderm and endoderm of the embryo (**Figure 3**). Most large animals have a central body cavity while some small animals lack a central cavity but have their central space filled with loosely packed cells.

1.9.3. Body cavity

Further study of anatomy reveals that animals can be divided into three basic groups based on their central body cavity: (1) acoelomate, (2) pseudocoelomate, and (3) coelomate (**Figure 4**).

A) Acoelomate (Figure 4 a), These are animals whose central space is filled with loosely packed cells known as mesenchyme. Body fluid percolate through irregular space between cells and carry nutrients to the cells and assist in removing wastes from the cells. Example : Flatworms, phylum : **Platyhelminthes**

B) Pseudocoelomate (Figure 4 b), the mesoderm provides muscles and various apparatus, but no parenchyma. These animals have a body cavity filled with fluid, lined on the external side by the mesoderm and on the internal side by the endoderm. It is actually a remnant of the embryonic blastocoels. This cavity is called pseudocoel, and includes the phyla of **Nemathelminthes** (Roundworms) and **Rotifera**.

C) Coelomate (Figure 4 c), animals with an extensive fluid-filled cavity in the mesoderm known as the coelom. The body cavity is entirely surrounded by mesoderm tissue. These tissues form symmetrical paired cavities on either side of the digestive tract, and includes the following major phyla:

1. Phylum : **Annelida**
2. Phylum : **Mollusca**
3. Phylum : **Arthropoda**
4. Phylum : **Echinodermata**
5. Phylum : **Chordata**.

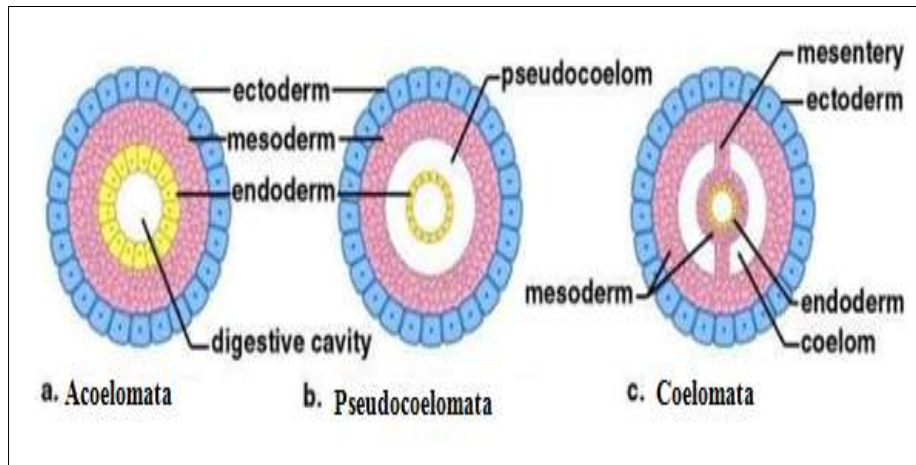


Figure 4. Animal body types

1.9.4. Fate of the blastopore

Depending on the fate of the blastopore (orifice of the blastula), coelomate can be divided into two distinct evolutionary lines:

A) Protostomes (Protostomy) (**Proto** = first, **stoma**=mouth). The embryonic blastopore gives the mouth, (mouth formed **first**). Their nervous system is located in the anterior part, metamerized and connected to a ventral nerve chain (Hyponeurians) (**Figure 5 a**).

Ex. Annelids, Molluscs, Arthropods.

B) Deuterostomes (Deterostomy) (**Deutero** = second). The blastopore gives the anus, the mouth is then pierced secondarily (mouth formed secondly) (**Figure 5 b**).

Ex. Echinodermata and Chordata.

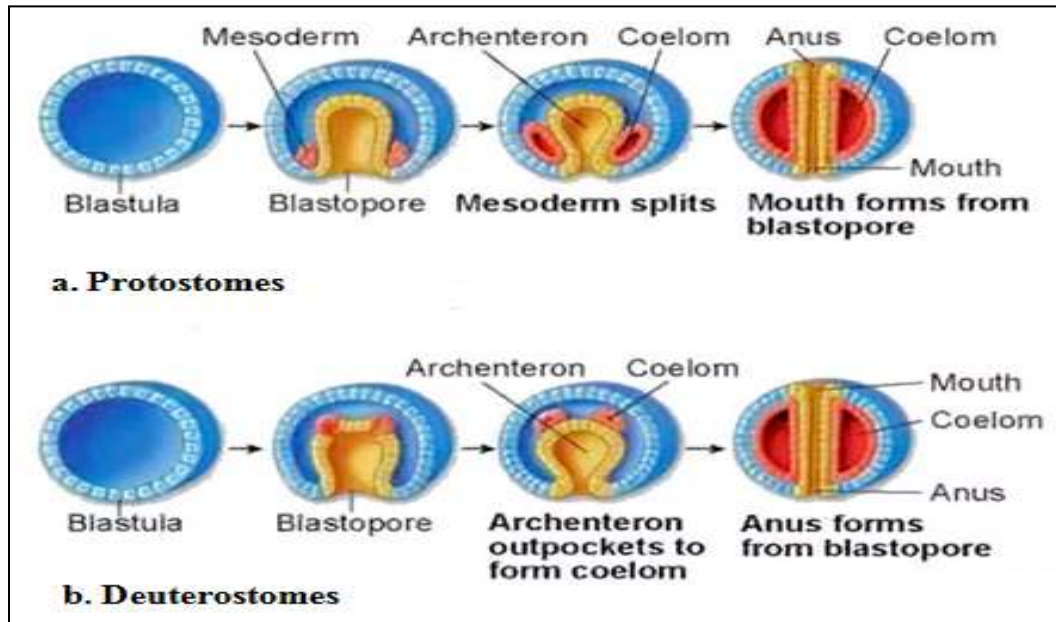


Figure 5. Developement of protostomes and deuterostomes.

1.9.5. Structure of nervous system

According to structure of the nervous system, it is possible to distinguish three classes of nervous system:

- 1) **Epithelioneurians** (nerves in the epithelium). The nervous system is generally imperfectly free of the ectoderm. Example: phylum Echinodermata.
- 2) **Hyponeurians** include animal with a system ventral nerve. Ex. Annelids, Molluscs, Arthropods.
- 3) **Epineurians** (dorsal nervous system). They have nerve centers located **above** the digestive tract. Example: Chordata.

1.10. Other classification criteria

1.10.1. Segmentation

The key difference between protostomes and deuterostomes lies in the development of their embryonic cells. Protostomes form the mouth first during embryogenesis, whereas deuterostomes develop the anus first.

Both protostomes and deuterostomes are organisms with a tube-within-a-tube body plan. The major difference between the two is based on the fate of the blastopore (**Figure 6**).

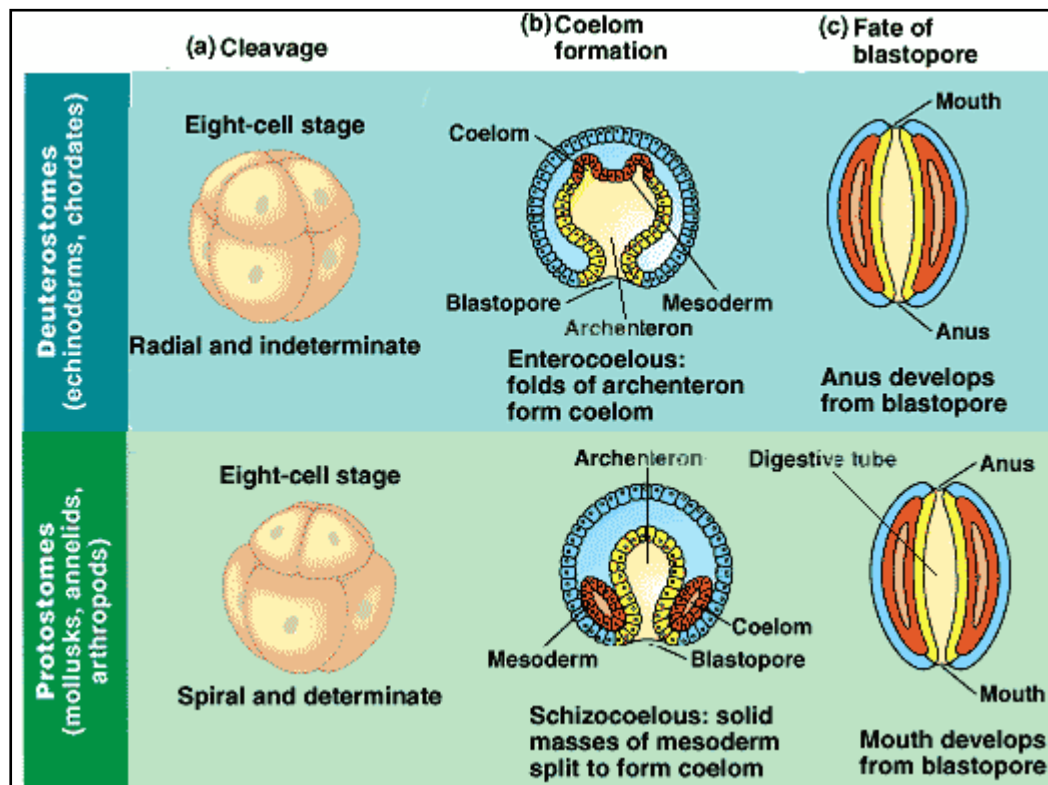


Figure 6. Protostomes and deuterostomes and cleavage type.

I.10.2. Symmetrical plan

Classification provides a systematic framework for the study of species, the identification of relationships between them, and the assignment of newly described species to specific groups. Symmetry is a critical factor in the classification of animals, given that it is one of the many classification criteria employed in this field. Symmetry facilitates the organisation and comprehension of the arrangement and function of body structures in animals.

In the field of biology, the term symmetry is defined as the balanced arrangement of body parts. It can also be defined as the arrangement of structures. Both of these are around a central axis. The central axis is also called a dividing line.

An organism is said to possess symmetry when its body parts exhibit regularity and correspondence in size, shape, and relative position. Symmetry represents a fundamental aspect of animal organisation and evolution, frequently exerting influence on behaviour, movement and ecological roles.

Symmetry is defined as the dividing line that separates an organism's body into mirrored halves. The classification of animals according to their symmetry is of paramount importance for the purposes of study and taxonomy.

Animals manifest diverse forms of symmetry in accordance with their evolutionary adaptations. These include asymmetry, radial symmetry and bilateral symmetry. Each type is distinguished by its unique characteristics and biological significance (**Figure 7**).

1) Asymmetry

The term is used to describe when an organism's body It cannot be divided into two identical halves by any plane or point. Example: **sponges**.

2) Radial Symmetry

Radial symmetry is characterised by the arrangement of body parts around a central axis, akin to the spokes of a wheel. These organisms are notable for their absence of clearly defined left and right sides, yet they may possess distinct oral (mouth) and aboral (opposite to mouth) surfaces. Radial symmetry is a structural characteristic that is particularly beneficial for organisms that have a sessile (fixed in one place) or floating lifestyle, as it ensures equal interaction with their surroundings.

Radial symmetry describes an animal's up-and-down orientation: any plane cut through the organism along its longitudinal axis produces equal halves, but there is no definite right or left side. This plan is mostly found in aquatic animals, particularly those that attach themselves to a base, such as a rock or a boat, and extract their food from the surrounding water as it flows past. **Examples:** Found in Coelenterates (**e.g., Hydra, jellyfish**), and Echinoderms (**e.g., starfish**).

3) Bilateral Symmetry

In the context of bilateral symmetry, Body parts are arranged on opposite sides. These sides are on a single median plane. Thereby resulting in two mirror-image halves. This symmetry is a pervasive feature of the majority of animal groups, particularly those that exhibit active movement and complex behaviours. Additional terminology employed for the description of anatomical positions includes the terms anterior (front), posterior (rear), dorsal (towards the back), and ventral (towards the stomach). Bilateral symmetry is a characteristic that is observed in both terrestrial and aquatic animals. This anatomical trait enables a high level of mobility. Bilateral symmetry has been shown to be closely linked to cephalisation, which is defined as the concentration of sensory organs and nervous tissue at the front of the body (head). This adaptation has been demonstrated to enhance directional movement, sensory perception, and environmental interaction. Examples include: Observed in annelids, arthropods and vertebrates, including humans.

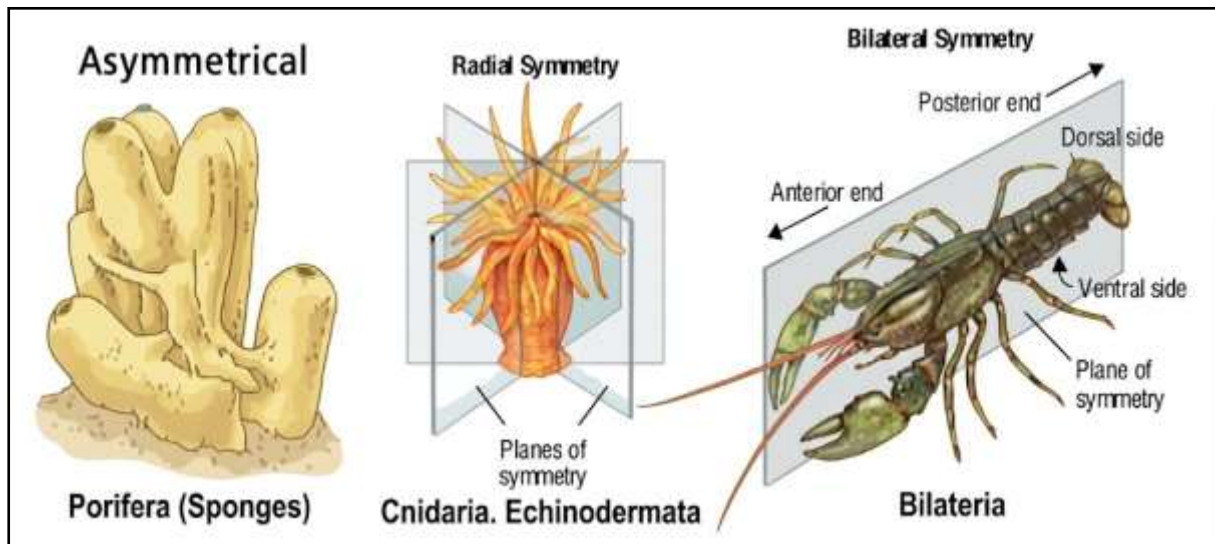


Figure 7. Types of symmetry.

1.10.3. Metamerism

Metameric segmentation, also known as metamerism, is a type of body plan found in some animals. It involves the repeated occurrence of similar body segments, known as metameres or somites, in a serial pattern (**Figure 8**). Each metamere or somite is structurally similar both externally and internally, and is constructed on the basis of a fundamental plan.

Metamerism was first documented in annelids within the animal kingdom. The most successful animals, including arthropods and chordates, also demonstrate metameric segmentation. The following four types are distinguished:

- 1) **Metameric segments** (true segmentation): the body is divided into segments, both internally and externally. Example: **Annelids**.
- 2) **External segmentation**. Example: **Arthropoda**.
- 3) **Internal segmentation**: Example: Chordata
- 4) **Pseudometameric segments** (false segmentation): the body segments are not formed from the embryo and are therefore known as pseudometamerism. Example: **Tapeworm**.

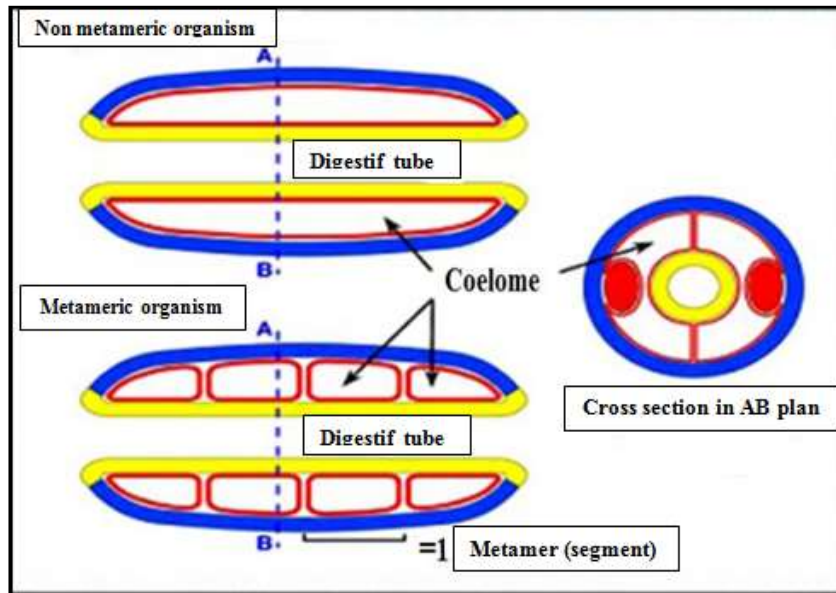


Figure 8. Presentation of metameric segment.

I.10.4. Level of organisation

The classification of animals is typically based on various criteria, and in this particular instance, the classification system under discussion is divided into five types.

With regard to the level of organisation :

1) The protoplasmic level of organisation : It is characterised by the cellular aspect of the body, which is responsible for executing all biological activities. For example, protozoa are characterised by this cellular aspect.

2) The cellular level of organisation is characterised by the cells of body are present in loose aggregates. It is imperative to note that the performance of all functions is contingent upon the collective execution of these cells. Example : The following essay will explore the function of **Sponges**.

3) Tissue level of organisation. The cells of an organism unite to form a tissue system that facilitates different functions. Examples include Coelenterata and Ctenophora.

4) Organ level of organisation is defined as the tissues occurs the combination of these elements results in the formation of organs. For instance : The taxonomic classification of **Platyhelminthes** is as follows.

5) Organ system level of organisation It is the level at which the various organ systems of an organism combine to form a complex system that helps the whole organism to function.

Examples include: The taxonomic classification system under consideration ranges from Aschelminthes to Chordata.

I.10.5. Skeleton

The framework of the body that gives animals their shape and protects them is known as the skeleton. There are two types of skeleton, which are categorised by their position.

1) Endoskeleton: The structure is hard. It is inside the body. Examples include: Bones are present in the body, like in humans.

2) Exoskeleton: It is present outside the body. There are many different types, such as:

-  Calcareous shells in molluscs.
-  Scales covering the epidermal of reptiles.
-  Feathers in birds.
-  Hair, nails, claws and horns in mammals.

I.10.6. Notochord

It is described as a solid, unjointed, mesodermal rod. It is located on the dorsal side of the body. Animals fall into two groups depending on whether it is present or absent:

1) No-chordates : Organisms that lack a notochord are known as non-chordates.

Examples include: Porifera to hemichordates.

2) Chordates : Organisms that possess a notochord are known as chordates. Examples range from fish to mammals.

I.10. 7. Type of cleavage

1) Mosaic (determinate cleavage) : A complete embryo is formed from all of the blastomeres. If any of these cells become detached, embryo formation will cease. Example: **Annelids.**

2) Non-mosaic (non determinate cleavage) : If some blastomeres are separated in the early stages of development, the remaining ones will develop into a complete embryo. Example: chordates.

I.10.8. Development

1) Indirect : The young do not resemble their parents. It undergoes metamorphosis through a number of larval or nymphal stages before developing into an adult. **Examples:** mosquito, frog, tapeworm.

2) Direct : The young one is said to resemble the adult. It does not undergo metamorphosis. Examples: Humans and birds.

I.10.9. Type of eggs : depending on quality of yolk, there are three types :

1) Microlecithal: The amount of yolk in the egg has reduced. Examples: Sea urchin eggs.

2) Mesolecithal: The level of yolk in the egg is considered moderate. **Examples:** Eggs from various animals, including frogs, fish and toads.

3) Macrolecithal: The egg contains a high quantity of yolk. **Examples:** Eggs from birds, reptiles and bony fish.

The distribution of yolk in the cytoplasm of an egg can be categorised into three types:

3.1. Homolecithal: The yolk is distributed evenly. Examples: The eggs of annelids, molluscs and protochordates

3.2. Telolecithal: The yolk is concentrated in the vegetal half. Examples: Eggs of amphibians.

3.3. Meiolecithal : The yolk is present throughout the cytoplasm, except for a small disc-shaped area reserved for the nucleus. Examples: Eggs of reptiles.

3.4. Centrolecithal: The yolk is located at the centre of the cell. Examples: The eggs of insects.

I.10.10. Body temperature

Organisms are classified into two types based on body temperature:

1) Homeotherms (warm-blooded animals): Their body temperature remains constant, regardless of changes in the surrounding environment. Examples: Birds and mammals.

2) Poikilotherms (cold-blooded animals): Their body temperature varies according to the temperature of their surroundings. Examples: Amphibians, fish and reptiles.

I.10.11. Mode of digestion

Digestion is classified into two types based on its location:

1) Intracellular: Digestion occurs inside the body's cells. Example: Amoeba.

2) Extracellular digestion : takes place outside the cell within a cavity of an organ.

Examples: Hydra.

I.10.12. Digestif system

There are two types:

1) Incomplete: A single opening that serves as both the mouth and the anus. Example:

Platyhelminthes.

2) Complete: Two separate openings, meaning both a mouth and an anus are present.

Examples: Aschelminthes, annelids, arthropods and chordates.

I.10.13. Respiration mode

Organisms exhibit two types of respiration:

1) Aerobic respiration: Organisms respire using oxygen. Examples: Mammals, reptiles and coelenterates.

2) Anaerobic respiration: Organisms respire in the absence of oxygen. Example: Flatworms.

I.10.14. Circulation mode

1) Open circulation: In this type of circulation, blood flows through spaces known as sinuses or haemocoel. There is no capillary system present. Blood moves at low pressure. Body tissues and vital organs exchange respiratory gases, nutrients and waste products directly with the blood. Examples of organisms with this type of circulation include Arthropoda and Mollusca.

2) Close circulation : In this circulation system, blood moves through blood vessels.

It can flow under either high or low pressure. Examples of organisms with this circulatory system include annelids and mammals.

I.10.15. Excretion mode

The process by which nitrogenous waste is removed from the body is called excretion. There are different types of excretion, depending on which type of nitrogenous waste is involved

1) Ammonotelism: This occurs when ammonia is the primary nitrogenous waste product. Animals that excrete ammonia are called ammonotelic. Examples include sponges, coelenterates, ctenophores and echinoderms.

2) Ureotelism: This occurs when urea is the main form of nitrogen waste. Animals that excrete urea are known as ureotelic. Examples include many terrestrial amphibians, marine fish and mammals.

3) Uricotelism: This occurs when uric acid is the primary form of nitrogenous waste. Animals that excrete uric acid are called uricotelic. Examples include land snails, insects, reptiles and birds.

I.11. Organization plan of animalia (figure 9).

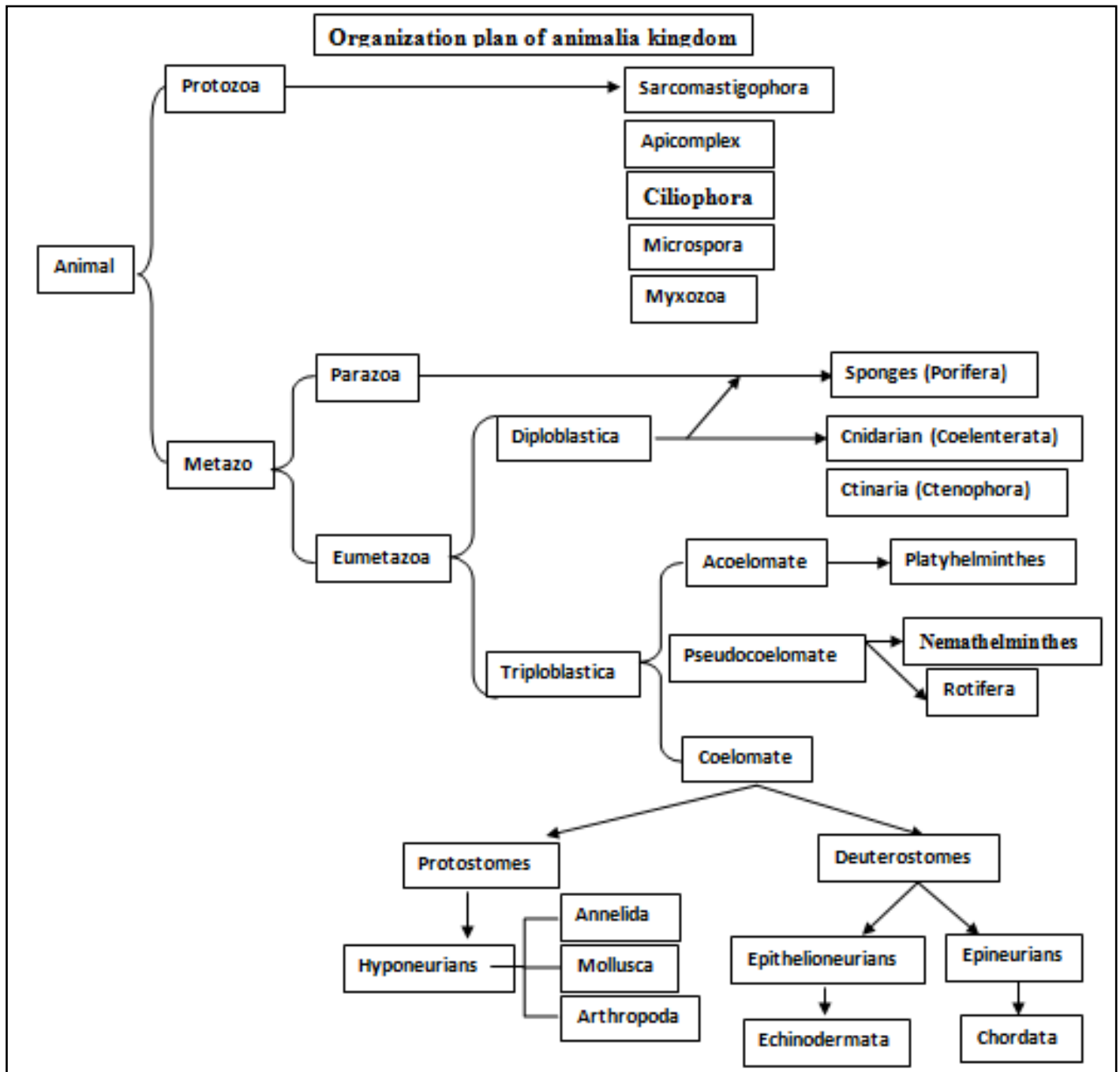


Figure 9. Organisation of animalia kingdom.

Introduction

Initially, they were classified as animals, but they could not truly be considered as such since they exhibited characteristics of both plants and animals, as seen in *Euglena*. Consequently, Haeckel placed them in a separate kingdom called Protista. This classification was later retained by Robert Whittaker in his five-kingdom system. For the purpose of this discussion, however, we will follow the traditional approach and study them as a phylum within the non-Chordata. The protozoa subkingdom includes more than 50,000 species found in almost all habitats where moisture is present.

2.1. General characters

Protos = One

These are eukaryotic animals, meaning they have a nucleus, and they are unicellular organisms. In other words, a single cell performs all vital functions, such as respiration, digestion, excretion and reproduction. In most cases, there is only one nucleus in the cytoplasm, which has distinct nucleoli and is often referred to as the endosome. The cytoplasm is usually differentiated into an outer, clear ectoplasm and an inner, granular endoplasm. The cell is covered by a delicate plasma membrane or a living pellicle.

2.1.1. Size : The vast majority are very small and can only be seen with the aid of a light microscope. Some of them are only 2–3 μm in size. The smallest are the Sporozoa, as well as certain intracellular parasites. The largest are amoebas, which can reach 5 mm.

2.1.2. Habitats : Present very diverse environments and lifestyles:

- Aquatic encountered both in marine (*Foraminifera*), fresh water (*Paramecium*)
- Terrestrial (land, soil), moist soil (*Amoeba*).
- Biological fluids : obligatory extracellular parasites (*Trypanosoma*) or intracellular (red blood cells (Plasmodium))

2.1.3. Level of body organisation: Protoplasmic level :

It consists of protoplasm and one or more nuclei. It may be enveloped by a plasmalemma, pellicle, cyst, theca or shell.

2.1.4. Locomotion

Some are mobile, locomotion is done by :

- Pseudopods (Rhizopodes) (*Amoeba*),
- Cilia (*Paramecium*)
- Flagella (*Trypanosoma*)
- Fixed (no locomotory organelles) (*Plasmodium*).

2.1.5. Mode of life

- Free living (*Paramecium*).
- Parasitic (*Plasmodium*).
- Symbiote (*Trychonympha sp*).
- Mutualistic

2.1.6. Mode of Nutrition

- **Autotrophy** (*Euglena*)
- **Heterotrophy** : this mode of nutrition regroup :
 - Saprophytic (feeding on liquid food).
 - Holozoic : animal –like.
 - Holophytic : plant-like.
 - Saprozoic (feed on dead organism).
 - Parasitic.

2.1.7. Digestion

Food vacuoles (phagotrophy).

Absence of vacuoles (Osmotrophy).

2.1.8. Respiration

Many protozoa rely on aerobic respiration. The exchange of respiratory gases occurs through simple diffusion across the body surface. However, some protozoa are capable of anaerobic respiration, which occurs in the absence of a suitable concentration of free oxygen in the surrounding medium.

2.1.9. Excretion

The excretion of catabolic nitrogenous wastes (mostly in the form of ammonia) also takes place by diffusion through the body surface. There are no specialised excretory organelles.

2.1.10. Osmoregulatory organelles : They are characterised by the presence of contractile vacuoles and are found in the majority of freshwater protozoa.

2.1.11. Reproduction : All protozoa can reproduce asexually, either through binary fission or multiple fission. However, some protozoa can also reproduce sexually by producing male and female gametes.

2.1.12. Encystment : This is a common feature of the life cycle of many protozoa, whereby the organism secretes a protective cyst around itself to enable it to survive in adverse environmental conditions and disperse.

II.2. Classification

The classification criteria are based on:

- The type of locomotory organelles found in the various species
- The type of development cycle

The Protozoa are divided into five main phyla.

II.2.1. Phylum Sarcomastigophora (Rhizomastigophora)

II.2.2. Phylum Apicomplexa (Sporozoa)

II.2.3. Phylum : Ciliophora

II.2.4. Phylum : Microspora

II.2.5. Phylum : Myxozoa (Cnidosporida).

2.2.1. Phylum SARCOMASTIGOPHORA

The word comes from the Greek '*sarkos*', meaning '*fleshy*', '*mastigo*', meaning '*whip*', and '*phoros*', meaning 'to bear'.

The phylum Sarcomastigophora is divided into the following two subphyla::

- **Sub-phylum Sarcodina** : Movement is by means of pseudopodia, which can take a variety of forms
- **Sub-phylum Mastigophora** : Movement is by means of one or more flagella.

2.2.1. 1. Subphylum SARCODINA

Protozoa with use temporary protoplasmic projection known as pseudopodia for locomotion. Free-living members are either fresh water or marine inhabitants. Certain species live in association with other organisms either as commensals or as parasites. *Amoeba* ; *Entamoeba* and Foraminifera are common examples of this subphylum. The systematic is based on the presence or absence of the external shell. This is also known as the theca or test. It is also based on the morphology of pseudopodia.

- **Diversity**: A relatively small group (200 species).
- **Shape**: The body is constantly changing (amoebae).
- **Life mode**: It can be :
 - Free-living : Example: *Amoeba proteus*.
 - Parasitic : Example: *Entamoeba histolytica*, *Entamoeba gingivalis*.
 - Symbiotic: Example *Entamoeba coli*.
- **Habitat and distribution**: Organisms generally free-living in seas, fresh waters and moist land.
- **Morphology**

Under the microscope, a living amoeba appears as an irregular, jelly-like body covered by a thin living membrane known as the plasma membrane or plasmalemma.

The cytoplasm is divided into ectoplasm (the outer, transparent layer) and endoplasm (the inner, granular layer). The endoplasm contains an oval nucleus, a pulsating spherical contractile vacuole and food vacuoles (**Figure 10 a**).

➤ Locomotion

Amoeba moves and captures food by means of the pseudopodia which arises at any point on the body surface. This sort of irregular movement is very slow and is called **amoeboid** movement. Several pseudopodia may be developing at one end at the same time (**figure 10 b**).

➤ Nutrition

The amoeba is holozoic in its nutrition, forming a food vacuole inside the cytoplasm. Digestion starts immediately under the effect of digestive enzymes, which are secreted into the food vacuole (**Figure 10 b**). It has recently been demonstrated that amoebae can also obtain dissolved organic matter from the surrounding environment by pinocytosis.

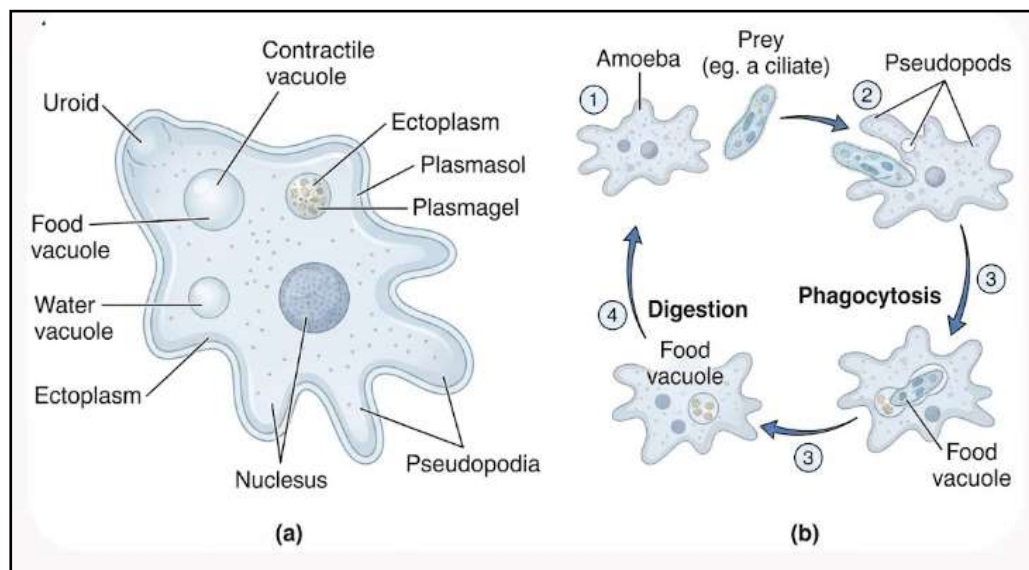


Figure 10. Amoeba morphology (a) ; Amoeboid movement, food capture and nutrition (b).

➤ Reproduction

Amoeba reproduce only asexually by **binary fission** (**Figure 11**). The process of division takes about 30 minutes.

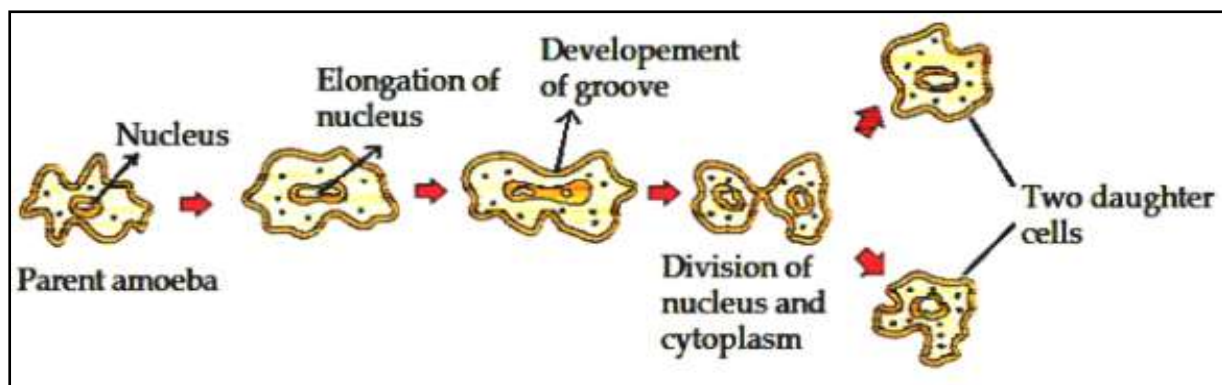


Figure 11. Binary fission in *Amoeba*.

➤ Osmoregulation

This is carried out by a pulsating contractile vacuole, which bursts at regular intervals to expel excess water that has diffused into the cytoplasm from the surrounding medium.

➤ Respiration and excretion

Exchange of respiratory gases between *Amoeba* and its environment takes place by simple **diffusion**. The product of nitrogenous metabolism diffuse in a similar way through the body surface to the outside.

➤ Encystment

Under unfavourable conditions, such as the drying up of the water in environment, *Amoeba* withdraws its pseudopodia, become spherical and forms a tough resistant cyst around itself.

Classification

Sarcodina are classified according to the presence or absence of an outer shell, as well as the morphology of their pseudopods, which can be lobed, digitate, filiform or anastomosed (reticulopodia) (Figure 12). The Sarcodina are classified into two superclasses: Rhizopoda and Actinopoda.

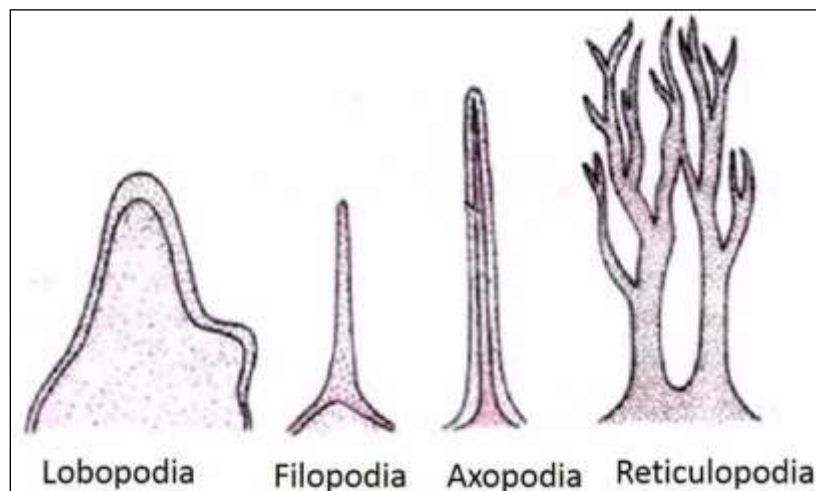


Figure 12. Different type of pseudopodia.

1.1.1. Superclass Rhizopoda (true Amoeba).

This superclass regroup two classes : **Lobosea** and **Foraminifera (Foratus)**

1. Class Lobosea

- ✓ Generally single nucleated species
- ✓ It is found in humid areas, on decomposing matter in shallow water or on the substrate of freshwater ponds, lakes and slow-moving streams.
- ✓ Lobed pseudopodia, filiform to a greater or lesser extent.
- ✓ Some parasitize the intestines, lungs and liver of the human body.
- ✓ Feed on the protists and bacteria.
- ✓ Food incorporated in the form of vacule.
- ✓ Engulf food by phagocytosis.
- ✓ Asexual reproduction : binary fission.
- ✓ No sexual reproduction is known to occur

Class Lobosea is divided into subclass : **Gymnamoeba** and **Thecamoebae**.

1.1. Subclass Gymnamoeba : Naked without test or shell.

1.1.1. Order Amoebida

Example 1 : *Amoeba proteus (Chaos diffluens)*, free living Amoeba of freshwater with 500 µm.

Example 2 : parasitic : *Entamoeba histolytica*

Entamoeba shares many characteristics with Amoeba, but the former lives as an endoparasite in the large intestine of certain mammalian hosts. Three species of *Entamoeba* infect humans: *E. histolytica*, *E. coli* and *E. gingivalis*. Several other species occur in other mammals; for example, *Entamoeba mui* is a parasite of rats and mice. *Entamoeba histolytica* causes dysentery (intestinal amoebiasis) by invading the mucosa and submucosa layers of the large intestine in human beings. *E. histolytica* are commonly found in tropical and subtropical countries. The life cycle of *E. histolytica* begins and ends inside one single host, i.e., an individual human being (**Figure 13**).

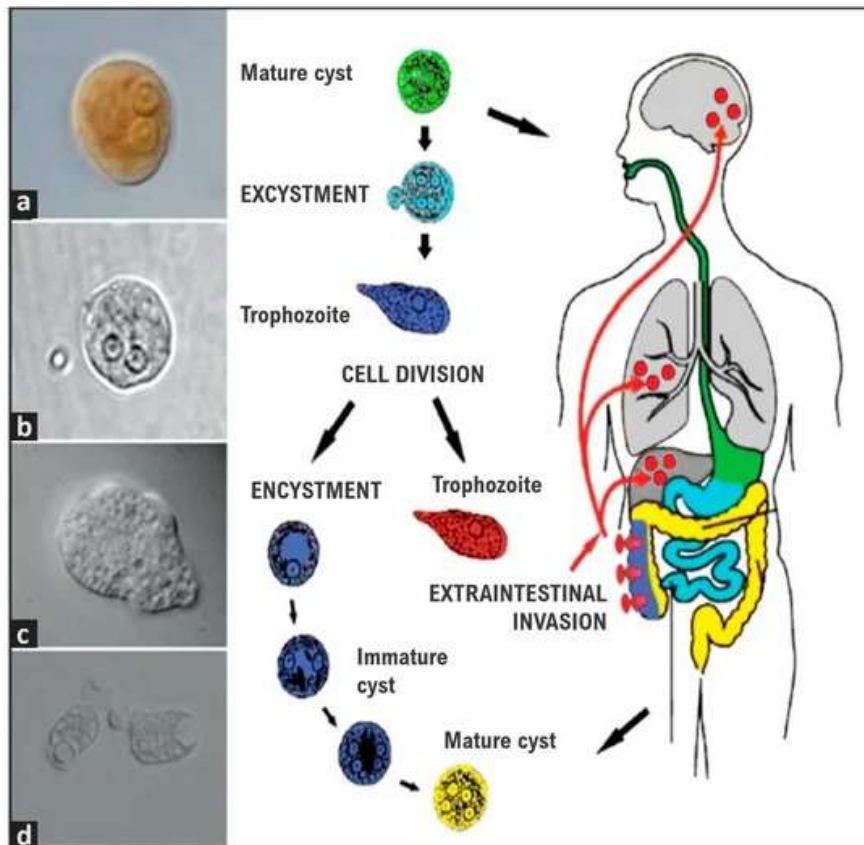


Figure 13. The life cycle of *E. histolytica*/E. (a) mature cyst stained; (b) mature cyst without staining; (c) trophozoite; (d) trophozoites of *E. histolytica* with phagocytosed erythrocytes.

Example 3 : parasitic *Entamoeba coli*

It is considered non-pathogenic and is found worldwide. It frequently exists as a commensal parasite in the human gastrointestinal tract. As with other intestinal amoebae, *E. coli* is transmitted by ingesting infected cysts via contaminated food, water or drinks. Its life cycle is similar to that of *E. histolytica*, but it does not have an invasive stage or ingest red blood cells. There are no clinical symptoms during or after infection by this parasite.

Example 4 : parasitic *Entamoeba gingivalis*

It is the first amoeba to be recovered from a human specimen, having been discovered in 1849. Infection with *E. gingivalis* can occur in both the mouth and the genital tract. It is nonpathogenic and there are no clinical symptoms during or after infection by this parasite. Trophozoites are frequently found in patients with pyorrhea alveolaris. *E. gingivalis* infections are contracted via mouth-to-mouth contact (kissing). 2. Droplet contamination. 3. Sexual intercourse. They may also be transmitted through contaminated drinking utensils or intrauterine devices. There is no known cyst stage of *E. gingivalis*; only the trophozoite stage is present.

1.2. Subclass : Thecamoebians or Testacea

This diverse group includes theca- or shell-bearing amoebae (testaceous rhizopods). While the majority of species have lobosa-like pseudopods, some genera have filopodia (Figure 14).

Their habitats and distribution: they live in open freshwater or in the film of water covering the leaves of plants, mosses, or soil fragments. Testacea are covered by protective chitinous shells. Examples: *Diffugia* and *Arcella*.

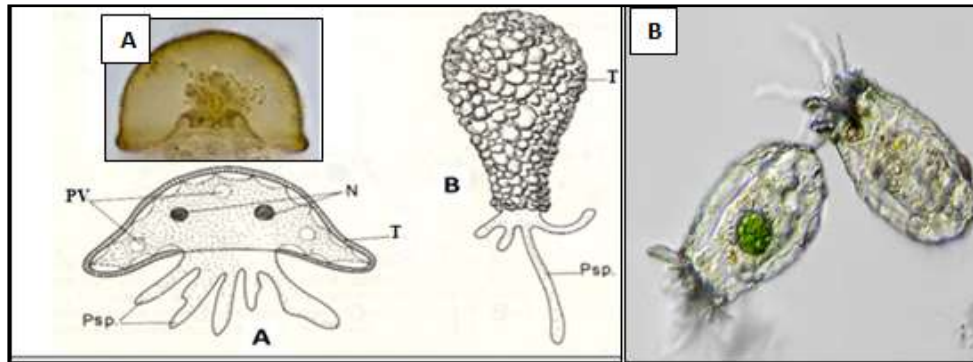


Figure 14. *Arcella* sp (A), *Diffugia* sp (B), T: Theca (shell), n : nucleus, PV : Pulsatile vacuoles ; Psp : Pseudopode.

2. Class Foraminifera

- The Foraminifera class is the most important group of microfossils. They are abundant in rocks and comprise numerous species. They provide valuable information about dating strata and reconstructing sedimentary environments.
- Single-celled organisms protected by a hard shell or test, known as forams or bygs, which can be perforated or imperforate. (figure 15).

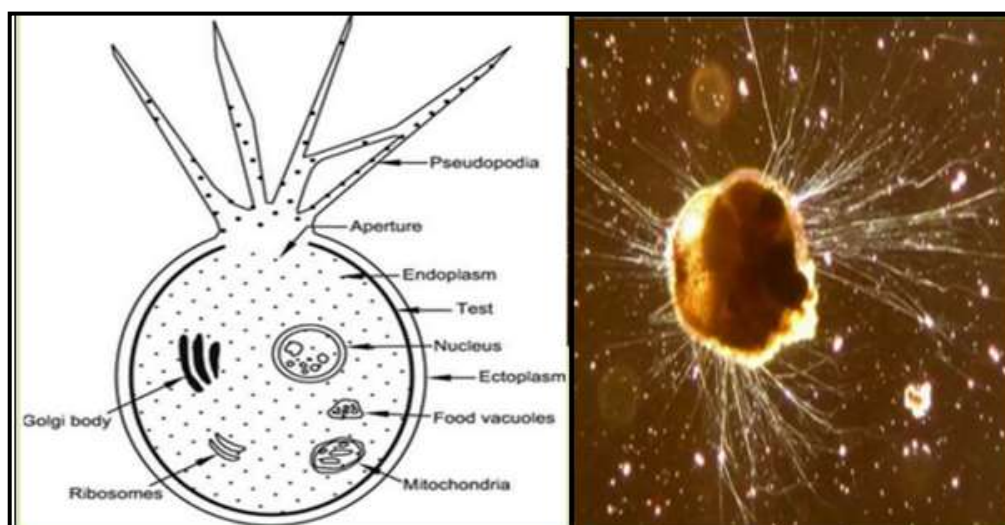


Figure 15. Benthic foraminifera in cross section.

Shells are composed of a variety of minerals, but three main categories have been documented: organic, calcareous and agglutinated, and occasionally siliceous.

Their shell (test) which consist of single or multiple chambers (**Figure 16**) , each chamber is interconnected by an opening (foramen) or several opening (foramina).

- Found in all marine environments and they may be planktonic or benthic in mode of life.
- They are an estimated 4000 species living in the word oceans today. 40 species are planktonic.
- Size range from 100 µm to almost 20 cm long and are preserved in variety of rock type.
- Nutrition : they catch their food with thread-like pseudopodia that extend from one or more opertures in the shell Their food is made up of bacterial, algae, larvae of invertebrates (mollusks, echinoderms or crustaceans).
- Reproduction : Alternation of asexual and sexual generation.

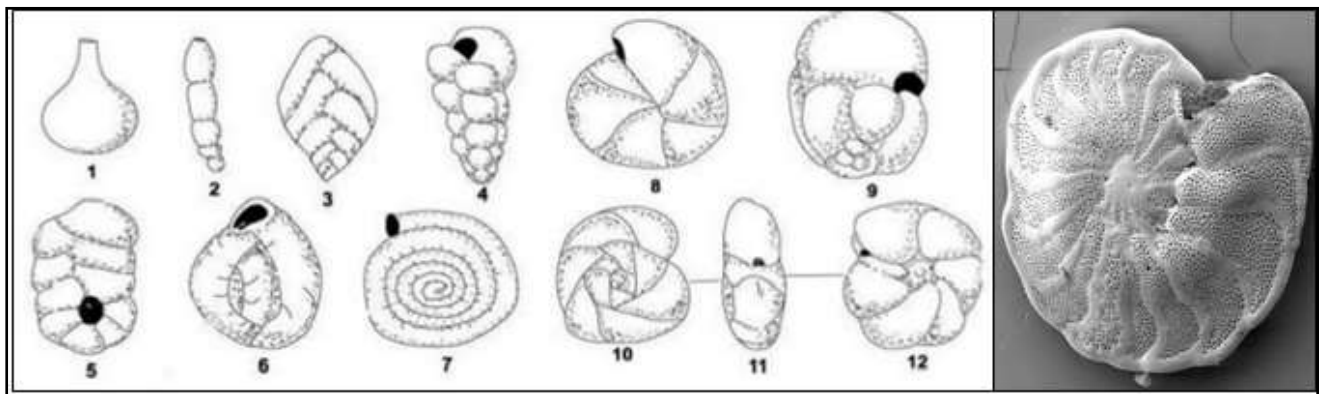


Figure 16. Principal type of chambers from Foraminifera

*1 : single chamber ; 2 : Uniserial ; 3 : Biserial ; 4 : Triserial ; 5 : Planispiral ; 6 : Milloline ; 7 : Planispiral evolute ;
8 : Planispiral involute ; 9 : Streptospiral ; 10-11-12 : Trophospiral.*

1.1.2. Superclass Actinopoda

- Unicellular marine organisms
- Spherical body with calcareous test and radial arrangement of the pseudopodia
- The majority of actinopods have calcareous or siliceous (SiO₂) external skeleton. They are spicules and cytoplasmic extensions (filopodia and axopodia) project from the cell body.
- Axopodia are composed of bundles of microtubules, while filopodia are simple cytoplasmic extensions.

- The spicules, which are covered in cytoplasm, are formed by an endoskeleton which varies in composition according to the species.
- Free living, they are adapted to planktonic life planktonic.
- Reproduction is asexual by binary division or budding or sexual with the involvement of cysts
- **Classification** : Actinopoda is divided in three classes : Acantharea, Phaeodarea (Radiolarians) and Heliozoans (**Figure 17**).

1.1.2.1. Class Acantharea

- Skeleton with 10 to 20 spicules with radial arrangement
- Ectoplasm contains symbiotic algae (Zooxanthellae)
- Pelagic marine, planktonic, solitary or colonial.
- Slender pseudopods and axopods for prey capture
- Reproduction : asexual by binary fission.
- Endoplasm containing a nucleus, digestive vacuoles, lipids and pigments
- **Example** : *Doraspis sp* ; *Acanthoplegma sp*

1.1.2.2. Class Phaeodarea (Radiolarians)

- Habitat: marine. They are either suspended at the surface (plankton), found at varying depths (zonarial) or near the bottom (abyssal). They are part of the zooplankton
- Large size non motile
- They may be solitary or colonial, some colonies as many centimeters.
- The skeleton is either siliceous or made of spicules, or it is perforated and made of definitely arranged spicules of proteid matter (acanthin).
- Reproduction occurs by fission and by zoospores formed in the central capsule.

Examples : *Thalassicolla nucleata* ; *Thalassicolla pellucida*

1.1.2.3. Class Heliozoans

- Freshwater or marine actinopods
 - Sarcodina have radiating, non-anastomosing pseudopodia made of granular protoplasm. The pseudopods are fine rays and can be filopods or axopods arranged in a radial manner.
 - Free or fixed by a stalk
 - Spherical or ovoid shape
- Naked or enclosed in shell
- Ectoplasm also contains zooxanthellae and numerous digestive and pulsatile vacuoles

- The skeleton is not always present.
- The endoplasm comprises one or more nuclei and generally a centrally located body towards which the radiate axopodia
- Reproduce by simple division or budding
- Example : *Actinolophus pedunculatus* ; *Acanthocystis aculeata*.

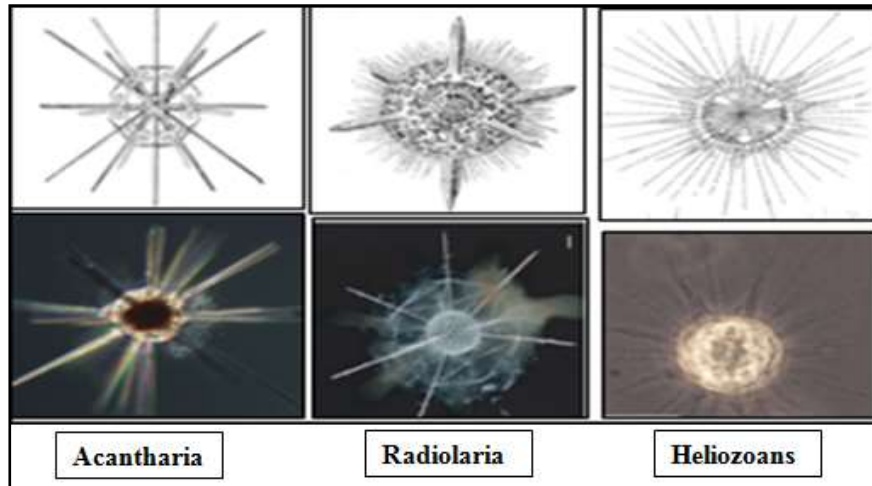


Figure 17. Different morphology of Actinopoda.

2.2.1.2. Subphylum MASTIGOPHORA

Includes protozoa which move by one or more flagella. Many species live in fresh or marine water, and some live as parasites. This subphylum is divided into classes according to the presence or absence of chromatophores :

General characters

- ✚ **Locomotion** : one or more flagella.
- ✚ **Mode of life** : Free living Choanoflagellates (Rhizomastigines), parasites (trypanosomes) or symbiotic (xylophages).
- ✚ **Habitat** : They live in the freshwater, sea or moist soil, Body fluid
- ✚ **Reproduction** : Longitudinal binary fission

Classification

The general classification of flagellate is present in table 4.

Table 4. Global classification (taxonomy) from Mastigophora

Classe	Order	Example
Phytomastigophorea	Euglenida	<i>Euglena spirogera</i> ; <i>Euglena viridis</i>
	Volvocida	<i>Volvox sp</i>
Zoomastigophorea	Choanoflagellida	<i>Salpingoeca sp</i> ; <i>Codonosiga sp</i>
	Kinetoplastida	<i>Trypanosoma</i> , <i>Crithidia</i> , <i>Leptomonas</i> , <i>Leishmania</i>
	Diplomonadida	<i>Giardia intestinalis</i>
	Trichomonadida	<i>Trichomonas vaginalis</i>
	Hypermastigida	<i>Trychonympha agilis</i>

1.2.1. Class Phytomastigophorea includes plant-like free living flagellates which have chromatophore, Example : *Euglena* (**Figure 18**) lives as solitary individuals and *Volvox sp* lives in colonies (**Figure 18**).

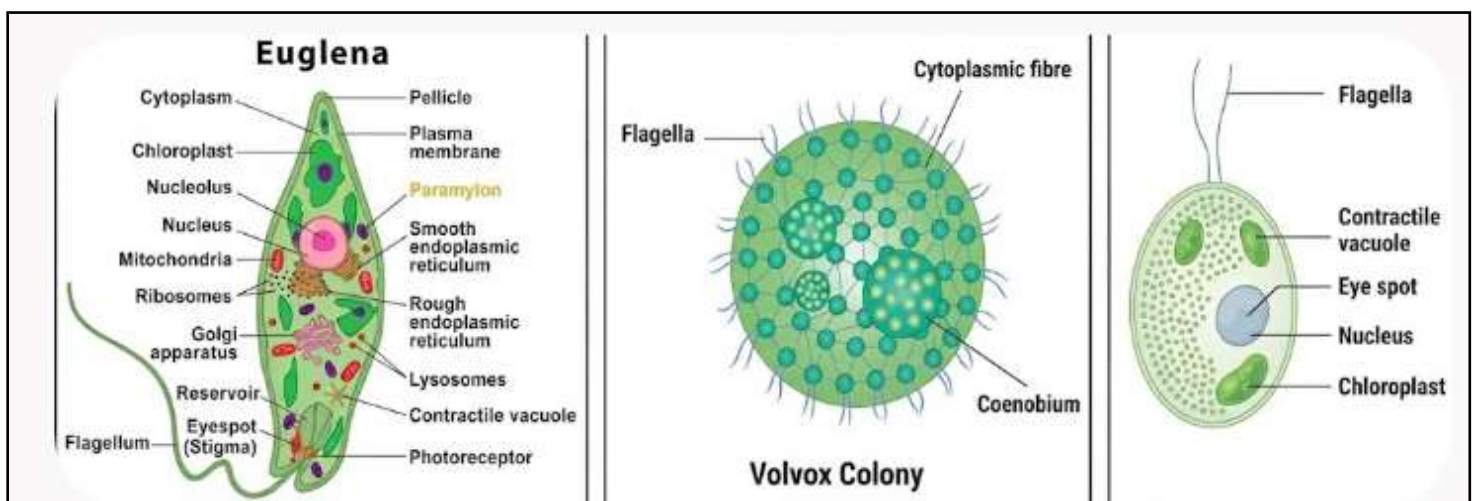


Figure 18. Structure of *Euglena* and *Volvox sp*.

1.2.2. Class Zoomastigophorea

Zooflagellates are a group of organisms that are commonly known by this name. They have a spherical, elongated body with a single central nucleus. These single-celled, heterotrophic eukaryotes may be symbiotic, free-living or parasitic. They have one or more flagella and some have an axostyle and a parabasal body. The body axis extends from the centrosome to the nucleus. They reproduce asexually by longitudinal binary fission. **(Figure 19).**

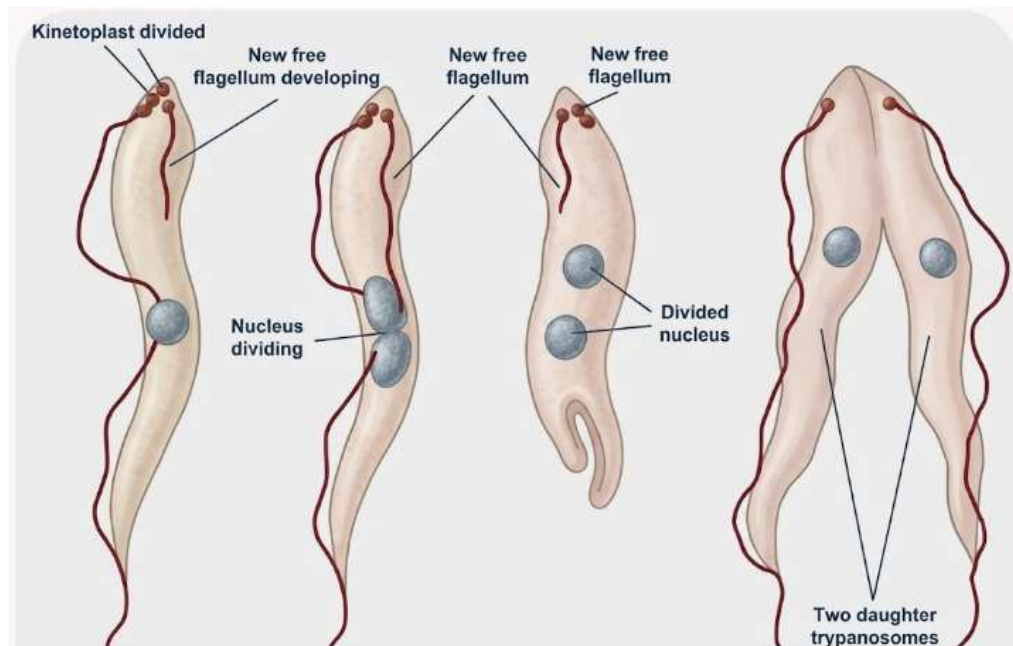


Figure 19. Longitudinal binary fission from Trypanosoma.

Classification: They are divided into the following six orders : Choanoflagellida, Kinetoplastida, Diplomonadida, Trichomonadida, Bodonida (Bodonina), Opalinida, Hypermastigida.

1.2.2.1. Order of Choanoflagellida (Rhizomastigines)

Choanoflagellates are a group of unicellular and colonial free-living flagellate eukaryotes with one or two flagella, Example: *Codonosiga* sp **(Figure 20 a)** (lives in colonnies) and lives as solitary individuals example : *Salpingoeca* sp **(Figure 20 b).**

1.2.2.2. Order of Kinetoplastids (Protomonadines)

Kinetoplastids are flagellated protozoa, which are unicellular eukaryotic organisms. They include free-living microorganisms, as well as parasites of diverse invertebrates and vertebrates. They present a single flagellum directed forwards and connected to the

cytoplasmic mass by an undulating membrane. The body of Trypanosoma (Figure 20), consists of following characteristics :

- 1. Pellicle :** The body is covered by a thin, elastic, firm membrane that maintains its shape. This membrane is also known as the cell membrane and encloses the cell organelles, including the nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus and ribosomes.
- 2. Flagellum :** A single flagellum is derived from a basal body located close to the posterior and the kinetoplast.
- 3. Undulating membrane :** The body is covered by a spiral-shaped membrane that is an adaptation for locomotion in the blood. This membrane is known as the flagellum.
- 4. Nucleus :** The nucleus of the parasite lies almost in the centre of the cell body, taking the form of a large, oval shape.
- 5. Cytoplasm :** The cytoplasm contains numerous greenish, refractile granules known as volutin granules. These granules store food particles, primarily glycogen and phosphate. The basal granule, also known as the blepharoplast or parabasal body, is located at the base of the flagellum.
- 6. Kinetoplast :** A small, spherical or disc-shaped kinetoplast is located just behind the basal body.

Characteristics

- They live in the blood or tissues of humans and other animals.
- They are comparatively complex in structure.
- They have well-developed organelles for locomotion.
- They complete their life cycle in two hosts: vertebrates and insects.
- While developing inside the insect host, they pass through various stages..

Trypanosoma Form

- 1.** They are usually parasites. Example: The Trypanosomides family. The members of this family can appear in four typical forms:
- 2.** Trypomastigote: bloodstream form; infectious from replicative.
- 3.** Epimastigote: replicative stage in insects.
- 4.** Promastigote: the infective stage of *Leishmania spp.*
- 5.** Amastigote: non-motile, intracellular stage in vertebrates.

Examples

1) Genus : *Trypanosoma* : according to their transmission mode, they are classified into 4 categories:

1.1. *Trypanosoma brucei* ; *Trypanosoma gambiensi* African **sleeping sickness** (African trypanosomiasis). Transmits by the fly called : Fly **Tsetse** ; *Glossina palpalis*

1.2. *Trypanosoma cruzi*- Chagas diseases (American trypanosomiasis). Transmits by *triatomine bug*.

1.3. *Trypanosoma evansi* : Is transmitted by flies, which play a role in the mechanical inoculation of horses, cows and dromedaries.

1.4. *Trypanosoma equiperdum* : Directly transmitted during sexual coitus in equidae (horses).

2) Genus: *Crithidia*

It is similar to *Trypanosoma*. The undulating membrane is not very well developed. The flagella inserts into the kinetosome, which is located in front of the nucleus. They are parasites of insects.

3) Genus: *Leptomonas*

They are characterized by the anterior position of their blepharoblast and the common existence of an intra-cytoplasmic flagellum. Usually, has a very anterior kinetosome (figure 20).

3) *Leishmania*

Leishmania is an obligate intracellular protozoan parasite belonging to the family Trypanosomidae. It spends part of its life cycle in the gut of a sandfly and part in the blood and tissues of a vertebrate host. *Leishmania* is responsible for the disease leishmaniasis. The parasite exists in two forms:

➤ **Amastigote**: This is the form found in human and other mammalian hosts. It is found inside monocytes, polymorphonuclear leucocytes, or endothelial cells. These small, round-to-oval bodies measure 2–3 µm in length. They are also known as *Leishmania donovani* (LD) bodies. **(Figure 20).**

➤ **Promastigote:** These forms are found in the midgut of sandflies and in culture media. The fully developed promastigotes are long. They measure between 15 μm and 25 μm in length, and between 1.5 μm and 3.5 μm in breadth. A single nucleus is located at the centre. The kinetoplast lies near the anterior end. The flagellum is single and delicate, measuring 15–28 μm . (**Figure 20**).

3.1. Cutaneous leishmaniasis

Cutaneous leishmaniasis (CL), also known as the "Oriental sore", is a parasitic skin infection. It is the most common form of the disease and causes skin lesions, mainly ulcers, on parts of the body that are exposed. These can leave life long scars and cause serious disability or stigma. Around 95% of CL cases occur in the Americas, the Mediterranean basin, the Middle East, and Central Asia. It is estimated that there are 600,000 to 1,000,000 new cases worldwide each year. The amastigote form infects the cells of the skin. The vector is a female from the genus *Phlebotomus*.

Examples :

Leishmania tropica minor : Vector : ***phlebotomus sergenti***

Leishmania major : Vector : ***phlebotomus pappatasi***

3.2. Visceral Leishmaniasis (Kala-Azar)

Visceral leishmaniasis (VL), also known as kala-azar, is caused by *Leishmania donovani* and is fatal if left untreated in over 95% of cases. Symptoms include irregular bouts of fever, weight loss, enlarged spleen and liver, and anaemia. Most cases occur in Brazil, East Africa, Sudan, Ethiopia, India, China, and South America. The vector species include *Phlebotomus argentipes* and *Phlebotomus orientalis*.

In the Mediterranean area and Central Asia, *Leishmania infantum* is the parasite, which is vectored by *Phlebotomus ariasi* and *Phlebotomus perniciosus*. It is estimated that there are 50,000 to 90,000 new cases of VL worldwide each year.

1.2.2.3. Order Diplomonadins (Holomastidins)

Small-sized zooflagellates, whether free-living or parasitic, have double organelles arranged symmetrically. *Giardia duodenalis* (synonyms: *Giardia lamblia* and *Giardia intestinalis*), hereafter referred to as 'Giardia', is the causative agent of giardiasis, one of the most common parasitic diarrhoeal diseases affecting humans. This flagellated protozoan colonises the proximal small intestine (the duodenum and jejunum). *Giardia* exists in two forms: trophozoite (vegetative form, 15 μm) and cyst (**Figure 20**).

In the *Giardia* life cycle, the mode of transmission is as follows: Ingesting cysts in contaminated water or food induces infection. Within an hour of ingestion, the cyst splits to form two trophozoites, which subsequently multiply by binary fission and colonise the duodenum. The trophozoites reside in the two upper intestines and feed by pinocytosis. Encystment typically takes place in the colon under unfavourable circumstances. The cysts are passed in faeces and can remain active for many weeks in soil and liquids.

1.2.2.4. Order Trichomonadins

Parasites protozoan monoxene of humans and several vertebrates with numerous flagella (3 to 6 flagella) in varied arrangements and a complex parabasal apparatus and is the cause of **trichomoniasis**.

Trichomonas has four (4) distinct species :

1-*Trichomonas intestinalis*: It lives in the cecum and the colon, where it eats bacteria. But whether it has a harmful role is still up for debate.

2- *Trichomonas vaginalis* (Figure 20): cause of vaginitis in women and urethritis in the man. *T. vaginalis* prefers to infect squamous epithelia rather than columnar epithelia. Cysteine proteases, lactic acid, and acetic acid are secreted, which disrupt glycogen levels and lower the pH in the vaginal fluid. *T. vaginalis* is an obligate parasite that requires direct contact with the vaginal, urethral, or prostatic tissue.

3- *Trichomonas hominis* : which habit in large intestine, non pathogenic

4- *Trichomonas tenax* : which habit in oral cavity and commensals.

Life cycle from : *Trypanosoma*, *Leishmania*, *Giardia* and *Trichomonas* is illustrated in figure 21.

1.2.2.5. Order of Bodonida

Bodonida live freely in stagnant water. They are characterised by the presence of two flagella: one directed forwards and the other behind, either free or attached to the cytoplasm by a small undulating membrane. They can be either free-living or parasitic. Example: ***Bodo saltans***.

1.2.2.6. Order Opalina

Opalina are large (100 to 300 μ) flagellates. Body is foliaceous and fusiform with many short flagella arranged in oblique rows all over the cell body. They lack centrosomes and axostyles. They contain many identical nuclei (syncytium). Mode of nutrition is osmotrophic. They divide by and asexual multiplication (longitudinal binary).

A single Class (Opalinata), with one Order (Opalinida).

Example: ***Opalina ranarum*** : Parasitic flagellates that live in the intestines of cold-blooded vertebrates (Poikilotherms such as amphibian (frogs).

1.2.2.7. Order **Hypermastigina (Hypermastigida)**

Uninucleate parasites with numerous flagella in various arrangements (**Figure 20**). They living in the rectal cavity of termite. It has several thousands of anterior flagella. Its symbiotic cytoplasm contains a number of bacteria which help to digest cellulose.

Example : *Trichonympha gilis*.

Life cycle of *Trypanosoma*, *Leishmania*, *Giardia* and *Trichomonas* was illustred in figure 21.

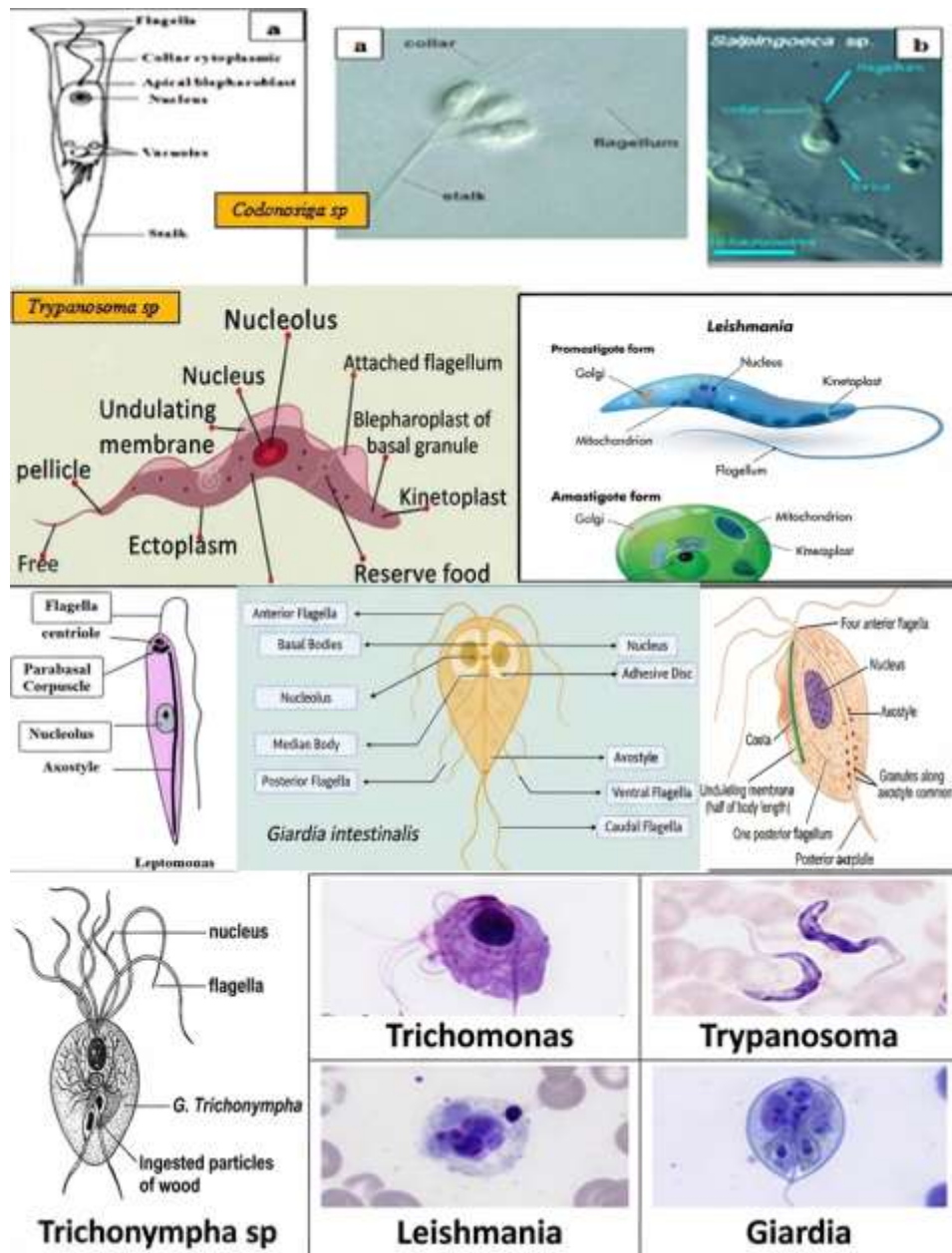


Figure 20. Different form of Zoomastigophorea

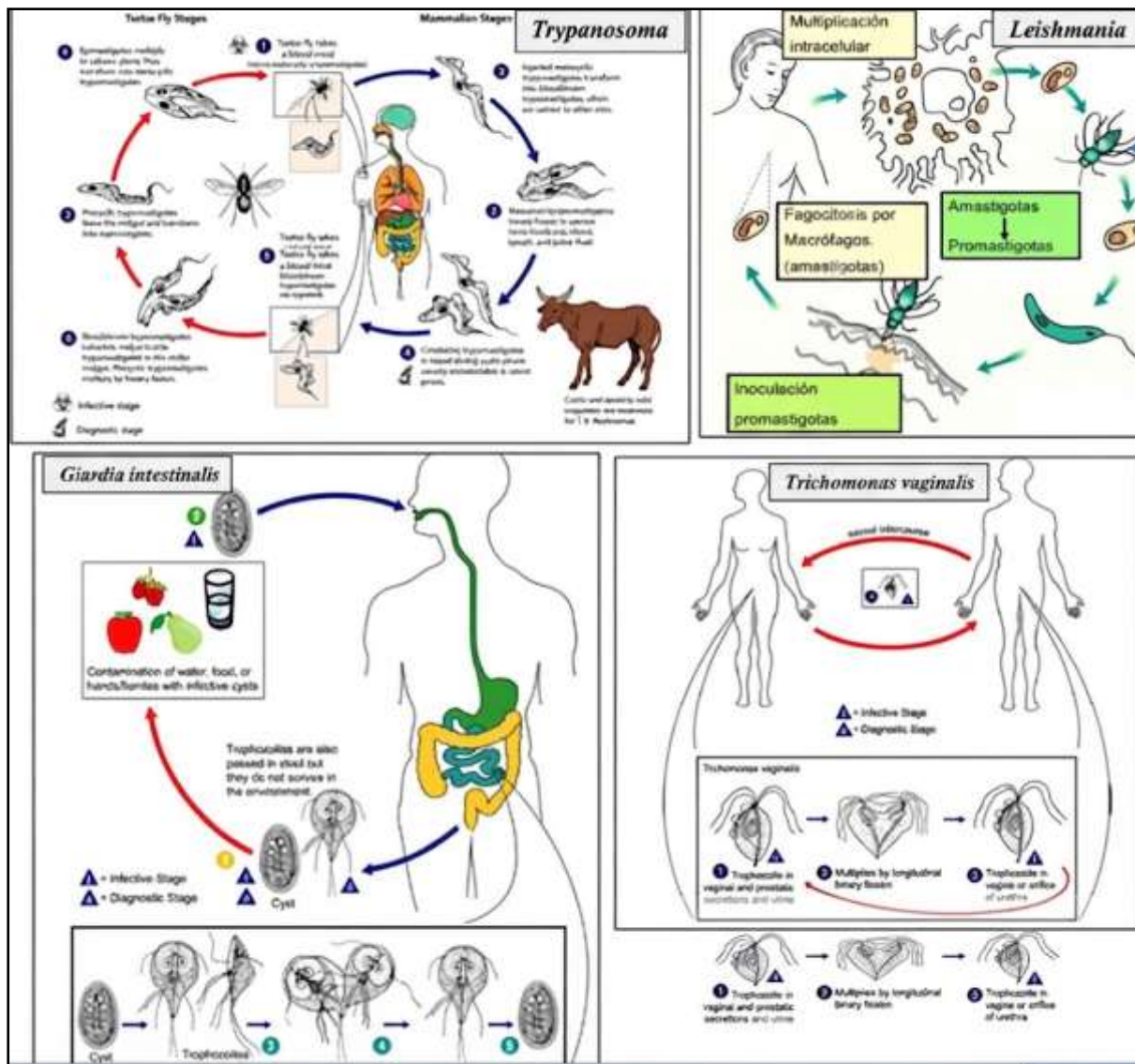


Figure 21. Life cycle of *Trypanosoma*, *Leishmania*, *Giardia* and *Trichomonas*

2.2.2. Phylum Apicomplexa ou Sporozoaires

General characteristics :

All parasites (**Intracellular** Parasites)

No distinct locomotory organelle (**Figure 22**).

Reproduce by **Spore**, a period of **asexual** replication (**schizogony**)

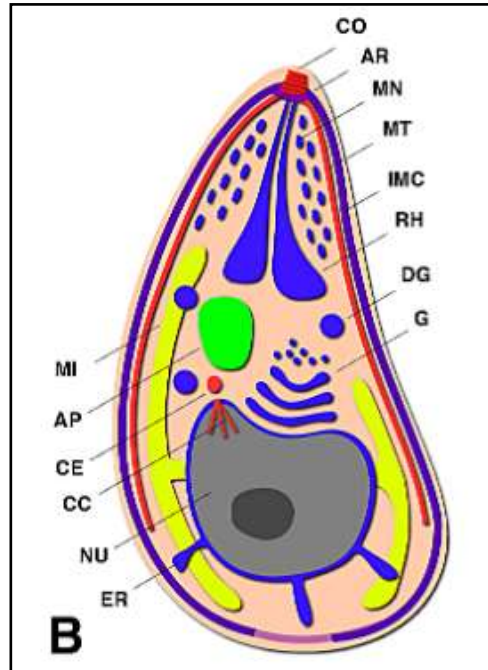


Figure 22. Schematic representation of apicomplexan.

(**Not all structures are present in all apicomplexans**). **AP**, apicoplast; **AR**, apical rings; **CC**, centrocone; **CE**, centrosome; **CO**, conoid; **DG**, dense granule; **ER**, endoplasmic reticulum; **G**, Golgi; **IMC**, inner membrane complex; **MI**, mitochondrion; **MN**, microneme; **MT**, subpellicular microtubule; **NU**, nucleus; **RH**, rhoptry.

Life cycle is **complex** and usually involves **asexual** and **sexual** reproduction (**gamogony**), and sometimes also **two hosts** (**Figure 23**).

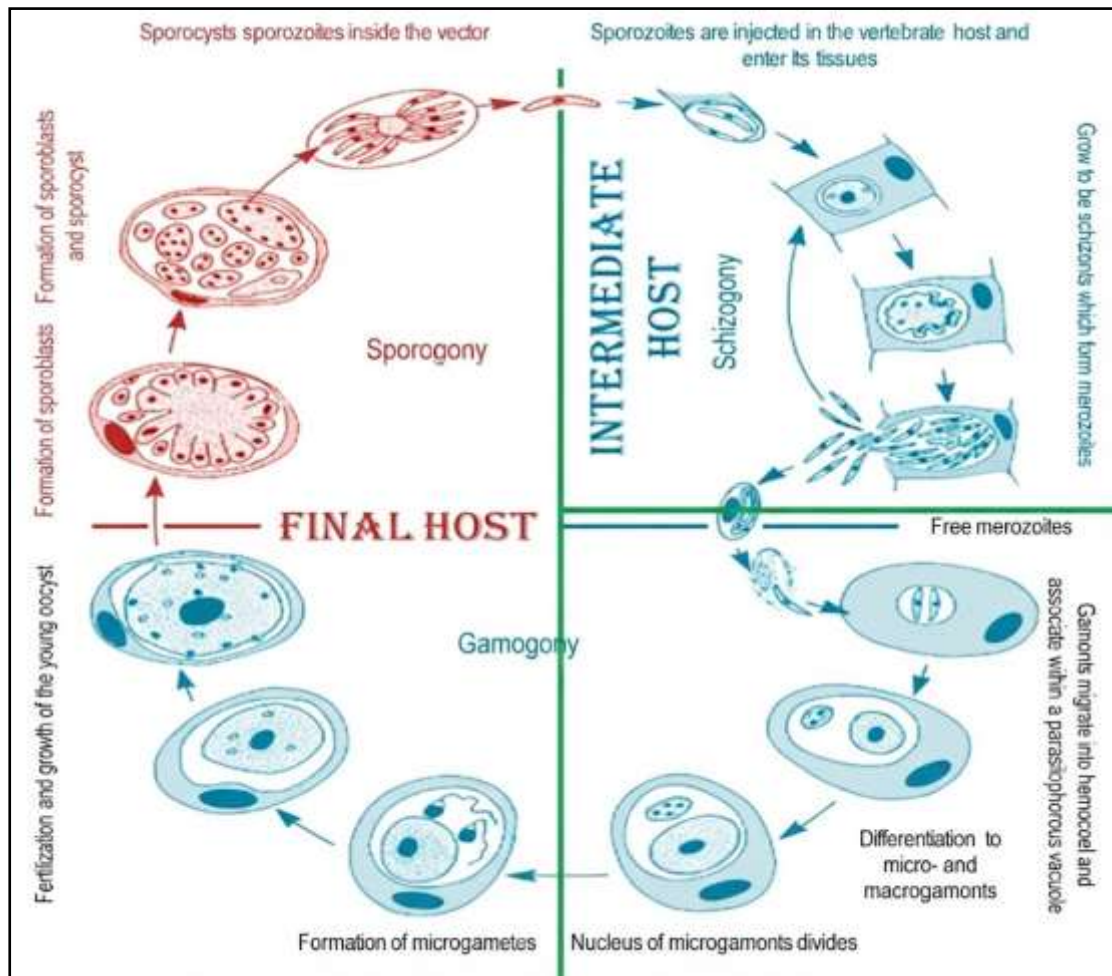


Figure 23 The life cycle of the apicomplexan parasites.

Classification, two classes : (SPOROZOEAE and PERKINSEAE)

1. Class SPOROZOEAE

- Monoxene parasites or heteroxenes
- Absence of locomotor organ
- Development cycle begins by a vermiform form: **Sporozoite**
- Classification: **three subclasses (GREGARINAE, COCCIDIA and PIROPLASMA).**

1.1. Subclass Gregarina

- Large gregarines: 3mm
- Mobile in the vegetative state
- Monoxene parasites of the general cavity of invertebrates or vertebrates
- Evolutionary cycle includes an asexual multiplication and a reproduction sexual.

1.2. Subclass Coccidia

- Small protozoa
- Immobile in the vegetative state
- **Intracellular** parasites of **intestinal** cells and **red blood** cells of invertebrate and vertebrates.
- Development cycle present alternately **Schizogony** and a **Gamogony**.
- **Monoxene** and **heteroxenes** parasites.

1.2.2. Monoxene coccidia: Example: *Eimeria perforans*; *Eimeria stiedae* and *Eimeria zurnii*. *Eimeria stiedae* parasite of the intestinal epithelium of rabbit (**Figure 26**).

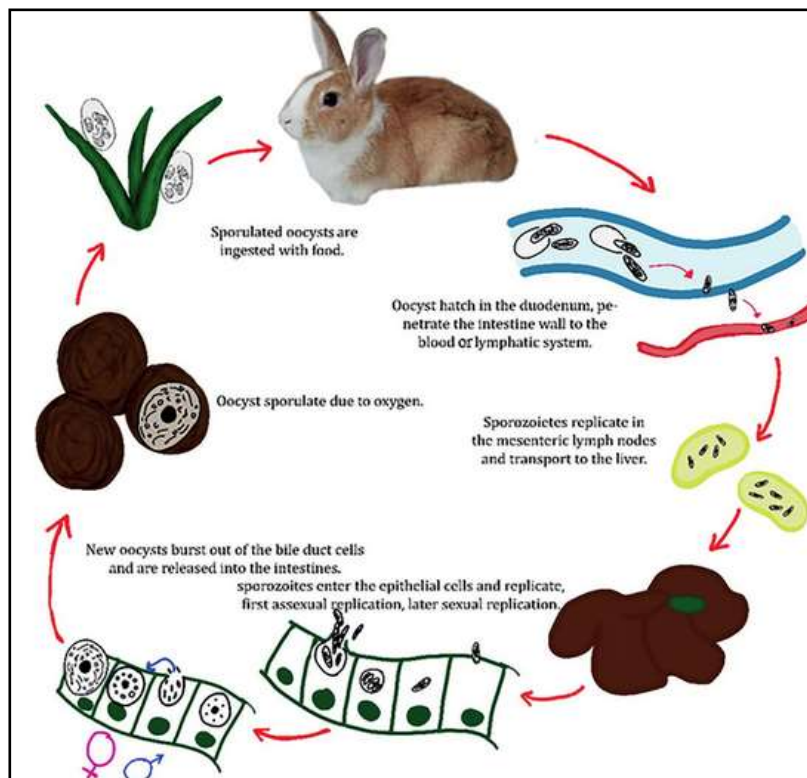


Figure 26. Life cycle of *Eimeria stiedae*.

The **Pathogenic** role of different species:

- *Eimeria perforans*: causes fatal diarrhea in the rabbit
- *Eimeria stiedae*: agent of hepatic coccidiosis in rabbit bile ducts
- *Eimeria zurnii*: red diarrhea in calves.

1.2.2. Heteroxenous coccidia= Blood coccidia = hemosporidia.

- **Schizogony** within **Red blood cells**
- Gamogony in an **Insect Diptera: Anopheles** (see life cycle in figure 27)

- Vertebrate parasites
- **Example 1 : Malaria (paludism) agents.** Three species: agents of malaria are:
 - *Plasmodium falciparum*: fevers daily (most dangerous)
 - *Plasmodium vivax*: benign third-party fever (48 hours).
 - *Plasmodium malariae*: quartan fever (72 h) = malaria.

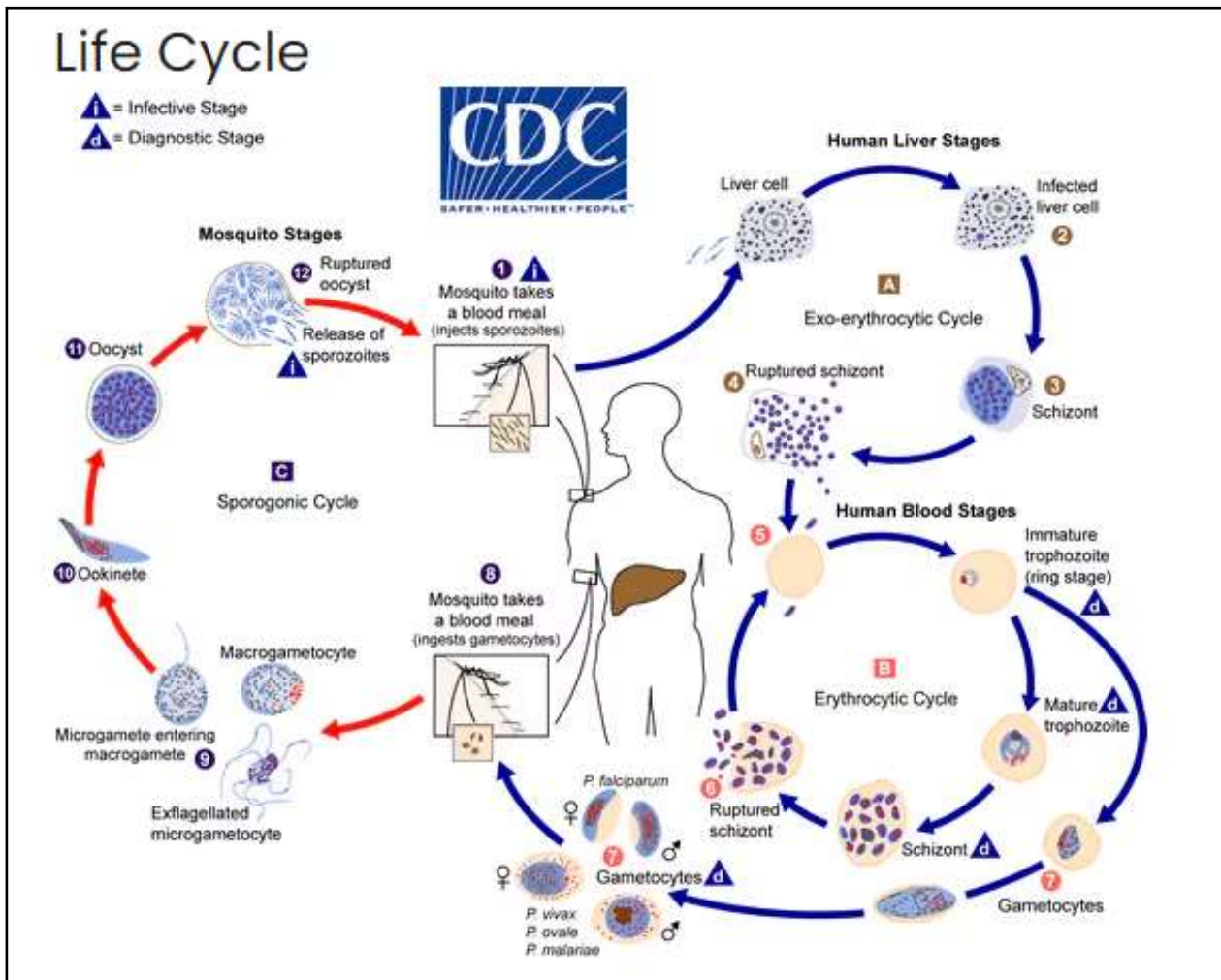


Figure 27. Life cycle of malaria of the genus *Plasmodium*.

Example 2 : Toxoplasmosis : Example : *Toxoplasma gondii* (the pathogenesis of toxoplasmic humans hydrocephalus from pregnancy women). Life cycle is illustrated in figure 28.

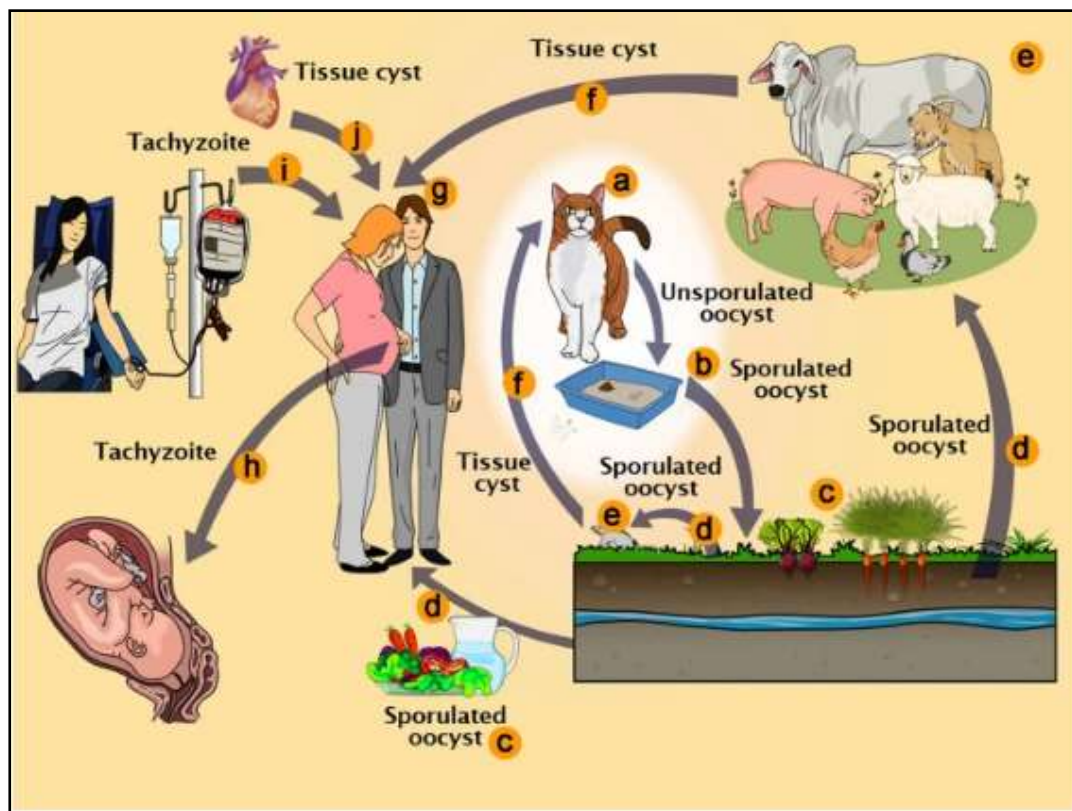


Figure 28. Life cycle of *Toxoplasma gondii*.

Toxoplasma gondii pathways of transmission. (a) Feline definitive host (cat). (b) Unsporulated oocysts in cat feces. (c) Food contaminated with sporulated oocysts. (d) Oocysts may be ingested by intermediate hosts via water or raw vegetables. (e) Intermediate hosts (e.g. cattle, sheep, poultry and swine). (f) Ingestion of tissue cysts in uncooked meat. (g) Intermediate hosts (humans). (h) Tachyzoites transmitted through the placenta to the fetus. (i) Transmission by blood transfusion and organ transplant (j).

1.3. Subclass Piroplasma

- Piriform body, rounded, rods or amoeboids
- Heteroxenous parasites of vertebrates
- Live in red blood cells.
- Transmitted by ticks Mites.
- Reproduce by Spore, a period of **asexual** replication (**schizogony**), **absence** of **gamogony**.

Examples: three Genus: *Babesia* ; *Theileria* and *Piroplasma*.

2. Class Perkinsea

- Have zoospores which resemble sporozoites but flagellate
- Do not have **sexual reproduction**
- Infect molluscs (e.g. calms).

Example : *Perkinsus qugwadi* (Figure 29, illustrated from arrows).



Figure 29. Digestive gland of *Patinopecten yessoensis* containing numerous pustules (**arrows**) caused by *Perkinsus qugwadi*

2.2.3. Phylum CILIOPHORA (CILIATES)

1. Definition

In Greek : Cilio = Cilia ; **Phoros** = who carries **Vibratile cilia** or organelles ciliary = **Infusoria**.

Approximately **8,000** species have been described and, of these, **3,000** species are symbionts.

As examples of this group, *Paramecium*, *Vorticella* and *Balantidium*.

This group includes protozoa which have cilia as locomotory organelle.

Ciliates form a distinct group of single-celled eukaryotes. They are unique among eukaryotes for two reasons: they have two types of nuclei, and they reproduce sexually through a process known as conjugation. They host two types of nuclei in the same cytoplasm: One is a large nucleus known as the macronucleus, and the other is a small nucleus referred to as the micronucleus.

2. General characteristics

The body is surrounded by a firm pellicle, and the cytoplasm is divided into an outer, clear area called the ectoplasm and an inner, granular area called the endoplasm.

The cytoplasm contains several food vacuoles and two contractile vacuoles, one located at the anterior end and the other near the posterior end of the body. Each contractile system consists of a central vacuole, into which a number of elongated, pear-shaped, radiating canals lead, as well as mitochondria and dictyosomes (**Figure 30**).

Nutrition (feeding) is **Holozoic (heterotroph)** and feeds mainly on bacteria, although it may also feed on minute animals or unicellular plants.

There are **free-living** as well as commensal species or parasites

Habitats : Ciliates are found in virtually every terrestrial and aquatic environment (oceans, lakes, rivers), ponds across the globe in freshwater and brackish water habitats and play a pivotal role in planktonic food webs.

Osmoregulation : as in other protozoa inhabiting in freshwater; osmoregulation is carried out by the two contractile vacuole system. Excess water first accumulates in the radiating canals then passed into the central vacuole from which it is discharged through a minute pore in the pellicle.

Respiration and excretion: The exchange of oxygen and carbon dioxide takes place through the body surface by simple diffusion. Nitrogenous waste products are also excreted by simple diffusion.

Reproduction : They may be asexual, undergoing transverse binary fission (Figure 30), or they may undergo a special sexual process known as conjugation (Figure 30). In binary fission, the micronucleus divides by mitosis into two micronuclei that move towards opposite ends of the body. Then, the macronucleus divides transversely and other organelles, such as the contractile vacuole, oral groove, cytoplasm and cytopharynx, duplicate. Transverse binary fission takes about 2 hours to complete and occurs one to four times per day. However, when conditions are unfavourable, the organism can reproduce sexually. This form of sexual reproduction is called conjugation. During conjugation, two paramecia join at the oral groove where they exchange genetic material. They then separate and divide asexually.

3. Classification

Classification is based on hair (cilia) characteristics. They are three classes:

1-OLIGOHYMENOPHOREA

2-POLYHYMENOPHOREA

3-KINETOPHRAGMINOPHOREA

3.1. Class Oligohymenophorea

Mouth or cytosome opens at the bottom of a oral cavity. Two subclasses are found:

- **Hymenostomatia**
- **Peritrichia.**

3.1.1. Subclass Hymenostomatia

They are characterised by a uniform body ciliature and a well-defined buccal cavity, the latter consisting of an undulating membrane. Three orders have been described:

1. Order Hymenostomatida : Example : *Paramecium caudatum* ; *Paramecium aurella* ; *Paramecium bursaria*.

2. Order Scuticociliatida, little ciliation; Example : *Boveria*.

3. Ordre Astomatida : characterise by : Often long body, Uniform ciliature, Mouth absent, Endoparasite of invertebrates and vertebrates. Example: *Cepedietta*.

3.1.2. Subclass Peritrichia : Presentes by a single order **Peritrichida:**

- Appearance of an urn
- Has a peduncle that can roll up
- Very dense colony
- Mouth surrounded by a fringe of membranous; Example: ***Vorticella sp* (Figure 30)**

3.2. Class Polyhymenophorea = Spirotriches

- Large size and free-living
- Great development of the adoral region (mouth)
- Mouth surrounded by a fringe of membrane.
- Colonizes various habitats
- **Three Orders** are disting:

1. Order Heterotrichida example : *Stentor sp*, *Balantidium coli* (Figure 30).

Several species of this parasite ciliate infect fishes, amphibians, pigs, sheep, monkeys and camels. ***Balantidium coli***, a large ciliated is only species of ciliates which infect humans. It has been reported in all parts of the world and is responsible for the disease balantidiasis, which includes acute diarrhoea, haemorrhagic diarrhoea, ulceration of the gut wall, dysentery, colitis and abdominal pain. There are two developmental stages: the trophozoite stage and the cyst stage (the infectious stage)

2. Order Hypotrichida : Example : *Stylonychia sp* (Figure 30)

- Very mobile
- Cilia associated with membranes (**Cirri**).

3. Order Oligotrichida : Example : *Codonella sp*. (Figure 30)

Ovoid or elongated body, equipped with a protected tail by thick film or cubicle

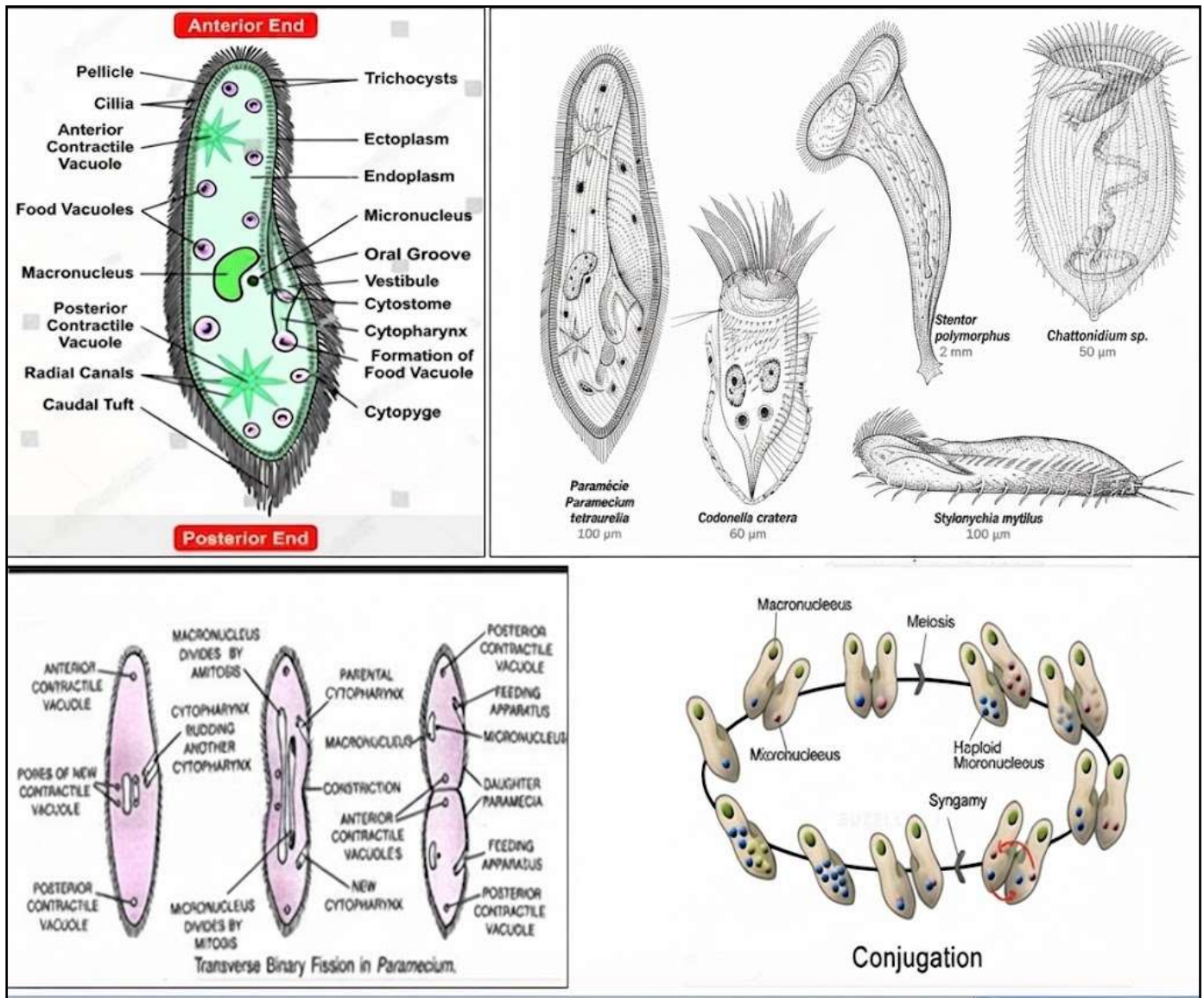


Figure 30. Morphology of ciliata, binary fission and conjugation.

2.2.4. Phylum MICROSPORA (MICROSPORIDIA)

- Unicellular, obligate Intracellular parasite found in nearly all major animal groups (Figure 31).
- Reproduce in the host by producing spores (Sporegony).
- Spores are either oval or cylindrical in shape and are always found with a polar filament or tubule.
- **Spore** : Infective stage of microsporidia.

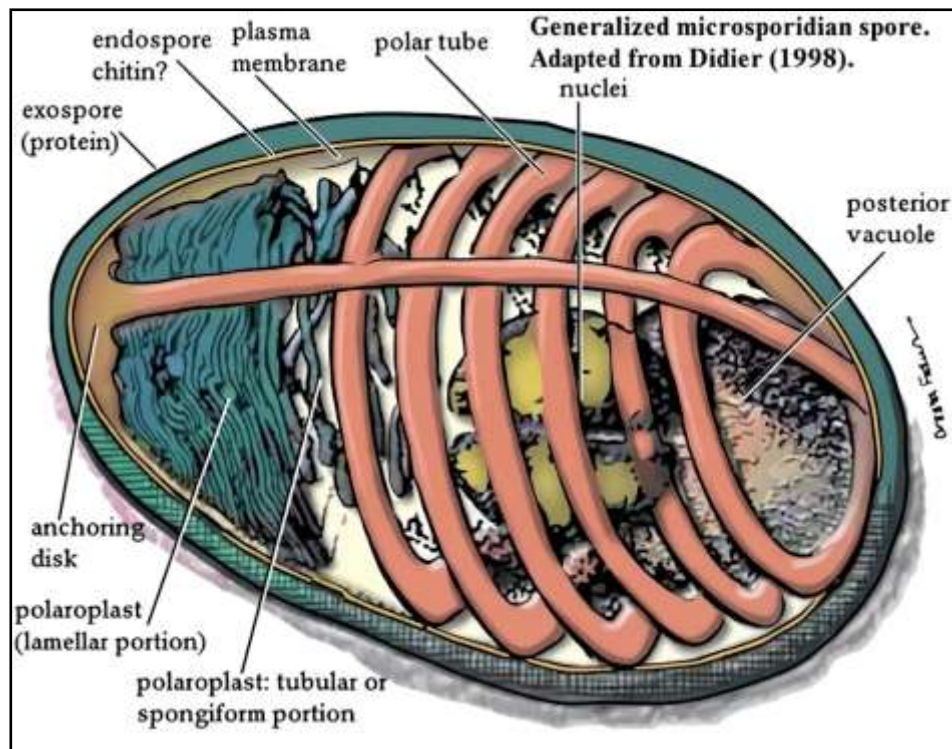


Figure 31. Diagram of microsporidia.

1. Classification

Microsporidia are classified in two classes : **Microspora** and **Rudimicrosporea**.

1.1. Class **Microspora** presents by two species :

A) ***Nosema bombicis*** : causative agents of pebrine disease from Silkworm: ***Bombyx mori***.

B) ***Nosema apis*** : tissue parasite of the honey bee: ***Apis mellifera***.

1.2. Class **Rudimicrosporea**: Example, genus *Amphiacantha*, parasites of Annelida Polychaeta.

2.2.5. Phylum MYXOZOA

Myxozoa is a Greek word, **Myxa**-slime or mucus and **Zoon**- means animals. 1350 species in 52 genera described.

They are a group of obligate aquatic parasites that primarily infect fish, but can also infect reptiles, platyhelminthes, octopuses, amphibians, various invertebrates and humans.

They are spore-forming endoparasites of freshwater and marine fish. Myoliquifaction is the main pathology caused by this parasite in fish, degrading the quality of the flesh.

Their life cycle is not fully understood.

1. Classification

Comprised of two classes: Myxosporea and Actinosporea.

1.1. Class Myxosporea

- Parasites of poikilothermic vertebrates
- Will infect body cavities, such as the urinary tract, and are therefore called coelozomic.

Some infect various tissues and are called histozoic.

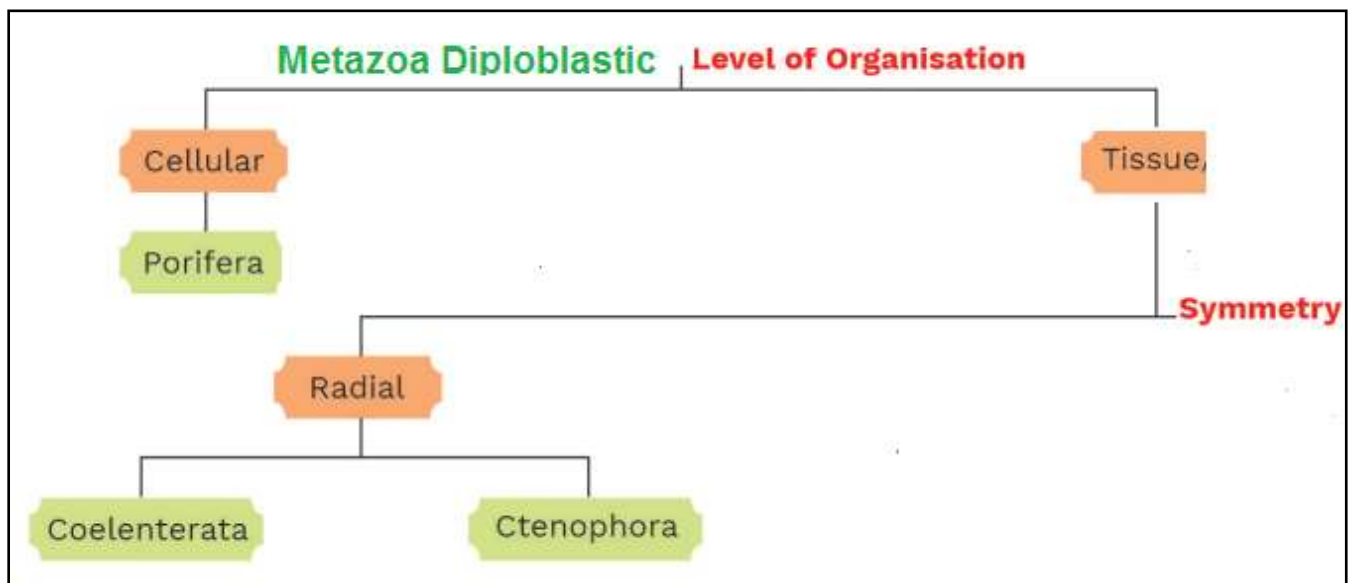
- • Trophozoites vary in size and appearance, as well as in the number of spores they produce.
- Their cells contain most organelles, except for centrioles
- Examples: *Myxobolus sp*; *Trilospora sp*.

1.2. Class Actinosporea : Parasites of Annelida

Chapter : III

Kingdom Animalia

Subkingdom : Metazoa



Diploblastica

1. Phylum PORIFERA (SPONGES).

Sponges are mostly marine, sessile animals that show little or no detectable movement.

Regarded as the most primitive multicellular organisms, they are classified as Parazoa. **In Greek** : Porifera means : **Por** : passage, pore bearing

1.1. General characters

Metazoa, Diploplastica : made of two cells layers : **Ectoderm** and **Endoderm**.

Asymetric body plan.

No specialized tissu or organ system : **Cellular level**.

Morphology (Figure 32) : The body is perforated by numerous pores, canals and chambers through which water flows continuously. Inside the body, there is a single cavity that is lined with peculiar flagellated cells known as choanocytes. The sponge has a skeleton made of calcareous, siliceous or organic sponge fibres. The sponge's body is an efficient water filter; some large sponges can filter 1,500 litres each day. They range in size from 1 cm to 1 metre in diameter.

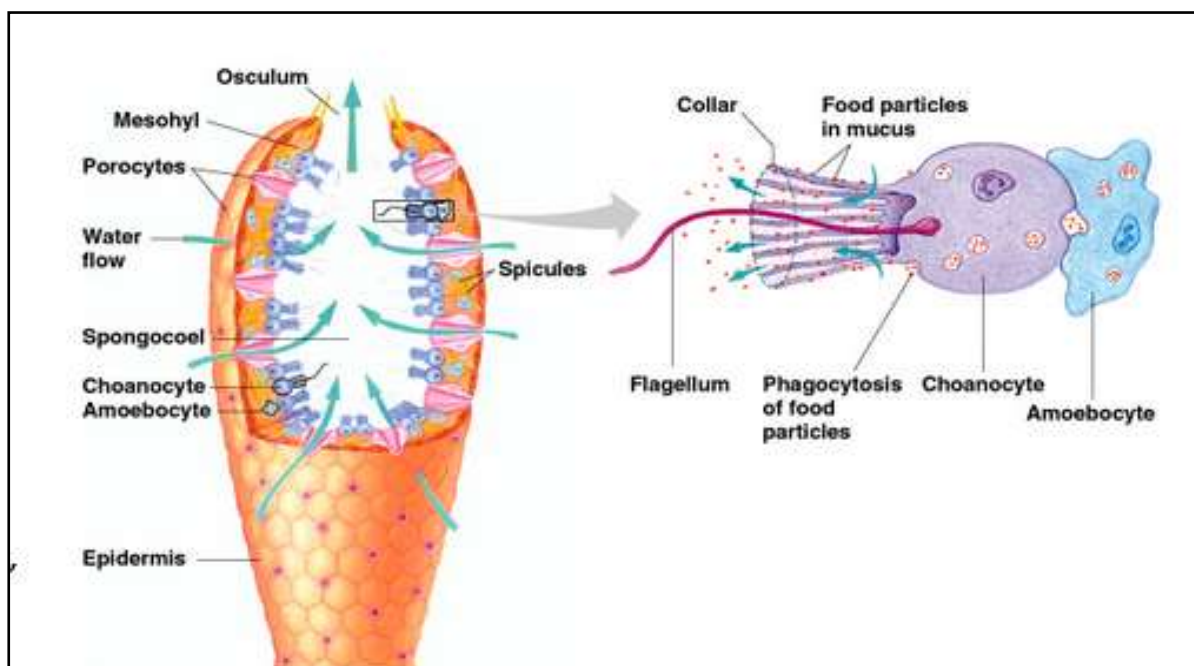


Figure 32. Sponge schematic from.

Feeding and digestion : They have no mouth or digestive tract. They are holozoic, meaning digestion takes place entirely intracellularly (inside cells). They sift food particles from the water using water flow and collar cells for filtration.

Circulation : Takes place through diffusion when enters the body through incurrent pore.

Respiration : diffusion of oxygen and carbone dioxide using specialized cells takes place when water enters the body through an outer pore.

Excretion : Diffusion of wastes including ammonia and carbone dioxide and into the water and released through an excurrent pore or **Osculum**.

Nervous : They have not sensory or nerve cells.

Movement : The adults are sessile, meaning they remain attached and do not move. Larvae, on the other hand, are mobile.

Habitat : Approximately 8,300 species of sponge exist. The vast majority of these are marine, with a few inhabiting brackish water and 150 species living in freshwater.

Ecological important :

- It provides habitats for many other animals. These include snails, shrimp, sea stars and bacteria
- It serves as a food source for other animals..

Reproduction (Figure 33): They reproduce asexually ; from when condition are unfavourable by :

- **Budding, mitotic** growth and break off.
- **Fragmentation** : part of sponge break off.
- **Gemmules** : A collection of cells enclosed by a hard outer covering contains spicules.
- They reproduce sexually by producing gametes and have free-swimming larvae. Sponges are hermaphroditic, meaning they produce both eggs and sperm and contain both male and female sexual organs. To increase the chance of fertilisation, they do not fertilise their own eggs with their own sperm.

Sperm are released out of the osculum and swim to another sponge with the help of currents. They enter the sponge through the anchor pore and are picked up by collar cells. They are then carried to an egg by amoebocytes and fertilisation occurs. The zygote then develops into a flagellated larva that is mobile and can be dispersed.

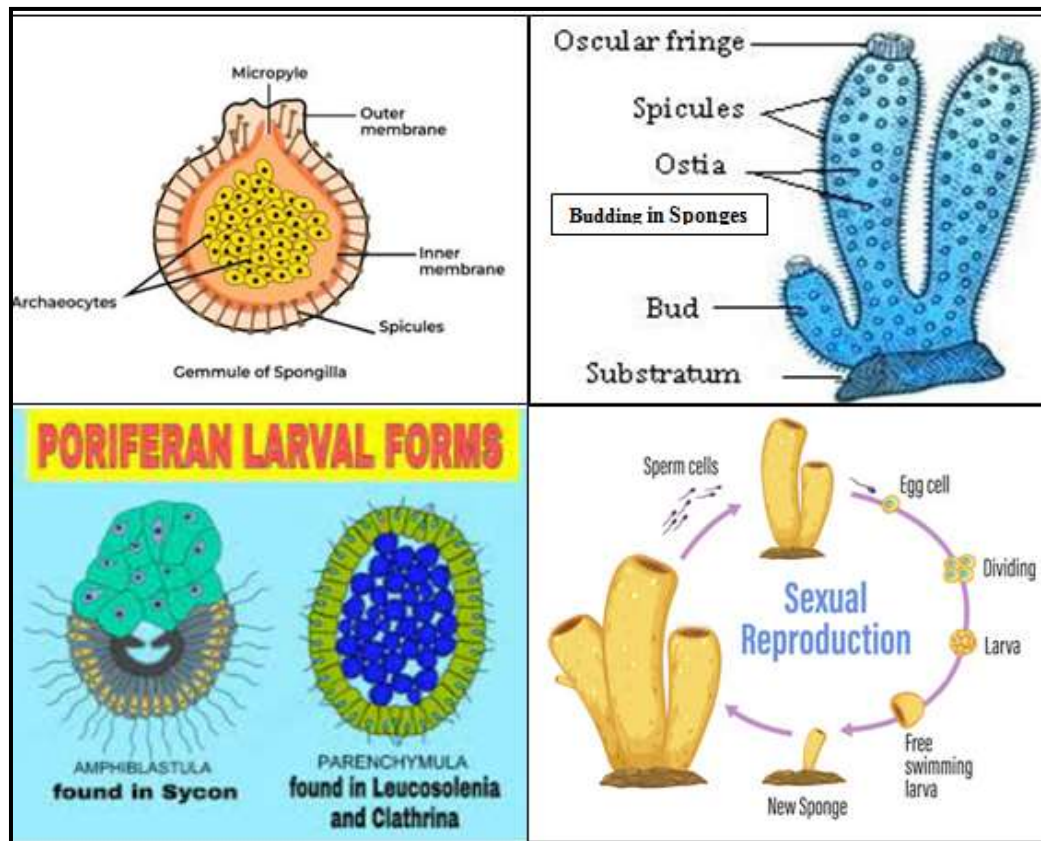


Figure 33. Reproduction in Sponges

1.2. Specialized cell types: (Figure 34).

- **Choanocytes:** These cells line the spongocoel and propel water towards the osculum. They are primarily responsible for capturing food, which they filter from the passing water. They then ingest the food and package it in Golgi bodies, transferring it to archeocytes, which then transfer it to other cells. Choanocytes closely resemble choanoflagellates.

Pinacocytes: They line and protect the outer surface and may also ingest food particles that are too large to pass through the pores. They also secrete a massive external skeleton if there is one.

- **Porocytes:** They line the pores and control the size of the ostia.
- **Archeocytes :** (also known as "amoebocytes"): Amoeboid cells that occupy the mesohyl and digest and transport nutrients. Archeocytes are totipotent, meaning they are capable of transforming into most other cell types when needed (including ova)
- **Sclerocytes:** They inhabit the mesohyl and lay down mineral spicules.
- **Spongocytes:** They inhabit the mesohyl and secrete a form of collagen which polymerises to form spongin fibres.

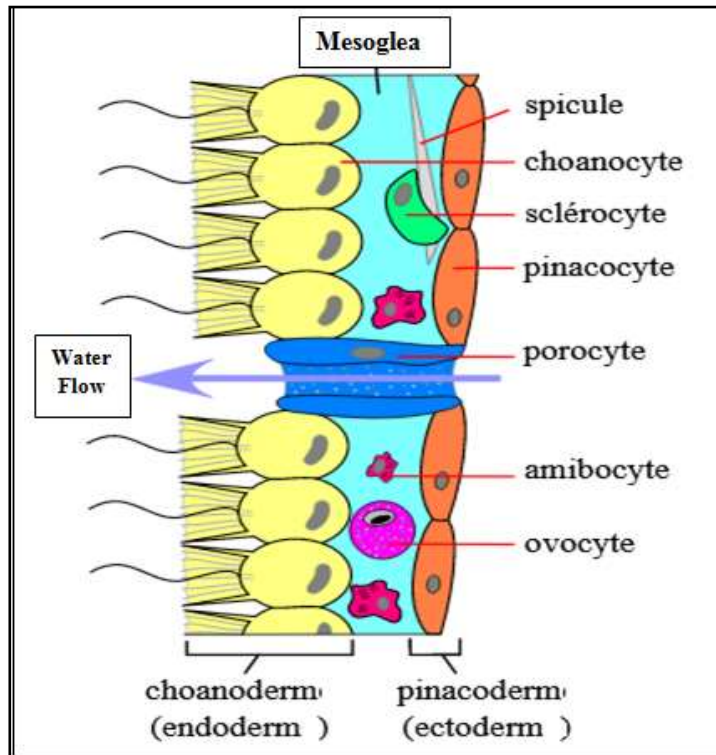


Figure 34. Different type of Sponge cell.

1.3. Fractal architecture: (Figure 35).

While all sponges adhere to this body plan, many increase its complexity by repeating it in a fractal manner. In the schematic on the right, the choanocyte-endoderm is highlighted in red. Grade sponges consist of single cylindrical units.

2. Sycon : Grade sponges are made up of many ascon-type units, which are formed by pleated folds in the inner surface. Macroscopic incurrent canals in them bring external water to the pores.

3. Leucon : Leuconcon-type units with complex three-dimensional networks of incurrent canals and choanocyte chambers make up grade sponges, which are composites.

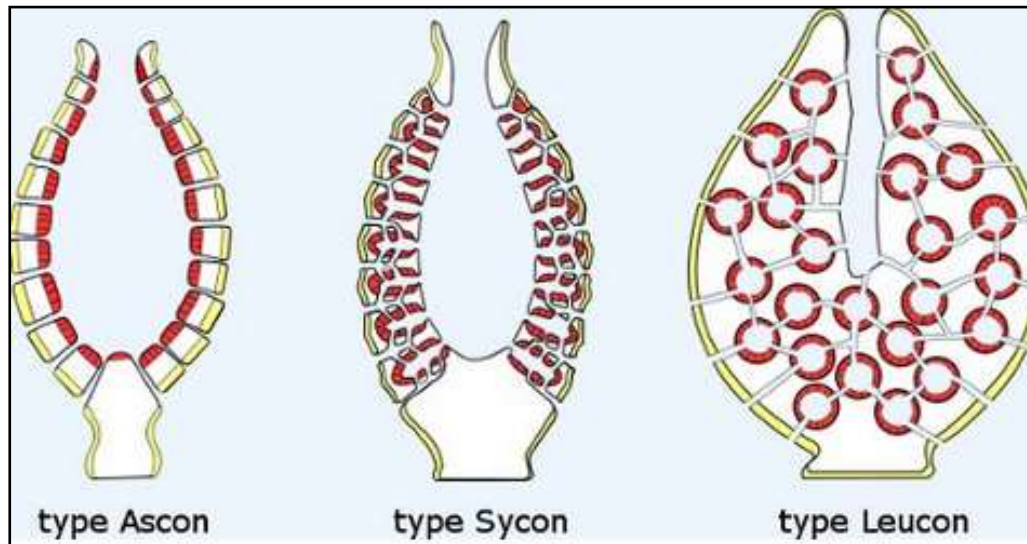


Figure 35. Sponge organizational grades.

1.4. Classification of Spicule: (Figure 36).

Skeletal structure of sponge are spicule and spongy fibers. Spicules are found by carbonates or lime or silica. Spicules or sclerites are definite bodies with a crystalline appearance.

They generally consist of simple spines or radiating spines.

They have an organic axis around which inorganic substances, such as calcium carbonate or hydrated silica, are deposited. Spicules are secreted by mesenchyme cells called scleroblasts.

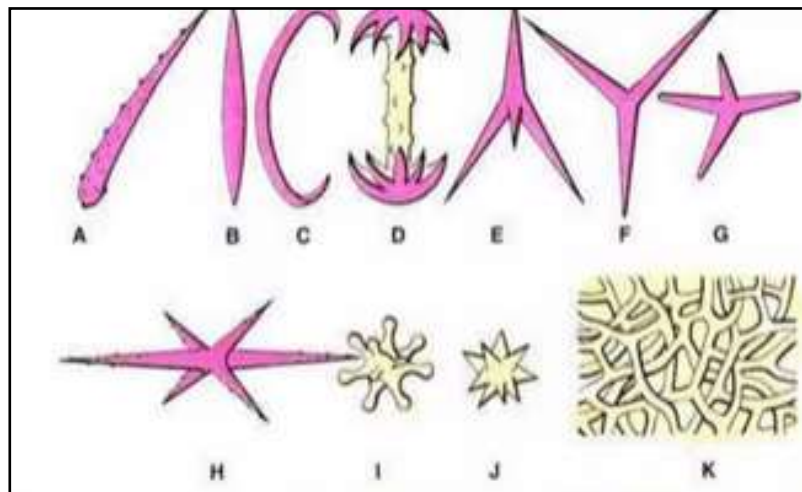


Figure 36. Spicule and spongy fibers

A : Monactinal monaxon ; B : Diactinal monaxon ; C : Curved monaxon ; D : monaxon with hooked ends ; E : Tetraxon ; F : Triradial ; G : Calthrops ; H : Hexactinal triaxon ; I and J : Polyaxon ; K : Spongy fibers.

1.5. Classification

Sponges are classified according to the presence or absence of spicules, their composition and form, or the nature of the spicules (i.e. their role in the skeleton and defence). This phylum can be divided into three classes: Calcareous sponges, Hexactinellida sponges, and Demosponges.

1.5.1. Class Calcrea

- Calcareous sponges have spicules made of calcium carbonate.
- Spicules are straight or have 3–4 rays.
- Most are small and tube- or vase-shaped.
- Some are bright red, yellow or purple.
- Found in shallow marine habitats at depths of up to 50 metres.
- Asconoid, syconoid and Leuconoid canal forms.

Examples : *Leucosolenia*, *Scypba*, *Leucandra*, *Leucilla*.....

1.5.2. Class Hexactinellida

- Glass sponge with six-rayed spicules made of silica.
- Deep-sea forms found at depths of up to 500 metres.
- Root spicules attach them to the substrate.
- Fragile glass skeletons mean they can only live in areas of clear, gently flowing water.
- Body design shows both syconoid and Leuconoid canal forms.

Example : *Euplectella*

1.5.3. Class Demospongiae

- This class contains 95% of all living sponge species.
- This is the only class that contains species without spicules at all. Some species only have skeletons made of spongin.
- If they do have spicules, they are made of silica but are not six-rayed.
- This is the only class with freshwater species, the Spongillia.
- Commercial bath sponges are harvested from this class.
- All species in this class have a Leuconoid canal design

Example : *Euspongia officinalis*

2. Phylum CNIDARIA (Coelenterata).

2.1. General characters

The name Cnidaria comes from the Greek word CNIDOS, which means stinging nettle.

2.1.1. Embryological and Structure

Metazoa have a diploblastic level of tissue organisation (Figure 37). The embryo gives rise to an outer layer of the wall called the epidermis, while the inner layer of the body wall, the gastrodermis, is derived from the endoderm. The gastrodermis is also known as the gastrovascular cavity or the coelenteron. This digestive cavity has a single opening to the outside: the mouth. The cells of the epidermis and gastrodermis differentiate into various cell types responsible for protection, coordination of movement, digestion and absorption. A jelly-like layer called the mesoglea lies between the epidermis and the gastrodermis.

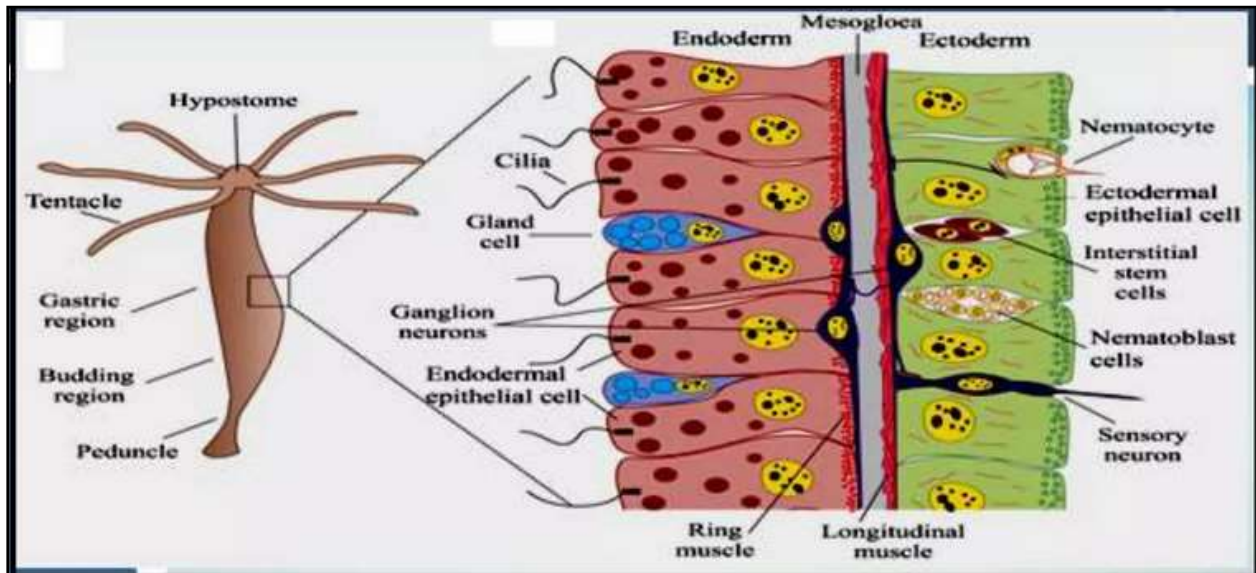


Figure 37. Body wall of Cnidarian

One characteristic of cells in this phylum is that they produce structures called cnidae, which are used for attachment, defence and feeding. A cnida is a fluid-filled intracellular capsule enclosing a coiled hollow tube. The cnidocyte usually has a modified cilia called a cnidocil. (Figure 38).

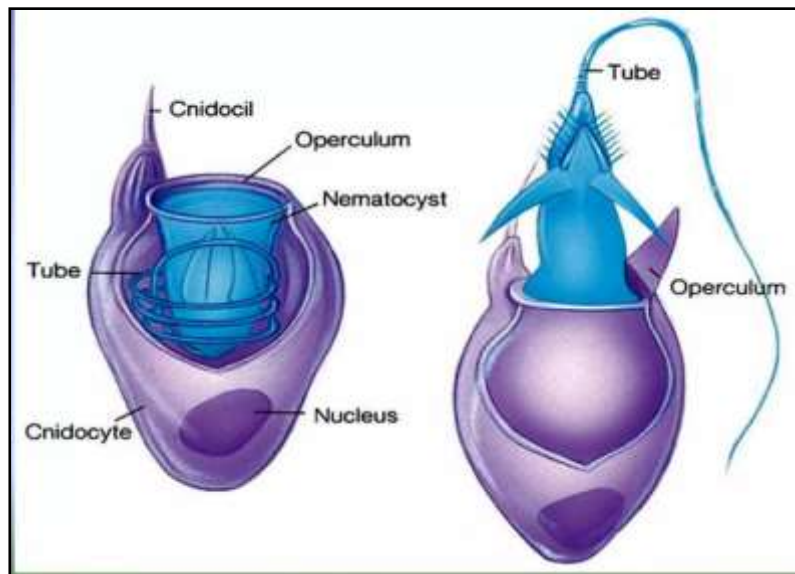


Figure 38. Cnidocyte structure and Nematocyt discharge.

2.1.2. Cnidarian form

Cnidarians have **two body form** in their **life cycle**, polype and medusa (**figure 39**).

Polype (63 %)	Medusa (8 %)
Sessile stage	Free-swimming
Attach at aboral end	Mouth pointed upward
Asexual stage	Sexual stage
Cylindrical body (Column)	Body is like inverted bowl
Mouth pointed upward surrounded by food-gathering tentacles	Usually Dioecious
Budant mesoglea	Abudant mesoglea

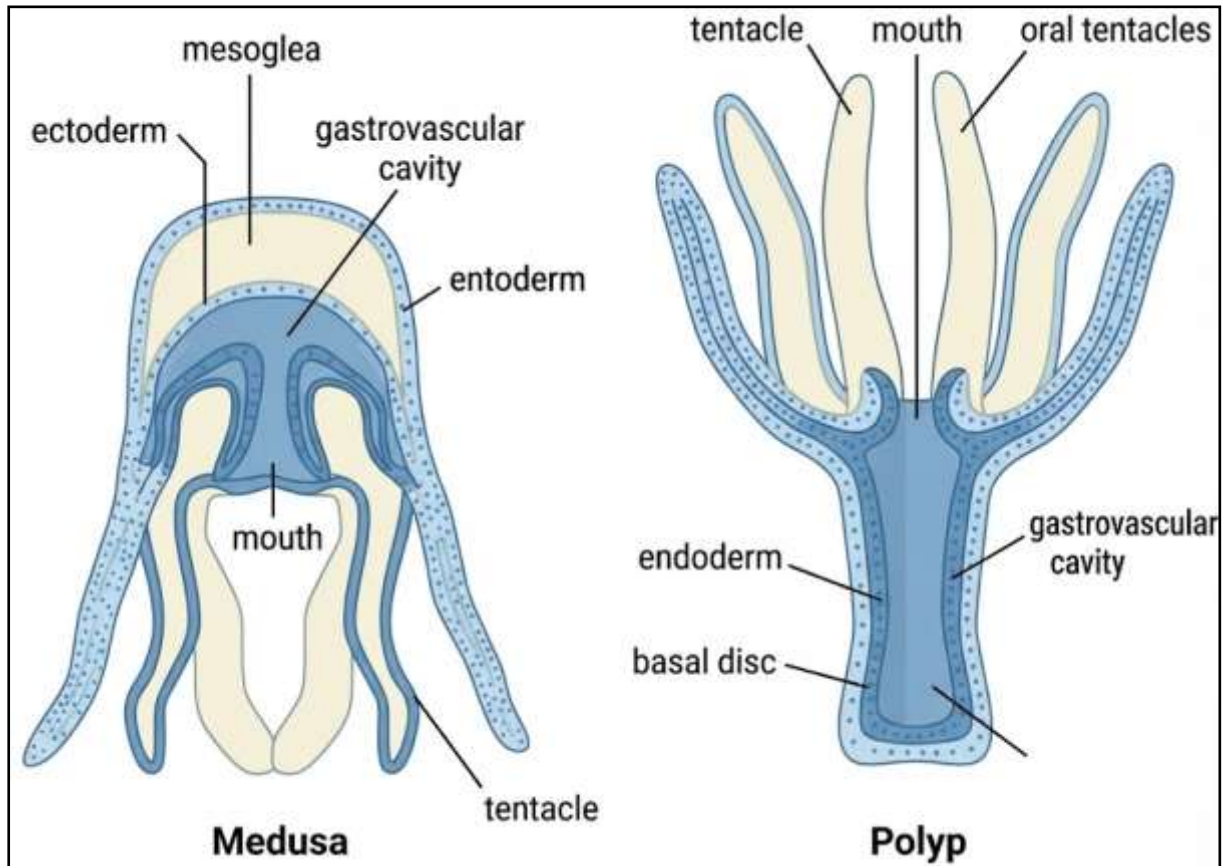


Figure 39. Body form of medusa and polyp.

2.1.3. Symmetry : radially symmetrical animals.

2.1.4. Feeding and digestion

- Cnidarians pull their prey into their gastrovascular cavities (Figure 40).
- The gastrovascular cavity is a digestive chamber with one opening.
- Digestive takes place outside the cells.
- Cnidarians are holozoic and typically carnivorous feeding on minute crustaceans, insects, small aquatic animals, molluscs which come within reach of its tentacles.

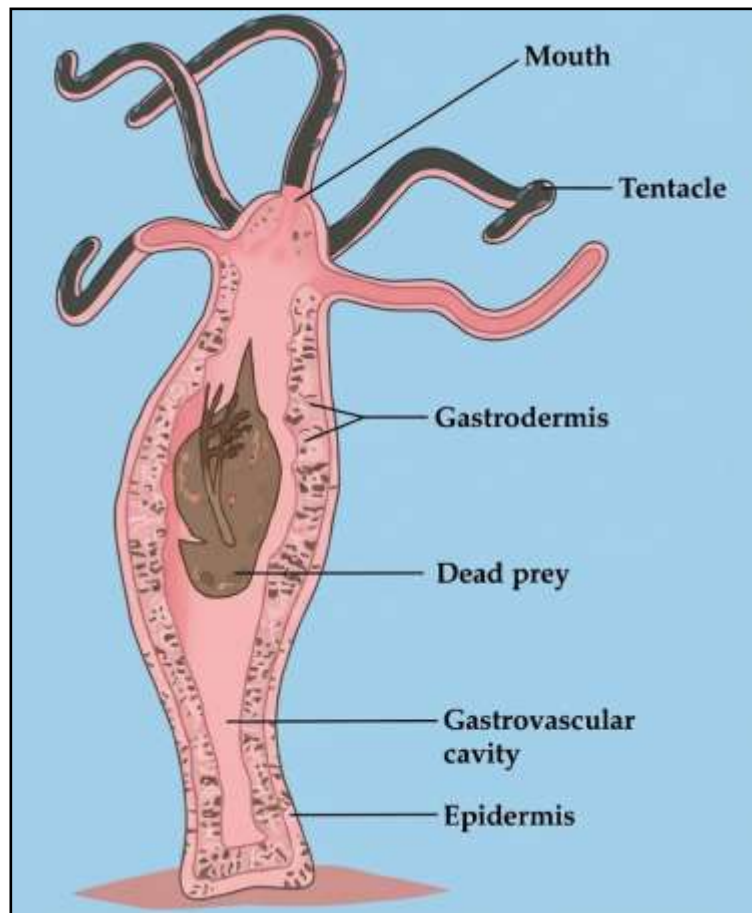


Figure 40. Gastrovascular cavity.

2.1.5. Respiration and excretion

No excretory or respiratory system. Integumentary exchange, gases diffuse directly across a moist body surface of the ectoderm and endoderm.

2.1.6. Reproduction (Figure 41).

- Most cnidarians are dioecious. Sperm and eggs are released either into the gastrovascular cavity or outside the body.
- Gametes produced by medusa.
- After fertilization zygote formed.
- Zygote transformed to Planula larva.
- Larva will form polype
- All cnidarians can reproduce asexually by budding

Alternation of generation and life cycle, most cnidarian possess two body forms in their life histories : Polyp and medusa.

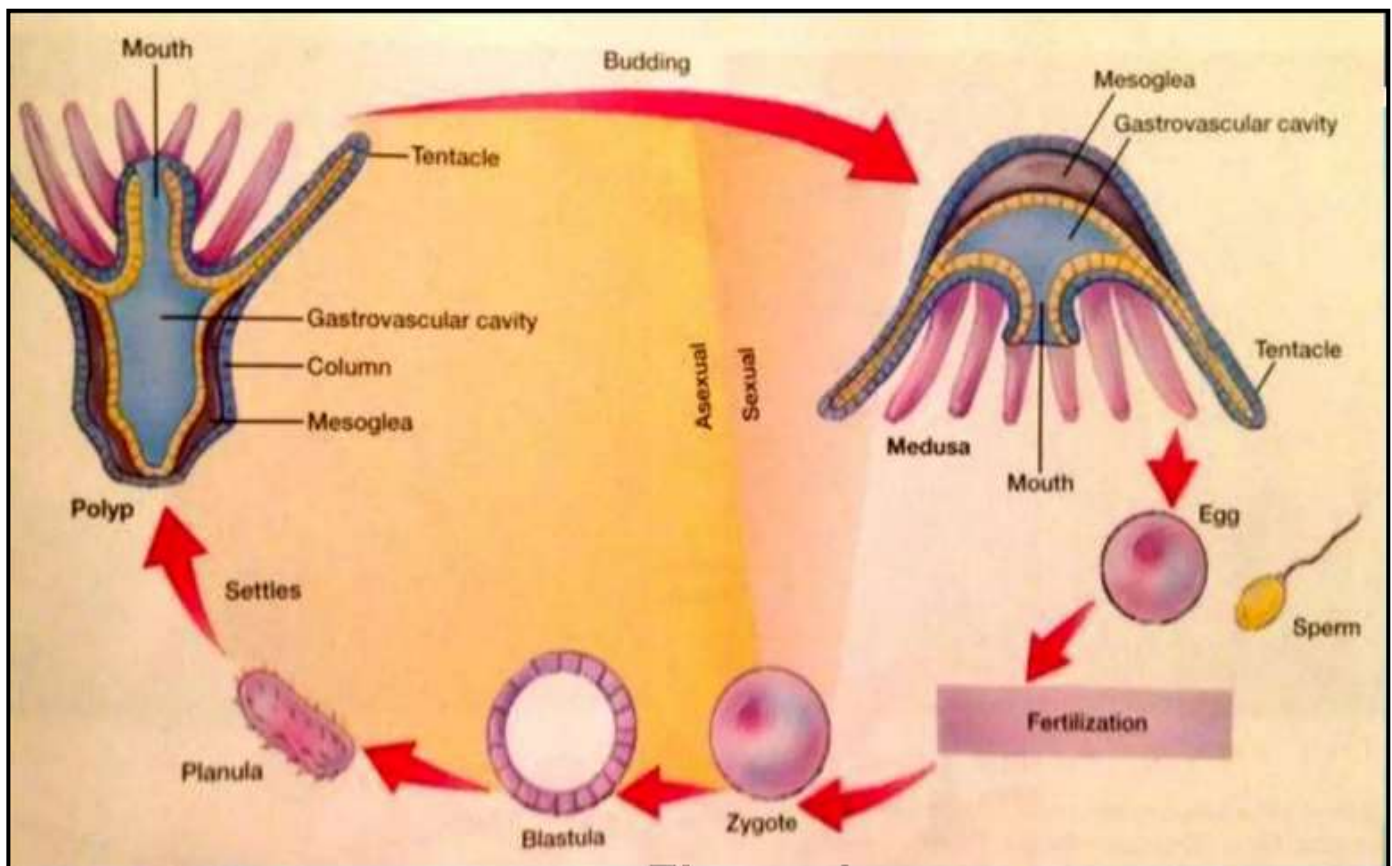


Figure 41. Reproduction and generalised Cnidarian life cycle.

2.1.7. Nervous system and senses

- No brain or central nervous system are present in cnidarians.
- Have a decentralised nervous system consisting of sensory neurons from various types of stimuli, such as odours and motor neurons.
- The cilia of the cnidocytes detect physical contact (**Figure 42**).

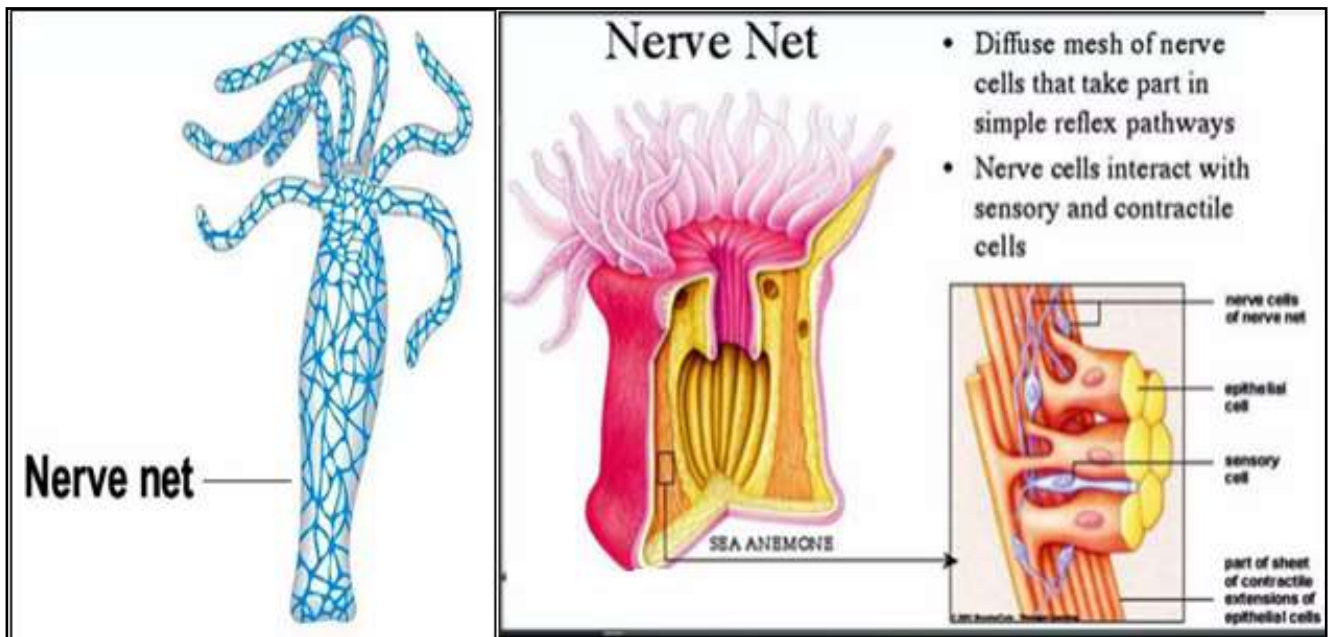


Figure 42. Cnidarian nervous system.

2.1.8. Hydrostatic skeleton and movement

- Cnidarians have Hydrostatic skeleton.
- Hydrostatic skeleton is water or fluid filled cavity. It give support to Cnidarian body.
- **Gastovascular** cavity act as a Hydrostatic skeleton.
- Epitheliomuscular cells are contractil cells help in movemont of polyp and medusa.

2.1.9. Habitat

- Aquatic ; most marine few freshwater.
- The cnidarians include over 9,000 species that play an important role in coral reef ecosystems.

2.2. Classification of the Cnidarian

The phylum cnidaria is classified into **4 classes** : **(Figure 43)**

1. Class **Hydrozoa**.
2. Classe **Scyphozoa**.
3. Class **Anthozoa**
4. Class **Cubozoa**.

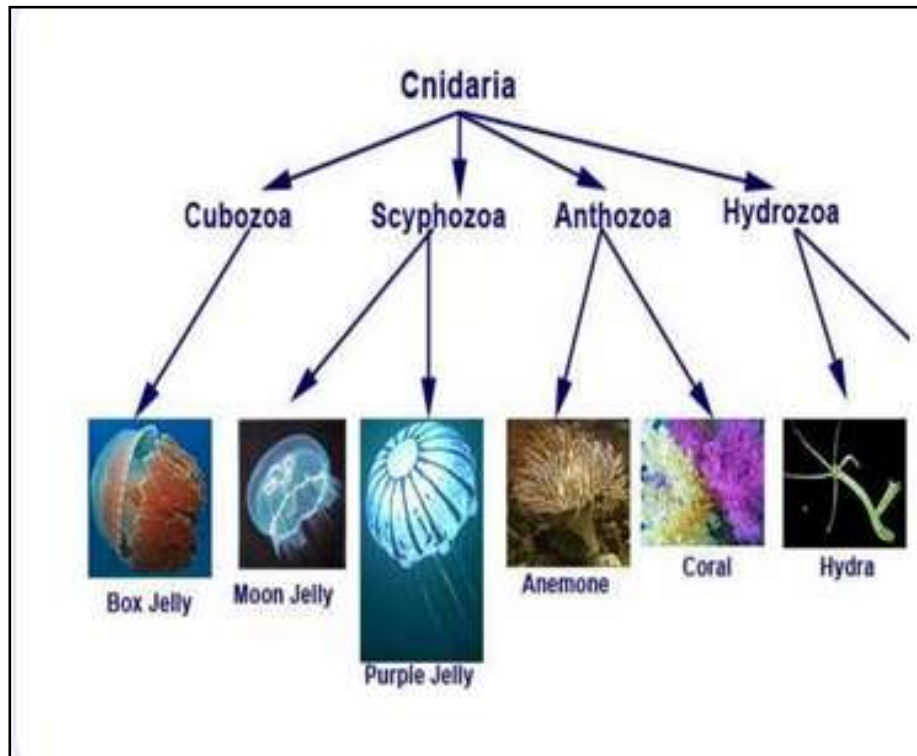


Figure 43. Cnidarian taxonomy.

2.2.1. Class Hydrozoa

- Hydrozoans are a type of Cnidarian that are small in size and relatively common.
- The majority of them are marine, with a smaller number being freshwater.
- Mesoglea is acellular
- Nematocyst are only in the epidermis.
- Some hydroid lost medusa stage.
- Gametes released outside the body.
- Colonial formation.
 - Entire colony has continuous gastrovascular cavity.
 - Feeding polyp called : Gastrozooids
 - Reproductive polyps called : Gonozooids.

Example : *Hydra*, *Obelia*

1. Hydra (Figure 44)

- Typical cnidaria body
- Cnidocyst present in epidermis
- One opening surrounded by tentacles.
- Attached aborally by pedal disc.
- Lacks medusa stage

- Reproductive by budding of polyps.
- Sexual reproductive occur also in polyps.
- Epidermal cells will form ovaries and testes that release eggs and sperm.
- After fertilization, zygote develop into adult.

2. Obelia (Figure 44)

This is a dimorphic marine coelenterate, exhibiting both a hydroid and a medusoid form during its life cycle. It consists mainly of marine species, with some freshwater species.

Obelia has a worldwide distribution except in the high Arctic and Antarctic seas.

They are usually found no deeper than 200 metres from the water's surface, growing in intertidal rock pools and at the lowest point of spring tides.

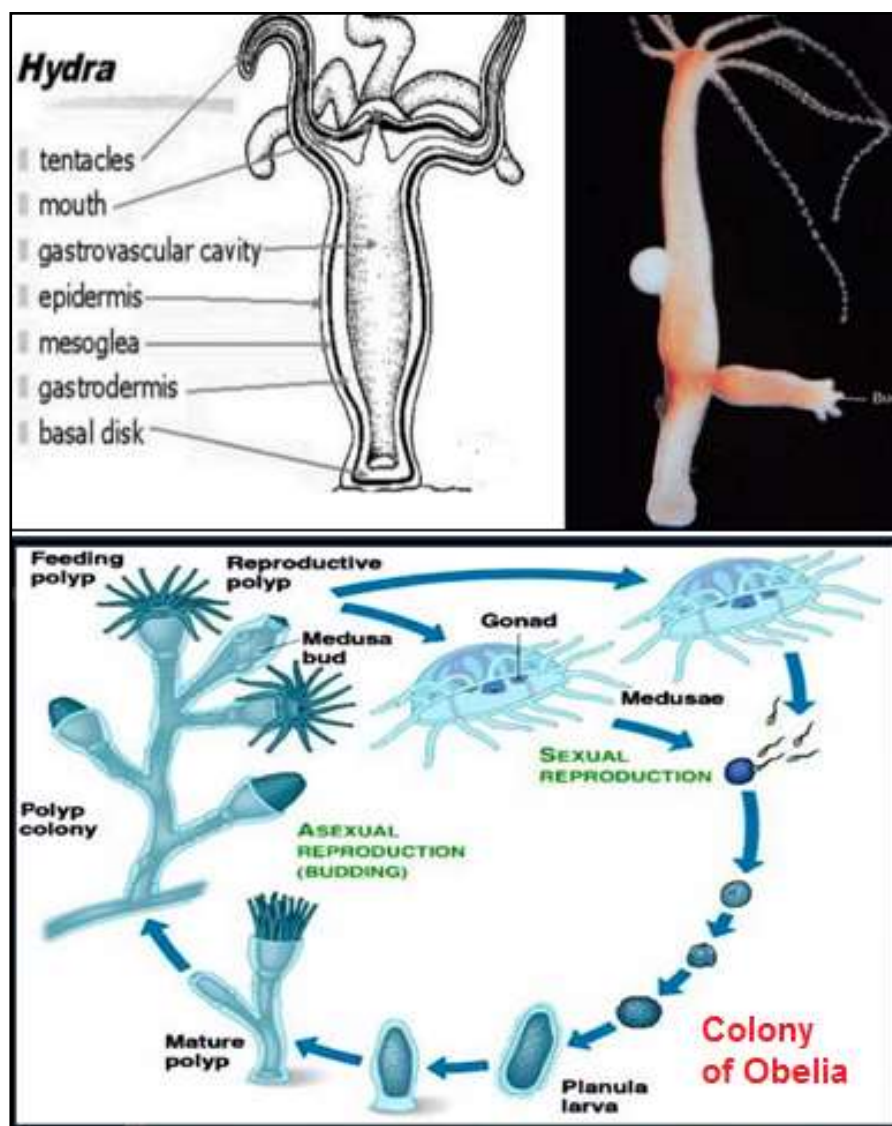


Figure 44. Hydra morphology and Obelia structure and life cycle.

2.2.2. Class Scyphozoa

- Exclusively marine true ‘**Jelly fish**’ (8 %).
- Amoeboid mesenchyme cells are present in mesoglea.
- Cnidocytes present in epidermis and gastrodermis.
- Gametes are gastrodermal in origin (released in gastrovascular cavity).
 - Dioecious
 - Many scyphozoans are harmless to human
 - Movement by rhythmical pulsation of the bell.
 - Most species drift or swim in open waters, even at depths of up to 3,000 metres.
 - Most range from 2 cm to 40 cm in diameter.
 - Common example is *Aurelia* (Figure 45).

Cellular structure of *Aurelia* are basically similar to those described in *Hydra* and *Obelia*.

Aurelia is characterised by :

- ✓ An extensively branched canal system is present.
- ✓ Cilia are present on gastrodermal cells, enabling them to circulate food.
- ✓ It feeds plankton.
- ✓ Statocyst sensors that detect static gravity
- ✓ **Planula** develop into a **Scyphistoma**

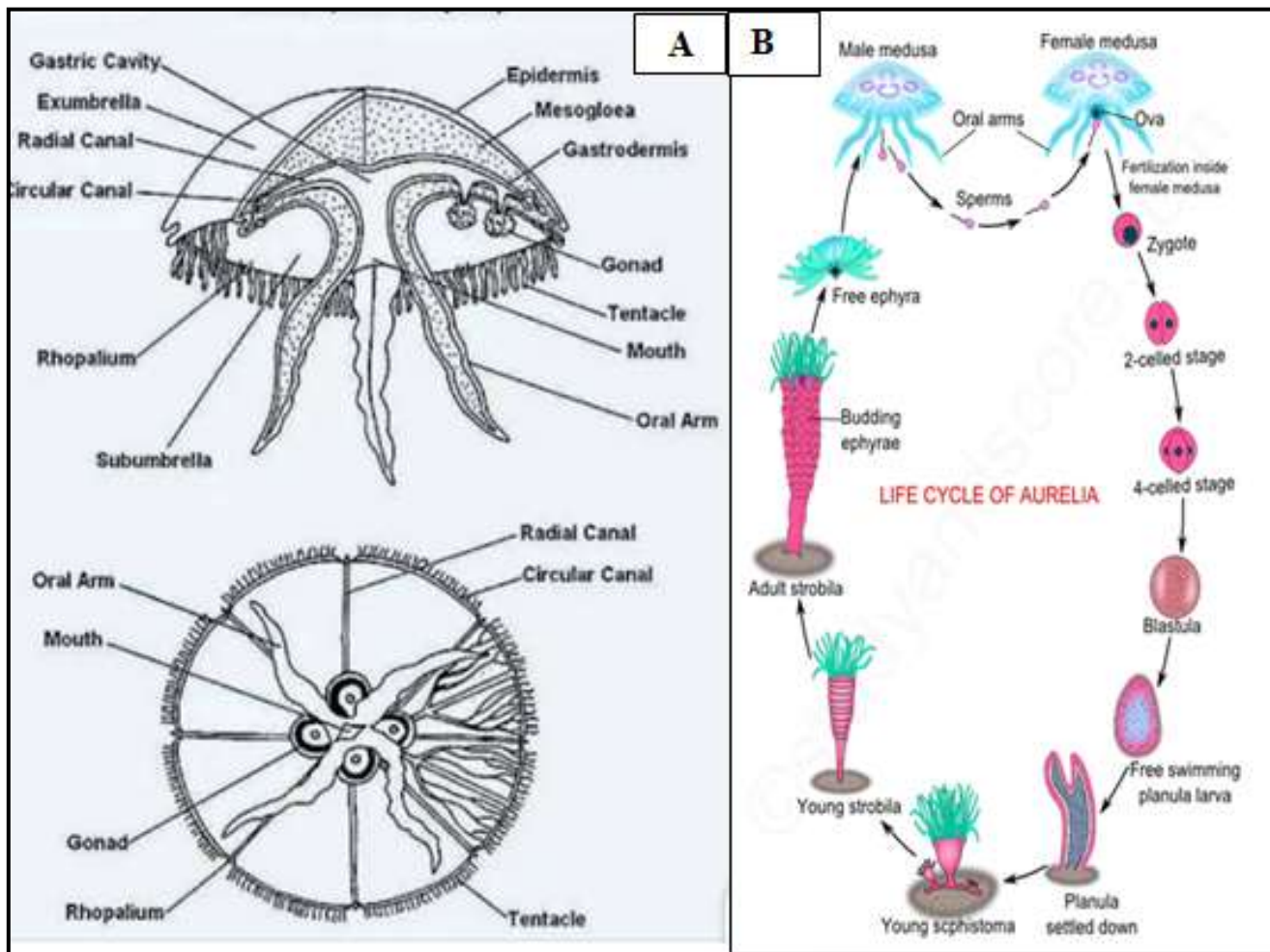


Figure 45. Morphology (A) and life cycle (B) of *Aurelia*.

2.2.3. Class Anthozoa

- Marine mostly sessile colonial or solitary
- Radial ou bilateral symmetry.
- Polyp with flower like appearance
- No medusa stage
- Mouth lead two pharynx ; mouth surround by tentacles. Feed invertebrates and fish.
- Anemones have limited locomotion
- Gastrovascular cavity divided into mesenteries containing cnidocytes and gonads
- Tentacles function to protect and catch food.
- No special organ for respiration or excretion.
- Monoecious or Dioecious
- Zygote develop in larva. Larva develop in adult animal (**Figure 46**).
- Common Anthozoa sea **Anemones** (**Figure 46**) and **Coral** sea (**Figure 46**).

2.2.4. Coral sea (8 %) (Figure 46).

- Soft bodies
- Body symmetry
- Similar to anemones
- Made of calcium carbonate
- Secret cap-shaped exoskeleton
- Sexual reproduction similar to anemones
- Asexual by Budding, live in colony
- Carnivorous
- Stinging tentacles arranged in a circle around the mouth

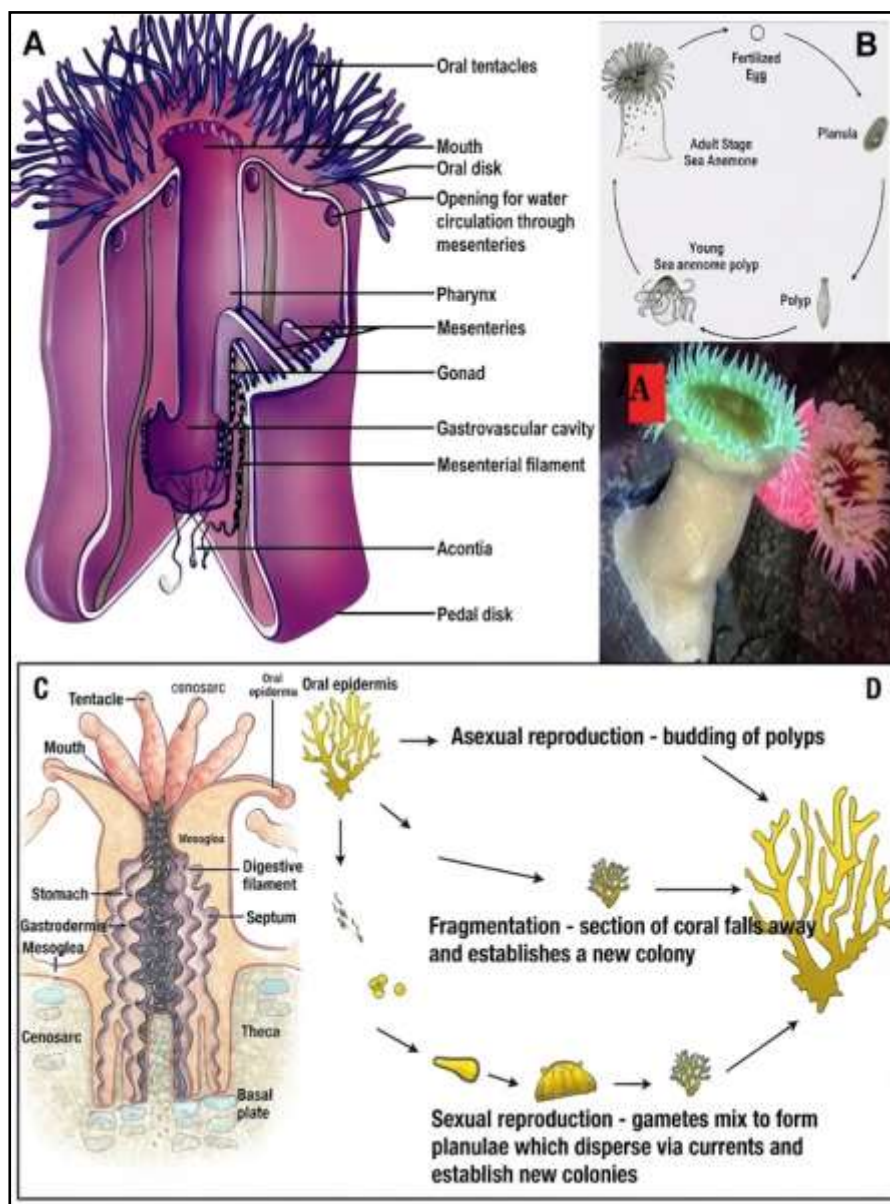


Figure 46. Anemones structure (A) and life cycle (B) ; Coral structure (C) and life cycle (D).

2.2.4. Class Cubozoa (Figure 47).

- Marine box jelly fish
- Similar to scyphozoans
- Square shaped or cuboidal shaped
- Four tentacles hang from each corner
- Active swimmer
- Polyps and medusa both present in life cycle.

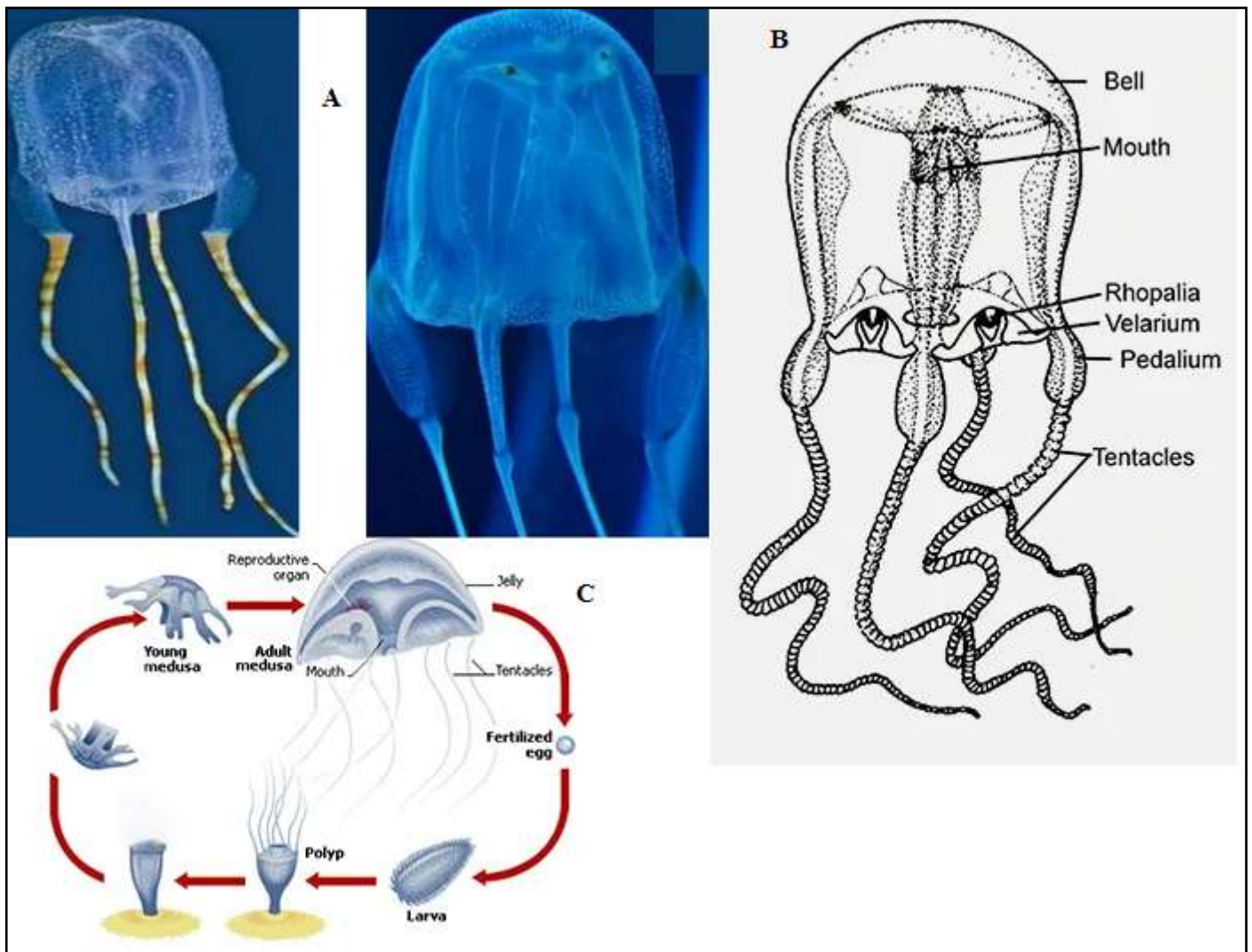


Figure 47. Cubozoa structure (A and B), life cycle (C).

3. Phylum Ctenophora

3.1. General characteristics

- Animal species belonging to the phylum Ctenophora (Greek: Ktenos: comb; phoros: to bear) are known as sea walnuts or comb jellies. **(Figure 48 A).**
- Metazoa, Diploblastica.
- The mesoglea is a gelatinous, cellular tissue that is found between the epidermis and the gastrodermis
- **Symmetry** : Biradial symmetry
- **Morphology** : Most ctenophores are spherical in shape, although several groups are flattened and/or elongated. They usually have two large tentacles. These tentacles have adhesive Colloblasts for capturing prey. **(Figure 48 B).**
- **Locomotion** : There are eight rows of ciliary bands, known as com rows, which are responsible for locomotion.
- **Habitat** : The approximately **90** described species. All ctenophora are exclusively marine.
- **Habits** : They feed on plankton and swim using cilia. Their power of regeneration is well marked.
- **Bioluminescence.**
- **Digestive tract : (Gastrovascular canal)** : It consists of a mouth, a pharynx, a stomach and two anal pores. The digestive tract is complete and digestion occurs both extracellularly and intracellularly.
- **Skeletal** : Simple diffusion is the only process present, as the circulatory, respiratory and excretory systems are absent.
- **Sense Organ** : The sense organ called the Statocyst for equilibrium (balance) is found at the opposite end of the mouth from the mouth itself.
- **Reproduction** Hermaphrodite animals; external fertilisation; the cydippid larva develops into an adult.
- **Nervous system** : No brain, just a nerve net.

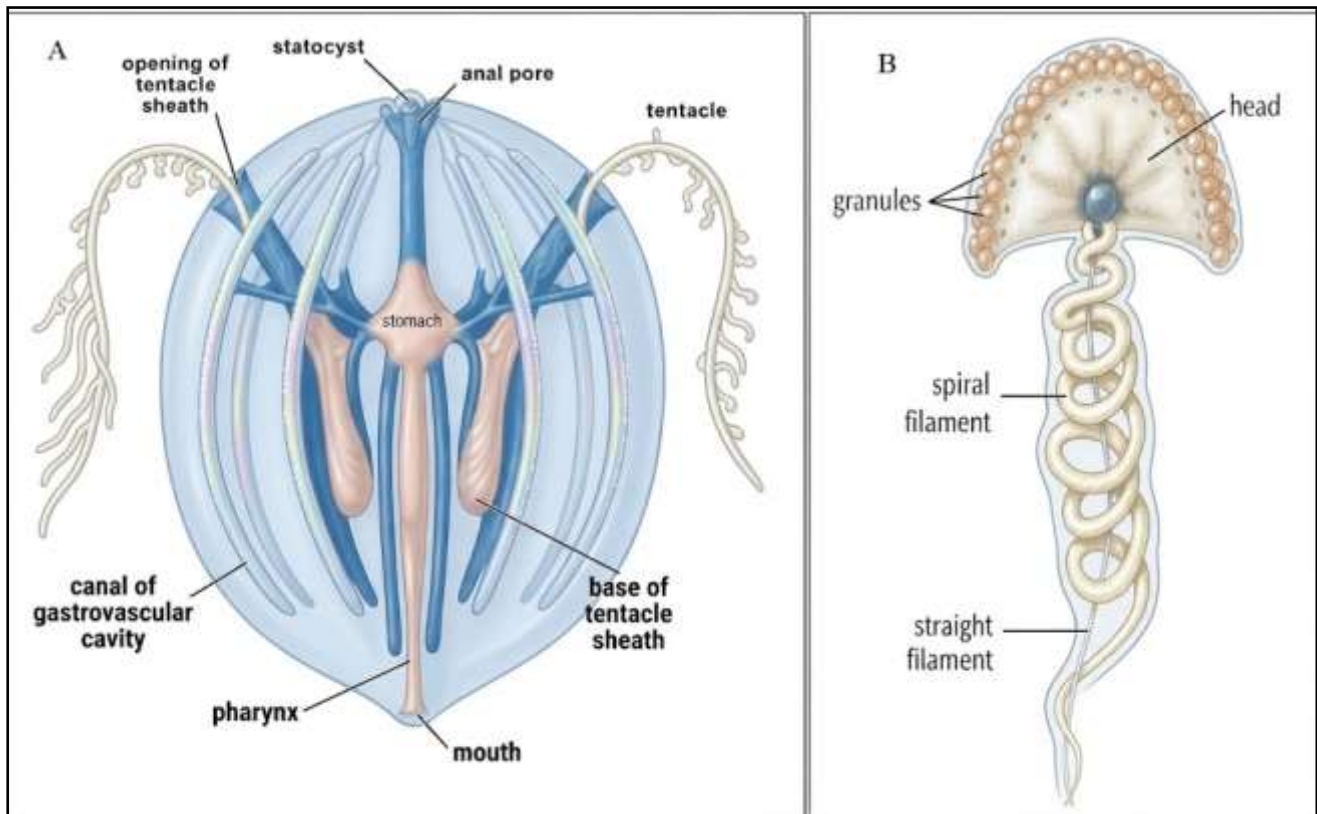


Figure 48. Diagram of ctenophora (A) and colloblast structure (B).

3.2. Classification : Two classes : **Tentaculata** and **Nuda**

3.2.1. Class Tentaculata : have two **long tentacles** ; large mouth part.

Example : **Order Lobata (Figure 49 A).**

3.2.2. Class Nuda : Lack tentacles ; Swim with plankton.

Example **Order Beroida : Beroe sp. (Figure 49 B).**

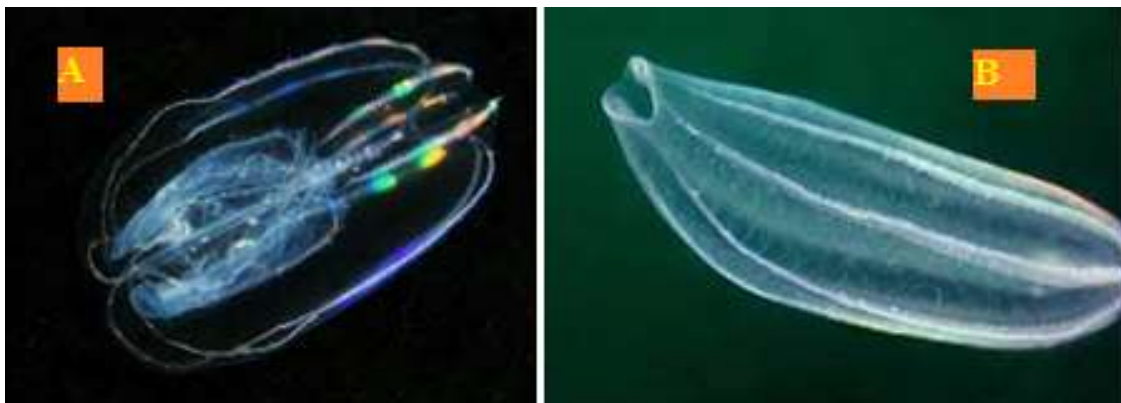
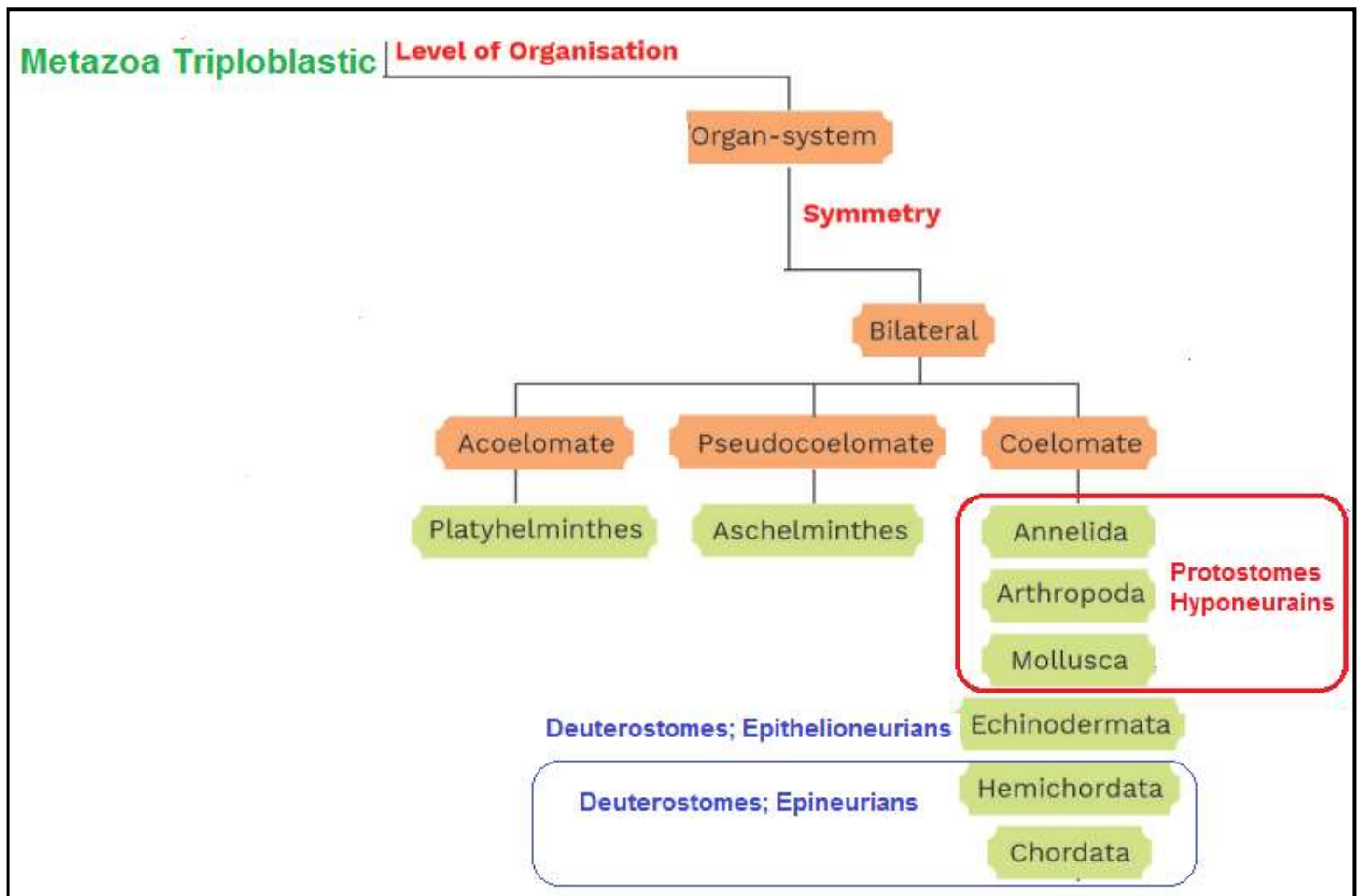


Figure 49. Tentaculata (A) and Nuda (B).

Chaptre **IV**: Subkingdom of **Metazoa**

Triploblastic



1. PLATYHELMINTHE (FLAT-WORMS)

In Greek : **Platy** : Flat ; **Helminthe** : Worm. The Platyhelminthes or flat-worms are the lowest triploblastic animals and the first to develop distinct organs system. This phylum includes a group of free-living aquatic form (Turbellaria) and two other groups of very important parasites, the flukes (Trematoda) and the tapeworms (Cestoda).

1. General characteristics of phylum Platyhelminthes

- Flatworm
- Body is Triploblastic
- Acoelomate animals, they possess no coelom ; the space between the internal organ are filled by loose parenchyma cells of mesodermal origin.
- The body of a Platyhelminthes is dorsoventrally flattened.
- Bilateral symmetry
- The body is covered by a single-layered epidermis or cuticle, which consists of scleroproteins and musculature.
- **Digestive system** : It is present in parasite form but incomplete in free-living form (only a mouth opening, but no anus)
- The respiratory and circulatory systems are not present.
- **Excretion** : Flame cells (solenocytes) are a special type of cell that helps with excretion and osmoregulation.
- **Reproduction** :
 - they are hermaphroditic. They are also monoecious.
 - Fertilisation is an internal process
 - Development can be either direct or indirect.
 - they can reproduce in two ways: asexually by budding, or sexually.
- **Nervous system** : Paired **lateral nerve** cords and **pair** of **cerebral ganglion**.
- **Ecology** : **Marine** and **terrestrial**. Over **20,000** species total.

2. Classification

Four different classes make up the phylum: Turbellaria, Monogenea, Trematoda and Cestoda.

2.1. Class Turbellaria (Planaria) :

Free-living flatworms ; Example : *Dugesia (Planaria)* (Figure 50).

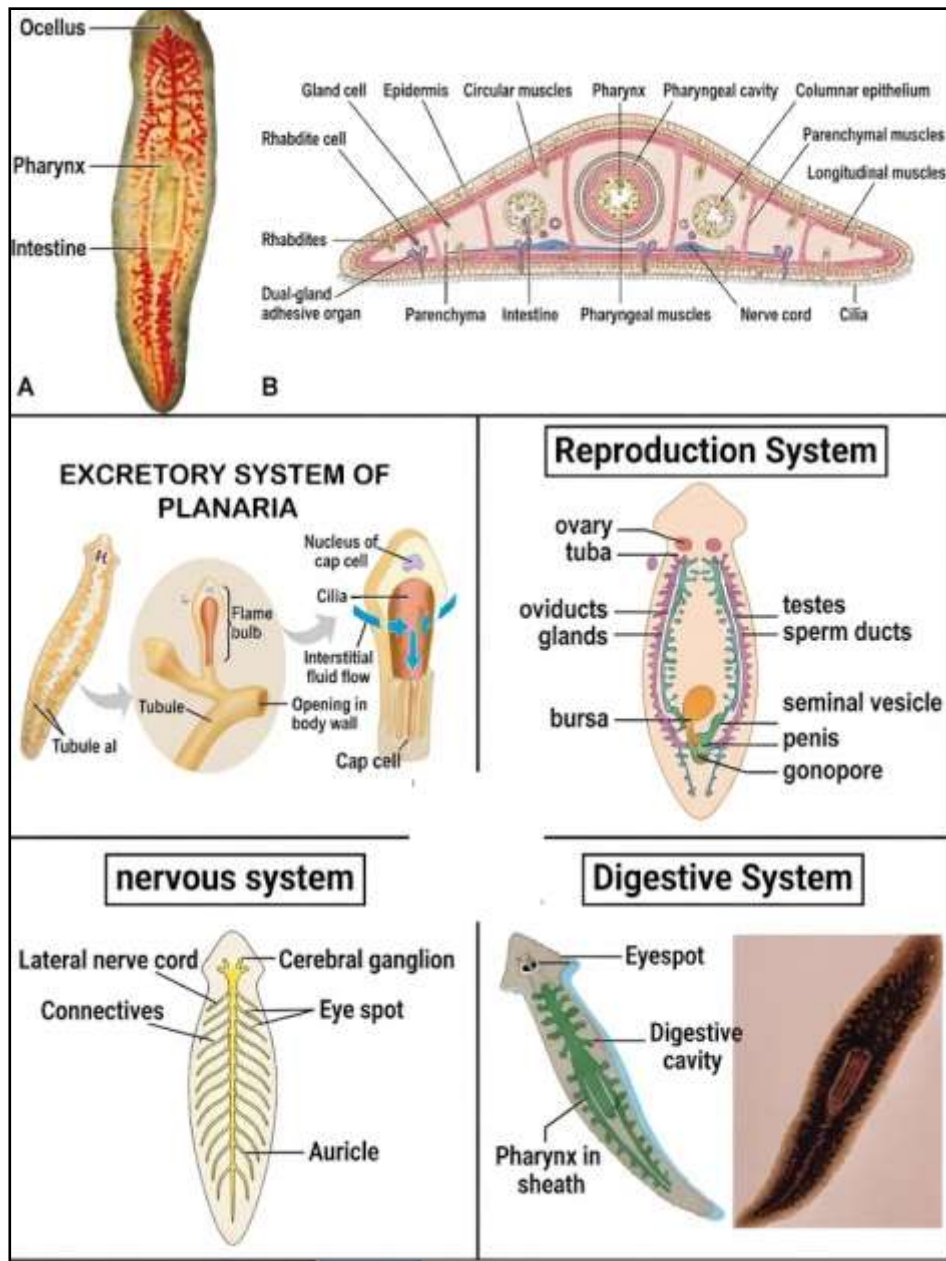
- They are free-living and found in both fresh and salt water. Some species are marine, while others are commensal or parasitic.
- The body is flattened from the back to the front, is unsegmented and shows bilateral symmetry.
- The anterior part is divided into a head.
- The body is covered by a single layer of epidermis that contains cilia for locomotion.
- The adhesive organs can be categorised as follows: glandular-epidermal, glandular-muscular and glandular-muscular.
- **Digestive system (Figure 50)** is **incomplete**, mouth is usually ventral and pharynx is tubular (**proboscis**). Most turbellarians are carnivores feed on organism such as protozoa, copepods, small worms, and minute molluscs. Certain species have particular dietary requirements and consume sponges and tunicates.
- **Reproductive system and reproduction: (Figure 50).**
 - Mostly **hermaphrodite**, reproduction is by both methods (sexual and asexual).
 - They are unable to self-fertilise (cross-fertilise) and thus need the sperm of other turbellarians to fertilise the egg.
 - The process of internal fertilisation involves the direct transfer of sperm from the male reproductive organ to the female reproductive organ.
 - Development is directed by the Muller larva.
 - They reproduce asexually by **transverse fission**.
 - Also shows regeneration.
- **Nervous system and sensory organ : (Figure 50).**
 - Eyes located on the dorsal anterior side
 - The ciliated pits are probably chemosensors. They are located behind the auricles on the head.
 - The brain is bilobed on its dorsal surface.
 - The nerves are arranged in pairs, three to four of them in total, and they are arranged longitudinally.

➤ **Excretory system (Figure 50).**

➤ **Protonephridial system:** comprises two longitudinal ducts that connect to a network of tubules branching throughout the body and ending in many large flame cells.

➤ **Flame cells** collect excess water and waste fluids.

➤ **Osmoregulation:** the removal of excess fluids from the organism, although small amounts of ammonia are also removed.



50 Figure. Diagram, cross section (A and B) and different systems of Planaria.

Classification of Planaria depend a blind **intestine** details depend on **Order** : (Figure 51)

1- Order Tricladida : It has one main anterior branch and two main posterior branches.

Example : *Dugesia*.

2- Order Polycladida : The gut has numerous branches that extend throughout the body.

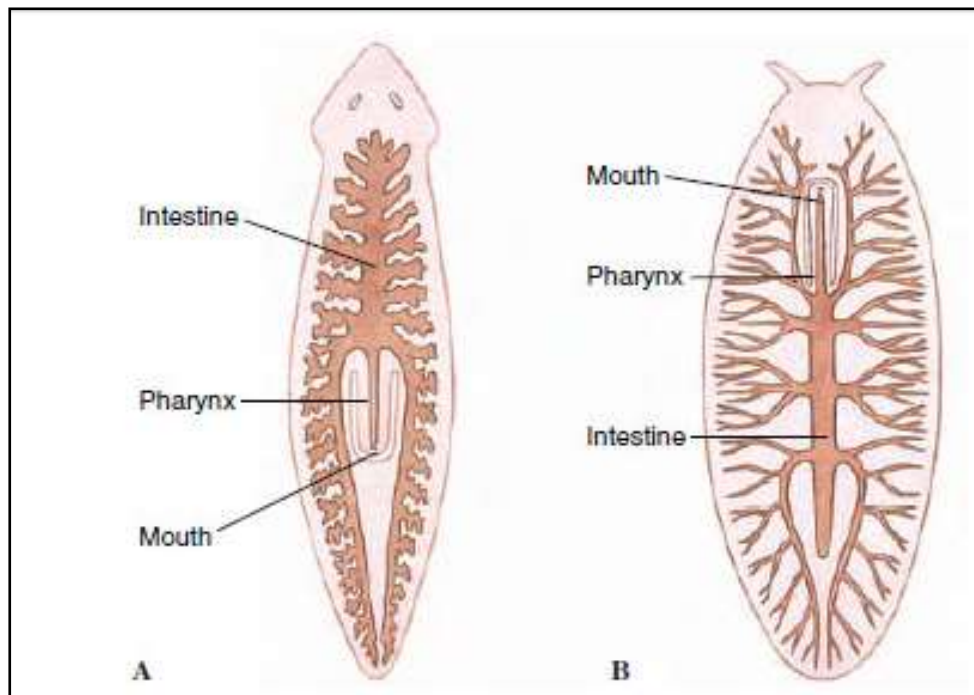


Figure 51. Intestinal pattern of two orders of turbellarians. **A**, Tricladida. **B**, Polycladida

2.2. Class Monogenea (Figure 52).

- Most species are ectoparasitic of fish.
- Some endoparasites of urinary bladder and mouth of reptiles and amphibian.
- Body covered by tegument
- Posterior hooks with opisthaptor.
- Direct cycle with single host (**Figure 52**).
- Larva hooked free swimming (**oncomiradium**).
 - Example : *Polystoma sp.* ; *Diplozoon paradoxum*

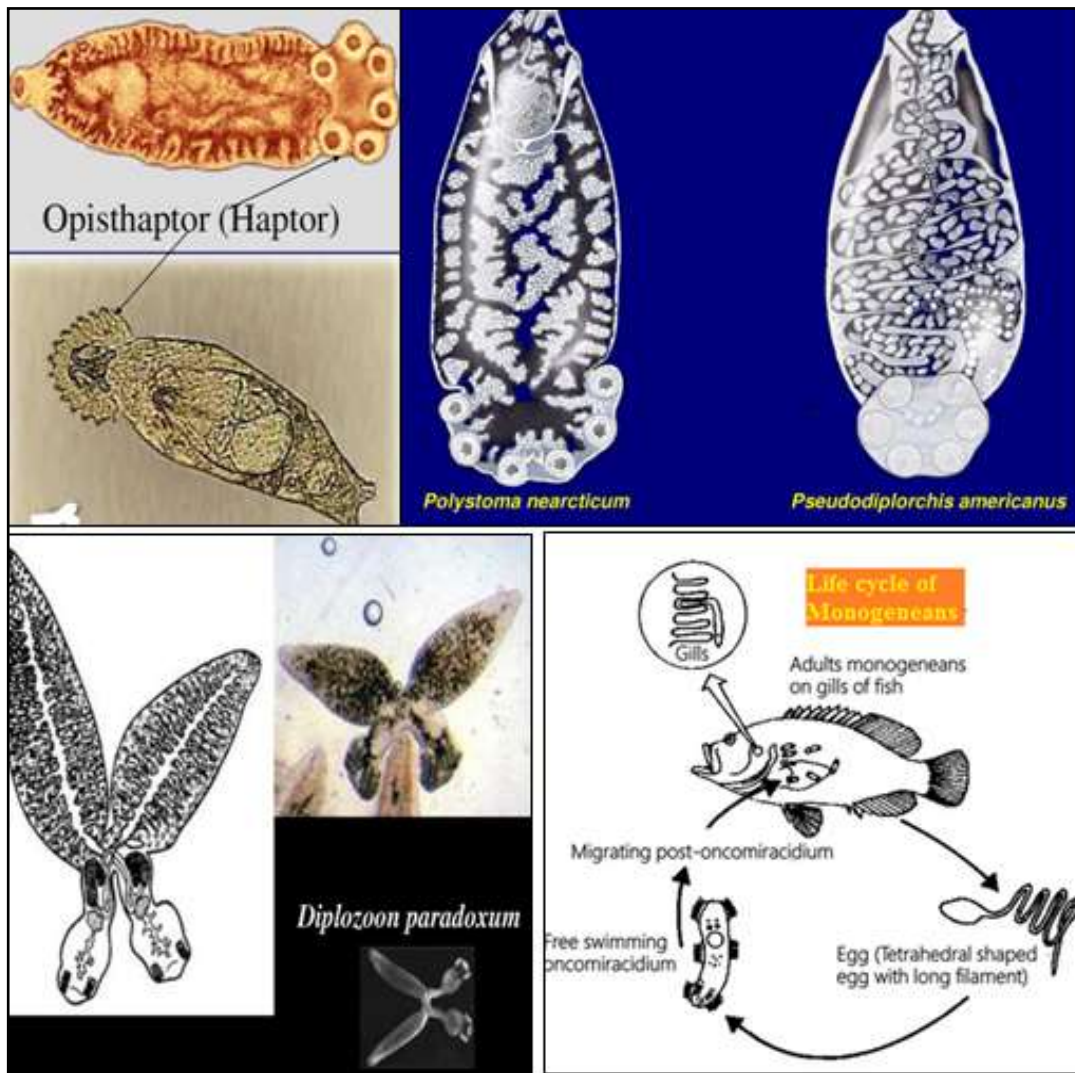


Figure 52. Morphology, examples and life cycle of Monogenea species.

2.3. Class Trematoda (Flukes) (Figure 53).

- They are ecto or endo-parasites, more commonly known as flukes..
- Structurally, trematoda are **similar** to **turbellarians**.
- **All parasitic**, mostly in **vertebrate**.
- The body's shape can be described as either leaf-like, elongated or oval.
- They lack an epidermis, but their body is covered by a thick cuticle (the tegument), although there is no ciliated syncytium. The cuticle protects the parasite against its host's digestive enzymes
- **Oral sucker (ventral sucker)** is surround the mouth, for adhesion (attachement), and acetabulum used for penetration to host body.

- **The digestive tract** is shaped like a tree, with two main branches and smaller ones. The mouth is located at the anterior end. The food is made up of the tissues or body fluids of the host, which are sucked in by the muscular pharynx.
 - **Excretory organ** : Protonephridia.
 - **Nervous system** They consist of a pair of cerebral ganglia and a longitudinal cord. Some larvae and flukes that are ectoparasites have sensory organs, such as dorsal eyespots.
 - **Reproductive system** : The majority of them are hermaphroditic and cross-fertilisation is exhibited by them.
 - **Life cycle** : It may be simple or complicated, involving one or more intermediate hosts and a larval stage. They have a parasitic life and develop a resistant cuticle, suckers and hooks, and a general lack of sense organs.
 - **Habitat** : according to their habitat :
- ✚ **Blood Flukes** : *Shistosoma* species.
 - ✚ **Liver Flukes** : *Fasciola* species.
 - ✚ **Intestinal Flukes** : *Fasciolopsis buski*.
 - ✚ **Lung Flukes** : *Paragononium sp.*

This class includes two distinct orders :

2.3.1. Order Monogenea (Monogenetic trematoda)

This order includes external or very rarely internal parasites which use one host and have a simple direct life cycles and direct development.

2.3.2. Order Digenea.

This order includes internal parasites or endoparasitic flatworms with complicated indirect life cycles. The transmission of the parasite from one host species, which is usually a vertebrate animal, to another requires a second host, which is usually an invertebrate animal. This second host is called the intermediate host.

Digenetic trematoda constitute a major group of flatworms which are commonly found in hosts belonging to almost every class of vertebrate animals. Including fish, amphibians, reptiles, birds and mammals.

According to their location in the body of the host, digenetic trematodes are described as hepatic, blood, intestinal or pulmonary flukes.

In the present text the morphology and the biology of the following trematodes are considered :

Liver Flukes : *Fasciola* species

Blood Flukes : *Shistosoma* species.

Intestinal Flukes : *Fasciolopsis buski*.

Lung Flukes : *Paragononium* species.

1.2.3.2.1. Liver flukes (FASCIOLA) (Figure 53).

Liver flukes, also known as *Fasciola hepatica*, are parasites that cause a disease known as fascioliasis. It is most common in sheep and cattle, but can also be found in other mammals and occasionally in humans.

➤ **Morphology**

✚ They are frequently over 30 mm long.

✚ The characteristics are a cone-shaped projection at the anterior end, followed by a pair of wide shoulders

➤ **Digestive system** : It has a mouth, a muscular pharynx, a short oesophagus and a two-branched enteron.

➤ **Muscles** are complex.

➤ **Excretory** : provide by many flame cells.

➤ **Nervous system** : There is a double ganglion and two lengthwise nerve cords, as well as various nerves.

➤ **Mode of transmission** The parasite is transmitted in two ways: by eating edible aquatic plants that contain metacercariae, or by drinking water in which metacercariae are present.

➤ **Reproduction system** : Hermaphroditic.

✚ **Metacercariae** excysts in the duodenum or jejunum and liberate the Juvenile fluke.

✚ The juvenile fluke penetrates the intestinal wall and reaches the liver capsule.

✚ The parasite burrows into the liver parenchyma, where it grows and develops.

✚ It becomes sexually mature within the bile duct.

Examples : *Fasciola hepatica* ; *Fasciola gigantica*.

Fasciola hepatica is also known as: the sheep liver fluke, the temperate liver fluke or the common liver fluke. *Fasciola gigantica* is known as the giant liver fluke or the tropical liver fluke. The life cycle of the *Fasciola* species is illustrated in Figure 53.

Fasciola hepatica and *gigantica*

- **Defenitive hot** : Sheep, Cattle, Other mammls and accidental in Human
- **Intermediate hot** : Freshwater snail.

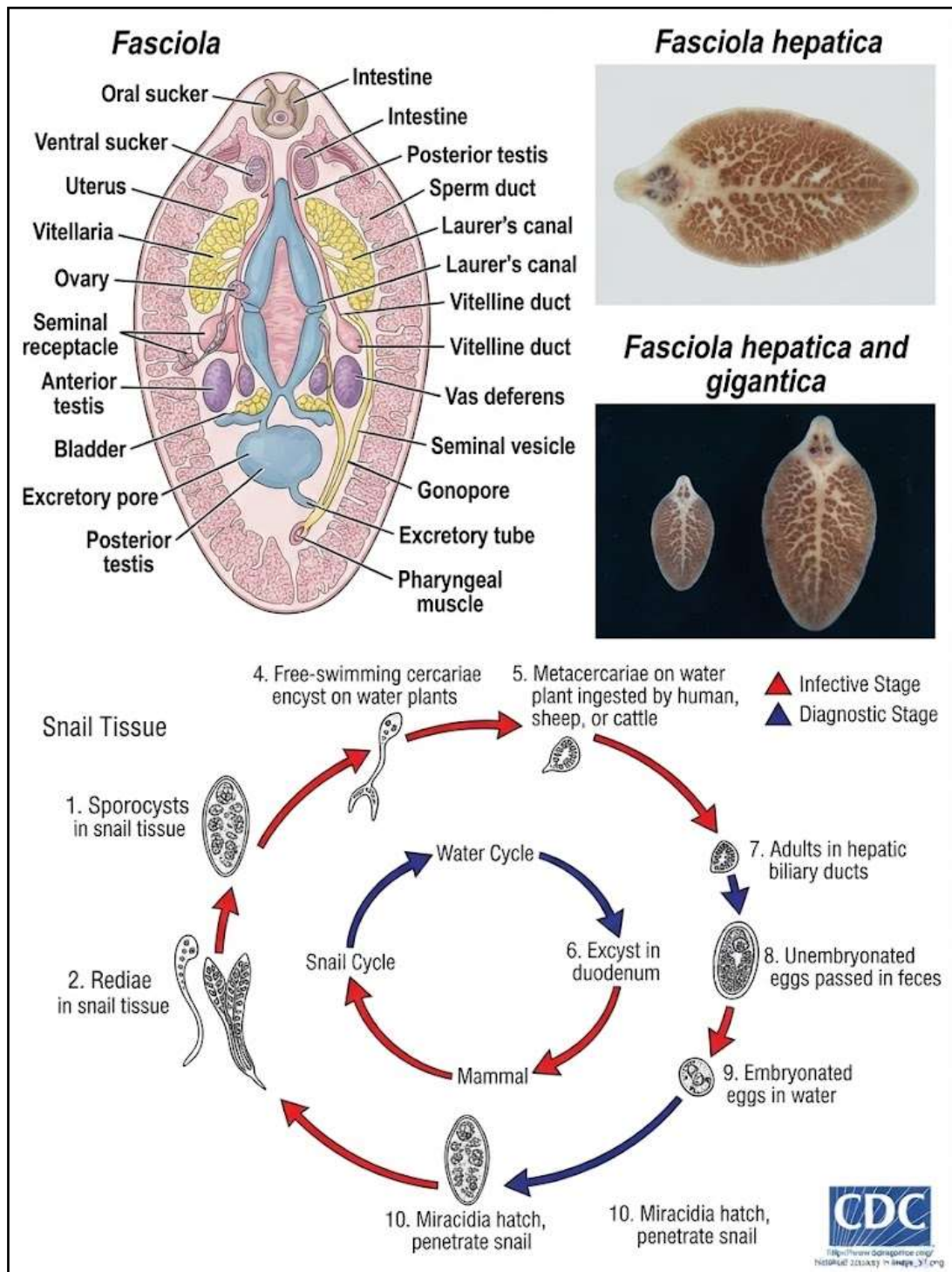


Figure 53. Diagram from *Fasciola* with different organ system and life cycle.

1.2.3.2.2. Blood flukes *Schistosoma* (Figure 54 A).

Shistosomiasis, also known as bilharzia, is an infection caused by blood flukes and is one of the world's major infectious diseases. More than 200 million people worldwide are infected with these flukes, which they acquire by swimming or walking in water where the intermediate snail host lives.

They differ from other trematodes in that they are dioecious.).

All species roughly similar.

Size 0,5-2,5 cm in length

Male short and wide, female **long thin**

Female adult reside in **gynecophoral** canal formed by **male body**.

Definitive host : Human

Intermediate host : snail

Invective stage : **Metacercariae**

Reservoirs : monkeys, cats, dogs, cattle, horses, swine

The human disease known as **Shistosomiasis, Bilharzia, Bilhariaziasis.**

Human blood flukes : **three major species (Figure 54).**

- ***Schistosoma haematobium*** : Perivesical **venous plexus** surrounding the **bladder**
- ***Schistosoma japonicum*** : **mesenteric veins** of the **small intestine**.
- ***Schistosoma mansoni*** : **mesenteric veinule** of large **bowel and rectum**

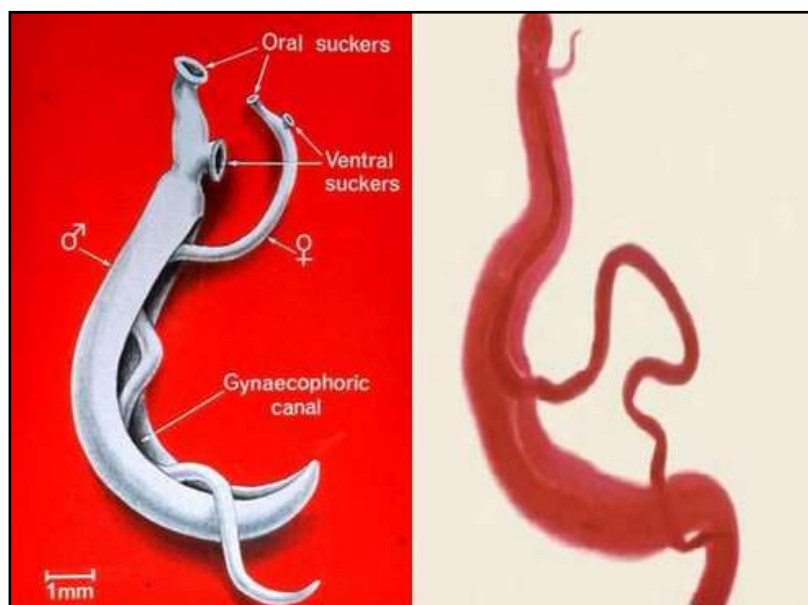


Figure 54 A. Morphology of *Schistosoma*.

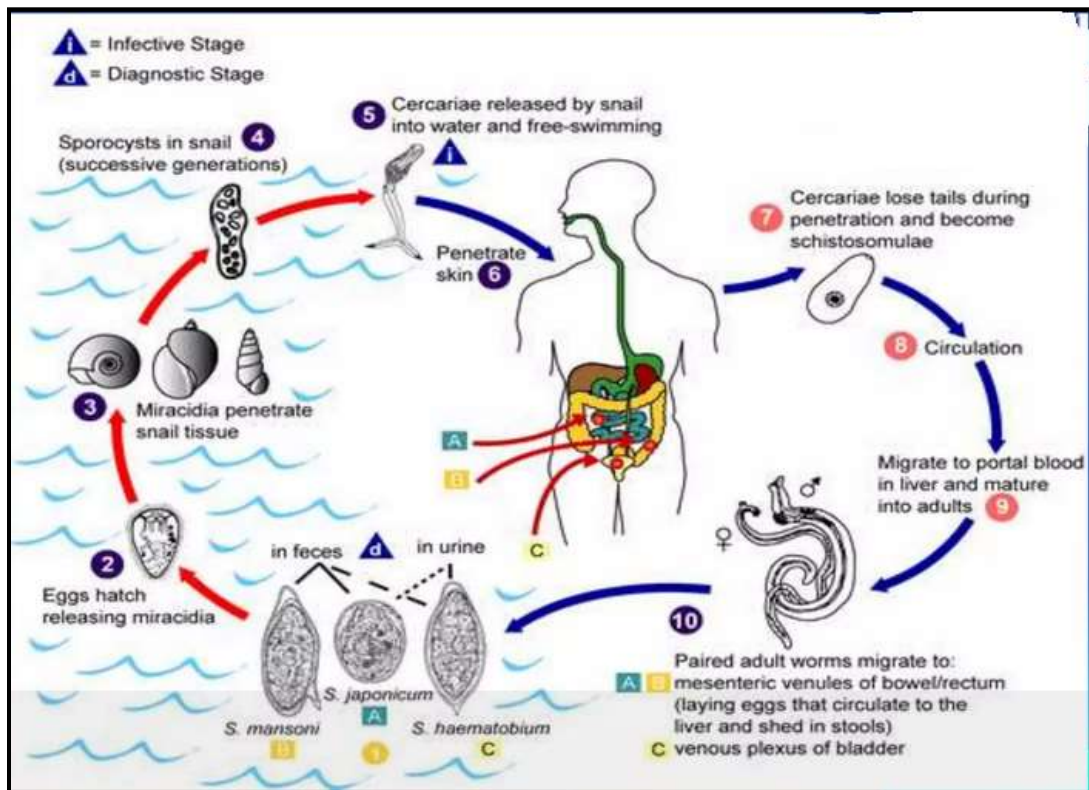


Figure 54 B. Morphology of *Schistosoma* and their life cycle.

1.2.3.2.3. Intestinal Flukes : *Fasciolopsis buski*.

Prevalent in **South Asia**. **Morphology and life cycle** : see figure 55.

Lives in **human** and pig's **Intestine**.

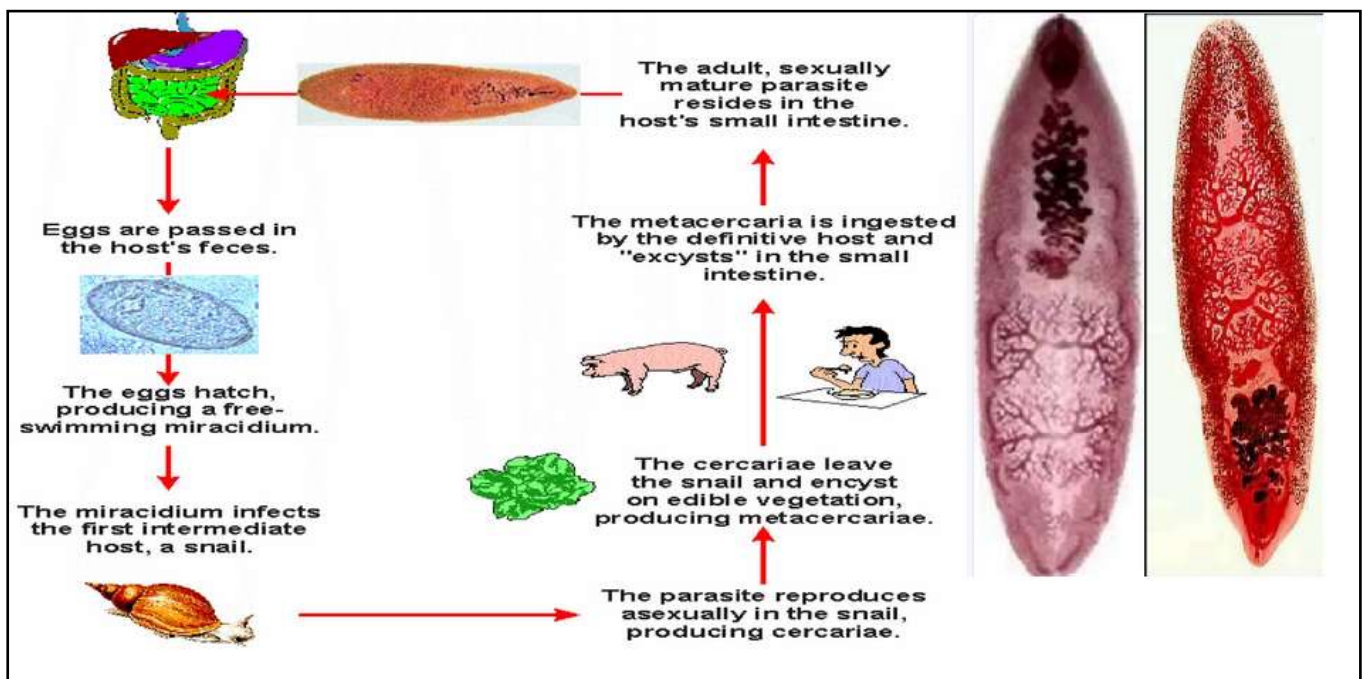


Figure 55. Morphology of *Fasciolopsis buski* and its life cycle.

1.2.3.2.4. Lung Flukes : *Paragonium* species (Figure 56).

- Also known as the Japanese lung fluke or the oriental lung fluke.
- It is the most common species of lung fluke that infects humans and is responsible for a significant number of cases of lung fluke infection.
- It cause **paragonimiasis**.
- **Geographic distribution** : Eastern Asia ; Africa ; South and central America

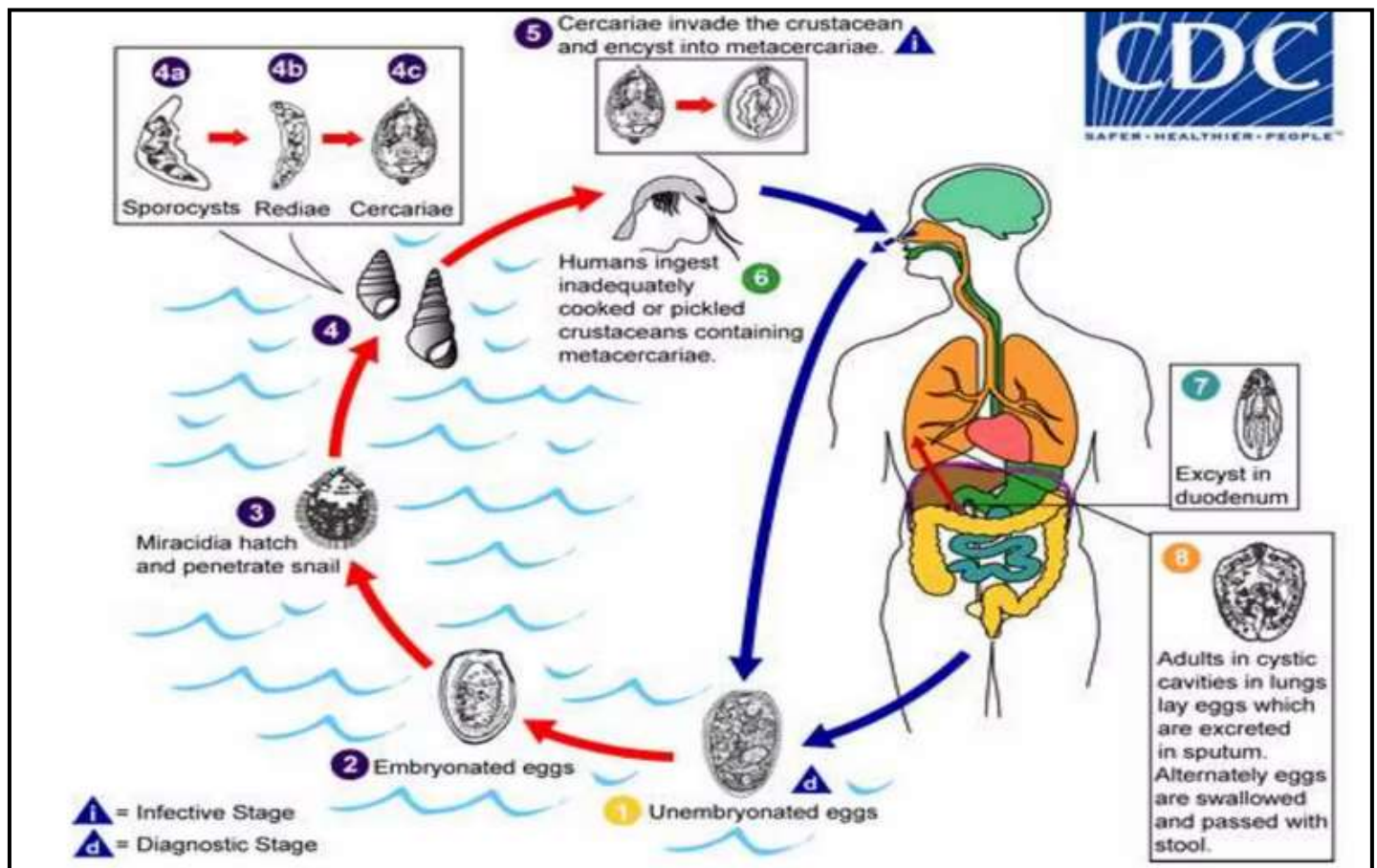
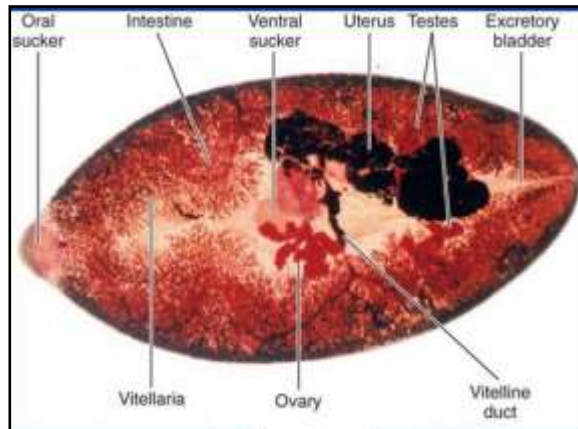


Figure 56. *Paragonium*, morphology and Life cycle.

2.4. Class Cestoda (Tapeworms) (Taenia) (Figure 57).

1.2.4.1. General features

- Tapeworms are long, segmented and tape-like.
- **It is dorsoventrally flattened.**
- The size varies greatly, ranging from a few millimetres to several metres.
- They are **endoparasite**.
- **Parasites** in the small intestine of humans and other vertebrates. Mostly slender and elongate
- They lack an epidermis, rhabdites and external cilia. Their bodies are covered in a layer of skin called the tegument with a complex muscle layers.
- A **typical cestode** usually consists of **head** or **scolex** followed by a **short neck** (unsegmented) and **body** or **strobila** consist of chain of segments called **Proglottids**.
- The **head or Scolex** bears **four suckers** as the organ of attachment which may be armed with **hooks**.
- **The Scolex** may have two long muscular gooves called Bothria instead of suckers (**Cotyloda**).
- **Neck** is **unsegmented** portion situated just posterior to the Scolex,
- Which continuously produces proglottids (segment) by metameric repetition of their reproductive organ.
- **Strobila** constitutes the main bulk of the body and made up of the chain of immature, mature and gravid proglottids segments.
- **Proglottids** as follows
 - **Immature:** small anterior segments.
 - **Mature:** middle, moderate-sized segment.
 - **Gravid:** posterior large-size segments.

After fertilisation, all the reproductive organs slowly degenerate and the proglottids become filled with eggs. These are then called gravid proglottids.

After shedding of gravid segment, the eggs in gravid proglottids are liberated either by disintegration of proglottids (**Apolysis**). Under electron microscope, this outer limiting membrane of the tegument and contains numerous structure such as mitochondria, golgi apparatus, ribosomes, endoplasmic reticulum...

- **Digestive system :** The alimentary tract is absent in cestodes. They live and feed on living hosts, depriving them of nourishment while disrupting their nutrient absorption, which causes weakness and disease.

➤ **Excretory system** : The excretory system is also referred to as the osmoregulatory system, and is made up of nephridial cells and excretory canals.

➤ **Reproductive system** : Hermaphrodites have both male and female reproductive organs in each proglottid.

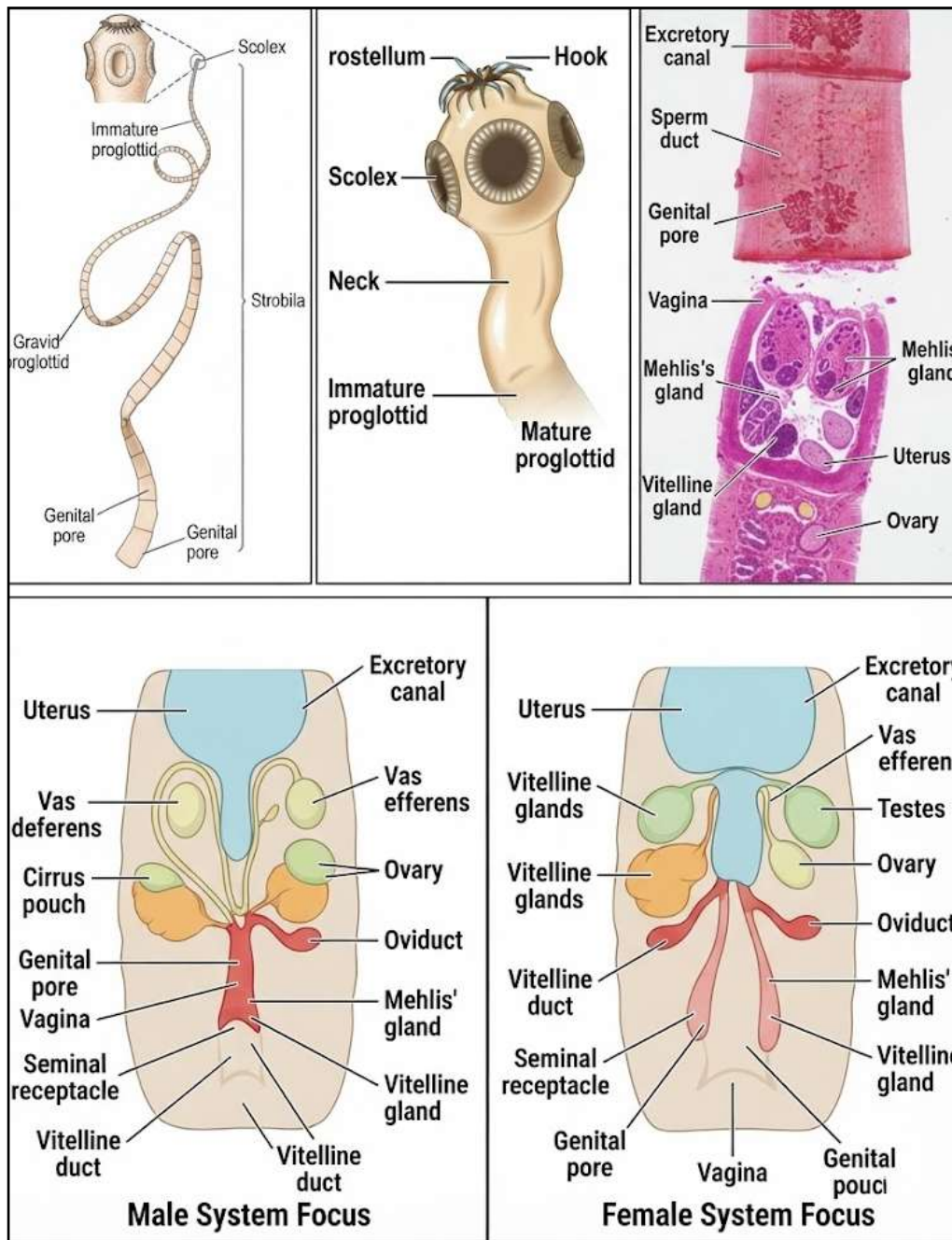


Figure 57. Morphology of tapeworm, proglottid and different organ system.

1.2.4.2. Systemic classification of class Cestoda

1.2.4.2.1. Sub class Cestodaria (Figure 58).

- A class of small worms that do not have a scolex. With a sucker for attachment,
- Their body is **individed**.

- One set of the reproductive organ is required.
- Lack digestive tract.

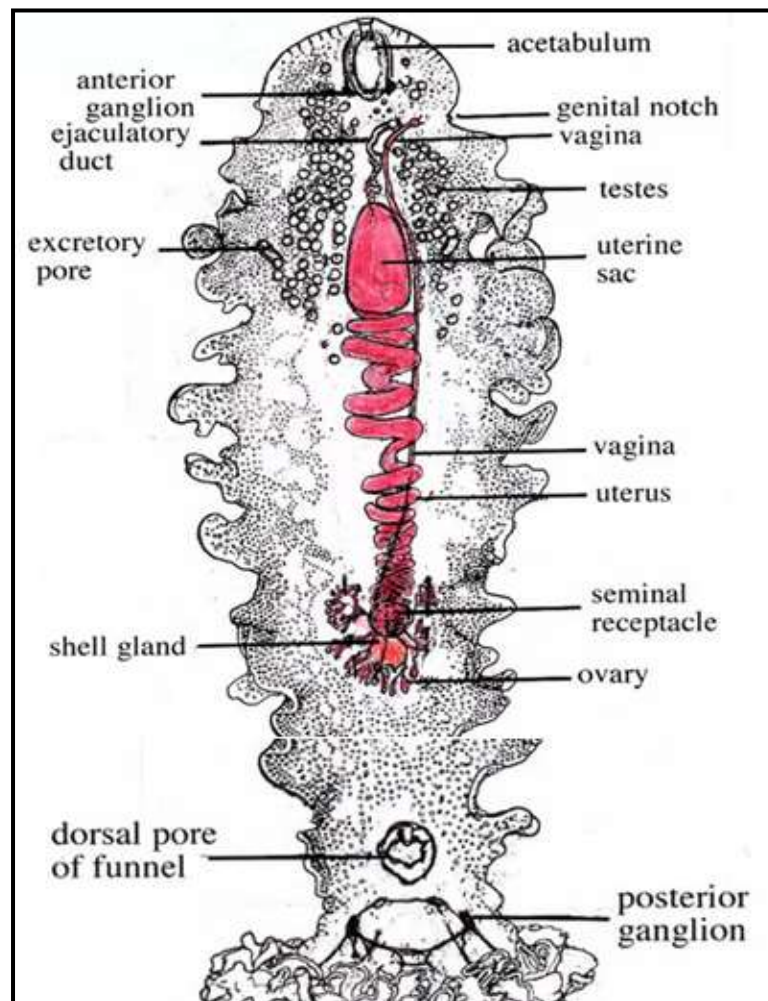


Figure 58. Cestodaria morphology

1.2.4.2.2. Subclass Eucestoda

- Have **Scolex**
- Classification in **2 Orders** showed in table 5

Table 5. Classification of Eucestoda.

Order	Family	Genus species
Cyclophyllidea	Dilepididae	<i>Dipylidium caninum</i>
		<i>Choanotaenia</i> spp.
	Davaineidae	<i>Raillietina</i> spp.
	Anoplocephalidae	<i>Anoplocephala</i> spp.
		<i>Moniezia</i> spp.
	Taeniidae	<i>Taenia</i> spp. <i>Echinococcus</i> spp.
	Mesocestoididae	<i>Mesocestoides</i> spp.
Pseudophyllidea	Diphylobothriidae	<i>Diphylobothrium latum</i>
		<i>Spirometra</i> spp.

Classification based on the habitat of the tapeworm.

A) Intestinal cestodes are adult worms that reside in the human intestine.

- *Taenia saginata* and *Taenia solium* causing **intestinal Taeniasis**.
- *Hymenolepis* species
- *Dipylidium* species.
- *Diphylobothrium* species

B) Somatic/ Tissue cestodes (Larvae in human, Muscle/ Organ)

- *Taenia solium* causing **Cysticercosis**.
- *Echinococcus* species
- *Spirometra* species

A.1. The tapeworms known to cause zoonotic infection in human are : (Figure 59).

1. *Taenia solium* (Figure 59)

- ✚ **Pork** tapeworm
- ✚ **Human** are the **definitive hosts (DH)**.
- ✚ **Pigs** are the **intermediate hosts (IH)**.
- ✚ Causing **cysticercosis**.

2. *Taenia saginata* (Figure 59)

- ✚ **Beef** tapeworm
- ✚ **Human** are the **definitive hosts**.
- ✚ **Cattle** are the **intermediate host**.
- ✚ **Intestinal taeniasis**.

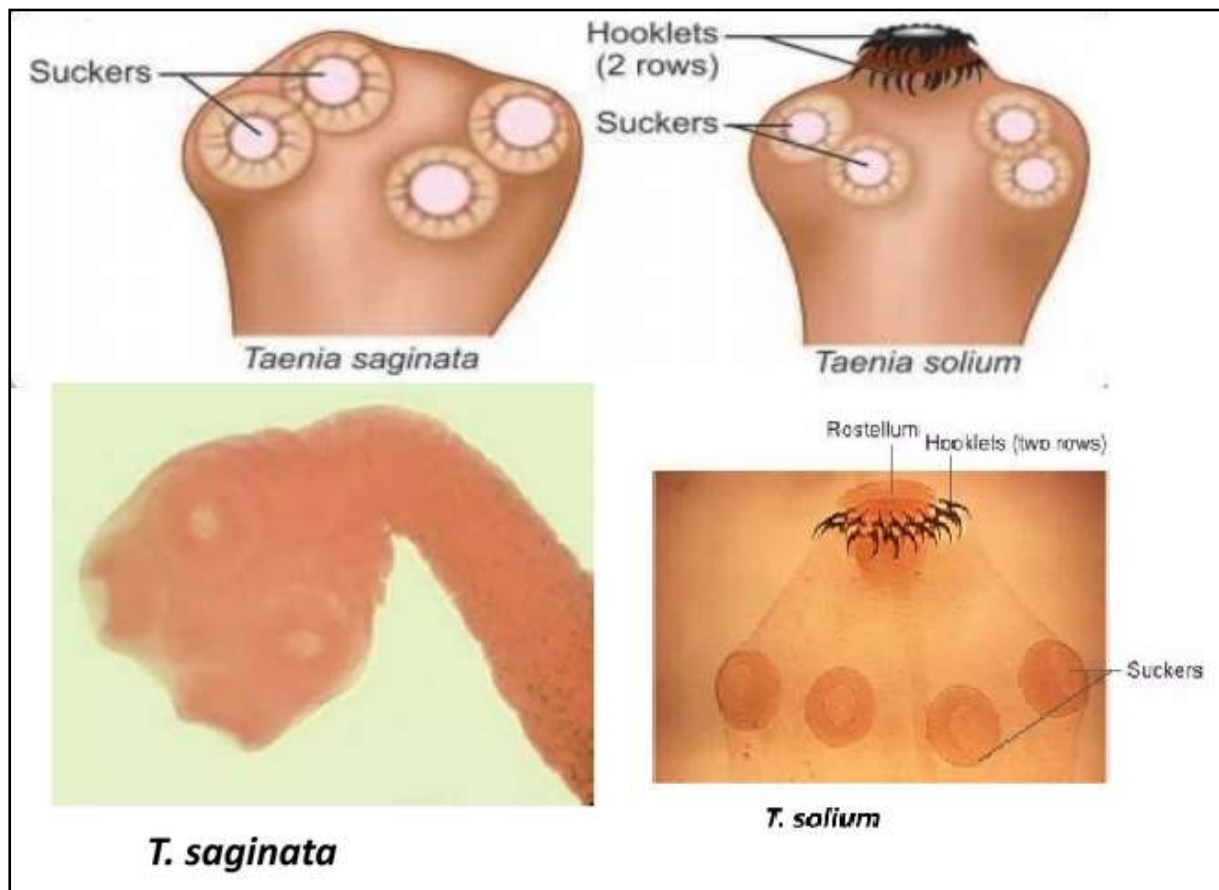
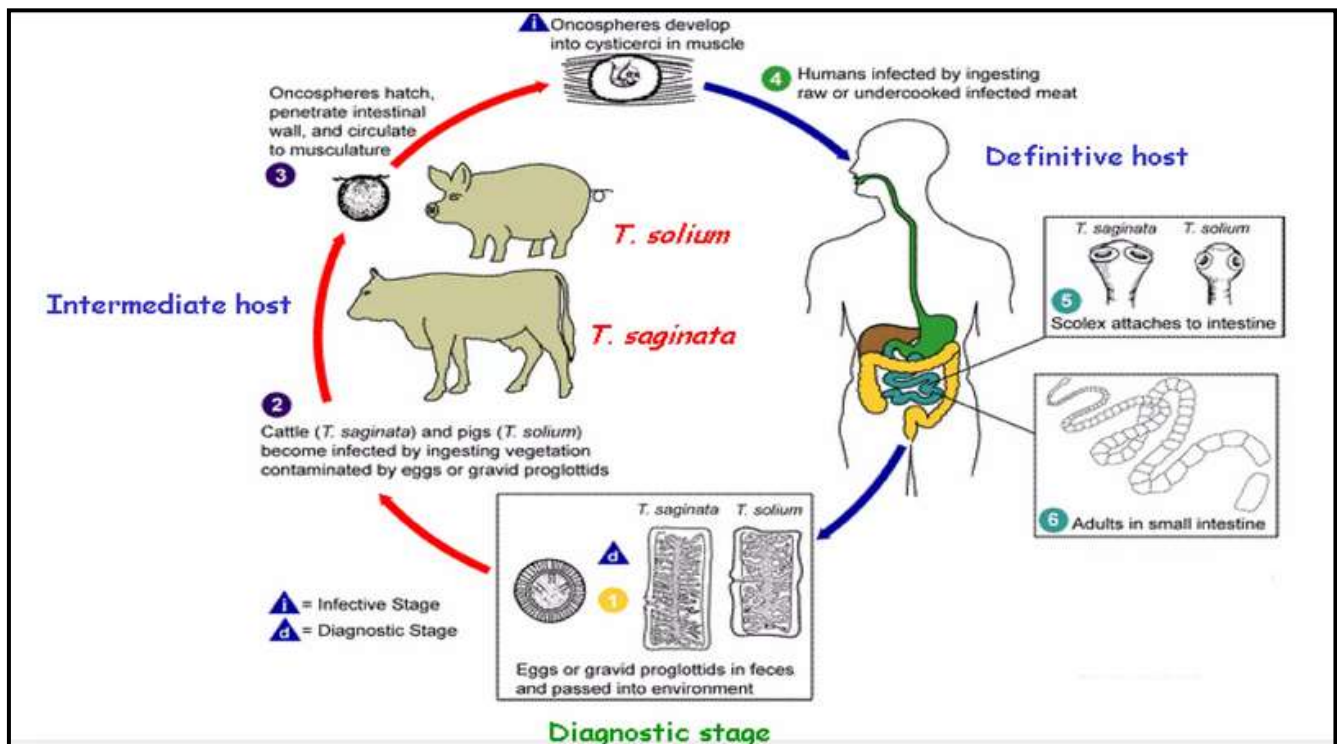


Figure 59. Scolex of *Taenia saginata* and *Taenia solium*.

Taenia Life Cycle (Figure 60).**Figure 60.** Taenia Life Cycle.Differences between *Taenia saginata* and *Taenia solium* (Table 5).**Table 5.** Differences between *Taenia saginata* and *Taenia solium*.

	<i>T. solium</i>	<i>T. saginata</i>	
Size Body length	2-4 meters	up to 10 meters (70' worms have been reported)	 
Scolex	4 suckers, rostellum & hooklets	4 suckers	 
Mature proglottid Ovary	3 lobes	2 lobes	 
Testes	150-200	300- 400	
Gravid proglottid: Uterine branches	7-12	15-30	 
Life expectancy -	25 years or more	25 years or more	

3. *Hymenolepis nana*

Scolex : Subglobular.

4 suckers.

Armed with single row 20-30 hooklets.

Life cycle in figure 61

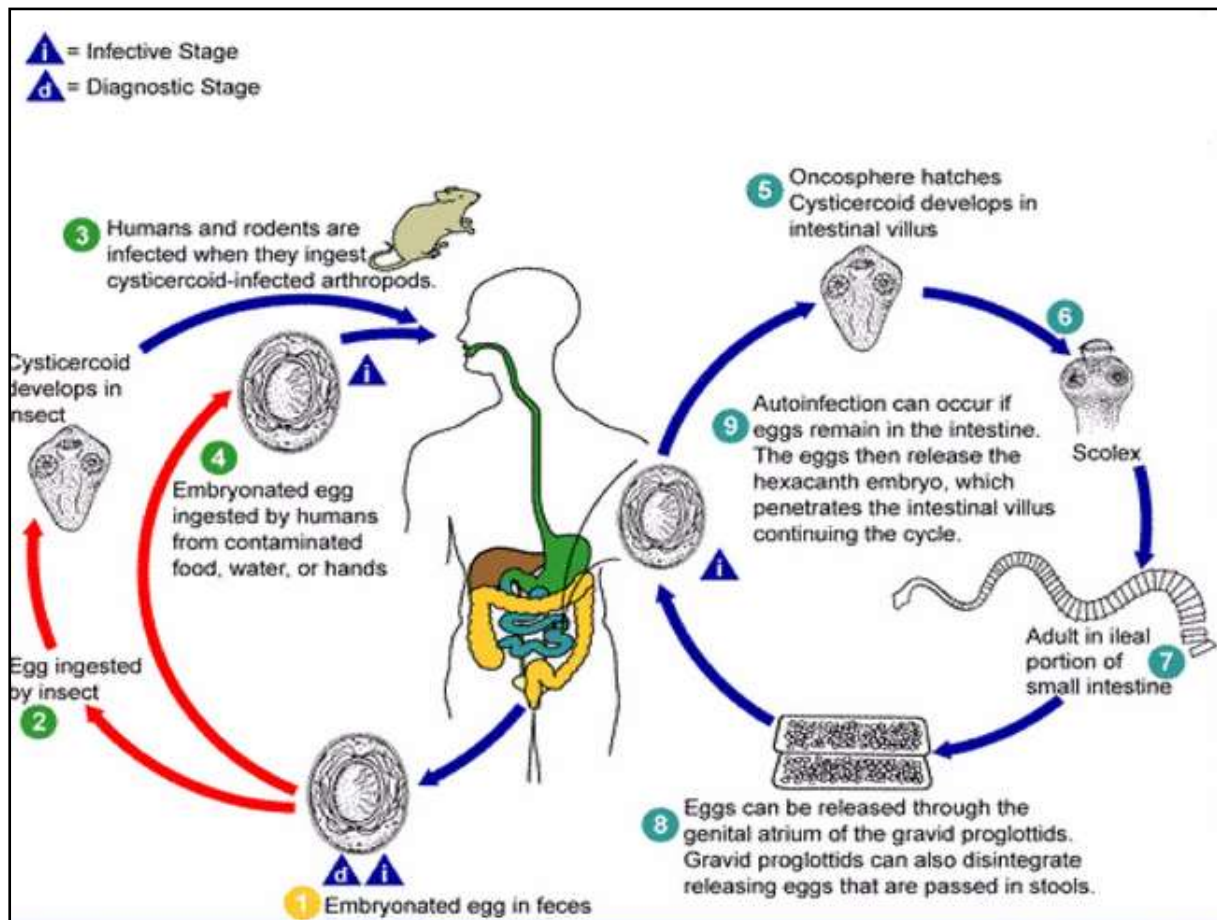


Figure 61. Life Cycle of *Hymenolepis nana*.

4. *Taenia Echinococcus* : *Echinococcus granulosus*.

✚ Dog tapeworms

✚ Hydatid worms.

✚ Adult worm are **Small 3-6 mm**

✚ **3 segments** occasionally 4.

✚ It has a protrusible rostellum with two circular rows of hooks (4 suckers).

Life cycle in figure 62.

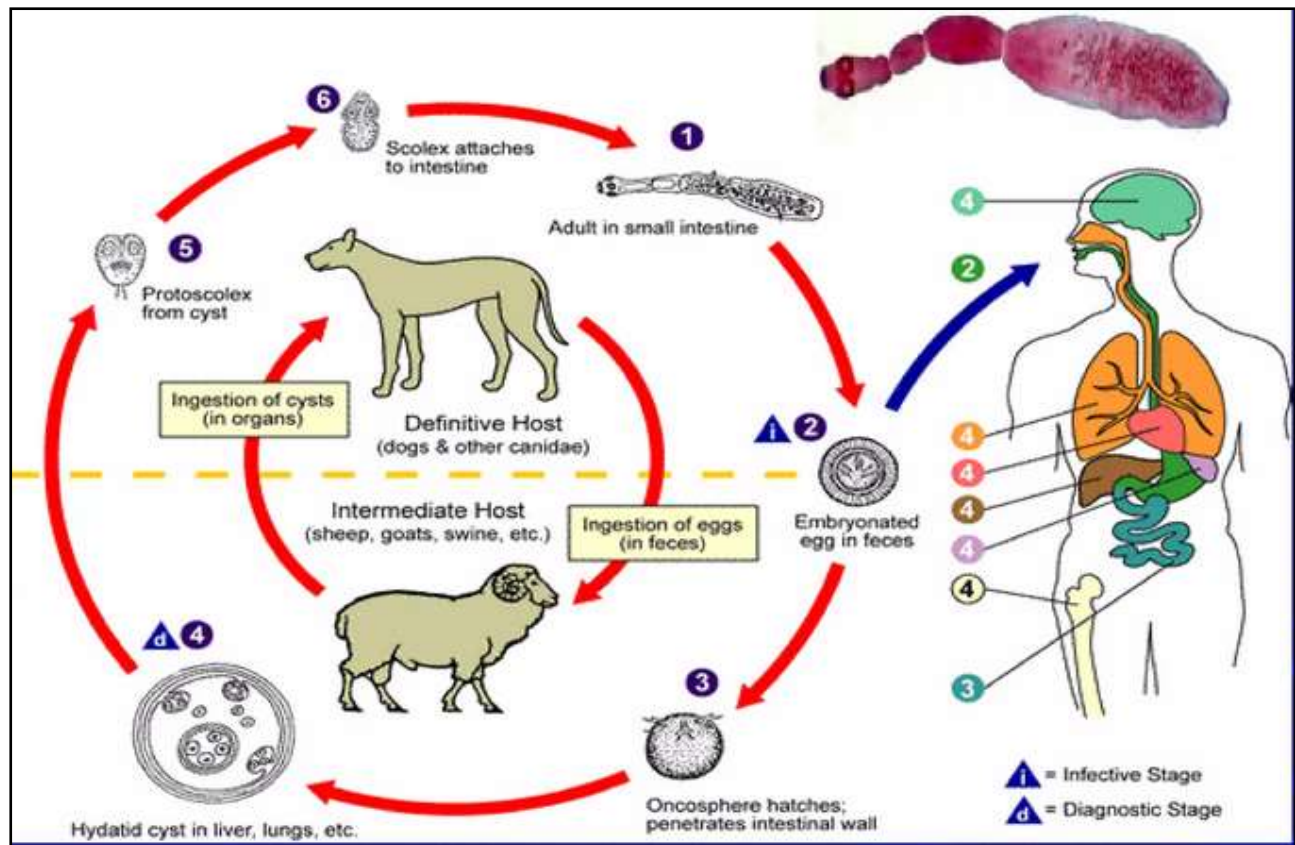


Figure 62. Life Cycle of *Echinococcus granulosus*.

5. *Dypilidium sp* (Dog tapeworm)

- ✚ Scolex small and globualr
- ✚ Rostellum has 1-7 rows of rose hookletes.
- ✚ 200 proglotids

2. Order Pseudophyllidea

Example : *Diphyllobothrium latum*

- ✚ Elongate head bears two longitudinal slit like grooves called bothria without sukers.
- ✚ **Fish** tapeworm or broad tapeworm
- ✚ **10-12** meters, 3000- 4000 segments

Life cycle in figure 63.

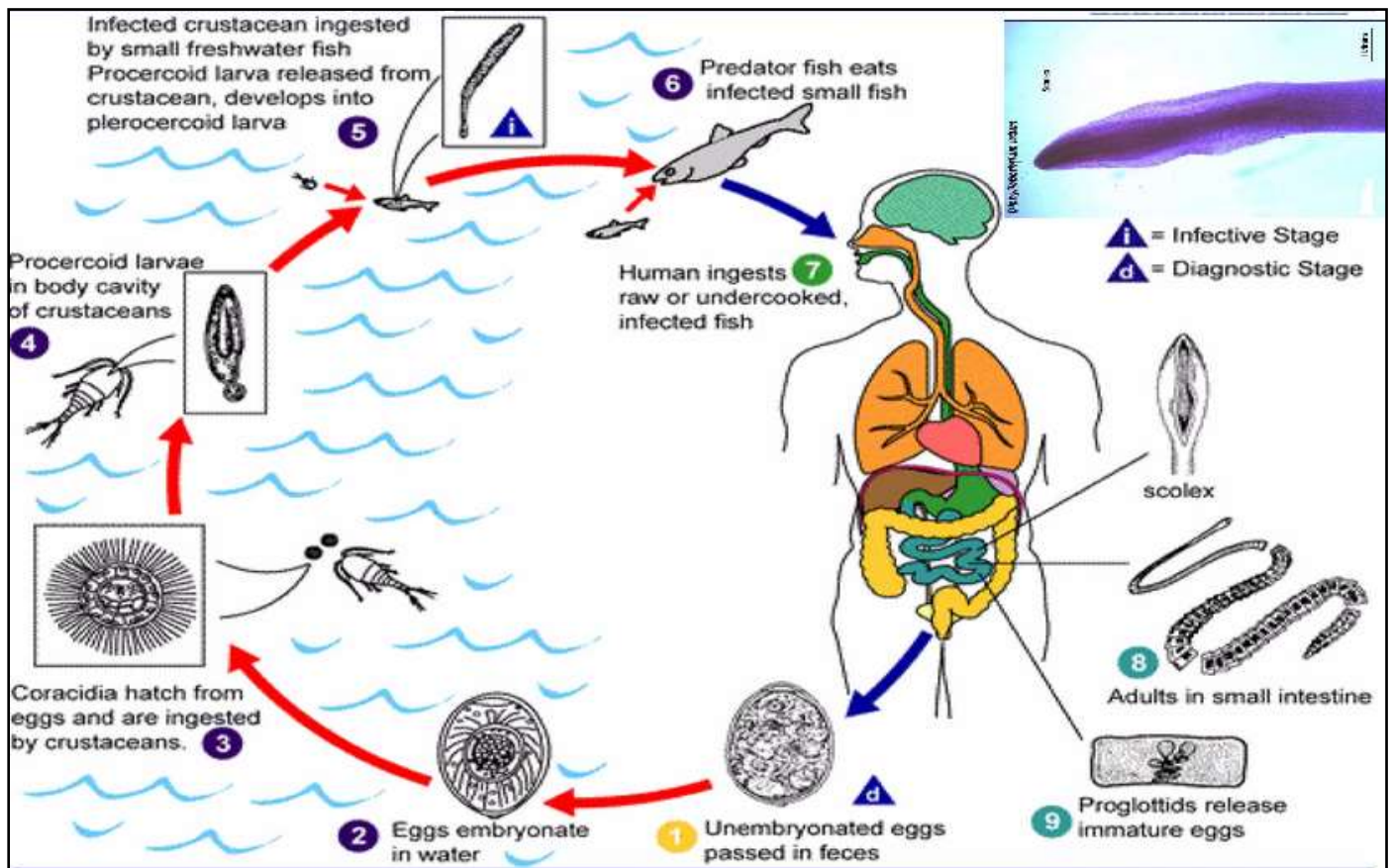


Figure 63. Life Cycle of *Diphyllobothrium latum*.

A difference between Cyclophyllidean and Pseudophyllidean cestode is illustrated in table 6.

Table 6. Different criteria between Cyclophyllidean and Pseudophyllidean cestode.

	Cyclophyllidean	Pseudophyllidean
Head	Bears 4 cup-like muscular suckers (ocetabula In <i>T. solium</i> and <i>H.nana</i> , the scolex has a beak-like apical protrusion called the rostellum.	Bears two longitudinal slit like grooves called bothria
Uterus	Branching may or may not be present	No branching ; The convoluted uterine tube assumes the form of a rosette.
Uterine pore	Absent	Present
Common genital pore	Lateral	It is located ventrally in the midline.

Egg	The egg is not operculated. The egg is round to oval in shape and is covered by two layers. The outer layer is an egg shell or capsule filled with yolk. The inner layer is a thin, radially streaked embryophore surrounding the embryo. The eggs are embryonated from the beginning and contain six hooklets. 	The eggs are ovoid and operculated, surrounded by a single layer called the egg shell or capsule. Inside this, the embryo is present, containing three pairs of hooklets. The membrane lining the embryo is ciliated. When the eggs are first laid in faeces, they are not embryonated. Maturation takes place later in water. 
Larva	Larva contain bladder like-sac (not solid) + Cysticercus : Larva stage of <i>Taenia</i> + Hydatid cyst : larva stage of <i>Echinococcus</i> + Cysticercoid : larval stage of <i>Hymenolepis</i>.	Larva is solid without any sac + Coracidium: the first larval stage of Diphyllbothrium. + Proceroid: second-stage larva of Diphyllbothrium. + Plerocercoid: third-stage larva of Diphyllbothrium.

Nemathelminthes (NEMATODA = ASHELMINTHES).

1. Characteristics of phylum Nematoda

- **Origin** of the word **nematoda** : in Greek **nema** = thread ; **oides** = resembling.
- Animal in this phylum include : A variety of **free living, predaceous** and **parasitic** round worms.
- Parasitic of human beings, other vertebrates, invertebrates and plants.
- **Triploplastic** and **pseudocoelomate** animals with 4 opening : mouth, anus, vulva and excretory pore.
- **Bilaterally** symmetrical animals.
- **Organ system** level of organisation
- **Sexual dimorphism** : Females are larger than male
- **Nematoda** body is **cylindrical in shape, flexible** and made up of nonliving cuticle, non segmented animals
- The body **covered** with a thick layer of finely ridged or smooth cuticle, cellular or syncytial epidermis and longitudinal muscles in **four bands**.
- The majority are under 5 cm long, but some parasitic forms can be more than 1 mm long.

The digestive tract (the alimentary canal) of nematodes consists of:

- + A mouth;
- + A muscular pharynx;
- + A long, nonmuscular intestine;
- + A short rectum;
- + A terminal anus. (**Figure 64 A**)

➤ **Reproduction organ** : (**Figure 64 A**)

- + Most nematodes are dioecious, meaning they are usually sexual.
- + Males are smaller than females and have a pair of copulatory spicules inserted into the vagina. The male releases his sperm through the anus, which is also called the cloaca.
- + **Fertilisation** is internal, with the eggs usually being stored in the uterus until they are deposited.
- + A female may lay up to 100,000 fertilised eggs per day.
- + **Zygotes** are hardy cells that can survive in harsh conditions.
- + Developement among free-living forms is typically direct.

✚ **Circulation** : nematodes don't have a circulatory system, fluids are dispersed into the pseudocoelom.

➤ **Respiratory system** : Nematodes have no respiratory system for taking up or distributing oxygen. Instead, they use diffusion through their skin to breathe.

✚ **Excretory system and osmoregulation** : excretory **glands** and **canal (tubes)** or both **and anus** through to be involved in **osmoregulation**, ionic regulation, excretion of waste metabolites ammonia secreted through body wall (**Figure 64 B**).

✚ **Nervous system**, It consists of ring-shaped ganglia (the brain), dorsal and ventral nerve cords. The sensory organs are in the form of pits, eye spots and sensory papillae, which are called amphids at the anterior end and plasmids at the posterior end. The amphids and plasmidia are chemosensory organs. (**Figure 64 B and C**).

➤ **Movement** : generated by **alternating contraction** of **longitudinal muscle** on each side of the body is due to the Fluid –filled **pseudocoel** constitute a **hydrostatic skeleton**. The interaction of their **muscle**, **cuticle** and **fluid-filled** pseudocoel aid the movement of nematodes.

➤ **Environments or habitats**, including aquatic form living in sea, oceans (50 %) and freshwater, terrestrial in soil (25 %). They are also many parasitic inside animals (15 %) and forms which attack all kinds of plant (10 %). Soils form the polar region from tropics About **25000** species have been named.

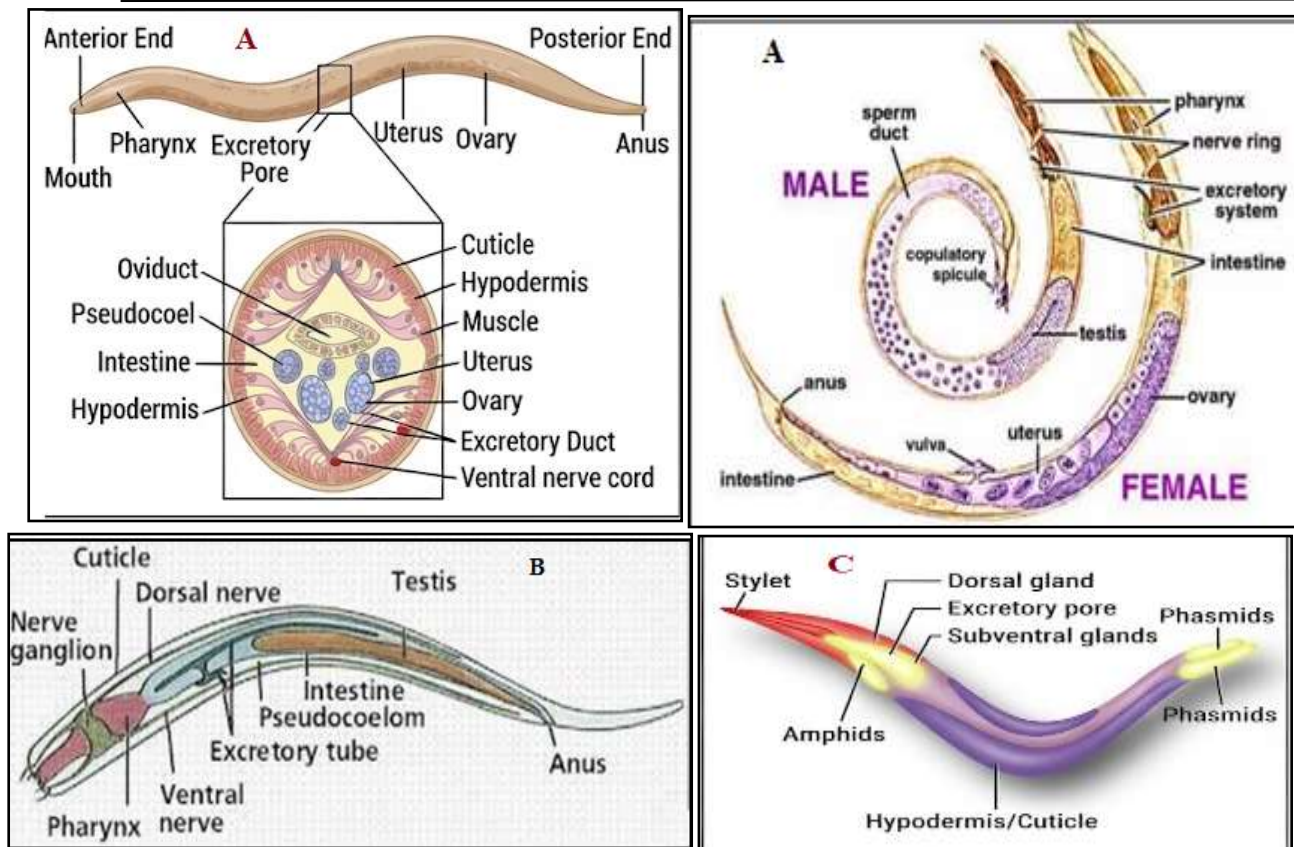


Figure 64. General morphology of Nematoda (A) and different organ system in A, B and C.

2. Taxonomy of the phylum nematoda

The phylum Nematoda is divided into two classes :

2.1. Class Adenophorea (Aphamidia)

2.1.1. Class Secernentea (Phasmidia).

2.1.2. Class Adenophorea (Aphamidia)

2.1.1. Class Secernentea (Phasmidia).

✚ Phasmids are absent. The phasmide are unicellular sensilla located in the lateral tail region (caudal sensory organs).

✚ The excretory system is either rudimentary or poorly developed.

✚ Only one spicule is present in the male.

✚ Divided in 6 orders

✚ Example : *Trichuris sp.*

The worms has thin anterior and thick posterior part

They attached in intestine mucosa by embedding their anterior part.

They feed on tissue fluid not blood.

Worldwide distribution : Asia (more common), less in Africa and South America.

Complications : Colonic, Ulceration of large intestine, anemia and rectal prolapses.

General morphology and life Cycle is presented in figure 65.

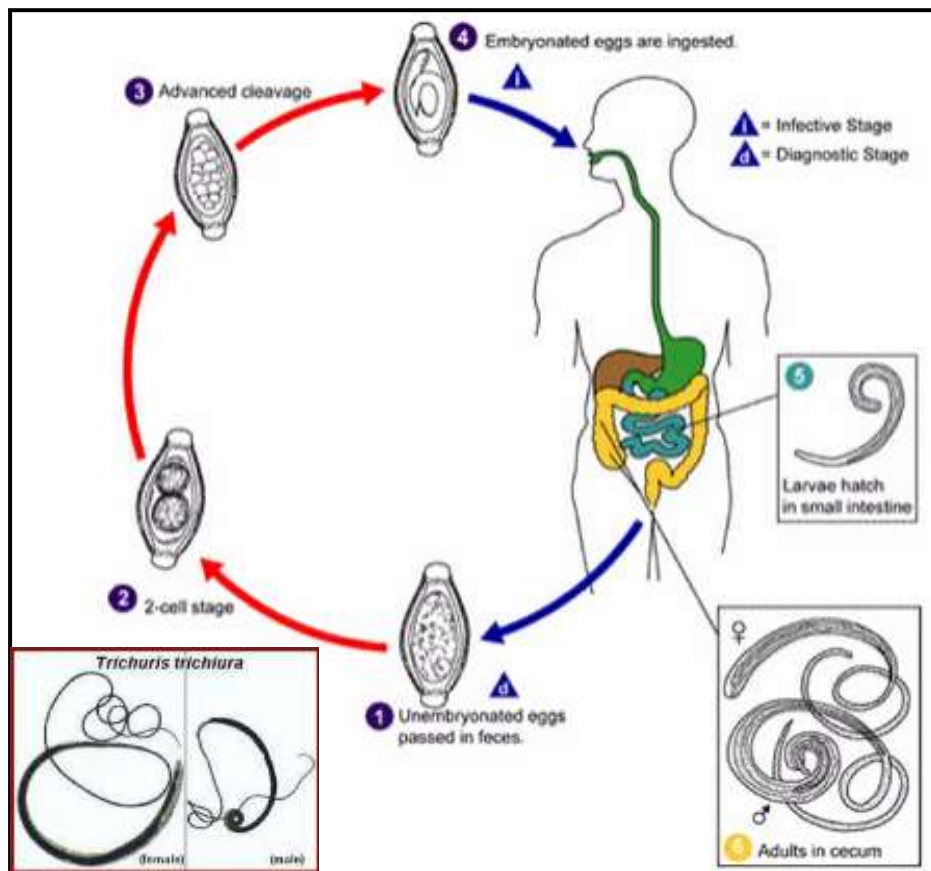


Figure 65. General morphology and life Cycle from *Trichuris sp.*

2.1.2. Class Secernentea (Phasmodia)

- ✚ They have phasmods posterior to the anus.
- ✚ The excretory system is present. It is also well developed.
- ✚ Male provide two spicules.
- ✚ Lives in **tropical area** with **poor sanitation**
- ✚ Most common **parasites in human**.
- ✚ **Lives in intestine** of the **host** but can **migrate** to the heart, lungs or brain.
- ✚ Divided in **10 orders**
- ✚ Example : *Ascaris*, *Enterobius*, *Strongyloides (Rhabditis)*, *Onchocerca (filarial nematodes)*, etc.....

2.2.2.1. Order Ascaroidea

Example : *Ascaris lombricoïdes*

- *Ascaris lombricoïdes* is the largest nematode that lives on the human intestine.
- *Ascaris lombricoïdes* It is an intestinal worm that is found in the small intestine of humans, mainly in the jejunum and upper part of the ileum.
- Children are more affected by this than adults.
- May inhabit a **single host (Monoxenous)**.
- **High prevalence** in Asia, South America and Africa
- **Complications** : The worm also produce : various allergic toxin which manifestes by fever, conjunctivitis, irritation, intestinal obstruction, appendicitis, panceatitis and biliary complication.
- **Life cycle** is passed only **one host man (Figure 66)**.

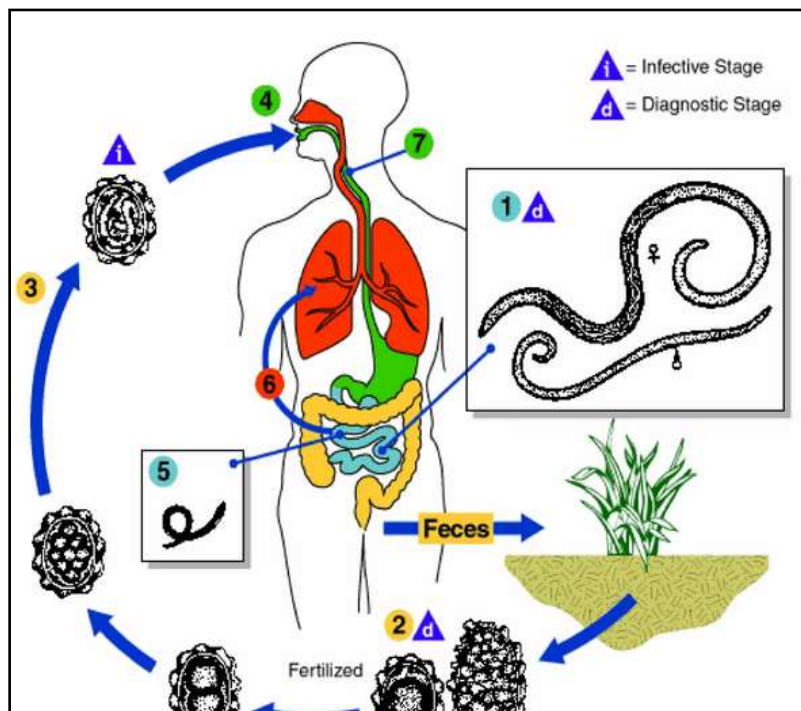


Figure 66. life Cycle from *Ascaris lombricoïdes*.

2.1.2.1. Order Oxyuroidea (Pinworms)

Example : *Enterobius vermicularis*

Nematodes and **common intestinal humain**

✚ The mal worms has a lengh of **2 to 5 mm**.

The female is dominant and has lengh of **8 to 13 mm**.

✚ **Monoxenous** : a single-host human

- + Infective forms occur through the embryonated egg.
 - + **Route** through faecal-oral transmission
 - + **The eggs** transform into larvae within the small intestine within five weeks.
 - + The larvae undergo molting in the ileum and finally enter the adult caecum within 15 to 30 days.
 - + **Male dies** after **fertilization**.
 - + They migrate to the rectum and come out through the anus at night. After that, the female lays eggs on the perineal and anal skin. Then the female dies..
 - + 1 worm = 5000 -17000 eggs.
 - + Become **infective** in 6 hours.
 - + Completes life cycle in 2 weeks – 2 months.
 - + **Clinical manifestations** : **Enterobiasis** includes neurosis, nail biting, grinding teeth at night. The **movement worm** and the **eggs** cause **itching**.
 - + **Epidemiology** : Found **worldwide**, most commonly in **USA**.
- Cycle life shows in figure 67.

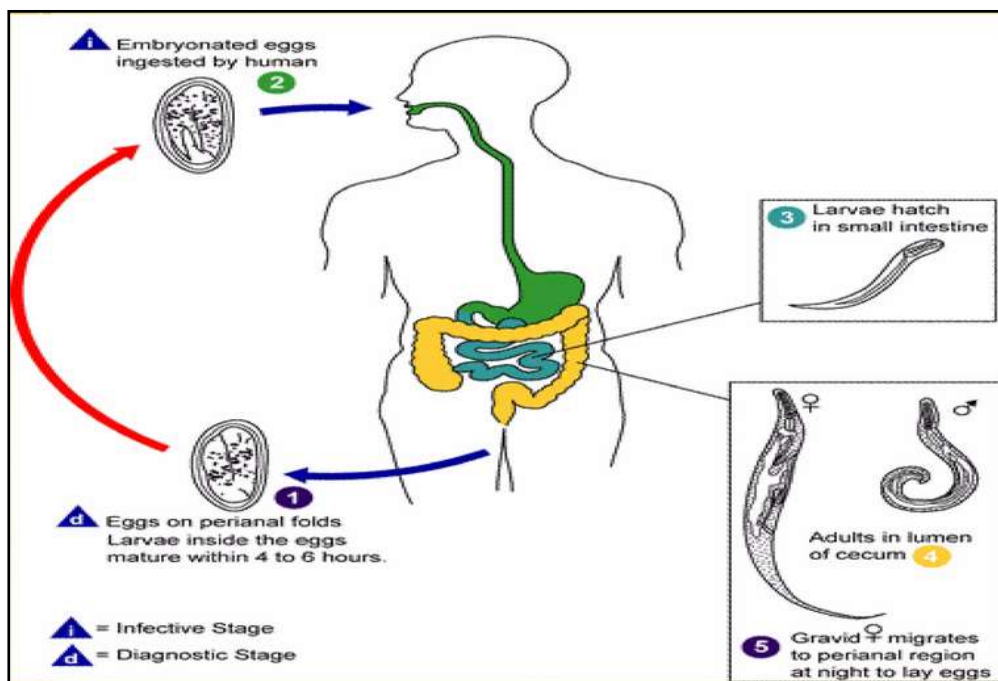


Figure 67. Life cycle of *Enterobius vermicularis*.

2.1.2.2. Order Strongyloidea (Threadworm)

Example 1 : *Anguillula stercoralis*

✚ **Stronguloides intestinalis** : example : *Anguillula stercoralis*.

✚ Known as **Cochin China Diarrhoea**

✚ **Female** live in superficial tissue of the **small intestine (duodenum, jejunum)** (2 mm long)

✚ **Principam host** : man with 28 incubation period.

✚ **Defenitive host** : human, dog and cat.

✚ **Route infection** : **Filariform Larva (third stage larva)** penetrate the **Skin** of human.

✚ **Geographisc distribution** : Cosmopolitan parasite mainly in moist and warm area of low hygiene

✚ **Clinical manifestation** : Dermatitis, itching, larva currens and mild hemmorrhage at th site where the skin has been penetrated, tissue damage (sempsis and ulcers), Pneumonia (**Loeffler's Syndrome**).

✚ Life cycle in figure 68.

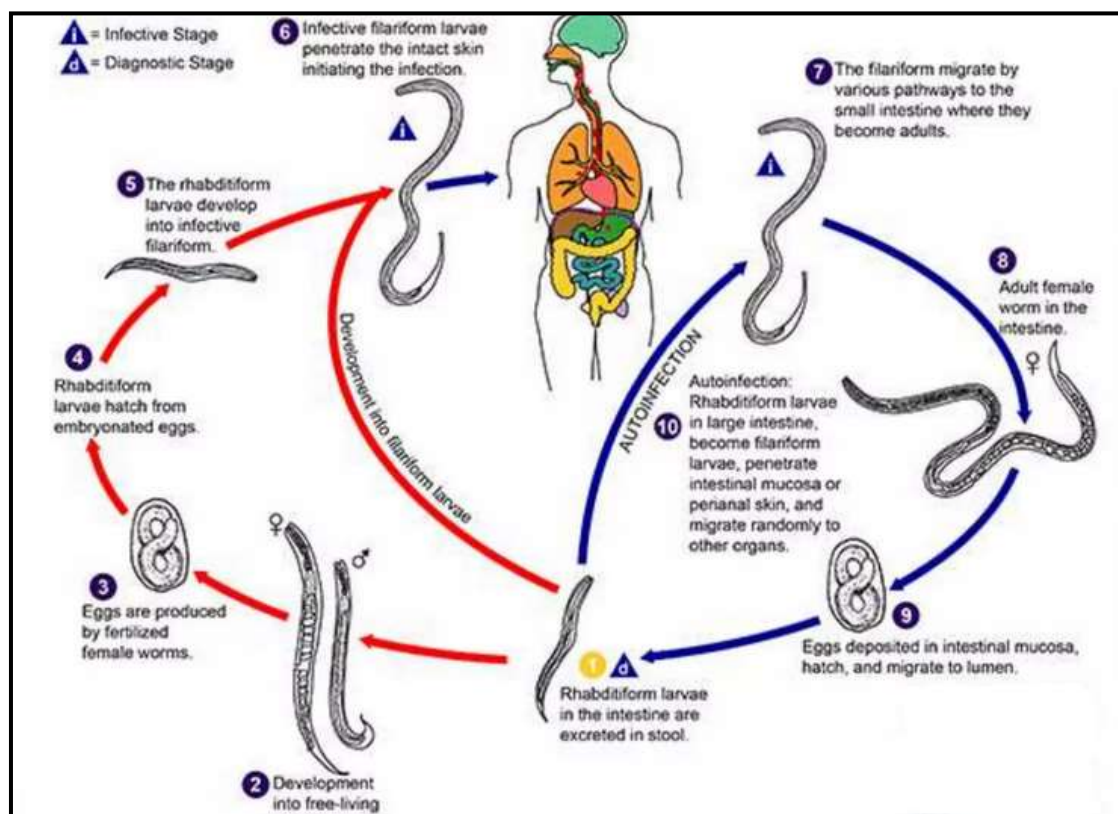


Figure 68. Life cycle of *Anguillula stercoralis*.

Example 2 : *Ankylostoma duodenale* (The Hookworms) (Figure 69).

- + Hookworms are among the most voracious blood feeders in the nematode world.
- + Cylindrical with the head bent sharply backwards.
- + The two main species that infect around 900 million people worldwide are:
 - ✓ *Necator americanus* : known as american killer also known the **new word hookworm**.
 - ✓ *Ancylostoma duodenale* : known as the old hookworm
 - + **Definive host** : human.
 - + **Morphology adult** : There are two pairs of curved teeth on the ventral wall of its buccal capsule.
 - + The mal worms has a lengh of **8 to 11 mm**.
 - + The female has lengh of **8 10 to 13 mm**.
 - + **Egg production** : 2500/day.
 - + **Penetration** : Skin, infective stage (Filariform larva).

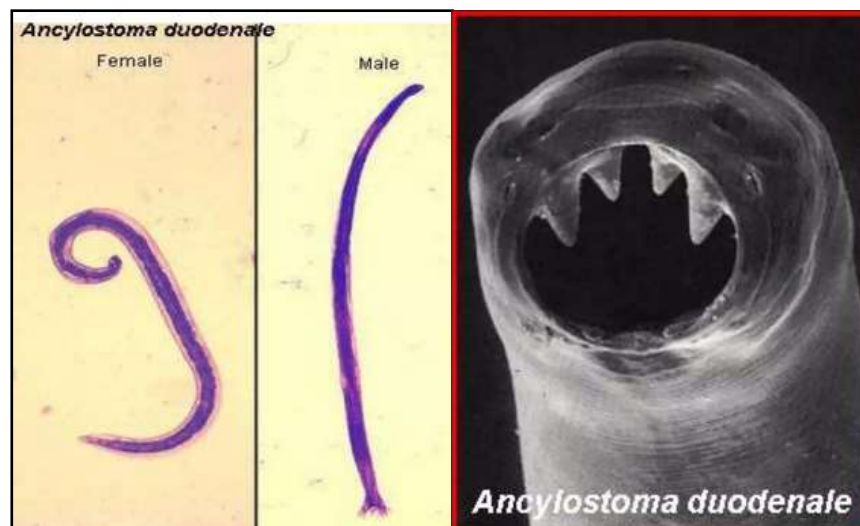


Figure 69. *Ancylostoma duodenale* morphology.

+ Geographic distribution :

- *Ancylostoma duodenale* : north –temperate zone of the eastern hemisphere : Southern Europe, Northern Africa, India, China, and southern Asia.
- *Necator americanus* : It was first discovered in Brazil and Texas, but was later found in Africa, India, Southeast Asia, China, and the Southwest Pacific Island.

Life cycle in figure 70

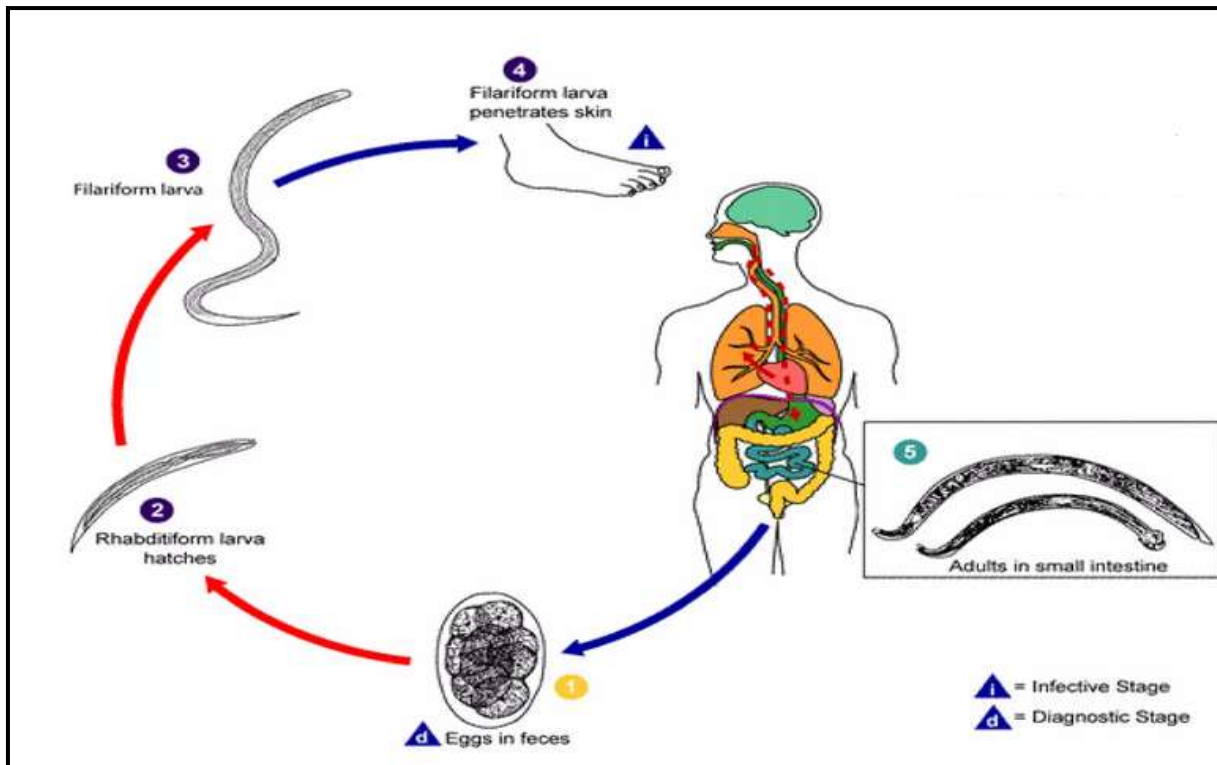


Figure 70. Life cycle of *Ancylostoma duodenale*.

2.1.2.3. Order Filarioidea (Spirurida)

✚ This group include **spirurate filiforme** nematodes adapted to inhabiting the deeper tissues
eg : **circulatory lymphatic** and **connective tissue layers**.

✚ They are **transmitted** by **blood sucking insects**.

✚ **8 spp** of **filarial worms** infecting man how is definitive host of them 6 are pathogens.

✚ *Wuchereria bancrofti*, *Brugia malayi*, *Brugia tumori*, causes **lymphatic filariasis**.

✚ *Loa loa* causes **calabar swelling** and **allergic reactions**.

✚ *Onchocerca volvulus* causes **eye lesion** and **dermatitis**

✚ *Mansonella streptocerca* lead to **skin diseases**.

Example : *Wucheraria bancrofti*

✚ It affects over 120 million people, primarily in Africa and other tropical and subtropical countries. It largely affects areas across the broad equatorial belt, including Africa, the Nile Delta and Turkey. India, the East indies, Southeast Asia, Phillipine, Oceianic Island, Australia, and part of South Africa).

- ✚ It is caused by filarial nematodes (roundworms) that inhabit the lymphatic system and subcutaneous tissues of humans. There are eight main species that infect humans, but only three of these are responsible for most of the morbidity due to filariasis.
- ✚ If left untreated, the infection can develop into a chronic disease called elephantiasis.
- ✚ There are limited treatment options available, and no vaccine has been developed.
- ✚ Mosquitoes that carry *Wuchereria bancrofti* prefer to feed on human blood, and it appears that humans are the only naturally infected animal.

Morphology : (Figure 71).

- *W. bancrofti* exhibits considerable sexual dimorphism.
- It is filiform in shape, tapering at both ends.
- The male measures 2.5–4 cm in length and 0.1 mm in thickness. The tail end is curved ventrally and contains two spicules of unequal length.
- Females are longer than males, measuring 8–10 cm in length and 0.2–0.3 mm in thickness. Their tail end is narrow and pointed. Females are oviparous.
- The adults obtain their nourishment from the lymphatic system.
- The adult worms have a long lifespan, probably several years (5–10 years or more).

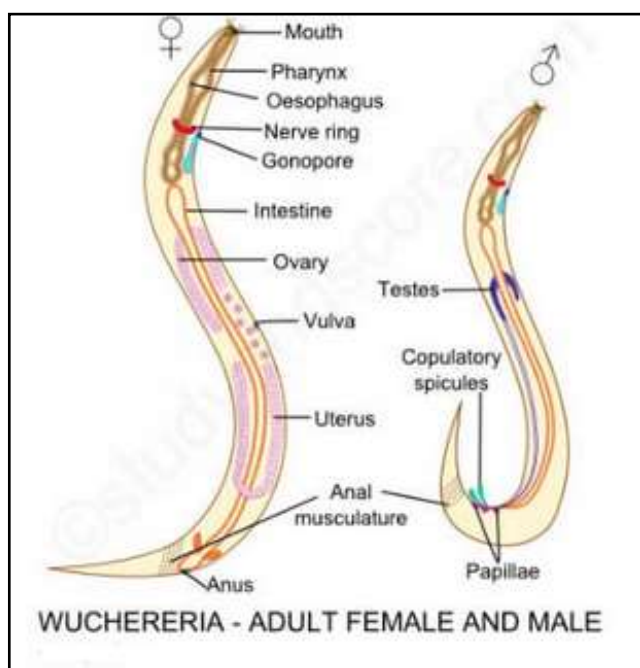


Figure 71. *Wucheraria bancrofti* Morphology

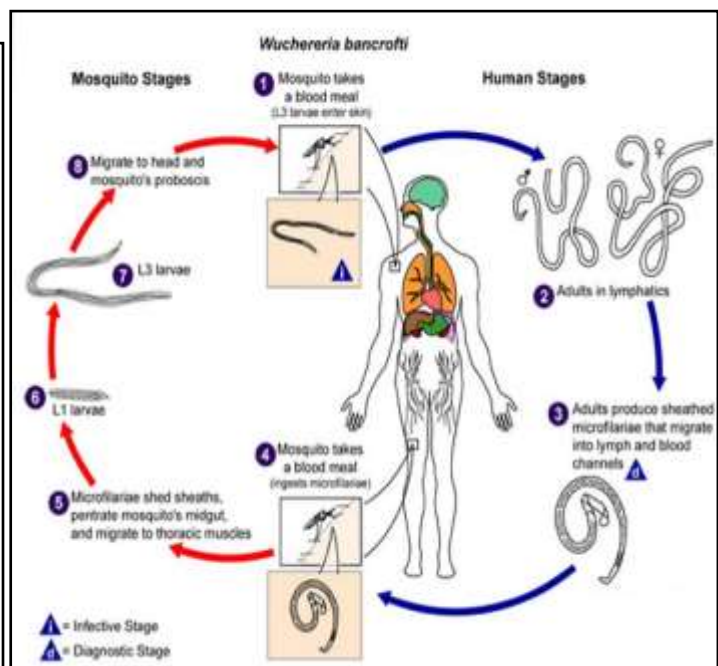


Figure 72. Life cycle of *Wucheraria bancrofti*

Chapter V : Subkingdom of Metazoa

Triploblastic

Cœlomates

Protostomes

Hyponeurians

5.1. Phylum Annelida

5.2. Phylum Mollusca

5.3. Phylum Arthropoda

Phylum : ANNELIDA (SEGMENTED WORMS)

The **annelida**, segmented or **ring worms**, comprise a large phylum mostly free-living animals Which inhabit the sea, freshwater and moist soil and few forms lives as ectoparasites. The annelida include such familiar forms as the earthworms and leechers as well as many less know marine bristle worms.

5.1. General characteristics of Phylum Annelida

- The are triploblastic coelomate animals, protostomes and hyponerians.
- The body exhibit a Bilateral symmetry and divided into linear series of segments and each segment is called **somites** or **metameres**.
- Each metamere is separated from the next by a transverse septum. **(Figure 73).**
- Each metamere acts as a hydrostatic skeleton
- Each metamer has longitudinal and circular muscles. Longitudinal muscle contraction causes the segments to shorten, while circular muscle contraction causes the segments to elongate. To prevent capture, some muscles are used for swimming, protection, or camouflage.
- Each segment usually bears one or more chitinous bristles called setae, which help to anchor the segments.
- The body is divided into three sections: the prosomium, the trunk, and the terminal pygidium, which contains the anus.
- The grade of organisation is defined as organ system grade.

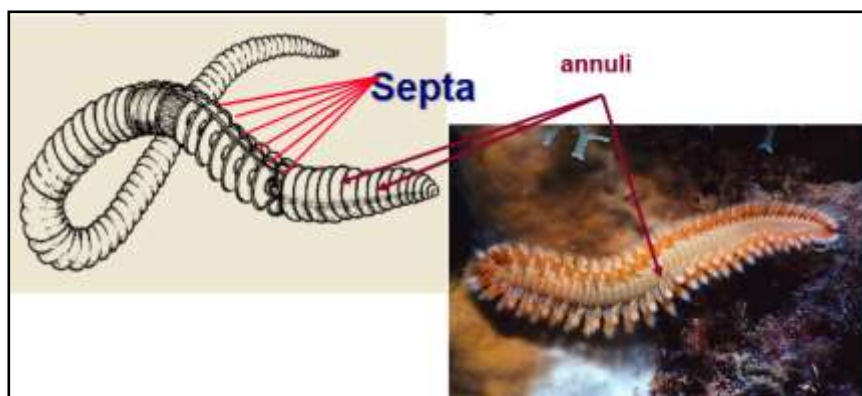


Figure 73. Organisation of annelida.

5.2. Organ system

5.2.1. Digestive system and feeding (Figure 74)

- Annelids have a complete digestive system that starts at the mouth and ends at the anus.
- Their systems contain a mouth beneath the prostomium, a pharynx containing teeth, an oesophagus, a crop, a gizzard, an intestine and an anus
- They use their muscles to assist with the mechanical digestion of food.
- First, food moves through the crop, where it is stored.
- Then it moves through the gizzard, where it is ground into small pieces.
- Digestive process: teeth and gizzard. Chemical process: hydrolysis in stomach and intestine.
- Absorption mostly occurs in the majority of the intestine.

The intestine is lined with yellowish chloragogue cells, which are equivalent to our. The liver is responsible for synthesising glycogen and fat and convert amino acids to urea and ammonia

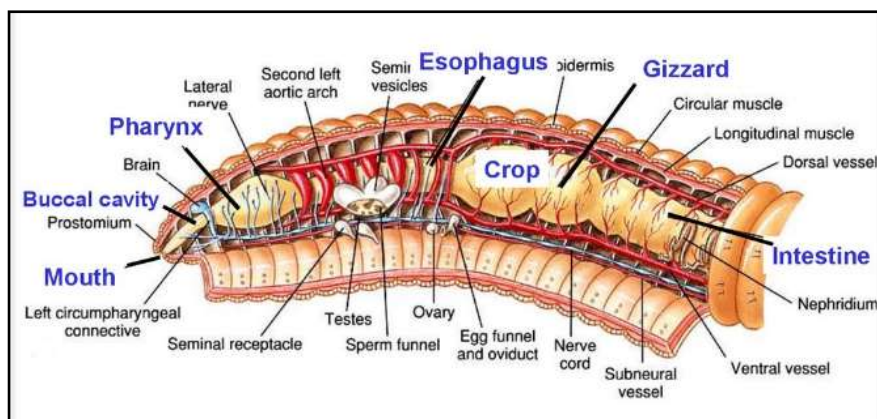


Figure 74. Organisation of digestive system of Annelids.

5.2.2. Circulatory system : (Figure 75).

Annelids have a true closed circulatory system. Blood is always enclosed and composed of longitudinal blood vessels, both dorsal and ventral, which run the length of the body and branch to every segment. **Dorsal vessels** pump blood anteriorly, while **ventral vessels** pump blood posteriorly. Amoeboid cells are present in the blood plasma, which is usually dissolved with haemoglobin to carry oxygen. Several hearts (five in the case of earthworms) are used to pump blood through the closed circuit.

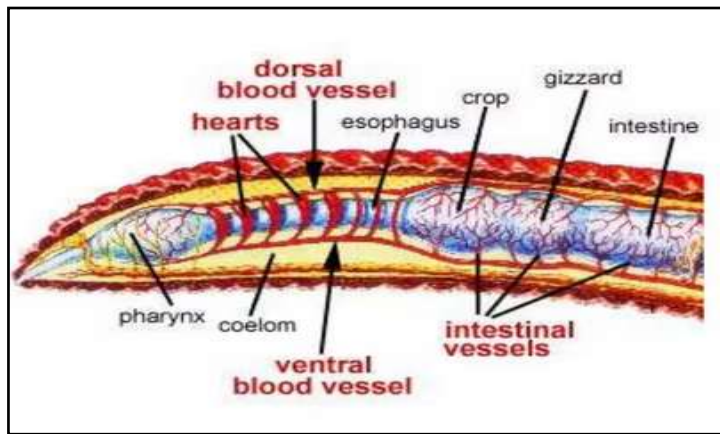


Figure 75. Organisation of circulatory system of Annelids.

5.2.3..Excretory system : (Figure 76).

They consist of a pair of nephridia (metanephridia) in each body segment. These are excretory tubes with ciliated funnels that remove waste from the coelomic fluid and open onto the outside via excretory pores.

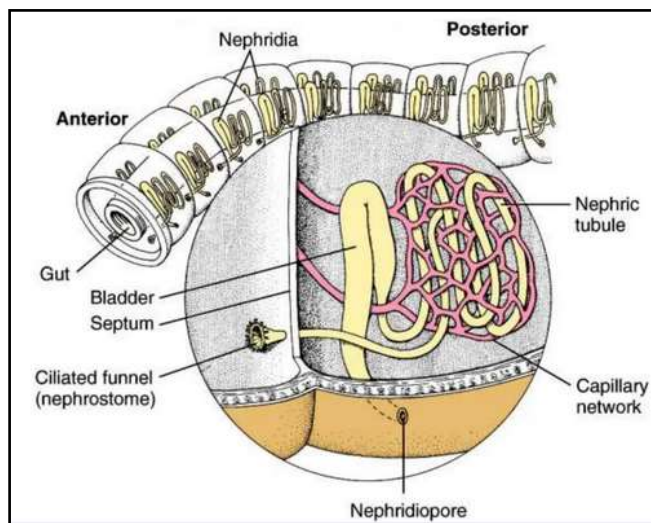


Figure 76. Organisation of Excretory system of Annelids.

3.2.4. Nervous system and sensory organs (Figure 77)

The nervous system of annelida species consists of a **brain**, a **pair of cerebral ganglia** and a **bilobed mass lying** above the pharynx in the third body segment. The cerebral ganglia are connected to a double nerve cord running along the mid ventral region, and to a pair of lateral nerves in each segment. The sensory system comprises tactile organs, taste buds, statocysts, photoreceptors cells and eyes with lenses.

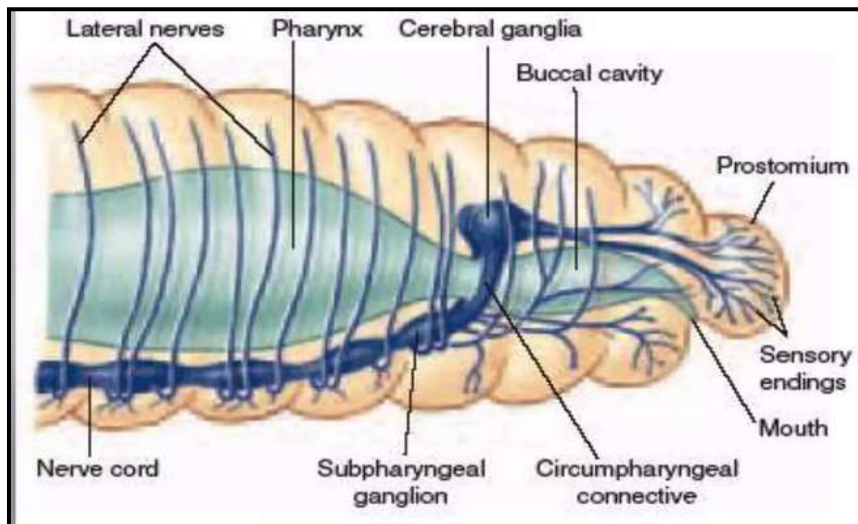


Figure 77. Organisation of Nervous system of Annelids.

5.2.5. Respiration :

It generally occurs by diffusion through the epidermis into the blood capillaries. Some aquatic forms have respiratory organs in their parapodia. A few have gills.

5.2.6. Reproduction and developement (Figure 78)

Sexes are usually **separate** (gonocoristic or dioecious), **hermaphroditic**, or **monoecious**. **Cross fertilisation** is common (see Figure 79). Some annelids (e.g. **marine sandworms**) are **dioecious** and release eggs and sperm into the marine environment. **Oligochaetes** are **hermaphroditic**, and during copulation they line up facing opposite directions. The **clitellum** secretes a **mucus** that holds the worms in place. Later, the clitellum acts as a **cocoon** in which the **fertilised eggs** develop. Fertilisation can be **either internal** or **external**. **Trochophore larvae** are remarkably similar to molluscs.

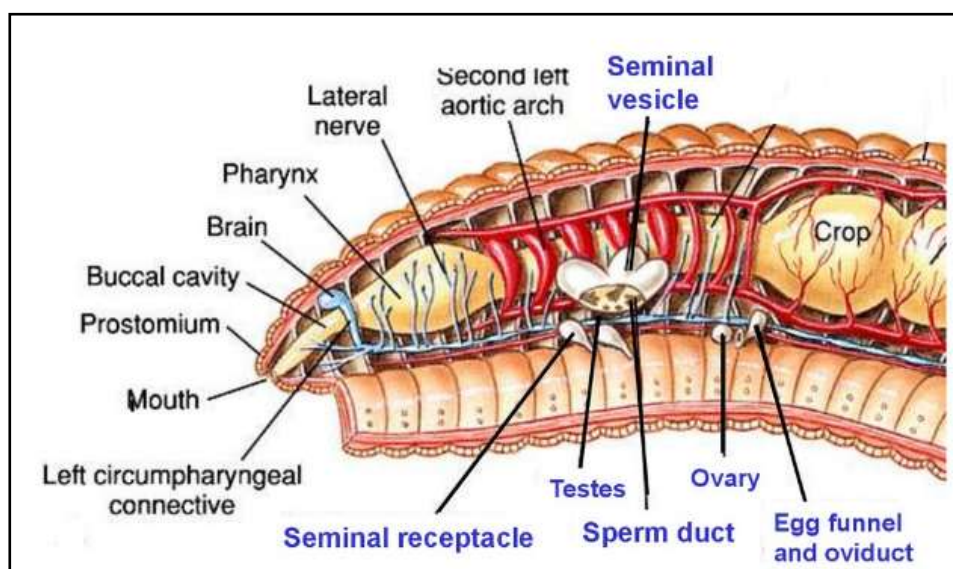


Figure 78. Reproduction organs of Annelids.

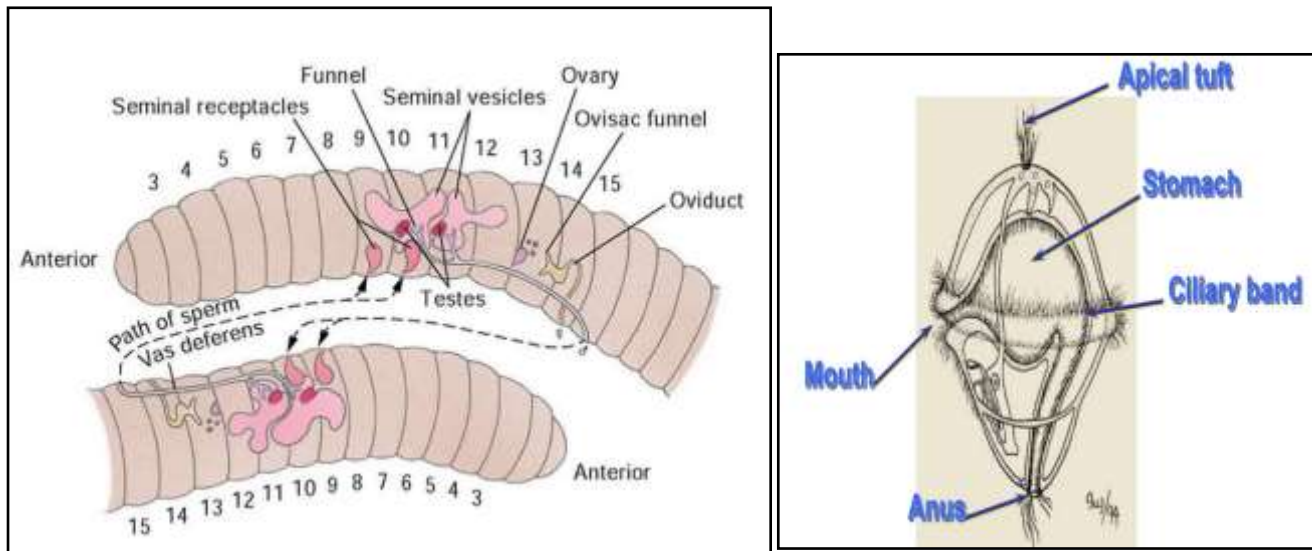


Figure 79. Cross fertilization of Earthworms (Right) and Trochophore larvae (Left).

Movement :

Coelom is filled with fluid (except leeches) which serves as **Hydrostatic skeleton**.

Annelids have **3 general types** of movement :

- 1- **Burrowing** : waves of peristaltic contractions sweep down the body. First, the animal elongates the contraction of the circular muscle. Second, the animal contracts the longitudinal muscle
- 2- **Crawling** : Polychaetes use their parapodia alternately to move across surfaces.
- 3- **Swimming** : mainly polychaetes and leeches undulate their bodies to move.

5.3. Annelids ecology

- **15000 species** has been found
- Annelids can be found in the ocean, in freshwater and in terrestrial soil.
- A burrowing animal that lives in the ground Feeds on organic matter in the soil.
- Predatory behaviour is exhibited by some, who hunt by hiding in rocks and corals and then ambushing their prey
- Some of them are carnivores that feed on blood, a group that includes leeches
- Earthworms are extremely important for terrestrial ecosystems, playing a vital role in maintaining soil health and biodiversity.
- The absence of earthworms would have a detrimental effect on plant growth, with knock-on consequences for the entire food chain.
- Earthworms help aerate soils. They also fertilise soils. They mix soils. And they provide proper drainage.

5.4. Taxonomic summary (Classification of Phylum Annelida)

Phylum annelida have **two major** classes :

5.4.1. Class Polychaeta : Many hairs (bristles) (marine worms). Divided into 2 subclasses :

5.4.1.1. Subclass Sedentaria

5.4.1.2. Subclass Errantia

5.4.2. Class Clitellata is divided into **2 subclasses**

5.4.2.1. Subclass Oligochaeta : Few hairs (bristles) (Earthworms)

5.4.2.2. Subclass Hirudinea (Leeches).

5.4.1. Class Polychaeta (Sand worms or Clam worm = Nereis) (Figure 88)

✚ Primarily **Marine worms**, including **sandworms** and **clamworms**. A few found in **freshwater**.

✚ **Largest** group of annelids. **10000 species 2/3rds** of all annelida species.

✚ Most are 5–10 cm long, but some grow to up to 3 metres..

✚ Often brightly coloured.

✚ A few are **pelagic** part of **plankton**

✚ It lives in crevices, old shells or burrows, and it also constructs tubes.

✚ **Important** in **marine food chain**

✚ Each segment is equipped with a pair of fleshy, paddle-like structures called parapodia, which are used for locomotion.

✚ The parapodia (parapodium) contain a large number of chitinous bristles, known as setae, which anchor the worm and are used for locomotion and respiration.

✚ **Prostomium** is well equipped with sensory and feeding structures

✚ Disting **head** with **eyes**, **palps**, and **tentacles**.

✚ **No clitellum**

✚ **Separate sexe**

✚ **Trochophore larvae** mostly **present**

✚ Although many polychaetes are active predators.

✚ A good examples : **Sabella**, **Nereis** (Clamworms).

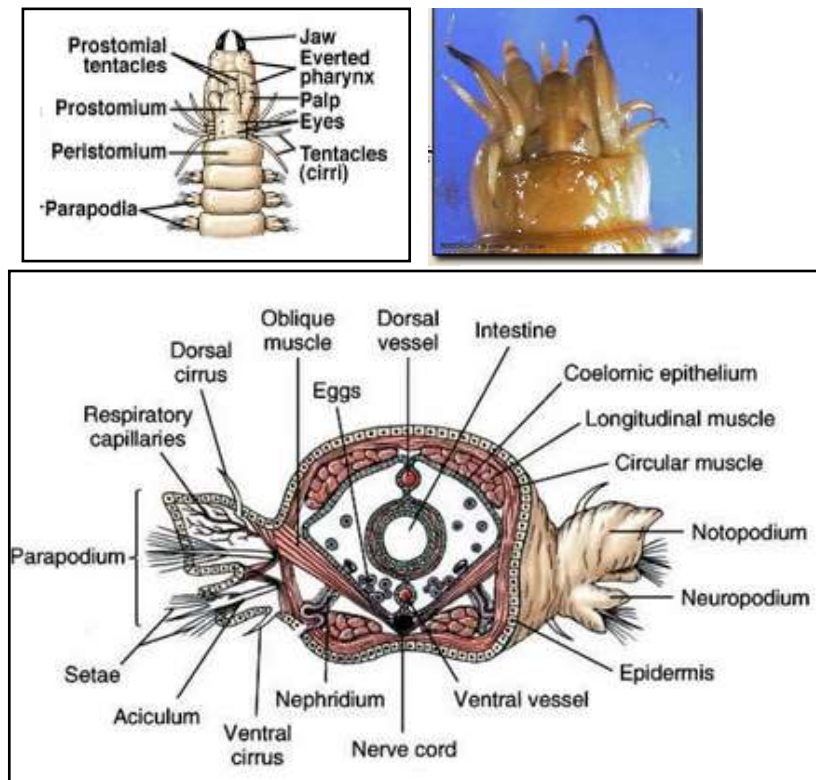


Figure 88. Polychaeta morphology. Cross section in Polychaeta and structure of parapodium.

Class Polychaeta is divided into **2 subclasses**

5.4.1.1. Subclass Sedentaria (Figure 89)

Many polychaetes burrow or live in tubes rather than crawling around on the sediment. They often develop various structures for gathering food, such as filter feeding.

Examples: Fan worms (1), sabellids (2), Christmas tree worms (3), spaghetti worms (4), chaetopterids (5) and lugworms (6).).

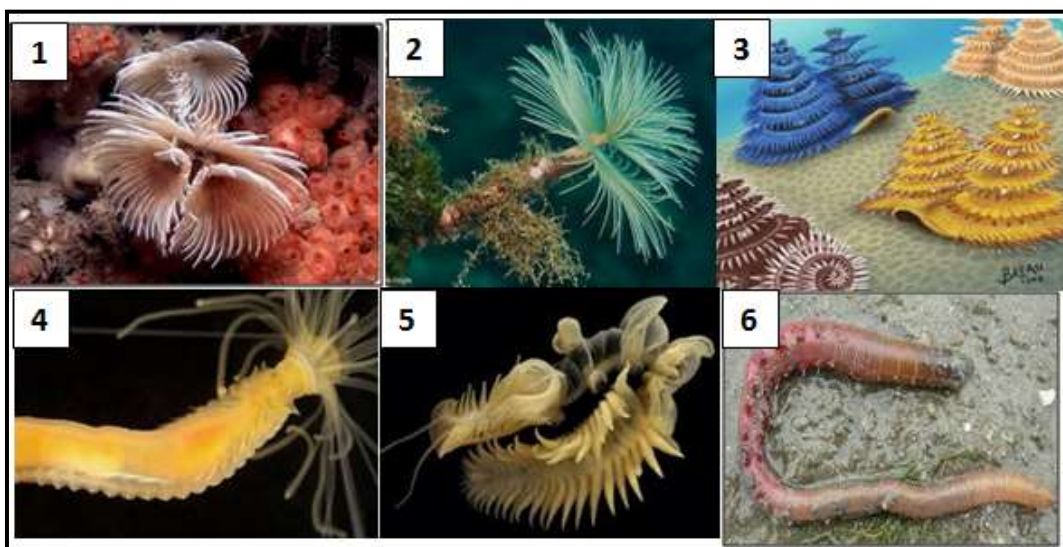


Figure 89. Examples of Sedentaria worms.

5.4.1.2. Subclass Errantia (Figure 90)

Errants = Wandering

Are free moving predatory forms some of which are free swimming, others crawl among rocks and shore animals and plants or burrow in the bottom sand and many construct tube in which they live.

Examples :

- ✓ *Nereis* (Rag worm = Clam worm) (1).
- ✓ *Aphrodite* (sea mouse) (2).
- ✓ *Polydora* (Scale worm) (3).
- ✓ *Eunice* (Palolo worm) (4)



Figure 90. Examples of **Errantia** worms.

5.4.2. Class Clitellata

5.4.2.1. Subclass Oligochaeta (few bristles).

- ✚ Over 3000 species
- ✚ Most are terrestrial, but many also live in freshwater and a few in marine or brackish environments.
- ✚ Aquatic species typically have larger setae than terrestrial species.
- ✚ The morphological structures are much simpler than those of polychaetes.

There are few setae per body segment, with most having four pairs of setae per segment using for the locomotion. The parapodia are absent.

- ✚ The body wall is a protective layer of collagenous cuticle that is secreted by the epidermis.

- ✚ Also has numerous mucous glands.

- ✚ **Prostomium** lacks sensory structures.

- ✚ Lack distinctive **head** region and have **no eyes**

- ✚ **Clitellum** is present

- ✚ Earthworm reproduction : Hermaphroditic, cross-fertilisation (exchange of sperm cells) can last for two to three hours. Cocoon deposited in the soil and a new worm emerges in two to three weeks

- ✚ **No respiratory organs** : They have no respiratory organs or parapodia and breathe through their skin. They have no lungs or gills.

- ✚ **Circulatory** : They have a double circulatory system involving coelomic fluid and a closed pumping system. It has a circulatory system with five pairs of hearts and haemoglobin in the blood to carry oxygen

- ✚ **The excretory organs** are the nephridia, which are found in pairs in each body segment.

- ✚ **Nervous system** : The cerebral ganglia and the ventral nerve cord. Although earthworms have no eyes, they do have numerous photoreceptors in their epidermis.

- ✚ Worms are a common bait for freshwater fishing.

- ✚ They are important in keeping the soil fertile, as they constantly turn over the earth and mix in organic matter.

Examples :

A). Aquatic Earthworm :

They are smaller, benthic and have longer setae. They are also more active. They have better developed sense organs. Some have gills and generally eat algae and detritus. Some have the ability to reproduce asexually (through budding).

Example : Tubifex (10 cm long) (Figure 91).



Figure 91. *Tubifex sp* worms.

B). Terrestrial Earthworm

They constitute a large proportion (80%) of the biomass inhabiting the soil. A total of 5,738 species are currently recognised worldwide. Earthworms are long with a cylindrical, elongated body. Their body is divided into 80-100 metameric segments. Earthworms are hermaphrodites and undergo cross-fertilisation during copulation. They enrich the soil.

Example : *Lombricus terrestris* (Figure 92 and 93).

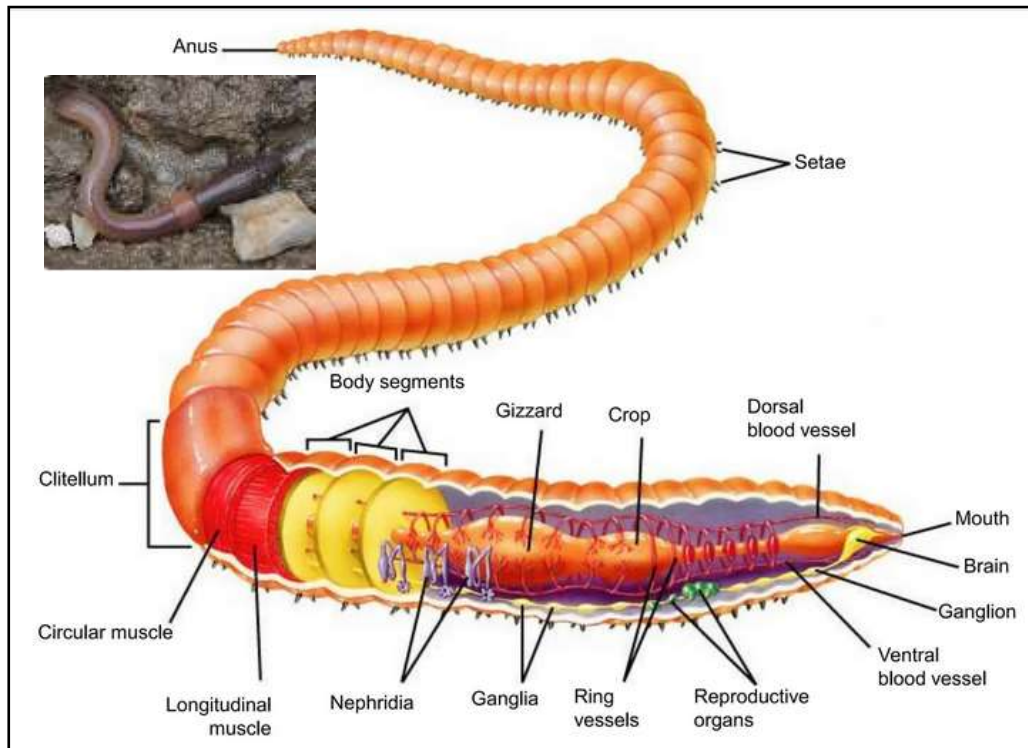


Figure 92. Diagram of Earthworm and their organ system.

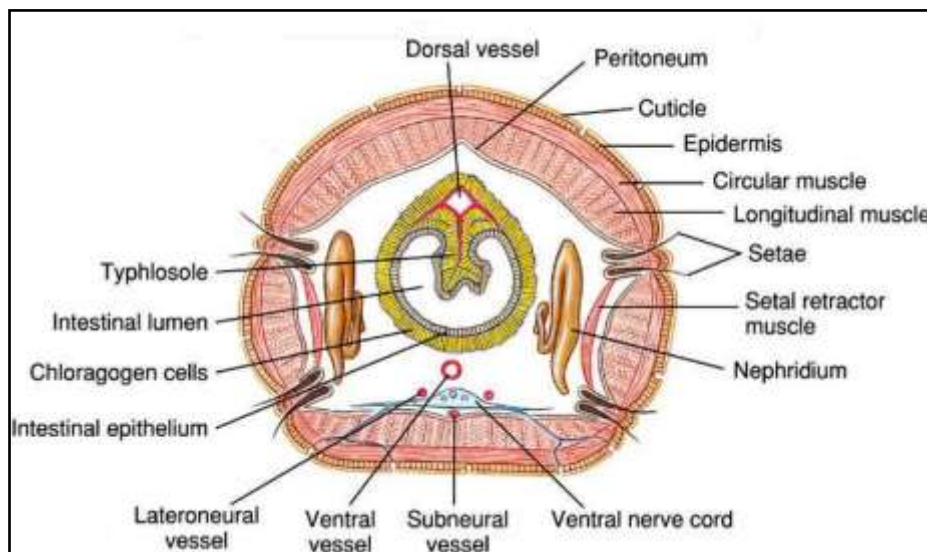


Figure 93. Cross section in Earthworm.

5.4.2.2. Subclass Class hirudinea (Leeches) (Figure 94).

- + No setae and parapodia
- + With anterior and posterior sucker.
- + Most lives in freshwater. A few marine and terrestrial
- + Usually no more then 6 cm in lengh. Some tropical species can reach 30 cm.
- + Unlike other annelids, its segments are not separated internally.
- + A fixed number of true segments. Usually 32, plus the prostomium and the pygidium.
- + Most are predators or scavengers. Very few are parasites.
- + After they attach to a host they release a substance called **Huridin** into the wound. This keeps the blood from clotting.
- + A leech can take in up 10 times its weight in blood a single feeding.
- + Example : *Hurido medecinalis* (Figure 94).

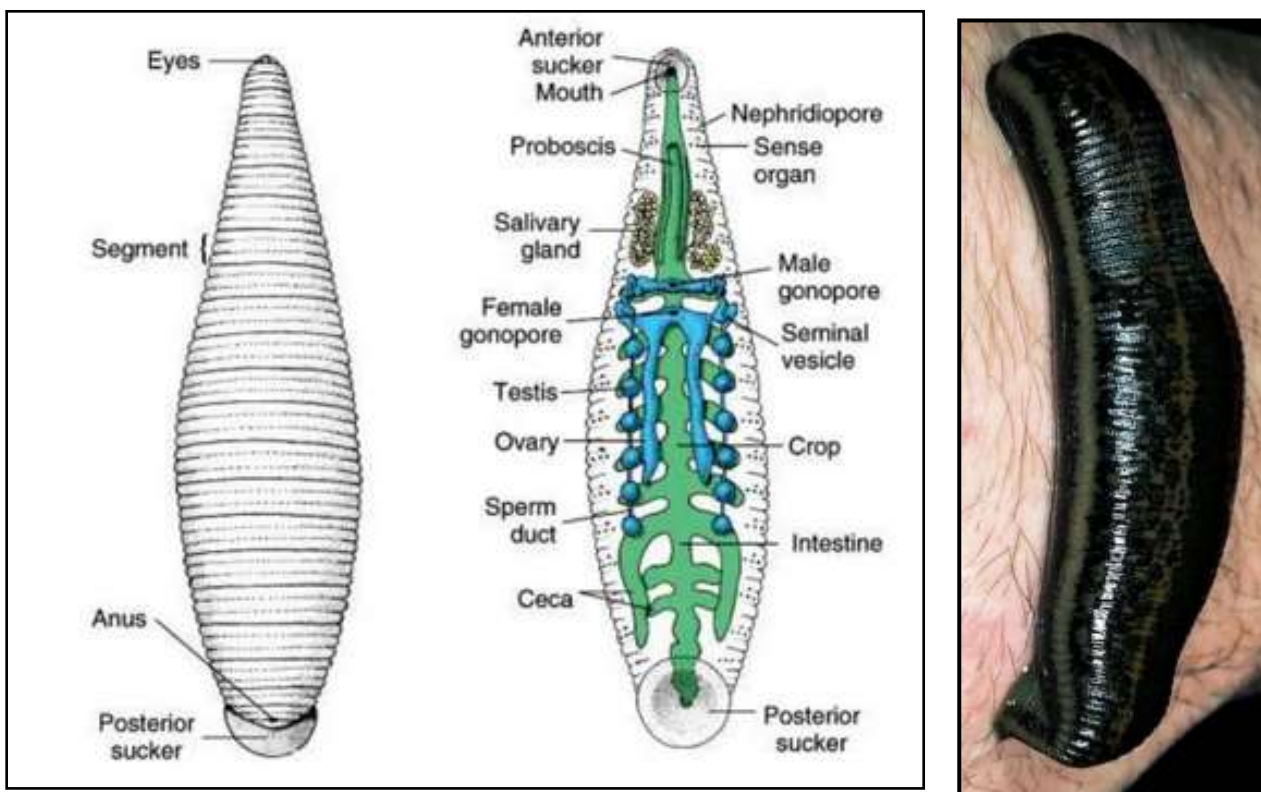


Figure 94. The anatomy of *Hurido medecinalis*.

Body wall : The coelom functions as a single, large chamber. There are no septae between the segments.

+ **Movement :** Leeches have a poor hydrostatic skeleton and no parapodia or setae. Aquatic species use their muscle layers to create the undulating swimming movement. They can also use suckers to move like inchworms.

- ✚ **Feeding and digestion :** Most species are predators of snails, worms and insect larvae. They have a protrusible pharynx with three jaws armed with teeth. Some are scavengers. Some are blood-sucking parasites. Digestion is very slow and they secrete few digestive enzymes, depending on bacterial digestion.
- ✚ **Respiration :** The majority of exchange gases are transmitted through the skin, while a select few aquatic organisms are equipped with gills.
- ✚ **Circulation :** Many species have no blood vessels; coelomic fluid performs the same function as blood. There may be haemoglobin in haemocoel fluid.
- ✚ **Excretion :** The number of pairs of nephridia possessed by leeches varies between 10 and 17.
- ✚ **Reproduction :** They are hermaphroditic and engage in cross-fertilisation. They have a clitellum and produce a cocoon that receives the eggs and sperm.
- ✚ **Nervous system :** The nervous system is similar to that of other annelids. However, leeches have two brains; one is composed of paired cerebral ganglia around the pharynx, as in other annelids. The other is located at the rear of the animal and consists of seven pairs of fused ganglia. The simple sense organs are much better developed in terrestrial species, which tend to be bloodsuckers.
- ✚ **Human impacts :** Medicinal uses: Hirudo was commonly used in biology labs to suck out 'bad blood'. They have also become leading research models for understanding how the nervous system works. Some of the chemicals that the leech uses to obtain and digest blood are being studied for use in the treatment of circulatory diseases.

5.2. Phylum : Mollusca

General characteristics

- + Metazoa free- living animals
- + Triploplastics, coelomates, they are bilaterally symmetrical, but gastropods are asymmetrical due to torsion.
- + Protostomes
- + Hyponeurians
- + They have soft, unsegmented bodies. They range in size from 1 mm to 18 metres. 80 % are under 5 cm.
- + **The body part** : the body is divided into three parts. The first part is the head. This is also known as cephalisation. The second part is the mantle. This is the covering of body parts. The third part is the visceral mass. This contains the internal organs.
- + **Head / foot** : A well-developed head with a mouth and sensory organs. Photosensory receptors range from simple eyes to complex eyes. Tentacles may be present. The foot, the locomotor organ, is located posterior to the mouth. The foot is usually ventral. It may be used for attachment to a substratum or for locomotion. Free-swimming forms have modified their feet into wings or fin-like swimming agents.
- + **Radula** : A rasping, tongue-like organ. It has rows of tiny backward-pointing teeth, up to 250,000 of them. It rasps off fine particles of food from surfaces. It acts as a conveyor belt, moving the particles to the digestive tract.
- + **Mantle and cavity** : Mantle is a sheath of skin on side of body. Secretes shell when present. Houses the gill or lungs. Exposed surface of mantle serves for gaseous exchange. Cephalopods use the head and mantle cavity to create jet propulsion.
- + **Skeletal** : mantle may secrete a shell. Use hydrostatic pressure for ventral muscular foot. Ventral muscular foot and other muscles present.

5.3. Organ system :

5.3.1. Digestive system : It is complete and developed, with a digestive gland (salivary glands and hepatopancreas) and a rasping tongue (radula). There are two openings: one to the oesophagus, which leads to the stomach and intestine, and finally to the anus.

5.3.2. Circulatory system : Open system in most groups, except for Cephalopoda (closed type) with dorsal heart (1-4 auricles and a ventricle), usually in pericardial cavity. Blood contains haemocyanin

5.3.3. Respiration : In **aquatic** forms, they are **ctenidia (gills)** in the mantle cavity; in **terrestrial** forms, they are **lungs**.

5.3.4. Excretory system : There is a pair of **nephridia** (1-6 pairs), and they usually connect to the pericardial cavity.

5.3.5. Advanced nervous system : The brain has various pairs of ganglia (cerebral, pleural, visceral and pedal) and connective commissures. It has sensory organs, such as eyes, sensory pappillae, statocysts and ospradia.

5.3.6. Endocrine system : Nervous systems produces hormones.

5.3.7. Reproductive system : There are various Dioecious species and a few Monoecious (hermaphrodite) species. The larva in marine environments is called a **trochophore** or a **veliger**, while in freshwater environments it is called a **glochidium**. Fertilisation is either **external** or **internal**, with **indirect** development.

5.3.8. Defense : Shells secrete poison from their ink sacs, quik movement.

5.3.9. Habitats and ecology important : The second largest phylum has over 100,000 described species and around 35,000 fossil species. They are found in a wide variety of ecological niches, including marine, freshwater and terrestrial environments. Most species live on the ocean floor and are sedentary, though some are free-swimming (Cephalopods).

5.3.10. Ecological important :

- ✓ **Clean** and **food source** (many used us food).
- ✓ Some are predaceous carnivores
- ✓ Culturing of pearls.
- ✓ Snails and slugs are both garden pests.
- ✓ Some snails act as intermediate hosts for parasites.

5.4. Taxonomy of Phylum Mollusca

Molluscs are classified based on characteristics such as the **foot**, **mantle**, **shell**, radula and **respiratory organs**. There are seven classes in total, three of which are particularly notable: **Bivalvia**, **Gastropoda** and **Cephalopoda**.

5.4.1. Class Monoplacophora

- ✚ **Mono**= single ; **placo** = shell ; **Phora** (bearing)
- ✚ A primitive mollusc with a **single-piece shell**.
- ✚ **Habitat**: exclusively **marine**.
- ✚ The **head** is present, but there are no eyes or tentacles..
- ✚ There are 5 or 6 pairs of **external gills**.
- ✚ **Excretion**: Nephridia are arranged serially. There are 6 pairs of them.
- ✚ **Reproduction** : Dioecious animals
- ✚ Examples : *Neopilina galathea* (Figure 95).

5.4.2. Class polyplacophora (Amphineura)

- ✚ **Poly** = many
- ✚ **Habitat**: It is predominantly marine.
- ✚ The body is elongated
- ✚ The eye and tentacles are absent
- ✚ The radula is present.
- ✚ Ctenidia are lateral and multiple, Example : *Chiton* (Figure 95).

5.4.3. Classe Aplacophora (Solenogasters)

- ✚ The body is cylindrical with bilaterally symmetrical
- ✚ 320 spp, all marine
- ✚ No shell, but has a body wall made up calcium spicule
- ✚ They are generally found in ocean floor.
- ✚ No fossil record.
- ✚ Radula used for grasping
- ✚ Live in burrow of the substrate, some live among corals
- ✚ Respiration gills
- ✚ Monoecious or Dioecious
- ✚ Eat cnidarians.
- ✚ Examples : *Chaetoderma*, *Neomenia* (Figure 95).

5.4.4. Classe Scaphopoda

- ✚ Found in marine environment
- ✚ The body is elongated dorsoventrally and encased in a tapered, tubular one-piece shell that is open at both ends and contains tooth or tusk shells. The eyes and tentacles are absent, and the foot is reduced.
- ✚ **Circulatory system** is simple. Hearts is rudimentary, pericardial sinus is absent.
- ✚ **Excretion** by a pair of nephridia.
- ✚ **Reproduction** : sexe are separate, sexual dimorphism is absent. Only one gonad is present. Life history includes Trochophore and Veliger Larvae.
- ✚ Example : *Dentalium*, *Siphonodentalium* (Figure 95).

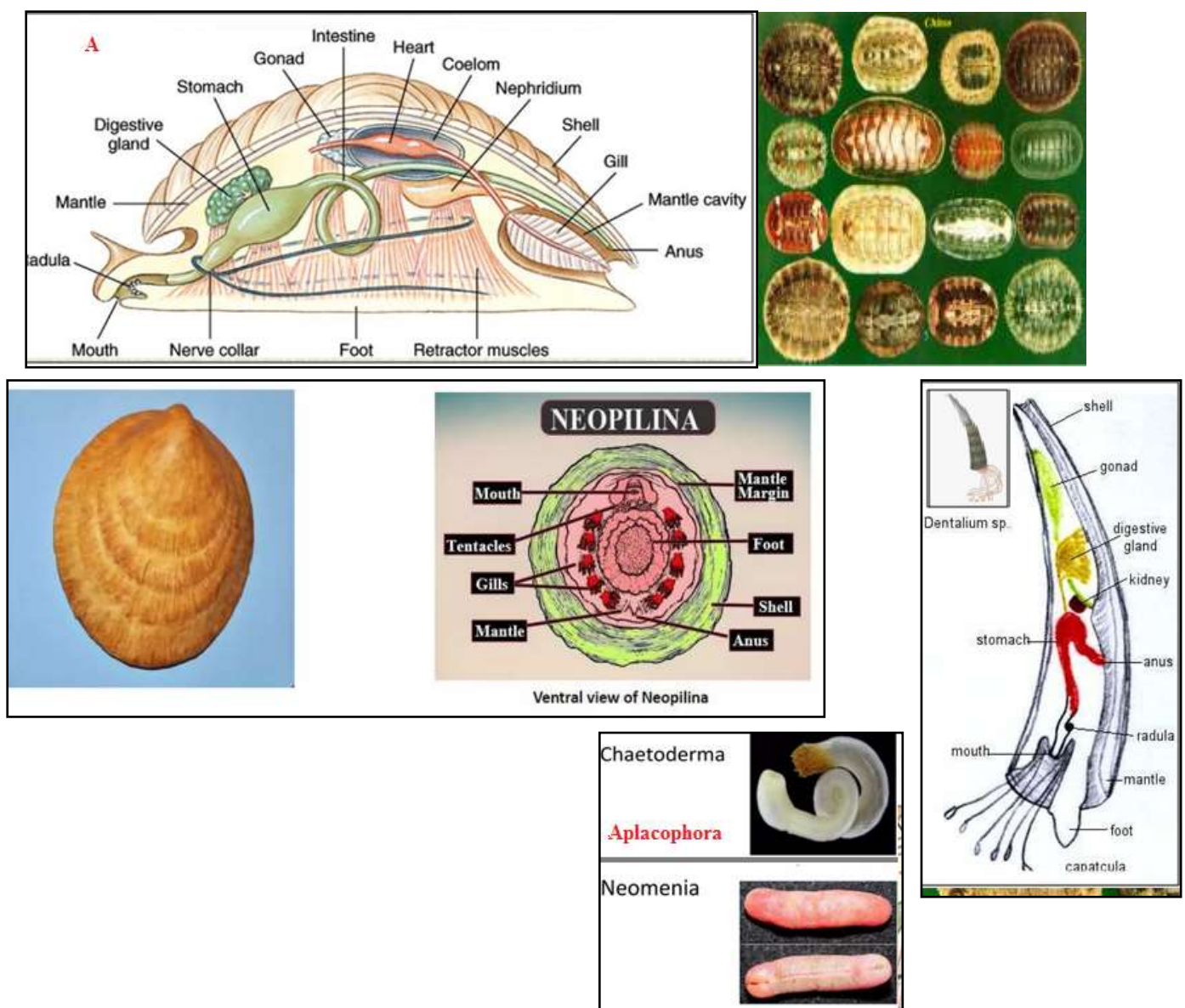


Figure 95. Generalized Mollusc anatomy (A), morphology of *Neopilina*, *Chiton*, Aplacophora and Scaphopoda (*Dentalium*).

5.4.5. Class Bivalvia (Pelecypoda) (Figure 96).

- + They reside in aquatic habits. They constitute second largest Mollusc class
- + **Bivalves** because of shell with two halves joined with hinge teeth. Body is laterally compressed.
- + **Head** is distinct. Eye and tentacles absent. But labial palps are present near the mouth which help in feeding.
- + **Foot** is flat and is in the form of axe which helps in the movement at the bottom of water. In some byssus apparatus helps to adhere to substratum.
- + **Muscles** are well developed. The two halves of the shell open and close by contraction and relaxation of two adductor muscles.
- + **Mantel** covered body on the dorsal and lateral sides. At posterior end the mantle forms two siphons called inhalant siphon and exhalant siphon
- + **Respiration** : a pair of lamellar ctenidia projecting ventrally into mantle cavity.
- + A buccal mass without a radula. Subradula and odontophore present. The alimentary canal is a coiled tube containing a crystalline style in the intestine.
- + These are **ciliary feeders**.
- + **Excretion** by kidney are simple and glandular.
- + **Circulation** : Blood contains corpuscles and haemocyanin as a pigment. The heart has two auricles and a ventricle, surrounded by pericardium, and a single aorta arises from its anterior part.
- + **Nervous system** : Cerebral, pedal and pleural ganglia are seen in nervous system. Sense organs are located on the margin of mantle folds.
- + **Reproduction** : Sexes are separate. Some hermaphrodites. Single pair of gonads are present. Gonoducts open into mantle cavity. Life history includes trochophore and veliger larvae.

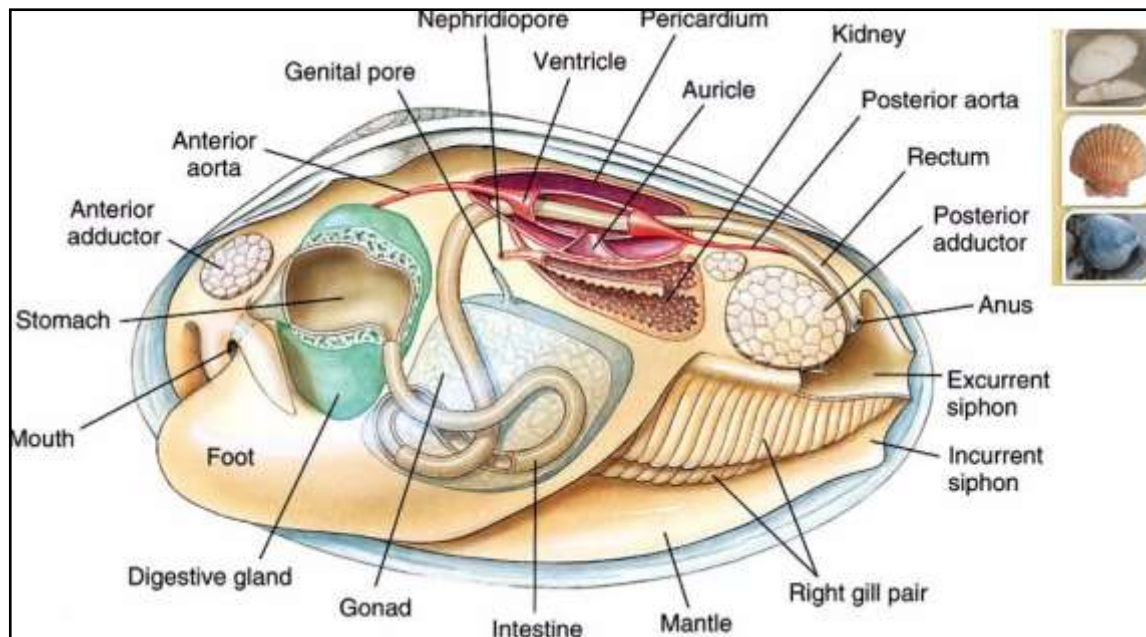


Figure 96. Bivalve anatomy.

Pelecypoda is divided into **three sub classes** :

5.4.5.1. Sub-class Protobranchiata

Primitive, small marine bivalves. Proto = gill first. Gills with simple filaments = ctenoid gills, no siphon, often taxodont hinge.

Examples : *Nucula*, *Yoldia*.

5.4.5.2. Sub-class Lamellibranchiata

✓ 80% of bivalves. They have a symmetrical soft body enclosed in a shell with two valves that often fit together perfectly.

✓ **Mantle** formed of two lateral lobes that secrete the two valves of the shell.

✓ Axe-shaped foot = pelecypods are often burrowers.

✓ Reduced cephalic region, represented externally by the mouth and palps.

✓ No buccal bulb or radula.

✓ **Respiratory system** by lamellar gills.

✓ Microphages (feed on particles)

Exampes : *Pinctada*, *Mytilus*, *Unio*, *Teredo*, *Pecten*.

5.4.5.3. Sub-class Septibranchiata

Gills modified into a muscular partition pierced with pores = Palatal septum. Shell extended posteriorly by a tube containing the siphon.

Example: *Mytilus edulis* (Mussel), *Poromya*, *Cuspidaria*.

5.4.6. Gastropoda (Figure 97)

- ✚ Gastropoda in Greek : **Gastro** : Stomach, **Pod** : foot
- ✚ They are found either on land or in fresh or in marin water.
- ✚ 75 % of Mollusc species are Gastropods (great diversity).
- ✚ **Head** is distinct bears tentacles, eyes, and mouth.
- ✚ Body covered by one **shell** it spiral in shape.
- ✚ **The foot** is ventral.it is a flat large muscular organ modified for swimming and burrowing
- ✚ **Respiration** by ctenidia, lung or both.
- ✚ **Heart** is with two auricles and a ventricle. Pericardial space surrounds it. Haemocyanin/ haemoglobin blood pigment
- ✚ **Excretion** : One or two pair of kidneys for excretion
- ✚ Well developed **nervous system**, nerve in the shape of '8' due to torsion. A system nervous called streptoneury/ chiasstoneury.
- ✚ **Reproduction** : Unisexual or hermaphrodites. Only one gonad near hepatopancreas
- ✚ **Trochophore** or veliger larvae in life history.

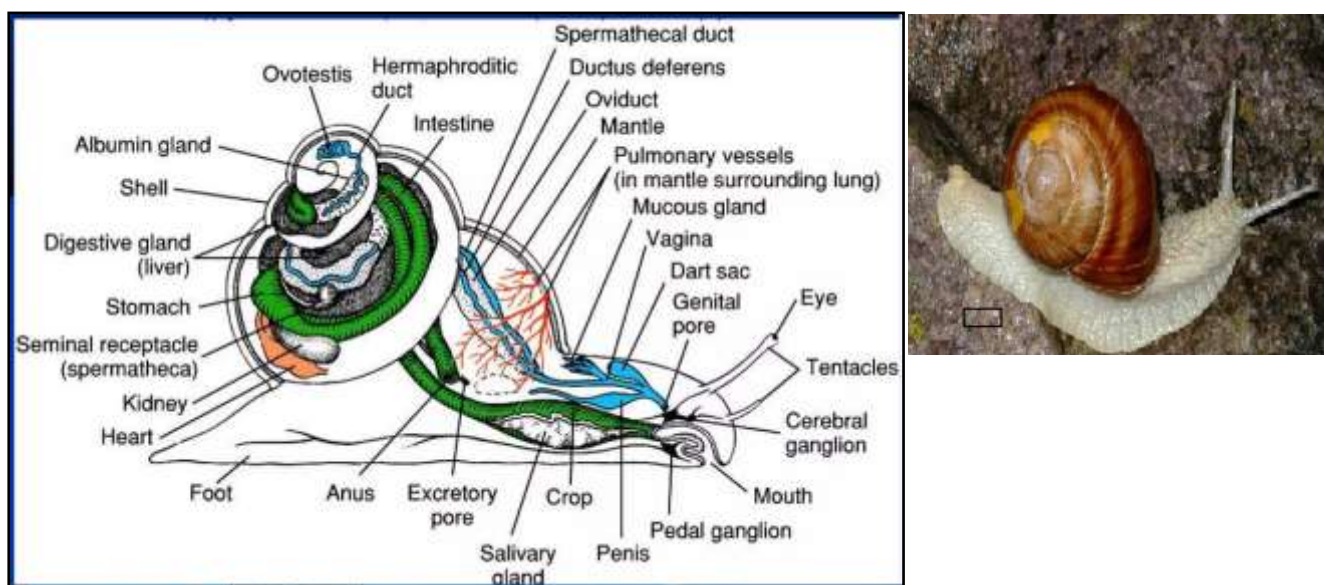


Figure 97. Generalized Gastropod anatomy.

Gastropoda is divided into three sub- classes :

5.4.6.1. Sub-class Prosobranchiata (streptoneura)

- ✓ **Proso**: forward, **branchia**: gill. Strepto: crossed, Neura: nerve.
- ✓ They have the anterior position of the mantle cavity.
- ✓ Gills located in front of the heart.

- ✓ Anus and mantle cavity close to the mouth.
- ✓ The nephridia connect with the pericardial coelom.
- ✓ The nerve cord shows the characteristic “X” cross.
- ✓ Shell developed, and can be closed by an operculum (attached to the middle of the foot).
- ✓ The sexes are usually separate.
- ✓ Shell developed, and can be closed by an operculum (attached to the middle of the foot).
- ✓ The sexes are generally separate (gonochoric).
- ✓ Mostly marine.
- ✓ This is the only group of commercial importance.
- ✓ Examples : **Patella, Nerita, Cyprea, Pila, Murex.**

Generally classified based on the level of reduction of paired organs (auricles, gills, kidneys).

Divided into 3 orders: **Monotocards, Diotocards** and **Heterocards**.

1. Order Monotocards (Monotocardia) or Mesogastropods

- ✓ **Mono** : Single; **Otos** : auricle; **Cardia** : heart
- ✓ Monotocards have only one auricle, one kidney, and one gill.
- ✓ They have a coupling organ.
- ✓ Carnivores with well-developed siphon.
- ✓ Example: *Littorina*

2. Order Diotocards (Diocardia) or Archeogasteropods

- ✓ Marine, primitive and herbivorous.
 - ✓ **Di** = two or double, **Otos** : auricle, **Cardia** : heart: heart with two auricles
 - ✓ Diotocards have a heart with two atria adjacent to the ventricle, which is traversed by the rectum.
 - ✓ The gills are pectinate bearing a single row of filaments and often with a nacreous shell.
- Example: *Haliotis sp.*

3. Order Heterocards

Cardia : heart. Heterocards, most are marine. They have only one atrium and two unequal kidneys, both located on the left side of the pericardium. Branches vary in number

Example: *Patella rustica*.

5.4.6.2. Sub-class Opisthobranchiata (Eutyneury)

- ✓ **Opisthen**: behind, backward; **branchia**: gill
- ✓ A single gill located behind the heart.
- ✓ They are hermaphrodites: gonad = ovotestis.
- ✓ Nervous system: incomplete torsion.

The subclass Opisthobranchia comprises two orders: **Nudibranchia** and **Tectibranchia**

1. Order Nudibranchia

- ✓ From the Latin **Nudi**, Nudus: naked and **Branchiae**, brankhia: gills.
- ✓ Crawling mollusks without shells.
- ✓ Hermaphrodites.
- ✓ Respiration occurs through external gills (naked dorsal gills), but can be exclusively cutaneous.

Example: **Tethys** (sea slug).

2. Order Tectibranchia

Tectus: cover, **brankhia** : gills.

- ✓ It has a more or less reduced internal shell covered by a mantle that protects the gills.
- ✓ A single lateral gill protected by a mantle.
- ✓ Highly developed parapodia, which act as fins.
- ✓ Example: *Aplysia* (sea hare)

5.4.6.3. Sub-class Pulmonata

Terrestrial snails / slugs, freshwater ; Veliger larva ; the gill cavity without gills forms a lung that opens onto the pneumostome. They are hermaphrodites with internal fertilization based on cross-fertilization. They have a single kidney and a single atrium.

This subclass divided into 2 orders:

1. Order Basommatophora

These are the primitive pulmonates that live mainly in freshwater. They have pair of sensory contractile tentacles and 2 non-pedunculated (sessile) eyes at the base of the tentacles.

The shell is always present. Separate male and female orifices.

Example: ***Bulinus***; ***Lymnaea cailliaudi***; ***Lymnaea truncatula***.

2. Order Stylommatophora

Terrestrial species, also with a single male and female orifices. Shell present or absent.

Four (two pairs) retractable tentacles, the two large ones bearing eyes at their tips.

Examples: *Helix aspersa*: (with shell). *Milax gagates* (slugs, without shell).

5.4.7. Class Cephalopoda (Figure 98).

- + In Greek **Kephal**= head ; **podos** = foot.
 - + Most complex mollusks and also the most complex invertebrate.
 - + They are mostly found in marine environment.
 - + Bilaterally symmetrical.
 - + Active free swimming
 - + **The body** is divided into a head and a trunk. The head is distinct and bears a pair of well-developed eyes.
 - + **Head** is bearing 8-10 arms around mouth which bears suckers.
 - + **Visceral mass** is uncoiled and covered on all sides by mantle.
 - + **Mantle** encloses pallial cavity in which gills are located.
 - + **Shell** is internal (Sepia (cuttlefish), squid), external (Nautilus) or absent (Octopus).
 - + **Foot** is modified into arms around mouth and a funnel or siphone through which water is pumped out from pallial cavity.
 - + **Radula** and pair of jaws are present in buccal cavity.
 - + Two pairs of **salivary glands** and other glands.
 - + Most of them are **predators** that use their arms and tentacles to capture prey, which they then rip apart with their beaks.
 - + **Closed** blood vascular system
 - + Kidney and **ctenidia** are one or two pairs.
 - + Sexes are **separate**, **Gonad is single**.
 - + In male one pair of arms is modified to form a copulatory organ (Hectacotylized).
- Development is **direct**.

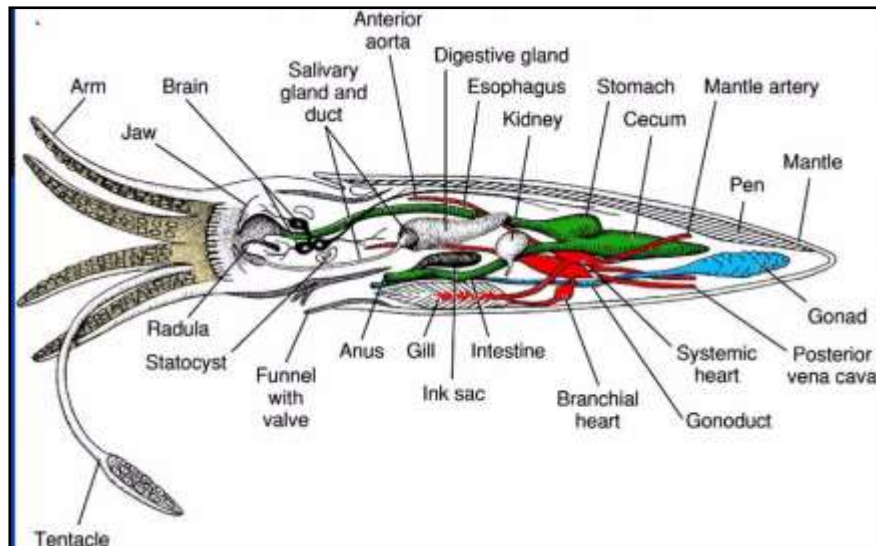


Figure 98. Generalized Cephalopod anatomy

Cephalopoda is divided into two sub-classes and two ordres :

5.4.7.1. Sub-class Tetrabranchiata

Four gills, four auricles, four kidneys, external shell.

Example: *Nautilus sp.* (The only current representative)

5.4.7.2. Sub-class Dibranchiata

Two gills, two auricles, two kidneys, internal shell or no shell.

Examples : Sepia, Squid, Loligo.

This Subclass divided into two orders distinct :

1. Order Decapoda (10 arms) :

Deca : ten and **podos** : foot.

(10) arms: 8 short arms (tentacles) and 2 long arms. Internal shell. Lateral fin.

Stalked suckers. Funnel attached to the mantle by two snap fasteners.

Examples: *Loligo vulgaris* (squid ; Figure 99 A), *Sepia officinalis* (cuttlefish or sepia ; Figure 99 (a dorsal view, b Ventral view) ; *Nautilus sp* (Figure 99 C).

2. Order Octapoda (8 arms)

Octo : Eight and **podos** : foot. (8) arms longer than the body (tentacles). No shell. No fins. Sessile suction cups. Funnel without pressure buttons. Example: *Octopus vulgaris* (Figure 99 D).

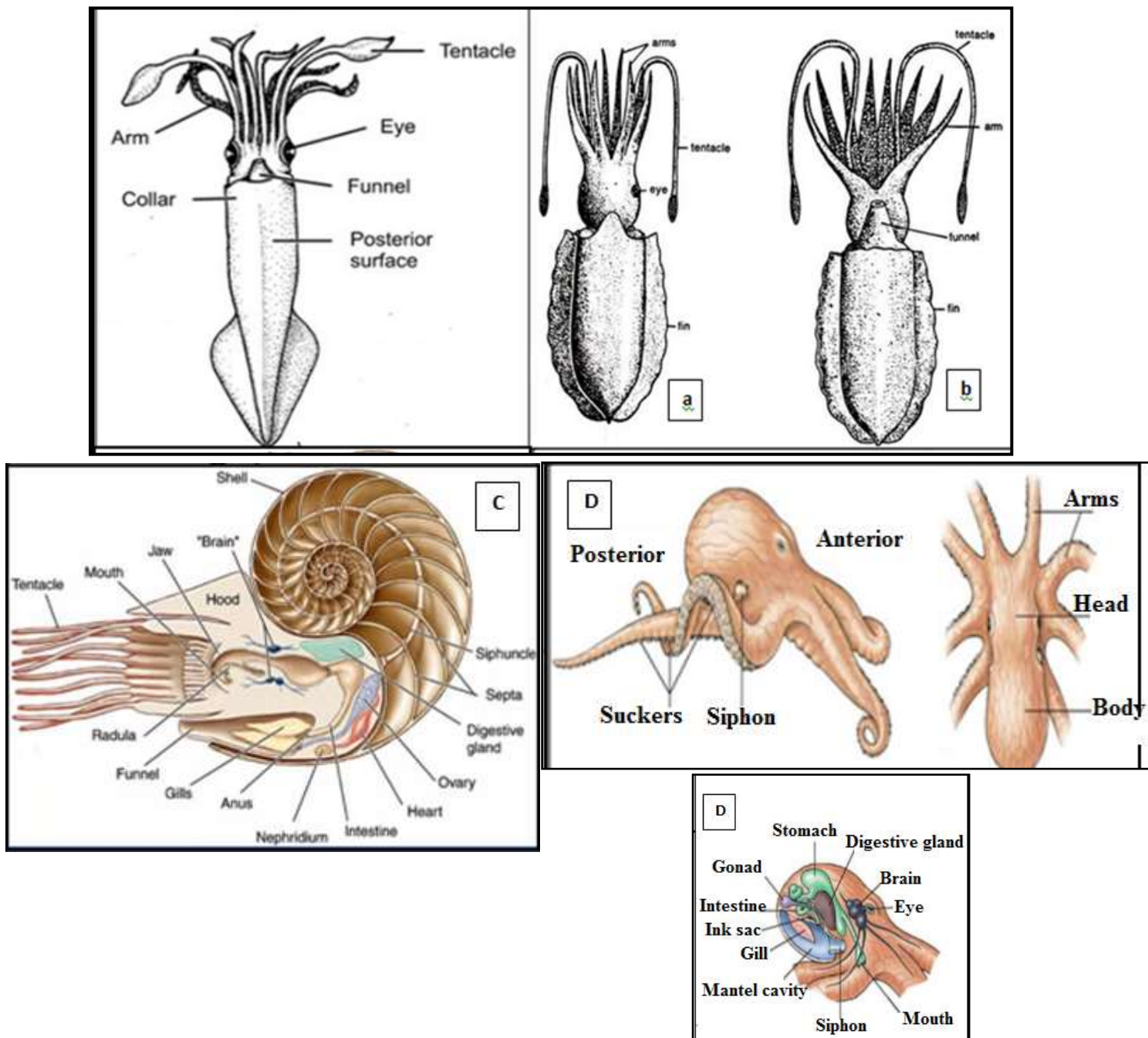


Figure 99. Morphology of Cephalopods. (A) squid (a) Dorsal view ; (b) Ventral view of *Sepia officinalis* ; (c) : *Nautilus* ; (D) : *Octopus vulgaris*.

5.3. Phylum : PHYLUM ARTHROPODA

Arthropoda is the largest phylum in the animal kingdom. About three fourth of the species belong to this group. It is very successful group that has invaded all environments in land, fresh water, salt water, and every other environment. More than 83 % of all described animal species are arthropods.

5.3.1. General characters of arthropods

- ✚ Metazoa, Triploplastic, Coelomate, Bilaterally symmetrical, Protostomes, Hyponerians
- ✚ Organ system level
- ✚ Metamerically segmented body.
- ✚ Arthropoda Grow by **molting, shedding their exoskeleton** to allow for growth.
- ✚ They have paired jointed appendages that are specialised in many ways and adapted to perform various functions. The name Arthropoda means 'jointed legs' and refers to the type of limbs that these animals possess.

Their bodies are divided into a small number of segments, which differ in form and structure. They are usually also grouped into three main regions: the head, the thorax, and the abdomen. Some have a cephalothorax, where the head and thorax are fused together.

The body segments are covered with a thick hard **chitinous cuticle** which provide **protection** and support to the soft tissues and serve for the attachment of muscles. Therefore it is considered an **exoskeleton**. Exoskeleton composed of chitin (protection)

This cuticle is secreted by the epidermis in the form of a series of hard skeletal plates or sclerites are respectively (Figure 100) :

The dorsal plates : Tergum

1. **Sternum** a ventral plates.

2. **Pleuron** a lateral plate

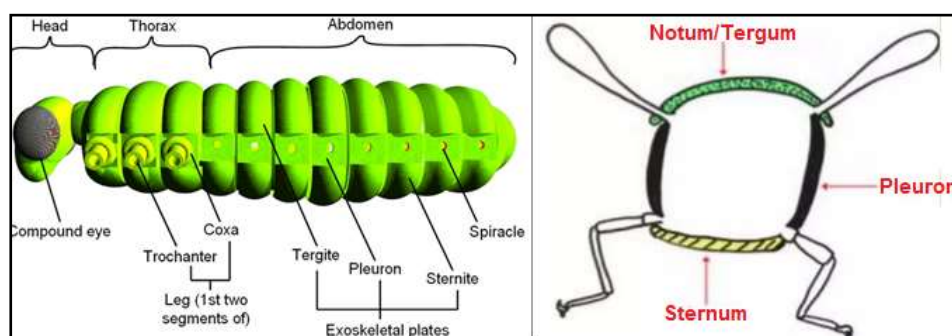


Figure 100. Exoskeleton of Arthropoda.

5.3.2. Organ system of arthropods

5.3.2.1. Digestif system (Figure 101)

- ✚ Alimentary canal is simple complete digestive system
- ✚ Eat everything.
- ✚ Specialized by segmentation.
- ✚ Food enters the body through the mouth and flows into the midgut, where it is broken down and pushed to the anus.
- ✚ Specialized mouthparts : piercing, sucking or mandible, biting, chewing.
- ✚ Divided into 3 main region : Foregut, Midgut, and Hindgut.
- ✓ The foregut and hindgut are both lined with chitin.
- ✓ The **foregut** is involved in ingestion, the mechanical breakdown of food and storage.
- ✓ The **hindgut** is involved with water absorption and formation of the feces.
- ✓ The **midgut** is not lined with chitin and is involved in digestion and absorption
- ✓ **Digestive gland** increase the surface area for digestion and absorption.

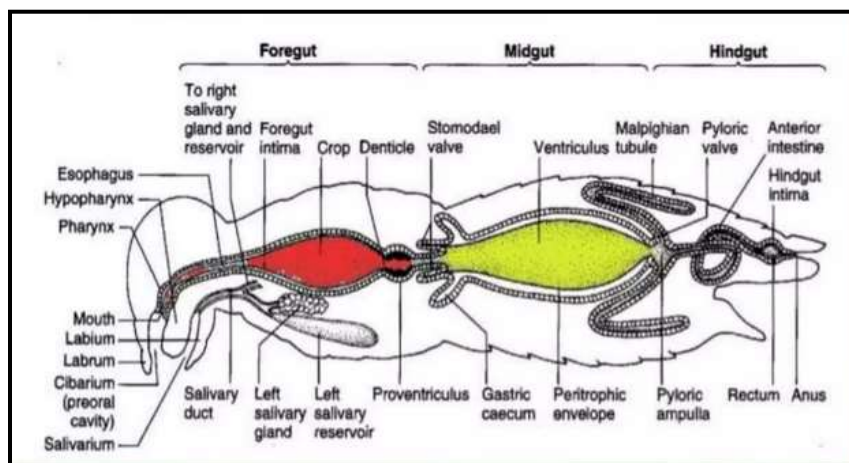


Figure 101. Digestive system of insects.

5.3.2. 2.Circulatory system (Figure 102)

- ✚ Open circulatory system.
- ✚ Body fluid called hemolymph (Not blood).
- ✚ Hemolymph is pumped by the heart to sinuses called the hemocoel.
- ✚ Body fluid enters pores to the organs and is propelled through arteries to the body.

5.3.2. 3.Nervous system (Figure 102).

Brain with a **ventral nerve cord**. There is a double chain of ganglia along the ventral surface of the arthropod. At the anterior end are three fused pairs of dorsal ganglia that constitute the brain. Much of the control of the arthropod's activities is in the central ganglia. The sense

organs are highly developed and include simple or compound eyes composed of many visual units called facets (ommatidia), sensory setae, statocysts, and a pair of antennae.

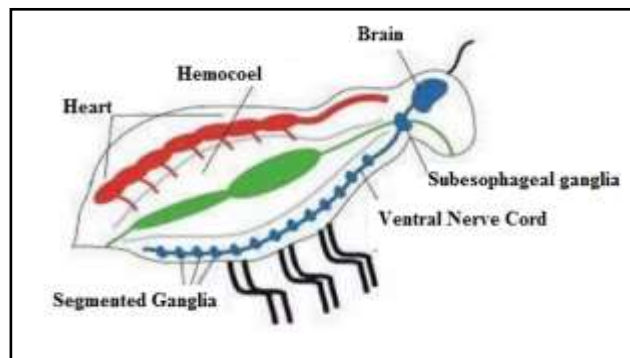


Figure 102. Circulatory system and nervous system of insects.

5.3.2. 4. Internal transport and excretion (Figure 103)

The major waste product is uric acid (uricotelic organisms), which is less toxic and conserves water. It is made by the **malpighian tubules (A)**, which collect liquid waste and send it to the hind gut in the form of nitrogenous waste. This is found in **terrestrial arthropods**. The **green glands (B)** collect and excrete urine in a similar way to kidneys. These are found in **aquatic arthropods**. The **coxal gland (antennal gland) (C)** and the **Malpighian tube** are found in **Arachnids (spiders)**.

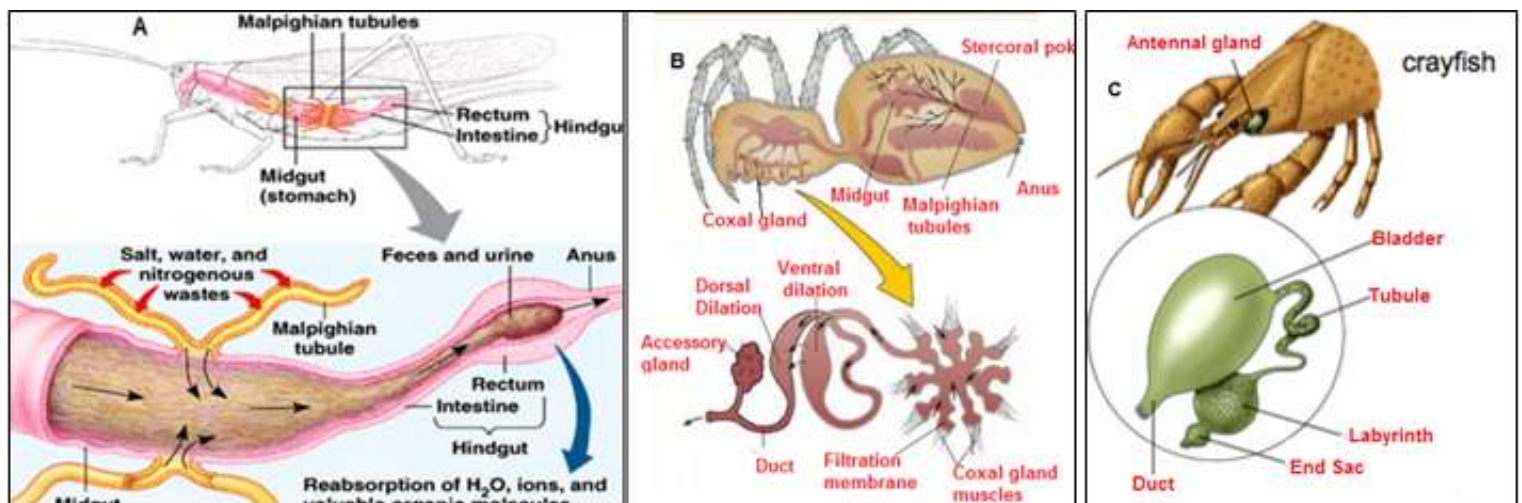


Figure 103. Excretory system of arthropods. (A) : insects ; (B) : Arachnida ; (C) Crustacea.

5.3.2.5. Respiratory advances (Figure 104).

Specialised respiratory structures enable arthropods to metabolise more efficiently and thus move rapidly.

✓ High metabolic rates require rapid oxygen delivery, which arthropods can accomplish with respiratory organs that have a large surface area for quickly collecting oxygen.

- ✓ **Gills:** many aquatic arthropods, such as crabs and lobsters, have gills which are usually modified appendages or outgrowths of the body wall.
- ✓ **Tracheae:** Terrestrial arthropods usually have internal gas exchange organs, which are invaginations of the integument. Insects have tracheae: a branching network of hollow tubes that conduct air to every cell in every tissue.
- ✓ **Book lungs** in spiders: chambers with leaf-like plates for exchanging gases.

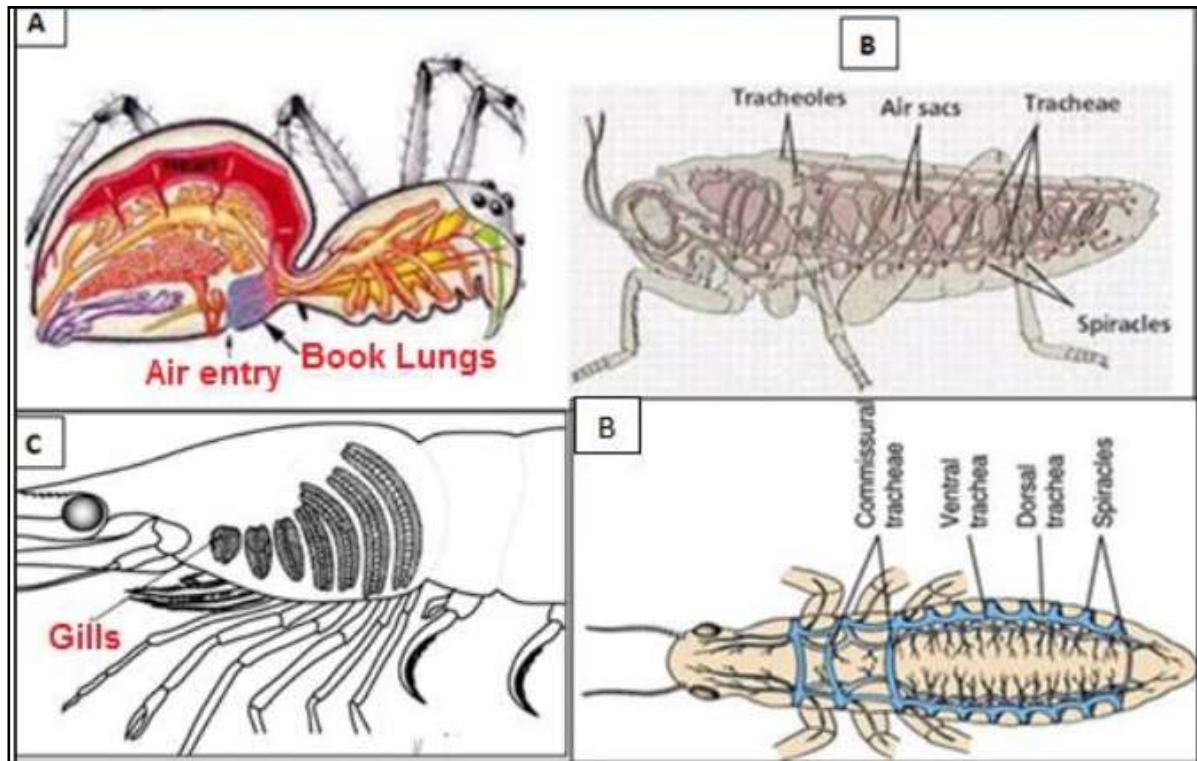


Figure 104. Respiratory system of arthropods. **(A)** : Arachnida ; **(B)** : Insects ;
(C) : Crustacea.

5.3.2.6. Reproduction system

Most reproduce sexually

Internal fertilization among the terrestrial form.

External fertilization in aquatic form.

Undergo metamorphosis : **(Figure 105)**

- **Complete egg** –larva- pupa-adult.
- **Incomplete egg**-juvenile- adult

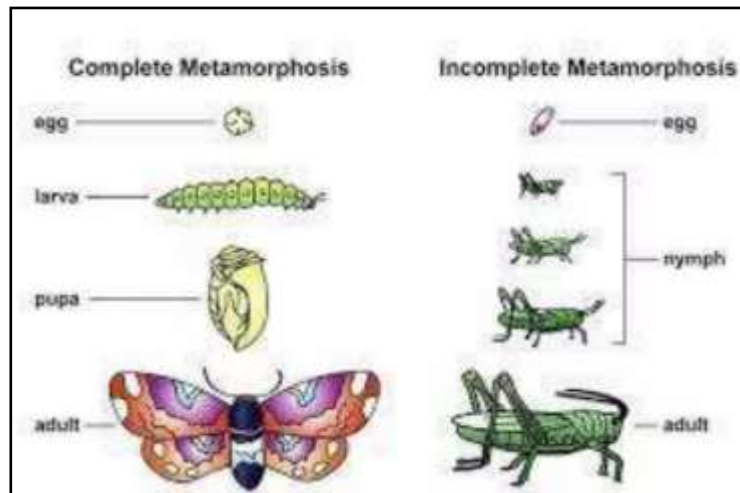


Figure 105. Metamorphosis in arthropods.

5.3.3. Classification

Phylum arthropoda is classified into five subphyla.

5.3.3.1. Subphylum Trilobita (Figure 106).

- ✓ A group of extinct **marine arthropods** about 200 million years ago.
- ✓ Could roll up like pill bugs
- ✓ They ranged in size from a few millimetres to 75 cm.
- ✓ The body is divided into three parts :
 - **Cephalon** (head), a single plate made up of several fused segments.
 - **Thorax**, consists of a number of segments hinged together.
 - **Pygidium (tail)**, also segmented but like the head, fused together into a single plate.
- ✓ **Compound eyes**, composed of radially arranged visual units.
- ✓ The dorsal surface of the body is protected by a strong **calcareous exoskeleton**.

The segment of cephalon and pygidium segments are fused together but are free and movable in the thorax.



Figure 106. Morphology of Trilobita

5.3.3.2. Subphylum Chelicerata

- ✓ Lives on land or in water.
- ✓ Have **chelicerae**, which serve as **pincers** or fangs, located **near the mouth** inject **prey** with **poison** and lack antennae.
- ✓ Body is usually composed of two regions : **Cephalothorax** (Prosoma) and **abdomen** (**Opisthosoma**) (**Figure 107**).
- ✓ The cephalothorax is typically covered on its dorsal side by the carapace.
- ✓ Six pairs of appendages: the first pair are modified feeding structures. Chelicerae; second pair are called **pedipalps**.
- ✓ There are four additional pairs of appendages. These act as walking legs for locomotion. There are no abdominal appendages. Simple eyes are usually present, and compound eyes are sometimes present.
- ✓ Ticks and mites have a single body section, with the head, thorax and abdomen fused together. Ticks feed on the blood of reptiles, birds and mammals, and they also spread diseases.
- ✓ Includes **horseshoe crabs**, **spiders**, **scorpions**, **ticks** and **mites**.

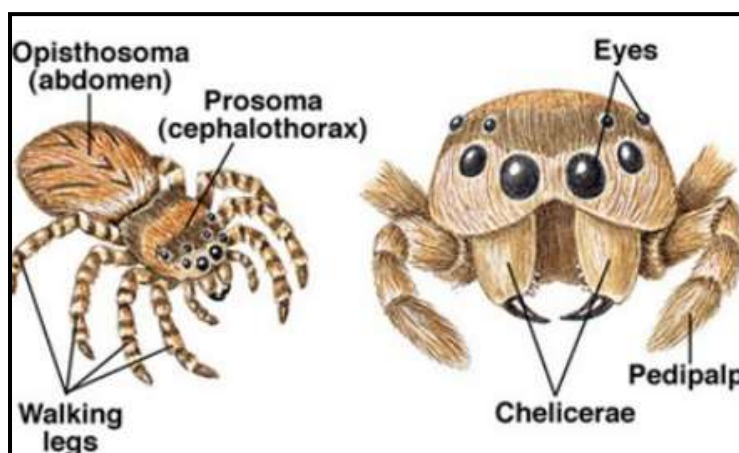


Figure 107. A generalized Chelicerata.

The **subphylum Chelicerata** is divided into **three classes** :

1. **Class Merostomata** : horseshoe crabs
2. **Class Arachnida** : Spiders, Scorpions.
3. **Class Pycnogonida** : Sea spiders.

1. Class Merostomata

They are considered living fossils. These marine chelicerates are commonly found off the Atlantic and Gulf coasts, where they search the muddy ocean floor for seaweed, worms, and molluscs. They have a large dorsal carapace bearing compound eyes. Their cephalothorax bears chelicerae, pedipalps, and four pairs of walking legs (the last pair are not chelate). The abdomen terminates in a long tail called the telson, which is used to turn the animal the right way up. They possess a series of gill plates called book gills, which are found on five segments. They feed on worms and molluscs at night. **Example : Horseshoe Crabs (Figure**

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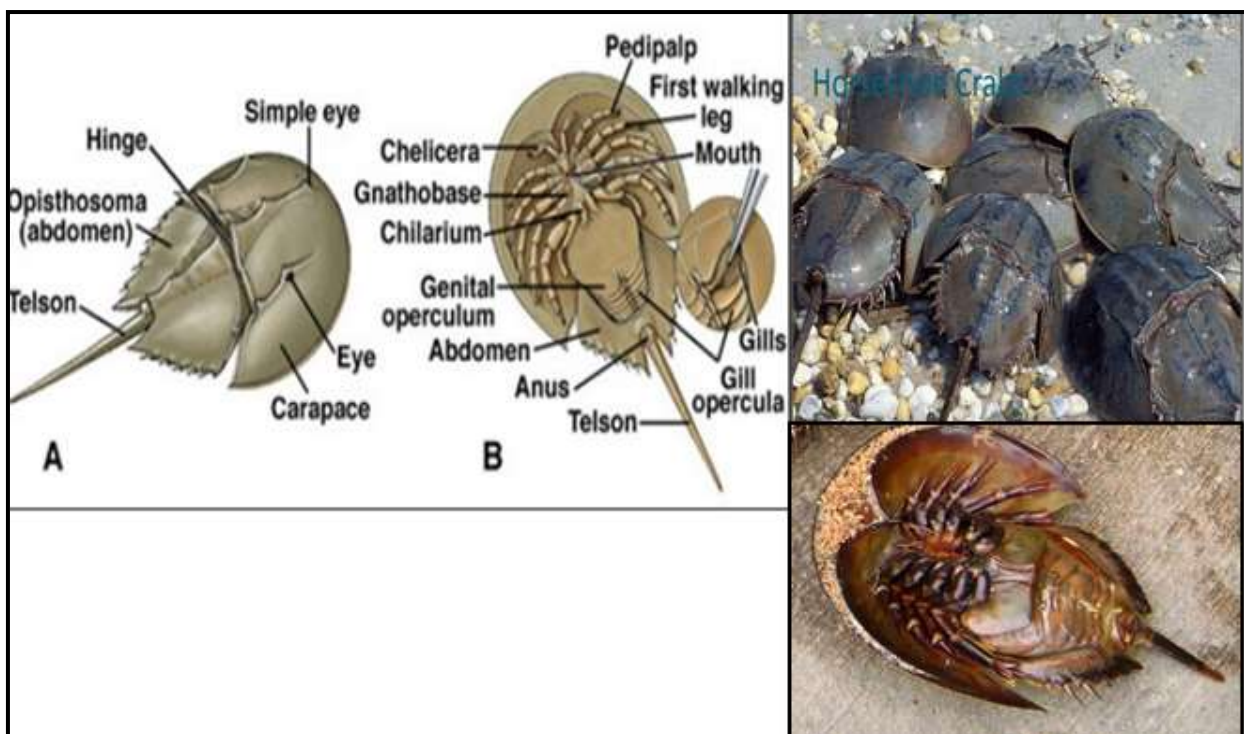


Figure 108. Merostomata ; Dorsal view (A), Ventral view (B).

5.3.1.2. Class Arachnida

Terrestrial habitats: The body is divided into two segments: the **cephalothorax** and the **abdomen**. The cephalothorax is attached to **four pairs** of legs, a pair of **chelicerae** and a pair of appendages called pedipalps. They usually have **eight simple eyes**, which at the very least can detect motion; for some of the predatory species, they can form crude images. Many species have evolved a poison gland associated with the chelicerae. **Respiration** is accomplished via **book lungs**, **trachea**, or both. Arachnids undergo **incomplete** metamorphosis.

Class Arachnida regroup **4 orders** :

- 1- **Order Araneae** : E.g. Spiders.
- 2- **Order Scorpionida** : E.g. Scorpions.
- 3- **Order Phalangida (Opiliones)** : E.g. Harvestmen.
- 4- **Order Acarina** : E.g. Ticks and mites.

1. Order Araneae (Figure 109).

There are over 35,000 species. The cephalothorax and abdomen show no external segmentation and are joined by a narrow pedicel. They are predators that mostly feed on insects and have chelicerae that function as fangs and bear ducts from their venom glands.

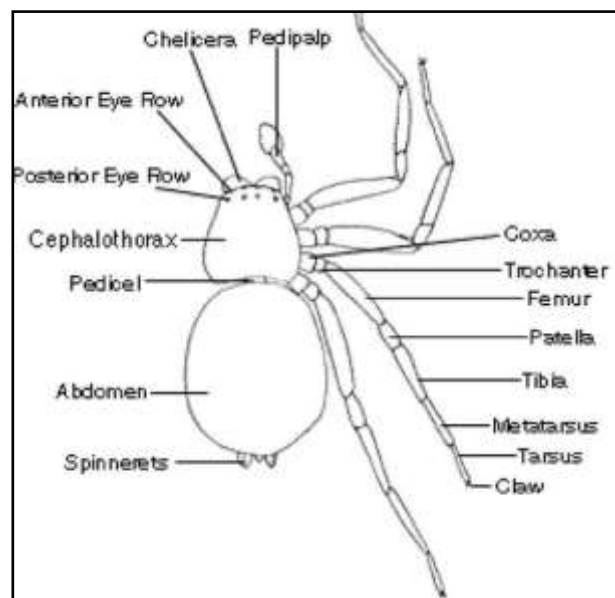


Figure 109. External morphology of Spider.

Many spiders and mites are capable of producing **silk**, which is produced by a silk gland that opens onto the exterior of the abdomen through spinnerets. This **silk** is used to build webs to trap prey, as well as nests to serve as retreats and egg cases.

It is also used to form draglines. Most spiders are predatory and have sensory hairs and relatively well-developed eyes for motion detection. Their internal organs comprise: Respiration occurs via book lungs and excretion occurs via the coxal gland and Malpighian tubules. They are separate sexes with incomplete metamorphosis. They have a complete digestive system. **(Figure 110).**

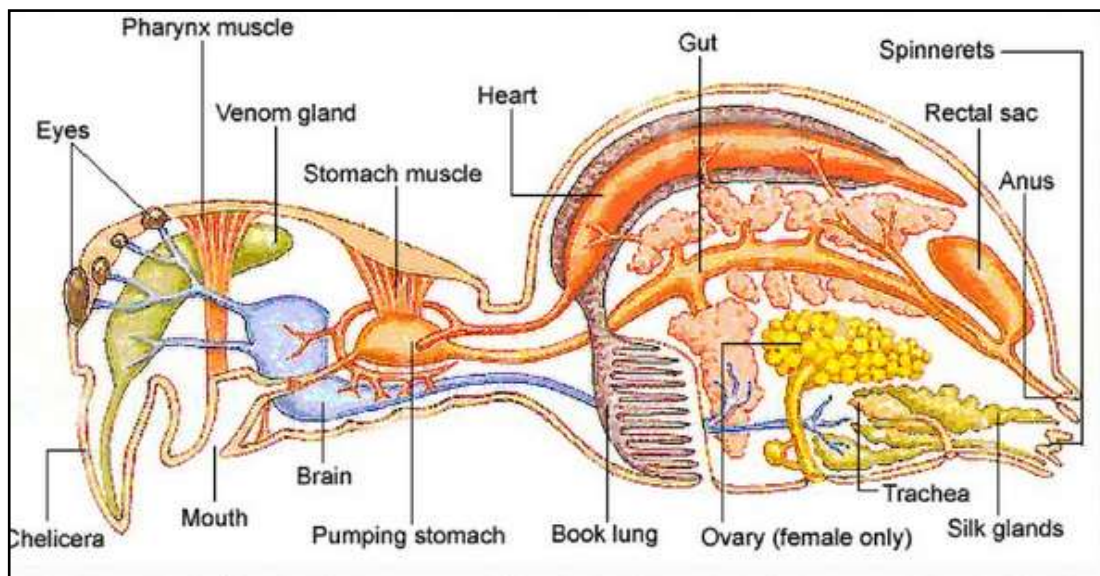


Figure 110. Anatomy of Spider.

2. Order Scorpionida (Figure 111)

They are common in tropical and subtropical regions. They are predatory carnivores that feed on insects. They have a cephalothorax (prosoma) with appendages and one to six pairs of eyes. The abdomen is divided into two regions: the preabdomen (mesosoma) and prostabdomen (metasoma), each of which is divided into six segments. They have a tail-like structure that ends in a stinging apparatus that injects venom. The prosoma bears the mouth and six pairs of appendages ventrally: a pair of chelicerae, a pair of pedipalps and four pairs of walking legs. The chelicerae are small and chelate. The respiratory organs are book lungs. The excretory organs include a pair of Malpighian tubules and a pair of coxal glands. The sexes are separate.

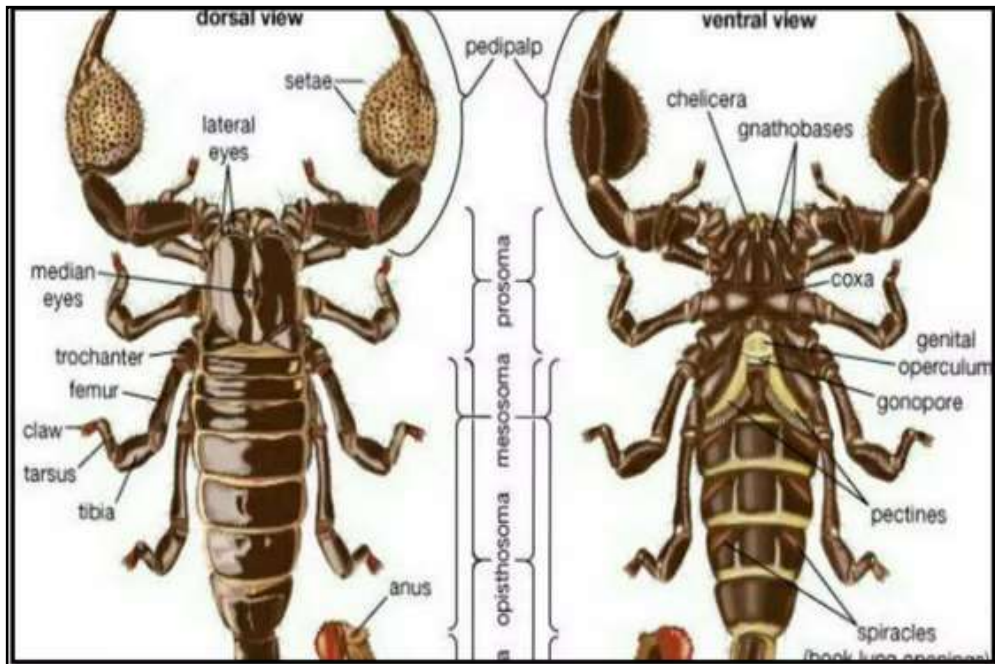


Figure 111. Morphology of Scorpion.

3. Phalangida (Opiliones) (Harvestmen) (Figure 112).

They are also called daddy-long-legs. It is not a spider as it doesn't have two distinct body parts. The abdomen and cephalothorax are joined together. It has four pairs of long, spindly legs and can shed them if grasped by a predator. The chelicerae are pincer-like. They feed mostly as scavengers. They have no venom or silk glands and provide a tracheal respiration.



Figure 112. Opiliones Morphology.

3. Order Acarina (Figure 113)

- ✓ **Cephalothorax and abdomen** completely fused ; sac like unsegmented body
- ✓ Highly specialized mouthparts **Capitulum**.
- ✓ Phytophagous, predatory, parasitic

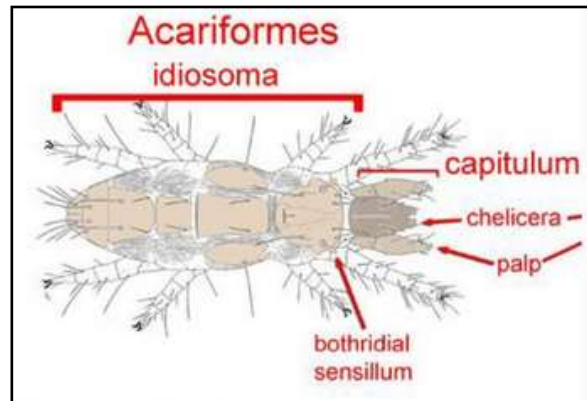


Figure 113. Acarimorphology.

Examples : Ticks and mites.

1. Ticks : They are larger than mites and have a macroscopic body with short or no hair. They are all parasitic (ectoparasites). They have four pairs of legs. They suck blood until they are enormously distended. They are among the world's premier disease vectors, second only to mosquitoes. They cause Lyme disease and tularemia. Examples include *Ixodes sp.* (Hard ticks) (**Figure 114A**) and *Argasidus sp.* (Soft ticks) (**Figure 114 B**).

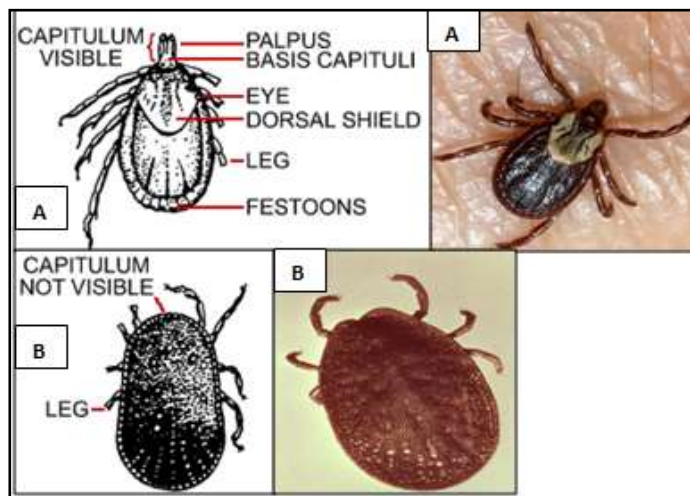


Figure 114. Ticks morphology.

2. Mites : They are small, microscopic and less than 1 mm long, with an adult length of up to 2 cm. The body is not clearly divided into a head, thorax and abdomen (the cephalothorax and abdomen are fused into an unsegmented, ovoid body). There are four pairs of legs. The body is covered in long hair. Some are parasites of plants and animals. They can sometimes cause allergies and dermatoses. They are agricultural pests. They feed on the dermal tissue of terrestrial vertebrates. Example: itch mites: *Sarcoptes scabiei* or *Acarus scabiei*, which cause scabies, a contagious skin disease marked by itching and small raised red spots (**Figure 115**).



Figure 115. Morphology of *Sarcoptes scabiei*.

5.3.1.3. Class Pygnogonida (sea spider) (Figure 116)

The Pygnogonida have small, thin bodies and usually four pairs of walking legs. They are found in all oceans, but are most common in polar seas. Some species have chelicerae and pedipalps.

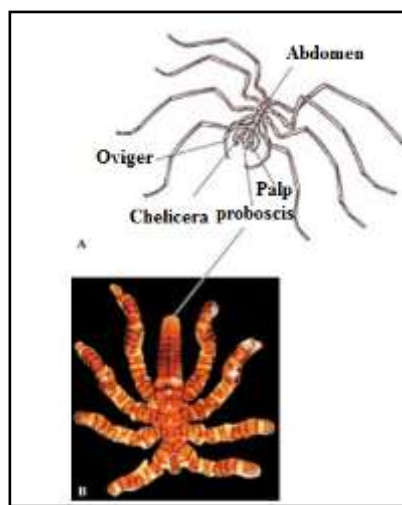


Figure 116. Morphology of Pygnogonida.

5.3.3.3. Subphylum Myriapoda

The term 'myriads' means 'many-footed' in Greek. These are mostly terrestrial and have an elongated body with numerous segments. The head is equipped with a pair of antennae, two pairs of jaws (maxillipeds) and a pair of simple eyes. They have numerous legs. A pair of mandibles is present inside the mouth. They breathe through tracheae and excrete through Malpighian tubules. They have separate sexes. The young resemble little adults and undergo no metamorphosis. The subphylum Myriapoda is divided into the **following classes** :

✚ **Chilopoda.**

✚ **Diplopoda**

✚ **Pauropoda.**

✚ **Symphyla.**

5.3.3.1. Class Chilopoda (Centipeds ; 100 feet) (Figure 117).

It has a flat, segmented body with a pair of legs on each segment. It is nocturnal. It has a head with maxillae and mandibles, two antennae, and either compound eyes or ocelli. The first pair of legs is modified into forcipules, or venom claws. The rest of the legs are maxillipeds with a sensory function. They are first-moving predators of small arthropods, earthworms and snails. Their bite can be annoying to humans. Sexes are separate and some species are oviparous, while others are viviparous. The young resemble little adults and undergo no metamorphosis. **Example : *Scolopendra sp***

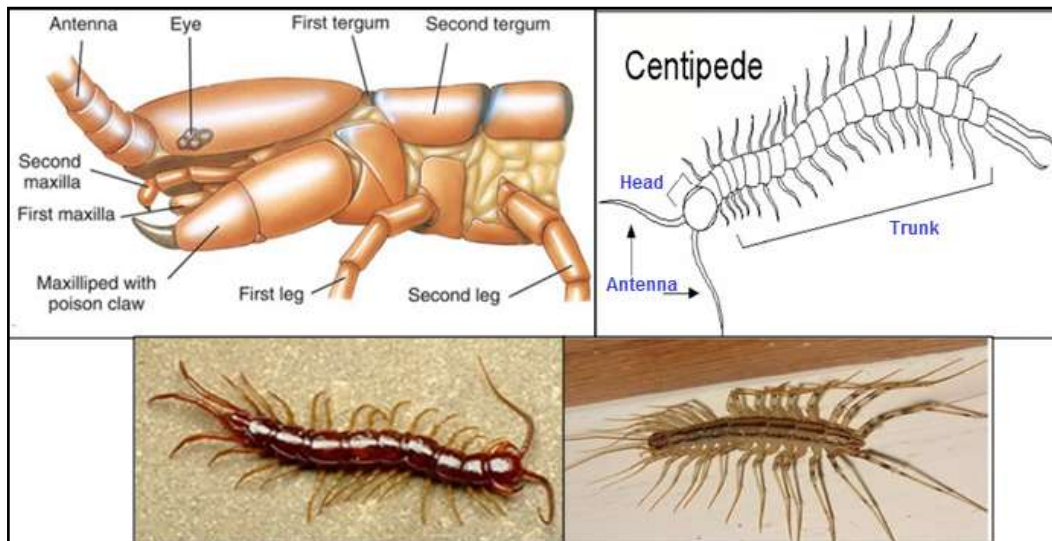


Figure 117. Morphology of Chilopoda.

5.3.3.2. Class Diplopoda (Millipedes ; 1000 feet) (Figure 118).

Each body segment has two pairs of legs. The abdominal segments each have two pairs. They have a cylindrical body made up of 25 to 100 segments. Millipedes are less active than centipedes. They secrete toxic or repellent fluids when disturbed. They are generally herbivorous and live on decaying plant and animal matter.

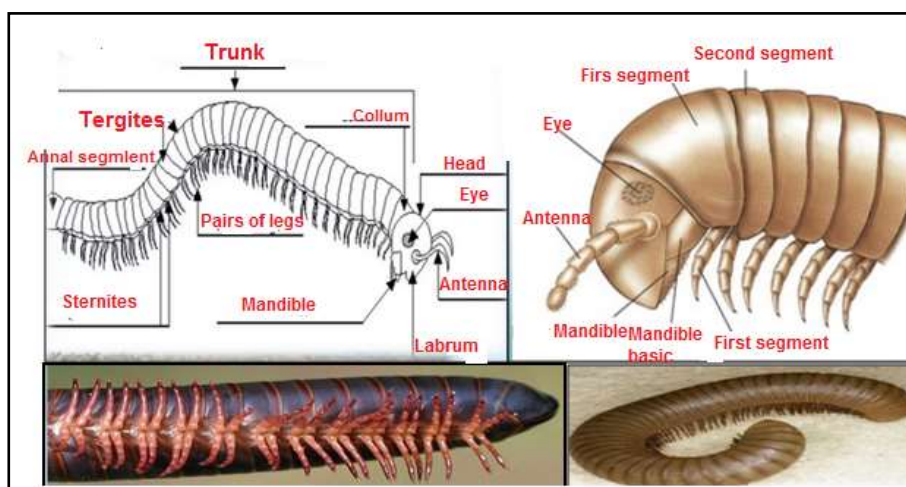


Figure 118. Morphology of Diplopoda.

5.3.3.3. Class Pauropoda (Figure 119 A)

The head lacks true eyes and has branched antennae and a pair of sense organs. It lacks tracheae, spiracles and a circulatory system.

5.2.3.4. Class Symphyla (Figure 119 B).

It lives in humus, leaf mould and debris. It is small (2–10 mm) with a centipede-like body. They have soft bodies with 14 segments and legs, and one segment bears a pair of spinnerets. The antennae are long and unbranched. They are eyeless, with sensory pits at the base of their antennae.

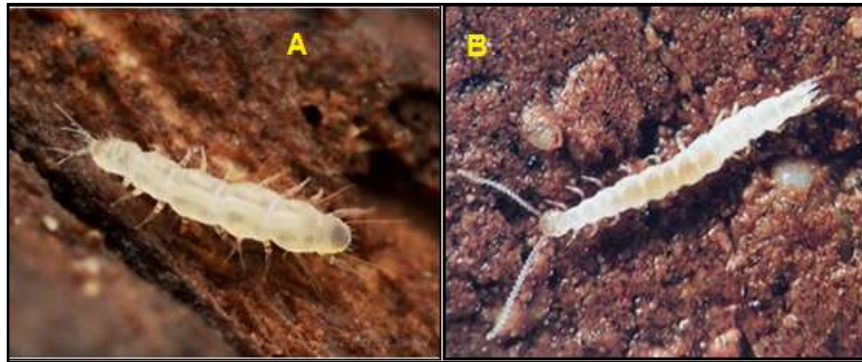


Figure 119. Morphology of Pauropoda (A) and Symphyla (B).

5.3.3.4. Subphylum Crustacea (Figure 120).

1. General features

- ✓ Crustacea are found in a variety of habitats, including marine, freshwater and terrestrial environments. In the marine environment, they are the most common arthropods. Over 80% of all named animal species are made up of insects and crustaceans. The Arthropod phylum (subphylum: Crustacea) contains over 67,000 extant species, and it is estimated that this number is actually several times higher. Crustaceans Grow by **molting**, shedding their exoskeleton to allow for growth.
- ✓ **Body elongated**, bilaterally symmetrical and it segmented in, **Cephalothorax** and **abdomen**. The secreted cuticle consists of chitin, proteins, and calcareous materials. The dorsal tergum and ventral sternum are the plates found on each somite that lack a carapace. They have two pairs antennae ; first pair is homologue to those of insects ; second pair is unique to the crustaceans. Second antennae serve a variety of purposes, including sensory functions.
- ✓ **19 segments** (13 thoracic and 6 abdominal), **Telson** present. **Peleopode** are swimming legs (swimmerets or swimming legs). **Periopods** are walking legs
- ✓ The head bears a pair of compound eyes and three pairs of mouthparts: a pair of mandibles and two pairs of maxillae, which are used for handling food. Primitively, the first three pairs of thoracic segments are maxillipeds and function in handling food. There are usually five

pairs of appendages: five walking legs and five chilipeds (pincer-like claws) for protection (Chilipeds, pincer-like claws). They usually have an extremely hard exoskeleton impregnated with calcium carbonate, called a carapace. Primitively, many of the crustaceans' appendages are biramous, with an outer exopod and an inner endopod (**Figure 121 A**).

2. Organ system

- ✓ **Feeding and digestive system** : Most predators feed on plankton, snails, worms, crustaceans and fish, while scavengers eat dead animal and plant matter.
- ✓ **Open circulatory system** with a dorsal heart and hemolymph that is conducted to the gills for oxygen and carbon dioxide exchange. The hemolymph may be colorless, reddish (haemoglobin) or bluish (hemocyanin), and contains respiratory pigments and ameboid cells.
- ✓ **Excretory system** : The antennal or maxillary gland is called the green gland.
- ✓ **Nervous system** : comprises a brain with a pair of oesophageal ganglia and a double ventral nerve cord, with a pair of ganglia in each somite controlling the appendages. Sensory system: Eyes, statocysts, tactile hairs, mouthparts and telson.
- ✓ **Separate sexes**, the larva is called a 'nauplius'. Unlike the adult, most crustaceans have a larval stage and undergo metamorphosis. Respiration is through **gills**.

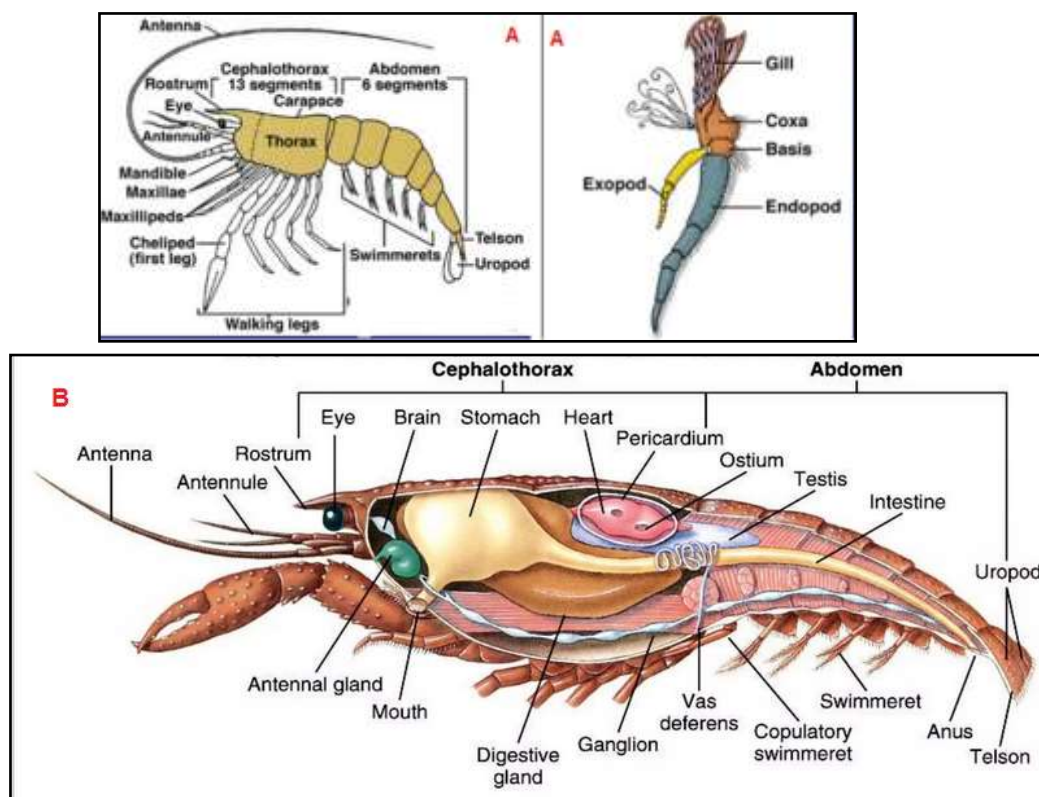


Figure 121. General body plan of Malacostraca (shrimp) (A) and general systems of Malacostraca (shrimp) (B).

3. Classification

Six classes of crustaceans are generally recognised :

1. Remipedia
2. Cephalocarida.
3. Branchiopoda
4. Ostracoda.
5. Maxillopoda.
6. Malacostraca.

1. Class Remipedia (Figure 122 A).

They were all found in caves connected to the sea. They have primitive features, including 25–38 segments and similar paired biramous swimming appendages.

2. Class Cephalocarida (Figure 122 B). e.g. Horseshoe shrimp

Only 9 species have been described in this class. They live on the seabed in coastal areas. They live in sediments from the intertidal zone to depths of 300 metres. Their thoracic limbs and two end maxillae are very similar. They lack eyes, a carapace and abdominal appendages. They are true hermaphrodites, discharging eggs and sperm through the same duct.

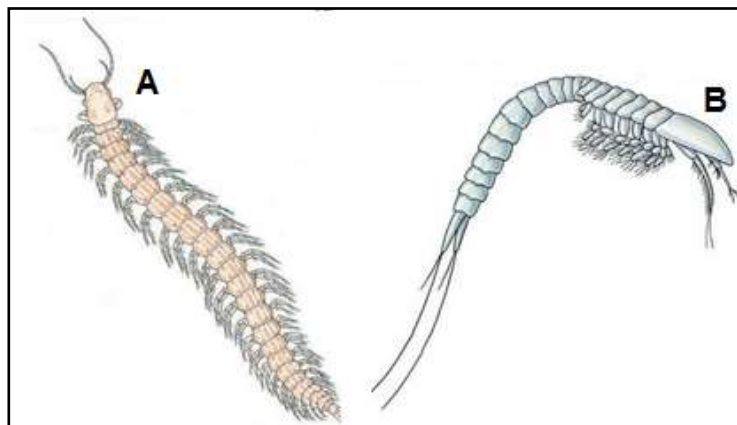


Figure 122. Morphology of Remipedia (A) ; Cephalocarida (**Horseshoe shrimp**) (B)

3. Class Branchiopoda (Figure 123).

Includes three orders :

(A).Order Notostraca : carapace forms a large dorsal shield e.g. **tadpole shrimp**,

(B).Order Anostraca : no carapace, examples : **fairy shrimp** and **brine shrimp**.

(C).Order Diplostraca : carapace enclose body but not head. Used as water fleas (indicators of water quality) ; e.g : *Daphnia magna*

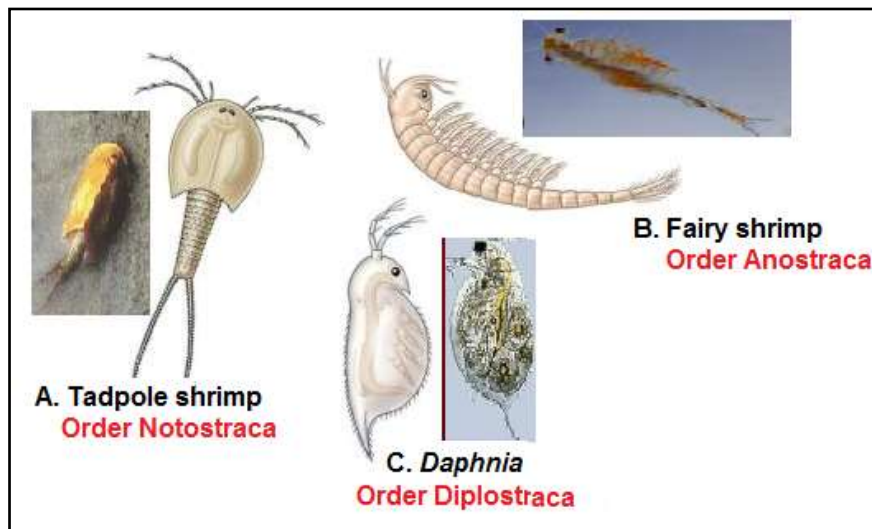


Figure 123. Morphology of different order of Branchiopoda.

4. Class Ostracoda (Figure 124).

Ostracods are enclosed in a two-part carapace and resemble a clam. They live in either marine or freshwater environments. They are mostly benthic and include suspension feeders, scavengers and herbivores..

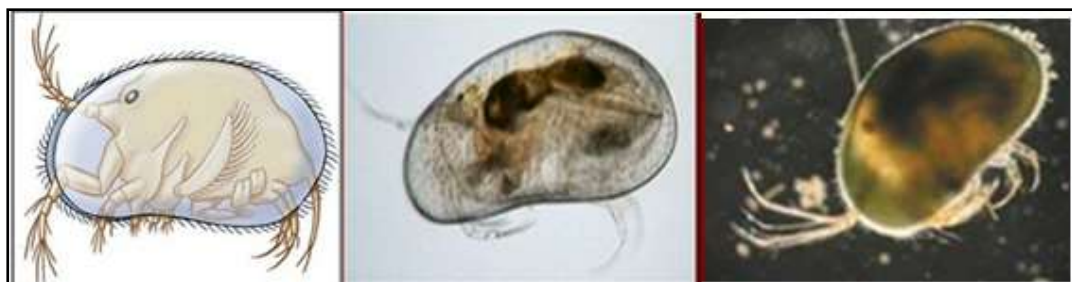


Figure 124. Morphology of Ostracoda.

5. Class Maxillopoda

Maxillopoda generally have five cephalic, six thoracic and four abdominal segments, plus a telson. The maxillopodan eye of the maxillopod nauplius is unique to this group. Many species of copepods are planktonic crustaceans. They lack a carapace. They use their antennules for swimming. Free-living copepods may be the dominant consumers. The marine copepod *Calanus* is the most abundant organism in zooplankton in terms of biomass. Cyclops and *Diaptomus* are important elements of freshwater plankton. Some free-living copepods act as intermediate hosts for human parasitic tapeworms and nematodes. This class is divided in **five subclasses** as following :

Subclass **Copepoda**. (Figure 125).

Subclass **Tantulocarida** (Figure 125 A).

Subclass **Branchiura** (Figure 125 B).

Subclass **Pentastomida** (Figure 125 C).

Subclass **Cirripedia** : marine and sessile as adults, feed with modified appendages called **cirr**

•Example ; Barnacles gooseneck (Figure 125 D 1). Barnacles (Figure 125 D 2).

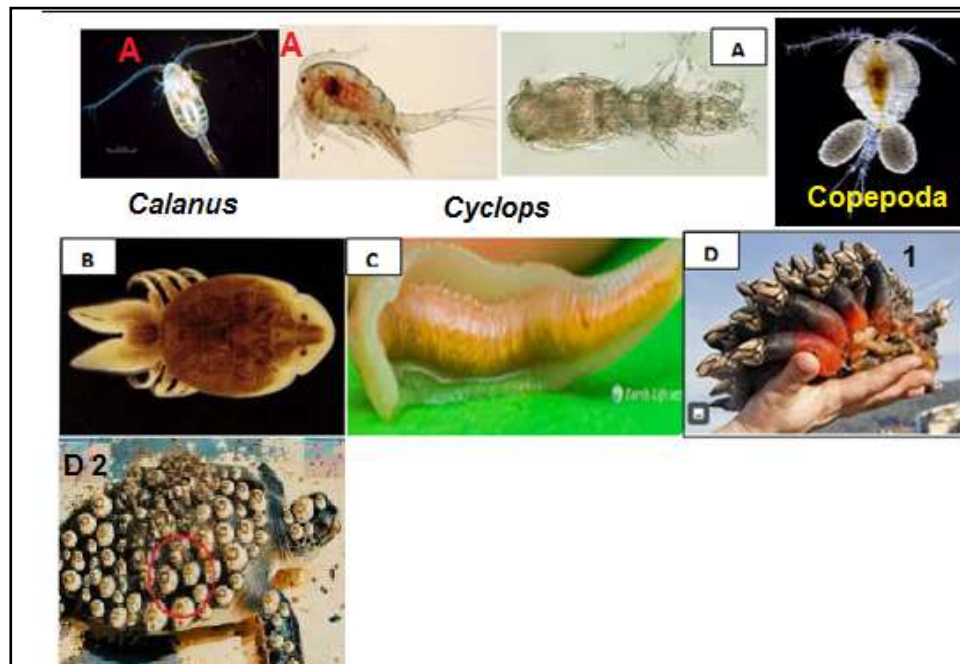


Figure 125. Morphology of subclasses of Maxillopoda.

6. Class Malacostraca

The largest class of the subphylum Crustacea includes crabs, lobsters and shrimp. They are usually marine, but some are freshwater. The body has 20 segments, very rarely 21. The head has 5 segments, the thorax has 8 segments, and the abdomen has 6 (Figure 126). Three thoracic segments are fused with the head to form the cephalothorax. There is an anterior rostrum and a posterior telson. The head has two pairs of antennae and compound eyes. The mouthparts have a mandible, maxillules and maxillae. The appendages of the cephalothorax form the maxillipeds. A carapace is usually present. It has an open circulatory system. Gas exchange occurs across the thin areas of the cuticle or in the gills. Most crustaceans are separate sexes. Many species brood their eggs in special chambers carried by their abdominal appendages. Most crustaceans have larval forms (nauplii). However, Crayfishes develop directly without a larval stage.

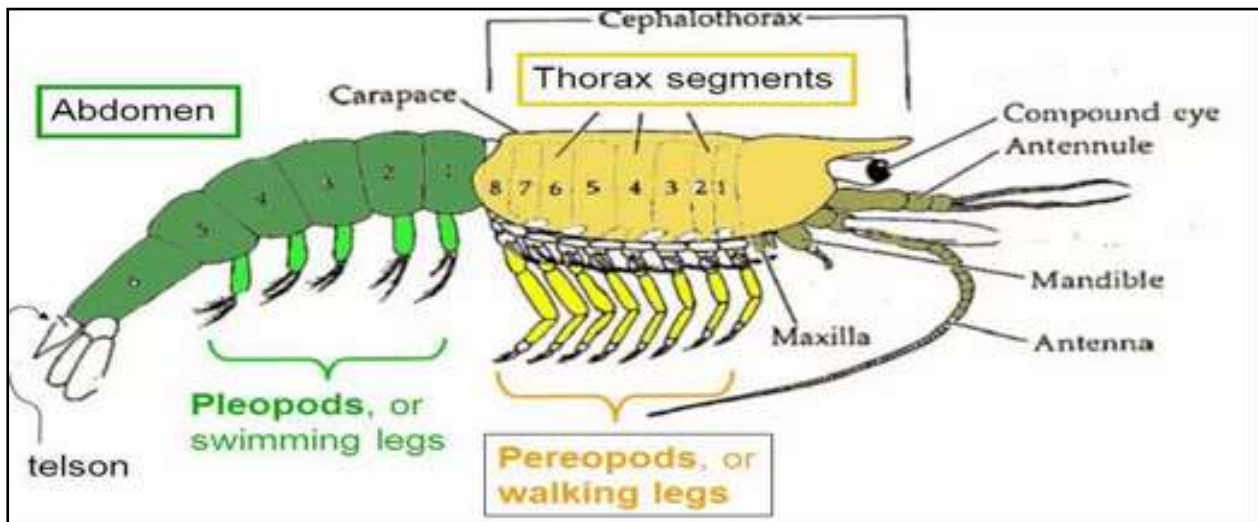


Figure 126. Morphological diagram of different segments from Malacostraca.

Class Malacostraca is divided in **four orders** as following :

1-Order Isopoda (Figure 127).

This includes pill bugs, sow bugs and rolley-polley. They are the only truly terrestrial crustaceans. They also have marine and freshwater forms. They are dorsoventrally flattened and lack a carapace. They have sessile compound eyes and are scavengers, predators and filter feeders. They have open circulation with a hemocoel, and excrete through a green gland. They respire through diffusion and gills, and are mostly dioecious with direct or indirect development.



Figure 127. Morphology of Isopoda.

Figure 127. Morphology of Isopoda.

2-Order Amphipoda (Figure 128).

There are many marine, terrestrial and freshwater forms. Amphipods resemble isopods in that they lack a carapace and have sessile compound eyes and one pair of maxillipeds. They have a laterally compressed body. Development is direct.

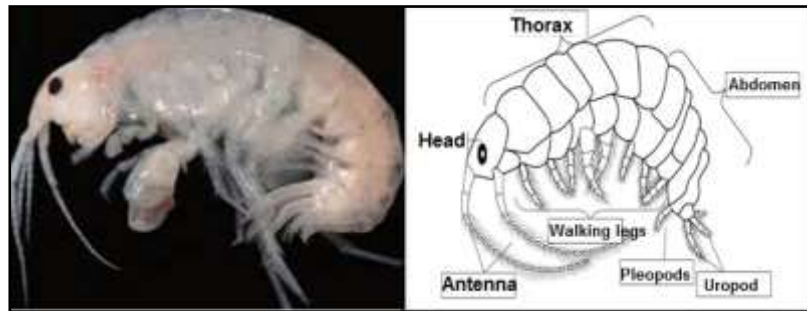


Figure 128. Morphological diagram of Amphipods.

3- Order Euphausiacea (Figure 129)

It contains approximately 90 species. It includes important ocean plankton called krill. Most of these species are bioluminescent, with a light-producing organ called a photophore. They are a major component of the diet of blue whales and many other fish. The eggs hatch as nauplii.

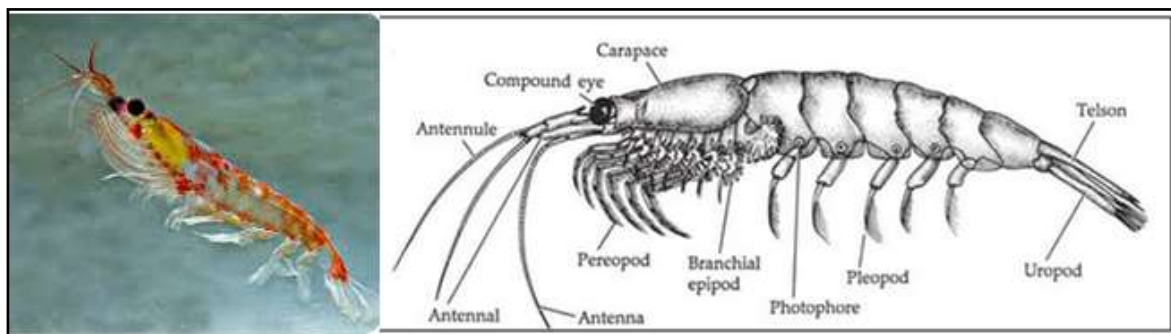


Figure 129. Morphological diagram of Krill.

4-Order Decapoda (Figure 130).

It includes 60% crustaceans. Almost all are marine. They are relatively large crustaceans and include lobsters (Figure 129A), crabs (Figure 129B) and shrimp (Figure 129C). They have three pairs of maxillipeds and five pairs of walking legs. The carapace covers most or all of the cephalothorax. Respiration: gills. Open circulatory system. Reproduction: Dioecious species with indirect development.



Figure 130. Morphological diagram of different Malacostraca.

5.3.3.5. Subphylum Hexapoda

1. Major features

✚ This is the most diverse taxon of Arthropoda, with around 1.1 million species described; they represent 70% of all animals, including bees, beetles, mayflies, stoneflies, cicadas and grasshoppers, to name a few. Key characteristics of the subphylum include:

✚ **Segmented body:** Body plan consisting of three parts (tagmata): head, thorax and abdomen.

✚ **The head** has six segments and bears compound eyes and antennae (segment two). Segment four bears mandibles for crushing food, segment five bears maxillae for chewing, and segment six bears the labium, which forms the lower lip of the mouth. Mouth lies between the fourth and fifth segment.

✚ **The thorax** has three pairs of jointed legs, hence the name 'Hexapoda'. Primitively the appendages of the Hexapoda are **Uniramous**.

✚ 1 pair of antenna (head) : Sensory (smell) Called “feelers”.

✚ 2 pairs of wings (thorax) : Called **forewings** and **hindwings**. Some are wingless (Silverfish).

✚ Exoskeleton made of **Chitin**.

✚ **Reproduction : dioecious**

✚ Development : Complete and incomplete **metamorphosis**.

✚ **Open circulatory system**.

✚ **Trachean** respiration, a few Hexapoda have gills.

✚ This phylum includes the **Apterygota (wingless, primitive)**; also **Ametabola** and relatively small insects; regouped (Class **Collembola**, Class **Diplura** Class **Protura** and Class **Thysanura**). The **Pterygota more advanced, winged** includes Class **Insecta**.

2. Classification

The **Hexapoda** are divided in **five classes** as following :

- 1- Class Collembola.
- 2- Class Diplura.
- 3- Class Protura.
- 4- Class Thysanura
- 5- Class Insecta.

2.1. Class Collembols (Figure 131).

- ✓ **Colla**, glue ; **embolon** : bar = Springtails
- ✓ **Small wingless** arthropods. 0.25 -10 mm in size long. **e.g. Springtails**
- ✓ **Ametabolous** metamorphosis with external reproduction
- ✓ **Habitats** : in soil, leaf litter, caves, freshwater and marine.
- ✓ The presence of the special structure known as the collophore (a ventral tube) on the first abdominal segment is primarily involved in excretion and water **transport**.
- ✓ Springing mechanism formed from retinaculum on segment 3, Furcula on segment 4
- ✓ **4 segmented** antennae.
- ✓ **6 abdominal** segments
- ✓ **Eyes** an either simple ocelli are absent
- ✓ **Mouth parts** developed : mandibles and maxillae ; chewing feed primarily on fungus.

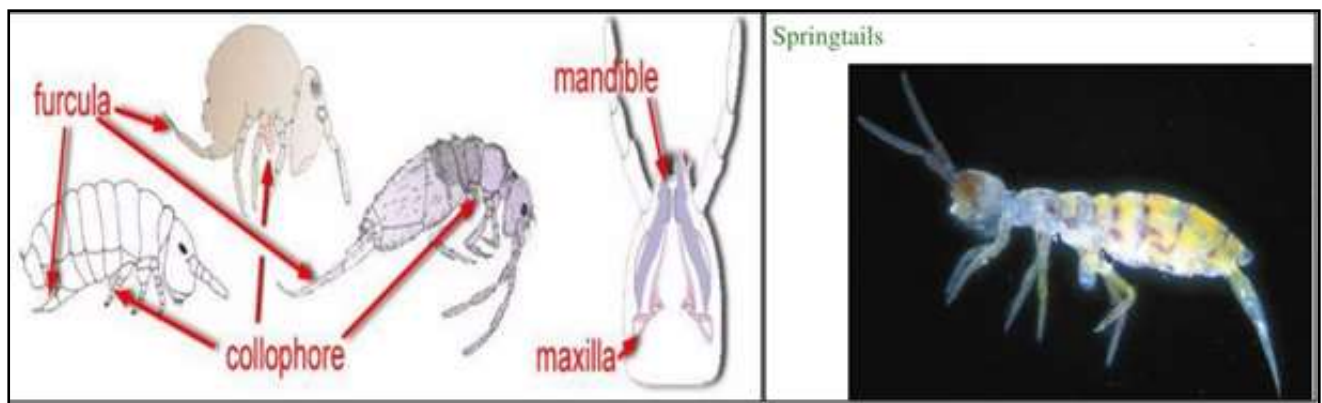


Figure 131. Morphology of Collembols.

2.2. Class Diplura (Figure 132).

- ✓ *Diplura*: from the Greek 'diplos' meaning 'double' and 'oura' meaning 'tail'. **Examples include Campodea sp. and Japyx sp**
- ✓ **Wingless** small insect
- ✓ Soft bodies unpigmented
- ✓ **Mouth part** chewing type (biting)
- ✓ **Antennae** are often segmented and filiform)
- ✓ The presence of compound eyes and ocelli is not observed.
- ✓ **Abdominal segment** (11) with paired lateral pregenital styliiform appendages.
- ✓ **Tracheal** system present.
- ✓ **Malpighian tubules** are absent.

✓ They live in concealed, damp situations in soil, under stones, in dead wood and among leaf litter, where they feed on decaying vegetable matter.

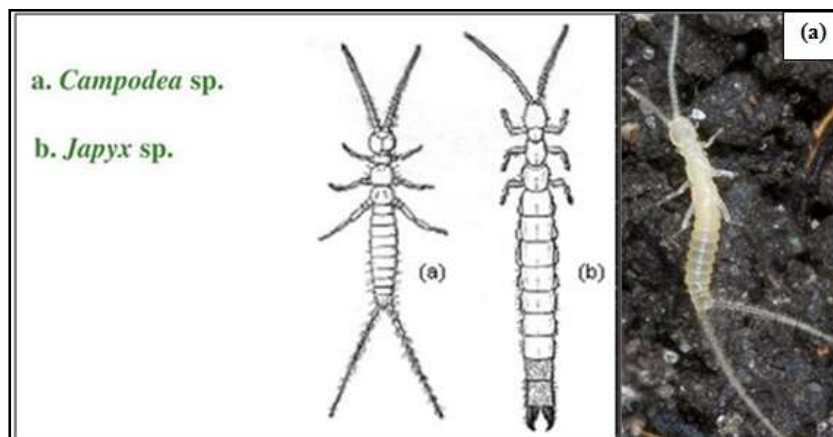


Figure 132. Morphology of Diplura.

2.3. Class Protura :

The word '**protura**' comes from the Greek '**protos**', meaning 'first', and '**aura**', meaning 'tail'. For example, *Acerentomon* sp. Proturans chiefly live in the soil, moss and leaf litter of moist temperate forests, but they have also been found beneath rocks or under the bark of trees, as well as in animal burrows. Proturans are white and lack eyes. They have a cone-shaped head. They have no antennae. Their mouthparts are piercing and sucking. They have three pairs of legs, with the first pair being larger and helping them to grip their surroundings, and tarsi with one segment. The abdomen has 12 segments. The cerci are absent (Figure 133).



Figure 133. Morphology of *Acerentomon* sp.

2.4. Class Thysanura

Thysanura, from the Greek 'thusanos' meaning fringe and 'aura' meaning tail. Domestic species such as Silverfish and firebrats can cause extensive damage to household goods. They are small insects with compound eyes and very long antennae. They have mouthparts for biting and chewing. Their body is covered in scales and their abdomen has 10 complete segments. They have long cerci and a median tail filament. Examples: *Lepisma saccharina* (silverfish) (Figure 1134a); *Thermobia domestica* (firebrat) (Figure 134b).



Figure 134. *Lepisma saccharina* (a) and *Thermobia domestica* (b).

2.5. Class Insecta

2.5.1. General characteristics

- ✓ More than 1 million known species.
- ✓ 80 % of all diversity of life on earth.
- ✓ **The insect body is usually divided into three parts: the head, the thorax and the abdomen.**
- ✓ The presence of compound eyes is confirmed.
- ✓ **Pair** of antennae.
- ✓ The thorax is made up of three segments and is equipped with three pairs of walking legs on the ventral side and two pairs of wings on the dorsal side.
- ✓ **The thorax** consists of three segments : the **Prothorax** (front), the **Mesothorax** (middle) and the **Metathorax** (back), each of these segments bears a **pair of legs** (Figure 135).
- ✓ The **Meso** and **Metathoracic** segments each bear a pair of wings **Forewings** and **Hindwings**.

The abdomen usually consists of eleven segments and bears no ambulatory appendages.

- ✓ **Mouth parts** adapted for chewing, piercing and sucking.
- ✓ **Digestive system** : complete, salivary glands and **Gastric Caeca** aid in digestion ; 3 regions of intestine Foregut, Midgut and Hindgut.
- ✓ Insects breathe through tracheae, which are open via segmentally arranged spiracles.
- ✓ **Excretion** in insects is by means of Malpighian tubules located in anterior portion of the Hindgut. Insects can have as few as 2 or as many as 100 Malpighian tubules.
- ✓ **Open circulatory system** consists of dorsal heart ; hemolymph collects in sinuses hemocoel.
- ✓ **Nervous system** : presence of double ventral nerve cord ; several pairs of ganglia per segment and well developed sense organs. Sensory reception with simple eyes (Ocelli) and compound eyes, antennae (single pair), chemoreceptors (tactile hairs) and sound includes Tympanic membranes reception on each side of body.
- ✓ **Reproduction** : **Separate sexes (Dioecious)**, **Viviparous** with **internal fertilization** and internal development ; eggs develop with **Yolk** thin protective shell. Eggs can be deposited with an **Ovipositor**. In insects **two types of development** : **Complete** and **incomplete** metamorphosis. Metamorphosis is controlled by hormones.
- ✓ **Incomplete metamorphosis** consists of three stages: egg – nymph – adult.
- ✓ **Complete metamorphosis** consists of four stages: egg, larva, pupa and adult.
- ✓ **Exoskeleton** for protection.
- ✓ **Mobility** : wings and legs.
- ✓ **Short life cycle** with high **reproductive success**.
- ✓ **Defense** : protective coloration, Mimicry and defensive chemicals.

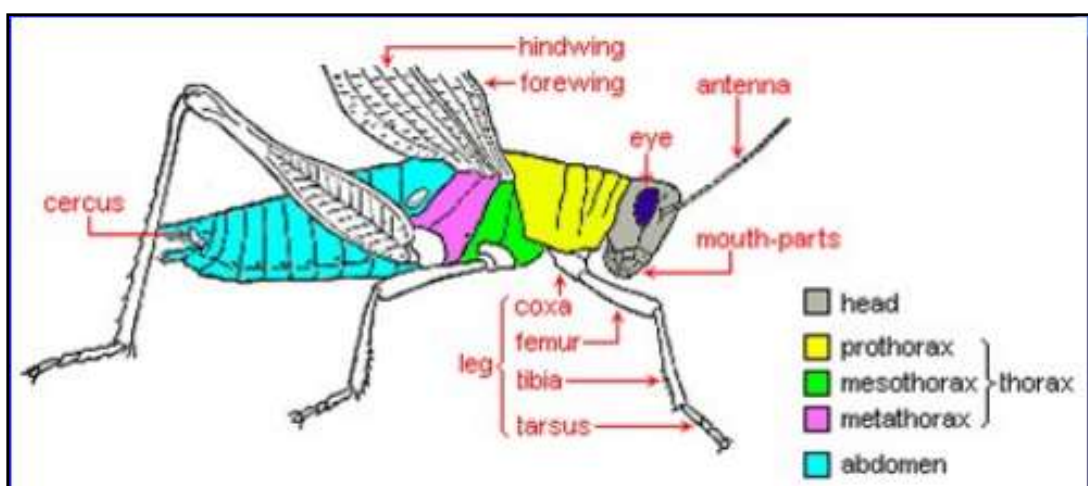


Figure 135. General morphology on insects.

✓ The **insects legs** is segmented in **5 basic plan (Figure 136)**.

1. Coxa
2. Trochanter
3. Femur
4. Tibia
5. Tarsus

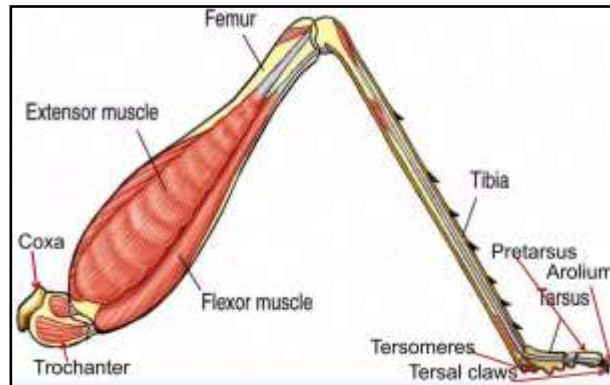


Figure 136. Basic morphology of insects leg.

2.5.2. Mouth parts of Insecta

A) The **five basic** components of mouthparts as following in figure 137.

- 1- **Labrum (upper lip):** a simple flap that covers the upper jaw.
- 2- **Mandibles (upper jaw):** a pair of jaws used for crushing or grinding food.
- 3- **The maxilla (upper jaw)** is sensory in function and responsible for taste.
- 4- **Hypopharynx:** Also known as the tongue, this tongue-like structure helps to mix food and saliva
- 5- **The labium (lower lip)** is a sensory organ.

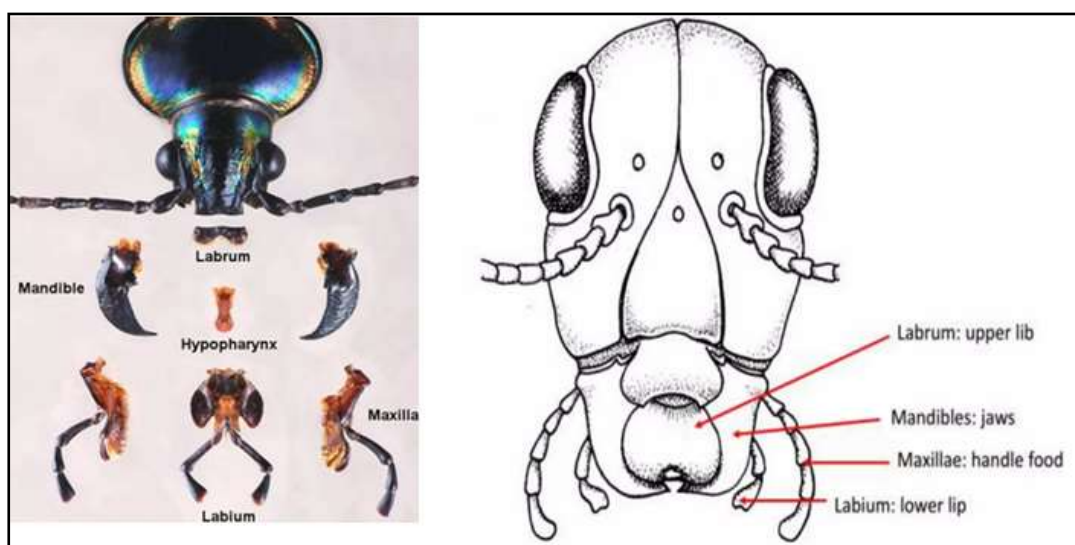


Figure 137. Mouth parts of insects

B) Types of mouth parts (137)

1- Biting and chewing.

2-Chewing and lapping.

3-Piercing and sucking (bug type)

4-Piercing and sucking (Mosquito type)

5-Sponging type

6-Siphoning type.

1- Biting and chewing (figure 138)

Primitive mouth parts
e.g ; Grasshoppers, Cockroach

2-Chewing and lapping e.g ; Honey bee.

Maxillae and **labium** are greatly.

3-Piercing and sucking (bug type)

Mouth parts modified into stylets for piercing plants and sucking out juices

e.g ; Box elder bug (order Hemiptera)

4-Piercing and sucking (Mosquito type)

In female **mosquito**, elongated labium encloses **6 stylets**

5-Sponging type

Found in **housefly**, **Blow flies**, **fruit flies**.

6-Siphoning type

The mouthparts of butterflies and moths. They are modified for sucking nectar from flowers. The proboscis, which is used for sucking up food, is formed by two galea from the first maxillae facing each other.

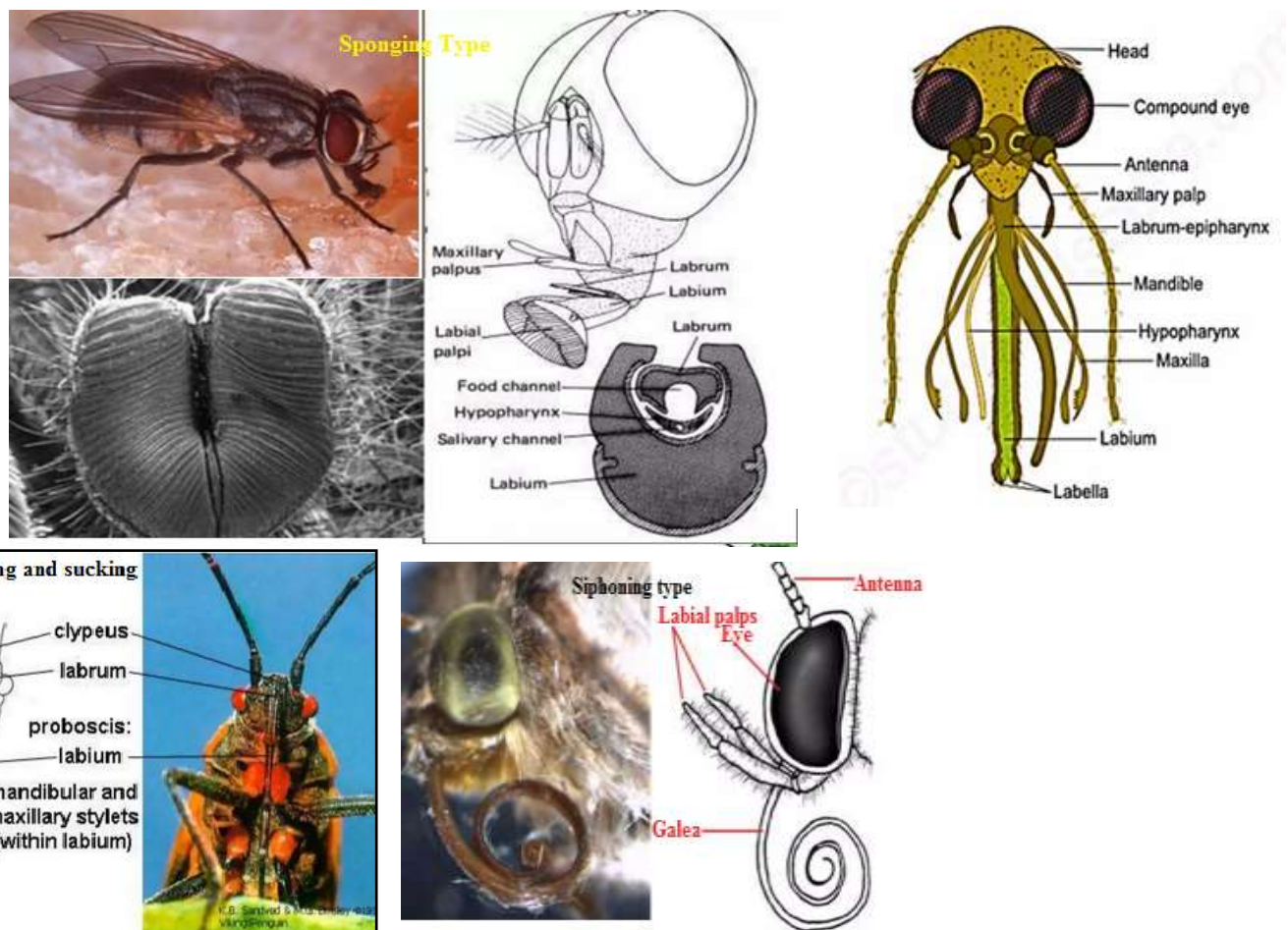
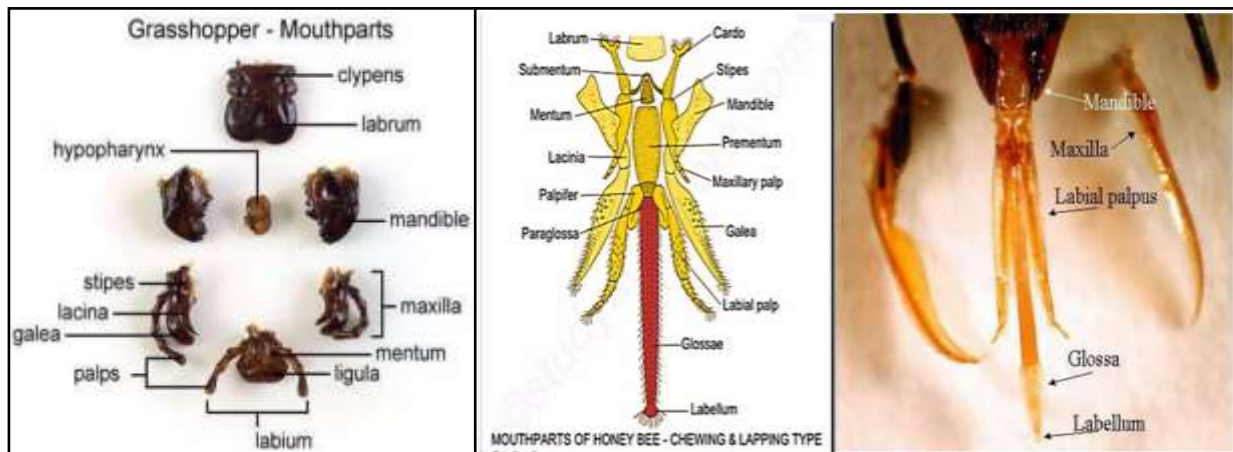


Figure. 138 Insect mouthparts

2.5.3. Development in Insects

In insects we found **three type of metamorphosis** :

1- Simple metamorphosis

- ✓ This includes external wing development and no period of inactivity.
- ✓ Ametabolous : **No** abvious between **Juveniles** and **adult**
- ✓ Hemimetabolous : **Nymph** look like small version of **adult** without wings
- ✓ Paurometabolous :

2- Intermediate

External wing and internal development also **with inactivity** period.

3- Complete metamorphosis

Internal wings development with period of inactivity.

2.5.4. Classification

The class Insecta has two subclasses :

1- Exopterygota

2- Endopterygota

1- Subclass Exopterygota

Insect with **simple metamorphosis** without pupal stage ; this subclass includes many orders :

1.1. Order Ephemeroptera : called **Mayflies**

- ✓ Body thin and elongate
- ✓ Large eyes ; very short antennae
- ✓ 10 abdominal segments
- ✓ Juveniles are aquatic called **Naiads**.
- ✓ 2 or 3 terminal tails on abdomen
- ✓ Mouth parts : Chewing
- ✓ Cycle life : **Hemimetabolous (Figure 137)**.

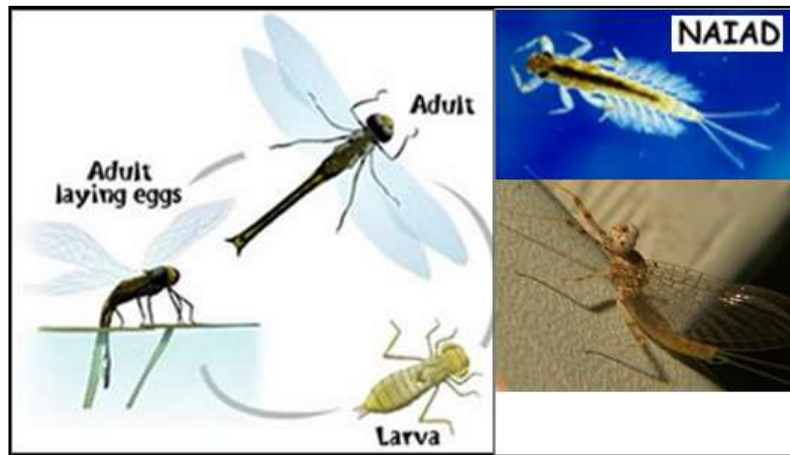


Figure 137. Cycle life of Mayflies.

1.2. Order Odonata

- ✓ Greek **odonto** : meaning tooth
- ✓ Long slender bodies.
- ✓ Eyes very large
- ✓ Well developed compound eyes
- ✓ Mouth part : Chewing
- ✓ e.g ; **Dragonflies** and **Damselflies**.
- ✓ Cycle life in figure : **Hemimetabolous (Figure 138).**

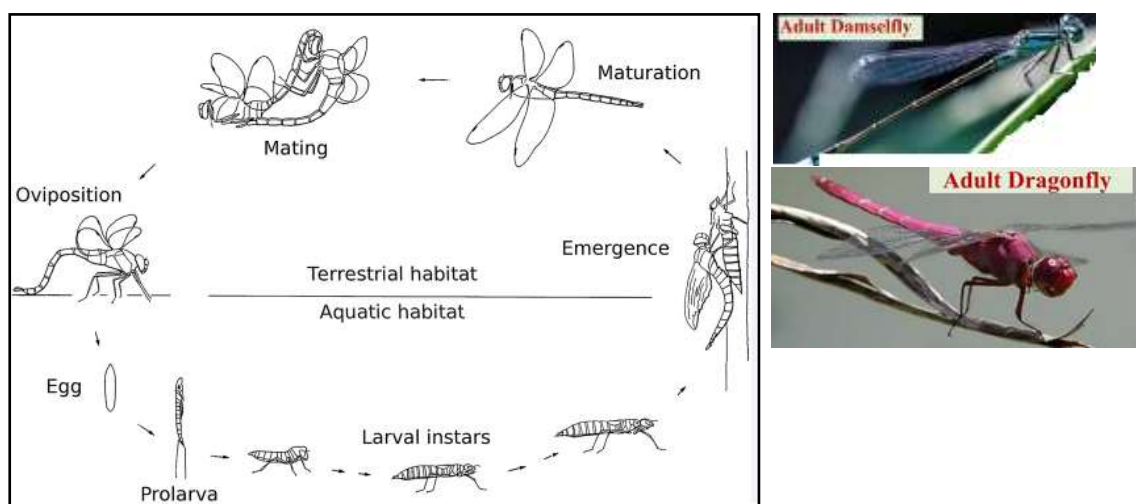


Figure 138. Morphology and life cycle of **Odonata**.

1.3. Order Plecoptera

- ✓ Plecoptera from Greek **Plektos** twised + **pteron** Wings
- ✓ A small group of aquatic insects, often referred to as stoneflies.
- ✓ Two long tail filaments

- ✓ Mouth part are mandibulate
- ✓ Abdomen with 10 segments.
- ✓ Gill on thorax
- ✓ All legs with two claws
- ✓ Fish food, scavengers.
- ✓ they are very sensitive to water contamination, which makes them a useful tool for ecologists who want to check the purity of water.
- ✓ Cycle life **Hemimetabolous (Figure 139).**

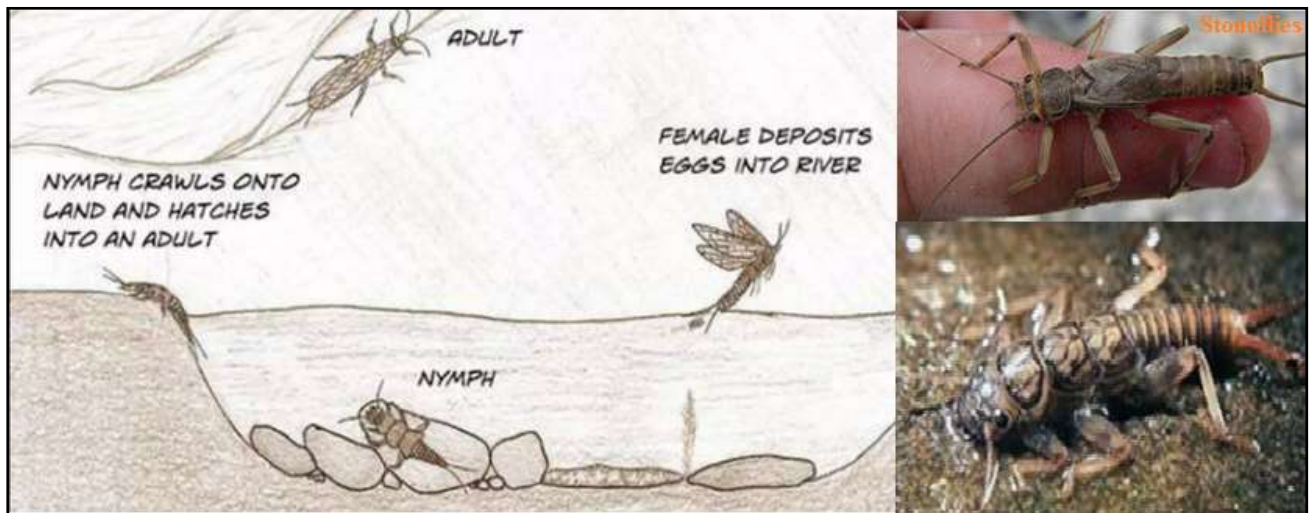


Figure 139. Plecoptera cycle life.

1.4. Order Orthoptera

- ✓ Orthoptera from Greek : **orthos** Straight + **pteron** wings
- ✓ Hind legs long modified for jumping.
- ✓ Strong chewing mouth parts.
- ✓ They feed almost exclusively on plants, though some will scavenge on dead plant and animal material.
- ✓ Life cycle : Paurometabolous (**Figure 140**)
- ✓ e.g ; Grasshoppers, locusts, crickets, katydids.

This order includes **two suborder** :

1.4.1. Suborder Caelifera = Grasshoppers, Locusts

- Back legs large modified for jumping to escape from predators
- Tarsus in 3 segments.
- Antennae usually shorter than body with less 30 segments

- The auditory organ (the tympanum) is located on either side of the first abdominal segment. Diurnal
- Mandibles are specialized for consuming monocot foliage.
- **Ovipositor** is short and horny
- Egg are laid in groups in soil inside shallow burrows
- **e.g ; Family Acrididae.**

1.4.2. Suborder Ensifera : Long horned Orthoptera e.g ; **Katydid**

- Many species are herbivorous and feed on dicot plants; others are carnivorous
- Hind femora are usually only somewhat enlarged (compare with the large femora of Caelifera)
- Antenna that are thread-like with more than 30 segments..
- The tarsi are made up of three to four segments.
- **Tympanum** on the front tibia is present in those groups that sing.
- Nocturnal
- Rely on crypsis
- Ovipositor: long and sword-like, sometimes needle-like; has six valves, four of which are found in Caelifera
- Egg are single insected into plant tissue or soil.

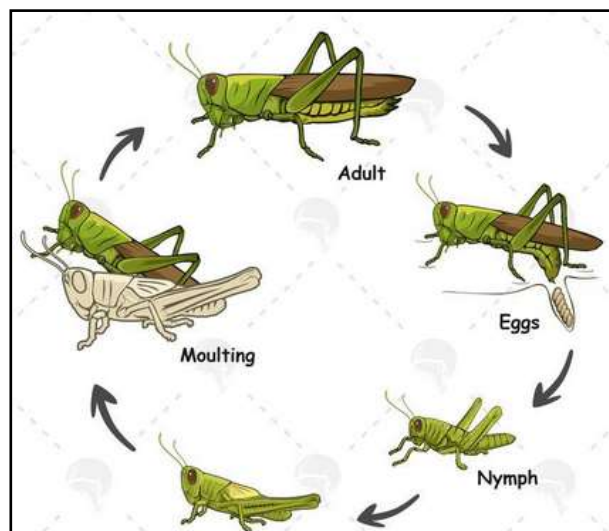


Figure 140. Cycle life of Grasshoppers.

1.5. Order Mantodea

- ✓ Large body elongate slow moving
- ✓ Front legs grasp prey.
- ✓ e.g ; *Chines mantis* ; *California mantis*.
- ✓ Life cycle ; **Paurometabolous (Figure 141).**

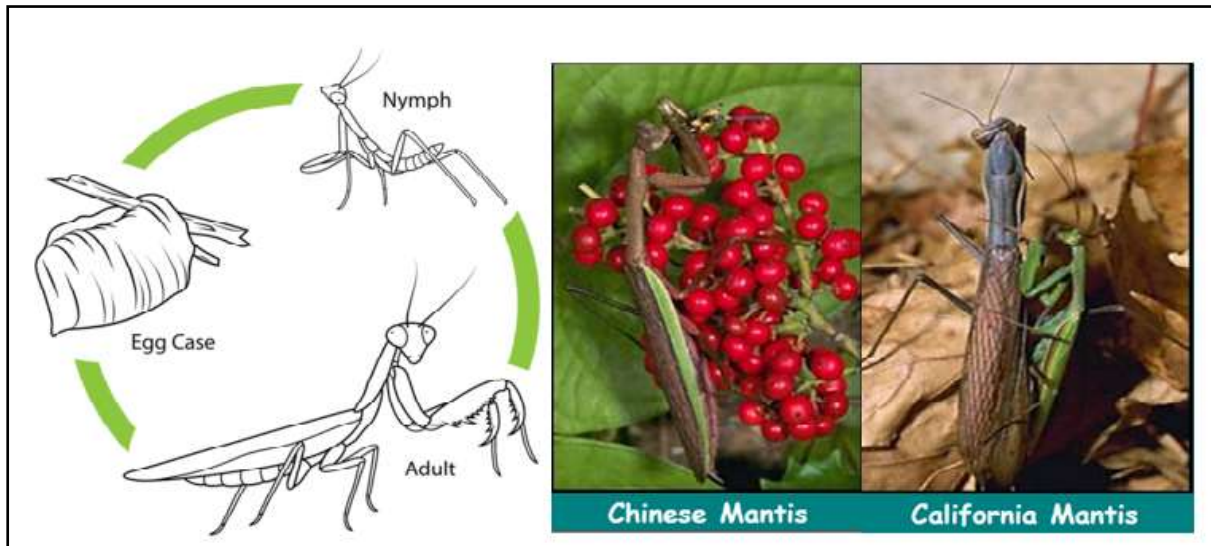


Figure 141. Cycle life of Praying Mantis

1.6. Order Dermaptera

- ✓ In Etymology « **Derma** » : means Skin « **Ptera** » means wings
- ✓ **Common Name** : Earwings.
- ✓ Dorsoventrally flattened.
- Mouth parts : Mandibulate.
- ✓ Tarsi 3 segment.
- ✓ Front wings short and leathery
- ✓ Hind **wings semicircular** and pleated (Fan like).
- ✓ **Cerci** elongate to form pincers (forceps).
 - ✓ They are mainly nocturne and occurs in crevices under back of trees, fallen logs and crawl beneath all kinds of debris on the ground.
 - ✓ Their food consists of wide range of living and dead plants and animal matter ; both phytopagous and predatory.
 - ✓ The forceps' primary functions include capturing prey, launching attacks and defending against them. On occasion, they also assist in folding the hind wings beneath the tegmina.

- ✓ Life cycle in figure **Paurometabolous (Figure 142).**

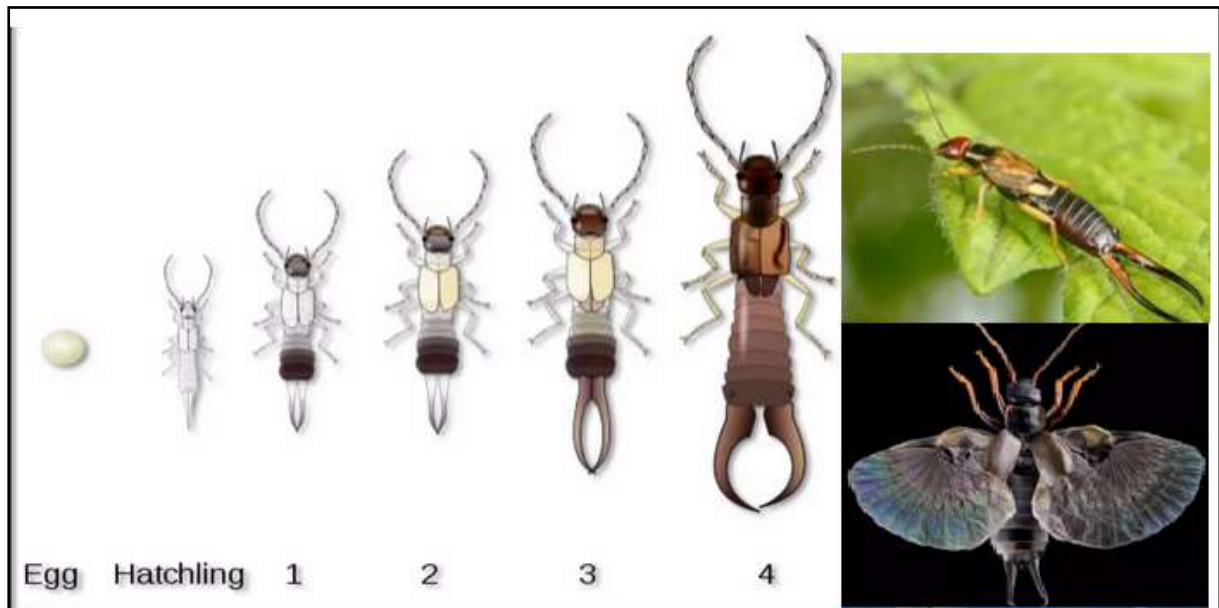


Figure 142. Cycle life of Dermaptera

1.7. Order Isoptera : Termites

- ✓ They are Small soft bodies
- ✓ Insects that are yellowish or whitish in colour.
- ✓ Liven in colonie sin wood.
- ✓ Life cycle with simple metamorphosis ; **Paurometabolous (Figure 143).**

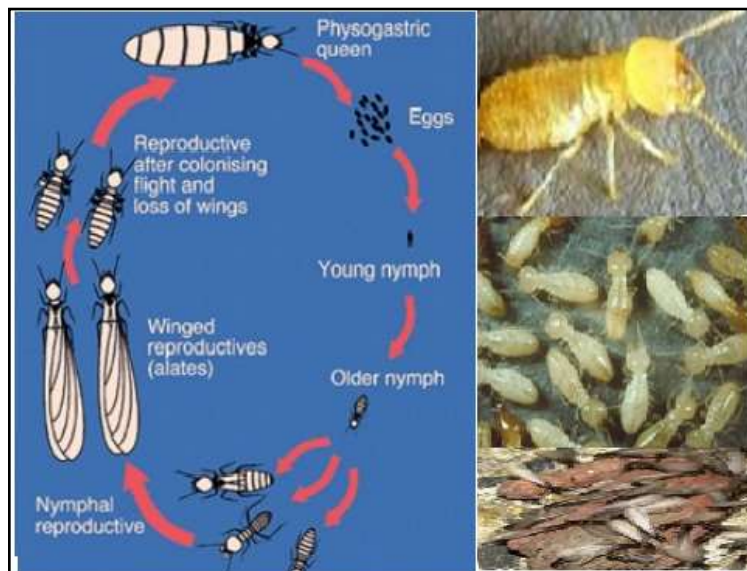
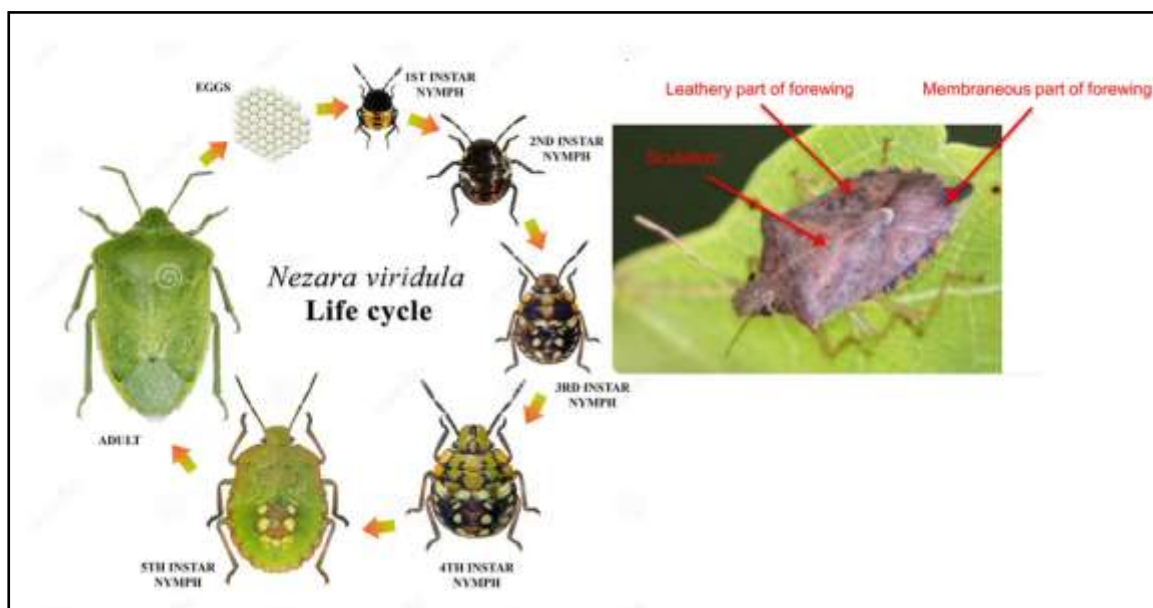


Figure 144. Life cycle of Isoptera.

1.8. Order Hemiptera

- ✓ **Hemi** : Half ; **Pteron** : Wings
- ✓ **Common Name** : True bugs
- ✓ Four wings, folded flat.
- ✓ **Piercing or sucking** mouth parts
- ✓ Found in almost habitats and around water
- ✓ Plant feeders ; predators.
- ✓ Posterior thorax is triangular called **Scutellum** (Figure 144)



- ✓ Life cycle in figure 144. **Paurometabolous**.

Figure 144. Life cycle of *Nezara viridula*.

1.9. Order Homoptera

- ✓ It may or may not have wings.
- ✓ Four wings are present and are held roof-like over the body.
- ✓ Feed on plants, which are their natural food source.
- ✓ Mouthparts is sucking type.
- ✓ e.g ; **Leafhoppers, Scales, Aphids, Mealybugs**.
- ✓ Cycle life in figure 145; **Paurometabolous**.

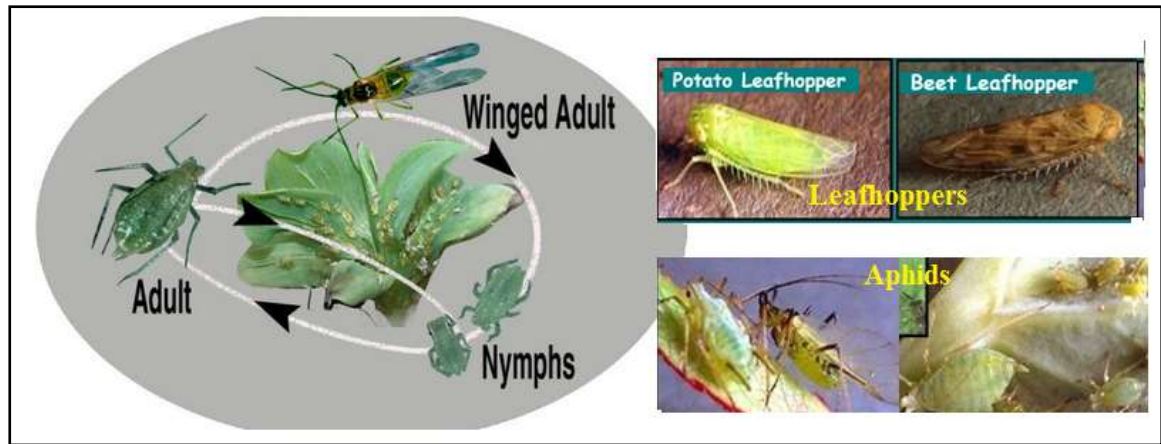


Figure 145. Life cycle of **Homoptera**.

2. Subclass Endopterygota

Insect with **metamorphosis** and presence of pupal (pupa) stage ; this subclass includes many orders :

2.1. Order Coleoptera

- ✓ The largest order of insects.
- ✓ Usually has two pairs of wings.
- ✓ The front pair are thick (elytra).
- ✓ Straight line down the middle of the back.
- ✓ Plant feeders, predators, scavengers and wood borers
- ✓ e.g ; Beetles ; Weevils. Lady bird beetles (Coccinel), Scarabs (Dung beetles).

Cycle life in figure 146 ; Holometabolous.



Figure 146. Collection and Morphology of **Coleoptera**.

2.2. Order Siphonaptera

- ✓ Common name: fleas.
- ✓ Small, wingless adults that are flattened laterally.
- ✓ Larvae live in the nests of various animals.
- ✓ Pests of animals and humans.
- ✓ Larva and adults not similar in appearance.
- ✓ Sucking mouth parts
- ✓ e.g ; *Xenopsylla sp.*

Life cycle in figure 147 ; Holometabolous.

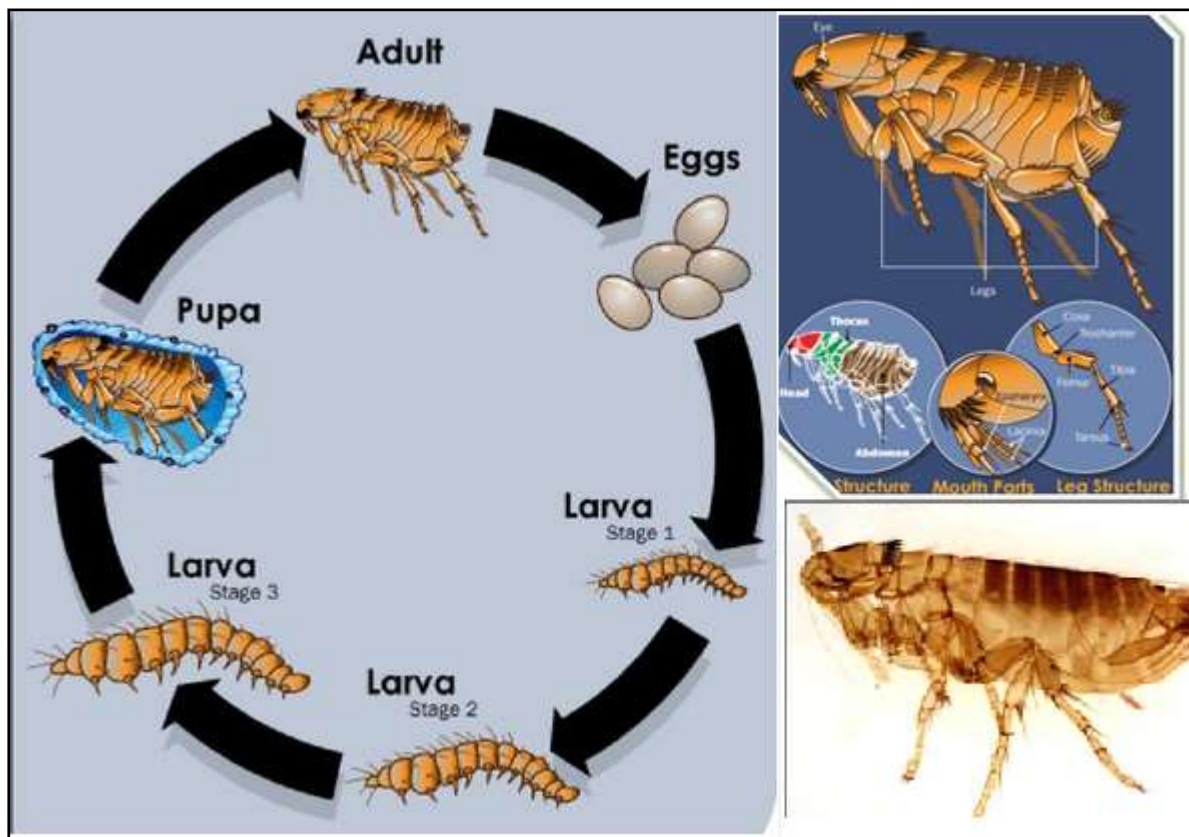


Figure 147. Life cycle of **Siphonaptera**.

2.3. Order Diptera

- ✓ Winged adults.
- ✓ Second pair of wings are **halteres**.
- ✓ Larvae and adults often in same habitat.
- ✓ Larva and adults not similar in appearance.
- ✓ Some spread diseases to humans and animals.
- ✓ Beneficial as pollinators.

- ✓ In mosquitos larvae are aquatic. Adult feed on nectar or blood (females only)
- ✓ e.g ; **True Flies, Mosquitos, Grants, Midges.**

Life cycle in figure 148

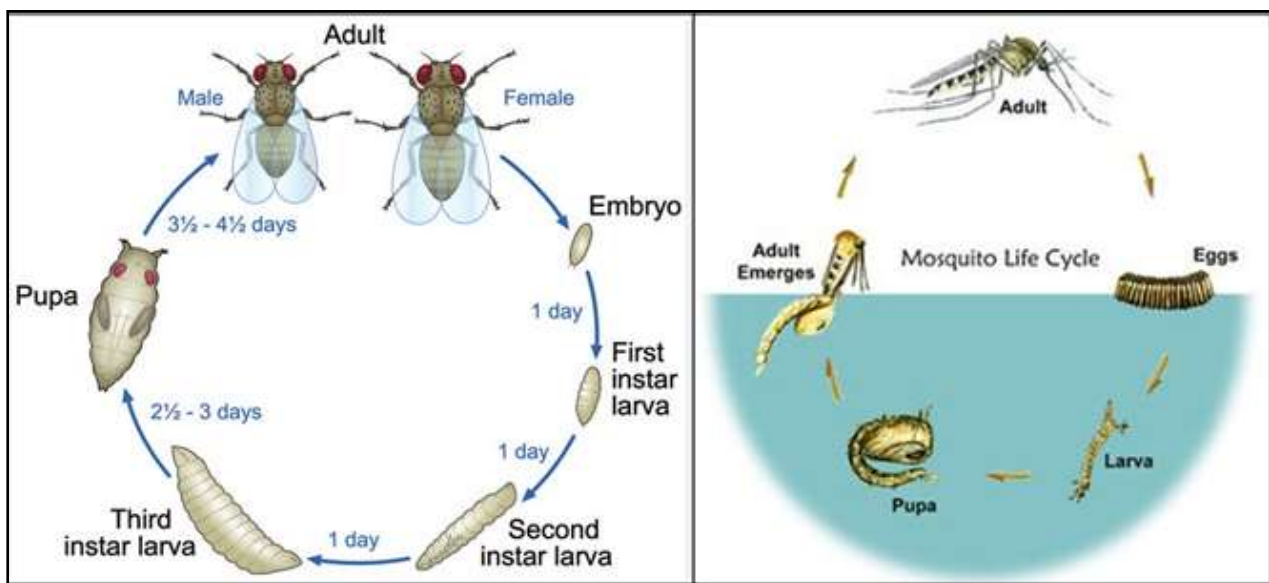


Figure 148. Life cycle of Diptera (Fly and Mosquito).

2.4. Order Hymenoptera

- ✓ In Etymology : **Hymen** : membrane ; **Ptera** : wings.
 - ✓ **Common names** : Ichneumonflies : Bees, Ants, Wasps, Sawflies, Horntails
 - ✓ Mouth part : chewing type (Larvae) ; Chewing –lapping type in adult.
 - ✓ Large compound eyes.
 - ✓ Antennae filliform, geniculate, clavate with 4-70 segments
 - ✓ The female usually has an Ovipositor that may be modified for sawing, piercing or stinging.
 - ✓ Complete metamorphosis.
 - ✓ Generally two orders : **Symphyta** (e.g ; Saw fly) and **Apocrita** (e.g ; Bee, Wasps, Ants).
 - ✓ Social system in which members are divided into : worker, drone and queen casts (Fig.198).
 - ✓ **Workers (infertile females)** are the most numerous and all female and are normally incapable of reproduction.
 - ✓ **Dones** are male whose function is to fertilize a young queen bee.
- Queen** is responsible to reproduction and she is only reproductive female in the colony. The bee cycle life is showed in figure 149.

	Egg	Larva	Pupa	Adult
Queen	Days 1-3	Days 4-9	Days 10-15	Day 16
Worker	Days 1-3	Days 4-9	Days 10-20	Day 21
Drone	Days 1-3	Days 4-9	Days 10-23	Day 24

Figure 149. Bee cycle life.

Importance of the Order :

1-Beneficials :

- **Pollinators** : honey bee, bumble bees, solitary bees
- **Hive products** : Honey, wax, medicines.

2- Pests : Agriculture : Phytophagous Sawflies.

2.5. Order Lepidoptera

- ✓ The word Lepidoptera of two Greek words : **Lepido** : Scale ; **Ptera** : wings.
- ✓ The order Lepidoptera includes butterflies, moths and skippers.
- ✓ About 180000 species of this order are described in 126 families and 46 super-families.
- ✓ 6-11 % : Butterflies.
- ✓ 90 % : moths
- ✓ 3500 species of skippers.
- ✓ One ocelli (simple eye).
- ✓ Adults have four membranous transparent and brightly colored wings.
- ✓ Hind wings are usually smaller than forewings, both largely or entirely covered with scale.
- ✓ Holometabolous insect (Figure 150).

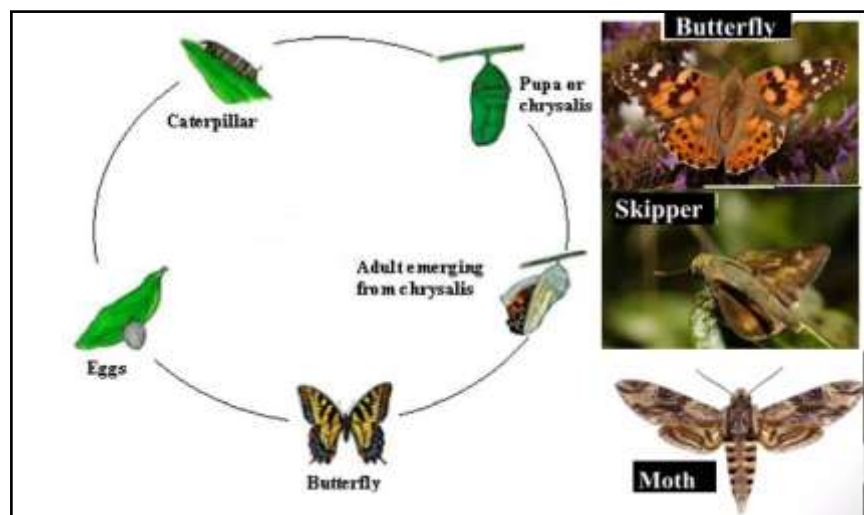


Figure 150. Life cycle of a Betterfly

Economic importance

Lepidoptera form an essential part of most natural terrestrial ecosystems.

- **Predation** : Adult Butterflies and moths preyed upon by birds and bats. Insect eating birds are largest predator.
- **Herbivores** : Lepidoptera help in plant growth regulation by nutrient cycling. When their population level is high they can act as agent of plant community succession.
- **Pollination**
- Some Butterflies and moths **are pests in agriculture** major pests includes tortricidae (e.g ; *Clepsia spectrana*), noctuidae (Looper, owlet moth and under wings) and pyralidae (e.g ; snout moth).
- **Domesticated Silkworm** moth (*Bombyx mori*), the larvae of which from silken.
- cocoons.

6.1. General characteristics of phylum Echinodermata

- + Name means : ‘**Spiny Skin**’
- + Metazoa
- + Body organisation: three layers — endoderm, mesoderm and ectoderm — known as triploblastic.
- + Body cavity : presence of coelome
- + Deuterostomes
- + Epithelioneurians
- + **Bilateral** symmetry in larva stage, but the adult exhibit **pentaradial** symmetrical.
- + Lack cephalization and have a few sensory organs.
- + Water vascular system aids in locomotion, feeding and attachment.
- + Body surface with five symmetrical radiating areas (Ambulacra).
- + Exclusively marine, all found on the bottom sea.
- + **Body type** : The body is radially symmetrical and divided into five parts, each of which is a multiple of five.

6.2. Organ Systems :

- A) Integumentary:** characterised by a thin epidermis.
- B) Skeleton:** mesodermal endoskeleton of calcareous plates (either movable or fixed)
- C) Digestive system :** complete, mouth and anus on aboral surface. Most use water vascular system to produce food.
- D) Circulatory system :** In general, there is no special system; use the water vascular system.
- E) Nervous system :** No brain, a diffused net typically of three rings centred on mouth region with radiating branches.
- F) Respiration system :** Skin gills (Dermal branchiae), cloacal respiratory in Holothuroidea.
- G) Excretion system :** isotonic, diffusion and tube feet.
- H) Reproductive system :** Sexes are usually separate and there is no sexual dimorphism. Fertilisation usually occurs in the sea. Larvae are bilaterally symmetrical and are usually free-swimming, but they have a good regenerative capacity by fragmentation. Many species can regenerate body parts if they lose an arm or their guts.
- I) Mouvement :** use tube feet and muscle fibers attached to endoskeleton. Some have flexible joints or movable spines.

6.3. Ecological roles

- Food source.
- Predators.
- Recycle nutriments.
- Chemicals : anticancer, antiviral.

6.4. Echinodermata taxonomy

The phylum Echinodermata is divided in five classes as following

1. Class **Asteroidea**.
2. Class **Ophiuroidea**.
3. Class **Echinoidea**
4. Class **Holothuroidea**.
5. Class **Crinoidea**.

1. Class Asteroidea

This includes sea stars, also known as starfish (Figure 151 A and B). Most have five arms radiating from a central disc, but some can have up to fifty. Each arm carries an equal share of the organ systems. Most sea stars are predators of bivalves and snails. Primary digestion is extracellular. They have coelomic circulation. Excretion is by diffusion. Sexual reproduction. External fertilisation. Planktonic eggs and larvae. Larval development: Bipinnaria larva Branchiolaria larva with Metamorphosis. The water vascular system contains (Figure 151C). **Madreporite** or sieve plates: Water enters the vascular system. **The ring canal** surrounds the mouth and leads to the **radial canals**. Five radial canals, one down each arm. The **Ampulla** is a muscular sac that controls the tube feet by forcing water into them. Tube feet create suction to adhere to the substrate and are involved in movement, feeding, excretion, respiration and as a sensory organ. The nervous system is associated with the epidermis via the circumoral nerve ring and radial nerve. There is also the presence of ocelli and diffuse sensory cells (Figure 151D).

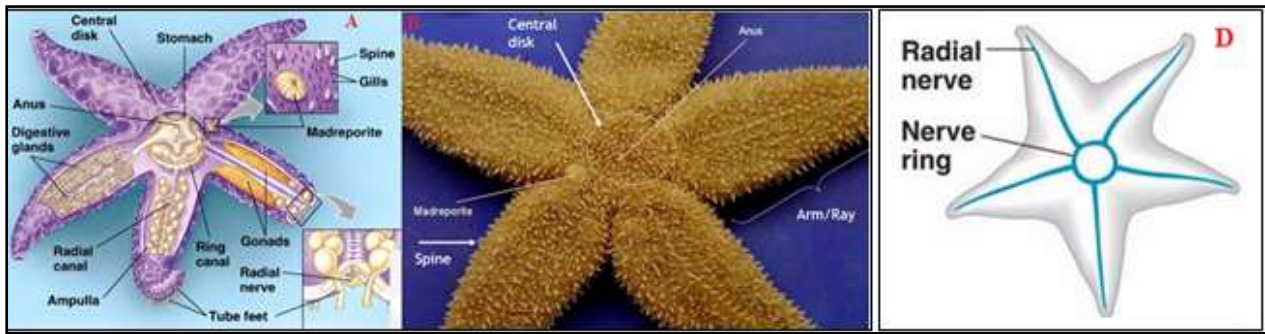


Figure 151. Internal anatomy of sea star (**A** ; ventral view and **B** ; dorsal view) ; (**C**) : the water vascular system ; (**D**) : nervous system.

2. Class Ophiuroidea

This includes brittle stars, basket stars and serpent stars (Figure 152). Their legs are proportionally longer and thinner than those of sea stars. This allows for better movement. Their organs are located in the central disc. The tube feet lack suckers.

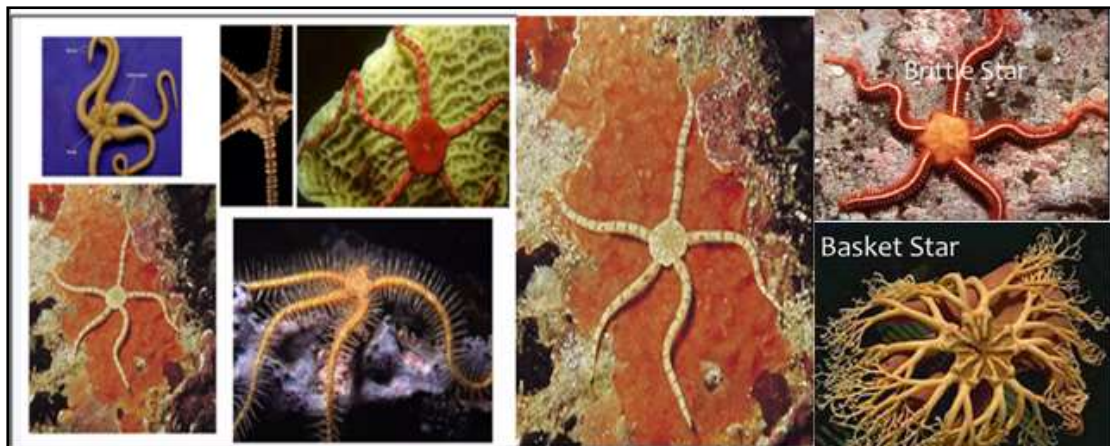


Figure 152. The photo gallery of **Ophiuroidea**.

3. Class Echinoidea

This class includes sea urchins, heart urchins and sand dollars). The body is formed into a round, rigid structure with movable spines and pedicellariae. The mouth is on the underside and the anus is on the top. The spines are sharp, hollow and sometimes contain venom. The mouth has an intricate system of jaws and muscles called the 'Aristotle's Lantern', which is used to bite algae and other food from the seabed.

Plates: Ten plates with alternating abulacral openings for tube feet and interabulacral bumps for spines (Figure 153).

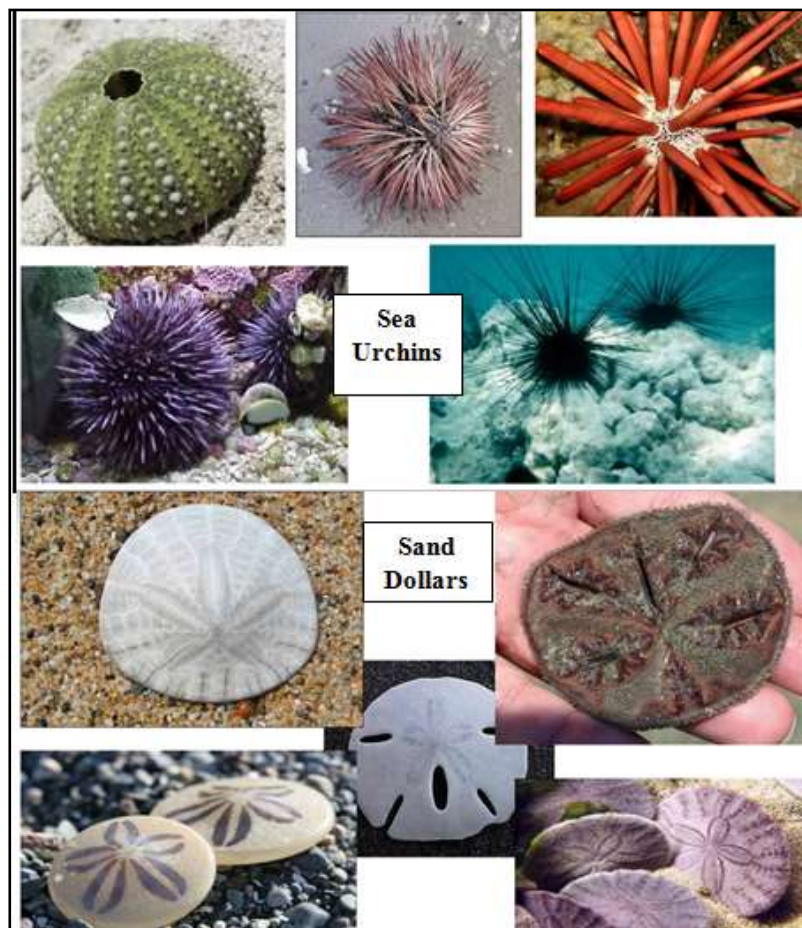
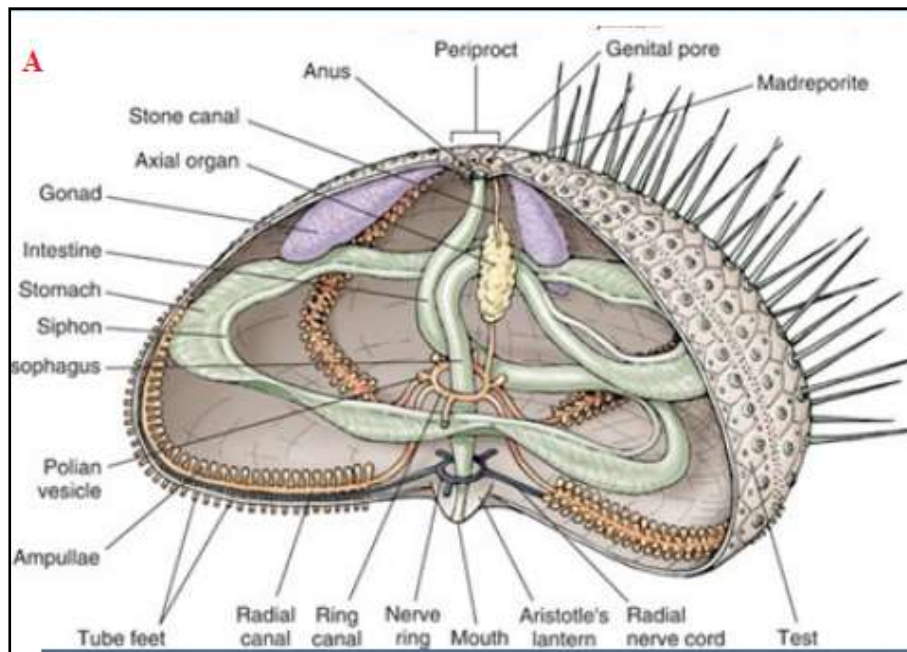


Figure 153. Sea Urchins and Sea Dollars morphology.

4. Class Holothuroidea (sea cucumbers)

Sea cucumbers are a group of economically important echinoderms. They are found on the sea floor worldwide, particularly in deeper ocean waters. They have a similar body plan to sea urchins, just stretched out from mouth to anus. They have an elongated, cylindrical, soft body with spines, and can grow to a length of 3 metres. Their small skeletal plates are buried under their leathery body wall. They have ten tentacles around their mouths that they use for locomotion and feeding. All the tentacles can be withdrawn into the mouth when the animal is disturbed. They have a complete digestive system. The gut is long and coiled. Holothuroidea are generally scavengers. Most cucumbers feed on plankton and decaying organic matter found in the sea. They exchange gases through their body surface. Sea cucumbers do not have a true brain. Reproduction: sexes are separate. Most sea cucumbers reproduce by releasing sperm and eggs into the seawater. Sea cucumbers breed twice a year (March to May and October to December). Defensive mechanisms (Figure 154 A, B, C and D). Many sea cucumbers have evolved a novel defensive mechanism that compensates for their lack of spines. Some secrete toxic substances when disturbed. Others discharge sticky filaments through the anus to discourage potential predators.

Economical uses and biological significance

Sea cucumbers are effective in treating cancer, arthritis, asthma, hypertension and other diseases. Sea cucumbers contain all the necessary fatty acids to potentially play an active role in tissue repair. Sea cucumber extracts are prepared and made into oils, creams and cosmetics.

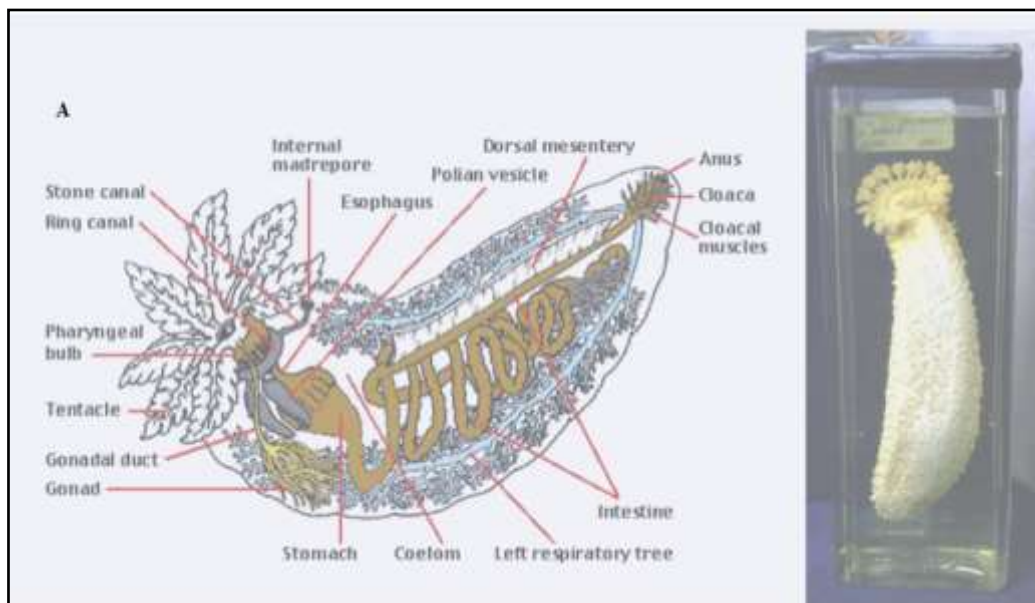


Figure 154. Internal anatomy of sea cucumbers.

5. Class of Crinoidea

They are commonly called sea Lilies and feather stars. Crinoids are the most ancient and primitive living class of echinoderms. Like echinoids, they exhibit five-fold symmetry. Attached, stalked crinoids are called sea Lilies. Attached, stalked crinoids are called sea Lilies.

This class also includes feather stars, which are free-living and can swim and crawl. The basic structure of their water vascular system is similar to that of other echinoderms. Ampullae are absent. They have an endoskeleton made of calcite plates. Most species lived in shallow shelf areas, away from the tides, at depths of up to 200 metres. Tube feet catch food and transfer it down the groove to the mouth. Figure 155 shows the morphology and examples of species of crinoids.

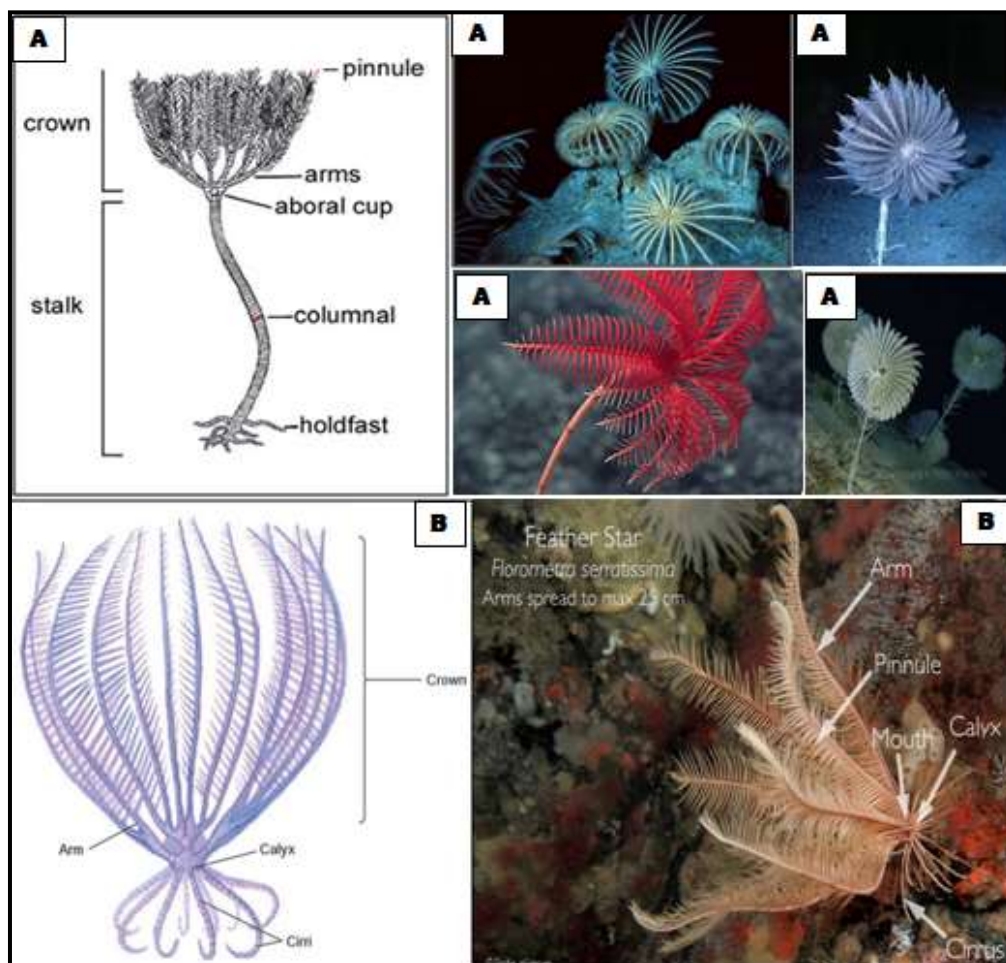


Figure 155. Morphology of sea Lillies (A) and Feather star (B).

7. Phylum CHORDATA

7.1. Genaral features

- ✚ Metazoa
- ✚ Triploblastica
- ✚ Coelomates, all have a body cavities
- ✚ All have bilateral symmetry.
- ✚ Deuterostomes.
- ✚ Epineurians.

The name 'Chordata' comes from the notochord, which is a rod-like, semi-rigid tissue enclosed in a sheath. The notochord is a flexible, rod-shaped structure found in the embryonic stage of all chordates, and in the adult stage of some species. Located between the digestive tube and the nerve cord, it provides skeletal support along the length of the body.

The chordate have **Four basic characteristics** : (Figure 156)

1. Notochord.
2. Dorsal hollow tubular nerve cord.
3. Pharyngeal poches and slits (cleft or pouches).
4. A postanal tail for propulsion

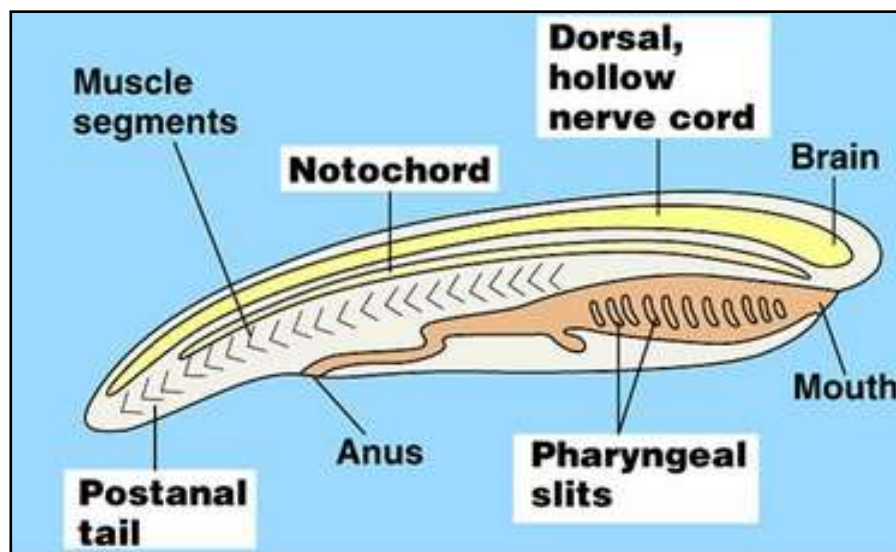


Figure 156. Genaral morphology of Chordata.

7.1.1. The notochord

All chordate embryos have a notochord: a stiff but flexible rod that provides internal support. It is the first part of the endoskeleton to appear in the embryo. It serves as an attachment point for muscles and can bend without shortening, allowing undulation. In vertebrates, a series of cartilaginous or bony vertebrae are derived from mesenchymal cells (**Figure 157**).

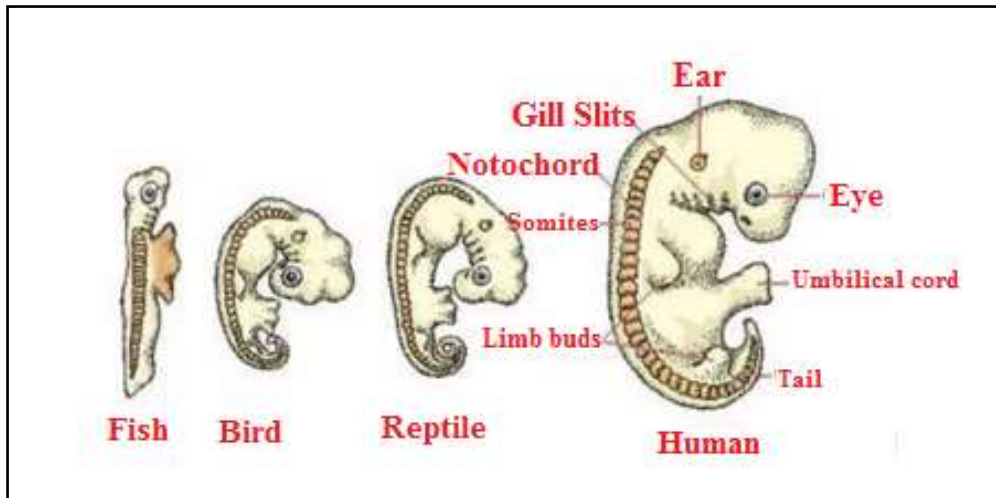


Figure 157. Presentation of Notochord.

7.1.2. Dorsal hollow : Nerve cord (spinal cord) (Figure 158).

It derives from the ectoderm. It is a fluid-filled tube of nerve tissue that runs the length of the animal, dorsal to the notochord. This nerve cord develops into the brain and spinal cord in most chordate embryos, forming the central nervous system.

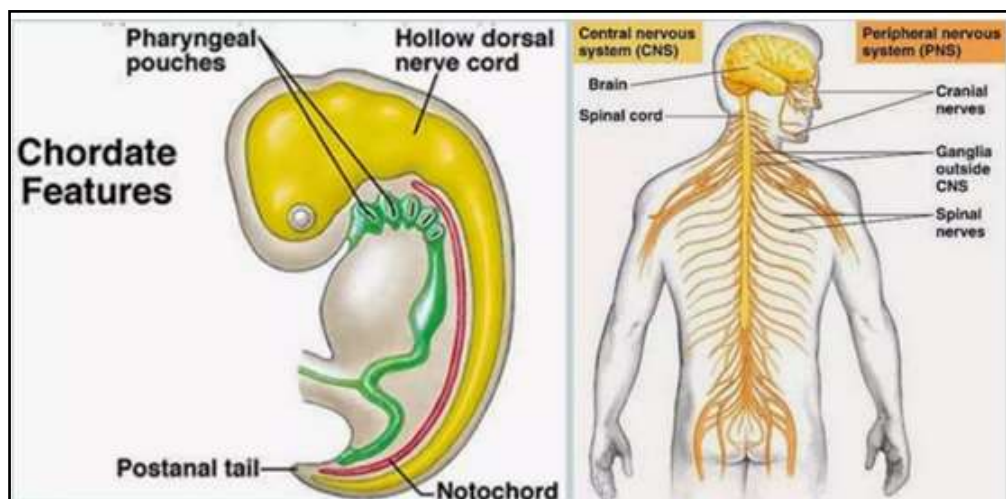


Figure 158. Hollow Dorsal nerve cord.

7.1.3. Pharyngeal poches and slits

These are pairs of openings through the pharynx, the region just behind the mouth, which connect to the outside environment. In organisms that live in an aquatic environment, the pharyngeal slits allow water to exit the mouth after it has entered during feeding. Some invertebrate chordates use the pharyngeal slits to filter food from the water that enters the mouth. Juvenile fish use them for breathing.

In adult fish, the gill slits develop into true gills. In reptiles, birds and mammals, the gill slits only occur during embryonic development. In these animals, the pharyngeal slits develop into the jaw, ears, head, neck, etc....

7.1.4. A postanal tail

The post-anal tail is an elongated posterior extension of the body that extends beyond the anus. The tail contains skeletal elements and muscles that provide locomotion in aquatic species. In some terrestrial vertebrates, the tail also aids balance, courtship and signalling when danger is near. In humans and other apes, the post-anal tail is present during embryonic development, but becomes vestigial in adulthood.

7.2. Classification of chordates (Figure 159).

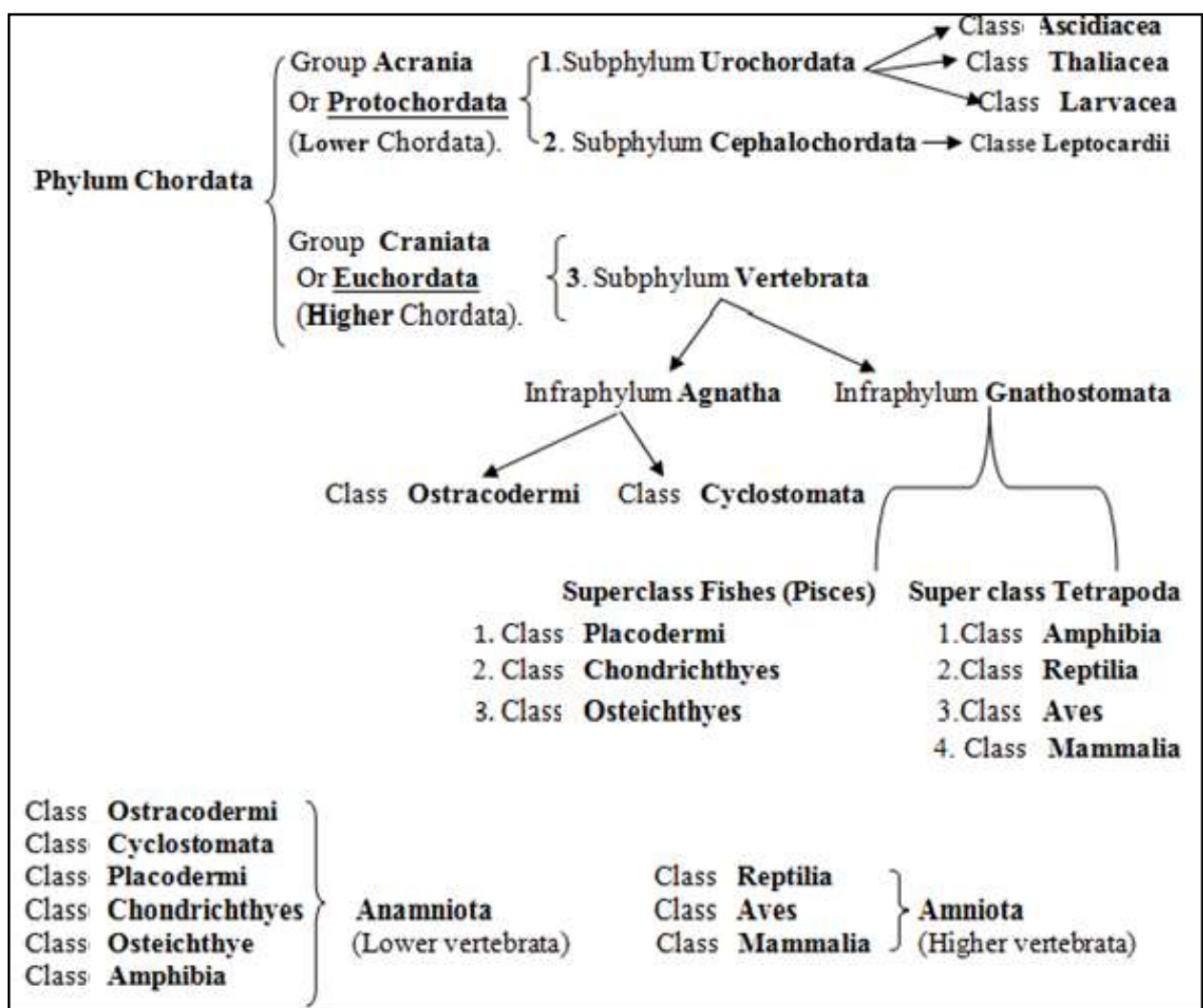


Figure 159. Outline classification of phylum Chordata.

7.2.1. Subphylum Urochordata or Tunicata (sea squirts) (Figure 160).

- ✓ Notocord, pharyngeal gill slits, nerve cord and tail are present in the free-swimming larval stage.
- ✓ Retain pharyngeal gill slits in adults.
- ✓ Water flows in through an incurrent siphon and is filtered by a mucus net on the pharyngeal gill slits.
- ✓ They are exclusively marine and found in all seas.
- ✓ Mostly sedentary (fixed), though some are pelagic or free-swimming.
- ✓ Simple, solitary or aggregated in groups (colonial).
- ✓ The adult body is sac-like, unsegmented and usually without a tail.
- ✓ The alimentary canal is complete. The pharynx (branchial sac) has two to several pairs of gill slits and they are ciliary feeders.
- ✓ Respiratory system: gill slits and test.
- ✓ Blood vascular system is open.
- ✓ Excretion occurs via the neural gland, the pyloric gland and the nephrocytes.
- ✓ Reproduction: mostly hermaphroditic with external fertilisation. Development is indirect, including a free-swimming, tailed larva with basic chordate characteristics.
- ✓ Asexual reproduction by budding is common.

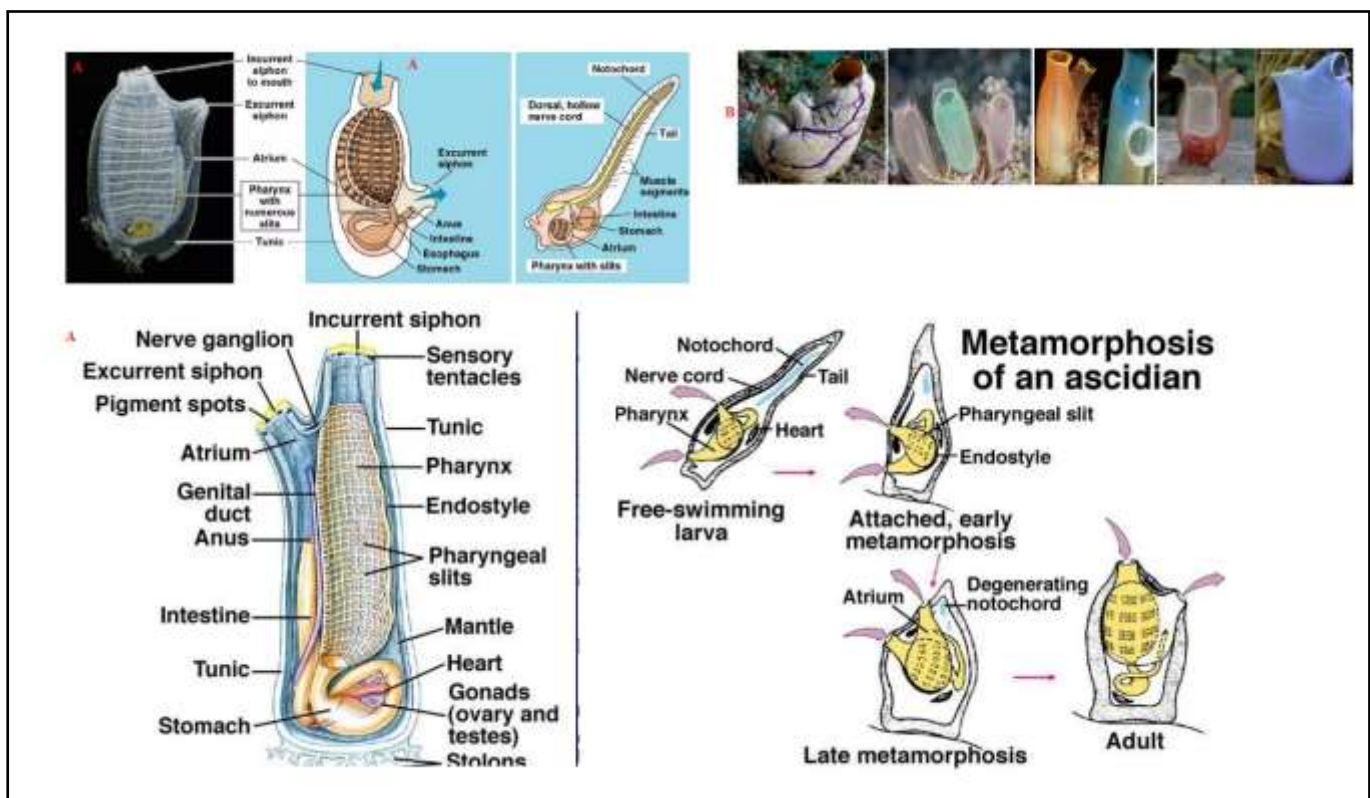


Figure 160. General morphology of Tunicata (A) ; metamorphosis and collection of an ascidian (C).

Urochordata is divided into **3 classes** :

1. Class Ascidiacea (Figure 161).

Live fixe, solitary or colonial ; Exemples : *Ascidia*, *Ciona*, *Phallusia*.

2. Class Thaliacea (Figure 161). Pelagic form, free living ; Exemples : *Pyrosoma*, *Doliolum*, *Doliopsis*, *Salpa*, *Cyclosalpa*.

3. Class Larvacea (Appendicularia) (Figure 161). Solitary, free swimming and pelagic ; Exemples : *Oikopleura*, *Appendicularia*

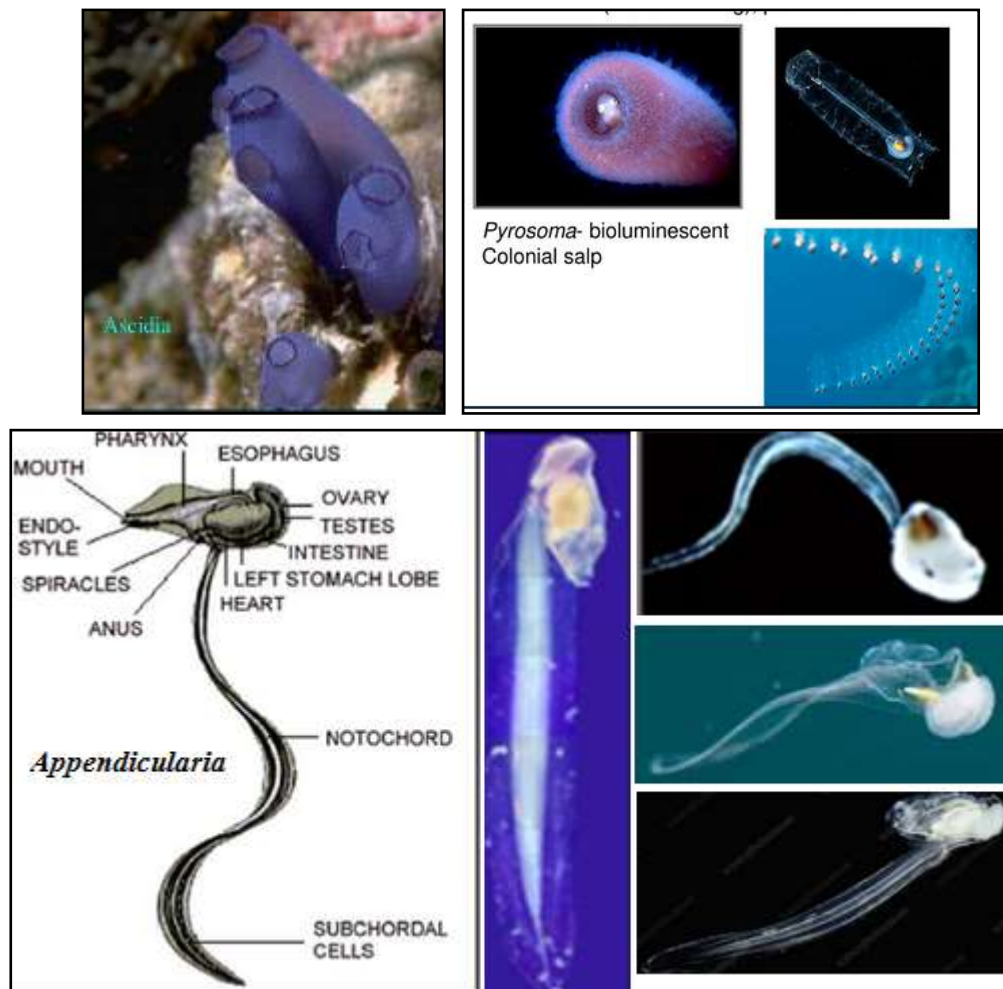


Figure 161. General morphology of different class of Tunicata.

7.2.2. Subphylum Cephalochordata (Lancelets or Lancelots)

- Marine and distributed in shallow waters.
- Shows four characteristics of chordates.
- Adult lancelets are 5–8 cm long, slender, fish-like, metameric and transparent.

Mostly sedentary and buried, with only the anterior end of the body projecting above the bottom sand in shallow regions of tropical and temperate oceans.

- They feed on plankton and are filter feeders, using their gill slits to capture food particles.
- They have a close circulatory system. Heart, blood cells and respiratory pigment are absent.
- Respiratory gases diffuse across the body.
- Excretion occurs via paired segmented protonephridia.
- The nervous system includes a nerve cord that is tubular and lacks ganglia, a brain and sense organs.
- Reproductive organs: sexes are separate and there are many pairs of segmented gonads with external fertilisation in seawater. Development is indirect and includes a free-swimming larval stage that undergoes progressive metamorphosis.

Classification : Unique class : **Leptocardii** ; Family : **Branchiostomidae**

Two genera : **Branchiostoma (Amphioxus)** (Figure 161 A) and **Asymmetron** (Figure 162 B)

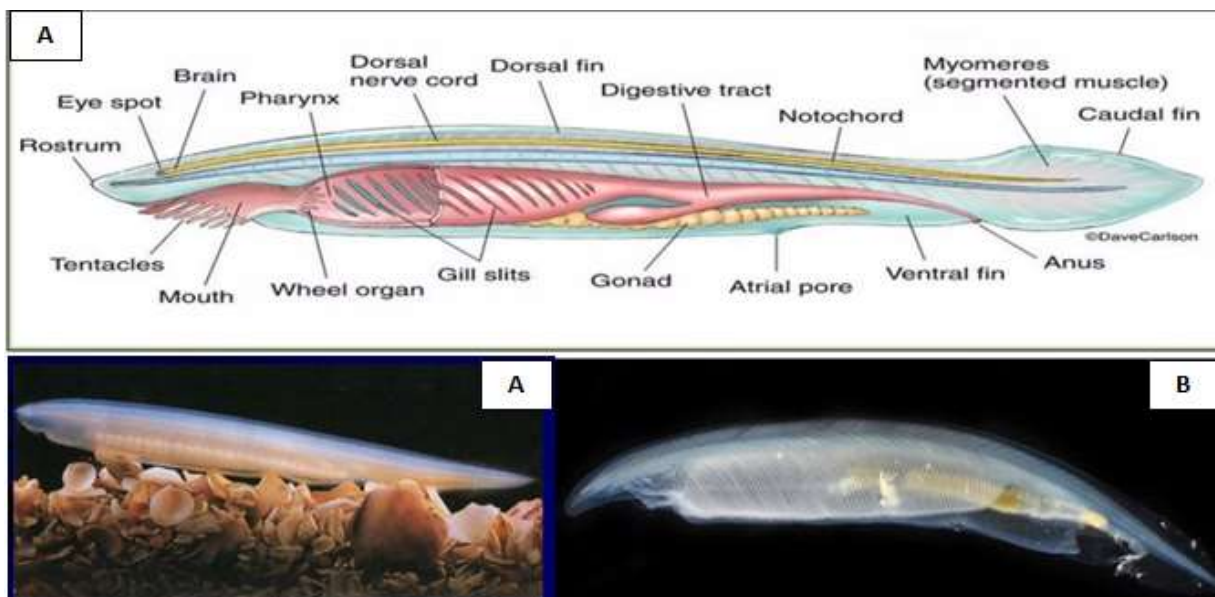


Figure 162. General morphology of Cephalochordata. (A) : *Amphioxus* and (B) : *Asymmetron*.

7.2.3. Subphylum Vertebrata (Vertebrates)

7.2.3.1. General features of Vertebrata

- This is the largest group of the three chordate phyla, with around 60,000 species. The backbone (vertebrae) surrounds and protects the nerve cord.
- The defining feature is the vertebral column, which replaces the notochord.
- There is a presence of vertebrae: metamerised cartilaginous or bony pieces (repeated along the body) which surround the spinal cord.
- The skull and vertebrae are made of either bone or cartilage.
- The presence of a bony or cartilaginous skull, inside which the brain is found.

➤ The dorsal nerve cord is subdivided into: Central nervous system: brain and spinal cord. The central nervous system (CNS) comprises the brain (olfactory lobes, cerebrum and optic lobes).

➤ The peripheral nervous system comprises nerves.

➤ Cranial (cerebral) nerves, spinal nerves, and sensory organs.

➤ Endotherms (warm-blooded animals) that maintain a constant body temperature.

➤ Ectotherms (cold-blooded animals) have a body temperature that changes with their environment.

➤ Central nervous system: the brain and the spinal cord (development of dorsal nerve tube).

➤ Deuterostomia: the anus is formed first.

➤ Complete digestive system with a separate mouth and anus.

➤ Closed circulatory system. The blood contains red blood cells with haemoglobin (a respiratory pigment). The presence of a ventral heart.

➤ The respiratory system is formed of gills in aquatic chordates (fish and amphibian larvae) and lungs in terrestrial chordates (mammals, birds and reptiles).

➤ The excretory system consists of nephrons grouped into two symmetrical kidneys.

➤ Reproduction is exclusively sexual (gonochoric).

➤ Locomotion is provided by multisegmental limbs.

The subphylum vertebrates is subdivided into two infraphyla based on the presence or absence of a jaw.

7.2.3.2. Classification of vertebrates

1. Agnathans (Jawless Vertebrates) : Lack lower jaws, feed by suction Includes lampreys and hagfish

2. Gnathostomes (Jawed Vertebrates) was divided into : Tetrapods (land vertebrates), including: Amphibians (Batrachians), Reptiles, Birds and Mammal

1. Infraphylum Agnatha

1. 1.General characteristics

✚ It has a rounded, elongated, cylindrical body (eel-like).

✚ It has no jaws (agnaths) and no paired fins.

✚ Digestive system: mouth, pharynx, oesophagus, intestine, liver, rectum and anus (no stomach).

✚ Feeding: lampreys are parasites of commercial fish and hagfish are predators of fish.

✚ The nervous system comprises a dorsal nerve cord and a differentiated brain. The lamprey has a cerebellum, which the hagfish lacks, as well as other sense organs for taste, smell and hearing.

✚ Separate sexes.

1.2. Classification

1.2.1. Class Cyclostomata

Jawless fishes of today, without scales and paired fins. Eg : Myxine (Hagfish), Petromyson (Lamprey).

1.2.1.1. Order Myxiniformes (Hagfishes) (Figure 163).

- ✓ In Greek *Myxa* = *slime*
- ✓ No eyes, jaws, scales or paired fin
- ✓ 4-6 tentacles around the mouth
- ✓ Scavengers predators on annelids, mollusks, crustaceans, dead or dying fish.
- ✓ Secret milk slime when threatened.
- ✓ Strictly marine.

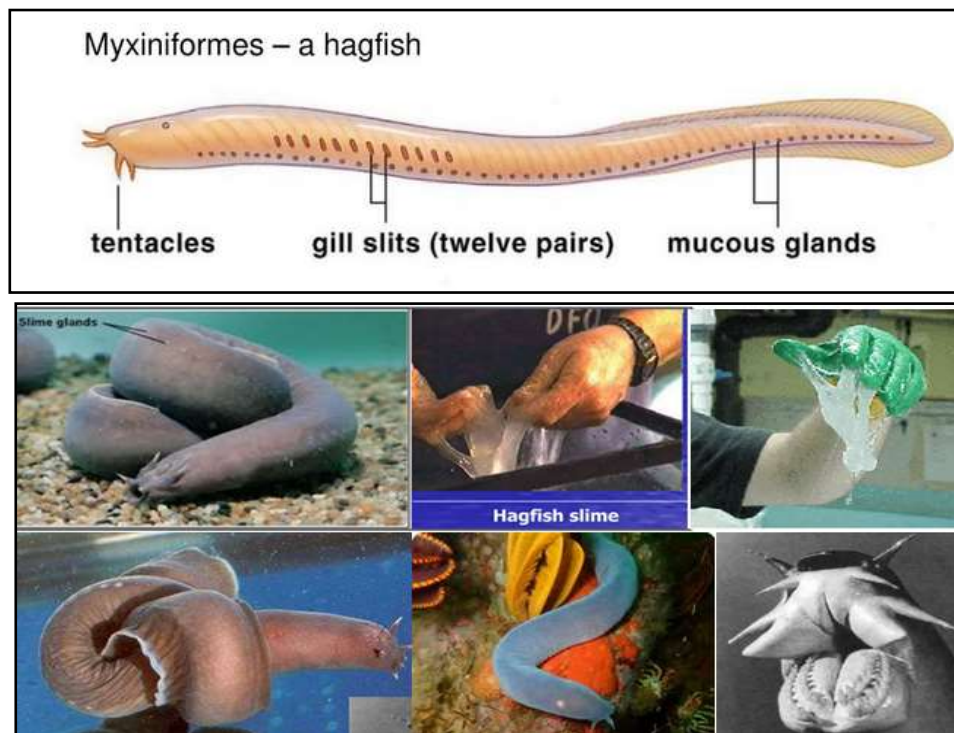


Figure 163. General morphology of Hagfish.

1.2.1.2. Order Petromyzontida (Lampreys = *Petromyson*) (Figure 164).

- ✓ In Greek : **Petros** = **stone** ; **myzon** = **sucking**.
- ✓ Marine and freshwater.
- ✓ Sucker like oral disc or tongue with keratinized teeth
- ✓ Can be up to 1 meter long.
- ✓ Parasitic form attach to prey and suck out fluid.
- ✓ Single dorsal fin.

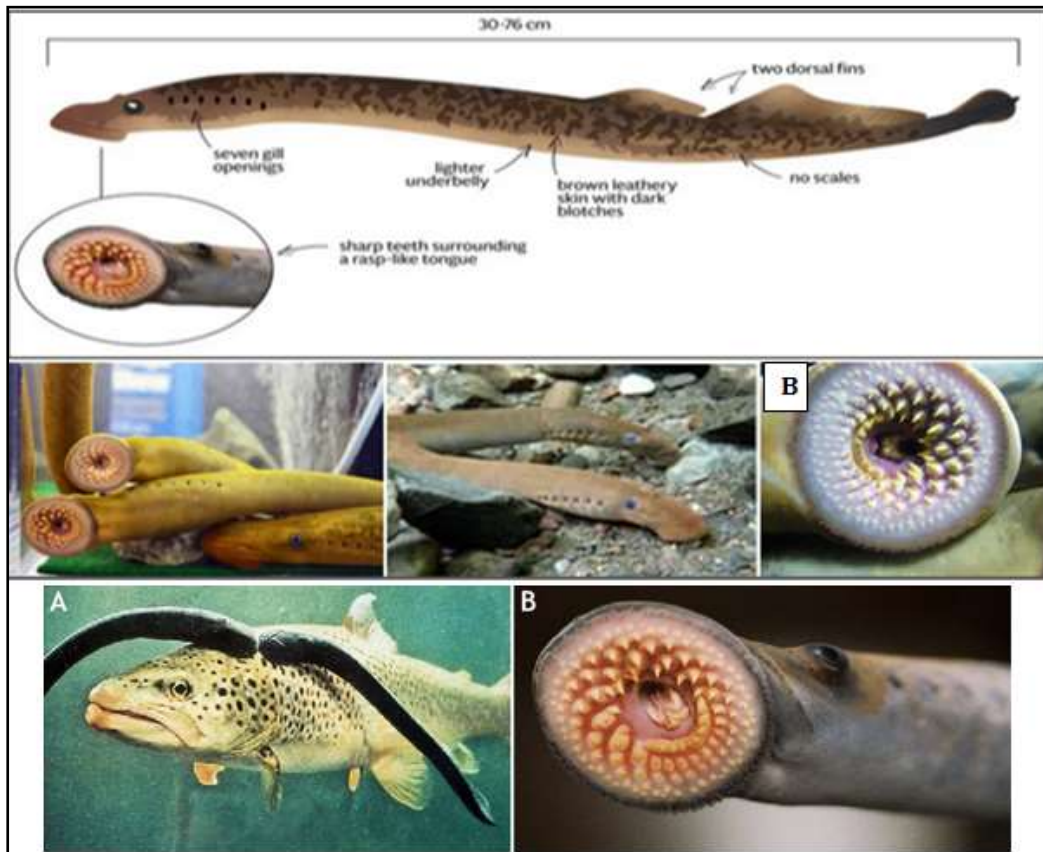


Figure 164. Morphology of Lamprey, **(A)** : Parasitic form ; **(B)** : Mouth morphology.

2. Infraphylum Gnathostomata

2.1. General Characters of Gnathostomata:

1. All members of this group have two well-formed jaws that encircle the mouth aperture.
2. Paired, and sometimes jointed, appendages are present in gnathostomata.
3. A calcified, bony skull and vertebrae are characteristic features of gnathostomata.

Members of this group include fish (Chondrichthyans and Osteichthyans), amphibians, reptiles, birds and mammals.

2.2. Taxonomy of Gnathostomata:

2.2.1. Superclass Pisces (Fishes)

2.2.2. Superclass Tetrapoda

2.2.1. Superclass Pisces (Fishes)

1. Basic characters

- All are aquatic and cold-blooded (ectothermic; poikilothermes = variable body temperature).
- They are found in fresh, marine and brackish water.
- Their body is long, spindle-shaped and streamlined, divided into a head, trunk and tail.
- The body is covered by dermal scales, denticles or bony plates.
- External and middle ears are absent.
- They locomote with the help of various fins. The fins help the fish to move, steer, stop and balance.
- Well-developed sense of vision, hearing, taste and smell.
- Lateral line system: row of sense organs
- Respiration by gills (lungs in dipnoid fish). The heart has two chambers, one auricle and one ventricle.
- The digestive system is well developed.
- The nervous system comprises the brain and ten pairs of cranial nerves.
- Reproductive system: fish are unisexual and undergo internal or external fertilisation with direct development.
- Fishes are oviparous, viviparous or Ovoviviparous. Fishes are anamniote species. The amnion is absent in the embryonic stage; fish are included under Anamniota.

2. Pisces classification

2.1. Class Chondrichthyans

In Greek : **Chondros** = cartilage ; **Ichthys** = Fish

Cartilaginous fish have a skeleton, a ventral mouth, placoid scales, a heterocercal tail fin and five pairs of gill slits. Examples include Chimaeras (ratfish or ghost fish), sharks and rays. Ancient marine creatures known as cartilaginous fish are called chondrichthyans. Vertebrates. Although they are not as numerous and diverse as bony fish, their morphology is still important. Specialised musculature for swimming, sensory organs, powerful jaws and feeding are all adaptations. It is thanks to their habits that they have been able to survive in their environment.

1. General feature of Chondrichthyans

Habitat: They are found in saltwater. They are mostly marine and predaceous.

They have an entirely cartilaginous endoskeleton without true bones.

Body structure: They have a streamlined, fusiform body and an exoskeleton formed of placoid dermal scales.

Males have claspers (myxopterygia and pterygopodia) on their pelvic fins for copulation.

Fins: They have fins which help them to swim. The paired fins are the pelvic and pectoral fins, while the unpaired fins are the dorsal, ventral and caudal fins.

The tail fin (caudal) is unequal (heterocercal). Buoyancy

No swim bladder

Store oil in large liver : liver rich in **squalene (lipids)** helps with buoyancy

Heterocercal tail : asymmetric creat lift.

Horizontal pectoral fin : also provide lift.

Can not swim in revers like bony fish

Digestive system :

The mouth is long and crescent-shaped, located ventrally, and the gut opens at the cloacal opening.

The teeth are modified placoid scales. They are not fused to the jaw and are arranged in two rows, with the back row replacing the missing front teeth. Depending on the species, the teeth may be serrated for cutting, sharp for gripping or flat for scraping surfaces, as seen in rays.

The intestine has scroll valves.

Digestion is extracellular.

Respiration :

There are external nares present. Gill slits are usually present in pairs, four to seven of which are not covered by the operculum. The gills are lamelliform. The air bladder is absent, so they must swim continuously to prevent sinking.

Circulatory system :

The heart has two chambers and is venous. Biconvex red blood corpuscles consist of a nucleus. They are cold-blooded. The renal portal system is well developed.

Nervous system :

The brain has a large olfactory lobe and a small cerebellum. There are ten pairs of cranial nerves. The sensory organs are the eyes, which have a nictitating membrane and spiracles behind each eye, and the internal ear, which has Ampullae of Lorenzini: electroreceptors on the dorsal surface of the head that detect vibrations and electric fields emitted by prey.

These are tiny pores covering the shark's snout that detect electrical impulses in the water. These pores can help a shark to locate prey, to orient itself and to detect changes in water temperature. The lateral line system is present on the body and contains rheoreceptors. This consists of 100 or more sensory organs (neuromasts) that are typically arranged in lines on or just under the skin of the head and body. This system is absent from all reptiles, birds and mammals, even those that are aquatic, such as turtles, dolphins and whales. The neuromasts along the body detect vibrations and water currents.

Excretory system

Paired of kidneys which are mesonephric. Excretion is Ureotelic

Reproduction :

In males, the pelvic fins bear claspers that assist with copulation. The cloaca lies between the two pelvic fins. The oviducts are known as Müllerian ducts and the gonads are in pairs and open into the cloaca. Fertilisation is internal. Development is direct, without metamorphosis. Females of cartilaginous fish exhibit internal fertilisation and various reproductive strategies, including oviparity and ovoviviparity. Most sharks and all rays are viviparous and possess a yolk sac placenta

Viviparous:

Develop a **placenta** to nourish the embryo.

This adaptation has contributed to their evolutionary success of **60% of chondrichthyans** use this method, mostly **large active species**.

• Ovoviviparous:

Embryos develop inside the **oviduct**, nourished by their **yolk sac** until birth.

Variations in embryo nutrition include:

- **Histotrophy:** Embryo feeds on **uterine secretions**
- **Oophagy:** Embryo **consumes unfertilized eggs** in the uterus.
- **Adelphophagy (intrauterine cannibalism):** Strongest embryo **eats siblings** before or after hatching.

2. Taxonomy of Cartilaginous Fish

Currently, there are **8 orders of sharks with 400 species** and **4 orders of rays with 500 species**. This classe is divided into subclasses :

2.1. Subclass Holocephali eg : Chimaeras (Figure 165).

Name meaning: **Holo** = whole / **cephale** = head

Body is elongated body with a **prominent head and whip-like tail**.

Males have **claspers** to hold females during copulation.

Rabbit-like snout.

Jaws and Teeth:

No separate teeth, but **flat, plate-like structures**.

Upper jaw is completely fused to the skull (unlike sharks).

This group includes **47 species**

Size: Can grow up to **2 meters** in length.

• **Defense:** A venomous spine on the dorsal fin.

• **Diet :** Feeds on **crustaceans, mollusks, echinoderms, small fish, and algae** by crushing food.

Example : **Chimaera**: ‘Rat fish’ or ‘King of herrings’, hydrolagus, callorhynchus.

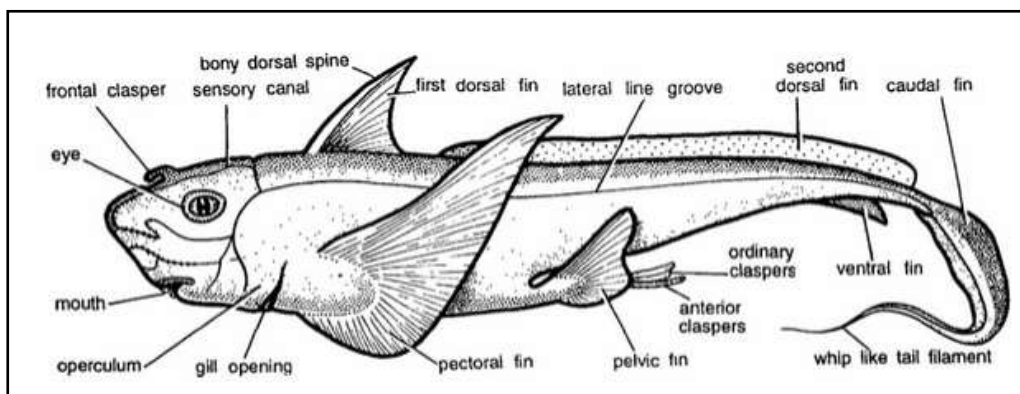


Figure 165. Morphology of Chimaeras.

2.2. Subclass Elasmobranchii (Elasmobranchs) : Shark and Rays

This is the largest subclass, including sharks, rays and skates (Figure 166).

- Skin covered by placoid scales.
- Operculum absent
- There are 5 to 7 pairs of naked gill slits without any operculum. In *Hexanchus*, there are six pairs, and in *Heptanchus*, seven pairs.

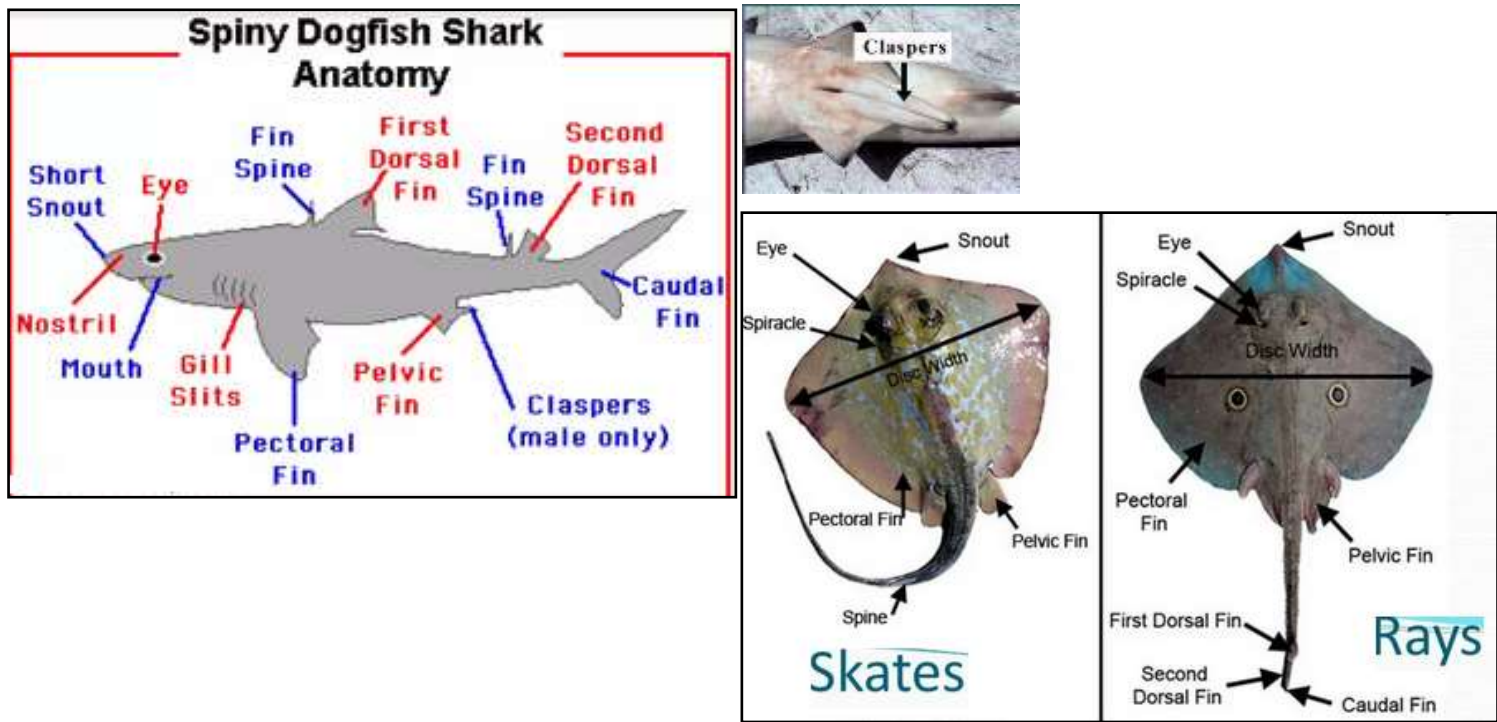


Figure 166. Photos gallery of Elasmobranchii species.

A. Sharks (Selachii) :

They live in the warm waters of the tropics. They have acute vision and a keen sense of smell. Sharks are very large animals. They are active predators and pleurotrematic elasmobranchs with lateral gill openings. Sharks are viviparous.

Example of Shark

1. Rhinodon or Rhincodon

It is commonly known as the whale shark. It is the largest fish and the second largest vertebrate. It is notorious for frequently attacking humans.

2. Scoliodon :

It is called the Indian dogfish. It is used for study in laboratories because of its small size. The dried skin of a shark is called shagreen. It is used in the polishing industry.

3. Stegostoma : (Tiger or Zebra shark)

It exhibits brilliant colouration of dark stripes over yellow background.

4. **Sphyrna (Zygaena) :**

It is abundant in the Indian Ocean and is commonly known as the hammerhead shark. Its head is mallet-shaped, with a prominent lateral lobe bearing an eye on its distal end on either side.

B. Rays and Skates (Batoidea) :

They are more diverse than sharks. They are specialised for bottom dwelling. Their body is greatly flattened dorsoventrally. They are hypotrematic elasmobranchs with ventrally placed gill slits.

1. Myliobates : Sea Vampire or Eagle ray.

2. Torpedo: The torpedo is also known as the electric ray. They have well-developed electric organs that they use for defence and predation. Certain dorsal muscles have evolved into powerful electric organs.

3. Rhizomatous: It is commonly called a guitarfish. It is a skate with a depressed body and a tapering snout.

4. Pristis: (Saw fish) : The snout is elongated and blade-like, with a row of sharp, tooth-like scales. This formidable weapon is used for both defence and capturing food.

Distinguishing Features of Chondrichthyes

It has paired fins.

Placoid scales are present.

The tail fin is heterocercal.

It has paired gonads with gonoducts.

2.2. Classe Osteichthyes

In Greek : **Osteon** = Bone; **Ichthys** = Fish

Largest number of species of all vertebrates.

Freshwater and marine. These are true bony fish that live in both freshwater and seawater.

Cycloid, ctenoid and or placoid scales.

There are four pairs of gill slits, each of which is covered by an operculum.

They have no claspers.

The air bladder are present in most of them.

Economically important.

The classe **Osteichthyes** is divided into **two subclasses** :

2.2.1. Subclass Sarcopterygi (Figure 167).

In Greek ; *Sarco* = fleshy ; *Pterygium* = fins

Eg : *Latimeria*, *Neoceratodus* (Figure 167).

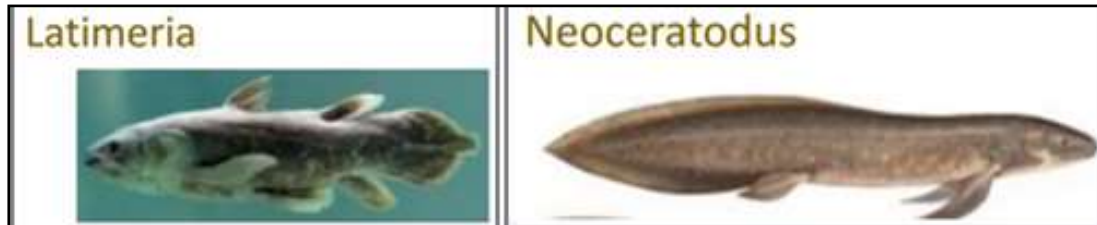


Figure 167. Photos gallery of Latimeria and Neoceratodus.

2.2.2. Subclass Actinopterygi (Ray fin) (Figure 169).

In Greek : *Aktis* = Ray ; *pteryx* = fin

Most diverse group of bony fish (15.000 species) and most advanced fishes.

More then 50 % of known fishes

Ctenoid scales.

Two dorsal fins.

Swim bladder moved away from any function for respiration, used only for buoyancy.

Fin are flexible controlled by muscle in body.

Eg : Salmo, Sardines, Labeo (Rohu), Hippocampus, Tuna, Swordfish, ect...

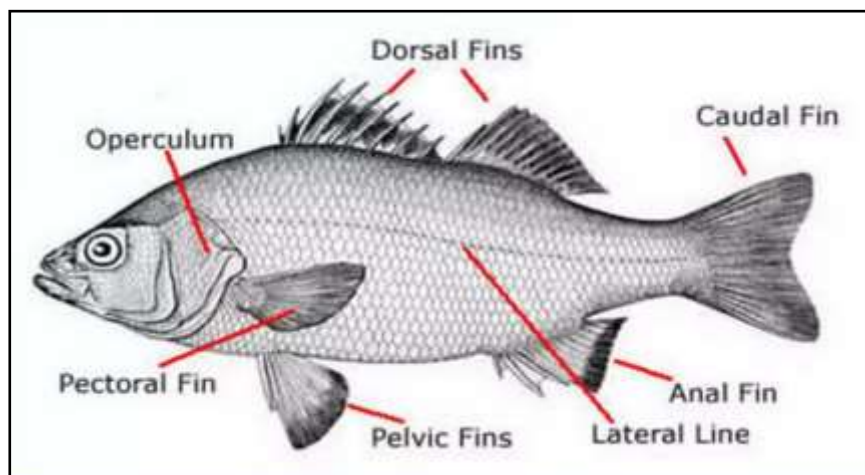


Figure 169. Basic external anatomy of Actinopterygi.

2.2.2. Superclass Tetrapoda

General characters

Tetrapoda (Greek ; *Tetra* = four ; *Podos* = Foot).

- ✚ They are primarily terrestrial, but some are secondarily aquatic.
- ✚ They have two pairs of pentadactyl limbs.
- ✚ Their bodies are covered by an exoskeleton of hair, feathers or scales.
- ✚ The lungs are the main respiratory organs. Amphibians may respire by gills, skin, or lungs.
- ✚ A three or four-chambered heart is present. **A body temperature : divide** a vertebrates in two groups : **Warm blooded (Homeotherms)** regroupe birds and mammals, Cold blooded (Poikilothermes) regroupe : Fishes, Amphibians and Reptiles
- ✚ They are divides into four classes : **Amphibian, Reptilia, Aves** ans **Mammalia**.

Classification

2.2.2.1. Class Amphibian

1. General characters

- ✚ The word 'amphibian' means 'double life' because they live in water and on land.
- ✚ Their skin is smooth and slimy due to the presence of mucus glands and pigment cells, and they have no external scales.
- ✚ They don't drink water; they absorb it through their thin, moist skin. They must live in water or damp habitats. Their brightly coloured skin warns predators away. This is called warning colouration.
- ✚ They are ectothermic (cold-blooded) and have two pairs of limbs for locomotion.
- ✚ They have a complete and well-developed digestive system and a closed circulatory system with a three-chambered heart (two atriums and one ventricle).
- ✚ Excretion occurs via the kidneys.
- ✚ They possess ten pairs of cranial nerves.
- ✚ They are separate sexes (dioecious) and the sexes are very similar in structure.
- ✚ Development is indirect with metamorphosis. They undergo metamorphosis, going from an aquatic larval stage to a terrestrial adult stage.
- ✚ Tadpoles are embryos in the larval stage, which is usually aquatic, and they breathe using gills.
- ✚ All species fertilise eggs externally except salamanders and gymnophiona species.
- ✚ Their eggs do not have a shell or membrane to prevent water loss, so they are laid in water.

- ✚ They are anamniote and oviparous species.
- ✚ There are approximately 2,500 species..
- ✚ Amphibian are divided into three Orders : **Apoda** (Gymnophiona or Caecilia), **Anura** (Salientia), **Urodela** (Caudata).

2. Taxonomy of Amphibians

1. Order Apoda: Caecilians or Gymnophions (Figure 170).

They are shaped like worms or snakes and have no legs and are 1.5 metres long. They live in tropical areas and are a primitive group of burrowing or aquatic amphibians. The tail is absent. Limbs bones and girdles are absent, ribs are long. They have a head with two rudimentary and non functional eyes, hence the name blind worms. The sensory organs (tentacle) is found between eyes and nostril. Both jaws possess numerous teeth. Male has protrusible copulatory organ with internal fertilization.

Larva has three pairs of external gills with direct or indirect development. Female is oviparous, egg are attached by transparent cords and cords are twisted together. The female coils around the egg and guards them.

Examples : Ichthyophis, Ureaotyphlus, Siphonops



Figure 170. Gymnophiona species.

2. Urodeles order (Caudata) (Figure 171).

In Greek : Caudata: Cauda: Tail; ara: Bear .Urodela are a group of amphibians with tails, consists of Newts and Salamanders. Their body is lizard like

- ✚ They live under stones or logs in damp woodlands.
- ✚ Their bodies are divided into three parts: a head, a trunk and a tail. The head and trunk are flat and the tail is laterally compressed. They have no tail fin.
- ✚ Two pairs of weak with a forelimbs (with four fingers) and hindlimbs (five fingers) are equal in size. Ribs are present, sternum is poorly developed. The parotid glands are modified as poison gill slits and external gills are absent
- ✚ Both jaws carry teeth
- ✚ Their eyes are small and well developed.
- ✚ Their skin is black and scaleless.
- ✚ Females collect spermatophores using their cloacal lips to facilitate internal fertilisation. The larva with three pairs of external gills.

Example : *Salamandra salamandra*



Figure 171. Urodeles species.

3. Anura order (Salientia); Frogs and Toads (Figure 172).

Anura in Greek: **a: without, oura: tail**. They are most successful of the living amphibians. Anura lack tail in adults. Have powerful legs for jumping, well developed, have two pairs of pentadactyl limbs are present. Hindlimbs are longer than forelimbs and they are used for leaping and swimming. Toes are connected by web. Head and trunk are fused, neck are absent. Sternum is present Ribs are rudimentary or absent. Skin is naked, scaleless and glandular. In adult gills, gill

openings are absent. They have ears to hear with, sticky tongues and vocal cords to call with. In male frogs, a pair of vocal sacs produce the croaking sound used to invite females for copulation.

Example: **Bufo bufo**



Figure 172. Frog and toads

2.2.2.2. Class Reptilia

1. General characters

- They were the first class of organisms to adapt to life on land. Most of them live in dry environments. They are creeping and burrowing terrestrial animals. Reptiles have a backbone and are therefore vertebrates.
- They have thick, dry skin that protects them from water loss. Their legs became stronger for walking, and they developed special eggs that could survive on dry land. They lack external ears.
- They are cold-blooded (poikilothermes) and are found in most of the warmer regions of the world.
- Their skin is dry and rough, without any glands, and is covered by an ectodermal or exoskeleton of horny scales or bony plates. Their bodies are divided into a head, a trunk and a tail.
- The body flexibility of reptiles ranges from the highly flexible forms found in snakes to the inflexible body of turtles. In addition, the tails of most turtles tend to be short compared with the long, heavy tails of crocodiles.
- They have pentadactyl limbs, each bearing claws. Snakes are an exception.
- Except for snakes, all reptiles have well-developed ears.
- They have a typical cloaca.
- They have a three-chambered heart, except for crocodiles and alligators, which have a four-chambered heart.
- They breathe using lungs.

- Their nervous system comprises 12 pairs of cranial nerves (except snakes, which have 10 pairs).
- Reptiles are generally uricotelic with metanephric kidneys.
- They are dioecious with sexual dimorphism present. All species fertilise eggs internally. The amniotic egg is surrounded by a shell that protects the developing embryo, which does not undergo a larval stage. They are oviparous, with very yolky eggs, and some snakes and lizards are Ovoviviparous, with fertilised eggs remaining inside the female for a long time before hatching.
- Complete digestive system: the vast majority of reptiles are carnivorous, although certain turtles and lizards are omnivorous or herbivorous.

2. Reptilia classification

Reptiles are divided into two subclasses :

2.1. Subclass : Anapsida with unique **Order Chelonia**

2.2. Subclass : Diapsida divided into **two Orders**.

2.2.1. Order Squamata.

A). Suborder 1 : Lacertilia (eg. Lizard).

B). Suborder 2 : Ophidia (eg. Snakes).

2.2.2. Order Crocodilia (eg. Crocodile, Alligator, Gharial).

2.2.3. Order Testudines (Chelonia) : Turtles and Tortoises

Chelone means turtles, testudines have short, broad body characterised by anapsid skull and they have protective bony or cartilaginous shells consisting of a dorsal carapace and a ventral plastron. The shell is fused to the backbone. Turtles are adapted to various habitats, including both aquatic and terrestrial environments. Teeth are absent, jaws with a horny keratin beak. Limbs articulated internally with ribs. For aquatic form, the limbs are modified into paddles. They have a single nasal opening and a short tail, sternum is absent. All are oviparous, female make nest by their hindlimbs and they lay the egg (5-100 egg). Marine turtles, freshwater terrapins and terrestrial tortoises. Sea turtles have a large upper eyelids that protect their eyes.

Example : *Testudo graeca*.

2.2.2. Subclass : Diapsida divided into **two Orders**.

2.2.2.1. Order Squamata : Lizards and Snakes

This order includes two sub-orders: Lizards and snakes, making it the largest order of reptiles (96 %). Squamates are characterised by their scaly skin, elongated bodies and the ability to shed their skin periodically. Their body is covered by a horny epidermal scales. Jacobson organ

(gustatory and olfactory organ) present in the roof of mouth. They characterise by their uniquely jointed skulls. Their jaws are also jointed. Both are strong and flexible.

A). Suborder Lacertilia or Sauriens (eg. Lizard).

Elongated body and short limbs. Sternum present, eyelids are movable, tympanum is present and both lungs well developed. Chameleon has an adaptive behavior to color change to chromatophore cells in the skin.

Example: *Chamaeleo chamaeleon*.

B). Suborder: Ophidiens (snakes):

The characteristics common to all snakes are :

- Elongated body (cylindrical shape), with scaly skin extremely flexible
- Forked tongue, presence of Jacobson organ
- Eyes without eyelids, tympanum is absent
- Particular articulation of the mouth
- Limbs and ribs are absent.

Example : *Cerastes cerastes*

2.2.2.2. Crocodilia Order : Crocodiles and Alligators (figure 173)

This order includes crocodiles, alligators, caimans, and gharials. These are large, semi-aquatic reptiles with a powerful build. Strong jaws and a muscular tail. They are well adapted to aquatic habitats and are known for their ambush hunting behaviour. The most well-known members of this order are crocodiles and alligators.

Example: *Nile crocodile*

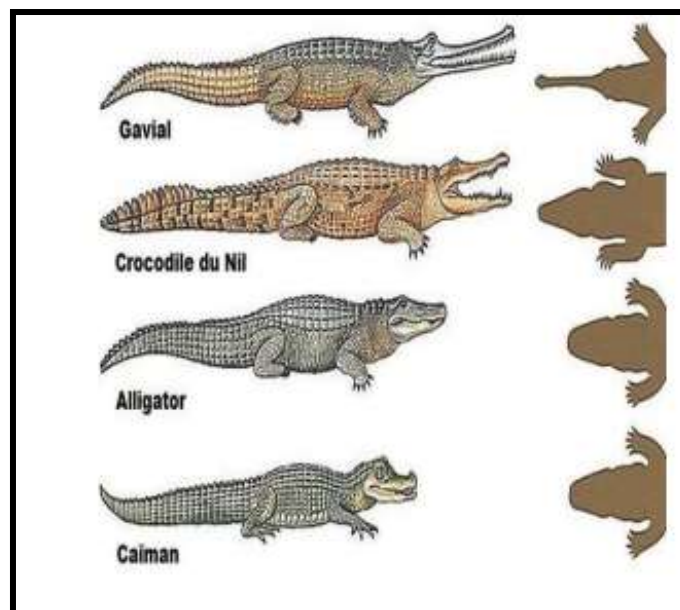


Figure 173. Different species of Crocodilia order.

2.2.2.3. Class Aves

1. Genaral characters

✚ The bird has a spindle-shaped body that is highly aero dynamically suited and covered in feathers. in each bird is different in shape color, texture and size. All feather have a stick in the center called shaft. They have hair like structure attached to the shaft. They have three different kinds of feather : **flight feather** (strong and stiff and found in wings and tail), **body feather** (colored feather that cover the body of the bird, other then the leg, beak and feet) and **down feather** (soft and fluffy and keep the bird warm and they are found close of the body).

✚ The mouth is equipped with a specialised exoskeletal structure called a beak. Birds do not have teeth. The beaks of birds are different from one another because they eat different kinds of food, and this helps them to catch and eat it.

✚ Skull is large with one occipital condyle.

✚ The forelimbs are modified into wings, which are powered by strong flight muscles.

✚ The hind limbs of birds have four clawed digits. The feet and claws of different birds are different.

✚ Birds have a good sense of hearing and good physical equilibrium. Eyes of birds possess pecten. Well developed third eyelid or nictitating membrane used for cleaning of eyeball.

✚ The larynx has no vocal cords. The voice is produced by a sound box or syrinx. The syrinx lies at the junction of the trachea and bronchi.

✚ Bones become pneumatic (spongy) to reduce body weight.

✚ The specialised respiratory system performs double respiration. Air sacs are present in association with the lungs. These air sacs are specialised structures that increase the amount of oxygen birds can take in. However, air sacs are not sites of gas exchange.

✚ Heart of birds is four chambred (two auricles and two ventricles). They have nucleated red blood cells.

✚ **Excretion** by kidneys. Kidneys have no bladder.

✚ **Endothermic** (Constant body temperature) animals (Homootherms) has enabled bird to survive in virtually every known environment.

✚ They have a complete digestive system and eat large amounts of food because they need a lot of energy to fly.

✚ **The sexes are separate.** The male has a pair of abdominal testicles, while the female has only a left ovary. They reproduce through internal fertilisation: during mating, the male birds press their cloaca together and release sperm. Development is direct.

Birds are oviparous animals that produce amniotic eggs with a large yolk. Birds build nests in which to lay eggs and protect their offspring. We found nests in trees, on the ground, on roofs, and among rocks.

✚ **Sexual dimorphism:** Males often have brighter colours or more elaborate plumage than females. This phenomenon is known as sexual selection and is driven by various factors, including mate choice. While the reasons for differences in appearance can vary, one common explanation is that females may prefer mates with certain characteristics, such as vibrant colours or intricate displays. These traits may indicate good health, genetic fitness, or the ability to provide for offspring. This is known as 'ornamental' or 'aesthetic' selection

✚ **Adaptation for flight :** reduce body weight, bones become pneumatic no teeth, no urinary bladder, no penis and only one ovary.

✚ Neognath birds have a **keeled sternum**, which provides an anchor for flight muscles

2. Classification of birds

This is based on the differences in the structure of the palate and the keel of the sternum (breastbone).

2.1. Subclasses: Paleognathae (Ratites)

Flightless birds their name "Paleognathae" means "Old jaws". In Greek: Palaaios: old; Gnathos: jaw. Plate Sternum referring to the relatively simple structure of their Jaw bones. Also called running birds lack ability to fly. They characterize by having a Palaeognathous plate and ratitae are ground dwelling, very large reaching up 4 meters in height, They have well-developed, powerful legs; small heads; and rudimentary wings covered in fluffy feathers that are useless for flight. All flightless bird lives in part of the world there are no carnivores. Tail feathers are irregularly or absent. They have no keel on their sternum. Ex: **Ostriches, Emus, kiwis, Rheas, and Cassowaries**. This class regroups the following orders:

2.1.1. Order Struthioniformes (Rheiformes) : Large, flightless birds with numerous fluffy plumes on their wings. Examples: ostriches, kiwis and Rheas.

2.1.2. Order Casuariiformes : Reduced wings: coarse, hair-like plumage. Examples: Cassowaries and emus.

2.1.3. Order Gaviiformes : Strong, straight bills are a diving adaptation that includes legs positioned far back on the body, bladelike tarsi and webbed feet, as well as heavy bones. Examples: Loons.

2.1.4. Order Sphenisciformes : Heavy body; flightless; flippers like wings for swimming; well insulated with fat. Example: Penguins.

2.2. Subclasses: Neognathae (Carinatae)

In Greek: Noes: 'modern' and 'ornithos': 'birds'. The sternum is usually keeled. This class is characterised by wings that have evolved for flight. Tail feathers are used for steering during flight..

2.2.1. Order Podicipediformes: Short wings, soft and dense plumage, and webbed feet with flattened nails. Example: Grebes.

2.2.2. Order Procellariiformes: They have tubular nostrils and a large nasal gland, as well as long, narrow wings. Examples: Albatrosses, shearwaters and petrels.

2.2.3. Order Pelecaniformes: They have four toes joined by a common web, rudimentary or absent nostrils, and a large gular sac. Examples: Pelicans and boobies.

2.2.4. Order Ciconiiformes: They are long-necked, long-legged waders that often fold their necks in flight. Example: Remus.

2.2.5. Order Anseriformes: South American screamers include ducks, geese and swans. The latter three species have wide, flat bills, dense undercoats and webbed feet

2.2.6. Order Falconiformes: It has a strong hooked beak, large wings and a raptorial foot. Examples: Vultures, hawks, eagles and ospreys.

2.2.7. Order Galliformes: It has a short beak, short concave wings and strong feet and claws. Examples: curassows, grouse, quail, pheasants and turkeys.

2.2.8. Order Gruiformes: Order characteristics variable and not diagnostic marsh birds including Cranes, Limpkins, Rail and Coot.

2.2.9. Order Charadriiformes: Order the characteristics variable. Examples: Shorebirds, gulls, terns and auks.

2.2.10. Order Columbiformes: Dense leathers, thin skin and a well-developed crop. Examples: Pigeons, doves and sand grouse.

2.2.11. Order Psittaciformes: The maxilla is hinged to the skull and the tongue is thick. The fourth toe is usually reversible and brightly coloured. Examples: Parrots, Lories and Macaws.

2.2.12. Order Cuculiformes: Reversible fourth toe, soft, tender skin. Examples: **Roadrunners** and **Cuckoos**.

2.2.13. Order Strigiformes: It has a large head with fixed eyes facing forwards and a raptorial foot. Example: Owls.

2.2.14. Order Caprimulgiformes: They have owl-like heads and plumage, but weak bills and feet. They are insectivorous. Examples: Whippoorwills and goatsuckers.

2.2.15. Order Apodiformes: Swifts and hummingbirds have long wings and weak feet.

2.2.16. Order Coraciiformes: They have a large head and beak and metallic plumage. Examples include kingfishers, todies, bee-eaters and rollers.

2.2.17. Order Piciformes: Woodpeckers have long, strong beaks and legs with a fourth toe that is permanently held in place. Examples include: Woodpeckers, toucans, honey guides and barbers.

3.2.2.18. Order Passeriformes: The largest order of birds, comprising 69 families of perching birds with a perching foot and variable external features. Examples include: Shallows, larks, crows, titmice, nuthatches, and many others.

2.2.2.4. Class Mammalia

1. General characters

- ✚ Mammals are class of **endothermic** (Constant body temperature) (**Homeotherms**) and give birth to their younger ones. Mammals can live in any climate.
- ✚ Body covered by hair or fur. Hair somewhere on their bodies, some have spines (**Hedgehog**), scales (**Pangolin**), or armored shell made of tough bony plates (**Armadillo**)
- ✚ Their skin possesses sebaceous gland (oil) and sweat glands.
- ✚ Dicondylic skull, generally with 7 cervical vertebrae
- ✚ Female have mammary glands for suckling young.
- ✚ Complete digestive system with heterodont and thecodont teeth. It can be Herbivores, carnivores or omnivores.
- ✚ Circulating system : Heart with four chambers (two atrium and two ventricles). Small and non-nucleated red blood cells.
- ✚ Excretion : Metanephric kidney, Ureotelic excretion.
- ✚ Separate sex. Mammals are Viviparous. Except egg laying Monotremes.
- ✚ Amniotes.
- ✚ Mammals have four limbs.
- ✚ Mammalian lungs have million of tiny air sacs called Alveoli.
- ✚ The diaphragm: A muscle at the bottom of the rib cage and abdominal cavity that moves to help with inhaling and exhaling.
- ✚ They possess 12 pairs of cranial nerves.

2. Classification :

Class Mammalia is divided **in three subclasses as following :**

2.1. Sub-class Prototheria (Monotremes)

Mammals that lay eggs have no placenta and have mammary glands without teats.. Echidna lives in various habitats across Australia and Tasmania and New Guinea. Duckbilled Platypus is found in

the Eastern part of Australia, including Tasmania. They inhabit Freshwater areas such as rivers, streams, and Lakes. Like reptiles and birds, they have a cloaca, which is a single opening for excretion and reproduction.

2.2. Sub-class Theria

2.2.1. Infra-class Metatheria (Marsupials):

Mammals with pouches have evolved over time. Marsupials have a short gestation period and give birth to underdeveloped young. They then crawl into the mother's pouch, where they continue to develop by attaching themselves to a teat for nourishment. The short-lived placenta provides limited nutrient transfer during gestation. Most nutrient exchange occurs after birth, during the pouch phase. Most marsupials live in Australia, except possums, which live in Australia, New Zealand and North America. Examples include: Opossums, kangaroos, koalas, and Tasmanian devils.

2.2.2. Infra-class Eutheria

Eutherians, also known as placental mammals, are the largest and most diverse group of mammals. Unlike marsupials (Metatherians), eutherian mammals give birth to relatively well-developed live young, which have undergone an extended period of gestation in the womb nourished by a complex placenta. Here are some key characteristics and examples of eutherian mammal's orders:

1. Order Rodentia: They are characterised by continuously growing incisors that they must gnaw to prevent them from overgrowing. Examples include mice, rats, squirrels and beavers. Examples: Mouse, rat, squirrel, beaver and porcupine.

2. Order Chiroptera: The digits support the membranous wings. Bats are the only mammals capable of sustained flight. They are characterised by their elongated fingers and the thin skin membranes that form their wings.

3. Order Carnivora: They have long canine teeth and pointed teeth. Carnivores are adapted for hunting and eating other animals. This order includes cats, dogs, bears and seals.

4. Order Cetacea: They are medium to very large in size, with paddle-like forelimbs and no hind limbs. Cetaceans are marine mammals that include whales, dolphins and porpoises.

5. Order Artiodactyla: Medium to large in size, with two to four toes, each with a hoof. Many have antlers or horns. Even-toed ungulates have an even number of toes on each foot and include animals such as deer, cattle, pigs and giraffes.

6. Order Perissodactyla: They are large and long-legged with one or three toes, each with a hoof, and they have grinding teeth. Odd-toed ungulates have an odd number of toes on each foot. This group includes horses, zebras and rhinoceroses.

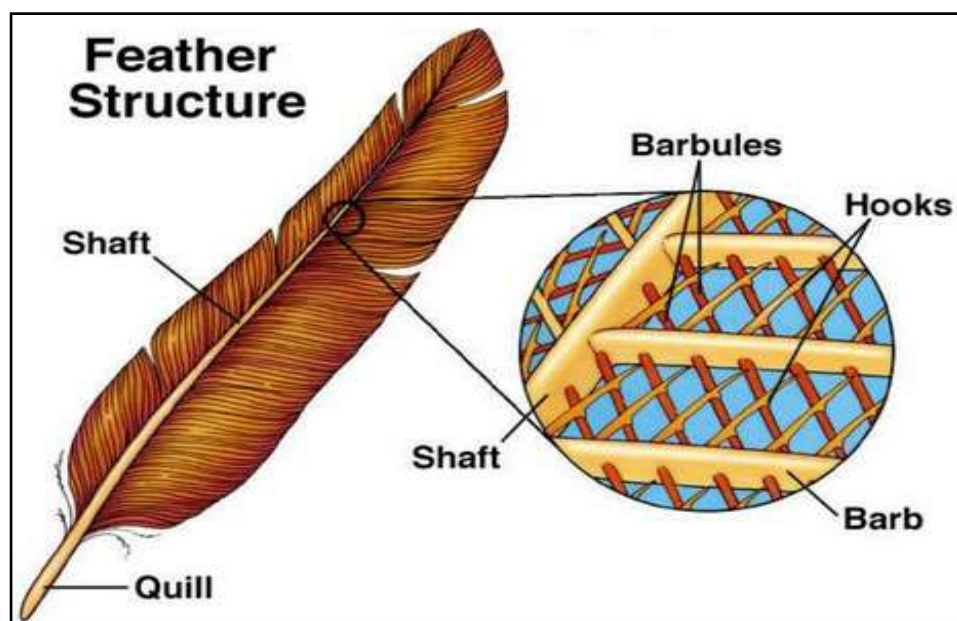
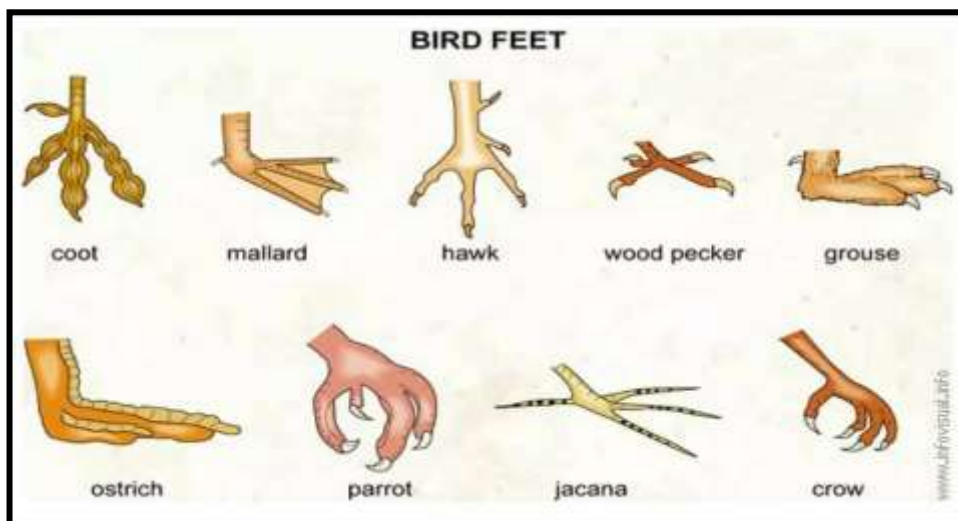
7. Order Lagomorpha: They have chisel-like incisors, longer hind legs than front legs, and are herbivorous. Lagomorphs include rabbits, hares and pikas. They are characterised by their continuously growing incisors and hind limb adaptations for hopping.

8. Order Proboscidea: They are large in size, with trunks, pillow-like limbs and broad, padded feet. They are the only living members of this order. They are known for their long trunks and large tusks.

9. Order Insectivora (Lipotyphia): Primitive, with small, sharp teeth. This order includes small insectivorous mammals such as shrews, hedgehogs and moles.

10. Order Primates: They are mostly tree-dwelling, with a freely movable head on their neck, five digits (usually with nails) and opposable thumbs and/or large toes. Primates, including monkeys and apes, are characterised by advanced cognitive abilities, forward-facing eyes and hands that can grasp. Examples: Lemur, monkey, gibbon, chimpanzee and gorilla.

Annexes



Sub-class **Prototheria** (Monotremes)



Echidnas



spiny anteaters



Platypus

Sub-class **Metatheria** (Marsupials) Mammals



Wombat

Sugar Glider

Koala

Opossum

Kangaroo

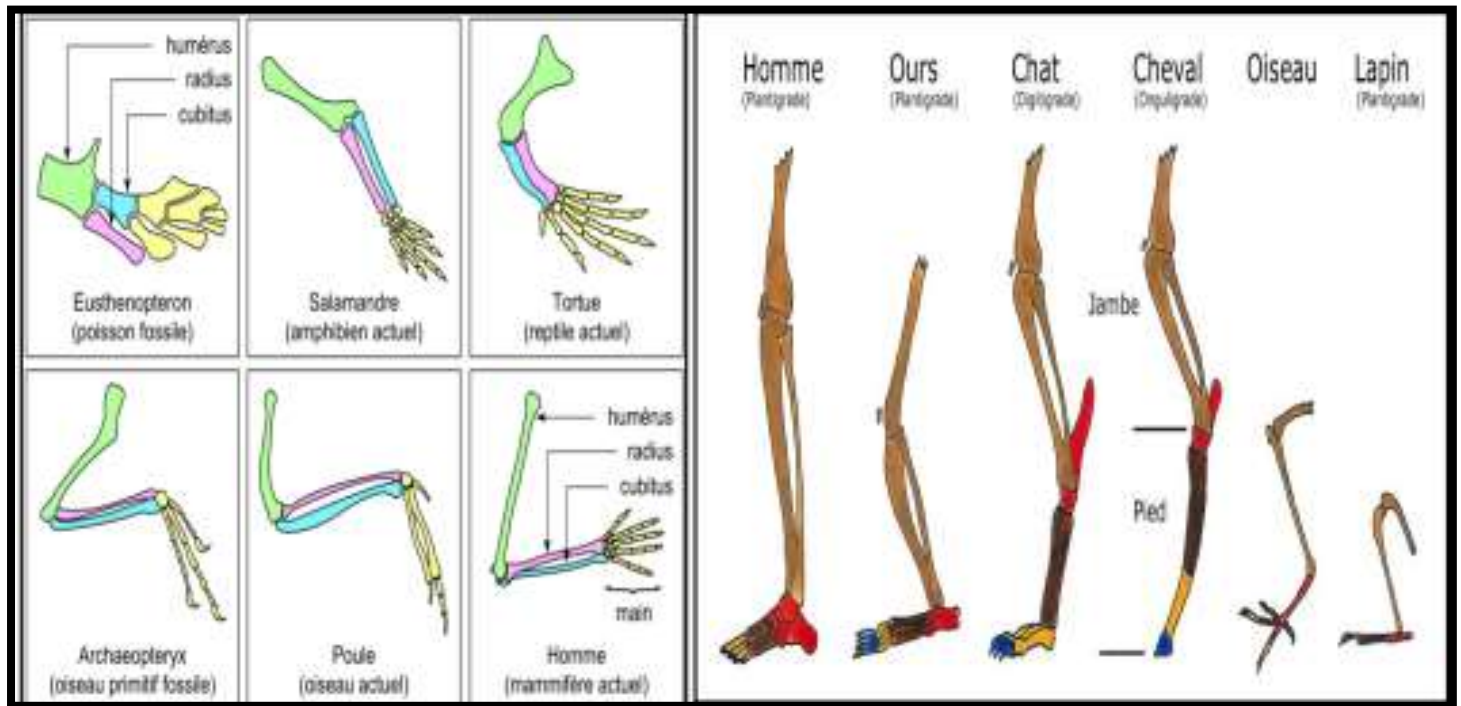
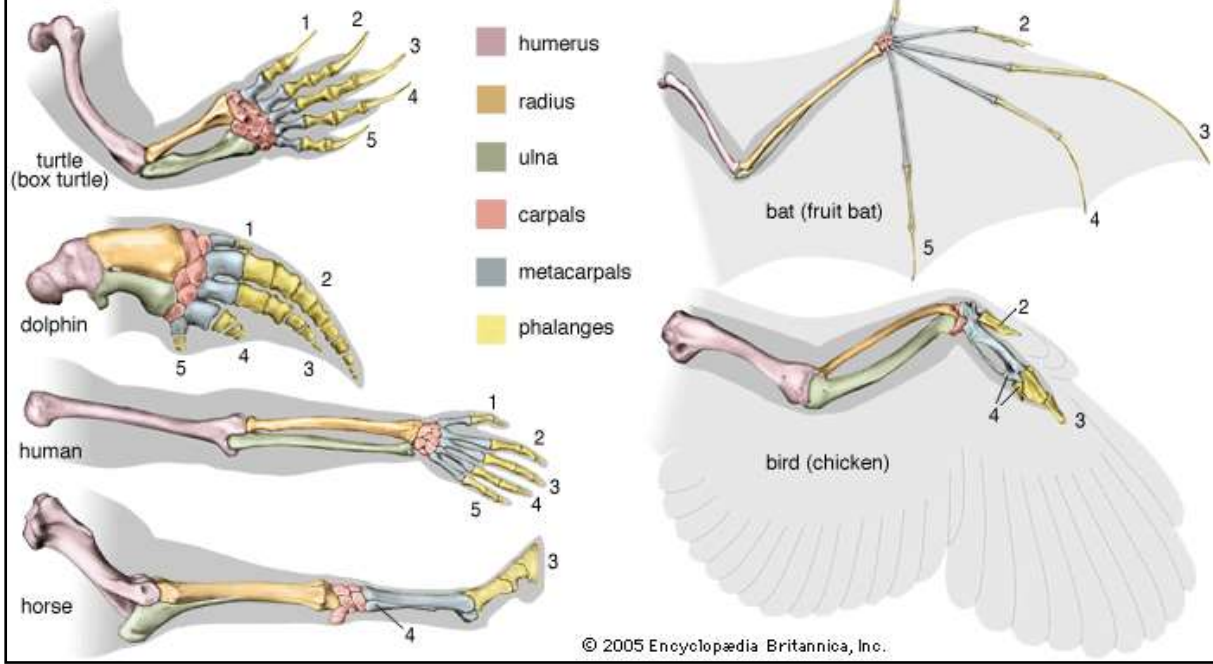
Numbat

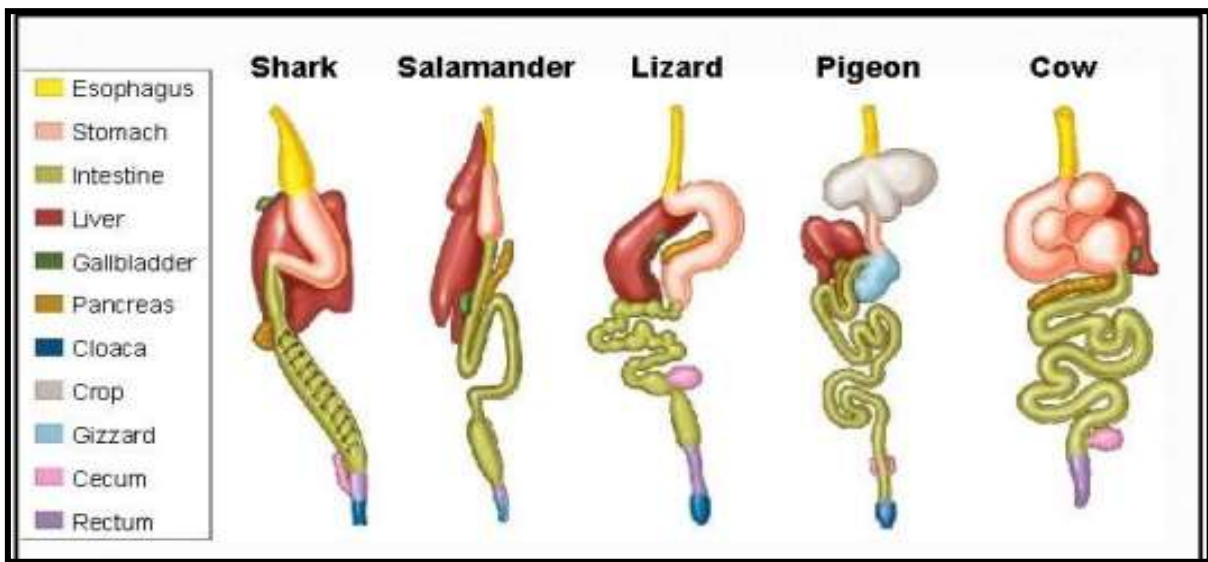
Wallaby

Quoll

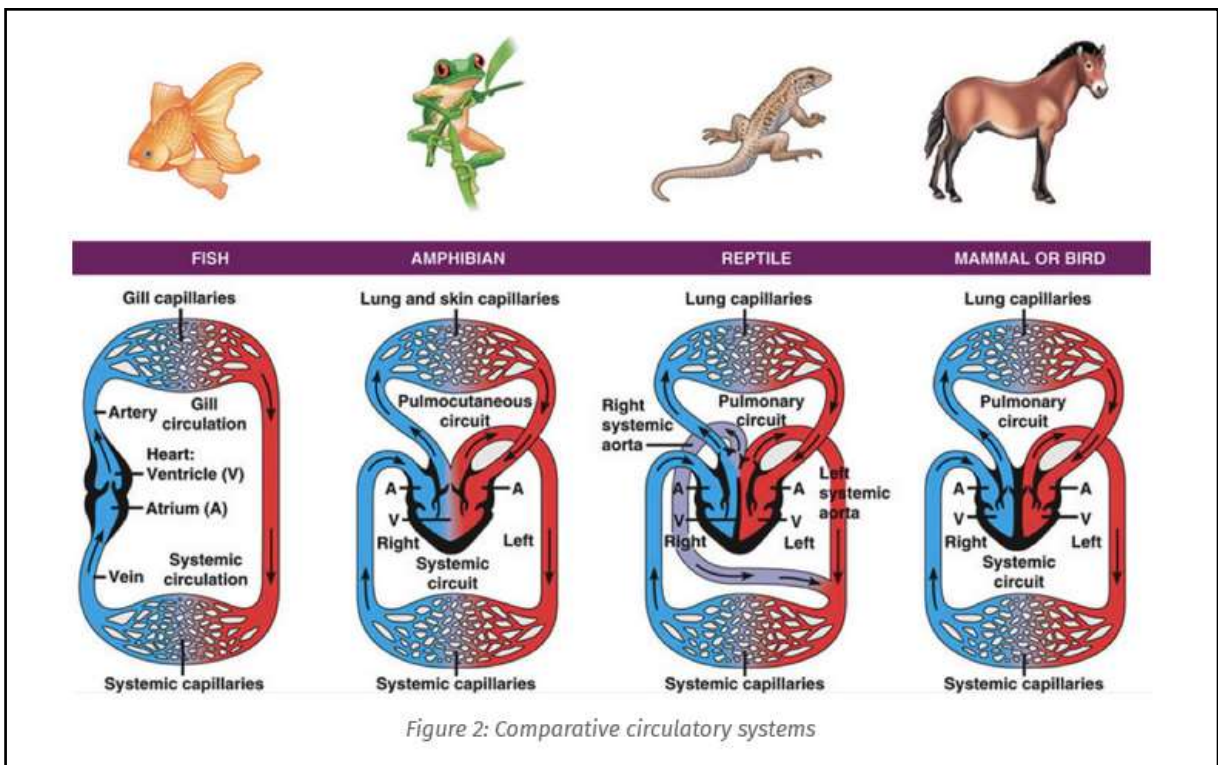
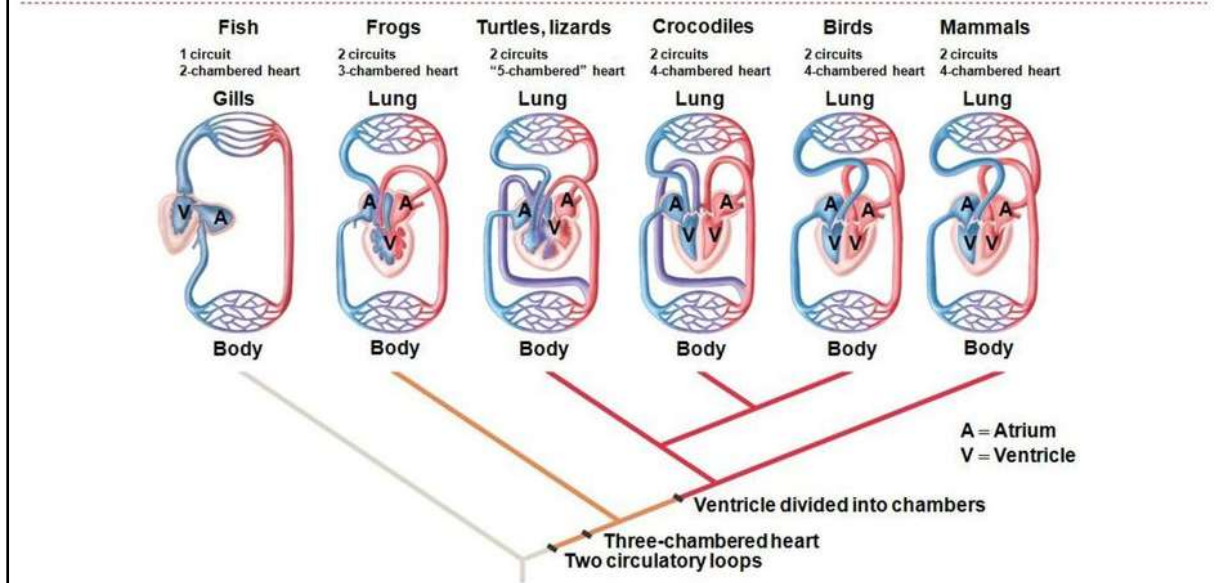
Tasmanian Devil

Homologies of the forelimb in six vertebrates





Comparative Anatomy of Vertebrate Hearts



olfactory lobe
(part of forebrain)

forebrain

midbrain

hindbrain



FISH
(shark)



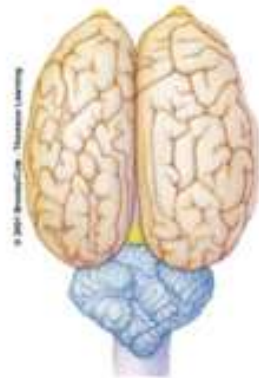
AMPHIBIAN
(frog)



REPTILE
(alligator)



BIRD
(goose)



MAMMAL
(horse)

Comparative cephalization

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