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Ferhat ABBAS University of Setif

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Lectures in

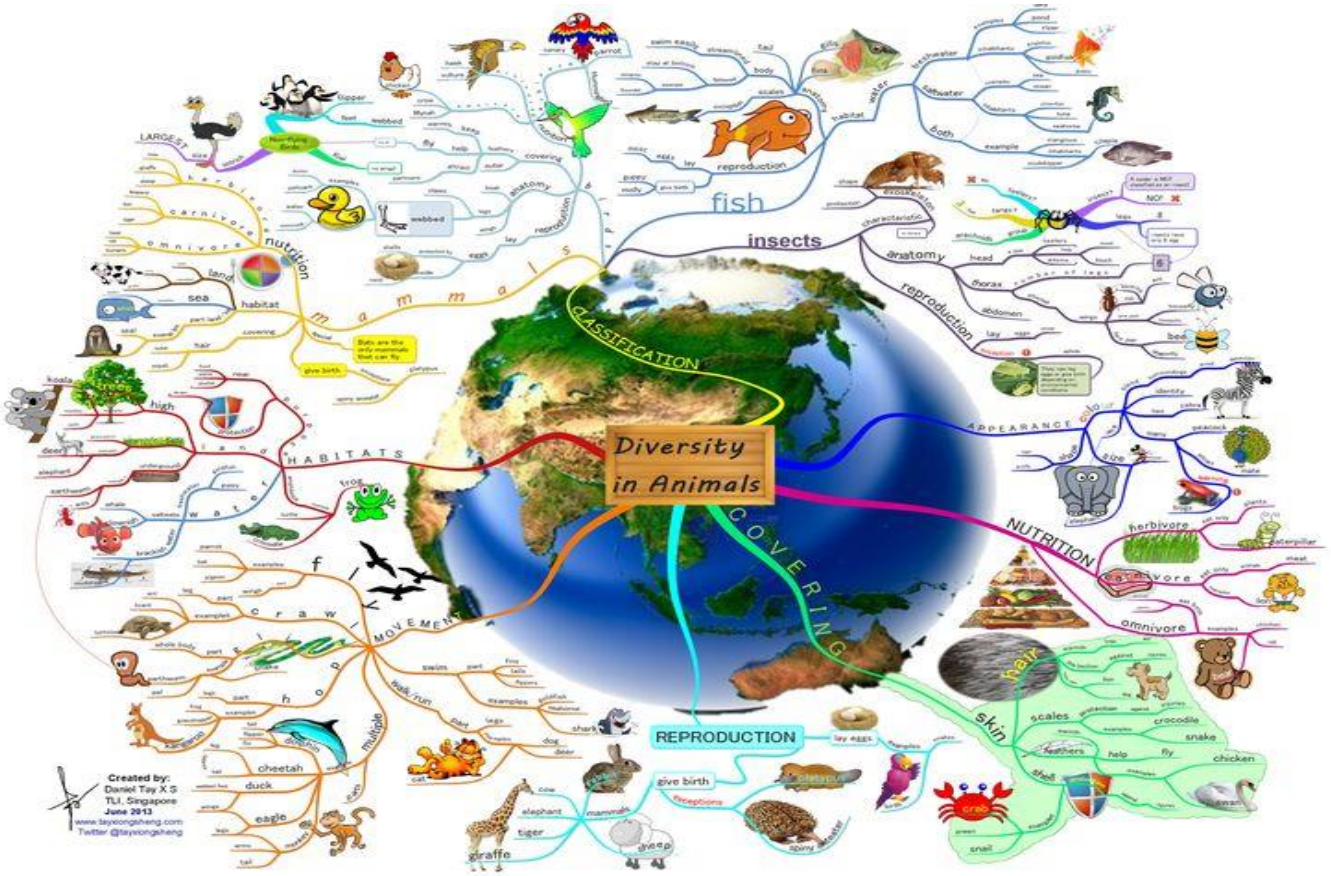
Module: Zoology

Lessons Designed for Second-Year LMD Students

Presented by

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Chaptre I
Introductin

1. Introduction of Zoology

1.1. Subfields of zoology

Zoology { **Zoo**= Animal
Logos = Knowledge =Study

- Is the branch of biology dedicated to the study of animals.
- This field encompasses all aspects of animal life, from the tiniest microscopic organisms to the largest mammals on Earth.
- Zoology encompasses studying animals from multiple angles, including their structure (anatomy), functions (physiology), evolution over time, behavior and interactions, and their relationships with the environment (ecology) and other species.

Zoology draws on many disciplines, including core sciences like Genetics, Physiology, Ecology, Evolution, Anatomy, and Biochemistry, as well as fields such as Psychology and Anthropology for animal behavior. It also incorporates the practical applications of disciplines like Data Science, Biotechnology, and Geosciences for areas like conservation, environmental research, and understanding the wider ecosystem.

1.2. Branches of Zoology

Zoology is a major branch of biology that covers many aspects of animal life; thus, it is subdivided into the following branches on the bases of the characteristics that are being studied (**Figure 1**):

1.2.1. Morphology: The study of the external structure of animals.

1.2.2. Anatomy: The study of internal organ structures of animals.

1.2.3. Physiology: Is the study of the mechanical, physical, and biochemical functions of animals and structures (cells, organs, organ systems, etc) function.

1.2.4. Comparative anatomy: Studies the structure of animals.

1.2.5. Embryology: The study of the development of individual animals.

1.2.6. Molecular Biology: Studies the common genetic and developmental mechanisms of animals and plants.

1.2.7. Ecology: Study of how organisms interact and affect their environments, or vice versa.

1.2.8. Behavioral ecology: Is the study of the ecological and evolutionary basis for animal behavior, and the roles of behavior in enabling an animal to adapt to its environment (both intrinsic and extrinsic).

1.2.9. Ethology: Is the study of animal behavior.

1.2.10. Zooarchaeology: study of animal remains in relation to ancient people.

1.2.11. Zoogeography: Zoogeography is the scientific study of geographical distribution of animal species (both historic and contemporary) in the world.

1.2.12. Zoography: Zoography is study of animals and their habitats (also known as descriptive zoology).

1.2.13. Evolutionary biology: See of both animals and plants is considered in the articles on evolution, population genetics, heredity, variation, Mendelism, reproduction.

1.2.14. Evolution: Study of change over time (Molecular level to ecosystem level).

1.2.15. Systematics and taxonomy: Classify and group species via common descent and regional associations.

1.2.16. Paleontology: Is the study of prehistoric life, including organisms' evolution and interactions with each other and their environments. As a "historical science".

1.3. Sub-disciplines of Zoology

Zoology is divided into many subdisciplines that focus on specific groups like (**Figure 1**):
Entomology, Herpetology, Ichthyology, Mammalogy, Malacology, Arachnology, Carcinology, Cetology, Nematology, Protozoology, Parasitology, Neonatology, Ornithology, Primatology.

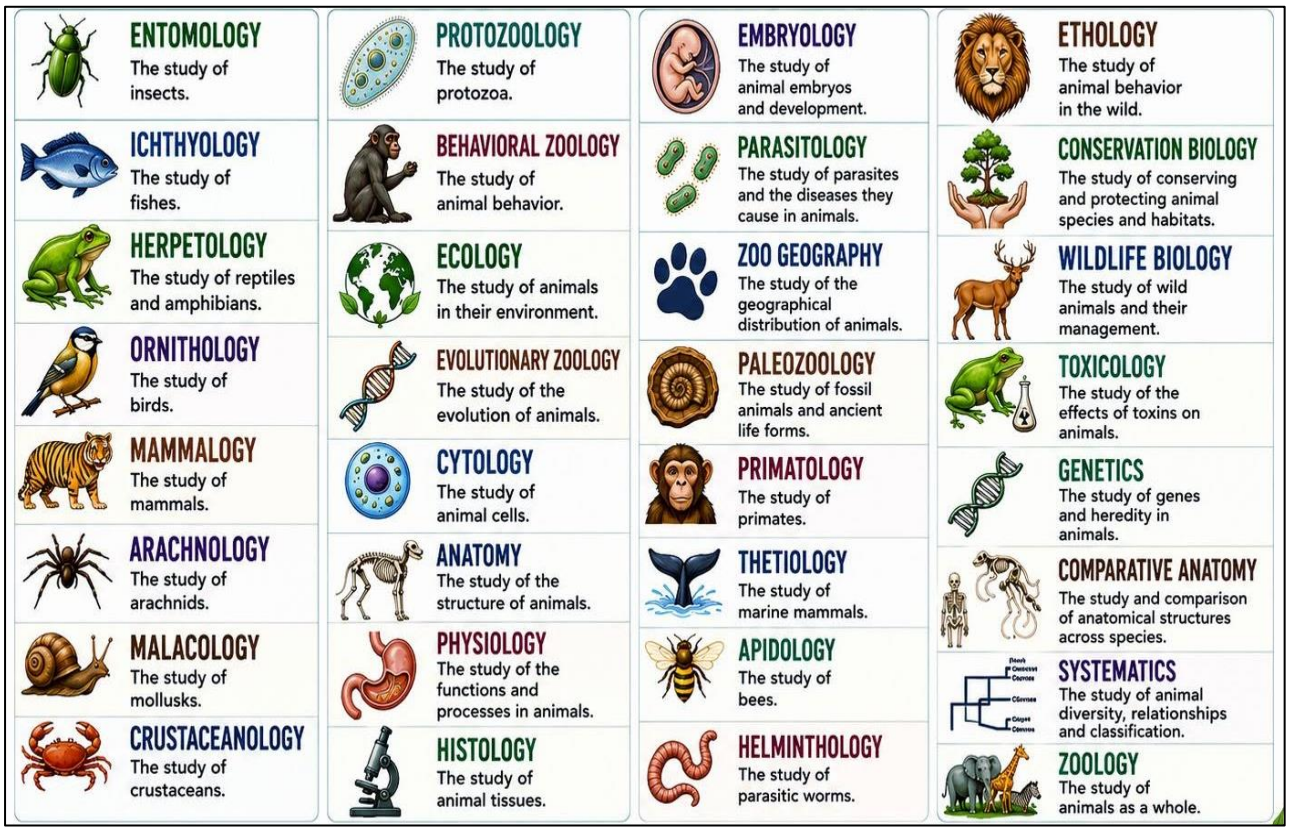


Figure 1: Some branches and Sub-disciplines of zoology.

2. Introduction to Living Things

Earth has numerous habitats with a wide range of living organisms inhabiting it. Living organisms show a variety of unique characters different from non-living matter. Classification is the process by which anything is grouped in a convenient category based on some easily observable characters (**Table 1; Figure 2**).

- Living things can be classified in into **five groups**

These are called **Kingdom**

Each kingdom contains organisms that have similar characteristic.

The five-kingdom classification was given by **Robert.H. Whittaker** in **1969**.

- This five-kingdom classification is based on characteristics such as:

➢ Cell Structure

There are two primary types**: Prokaryotic Cells** and **Eukaryotic Cells**

➢ Structural Organization

Based on this, organisms can be: Unicellular or Multicellular.

➢ Mode of Nutrition

Based on their nutritional habits, organisms can be classified into:

- ✓ Photo-autotrophy (Plantae).
- ✓ Absorptive Heterotrophy (Fungi).
- ✓ Ingestive Heterotrophy (Animalia).

➢ Ecological Lifestyle

Based on their ecological functions, they can be:

- ✓ Producers (Plantae).
- ✓ Decomposers (Fungi).
- ✓ Consumers (Animalia).

The five Kingdoms

The basic scheme of modern classification. Many other levels can be used; domain, the highest level within life, is both new and disputed.

Main articles: Kingdom (biology) and Domain (biology). Well before discovery of Carl Linnaeus (Botanist) plants and animals were considered separate kingdoms. Linnaeus used this as the top rank, dividing the physical world into the vegetable, animal and mineral kingdoms. As advances in microscopy made the classification of microorganisms possible, the number of kingdoms increased, five kingdoms being the most common (**Table 1; Figure 2**):

Table 1: Characteristics of the five kingdoms.

Kingdom	Characteristics
Monera (Bacteria)	Prokaryotes (no nucleus or organelles)
Protozoa (Protista)	Eukaryotes (nucleus and organelles present)
Plantae	Eukaryotes Multicellular Autotrophs Cellulose cell wall
Fungi	Eukaryotes Saprophytic heterotrophs Chitin cell wall
Animalia	Eukaryotes Multicellular Heterotrophs Absence of cell wall

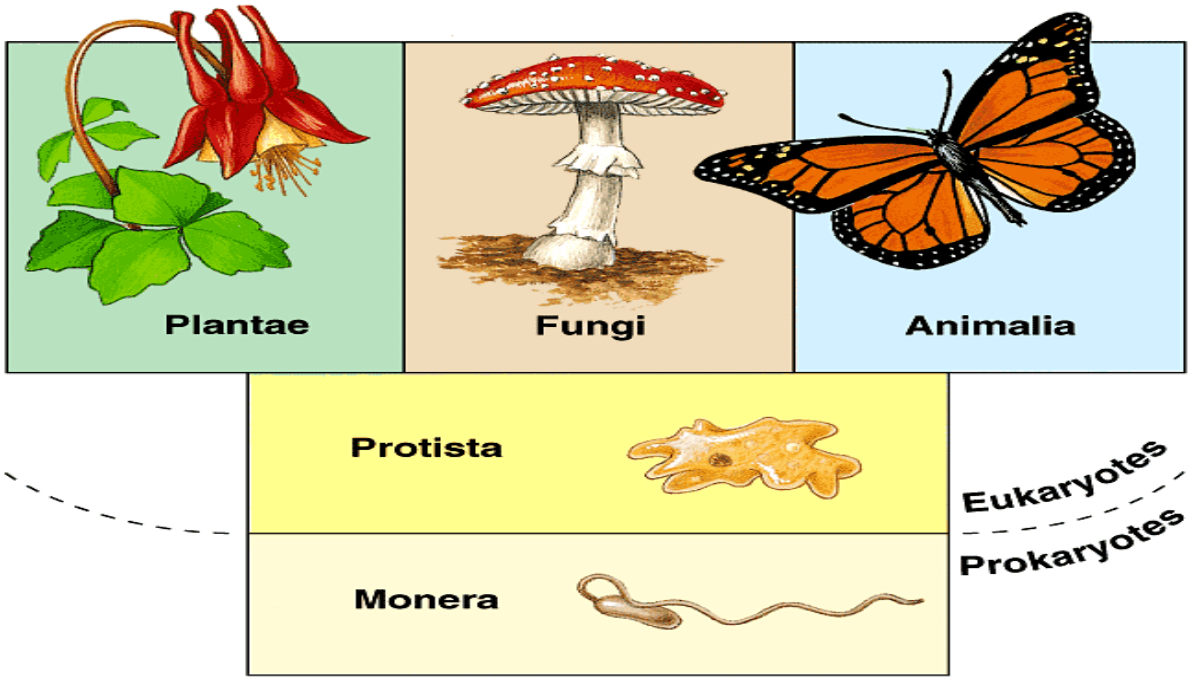


Figure 2: The five kingdoms of living organisms.

3. Introduction to Taxonomy and Systematic

As more and more data regarding life forms come to light, taxonomy becomes more and more refined. To understand diversity a system of taxonomy is required. Taxonomy allows understanding diversity better. This chapter will deal with how living beings are named, grouped and classified and some important features of these groups.

About 2.0 million types of animals and about 1.0 million types of plants have already been described and named and many new forms are discovered every year. Animals and plants vary greatly in their forms, structures and mode of life. To identify an organism of known characters from the vast number of organisms is simply impossible. The number and diversity of living organisms are so enormous that it is very difficult to study without classifying them into certain groups or categories. Thus, taxonomy allows us to identify and recognize organisms. Hence, in this chapter, you would learn about the role of taxonomy in the classifying the organisms and its relationship with systematic.

3.1. History of classifications

Many classifications have emerged over the years. Among the main classifications and important works that have shown the evolution of ideas and the principles on which successive classifications are based, those of:

3.1.1. Aristotle (384 – 322 BC)

Aristotle (384-332 B.C.) who is known as "**Father of Zoology**" classified animals on the basis of their morphology and categorized into three groups namely as: Verms, Insecta, Vertebrata.
He classified a total of 520 species of animals in his book "**Histiria Animalium**". He is also known as: "**Father of Biological Classification**".

3.1.2. John Ray (1627-1705)

John Ray (1627-1705) was first coined the term "**species**" and described 18000 plants in his book entitled "**Historia Generalis Plantarum**" which was published in three volumes between 1686 to 1704. He was the **first person** who made a differentiation between **genus and species**.

• He divided animals into those with blood and those without blood.

• He also classified animals based on gills, lungs, claws, teeth and other structures.

3.1.3. Linnaeus (1707-1773 AD)

Carolus Linnaeus (1707-1778), who used "**Binomial Nomenclature**" system of classification instead of using common name of plants and animals both in his famous book entitled "**Systema Naturae**". He listed 9378 species of plants and animals in his book which had published in 1735. Because of

using a scientific system of classification firstly, **Carolus Linnaeus** has been crowned with the title of "**Father of Modern Taxonomy**".

He seeks the affinities existing between beings based on **anatomical characteristics**.

Linnaeus used an organisms morphology (form and structure), to categorize it.

He distinguished six major animal categories:

- ✓ Worms – Insects – Fish – Amphibians – birds – mammals.

He proposes: The **notion of Species** is stated and, in this way, a new basis is provided for the classification.

3.1.3. Lamarck (1744- 1829 AD)

In 1806, Lamarck established his "table of the animal kingdom".

He based on the **presence or absence of vertebrae**; He distinguished two major animal categories:

- ✓ Vertebrae: Mammals, Birds, Reptiles, Fish.
- ✓ Invertebrates: Molluscs, Annelids, Crustaceans, Arachnids, Insects, Intestinal worms, Radiates, Polyps.

3.1.4. Cuvier (1769-1832 AD)

French anatomist, his work is based on **comparative anatomy**. He researched homologies and for the first time, the study of fossils is associated with that of current forms.

He distinguished four major structural plans in the animal world:

- Vertebrates, Molluscs, Articulates and Zoophytes.

All animals can be attached to one of these basic plans.

These four classifications are currently only of historical interest.

3.1.5. Cuénot's family tree (1940)

This tree has the characteristic shape of a tree, the complication of the forms increases over time, that is to say from the foot to the top. On the trunk, the various phyla, branches or clades are attached. A branch is normally divided into classes, classes into orders, orders into families.

3.1.6. Robert Harding Whittaker (1920 -1980)

Robert Harding Whittaker (1920 -1980) was a distinguished American plant ecologist.

He was the first to propose the **five-kingdom of organisms.**

taxonomic classification of the world's biota into the Animalia, Plantae, Fungi, Protista, and Monera in 1969.

3.2. Definition of Classification

In biology, Classification is the arrangement of organisms into orderly groups based on their similarities.

Biological classification is the process of organizing living organisms into groups based on their similarities and differences.

The science of naming and classifying organisms is called **taxonomy**.

3.3. Definition of Taxonomy

The term is derived from the Greek taxis ("arrangement") and nomos ("law, rules"). means "arrangement by rules". The **term taxonomy** was first coined by **A. P. de Candolle in 1813**.

Taxonomy is the branch of biology dealing with the naming, identification, and classification of organisms.

A **taxon** is referred to as a group of organisms classified as a unit.

3.4. Definition of Systematics

Systematics (Gk., Systema - a system of classification). Term systematics was **first described** by **Carolus Linnaeus** (1707-1778) in his book "Systema Naturae". Systematics may be defined as the scientific study of taxonomy which deals identification, nomenclature, and classification of all living individuals and relationships among them are called systematic.

The branch of science dealing with identification, nomenclature, description and classification of organisms based on unique properties of every species and group of species at every level of classification.

Generally, the terms systematics and taxonomy are used interchangeably but some scientists like Simpson (1961) relate them to separate field.

According to him, Systematics is the study of diversity of organisms and all their comparative and evolutionary relationships based on comparative anatomy, comparative ecology, comparative physiology and comparative biochemistry.

3.4. Definition of Biosystematics

The term New Systematics (neosystematics or biosystematics) was proposed by **J. Huxley** in 1940 to consider some new branches of taxonomy like Morphotaxonomy, Karyotaxonomy, Cytotaxonomy, Experimental Taxonomy, Biochemical Taxonomy, Chemotaxonomy and Numerical Taxonomy etc. Besides this "New Systematics" also deals many aspects of morphology, ecology, biochemistry, physiology, cytology and genetics etc.

3.4. Linnaean Hierarchy

Chaptre I **3. Introduction to Taxonomy and Systematic**

The hierarchy may be defined as a system of arrangements of taxonomic categories for classification in a logical sequence. Generally, hierarchy means "a series of a succession of different rank". **Firstly, it is established** by **C. Linnaeus** in the animal kingdom, therefore, it is known as a **Linnean hierarchy**.

The Linnaean system of classification consists of a hierarchy of graded taxonomic (named) ranks that are called as taxa. Any given taxon (singular) may contain several lower taxa, which can be usually distinguished based on certain common characteristics. Such lower ranks may, in turn, be divided into a succession of progressively smaller ranks. The lower the rank of a group, the more similar are the organisms grouped in it. If any two given organisms can be grouped under the same lower rank or taxon, it implies that the two organisms are structurally, functionally, embryologically.

3.4.1. Definition of Taxonomic hierarchy

Taxonomic hierarchy is the process of arranging various organisms into successive levels of the biological classification either in a decreasing or an increasing order from kingdom to species and vice versa.

- Each of this level of the hierarchy is called the **taxonomic category** or **rank**. (**Figure 3**).
- In biological classification, the **taxonomical hierarchy** includes **seven major categories**, in descending order (**Figure 3**) are:

Kingdom: For long, living things are divided into kingdoms: plants and animals.

Phylum (Division): Each kingdom is divided into smaller groups called phylum.

Class: A phylum is divided into classes.

Order: Class is divided into orders.

Families: Order is divided into Families.

Genera: Family contains related genera.

Specie: A genus is composed of one or more species.

Kids prefer candy over fresh green salad

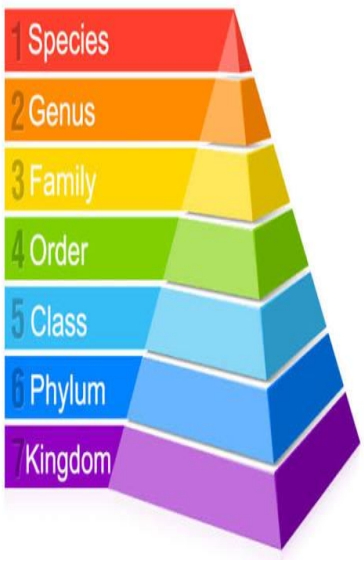


Figure 3: Categories of Taxonomic Hierarchy.

3.4.2. Intermediate categories

With the discovery of more and more organisms, it becomes difficult to place an organism in the traditional categories. Hence, to make the taxonomic position of a species more precise, the categories have been split by prefixing **"super"** or **"sub"** to the existing categories. As they are introduced later on in the hierarchical system, they are called intermediate categories.

Thus, we have:

Kingdom, Sub-kingdom**, Super**phylum**,** Phylum**, Sub-**phylum**, Super-**class**, Class, Sub**class**, Super-**order**, Order, Sub-**order**, Super-**family**, Family, Sub-**family, **Genera, Specie, Sub-**species.

3.4. Concept of species

Species is the basic unit of classification.

The term **species was coined by John Ray**, and in his book "Historia Generalis Plantarum" (3 volumes) in **1693** described species as a group of morphologically similar organisms arising from a common ancestor. Carolus Linnaeus in his book "Systema naturae" considered species as the basic unit of classification. Species can be defined as a group of organisms that have similar morphology and physiology and can interbreed to produce fertile offsprings. **Ex:** Horse x Horse = Foal (**Figure 4**). Two different species sharing same genus breeding often results in sterile offspring (**Figure 4**).

Ex: Horse x Donkey = Mule.

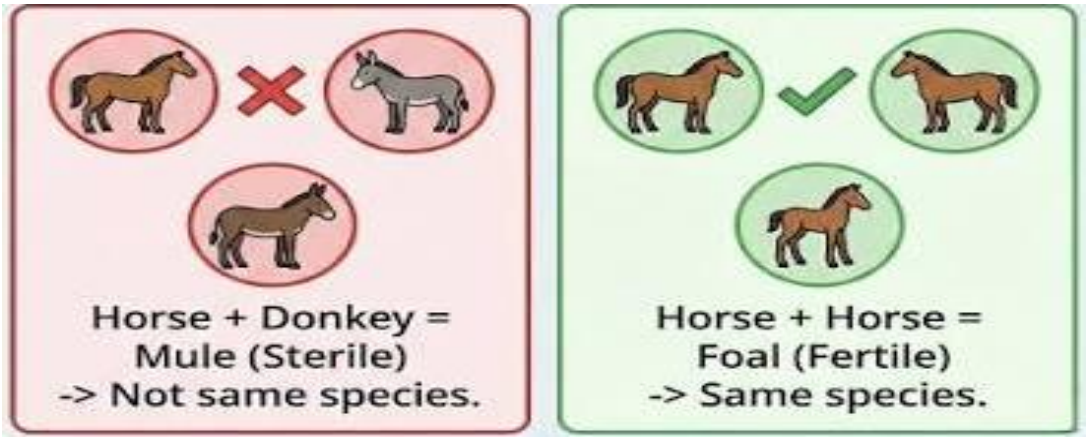


Figure 4: Speciation reproductive

3.5. Subspecies

Populations of species that occur in different areas and differ slightly from each other.

They have typological, local or regional differences.

A subspecies is a particular group within a species that has branched off, usually due to geographic isolation.

3.6. Advantage of hierarchical system of classification

- It gives information about the relationship of an organism with others.
- It helps in quick identification of a taxon.
- All the major traits present in an organism can be studied by noting the trait of various categories in which the organism is classified.
- It reduces the volume of traits by non-repetition of correlated traits of a high rank category in the lower rank category.

3.7. Binomial nomenclature

Different local names are given to specific organisms or animal which make it hard to identify globally. Various names of an organism make a lot of confusion. So, to get rid of this confusion scientists came up with this standard protocol. According to this, each organism would have one scientific name.

Binomial nomenclature is a formal system for naming living species.

Binomial nomenclature was proposed by **C. Linnaeus (1737)**. It is a system of naming animals. Such a name is called binomial name or binomen or scientific names.

It is named in Latin words. Hence it is also called Latin name.

According to this system, each animal is named by **two words**. The first word is called **genus name** and the second word is called **species name**. The genus name starts with a **capital letter** and the species name start with **small letter**. Both names should be **written in italics**.

Example: ***Lumbricus terrestris*** ***Lumbricus terrestris*** Lumbricus terrestris

genus **species** **Capital letter** **small letter**

3.8. Trinomial nomenclature

Binomial nomenclature is a method of naming the animals. Here each animal is named by three words. The first word represents the **genera,** the second word represents the **species and the third word** represents the **sub species.** This system is followed when there are two or more varieties (sub species) within species

Example: the house crow contains many varieties and they are named as follows:

Corvus splendes splendes House crow of India and Pakistan.

Corvus splendes insolens House crow of Burma.

Corvus splendes protegatus House crow of Sri Lanka.

3.9. Rules for writing scientific names

Chaptre I 3. Introduction to Taxonomy and Systematic

The International Code of Zoological Nomenclature (ICZN) framed certain rules in 1901 for naming the animals. These are the main rules:

- All the animals must by two words (Binomial). The subspecies can be named by three words (Trinomial).
- **Two-Part Name:** Each species name is made up of **two Latin** or Latinized words: the **genus name** and the **species name** (for example, *Homo sapiens*).
- **Italicization:** When written by hand, the full binomial name is frequently emphasized (for example, *Homo sapiens*) or underlined (for example, Homo sapiens).
- **Capitalization:** The genus name begins with an uppercase letter, while the species name begins with a lowercase letter (for example, ***H**omo **s**apiens*).
- **Genus Name Uniqueness:** The genus name must be unique within each kingdom. For example, there is only one Homo in the animal kingdom.
- **Specific name specificity:** The specific name is not necessarily unique on its own, but when paired with the genus name, it uniquely distinguishes a species within the genus.

For example, *Panthera leo* and *Panthera onca* are two separate species within the same genus.

- **Language and Grammar:** Names are typically in Latin or Latinized form. They frequently represent species traits or pay tribute to a specific individual.

The particular name frequently agrees grammatically with the genus name.

- **Authority:** The name of the person who first validly published the name may appear after the species name (**Example**., *Felis catus* (Linnaeus, 1758)).
- **Synonyms and Homonymy:** To avoid homonyms, each species' name must be unique within the genus. If two species are given the same name, the principle of priority applies, with the older name taking precedence.
- 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**.**
- **Changes and corrections:** The International Code of Nomenclature (ICN) for algae, fungus, and plants, as well as the International Code of Zoological Nomenclature (ICZN) for animals, govern the naming process and allow for alterations and corrections.
- **Standardized Naming**

Example: Earthworm

Lumbricus terrestris (Linnaeus, 1758).

Lumbricus terrestris (Linnaeus, 1758).

Lumbricus terrestris (L, 1758).

L. terrestris (L, 1758).

Lumbricus sp.

Chaptre I 3. Introduction to Taxonomy and Systematic

Zoological nomenclature

The nomenclature of the classical classification established a codified terminology which allows, given the sole ending (or **suffix**) of any taxon **(Table 2).**

Table 2 : Suffixes indicating taxonomic rank

Taxonomic rank	Suffixe
Order	-idea, -ida
Super-family	-oidea
Family	-idae
Sub-family	-inae
Genus	-us, -a, -um, -is, -os, -ina, -ium, -ides, -ella, -ula, -aster, -cola, -ensis, -oides, -opsis…

Kingdom: Animalia

Sub- Kingdom: Metazoa

Phylum (Division): Platyhelminthes

Class: Cestoda

Sub-classe: Eucestoda

Order: Cyclophyllidea

Family: Taeniidae

Genera: *Taenia*

Specie: *saginata*

Nom binominal : ***Taenia saginata*** ***OR*** **Taenia saginata**

4. Introduction to the animal kingdom

Kingdom Animalia is one of the divisions of the five Kingdom classification model. There is a vast diversity in the number and types of animals in nature **(Table 3)**. They range from unicellular to multicellular. They are found in the deepest of the oceans, in snow-covered mountains, from the poles to the equator. There are differences in the structure and forms of the different animals. But there are some fundamental features in them which show resemblance such as arrangement of cells, body plan, symmetry, segmentation, coelom, germ layer, body temperature, skeleton and notochord, types of digestive, respiratory, circulatory, excretory, and reproductive systems. We need to classify organisms to make our study easier and to study the interrelationship between different groups.

Table 3: 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

4.1. Featuers of kingdom animalia

- The organism under this kingdom is
  - ✓ Eukaryotes
  - ✓ Multicellular
  - ✓ Without any cell walls
- They are Heterotrophs and depend on plants for food or heterotrophic nutrition (herbivores carnivores, omnivores, saprobes).
- Their digestion process is done in the internal cavity stores fat. There is ingestion of food inside the body or nutrition is Holozoic. They have a fixed growth cycle with a definite shape or size for each phase or cycle.
- They can locomote or follow a clear movement
- Reproduce both sexually and asexually, animals show a great diversity in kinds of reproduction. some with well-developed alternation of generations, and follow sexual reproduction between male and female. This is the only reproduction method possible in these organisms.

4.2. Organizational plan of the animal kingdom

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

4.2.1. The number of cells (protozoa (unicellular) or metazoa (pluricellular))

The animal kingdom is divided into two subkingdoms according to the number of cells: sub-kingdoms of Protozoa and subkingdoms of Metazoa **(Figure 5).**

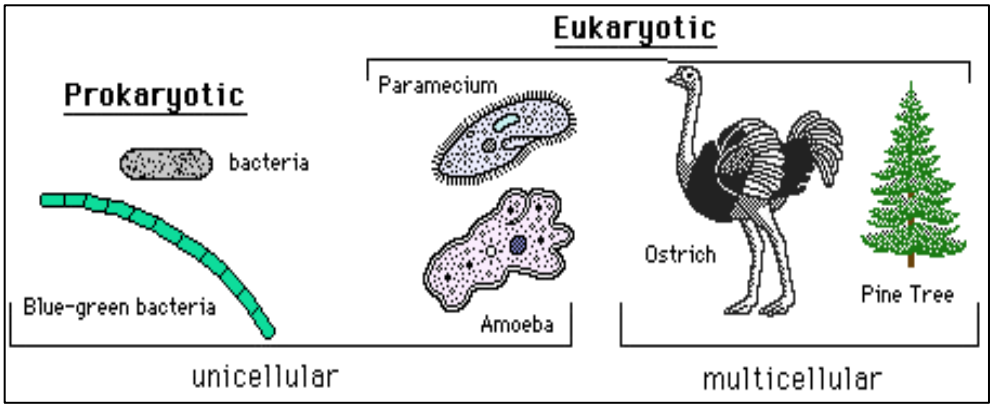


Figure 5: Depending on the number of cells.

4.2.2. The Number of germ cell layers or Embryonic layers (Diploblastic or Triploblastic) or Gastrulation

Tissues- collections of specialized cells working together and isolated from other tissues by membranous layers (germ layers).

This classification is based on number of embryonic cell layers and divided into two **(Figure 6)**:

4.2.2.1. Diploblastic Animals: Cells are arranged into two embryonic layers, i.e. outer ectoderm and inner endoderm. In between these layers, an undifferentiated jelly-like layer called mesoglea is present **(Figure 6a).**

Examples: Sponges, Cnidaria and Ctenophora.

4.2.2.2. Triploblastic Animals: Three embryonic layers are present i.e. outer ectoderm, middle mesoderm and inner endoderm. All the tissues and organs are formed from these three layers. Ectoderm give rise to epidermis and nervous system etc., mesoderm to muscles, endoskeleton, reproductive organs, coelom, etc, and endoderm to the alimentary canal, lungs, etc. **(Figure (6b).**

Examples: Platyhelminthes to Chordates.

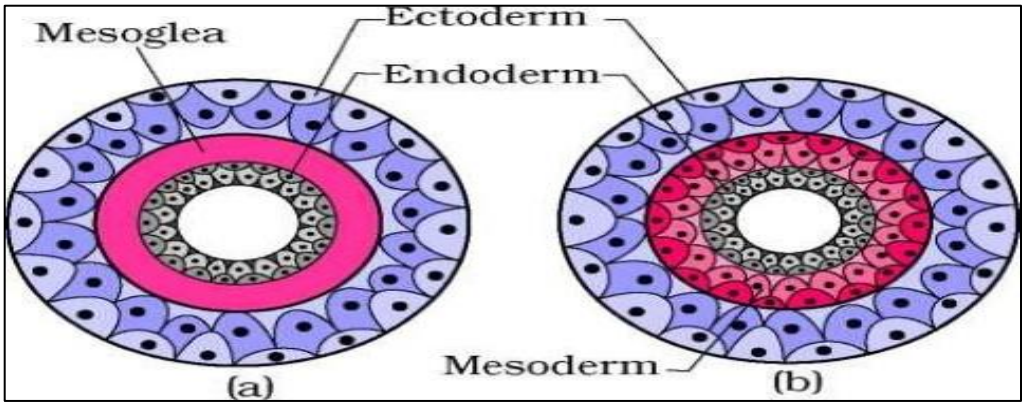


Figure 6: Showing germinal layers: (a) Diploblastic (b) Triploblastic.

4.2.3. Presence or Absence of a Coelom (Acoelomates or Pseudocoelomates or Coelomates) or Body Cavities

The fluid filled body cavity in between the body wall and the digestive tract of animals is called the coelom. The coelom is lined (lined with peritoneum) by mesodermal epithelium on either side. All the internal organs are suspended in the coelom **(Figure 7).**

❖ A peritoneum is a smooth transparent membrane that lines the abdomen and doubles back over the surfaces of the internal organs to form a continuous sac.

Functions of coelom:

❖ The coelom allows greater body flexibility.

❖ It acts as a shock absorber. In soft bodied animals it protects internal organs from external shocks.

❖ In some animals it acts as an internal skeleton.

❖ It accommodates visceral organs.

❖ Coelomic fluid reduces friction between visceral organs.

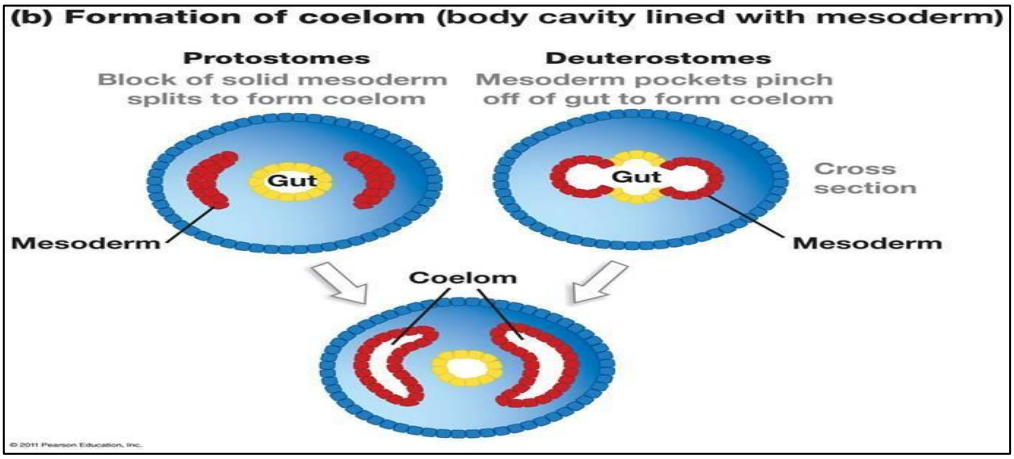


Figure 7: Formation of coelom (body cavity lined with mesoderm).

Chaptre I 4. Introduction to the animal kingdom

Animals are classified into three groups based on the nature of their coelom **(Figure 8)**.

4.2.3.1. Acoelomates (No Coelom): Body cavity is absent and coelomic space is occupied by parenchyma-like cells **(Figure 8a).** (The space between the body wall and gut is filled up by mesenchyme).

Examples: Platyhelminthes.

4.2.3.2. Pseudocoelomates (False coelom): Animals having false coelom **(Figure 8b).**

The space between the body wall and gut encloses a fluid filled cavity which is not lined by mesodermal epithelial cells (organs are free within the space, as there is no peritoneum bounding). Mesoderm appears as scattered pouches in between ectoderm and endoderm

In these animals pseudocoelom is formed from the embryonic cavity called blastocoel.

Examples: Roundworms.

4.2.3.3. Coelomates or Eucoelomates: Animals with true body cavity

A true coelom arises entirely within the mesoderm germ layer (The body-cavity present between the body wall and gut is lined by a peritoneum) **(Figure 8c).**

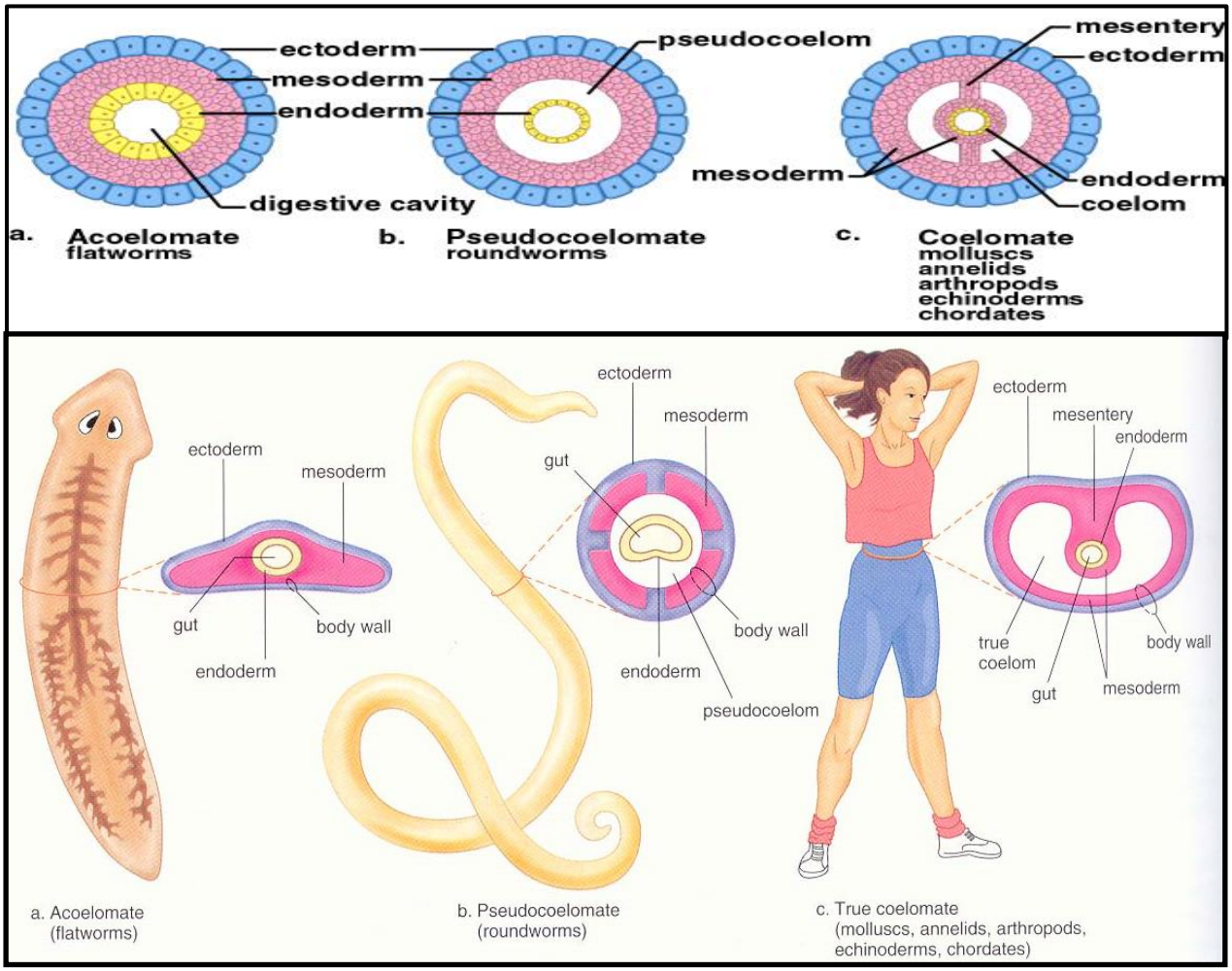


Figure 8: Diagrammatic sectional view of: (a) Coelomate (b) Pseudocoelomate (c) Acoelomate.

Body cavity completely lined with mesoderm. It is of three types:

- **Schizocoelom:** It develops due to the split in the mesoderm sheet **(Figure 9)**.

Examples: Arthropods, Molluscs, Annelids

- **Enterocoelom:** The mesoderm arises from the wall of the embryonic gut as a hollow outgrowth and forms the coelom **(Figure 9)**.

Examples: Echinoderms, Chordates

- **Haemocoelomates:** In Arthropods and Molluscs, the true coelom is reduced and filled with blood and known as haemocoel.

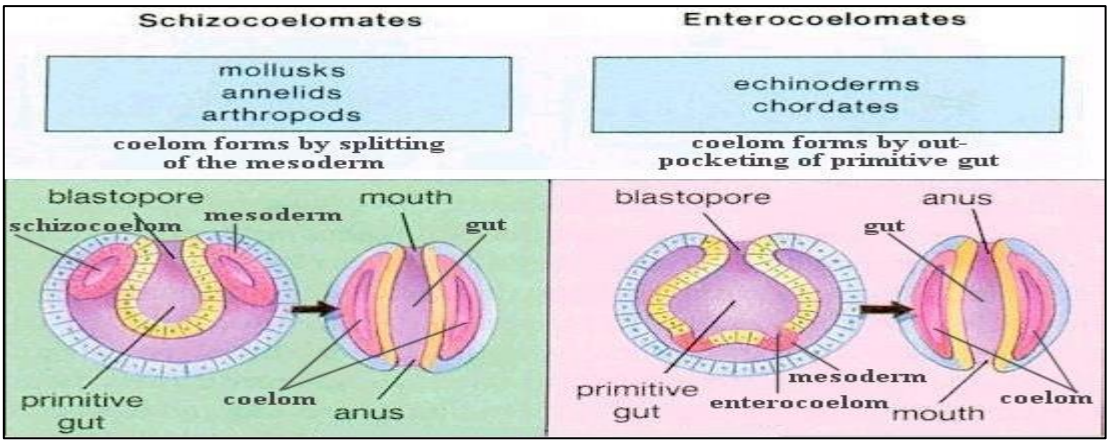


Figure: 9 Type of true coelom.

4.2.4. The fate of the blastopore (Protostomia or Deuterostomia)

Depending on the fate of the blastopore (orifice of the blastula), coelomate can be divided into two distinct evolutionary lines **(Figure 10)**:

✓ **The blastopore** is the **first opening in the embryo** – the point of invagination during gastrulation.

✓ The **blastopore** will **eventually become** either the **mouth** or the **anus.**

✓ **In protostome** development, the **blastopore becomes** the **mouth-first**, and **anus second.**

✓ The **term Protostomia** (from the Greek "**proto**," meaning **first**, and "**stoma**," meaning **mouth**).

✓ **In deuterostome** development, the **blastopore becomes** the **anus first** and **then the mouth.**

✓ The **term Deuterostomia** (from the Greek "**deutero**," meaning **second**, and "**stoma**," meaning **mouth**).

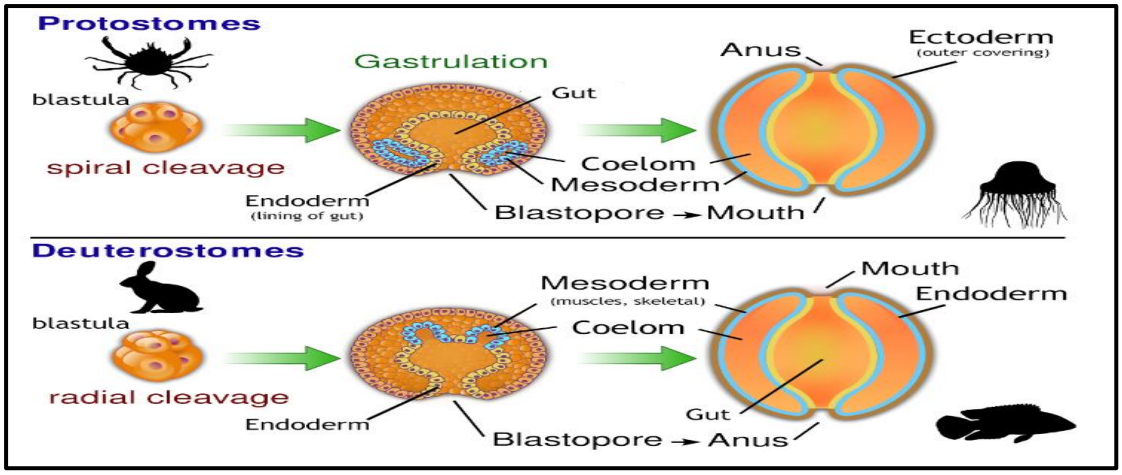


Figure 10: The Fate of the Embryonic Mouth or Blastopore.

4.2.5. Levels of organization

It exhibits considerable variation among animals.

Following are the major **types = 5 levels** (based on organization of cells) **(Figure 11)**:

4.2.5.1. Protoplasmic level of organisation: A cellular body performs all the biological activities.

Example: Protozoa.

4.2.5.2. Cellular level: The body is formed of loose cell aggregates. Cells are arranged as loose cell aggregates. It shows no co-ordination to form tissues.

Individual cells are capable of performing specific functions.

Examples: Sponges.

4.2.5.3. Tissue level: Cells are arranged into tissues.

Cells performing similar function are aggregated to form tissues.

Examples: Cnidaria, Coelenterates (hydra).

4.2.5.4. Organ level: Tissues are grouped to form organs.

Tissues are grouped together to form organs.

Each organ is assigned to execute specific function.

Examples: Platyhelminthes and other higher phyla.

4.2.5.5. Organ-system level -Organs have associated to form functional systems, carrying out a specific physiological function.

A group of organs working together as a larger unit is called an organ system

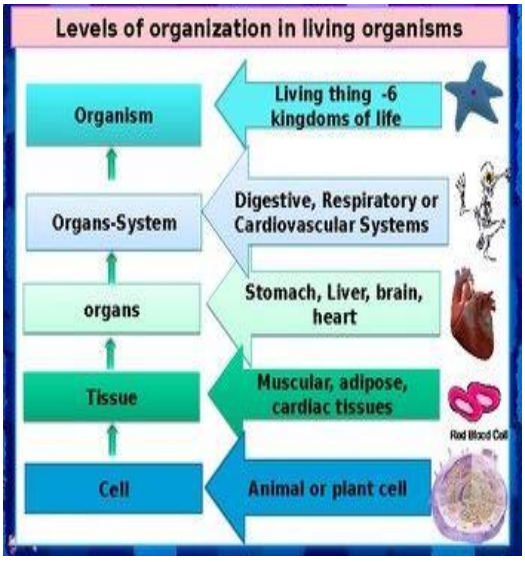


Figure 11: Levels of organization.

Chaptre I **4. Introduction to the animal kingdom**

Organ system exists in various patterns as illustrated below:

❖ **Digestive system**

In animals, the mouth, tongue, teeth, salivary glands, pharynx, oesophagus, stomach, small intestine, large intestine, liver, gall bladder, bile ducts and pancreas together constitute the digestive system. It is of two types **(Figure 12)**:

➢ **Incomplete:** digestive system has only a single opening to the outside of the body. It acts as both anus and the mouth.

Examples: Platyhelminthes and Coelenterates

➢ **Complete:** The digestive system has two separate openings at each end, the mouth and the anus.

Examples: all Vertebrates and In many invertebrates.

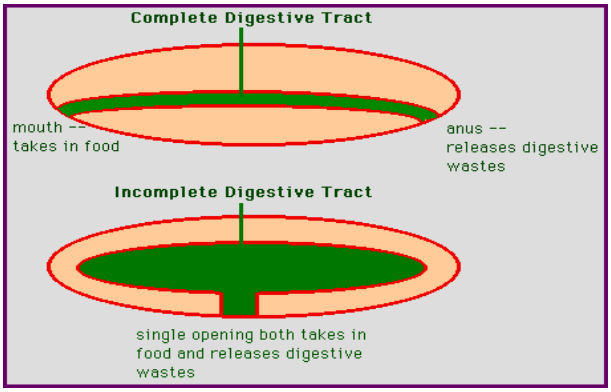


Figure 12: Type of digestive system.

❖ **Circulatory system**

It is of two types **(Figure 13)**:

➢ **Open type:** Blood is pumped out of the heart, and the tissues are bathed in it.

Examples: Arthropods and Molluscs

➢ **Closed type:** Blood flows inside blood vessels of varying diameters (arteries, veins, capillaries) without coming in direct contact with body cells.

Examples: In many invertebrates (Cephalopods), and all Vertebrates.

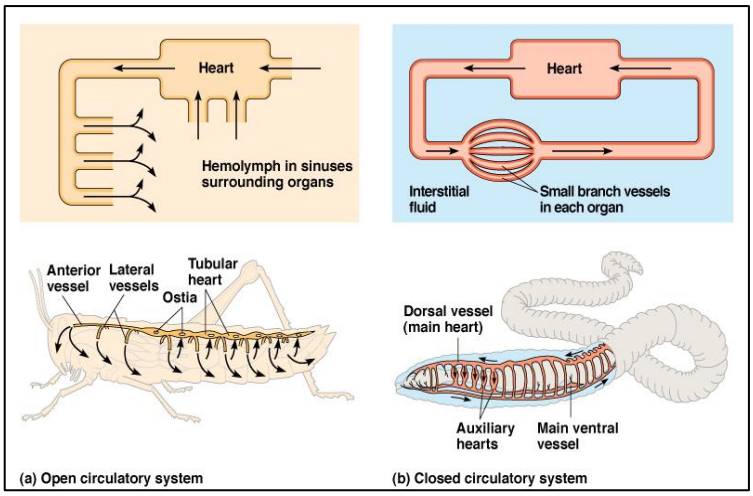


Figure 13: Circulatory systems in animals.

4.2.6. Body symmetry

Symmetry, in biology, the repetition of the parts in an animal or plant in an orderly fashion. Specifically, symmetry refers to a correspondence of body parts, in size, shape, and relative position, on opposite sides of a dividing line or distributed around a central point or axis. With the exception of radial symmetry, external form has little relation to internal anatomy, since animals of very different anatomical construction may have the same type of symmetry.

Animals can be categorised on the basis of their symmetry.

Animals exhibit 3 types of symmetry **(Figure 14):**

4.2.6.1. Asymmetry

Body cannot be divided in to two equal halves through any plane passing through centre.

Examples: Sponges.

4.2.6.2. Radial symmetry

Body can be cut into two exact halves through any plane which pass through the central axis. Such animals have two ends in the main body axis the oral and aboral end, but no left and right sides.

Examples: Coelenterates, Ctenophora and Echinodermata.

4.2.6.3. Bilateral Symmetry

Body can be divided into two identical halves only through a single plane passing through central axis. These animals have a front and rear end ("head" and "tail"). They also have an upper and lower side (dorsal vs. ventral). They have equivalent left and right lateral sides.

Examples: Annelids, Arthropods, etc.

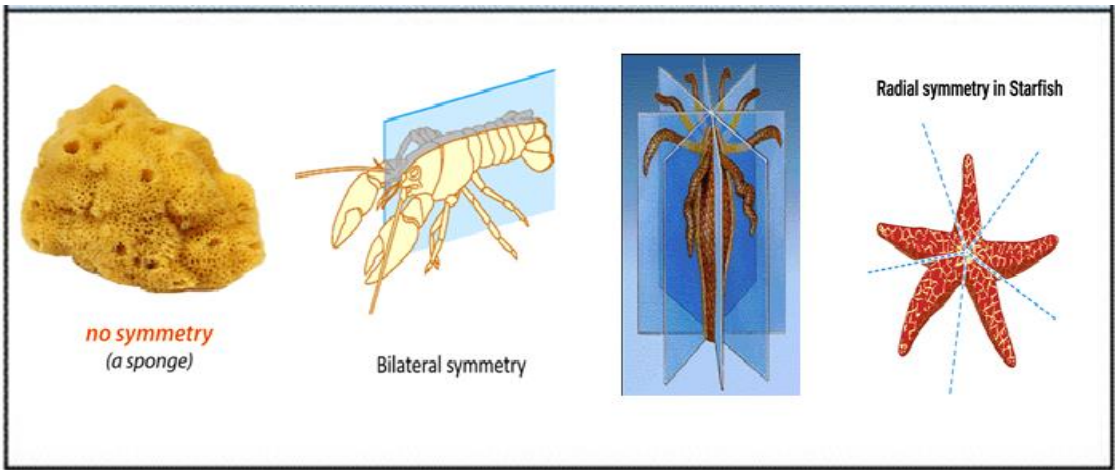


Figure 14: Types of Symmetries in animals.

4.2.7. The position of the nervous system

According to structure of the nervous system, it is possible to distinguish three classes of nervous system **(Figure 15):**

4.2.7.1. Hyponeurians: include animal with a system ventral nerve.

Examples: Annelids, Molluscs, Arthropods.

4.2.7.2. Epineurians (dorsal nervous system): They have nerve centers located above the digestive tract. **Examples:** Chordata.

4.2.7.3. Epithelioneurians (nerves in the epithelium): The nervous system is generally imperfectly free of the ectoderm.

Examples: Phylum Echinodermata.

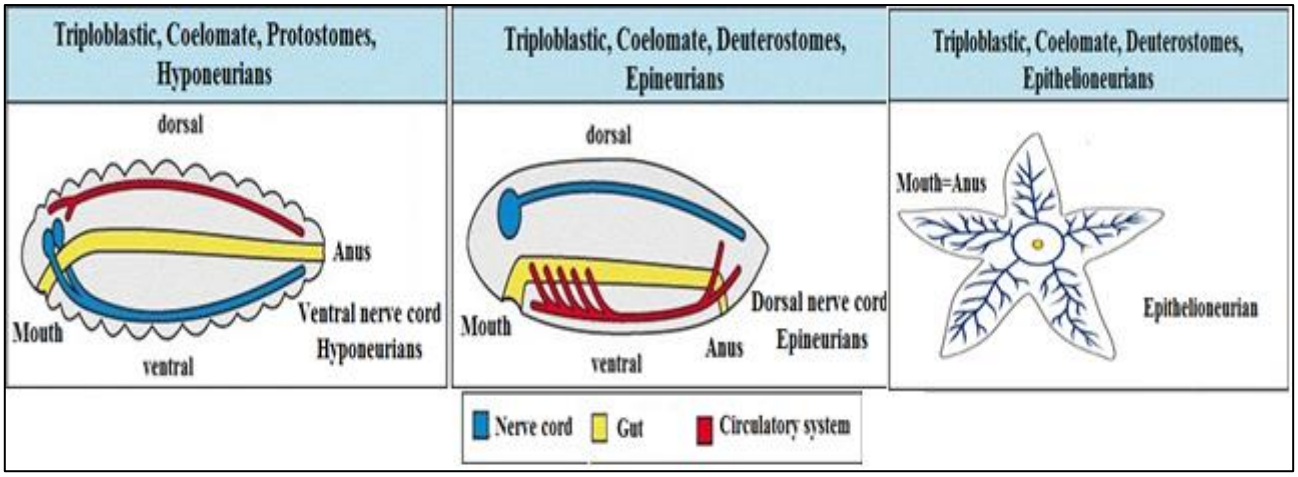


Figure 15: The position of the nervous system.

4.2.8. Metamerism (Segmentation)

In some animals the entire length of body is transversely divided in to a number of ring like parts called segments. This phenomenon of segmentation is called metamerism. It is of four types **(Figure 16):**

4.2.8.1. Metameric segments (True segmentation): The body is externally and internally divided into segments with a serial repetition of at least some organs. In earthworms the segmentation helps in locomotion. **Examples:** Annelida, Millipedes and Centipedes.

4.2.8.2. External Segmentation: In arthropods the metameric segments may be paired appendages for various functions such as legs for locomotion, antennae for sensory functions and mouth for feeding etc… **Examples:** In insects, these metameric segments are grouped to form body regions like head, thorax, and abdomen.

4.2.8.3. Internal Segmentation

Exemples : Chordata.

4.2.8.4. Pseudometameric segments (False segmentation): The segments of the body are not formed from the embryo and thus are known as pseudometamerism. **Exemples :** Tape worm.

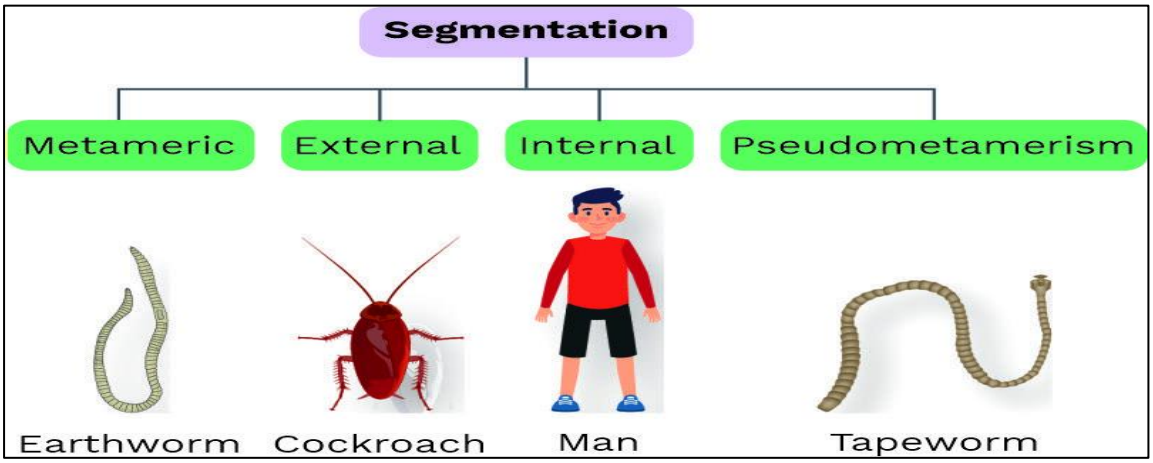


Figure 16: Types of Metamerism (Segmentation).

4.2.9. Presence of Notochord

It is a mesodermally derived rod like structure present dorsally during embryonic development in some animals.

It is a stiff and flexible rod of tissue running along the dorsal side below the nerve cord and above the alimentary canal.

➢ Based on the presence or absence of notochord, animals are classified in to 2 groups **(Figure17):**

4.2.9.1. Chordates: Animals with notochord. In chordates, the notochord is present at some stage in their life. **Exemples :** Fishes, Birds, Mammals, etc.

4.2.9.2. Non-chordates: Animals without notochord. They do not possess the notochord at any stage of their life. **Exemples :** Porifera to Echinoderms.

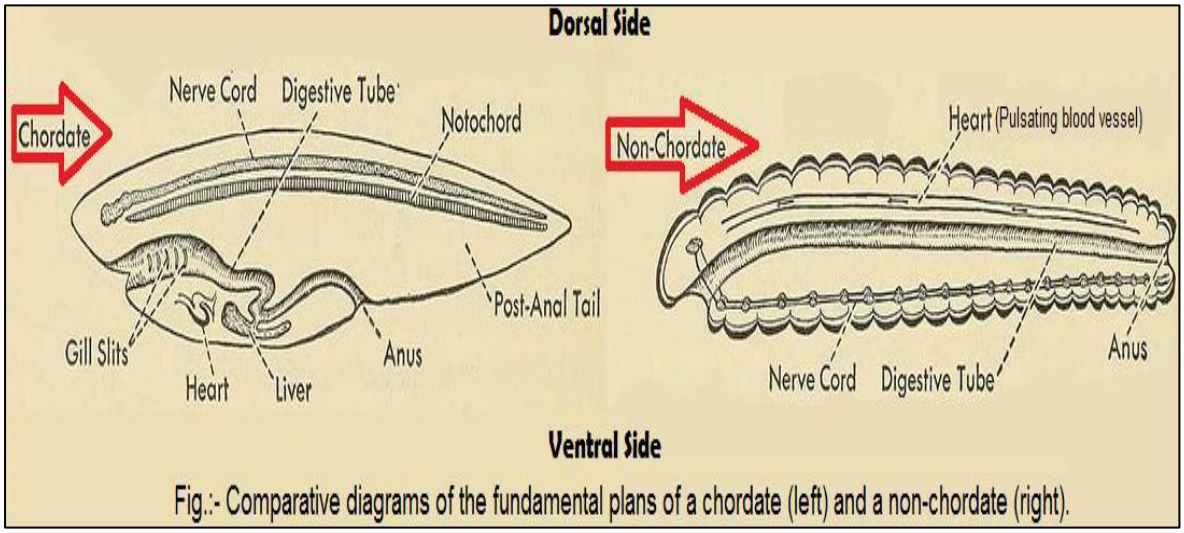


Fig.:- Comparative diagrams of the fundamental plans of a chordate (left) and a non-chordate (right).

Figure 17: Comparative digestive of the fundamental plans of a chordate and non-chordate.

4.2.10. Presence or absence of a vertebral column (backbone):

Presence or absence of a vertebral column (backbone) is the fundamental structural trait used in biology to classify the animal kingdom into two primary categories: vertebrates and invertebrates.

4.2.10.1. Vertebrates: Have a backbone, a well-developed internal skeleton made of bone or cartilage, and complex organ systems.

4.2.10.2. Invertebrates: No backbone, often have exoskeletons (outer coverings), and simpler organ systems.

4.2.11. Skeletal systems

The framework of the body that gives shape and protection to the animals is known as skeleton. Usually, one of three main kinds of skeletal systems **(Figure18)**:

4.2.11.1. Hydrostatic skeleton: Water fills spaces within the organism.

Examples: Cnidarians, Fatworms, Nematodes and Annelids.

4.2.11.2. Exoskeleton: It is present outside the body.

Examples: It is of different types like chitin in arthropods, Calcareous shells in Mollusca, Epidermal scales in reptiles, Feathers in birds, Hair, nails, claws, horns in Mammals.

4.2.11.3. Endoskeleton: Hard structure that is present inside the body.

Examples: Bones present inside the body, like Mammals.

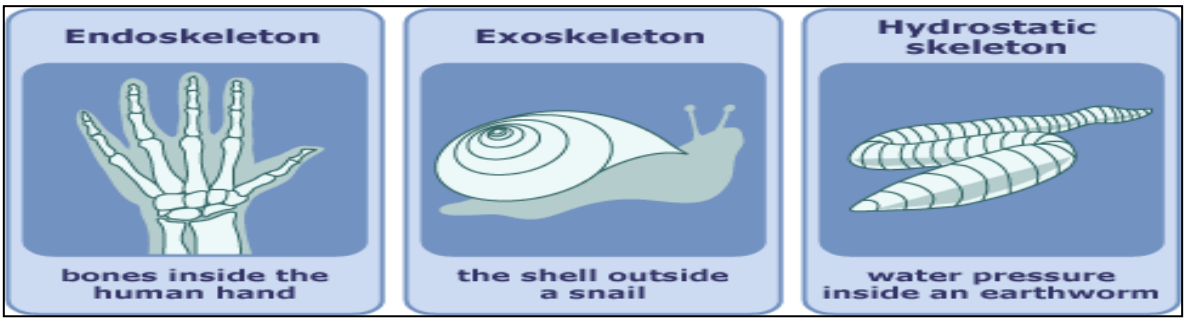


Figure 18: Types of support structures

4.2.12. Body Temperature

On the basis of body temperature, organisms are of two types :

4.2.12.1. Homeotherms (Warm-blooded animals) : The body temperature does not change with the change in ambient temperature. **Examples :** Birds, Mammals.

4.2.12.2. Poikilotherms (Cold-blooded animals) : The body temperature changes with the change in the ambient temperature. **Examples :** Amphibians, Pisces, Reptiles.

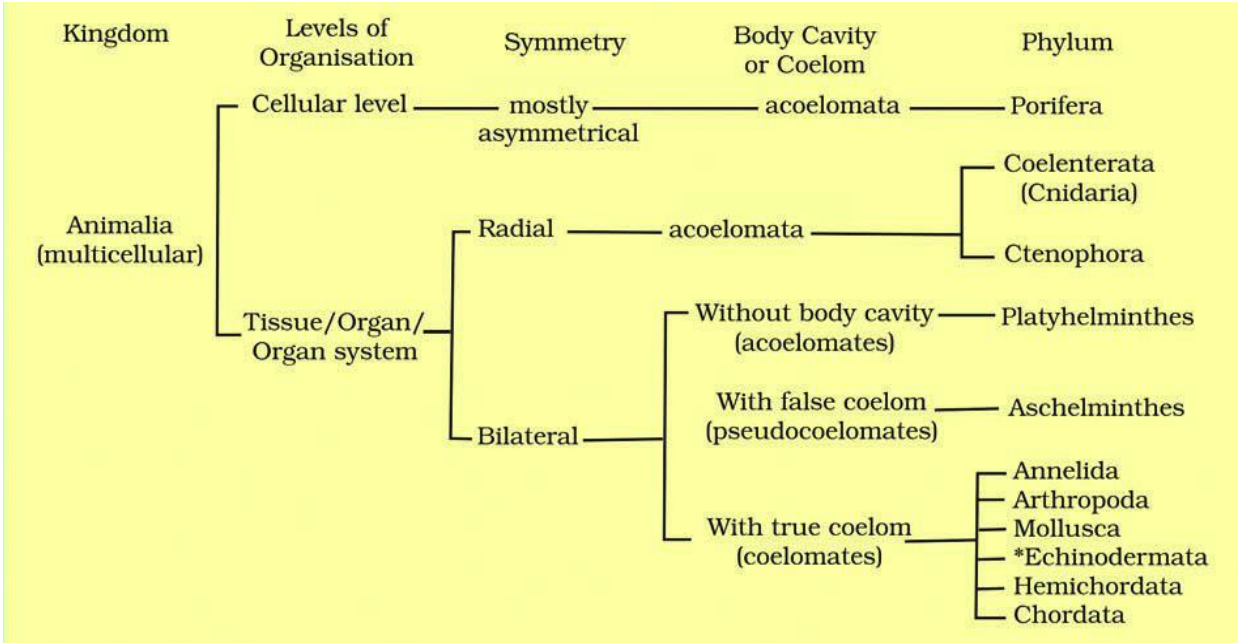


Figure 19: Organizational plan of the animal kingdom.

Chaptre II- Subkingdom of Protozoa

Subkingdom of Protozoa

Protozoa (Gr., protos = first ; zoon = animal) = **The First Animals.**

The Protozoa are considered to be a subkingdom of the kingdom Protista, although in the classical system they were placed in the kingdom Animalia. More than 50,000 species have been described, most of which are free-living organisms; protozoa are found in almost every possible habitat.

First discovered by **Antony Von Leeuwenhoek** in 1671.

Van Siebold (1845) identified protozoans **as single cellular organisms**.

Dobell named them as **acellular** or **Non-cellular animals**.

Goldfuss named these organisms as **Protozoans.**

General Characters of protozoa

- ✓ Minute, generally microscopic organisms 0.002 mm to 16mm in size.
- ✓ Eukaryotic organisms.
- ✓ The simplest and primitive of all the animals.
- ✓ Unicellular organisms.
- ✓ Without tissues and organs.

A protozoan body consists of only mass of protoplasm, so they are called acellular or non-cellular animals (without tissue and organs). They have one or more nuclei which are monomorphic or dimorphic.

- ➢ **Level of body organization or Grade of organization:** Protozoan animals exhibit Protoplasmic grade of organization. There is division of labor among varions organelles of the cell.
- ➢ Single cell performs all the vital activities thus the single cell acts like a whole body.
- ➢ **Habitat:** Mostly aquatic (fresh and salt water), Terrestrial**,** either free living (*Paramecium*) or parasitic (*Plasmodium*) or symbiotic or commensally or Pathogenic (*Entamoeba histolytica*, *Leishmania*).
- ➢ Lives in water, soil, air, on animals and inside the animals.
- ➢ They are solitary (existing alone/single) or colonial (individuals are alike and independent).
- ➢ **Locomotion:** They possess different types of locomotory organs **(Figure 20, 21)**.
- ✓ They may bear flagella (in Flagellata), cilia (Ciliata) or pseudopodia false foot (in Rhizopoda or Sarcodina), absent locomotory organs in the parasitic forms (in Sporozoa).
- ➢ **Great variety of shape:** Usually microscopic with oval, spherical elongated, ball shaped, some are flattened or ever-changing shape shapeless (or) irregular.
- ➢ **Body of protozoa:** The protozoan cell body is either naked or surrounded by a non-rigid pellicle. Cellulose is absent in the pellicle. Some protozoans secrete shells of various inorganic compounds as external covers or exoskeleton madeup of $CaCo_3$ or silica.
- ➢ **Cytoplasm:** Outer ectoplasm and inner endoplasm.

- **Body symmetry** : Symmetrical (*Actinopodeans*) or Radial (sessile forms) or Spherical, Bilateral (*Giardia*) or Asymmetrical (*Amoeba*).
- **Digestion:** Digestion is intracellular, occurs in food vacuoles.
- **Nutrition:** They are holozoic (animal-like) and feed largely on bacteria, microscopic algae and minute animals such as rotifers or on other protozoan's including members of their own species.
  - ✓ Some are holophytic (plant-like), they contain chlorophyll and prepare their own food by photosynthesis (*Euglena*).
  - ✓ Some are saprozoic (subsisting on dead organic matter) and saprophytic (feeding on liquid food).
  - ✓ The parasitic protozoans devour on materials obtained from the hosts (Monocystis).
- **Respiration:** No special respiratory organs, Respiration occurs by diffusion through the general body surface **(**Aerobic). Respiration is anaerobic in some parasitic forms
- **Excretion**: Through general body surface or through contractile vacuoles which serves mainly for osmoregulation. The excretory product is ammonia.
- **Osmoregulation:** The osmotic concentration of cell body, is maintained by one or more contractile vacuoles and these contractile vacuoles are help in excretion (in freshwater froms).
- **Mode of Reproduction (Figure 22)**

✓ **Asexually reproduction** is through Binary Fission (Transverse binary fission or Longitudinal binary fission) or Multiple fission (Schizogony), Budding, Sporulation, Plasmotomy.

✓ **Sexual reproduction** is performed by the fusion of gametes (syngamy)or by conjugation.

✓ Many forms undergo **encystment** to tide over unfavorabel conditions.

- **Life cycle:** The life cycle often complicated with alternation of asexual and sexual phases (alternation of generation).

Classification of Protozoa

Subkingdom protozoan's are a larger and varied group and possess a number of problems in its classification. The conventional scheme followed by Hyman (1940), Hickman (1961) B.M. Honigberg (1964), Store (1965) and Carlis (1967) etc. recognizes two subphyla on the basis of organs of locomotion and 5 Phyla, briefly outlined as follows:

1. Phylum : Sarcomastigophora.
2. Phylum : Apicomplexa (Sporozoa).
3. Phylum : Ciliophora.
4. Phylum : Microspora.
5. Phylum : Myxozoa.

Kingdom : Protista

Chaptre II **1. Subkingdom of Protozoa**

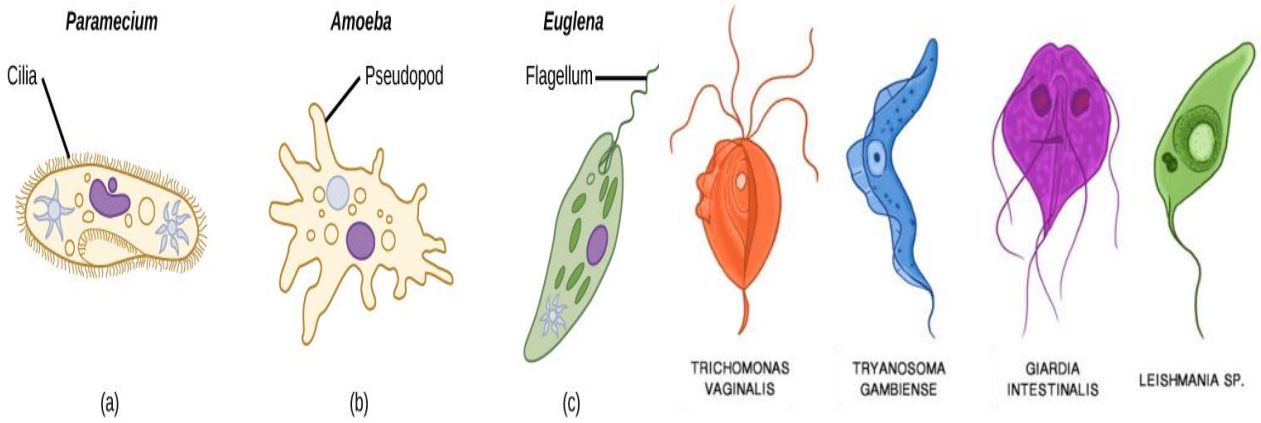


Figure 20: Locomotor organelles in Protozoa.

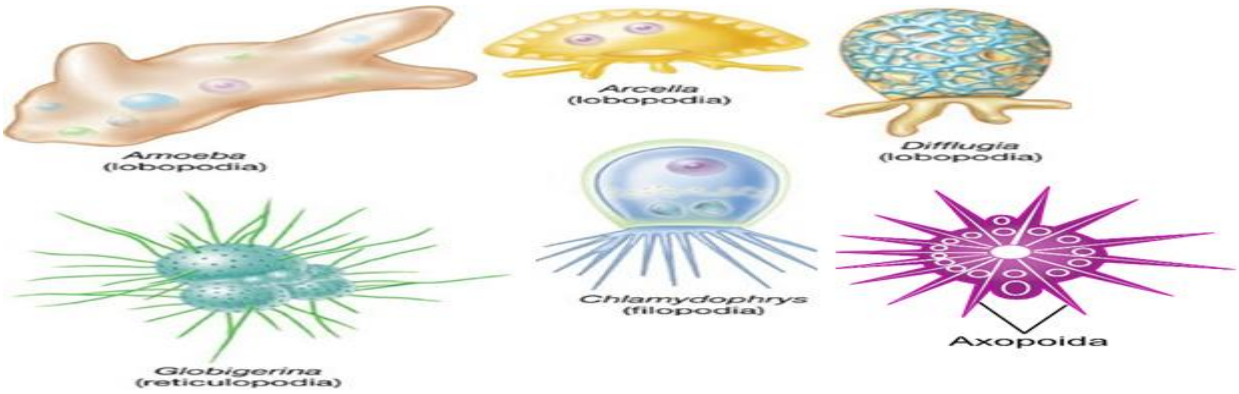


Figure 21: Type of pseudopodia.

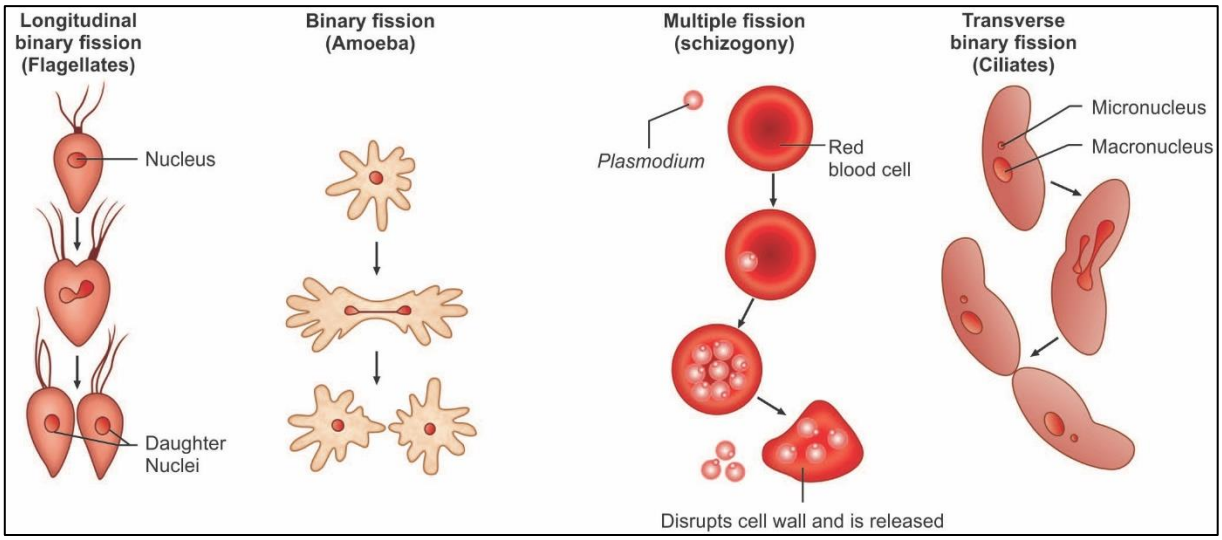


Figure 22: Type of reproduction in some Protozoa.

1. Phylum Sarcomastigophora

Gr: Sarcode = Fleshy; Mastix =Whip; Phoros = Bearing

- Locomotory organs are **flagella , pseudopodia** or any one of them **(Figure 20)**.
- The nucleus is of a single type (monomorphic).
- Body is covered by protective Pellicle.

Classification of Phylum Sarcomastigophora

This phylum is divided into two sub phyla: Subphyla Sarcodina and Subphyla Mastigophora

1.1. Subphyla Sarcodina

- Usually one nucleus is present.
- Body naked with out definitive shape or with external or internal skeletons, and solitary
- **Locomotary organ:** By Pseudopodia, Amoeboid locomotion **(Figure 20, 21)**.
- **Nutrition** is **holozoic or saprozoic**
- **Food vacuoles, contractile vacuoles** are present. Marine forms lack contractile vacuoles.
- **Mode of life:** Mostly free living (Example *Amoeba proteus*) but some are parasites (Example *Entamoeba histolytica*), some are Symbiotic (Example *Entamoeba coli*).
- **Habitat:** They live in the freshwater, sea or moist soil, biological fluids.
- **Respiration and excretion:** By simple diffusion.
- **Reproduction:** Asexually by Transverse binary fission **(Figure 22)** and sexually by syngamy.
- Some have a hard shell. **Examples:** *Arcella, Diffugia,*.

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 **(Figure 21)**.

They are divided into two superclasses: **Rhizopoda** and **Actinopoda**:

1.1.a. Super-class 1/ Rhizopoda

Locomotory organelles are pseudopodia (lobopodian or filopodia but never axopodia) **(Figure 21)**.

They are generally creeping forms.

This superclass divided into two classes: Class Lobosea and Class Foraminifera.

a.1. Class 1/ Lobosa

- 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.
- Asexual reproduction by binary fission.

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

a.1.1. Subclass 1/ Gymnamoebia/ Gymnamoebiens

Order 1 / Amoebida

- Body amoeboid shaped, without skeleton **(Figure 23)**.
- Pseudopodia (lobopodia) short with blunt ends **(Figure 21)**.
- Ectoplasm and endoplasm distinct.
- The contractile vacuole responsible for osmoregulation Without it the Amoeba would expand and burst.
- Largely fresh water, some parasites.
  - **Amoebiens parasites**. **Examples**: *Entamoeba histolytica:* That live in the digestion cannal but is able to effect the tissues like the liver, the lungs and the brain. Is the causative agent of the anatropous **disease amoebiasis** (Amoebic dysentery). The life cycle of *E. histolytica* begins and ends inside one single host, i.e., an individual human being **(Figure 24).**
  - *Entamoeba gingivalis:* is found in mouth near the base of the teeth.
  - ***Entamoeba coli E. coli*** is a nonpathogenic amoeba that colonizes the large intestine.
  - **Amoebiens libres.** **Examples:** *Amoeba proteus*.

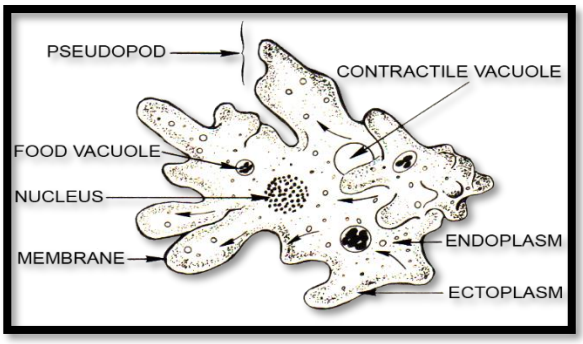


Figure 23: Structure of an *amoeba*.

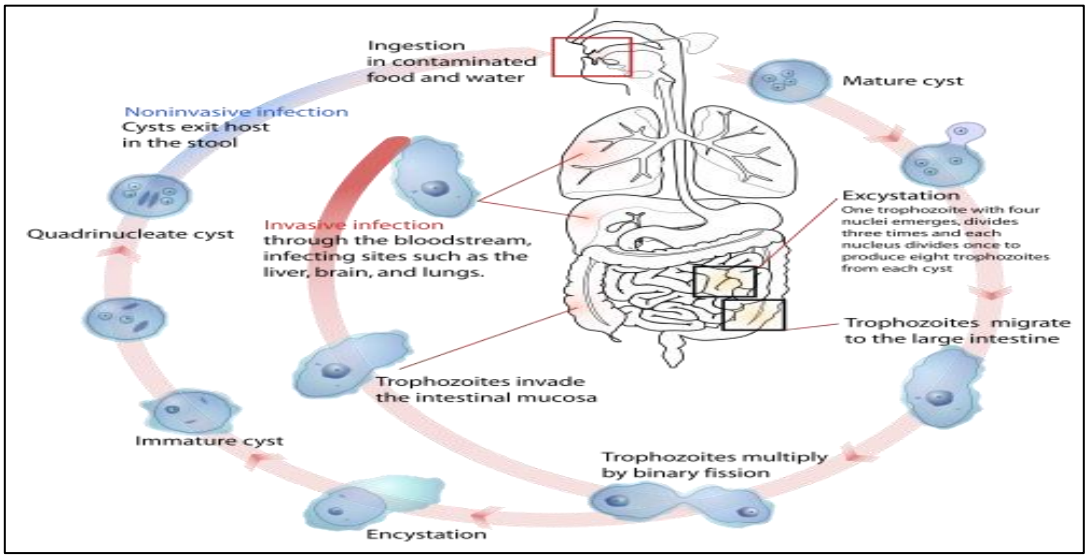


Figure 24: Life cycle of *Entamoeba histolytica.*

a.1.2. Subclass 2/ Testacea/ Thecamoebians

Ordre 1 /Arcellinida (Testacida)

- Body enclosed in one chambered shell **(Figure 25).**
- Shell with a single opening through which lobopodia protrude.
- Free living, found in fresh water.

Examples: *Difflugia*, *Arcella*, *Euglypha, Trichosida.*

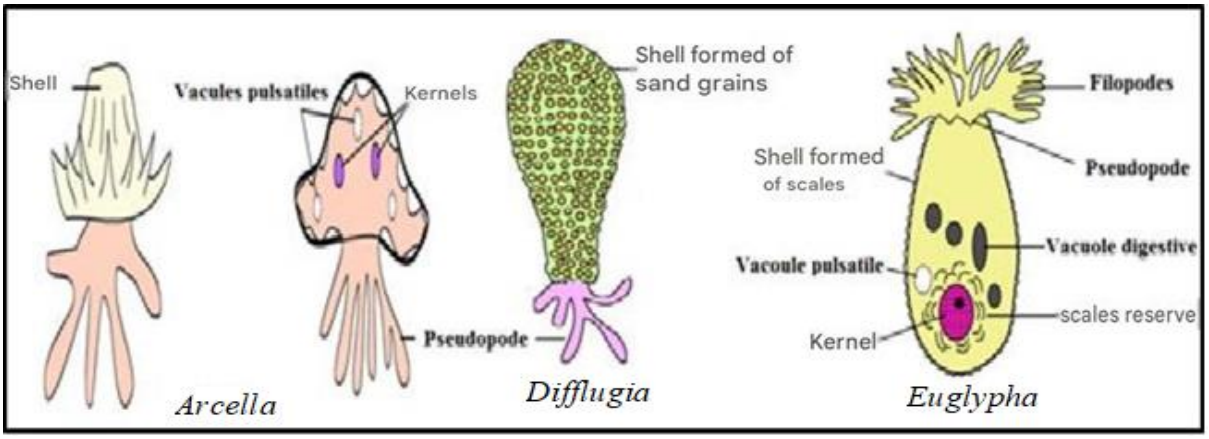


Figure 25 : Different forms of the theca and pseudopods in testate rhizopodes.

a.2. Class 2/ Granuloreticulosa /Foraminifera

They have finely granular reticulose rhizopodia (reticulopodia).

a.2.1. Order 1 /Foraminiferida

- Large sized with uni or multichambered shell **(Figure 26).**
- Shell with one or more opening through which reticulopodia emerge.
- Reticulopodia fine and branching is forming a network.
- Mainly marine.

Examples: *Globigerina.*

Foraminiferaare classified primarily on the bases composition and morphology of the test.

Three basic wall compositions are recognised, organic (protinaceous mucopolysaccharide i.e. the allogromiida), agglutinated and secreted calcium carbonate (or more rarely silica). That mean its classification ranges between order and phylum.

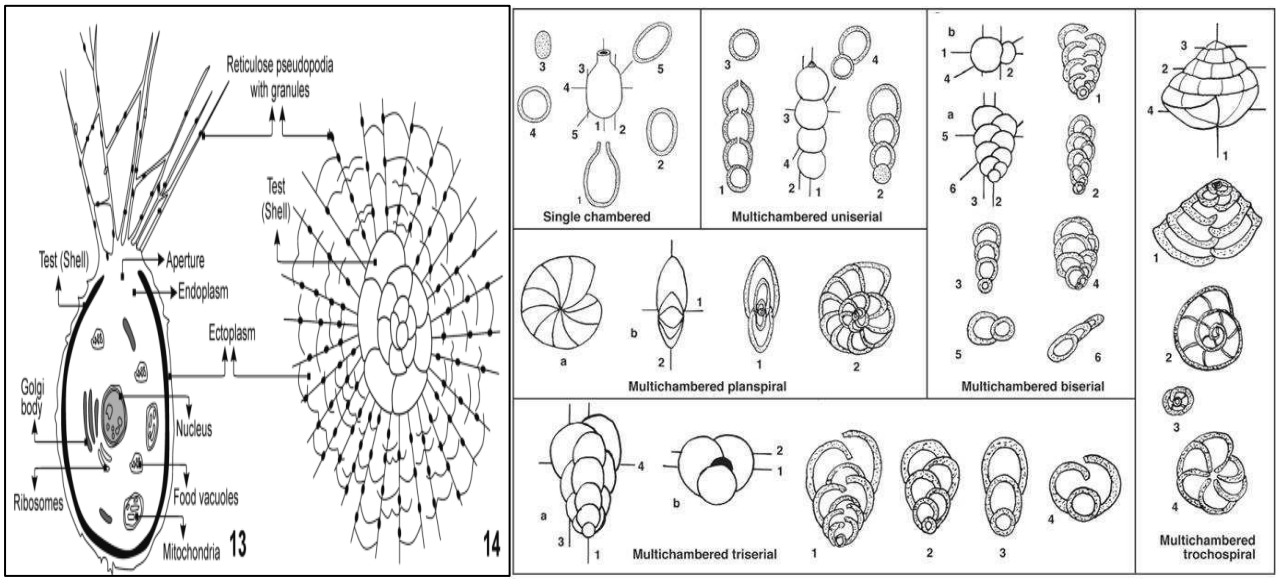


Figure 26 : Structure and different types of tests in foraminifera.

1.1.b. Super-class 2/ Actinopoda

- Unicellular marine organisms, Free living, they are adapted to planktonic life planktonic.
- Spherical body with calcaleous 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.
- Reproduction is asexual by binary division or budding or sexual with the involvement of cyst.

Classification : This superclass comprises three classes: **(Figure 27)**

b.1. Class 1/ Acantharea /Actantharia

- Central capsule non chitinoid and without pores.
- Skeleton of strontium sulphate.
- Pseudopodia are axopodia.
- Reproduction : asexual by binary fission.
- Pelagic marine, planktonic, solitary or colonial.

Examples: *Acanthrometra*.

They are divided into five orders:

Holacanthida ; Symphyacanthida ; Chaunacanthida ; Arthracanthida ; Actineliida.

Examples: *Dorataspis sp.*

b.2. Class 2/ Phaeodarea/ Radiolaria

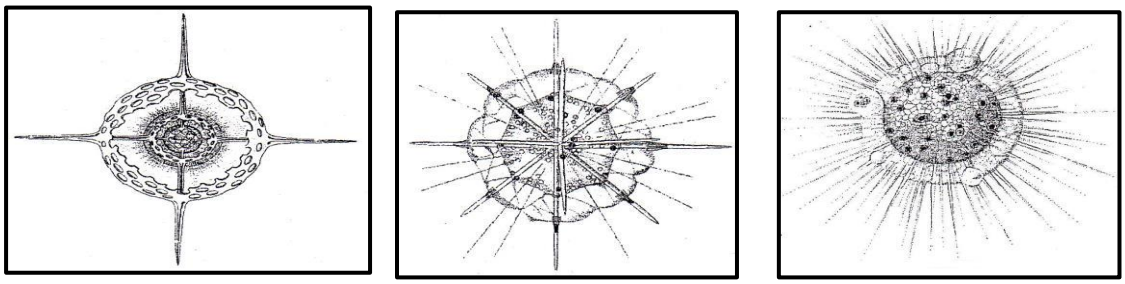
- Perforated central capsule separating the ectoplasm from endoplasm.
- Contractile vacuole absent.
- Pseudopodia are axopodia or filopodia.
- Skeleton of siliceous spicules.
- Marine.
- Reproduction occurs by fission and by zoospores formed in the central capsule.
- They may be solitary or colonial, some colonies as many centimeters.

Examples: *Collozoum ; Lampoxanthium.*

b.3. Classes 3 / Heliozoea

- Unicellular and spherical in shape, without any shell .
- Pseudopodia (axopodia) radiating.
- Body naked and differentiated into outer vacuolated ectoplasm and inner dense endoplasm.
- Nutrition holozoic.
- Mostly freshwater.
- Reproduce by simple division or budding

Examples: *Actinophyrus ; Clathrulina ; Actinosphaerium ; Acanthocystis aculeata ; Actinolophus pedunculatus.*



Acantharia Radiolaria Heliozoa

Figure 27 : Different forms of Actinopoda.

1.2. Subphyla Mastigophora/ Flagellata

Locomotory organ: One or more flagella **(Figure 28).**

Nutrition is **holozoic** or **saprozoic** mostly **parasitic.**

Mode of life: Few species are free living; Most parasitic form.

Habitat: They live in the freshwater, sea or moist soil, biological fluids.

Reproduction: Asexual reproduction by Longitudinal binary fission.

Examples: *Giardia, Euglena, Trypanosoma.*

They are divided into two classes: Phytomastigophora, and Zoomastigophora.

1.2.1. Classe 1/ Zoomastigophorea/Zooflagellata

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

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

Classification : There are six orders amongst them :

Kinetoplastida ; Diplomonadida ; Trichomonadida ; Hypermastigida ; Choanoflagellida ; Opalinida.

1.2.1.a. Order 1/ Kinetoplastida

- Small and more or less amoeboid in form.
- Flagella 1 or 2.
- Holozoic or saprozoic nutrition.
- Solitary or colonial.
- Parasitic forms living in blood.

Examples: *Leishmania, Trypanosoma.*

There are two sub-order: S/Order 1/ Trypanosomatina, S/ Order 2/ Bodonina **(Figure 28 A)**.

a.1. Sub Order 1/Trypanosomatina

Trypanosomes are hemoflagellates, live in the blood and tissues of their human hosts.

- **Genus***: **Trypanosoma***
  - ✓ ***Trypanosoma gambiense*** and ***Trypanosoma rhodesiense.***

Disease: Gambians trypanosomiasis , **west African sleeping sickness**.

Disease: Rhodesian trypanosomiasis, **East African sleeping sickness.**

Vector host : Transmits by tse Tse tse Fly = *Glossina palpalis* **(Figure 29 A).**

Habitat: in the blood stream ,lymphatic node.cerebrospinal fluid.brain.

✓ ***Trypanosoma cruzi***

Disease :Chagas diseases (American trypanosomiasis).

Vector host : Transmits by reduviid bug , kissing bugs (Triatoma infestans).

Habitat: In humans.

- **Genus: *Leishmania sp*=** Causative agents of leishmaniasis are members of the genus *Leihmania* species **(Figure 28 A).**

❖ *Leihmania donovani* (Visceral Leishmaniasis "**Kala azar**").

Habitat: Reticuloendothelial cells of the spleen liver ,bone marrow and visceral lymph nodes.

Vector host & life cycle: Passes its life cycle in two hosts. The vertebrate host is man and other animals Invertebrate host is the tsetse fly (genus Glossina) (Both male and female flies bite man and serve as vectors **(Figure 29 B).**

❖ *Leihmania tropica* (Cutaneous Leishmaniasis "**Oriental sore, Baghdad Button**").

Habitat: reticuloendothelial cells of the skin.

Vector host & life cycle:similar than leishmania donovani but the defferent is stay in The Skin

❖ *Leihmania braziliensis* (American leishmaniasis, Muco-cutaneous Leishmaniasis "**Espundia**").

Habitat: Reticuloendothelial cells of the mucous membrane of the mouth, oral cavity, pharynx or larynx.

Vector host & life cycle:similar than *leishmania donovani*, *L. Tropica* but the defferent is stay in The Skin of the mouth and nouse.

a.2. Sub Order 2/ Bodonina/ Bodonida

Example: *Bodo saltans*: free = Common in stagnant waters **(Figure 28 A).**

1.2.1.b. Order 2/ Diplomonadida

Flagella 3 or 8, one forming the border of undulating membrane **(Figure 28 B, C).**

- Uninucleate, sometimes multinucleate.
- Mostly intestinal parasites.

Example: *Giardia*, *Hexamita*.

b.1. Sub Order 1/ Diplomonadina

Examples: *Giardia intestinalis* (*Lamblia duodenalis*) A parasite that lives in the human intestine and causes hepatic diarrhoea **(Figure 28 B).**

1.2.1.C. Ordre 3/ Trichomonadida

Flagella 4-6 **(Figure 28 C).**

- One flagellum trailing.
- Parasites in genital passage.

Examples: *Trichomonas vaginalis* ; *Trichomonas intestinalis* ; *Trichomonas tenax* ; *Trichomonas caviae.*

Genus: *Trichomonas vaginalis*: Cause of vaginitis in women and urethritis in the man **(Figure 28 C)**.

b.2. Sub Order 2/ Enteromonadina

Examples: *Enteromonas hominis.*

1.2.1.4. Ordre 4 / Hypermastigina / Hypermastigida

Highly specialized forms with numerous flagella **(Figure 28 D)**.

- Kinetosomes or parabasal bodies arranged in a circle or longitudinal or spiral rows.
- Uninucleate or multinucleate.
- Mouth absent, food ingested by pseudopodia.
- Gut parasites of termites and cockroaches.

Examples: *Trichonympha agilis*; *Joenia annectens*; *Lophomonas*

1.2.1.5. Ordre 5/ Choanoflagellida/ Choanoflagellata

- Free living.
- Colonial.
- A collar around the base of a single flagellum **(Figure 28 E)**.
- Nutrition holozoic.

Examples: Solitaire = *Salpingoeca sp* ; Colonial = *Codonosiga sp.*

1.2.1.6. Ordre 6/ Opalinida

- Body covered by flagella or cilia.
- Nuclei 2 to many and monomorphic.
- Nutrition saprozoic.
- Reproduction by binary fission or by gametes.
- Parasites of frogs and toads.

Examples: *Opalina ranarum.*

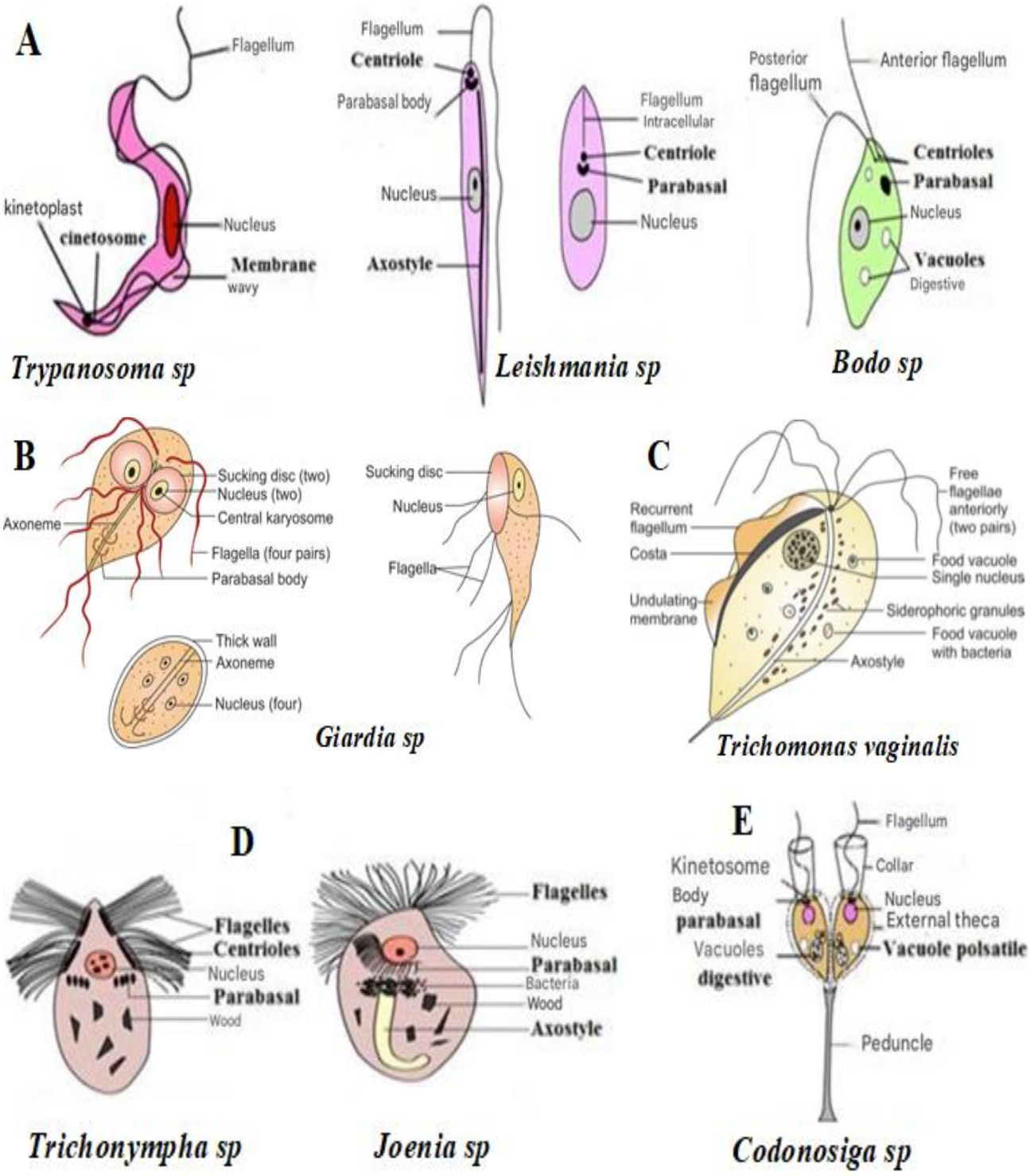


Figure 28 : Different forms of the Zoomastigophorea.

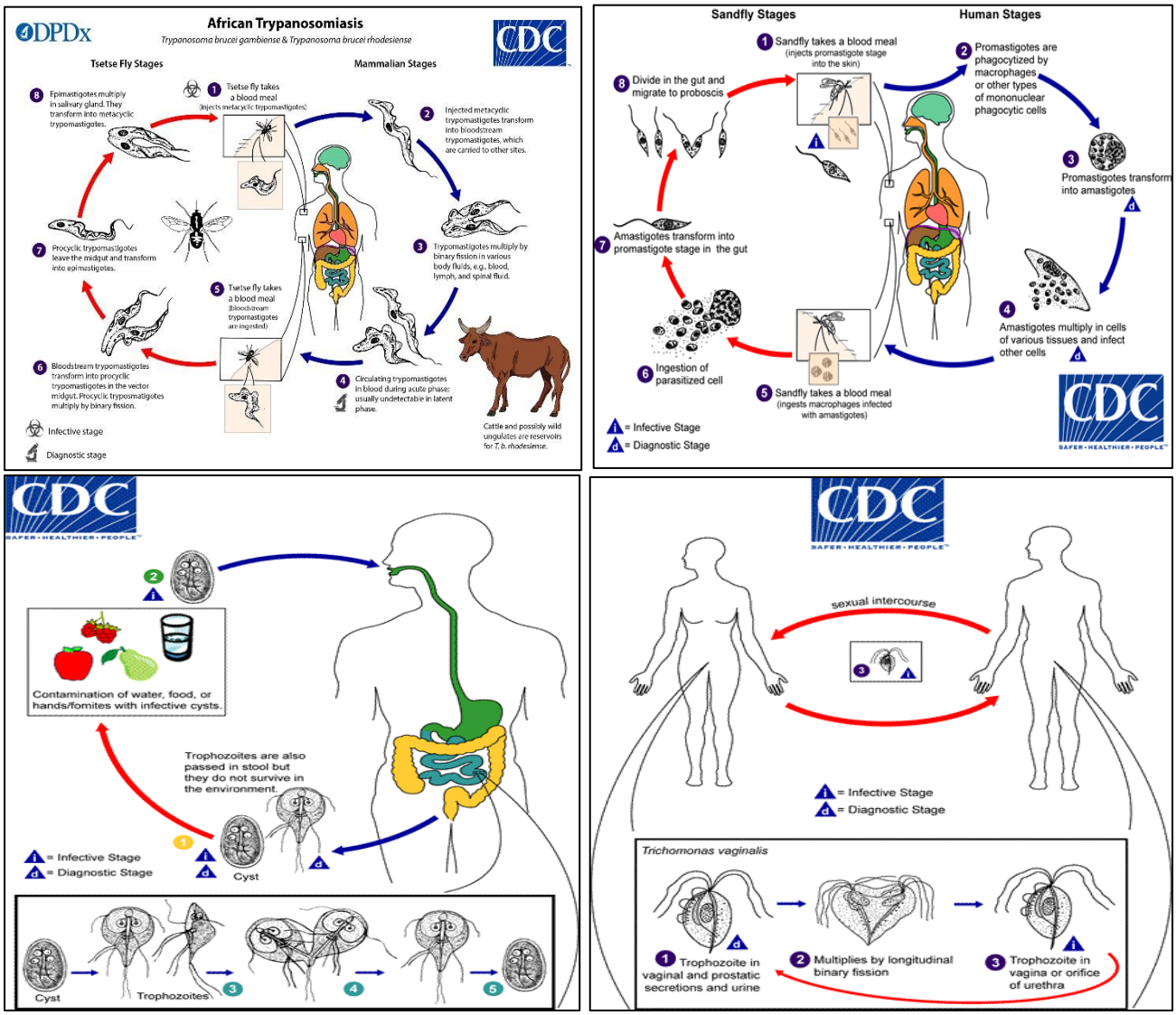


Figure 29 : Life cycle of *Trypanosoma*, *Leishmania*, *Giardia* and *Trichomona.*

1.2.2. Classe 2 / Phytomastigophorea

- Chlorophyll bearing chromatophores present.
- Nutrition holophytic or photophytic.
- Flagella 1 or 2 or many.

1.2.2.1. Ordre 1 / Euglenida

- Anterior end with a gullet or cytophyarynx leading into a reservoir.
- Flagella 1 or 2, and with mastigonemes.
- Chromatophores numerous and green.
- Mostly freshwater.

Examples: *Euglena spirogyra*; *Euglena viridis.*

1.2.2.2. Order 2 / Volvocida

- Small with rigid cellulose covering and no gullet.
- Flagella usually 2, sometimes more.
- Reserve foodstuff starch and oils.
- Stigma present.
- Mostly freshwater, some from colonies.

Examples: *Chlamydomonas, Volvox sp.*

1.2.2.3. Order 3 / Sillicoflagellida

Examples: *Dictyocha.*

1.2.2.4. Order 4 / Dinoflagellida

- Small and planktonic, naked and amoeboid or with a thick pellicle or theca.
- Flagella two.
- Chromatophores numerous, yellow or brown.
- Reserve food starch or oil or both.
- Stigma present; contractile vacuoles two.
- Some are bioluminescent.
- Largely marine.

Examples: *Noctiluca milia*, *Ceratium*, *Gymnodinium*.

2. Phylum Sporozoa /Apicomplexa

- **Locomotory organ:** Absent.
- Exclusively endoparasites (**Obligate parasites**).
- **Habitat:** Intracellular Parasites.
- **Digestion and feeding:** No digestive or contractile vacuoles is absent.
- **Nutrition** saprozoic.
- Body covered with pellicle **(Figure 30).**
- **Mode of life:** Usually 2 or more Hosts required.

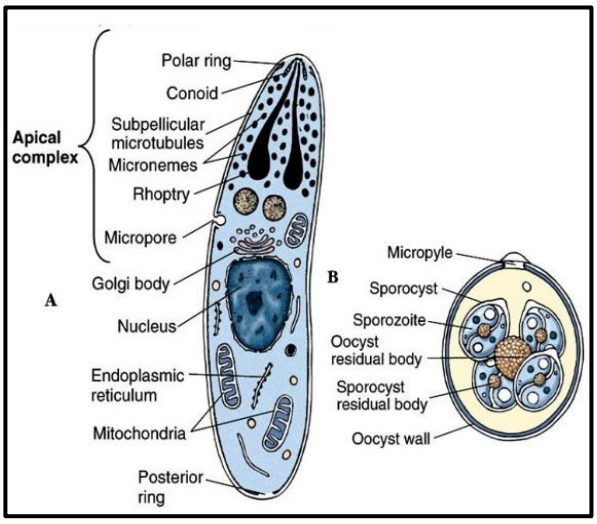


Figure 30: General structure of sporozoites.

- **Reproduction:** Asexual reproduction by multiple fission – schizogony – schizogonic cycle.

  Sexual reproduction by syngamy followed by spore formation. – sporogony sporogonic cycle Female – macrogametes; Male – microgametes
- **Life cycle:** Life cycle with alternating sexual and asexual generations **(Figure 31).**

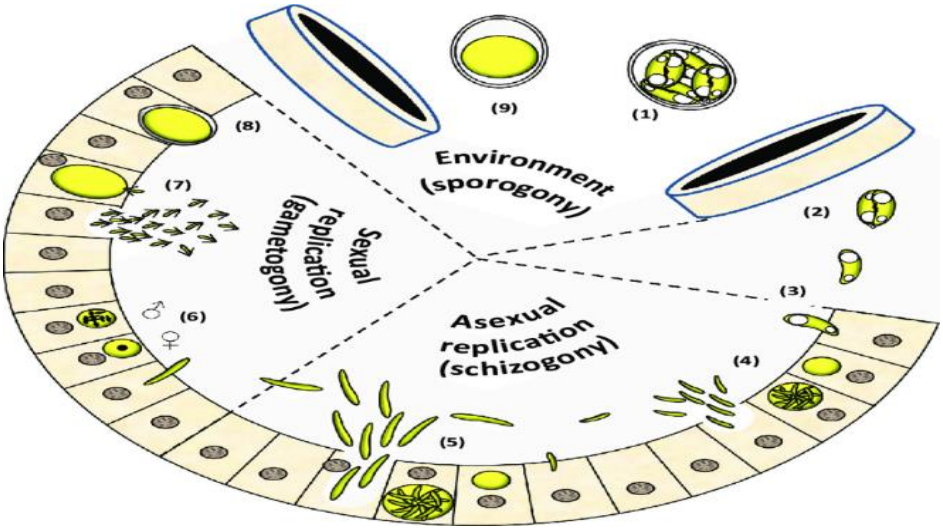


Figure 31: Life cycle of Apicomplexa

Classification of Phylum Sporozoa/Apicomplexa

There are Three classes : Class Conoidasida, Class Aconoidasida and Class Perkinsea

- Possess zoospores that resemble sporozoites but are flagellated.
- Do not reproduce sexually.
- Monoxenous.

Chaptre II- Subkingdom of Protozoa 2. Phylum Sporozoa /Apicomplexa

2.1. Class 1/ Conoidasida

Classification: three subclasses (Subclass Gregarinasina, Subclass Coccidiasina, and Piroplasma).

2.1.1. Subclass 1/ Gregarinasina / Gregarinia

- Parasites of Invertebrates or Vertebrates.
- Trophozoites large and found in the gut and body cavities (extracellular) of invertebrates.
- Zygote non motile but mobile in the vegetative state.
- Male and female gametes merogamous.
- Sporozoites found in sporocyst.
- Lif cycle includes an asexual multiplication and a reproduction sexual.

There are divided into two orders:

2.1.1.a. Order Archigregarinida Example : *Exoschizon.*

2.1.1.b. Order Eugregarinida Example : *Eimeria, Stylocephalus longicollis.*

b.1. Suborder/ Eimeriorina

- *Eimeria perforans* : Cses fatal diarrhea in the Rabbit.
- *Eimeria stiedae :Agent of hepatic coccidiosis in rabbit bile ducts.*
- *Eimeria zurnii :* Is a species of the parasite *Eimeria* that causes diarrheic disease known as eimeriosis in cattle (Bos taurus), and mainly affects younger animals.
- *Eimeria brunetti :* chicken (Gallus gallus domesticus) **(Figure 32).**

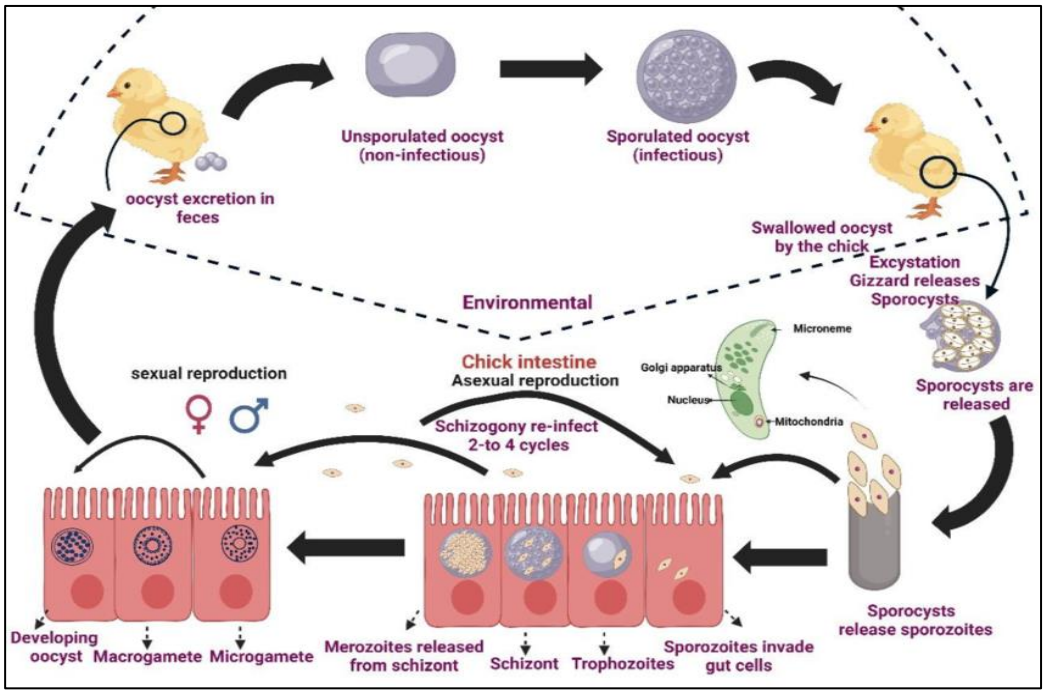


Figure 32: *Eimeria* life cycle.

Chaptre II- Subkingdom of Protozoa 2. Phylum Sporozoa /Apicomplexa

2.1.2. Subclass 2/ Coccidia/ Coccidiasina

- Trophozoites small and intracellular.
- Gametophytes dimorphic.
- Sporozoites in sporocysts.
- Blood or gut parasites of vertebrates.

2.1.2.a. Order 1 /Eucoccidiorida

✓ Parasite causes **eye and brain damage** in a baby, if untreated.

✓ Acute infection in older children and adults may be without symptoms, cause flu like illness or enlarged lymph glands.

Example : *Toxoplasma gandii*

Disease: Toxoplasmosis.

Final host : The Cat.

Intermidate Host: Human and some mamaleis like Bird, Mouse, Sheep.

Habitate: Organs like brain, skeletal and cardiac muscles, eye, liver, lymph node.

Life cycle: (Figure 33).

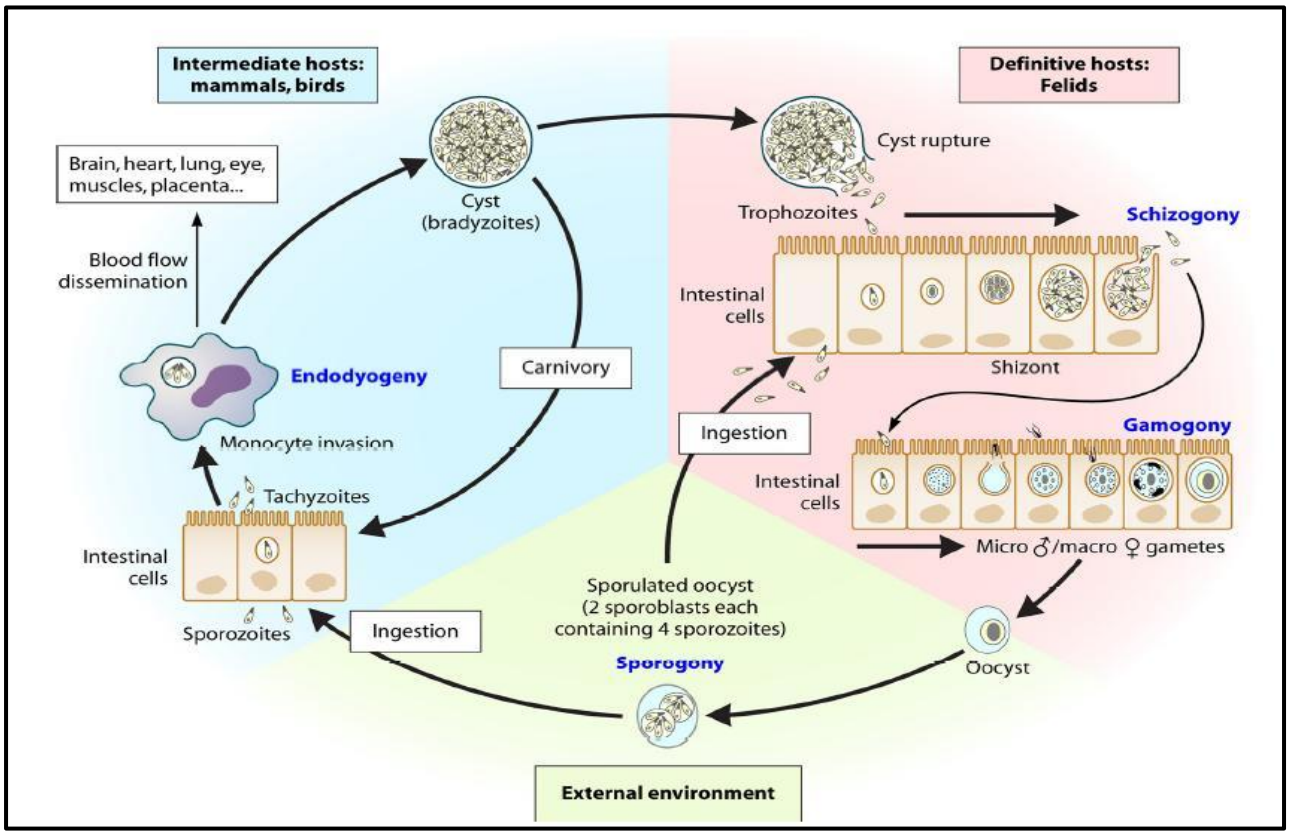


Figure 33: Scheme for the life cycle of *Toxoplasma gondii.*

2.2. Class 2/ Aconoidasida

2.2.1. Order 1 / Haemospororida

Macrogamete and microgamete develop separately. Syzygy does not occur. Ookinete has a conoid. Sporozoites have three walls. Heteroxenous: alternates between vertebrate host (in which merogony occurs) and invertebrate host (in which sporogony occurs). Usually blood parasites, transmitted by blood-sucking insects.

Example: **Malaria (Paludism)**

Intermediate host : Man.

Vector and final host : Transmits by Insect Diptera: Female Anophelis mosquito **(Figure 34).**

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.
- ✓ *Plasmodium* ovale.

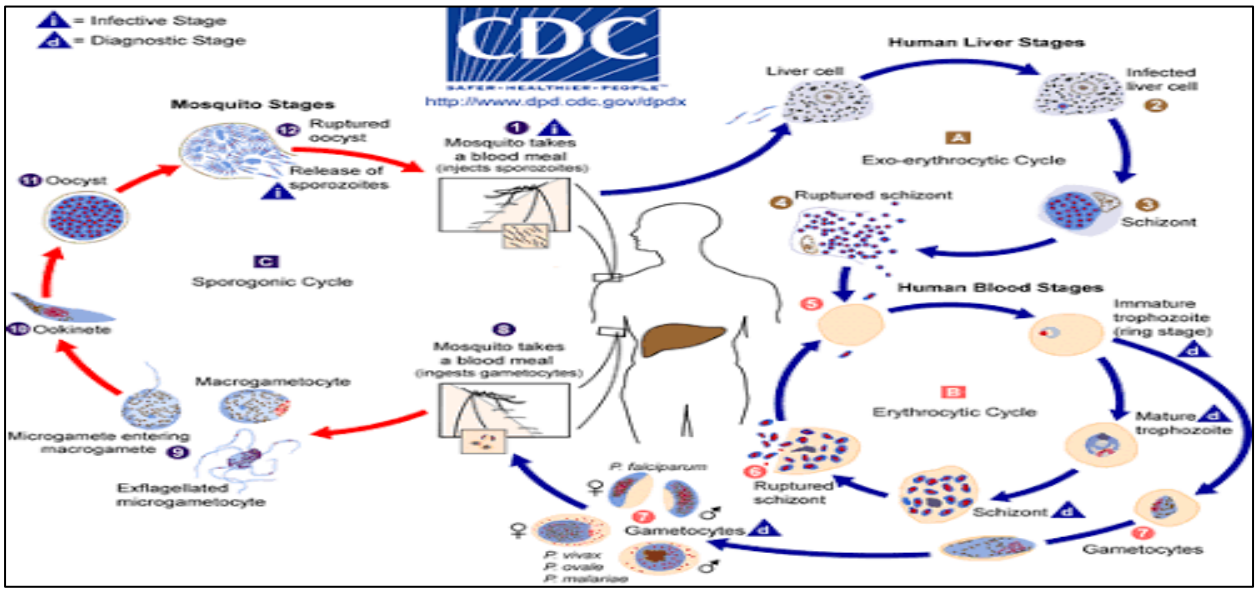


Figure 34: Life cycle of *Plasmodium falciparum* in humans and Anopheles mosquitoes.

2.3. Classe 3 / Perkinsea/ Perkinsasida

2.2.1. Order 1/ Perkinsida **(Figure 35).**

Have zoospores which resemble sporozoites but flagellate.

Do not have sexual reproduction.

Infect molluscs (Calms).

Examples: *Perkinsus marinus*, *Perkinsus atlanticus.*

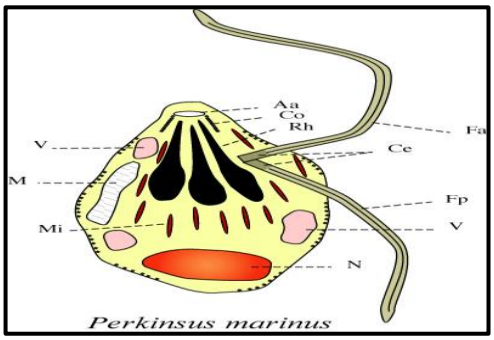


Figure 35 : *Perkinsus marinus.*

3. Phylum Cnidospora / Myxozoa

(Gr. Knide=nettle; spora=seed)

- Unicellular, obligate Intracellular parasite found in nearly all major animal groups.
- Spore are oval to cylindrical in shape with a polar filament or tubule **(Figure 36).**
- Parasites of invertebrate and fishes.
- Reproduce in the host by producing spores (Sporegony).
- **Spore**: Infective stage of microsporidia.
- Trophozoite has many nuclei.

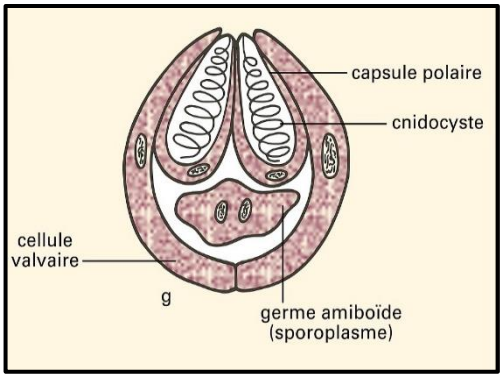


Figure 36: Structure of a spore.

Classification of Phylum Cnidospora / Myxozoa

Depending on the number of polar capsules, the Cnidosporidia in this phylum are subdivided into three classes.

3.1. Class 1 / Actinosporidies / Actinosporea

3.2. Class 2 / Microsporidea

- Spores small and with a univalved membrane.
- With or without polar capsule.
- Mainly parasitise insects.

Example: *Nosema apis, Nosema bombycis.*

3.3. Class 3 / Myxosporidea/ Myxosporea

- Spores develop from several nuclei.
- Spore within two or three valves.
- Parasites of vertebrates.

Example: *Myxobolus cerebralis*, *Myxobolus pfeifferi.*

3.3.1. Order 1/ Myxosporida

- Spores large and with a bivalve membrane.
- Polar capsule 1, 2 or 4; each with a filament.
- Tropozoites amoeboid.

Example: *Myxidium*.

3.3.2. Order 2/ Actinomyxida

- Spores larges and with a trivalved membrane.
- Polar capsule 3, each with a filament.

Example: *Triactinomyxon*, *Sphaeractinomyxon*.

4. Phylum Ciliophora / Ciliata/ Infusoria

La. Cilium =eye lid with lashes; phoros= bearing.

- **Locomotary organ:** Locomotor organelles cilia.
- Body covered by pellicle **(Figure 37).**
- Nuclei two types i.e. Have two kinds of nuclei large macronucleus and smaller micronucleus.
- One or more contractile vacuoles present.
- **Nutrition (feeding):** is Holozoic (heterotroph).
- **Mode of life:** Most ciliates are free living; however, some are commensalistic or mutualistic, and a few are parasitic.
- **Habitats:** Aquatic environment (oceans, lakes, rivers), ponds across the globe in freshwater and brackish water habitats and play a pivotal role in planktonic food webs.
- **Reproduction:** Asexual reproduction by binary fission. Sexual reproduction by conjugation.

Classification of Phylum Ciliophora / Ciliata/ Infusoria

Classification based primarily on the size and arrangement of the cilia (Holotricha, Peritricha, etc.), subdivided into three classes: Oligohymenophorea, Spirotriches, Kinetophragminophorea.

4.1. Class 1 / Oligohymenophorea

Oligo = few Hymen = membrane Phoros = bearing.

The mouth, or cytostome, opens at the base of the oral cavity.

The Oligohymenophorea are divided into two subclasses: **Hymenostomatia** and **Peritrichia**.

4.1.1. Subclass 1 / Hymenostomatia

- Uniform body ciliature.
- Well-defined buccal cavity.
- The latter consisting of an undulating membrane.

This Subclass are subdivided into three Orders : Hymenostomatida, Scuticociliatida, Astomatida.

4.1.1.1. Order 1/ Hymenostomatida

- Body small and with uniform cilia on body.
- Buccal cavity with undulating membrane and adoral zone of membrane cells.

Examples: *Paramecium caudatum*, *Colpidium*.

4.1.1.2. Order 2 / Scuticociliatida

Body uniformly sparsely ciliated.

Examples: *Boveria.*

4.1.1.3. Order 3 / Astomatida

- Cytostome absent.
- Body ciliation uniform.
- Parasites or commensals in gut and coelom of earthworm.

Example : *Cepedietta, Anoplophrya*, *Hoplitophyrya*.

4.1.2. Subclass2/ Peritrichia

- Adult without body cilia.
- Sessile organism.
- Mouth surrounded by a fringe of membranous structures.

4.1.2.1. Order 1 / Peritrichida

Example : *Vorticella sp, Carchesium.*

4.2. Class 2 / Spirotricha/ Spirotrichea

- Body cilia reduced.
- Buccal cilia well marked.

There are three orders: Heterotrichida, Hypotrichida and Oligotrichida.

4.2.1. Order 1 / Heterotrichida

Hetero: Different.

- Body encased in lorica.
- Body cilia usually absent.
- Body naked with uniform body cilia.

Example : *Bursaria*, *Stentor sp*, *Blepharisma*.

4.2.2. Order 2 / Hypotrichida

Hypo: abdominal.

- Body dorso-ventrally flattend.
- Body cilia at vental side, forming cirri.

Example : *Euplotes, Kerona, Stylonychia sp.*

4.2.3. Order 3 / Oligotrichida

- Body cilia reduced or absent.
- Buccal membranelles at front end only.

Example : *Strombidium, Halteria., Codonella sp*.

4.3. Class 3 / Kinetophragminophorea

*Ciliation of the cytostome is not very distinct.

*Absence of membranelles.

*They colonise all habitats.

*Ciliates reproduce mainly asexually: by transverse binary fission.

*This division begins with the division of the nuclear apparatus: the macronucleus splits into two and the micronucleus undergoes mitosis. The cytoplasm then constricts and the two halves separate. (This is known as cytodieresis or plasmotomy).

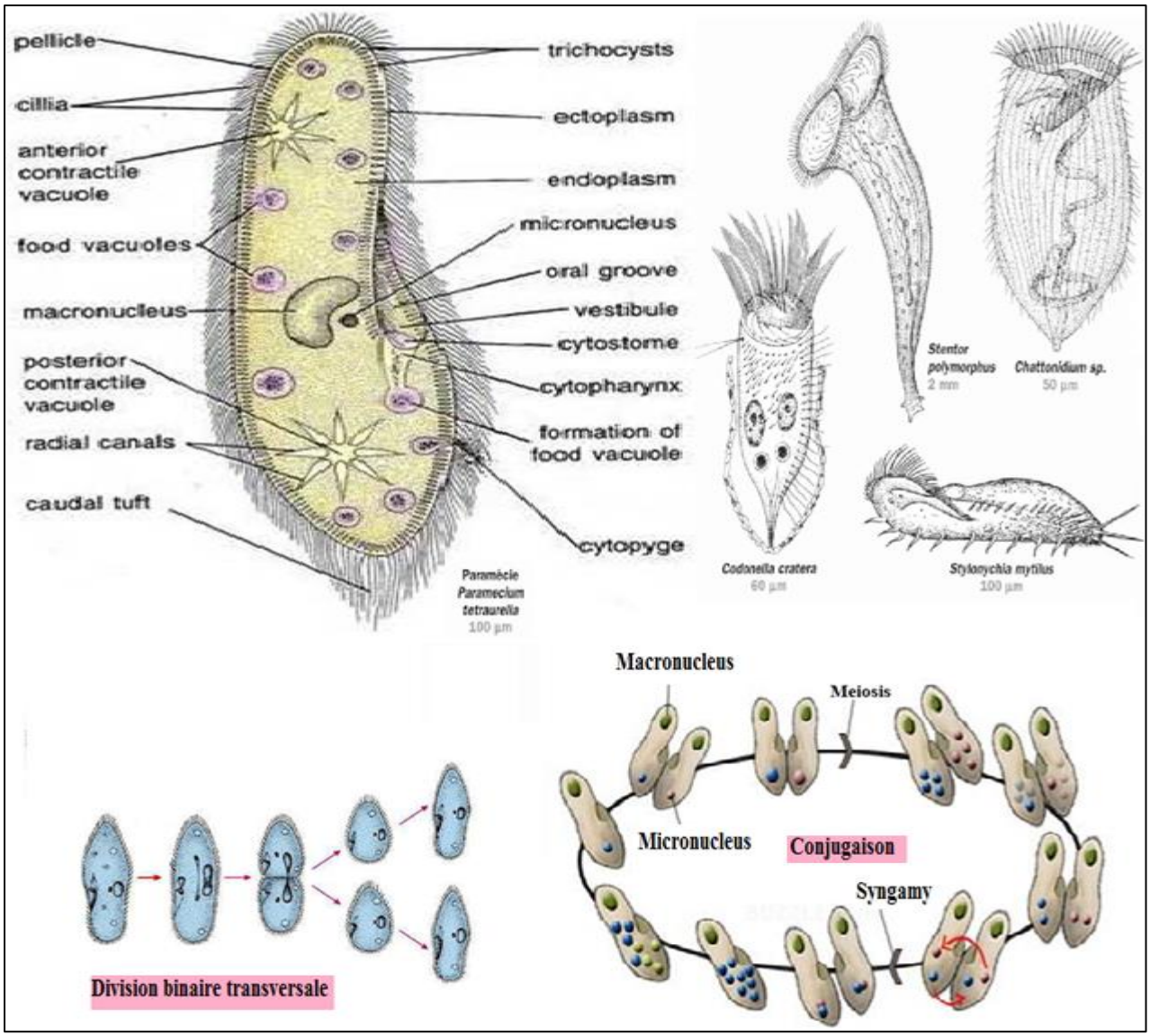


Figure 37: Some characteristics of ciliates.

Chaptre III

Subkingdom

Metazoa

Part 1.

Invertebrates

Diploblastic

III-1- Phylum: Porifera

1. Phylum Porifera

Members of phylum Porifera or sponges are most primitive of metazoans or multicellular animals. It includes more than 5,000 species. They appear to be quite life-less and plant like.

Porifera are a conspicuous and colorful component of many seascapes.

Greek: Pori = Pore, Pherin = Bearing.

Latin word (Porus= pore; ferre= to bear).

Members of Porifera are pore bearing animals, commonly known as **Sponges**. These are multicellular animals without tissue and organ system.

General characteristics of Phylum Porifera

Habitat: Aquatic, mostly marin, oceans and few are fresh water form (A single family of freshwater species. e.g., Spongilla), few are terrestrial.

Habit: These are solitary or sedentary, they remains attached to substratum and live in colony.

Grade of organization: These are primitive multicellular animals and have cellular level organization.

Symmetry: Asymmetrical or radially symmetrical.

Germ layer: Diploblastic animals. The adult body wall contains two layers, outer ectoderm (dermal layer) and inner endoderm (gastral layer). In between these two layers, there is a gelatinous and non-cellular mesoglea containing numerous free amoeboid cells (**Figure 38**).

The mesenchyme consist of numerous cells, cells are having different shape and size and performing different functions (**Figure 38**).

Coelom: Absent acoelomate, but the body contain large cavity, it is called as Spongocoal (**Figure 38**).

Endoskeleton: The body is supported by a skeleton made up of:

Either **calcareous spicules** (needles made up of calcium carbonate CaCO3) or siliceous spicules (silica) or sponging fibers (protein) (**Figure 38, 39**).

Nutrition: Heterotrophic, holozoic.

Digestion: It is Intracellular, no definite organ for feeding and digestion.

Nervous system: Absent.

Sensory: Absent.

Circulatory system: Absent.

Respiration system: Absent.

Excretory system: Absent.

Reproduction: Sponges reproduce both by asexual and sexual methods of reproduction (**Figure 40**).

- **Asexual:** By budding or gemmule or regeneration. The buds may be external or internal, the internal buds are called gemmuies. Both types of buds develop into new sponges.
- **Sexual:** Some sponge species reproduce sexually.

Sexes: These are mostly Hermaphrodite or Monoecious mostly protandrous, i.e. male sex cells develop irst. In some sponges the sexes are Gonochoric = separate or Dioecious.

Fertilization: Internal, Self-fertilization results in free-swimming larvae or external, Cross fertilization results in larvae; Sperms released in water are carried to the eggs by amoeboid cells. Fertilization occurs in mesenchyme and zygote is formed. Ciliata larvae free swimming.

Development is indirect through free swimming ciliated larva, the amphiblastula or parenchyma.

Body shape: Its shape (variable) sometime cylindrical, branching, globular, brightly or dull in colour, they are orange, red, yellow or green colour.

The body is perforated by pores and canals but lack other organs (mouth or nervous system).

Body wall has outer pinacoderm (dermal epithelium), inner choanoderm (gastral epithelium) and gelatinous non-cellular mesenchyma in between (**Figure 38**).

Surface of the body has numerous perforation called ostia (for the entry of water) and a large pore at the apex called osculum (for the exit of water) (**Figure 38**).

Canal system: They have a water canal system. Water enters through minute pores **(ostia)** in the body wall into a central cavity, spongocoel, from where it goes out through the large pore - osculum.

- **Body wall structure**

The body of sponge consists of two cellular layers (outer and inner) and between them there is a jelly-like layer (mesohyl):

1. The outer layer

This layer called epidermis and consists of two types of cells:

1. a. Pinacocytes (pinacoderm): They are plate-like cells that cover the exterior and some interior surfaces, and responsible for anchoring the base of sponge on suitable surface. Also, they digest food particles that are too large to enter from ostia.

1.b. Porocytes: They are tube-like cells that form valves around ostia to control the flow of water through the sponge by changing the size of the openings of the ostia.

2. The inner layer

Choanocytes (also known as "collar cells"): It is made of vase - shaped cells which have a collar of fine fibrils connected by microvilli to trap food particles by phagocytosis. Also, these cells contain a single flagellum that is used to propel water through the pores into a central cavity. Choanocyte can convert into sperm for sexual reproduction.

3. Mesohyl

It is a semi-fluid matrix consists of cells called **Archaeocytes** and supported by the skeletal elements. These cells can change into other cells to perform several functions in sponge:

3.a. They convert into **amoebocytes:** They have pseudopodia to pick up food particles from choanocytes, digest it, then carry nutrients, oxygen to other cells of sponge, and eliminate waste products.

3. b. They convert into **Oocytes (ovum)** for sexual reproduction.

3. c. They maintain the skeleton of sponge via converting into:

Spongioblast (secrete spongin fibers); Scleroblast (secrete spicules); Collencyte (secrete collagen fibrils).

3. d. They are the basis of some asexual reproduction during unfavorable condition by forming gemmules.

Skeleton of the sponge: Spicules are stiffened rods or spikes made of calcium carbonate or silica which are used for structure and defense.

- **Shapes of Sponges**

By beating their flagellum, Choanocytes keep the water flowing through canal system in the correct direction, water enters ostia to spongocoel and leaves through osculum. There are three types of canal system in sponges that result in different shapes (**Figure 41**):

- **Asconoid sponges:** They are the simplest shape of sponges, in which canals run straight from ostia to spongocoel. These sponges live in groups and have thin body wall (1 mm).
- **Syconoid sponges:** They have branching canals, so water not flow straight from ostia to spongocoel and body wall is pleated & become thicker (few cm). They do not live in groups.
- **Leuconoid sponges:** They have the most complicated shape of sponges because canals are longer, more branched, and lead to chambers. Therefore, these sponges have thick body wall (over 1 m), and there is no real spongocoel just a central exit leading to osculum. They live in large groups each sponge having its own osculum.

Classification of Phylum Porifera

The classification of sponge is **based chiefly on types of skeleton found in them**.

The phylum porifera is divided into **three classes**:

1.1. Class 1/ Calcispongiae/ Calcarea

- ✓ These are small sized calcareous sponges (10 cm in height).
- ✓ Solitary or colonial.
- ✓ Body cylindrical or vase like in shape.
- ✓ Skeleton formed of calcareous spicules which may be one, three, or four rayed.
- ✓ All are marine animals.
- ✓ Body organisation may be asconoid, Syconoid or lenconoid type.

Order 1/ Homocoela (Asconosa)

Example : *Leucosolenia, Clathrina.*

Order 2/ Heterocoela (Syconosa)

Example : *Sycon raphanus, Schypha*, *Grantia.*

1.2. Class 2/ Demospongiae/ Demospongea

- ✓ Solitary or colonial.
- ✓ Its body is cup or vase shaped.
- ✓ Demospongiae showed both small and large size.
- ✓ Spicules are seen monaxon or tetraxon.
- ✓ The canal system is leuconoid type.
- ✓ All are marine porifera but except freshwater sponges (Spongillidae).

The class Demospongiae is classified into the three Ordres.

Ordre 1/ Dictyoceratida

Exemple : *Spongia officinalis.*

Order 2/ Dendroceratida

Order 2/ Verongiida

Example : *Aplysina aerophoba.*

1.2. Class 3/ Hexactinellida

- ✓ Generally hyalospongiae are found in medium sized sponges but some time few sponges reached one meter in length.
- ✓ Have silicon based spicules.
- ✓ It is commonly known as glass sponges.
- ✓ Its body shape cylindrical, funnel shaped or cup shaped.
- ✓ The canal system was very typical and body organization Syconoid type.
- ✓ Hexactinellida class is found in deep marine water.

The class Hexactinellida is classified into the two Ordres.

Order 1/ Hexasterophora

Examples : *Euplectella aspergillum* (Venus's flower basket).

Order 2/ Amphidiscophora

Examples : *Hyalonema* (Glass-rope sponge), *Pheronema* (Bowl sponge).

III-1- Phylum: Porifera

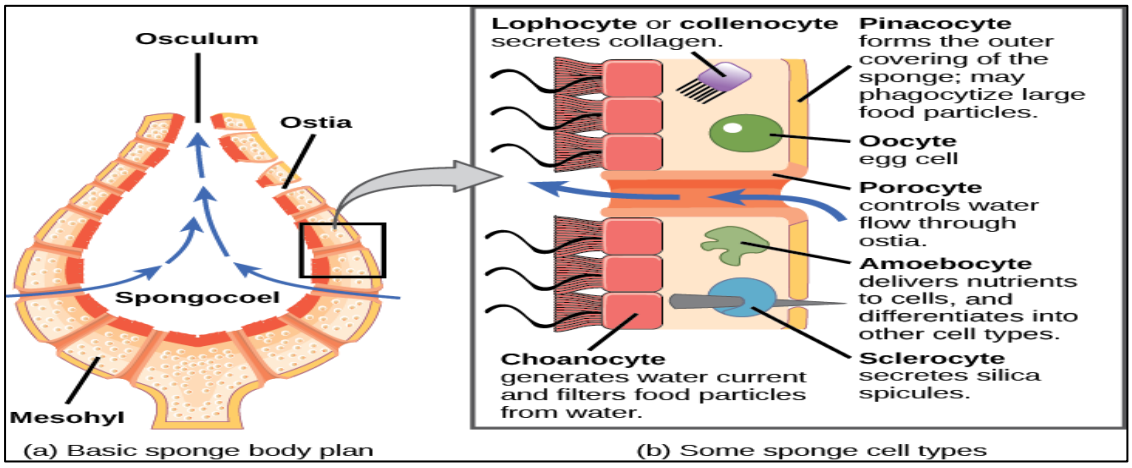


Figure 38 : The sponge's (a) basic body plan and (b) some of the specialized cell types found in sponges are shown.

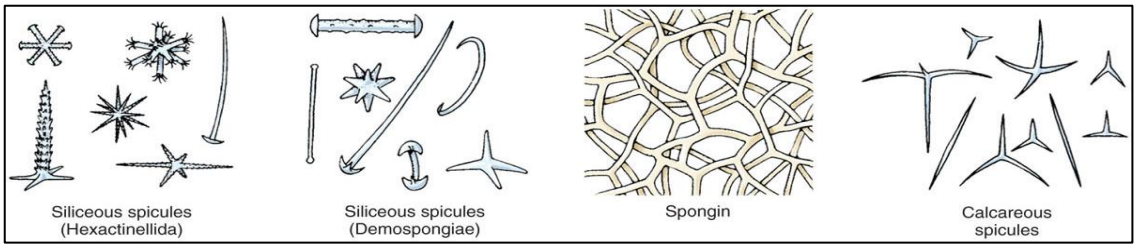


Figure 39: Skeletal Structures of Sponges.

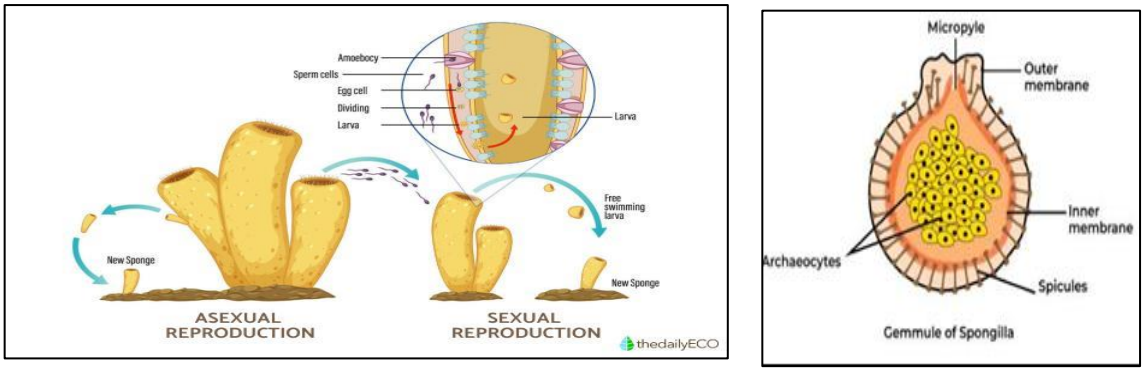


Figure 40: General Sponges Life Cycle.

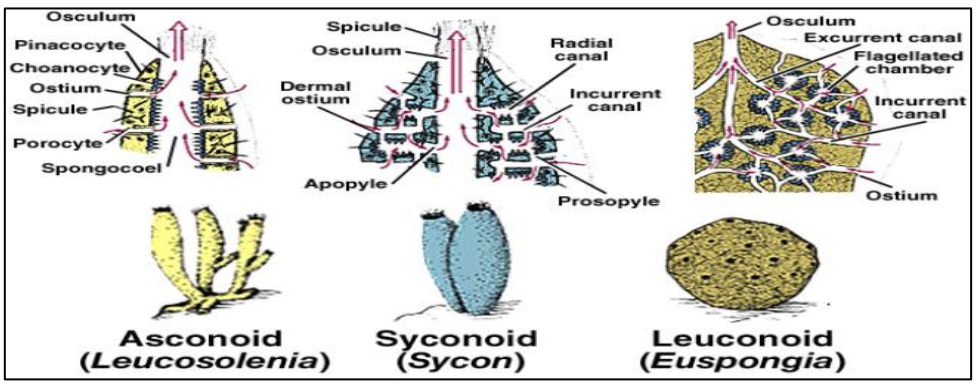


Figure 41: Three different body forms.

III-1- Phylum: Cnidaria

2. Phylum Cnidaria or Coelenterata

Phylum Cnidaria (formely known as coelenterata) includes about 9000 species. Some are found in fresh water, but the greater numbers are marines. Coelenterates (Gr. koilos- hollow + enteron- gut) are the simplest of eumetazoans. This interesting group of animals takes its name from the large cavity in the body that serves as the intestine. They include the hydra, jellyfish, sea anemones and corals.

Greek: Coel = Cavity, Knide = Stinging cells.

They have a central cavity called **coelenteron**. They have stinging cells. So, they are also known as **Cnidarians.**

Each cnidocyte has nematocyst that are barbed and are used to spear the prey.

A One kind of cell **characteristic** of the **phylum: Cnidocytes** produce stucture called **Cnidae** which are used in **attachement**, **defence** and **feeding** (**Figure 42**).

Characteristics of Cnidaria or Coelenterata

Habitat: These are mostly aquatic or oceans, marine habitat animals except Hydra fresh water.

Habit: They may exhibit solitary or colonial habitat. They are sessile or free-living.

Movement: Sessile or motile.

Locomotion is brought about by smooth muscle fibers.

Shape: Body shape is variable.

Grade of organization: These species exhibit a tissue-level organization.

Symmetry: They are mostly radially symmetrical but Sea Anemone is bi-radially symmetrical**.**

Germ layer: They are diploblastic animals, in which, the body is made up of two layers of cells:

- **Ectoderm –** One layer makes up the cells outside the body.
- **Endoderm –** The other forms the inner lining of the body (**Figure 42**).
- **Mesoglea –** Middle non-living jelly-like layer (**Figure 42**).

Coelom: Absent, acoelomate; but They have a central gastro-vascular cavity with a single opening (mouth/anus or hypostome) to gastrovascular cavity where food and water enter and wastes leave; called one-way digestive system**.**

Segmentation: none.

Skeleton either calcereous or horny and external or internal (Endoskeleton) but absent in few.

Hydrostatic- water pressure maintains shape.

Nutrition: Coelenterate animals are usually carnivorous.

Digestion: The digestion is both intracellular and extracellular.

Nervous system: Cephalization absent; a primitive form of nervous system, which consists of one or more networks or nerve cells and neurites located in the ectoderm and endoderm.

Sense organs: Are ocellii and statocysts.

Circulatory system: Absent.

Respiration system: Absent, Oxygen diffuses into body from water.

Excretory system: Absent, Excretion: They excrete and respire through simple diffusion.

Reproduction: Reproduction is both asexual and sexual methods (**Figure 43A**).

- **Asexual by:** Division (Longitudinale or Transversale) or Budding or Regeneration or Strobilation.
- **Asexual by:** Gamatic fusion.

Sexes: Most cnidarians are Dioecious. Sperm and eggs may be released into the gastrovascular cavity or outside of the body, they are hermaphrodites.

Fertilization: Internal or External.

Larves: Planula Larva free swimming Ciliata.

Development: Direct or indirect development.

The mouth: Is enclosed by thin and short tentacles.

Anus is absent.

Life cycle of Cnidarians (Figure 43B):

The life history exhibits the phenomena of alternation of generations or metagenesis in which the asexual polypoid, sessile generation alternates with sexual medusoid, freeswimming generation.

Those cnidarians which exist in both the forms exhibit alternation of generation (Metagenesis), i.e., polyps produce medusae asexually and medusae produce the polyps sexually (**Example :** *Obelia*).

- **Cnidarian Body Plans :**

Body Shape: Cnidarians exhibit two basic body forms called polyp and medusa (**Figure 44**).

- **Polyp:** Polyp-vase shaped, Tube – like; Mouth opens at top; tentacles surround mouth; Only have a small amount of mesoglea; Stays attached to underwater surface; asexual stage.
- **Medusa:** Mouth opens downward; Tentacles trail. Adapted to swim; Free floating and are often umbrella shaped; possess a large amount of mesoglea; sexual stage.

One of the most characteristic structures of all coelenterates is the stinging cells, called nematocysts. Nematocysts serve for adhesion, food capture and offence and defence.

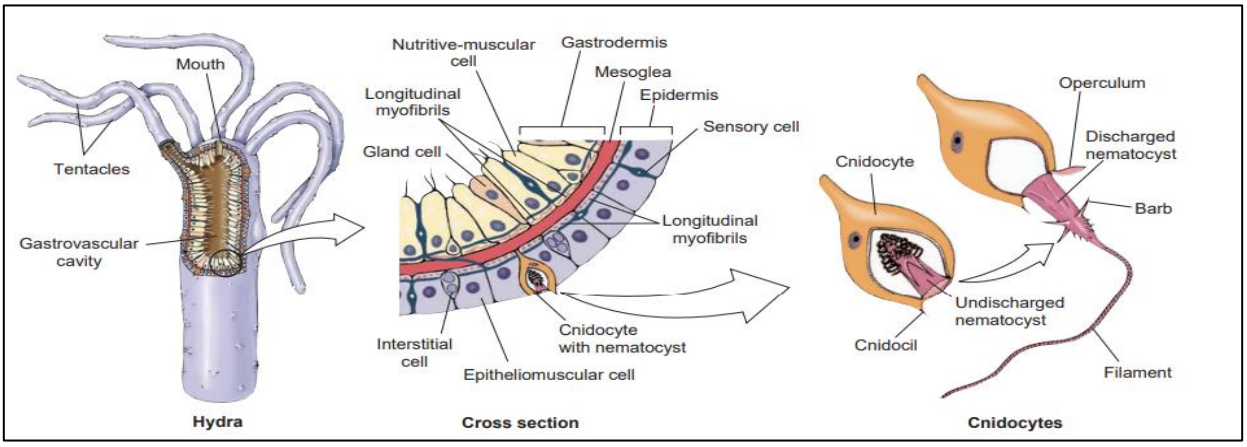


Figure 42: At right, structure of a stinging cell. Center, portion of the body wall of a hydra.

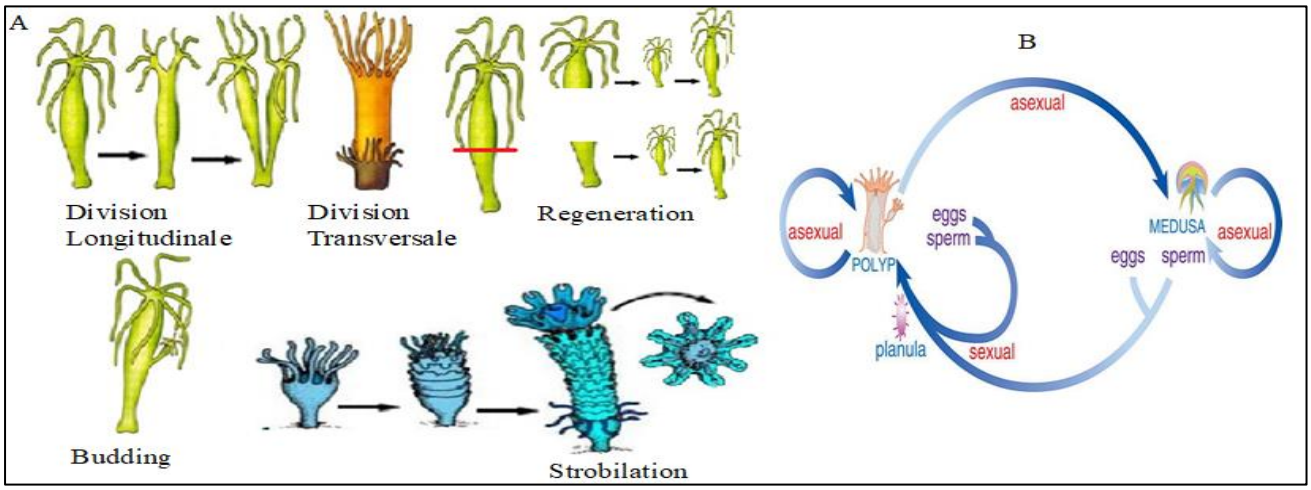


Figure 43: Type of Reproduction (A) General Cnidarian Life Cycle(B).

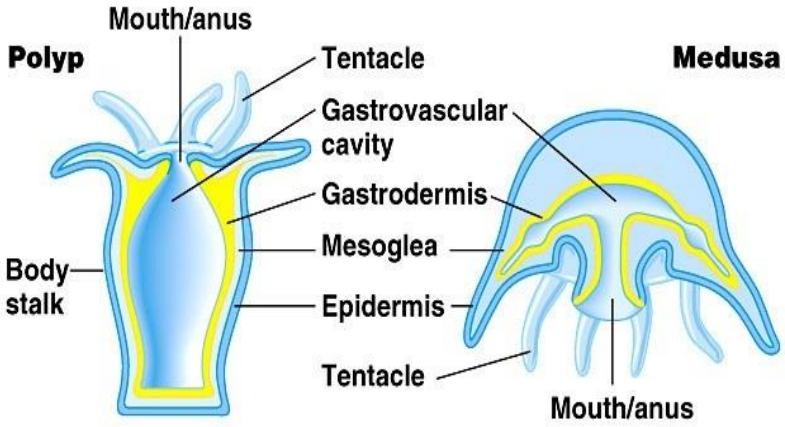


Figure 44: Cnidarian Body Plans. Cnidarians may exist in the polyp (left) or medusa (right) form.

Classification of Cnidaria

Phylum Cnidaria is classified into the following **four classes** on the basis of the **dominance of medusa or polyp phase** in the life cycle Anthozoa.

2.1. Class 1/ Hydrozoa

(Gr., hydra- water + zoon- animal).

- ✓ These are mostly marine species, found exclusively in freshwater.
- ✓ Few are found in colonies and few are found solitarily.
- ✓ They exhibit tetramerous or polymerous radial symmetry.
- ✓ Gastro-vascular cavity without stomodaeum, septa or nematocysts bearing gastric filament.
- ✓ They exhibit either only polyps or both asexual polyps and sexual medusa form.
- ✓ Polyp is dominant stage.
- ✓ Medusa stage is absent in few animals. Sometimes both polyp and medusa stages are present in few animals of this class (**Figure 45**).
- ✓ Medusa when present has vellum around margin.
- ✓ Gonads are epidermal in origin.
- ✓ Sex cells are shed directly to the outside.

It includes following orders: **Hydraires, Siphonophores, Hydrocorallines, Trachyliena.**

- ➢ **Order 1/ Hydraires**
  - ❖ They may be solitary or colonial.
  - ❖ The medusae form is absent or short-lived.
  - ❖ The sense organs are exclusively ectodermal.

Sub-Order (a)-Anthomedusae **Examples :** *Hydra, Tubularia.*

- ❖ Colonial or solitary.
- ❖ Polyps are not enclosed in hydrothecae.
- ❖ The medusae are naked without gonothecae.
- ❖ Medusae are tall and bell like.

Sub-Order (b)-Leptomedusae **Examples :** *Obelia.*

Colonial Hydrozoa.

- ❖ Polyps are enclosed in hydrothecae.
- ❖ The medusae are covered with gonothecae.
- ❖ Eye spots or ocelli are absent.

- **Order 2/ Siphonophora** **Examples :** *Physalia physalis, Velella spirans, Halistemma sp*, *Diphyes*.
- **Order 3/ Hydrocorallina** **Example :** *Millepora nodosa.*
- **Order 4/ Trachylina** **Example :** *Solmaris, Geryonia*.

2.2. Class 2 /Scyphozoa

(Gr. skyphos=cup, zoios-animals).

- ✓ They are exclusively marine and solitary forms.
- ✓ The medusa stage is dominant but the polyp stage reduced or absent (**Figure 47**).
- ✓ Medusa without vellum (**Figure 46**).
- ✓ The gonads are gastro-dermal and sex cells are shed or released in digestive cavity.

These are divided into three Ordre :

O1/Semaeostomeae, **O2**/ Rhizostomae, **O3**/Coronatae.

Ordre 1/ Semaeostomeae (Discomedusae)

- ❖ Most common free-swimming medusae found inhabiting the coastal water of all oceans.
- ❖ Gastric pouches and filaments are absents.
- ❖ They have flat saucer or disc-like umbrella.
- ❖ Eight tentaculocysts present.
- ❖ Mouth extending into 4 long oral arms.

Example : *Aurelia aurita*, *Pelagia*, *Cyanea*, *Chrysaora*

Ordre 2/ Rhizostomae **Example :** *Rhizostoma, Stomolophus*.

Ordre 3/ Coronatae **Example :** *Periphylla* , *Pericolpa* , *Nausithoe punctata.*

2.3. Classe 3 /Anthozoaires /Anthozoa

(Gr. anthos=flower, zoon=animal)

- ✓ They are found exclusively in the marine environment.
- ✓ May be solitary or colonial.
- ✓ Mesogloea contains fibrous connective tissues and amoeboid cells.
- ✓ Medusa is not (**Figure 48**).
- ✓ All are polyp forms, nomedusae.
- ✓ They have gastro-dermal gonads (**Figure 49**).
- ✓ Gasto-vascular cavity is divided into completed and incomplete septa.
- ✓ Skeleton either external or internal.
- ✓ Nervous system prepared by typical nerve net without a concentrated central nervous system.
- ✓ Fertilisation is external.

These are divided into three subclasses:

Subclass1/ Octocorallia (Alcyonaria)

- They are exclusively colonial.
- These are found in polyp form with 8 pinnate tentacles and 8 septa.
- Eight complete mesenteries are present.
- Polyps are dimorphic in some form

Example : Soft corals

- Colony mushroom-shaped.
- Polyps are dimorphic in some forms (Autozooides and Siphonozooides)
- Polyps proximally embedded in a fleshy mass or coenenchyme.
- Skeleton of separate calcareous spicules.

Subclass 2 / Hexacorallia (Zoantharia)

- They may be solitary or colonial.
- The tentacles are usually unbranched, numerous arranged in the multiple of 5 to 6 but never 8.
- Endoskeleton is calcareous type. Polyps are monomorphic.

Example : Sea-anemones

- Colonial or solitary.
- Skeleton absent.
- Tentacles and mesenteries are numerous.
- Large sized solitary anemones.
- Body muscular, often with an aboral pedal disc.

Subclass 3 /Tabulata **Example :** *Favosites* and *Halysites.*

2.4. Classe 4/ Cubozoa

- Most recently classified.
- Exist as both Polyp and Medusa.
- Medusa is the predominant form of this class. Polyp state develop directly to medusa.
- Base of each tentacle form Pedalium.
- Tentacle(s) present in each corner of umbrella margin.
- Bell margin with velarium.Bell may be cube or square-shape (**Figure 50**).
- Tetramerous (four part radial symmetry).
- Gonads are endodermal (found in the gatrodermis).
- Specialized sense organ called rhopalium.

III-1- Phylum: Cnidaria

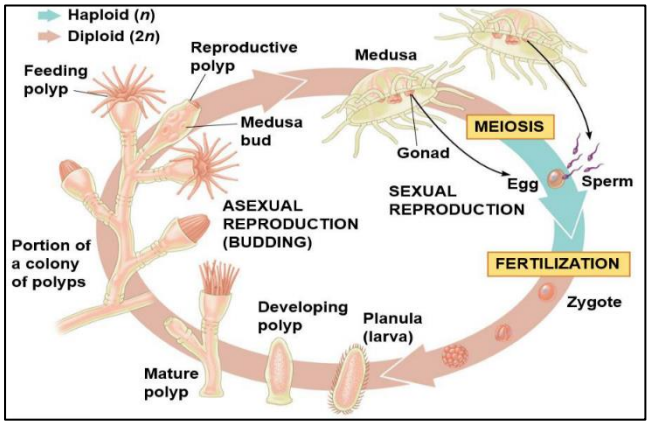


Figure 45: Life cycles of Hydrozoa.

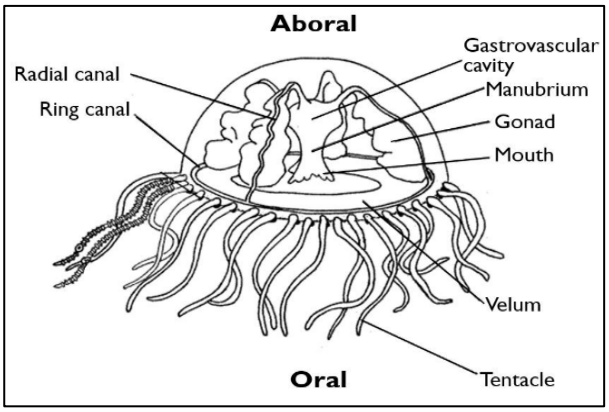


Figure 46: Hydrozoan Medusa Anatomy.

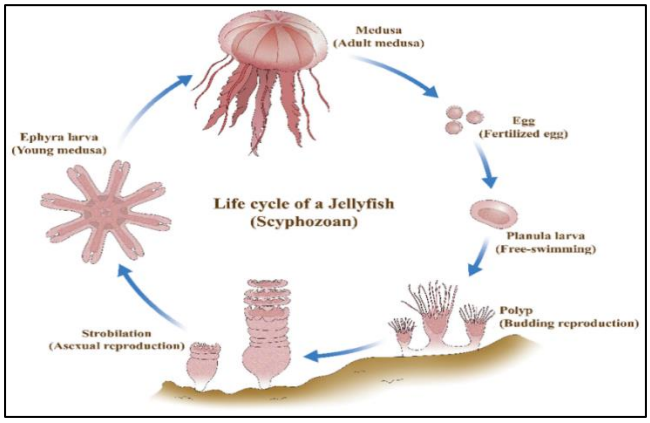


Figure 47: Life cycles of Scyphozoa.

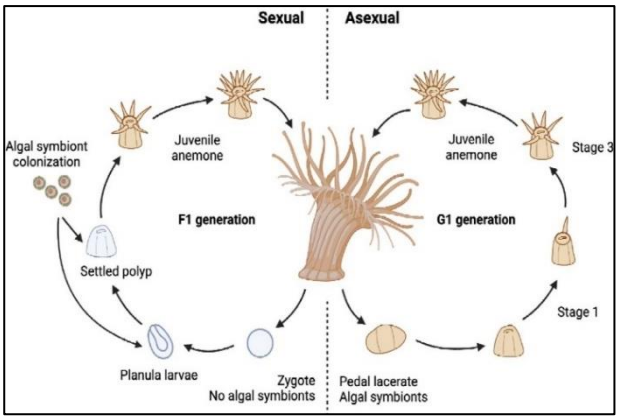


Figure 48: Life cycles of Anthozoa.

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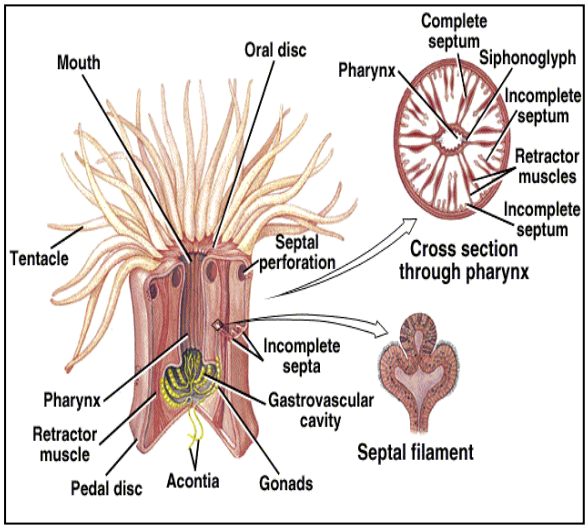


Figure 49: Anthozoa.Anatomy.

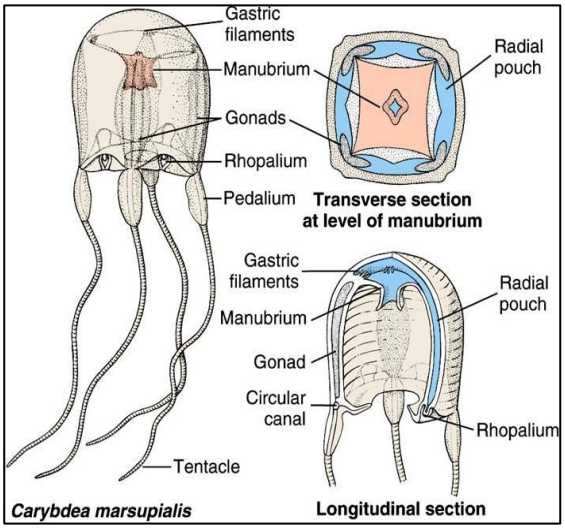


Figure 50: Cubozoa Anatomy.

III-1- Phylum: Ctenophora

3. Phylum Ctenophora

Phylum Ctenophora Characteristics

✓They are free-swimming, marine, solitary, pelagic animals. No polymorphism and no attached stages were found.

✓The body is transparent, gelatinous, pear-shaped, cylindrical, or flat or ribbon-shaped (**Figure 51).**

✓They have a biradially symmetrical body along an oral-aboral axis.

✓They have an external surface with comb-like 8 ciliary plates for locomotion. Hence name as comb jellies.

✓They have a pair of long, solid, retractile tentacles.

✓Their body organization is cell-tissue grade.

✓Their body is acoelomate and "diploblastic" having ectoderm and endoderm. The body wall has outer epidermis, inner gastrodermis, middle jelly-like mesoglea with scattered cells, and muscle fibers. So, Ctenophora may also be considered as "triploblastic".

✓Their digestive system contains the mouth, stomodaeum, complex gastrovascular canals, and 2 aboral anal pores.

✓They lack nematocysts.

✓They have special adhesive and sensory cells i.e. colloblasts or lasso cells present in tentacles which helps in food captures.

✓They lack skeletal, circulatory, respiratory, and excretory organs.

✓Their nervous system is diffused types and the aboral end bears a sensory organ, called statocyst.

✓They are monoecious (hermaphrodite); gonads are endodermal situated on walls of digestive canals.

✓Their development direct with characteristic cydippid larva.

✓They lack asexual reproduction and alternation of generation.

✓Regeneration and paedogenesis are common in them.

Phylum Ctenophora Classification

Phylum Ctenophora contains about 100 know species and grouped in 2 classes.

3.1. Class 1/ Tentaculata

- Adults with 2 long aboral tentacles.
- In some larva has tentacles, while adults have oral lobes.
- Mouth narrow and pharynx small.

Examples: *Mertensia*, *Pleurobrachia*, *Hormiphora.*

Examples: *Mnemiopsis*, *Bolinopsis.*

Examples: *Cestum*, *Velamen*

Examples: *Ctenoplana*, *Coeloplana*

Examples: *Thalassocalyce inconstans*.

3.2. Class 2. Nudu

- Body large, conical, and compressed laterally.
- Without tentacles and oral lobes.
- Wide mouth and large pharynx.
- Voracious feeder.

Examples: *Beroe ovata.*

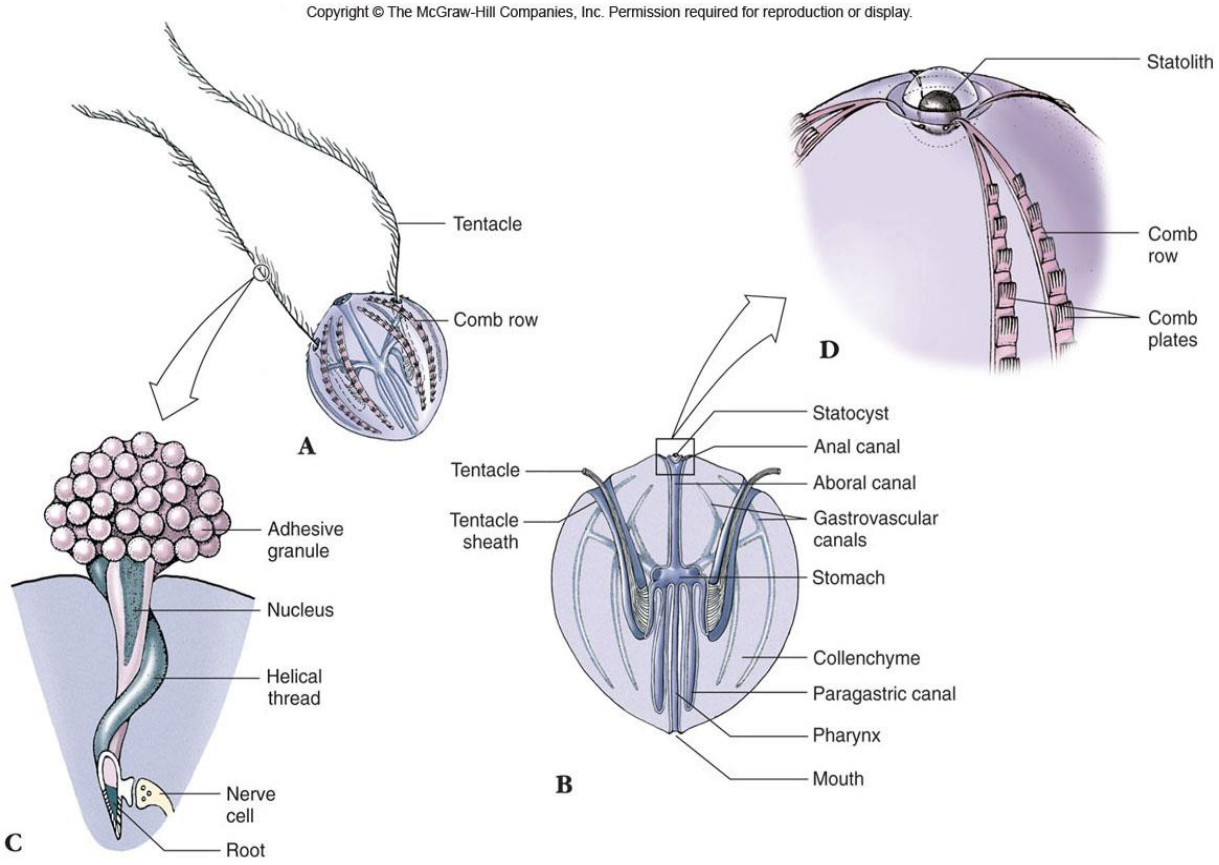


Figure 51 : Anatomy of a ctenophore (*Pleurobrachia pileus*).

Chaptre III
Subkingdom Metazoa
Part 1.
Invertebrates

Triploblastic

III-1- Phylum: Plathelminthes

1. Phylum : Plathelminthes

Greek: Platys = Flat, Helmins = Worms (Flatworms)

Understanding the general characters of Platyhelminthes and classification up to the order level.

General Characters of Platyhelminthes

- ✓ They have dorso-ventrally flattened body; hence they are called flatworms.

➢ **External Morphology:**

- ✓ **Shape:** Leaf-shaped or Ribbon-like (**Figure 52**).
- ✓ **Size:** Range from 1mm to 30 m.
- ✓ **Head**: Has Scolex with organs of fixation e.g. Suckers or Suckers and Hooks.
- ✓ **Segmentation:** Is absent i.e. body not metamerically segmented.
- ✓ **Bodies are covered in cilia** =>**Example**: Turbellaria.

➢ **Internal Anatomy:**

- ✓ **Germ layer:** They are **Triploblastic** animals with three germ layers.
- ✓ **Symmetry:** They are bilaterally symmetrical.
- ✓ **Body cavity or Coelom:** Acoelomates (Spaces between various organs filled with special mesodermal tissue, the mesenchyme or parenchyma).
- ✓ Mesodermal tissue called mesenchyme/parenchyma is present between the internal organs and all these are filled in a saclike body having no other opening.
- ✓ **Grade of organization:** They are the first animals to have organ level organization and cephalization (differentiation of heads).
- ✓ **Skeleton:** Absent.
- ✓ **Digestive system:** Digestive system branched and incomplete without anus. Alimentary canal with single opening.
    - Incomplete (**Example:** Turbellaria and Trematoda) or Absent (**Example:** Cestoda).
- ✓ **Nutrition:** Carnivore, Scavenger, Parasitic.
- ✓ **Digestion:** Extracellular.
- ✓ **Nervous system:** Is primitive, ladder like. It contains a pair of cerebral ganglia with longitudinal nerve cords connected by transverse nerves.
- ✓ **Sense organs:** Simple. Eye- spots or photo receptors in free living forms. **Example:** *Planaria.*
- ✓ **Circulatory system:** Absent.
- ✓ **Respiration system:** Absent; Diffusion of gases through the skin, skin must remain moist.
- ✓ **Excretory system:** Consists of single or paired protonephridia with flame cells or bulb (Primitive kidneys).

✓ **Muscular system:** Muscular system of mesodermal origin. The system consists of longitudinal, circular and oblique muscle layers beneath epidermis.

- Two layers of muscle tissue below the ectoderm layer.
- The longitudinal and circular layers of muscle tissue allow the planaria to contract, twist, turn, and are stimulated by the nervous system to allow movement.

✓ **Reproduction:** They are:

- ❖ **Asexual:** binary fission and regenerate any missing parts **Example:** *Planaria.*
- ❖ **Sexual: Example:** Trematoda, Cestoda

✓ **Sexes:** Most are (not all) Hermaphrodites (Monoecious) **Example:** (Turbellaria, Cestoda, Fasciolidae). Gonochoric (Dioecious) **Example:** (Schistosomatidae).

✓ **Fertilization:** Is internal

- ➢ May be => Self-Fertilization **Example:** Cestoda.
- ➢ May be => Cross-Fertilization **Example:** Turbellaria.

✓ **Development:** Direct **=> Example:** Turbellaria

or Indirect => **Example:** Trematoda and Cestoda.

✓ **Larva :** Are free swimming.

✓ **Life cycle:** Monoxenous (One Host) => **Example:** Fasciolidae.

Heteroxenous (One to more Intermediate hosts IH) => **Example:** Cestoda and Trematoda. One or more hosts are required to complete their life cycle and larval forms usually present.

✓ **Locomotion:** => Free living species have cilia => Can swim in water.

=> Parasites do not usually move.

✓ **Habit and Habitat:** These are mostly endoparasites found in animals including human beings. Some are free living like *Planaria* (Living in fresh water).

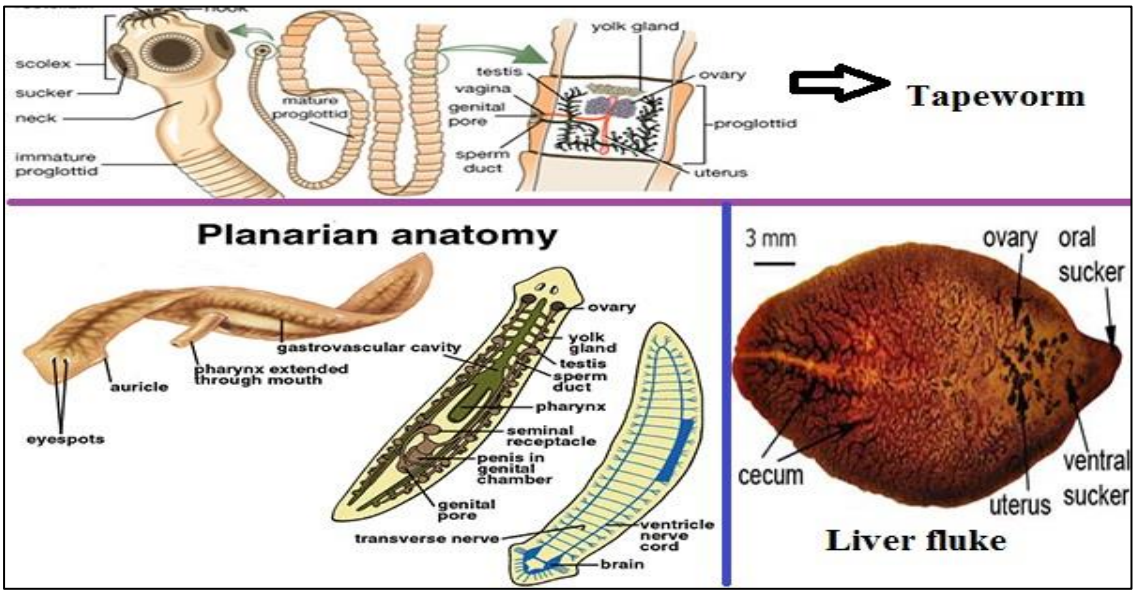


Figure 52 : Types of Platyhelminthes

Classification of Phylum Platyhelminthes

Chiefly on the basis of mode of life, phylum Platyhelminthes is divided into four classes.

Class 1. Turbellaria, Class 2. Trematoda, Class 3 Monogeneans, Class 4. Cestoda

1.1. Class 1/ Turbellaria

(Gr., Turbella- a little stirring).

- ✓ The class Turbellaria includes free-living freshwater or marine or Terrestrial.
- ✓ Usually non – parasitic, primarily carnivorous.
- ✓ Some Turbellaria can swim by undulations of the body margins, but most of them glide gracefully over surfaces along a trail of mucus, pushed by cilia on their ventral surface.
- ✓ Body unsegmented, flattened and covered with ciliated cellular or syncytial epidermis, containing mucus secreting cells and rod-shaped bodies called rhabdites (**Figure 53)**.
- ✓ Mouth ventral. Intestine preceded by muscular pharynx.
- ✓ Suckers absent.
- ✓ Ocelli (simple eyes) are present in some.
- ✓ Mostly hermaphroditic.
- ✓ Some reproduce asexually, sexual and by regeneration.
- ✓ Development usually direct.
- ✓ Life cycle simple.

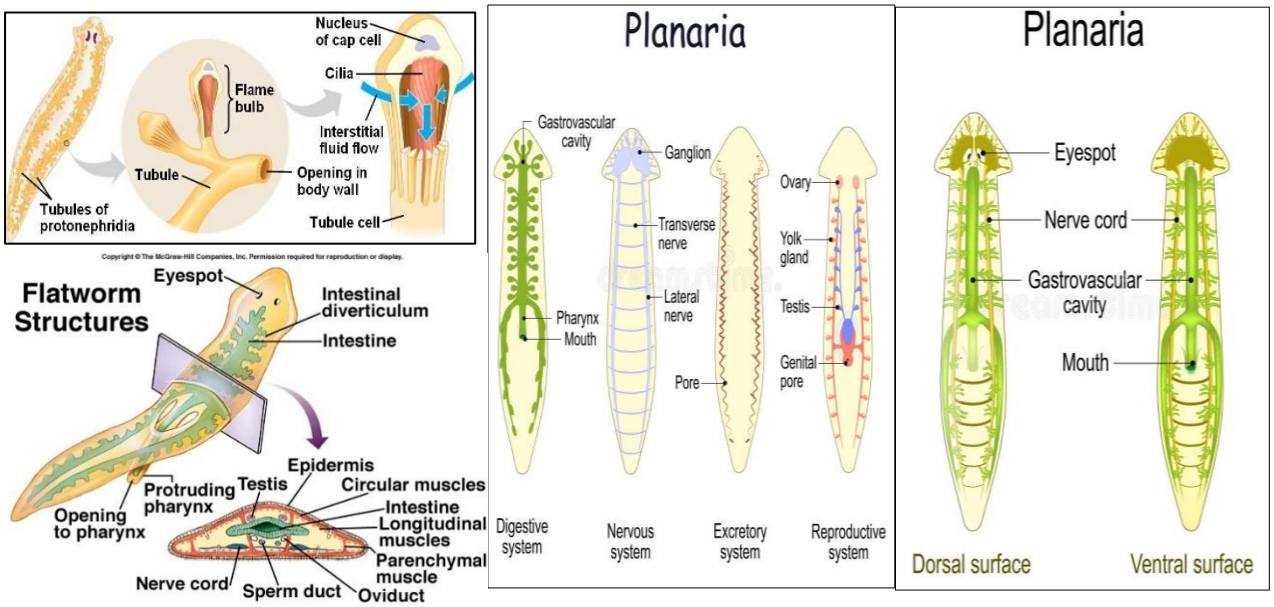


Figure 53 : *Planaria* anatomy, The Structure of Protonephridium

Classification of Class Turbellaria

Turbellarians are generally divided into five orders based on the different forms of their digestive cavity. They are:

1.1.1. Order 1/ Acoela: Have no digestive cavity.

Example: *Convoluta convoluta*. *Amphiscolops*, *Ectocotyle*, *Afronta*.

1.1.2. Order 2/ Rhabdocoela: Straight and unbranched digestive cavity.

Example: *Plagistomum*, *Catenula*, *Macrostomum*, *Microstomum*, *Mesostoma*, *Temnocephala*.

1.1.3. Order 3/ Polycladida: Gut sub-divided into numerous branches.

Example: *Notoplana*, *Thysanozoon*

1.1.4. Order 4/ Alloecoela: Sack-like or branched digestive cavity.

Example: *Proporoplana*, *Prorhynchus*, *Geocentrophora*, *Hypotrichina*, *Otoplana*.

1.1.5. Order 5 / Tricladida: Possess three-branched gut.

Example: *Ectoplana*, *Planaria*, *Bipalium*.

1.2. Class 2/ Trematoda

(Gr. Tremta- hole + eidos- form)

- ✓ Ecto- or endoparasitic flatworm, called flukes.
- ✓ Body unsegmented, dorso-ventrally flattened, leaf like (**Figure 54)**.
- ✓ Tegument thick but without cilia and rhabdites.
- ✓ Suckers and sometimes hooks present.
- ✓ Alimentary canal with anterior mouth, simple pharynx and two main branches.
- ✓ Three pairs of longitudinal nerve cords.
- ✓ Mostly monoecious (Hermaphrodite).
- ✓ Ovary single and testis two too many.
- ✓ Development direct (in ectoparasites) or indirect (in endoparasites) with alternation of hosts.
- ✓ Life history simple or typical.

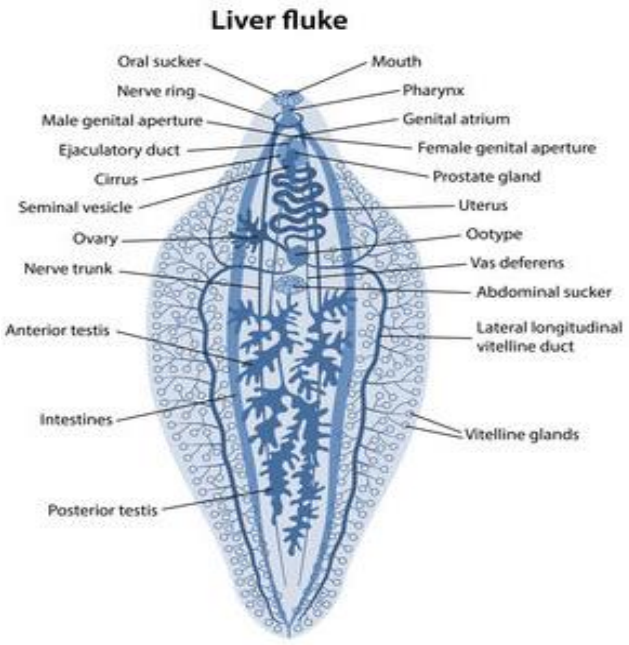


Figure 54 : Diagram of digenia trematoda with basic internal organs in longitudinal section.

Classification of Class Trematoda

Depending on the structure of their attachment apparatus and the number of hosts required for their development, trematodes are divided into:

1.2.1. Order 1 / Digenea

- Mostly endoparasites in vertebrates and invertebrates.
- Two suckers, oral and acetabulam, both devoid of hooks.
- Single posterior excretory pore.
- No vagina.
- Uterus long with numerous shelled eggs.
- Life cycle complex with numerous larval stages in two to three intermediate hosts.
- Larval forms reproduce asexually before metamorphosis.

Examples: *Bucephalus*, *Paramphistomum*, *Paagonimus*, *Schistosoma*, *Opisthorchis*.

- **Fa1/ Fasciolidae**
  - **Examples 1: *Fasciola hepatica***

Name of the disease: Fascioliasis hepatica, or Lever rot (common liver fluke, 2 to 3 cm).

Habitate: Bile ducts of sheep, goats, cows, horses, pigs, and sometimes humans.

Intermediate host: *Lymnaea trancatula*.

- **Examples 2: *Fasciola gigantica*** (giant liver fluke, 6 to 7 cm).

Final host: Herbivores (sheep, cattle) and humans.

Intermidate host: Snail (small aquatic gastropod mollusc: *Lymnaea truncatula*).

Adult parasite of the hepatobiliary system of sheep, humans and cattle.

- **Examples 3: *Fasciolopsis buski*** (large intestinal fluke).

Name of the disease: Fascioliasis.

Habitate: The duodenum and ileum of small intestine. It may be found in the stomach and large intestine.

The final host: Human and Pig.

Intermidate host: Segmentina / Hippeutism.

- **Examples 4:** *Heterophyes heterophyes*.

Name of the disease: Hetrophiasis.

Habitate: Small intestine among villi.

Final host: Humans, Cats, Dogs, and Foxes.

First intermediate host: *Pirenella conica*.

Second intermediate host: is *Tilapia mugil*.

Paragonimus westermani (lung fluke).

Name of the disease: Pulmonary distomiasis.

Habitate: The lungs.

Final host: Human.

First Intermidate host: Thiara snail.

Second Intermidate host: Cray Fish or Cramb.

- **Fa2/ Schistosomatidae** (**Figure 55**).
  - ***Schistosoma haematobium***

Name of the disease: Bilhariziasis or Urinary Bilhariziasis or Vesical Schistosomiasis.

Habitate: lower mesenteric vein, pelvic vessels, vesical plexus and portal vein and its branches.

Final host: The human.

Intermidate host: Physopssis and Bulinus snail

- ***Schistosoma mansoni***

Name of the disease: Schistosomiasis mansoni or Intestinal Schistosomiasis.

Infection site: branches of the lower mesenteric veins in the large intestine.

Middle host: Biomphalaria snail.

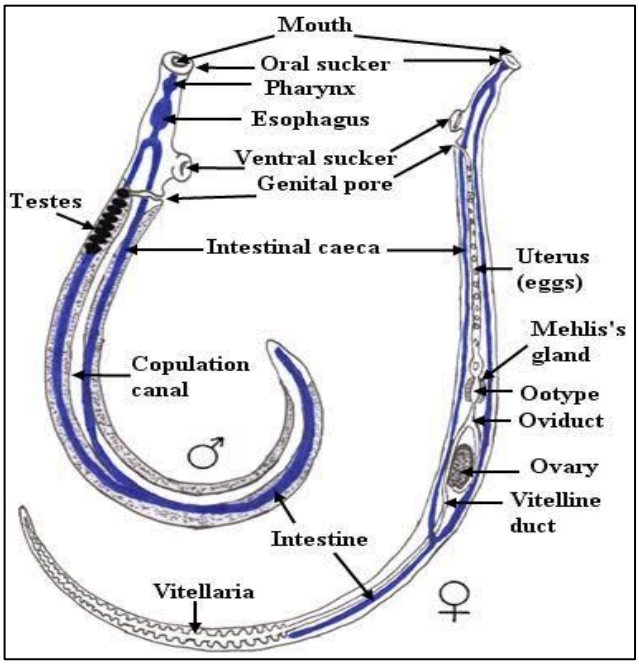


Figure 55 : Schematic diagram showing structural details of Schistosoma.

1.3. Class 3/ Monogenea

- ✓ Mostly ecto-parasitesim cold blooded aquatic vertebrates.
- ✓ Posterior adhesive organ or opisthaptor with suckers armed with hooks or spines.
- ✓ Excretory pores two, situated anteriorly on dorsal side.
- ✓ Vagina one or two.
- ✓ Uterus small with a few shelled eggs.
- ✓ Only a single host in life cycle.
- ✓ Free swimming ciliated larva called onchomiracidium.

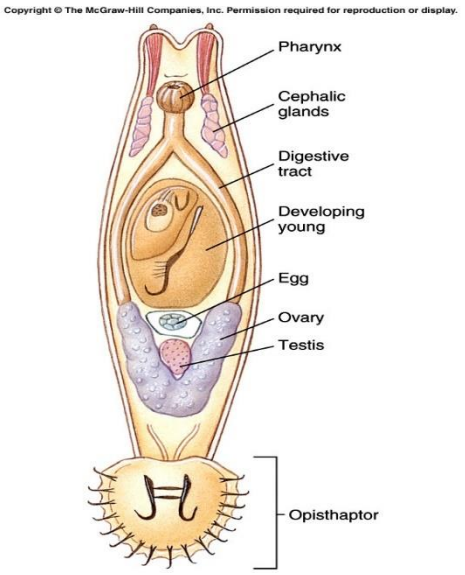

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Figure 56 : Schematic diagram showing structural details of Monogenea.

1.4. Class 4 / Cestoda

(Gr., kestos- girdle + eidos- form).

- ✓ Endoparasitic flatworms, called tapeworms.
- ✓ Body segmented, elongate, flat, ribbon-like (**Figure 57)**.
- ✓ The body has Scolex (head) with suckers, or hooks, or both. Neck and Strobila: consists of segments (proglottids).
- ✓ Tegument with microvilli.
- ✓ No alimentary canal.
- ✓ Excretion by flame cells.
- ✓ No sense organs.
- ✓ Genital system : hermaphrodite Each mature segment or proglottid (monoecious) contains usually one set of male and female organs(**Figure 57)**.
- ✓ Life cycle complicated involving one or more intermediate hosts (**Figure 60c,d,e and f)**.
- ✓ Embryos with hooks.

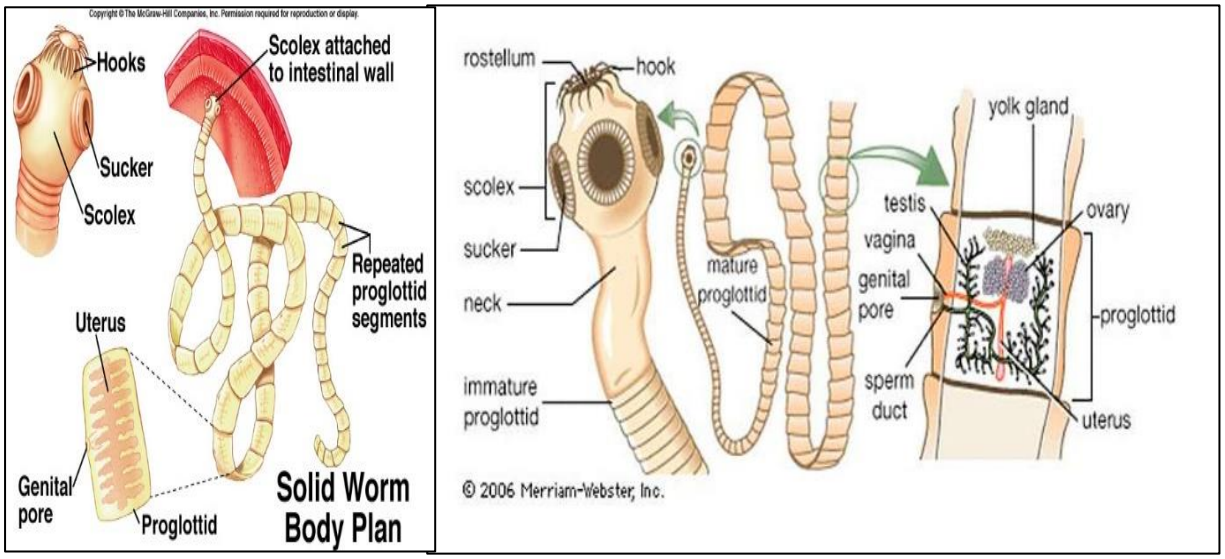


Figure 57 : Diagram of Cestoda with basic internal organs in longitudinal section.

Classification of Class Cestoda

Cestodes are classified on the basis of the morphology and structure of the scolex and the genital apparatus, as well as the characteristics of their life cycle. Class- Cestoda classified into two subclasses:

1.4.1. Subclass 1 / Cestodaria

- ✓ Body unsegmented, leaf- like, without scolex and strobila (monozoic or body undivided).
- ✓ Only one set of monoecious reproductive system.
- ✓ Larva lycophore with 10 hooks.

Subclass – Cestodaria divided into two orders:

1.4.1.1. Order - Amphilinidea **Example:** *Amphilina*.

1.4.1.2. Order- Gyrocotylidea **Example:** *Gyrocotyle.*

1.4.2. Subclass 2/ Eucestoda

- ✓ Body long, ribbon- like.
- ✓ Divided into scolex, neck and strobila with many proglottids (polyzoic).
- ✓ Mostly with several sets of monoecious reproductive organs.
- ✓ Larvae with six hooks.

Class- Eucestoda classified into eleven orders:

1.4.2.1. Order 1 / Cyclophyllidea (=Taenioidea)

- ➢ **Scolex:** Pear-shaped, 4 suckers, sometimes with hooks arranged in 1, 2 or more rings
- ➢ **Proglottid:** Lateral genital pore; no egg-laying opening.
- ➢ Habitat Both Taenia saginata and Taenia solium Adult worms live in the small intestine.
- ➢ **Life cycle:** 1 single IH.
- ➢ **Eggs or embryophores:** Hexacanth embryo (with 3 pairs of hooks).
- ➢ **Size:** Large (4 to 12 m in length, 1,000 to 2,000 'rings' or segments).
- ➢ **Lifespan:** 5 to 25 years.
- ➢ Parasitic in Amphibians, Reptiles, Birds and Most human parasitesa and Mammals.

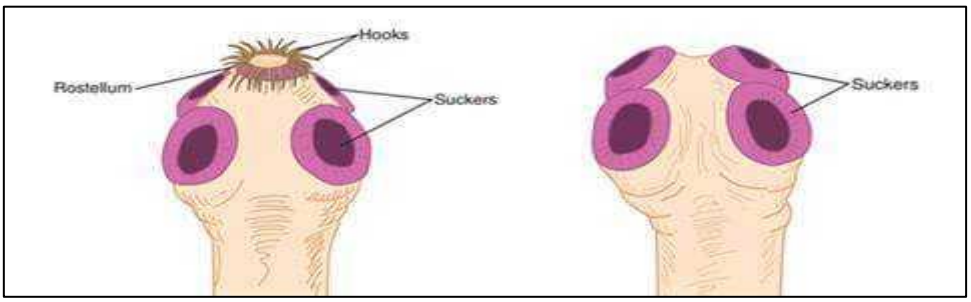


Figure 58 : Scolex of *Taenia saginata* and *Taenia solium.*

Example 1: ***Taenia solium*** (Pork tapeworm or armed tapeworm).

- ❖ **Scolex:** 4 suckers and Rostellum and hooks present (**Figure 68**).
- ❖ **Neck:** Short.
- ❖ **DH (Definitive hosts):** Humans (**Figure 60c**).
- ❖ **IH (Intermediate hosts):** Pig, occasionally man.
- ❖ **Size:** Large (4 to 8 m in length, **Proglottids:** 1,000 to 2,000 'rings' or segments).
- ❖ Site of Development: Muscle, small intestine,brain.

Example 2: ***Taenia saginata*** (beef tapeworm or unarmed tapeworm).

- ❖ **Scolex:** 4 suckers and Rostellum and hooks are absent (**Figure 58**).
- ❖ **Neck:** Long.

- **Genital pores:** irregularly alternating – fine, numerous and dichotomous uterine branches (after staining).
- **DH (Definitive hosts):** Humans (**Figure 60c**).
- **IH (Intermediate hosts):** Bovids (Cow).
- **Size:** Large (4 to 12 m in length, **Proglottids:** 1,000 to 2,000 'rings' or segments).
- **Site of Development:** Small intestine.

Example 3: ***Echinococcus granulosus***

- **Commen Name:** Hydatid Tapeworm.
- **Scolex:** With 4 suckers and a rostrum bearing a double crown of hooks.
- **The body (trunk) or strobilus:** Comprises 3 to 4 rings, the last of which is called the gravid or oigerous segment.
- **Definitive hosts (DH):** Canids (dogs) , foxes, wolves etc.
- **Intermediate hosts (IH):** Herbivores, Sheep,Goats, Camels pigs, cows and infects humans and is considered an emergency host that affects the liver / lungs (**Figure 60d**).
- **Name of the disease:** Hydatid disease // hydatidosis.
- **Site of infection:** Direct contact with dogs is the Liver, lung, bone (extraintestinal).

Example 4: ***Hymenolepis nana*** (Dwarf tapeworm).

- **Commen Name:** Dwarf tapeworm.
- **Scolex:** globular, 0.2 mm in diameter, with 4 suckers. A retractile rostellum with a crown of hooks (long handle, short blade and a guard).
- **The body (trunk) or strobilus:** 200 segments.
- **Definitive hosts (DH):** Man.
- **Intermediate hosts (IH):** Man, may be insects like flea larva or grain beetles**(Figure 60e).**
- **Name of the disease:**
- **Site of infection:** The small intestine.

1.4.2.2. Order / Pseudophyllidea

- **Scolex:** Elongated, 2 bothridia, no suckers or hooks.
- **Proglottis:** Medial ventral genital pore; medial ventral oviposition pore.
- **Size:** large, 1 to 12, up to 20 m, 3,000 to 4,000 segments.
- **Life cycle:** 2HI. Aquatic. Eggs or embryophores: operculated (with a valve).

Example: *Diphyllobothrium latum.* Parasitic in freshwater fisher (teleosts).

- **Commen Name:** The broad fish tapeworm.
- **Habitat :** The adult worm is found in the small intestine, usually in the ileum, where it lies folded in several loops with the scolex embedded in the mucosa.
- Adult worm can reach up to 10 meters long.

- **Scolex:** elongated with two longitudinal sucking grooves (bothria) instead of suckers or hooks.
- **Proglottids:** are broader than long, giving the name "broad tapeworm."
- **Eggs:** operculated, unembryonated when passed in feces.
- **Definitive host:** Humans are the principal definitive host **(Figure 60 f).**
- Intermediate hosts: **First intermediate host:** Copepod (Cyclops).

Second intermediate host: Freshwater Fish.

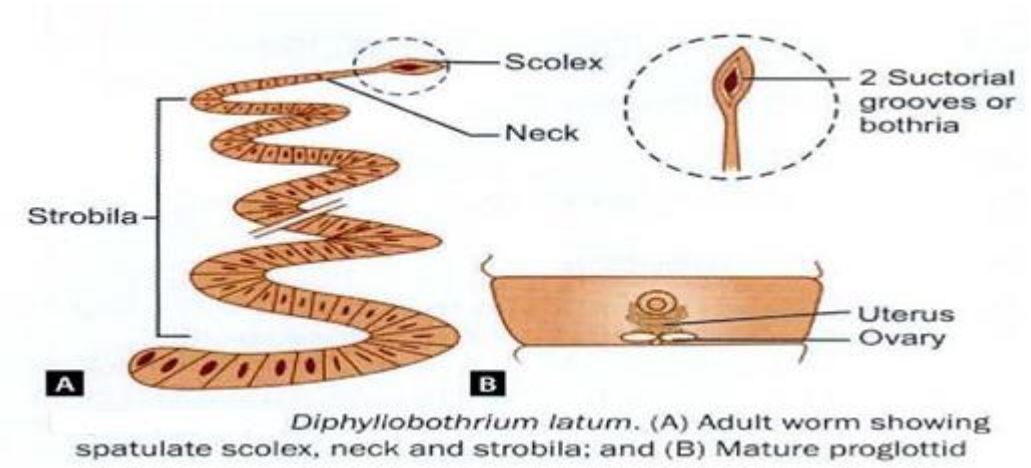
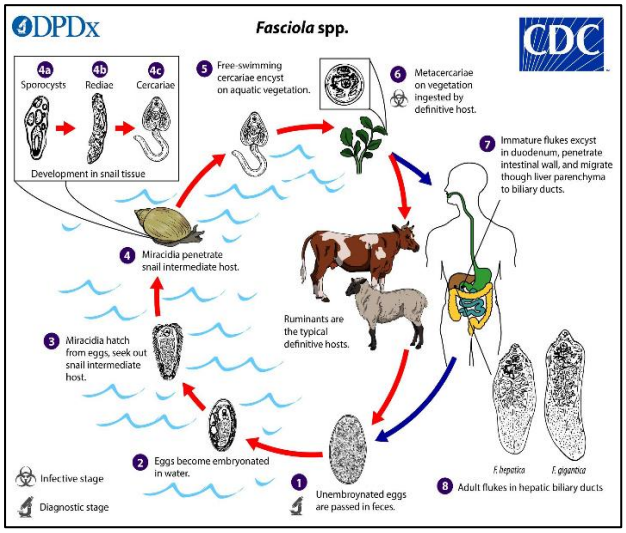


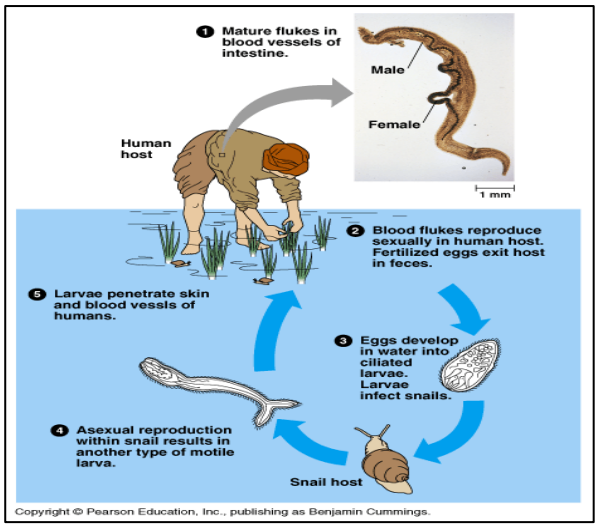
Figure 59: Diphyliobothrium latum. (A) adult worm showing spatulate scolex, neck and strobila : and (B) Mature proglottid.

Table 4. Examples of Tapeworms

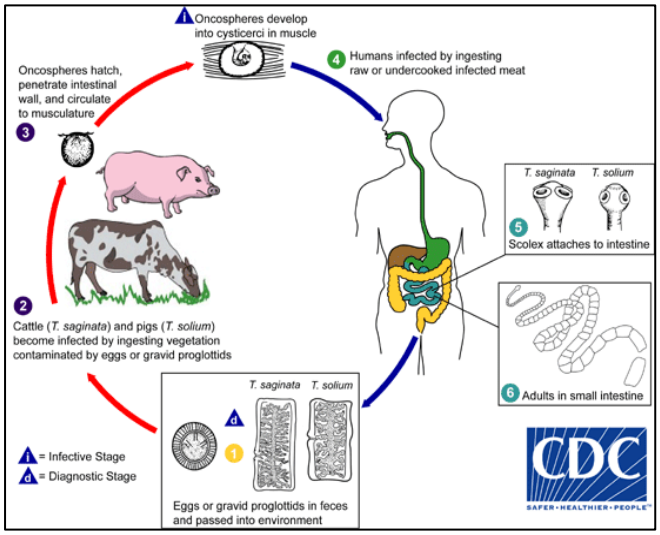
	Taenia solium	*Taenia saginata*	*Hymenolepis nana*	*Hymenolepis diminuta*	*Diphyllobothrium latum*	*Echinococcus granulosus*
Heads						
	4 suckers 2 rows of hooks	4 suckers No hooks	4 suckers single row of 20–30 hooks	4 suckers No hooks	2 Suctorial grooves or bothria No suckers, No hooks	4 suckers 2 rows of hooks
Proglottids						
	Longer than broad 7–12 uterine branches on each side	Longer than broad 15–30 uterine branches on each side	Broader than long	Broader than long	Broader than long Uterus coiled	Longer than broad



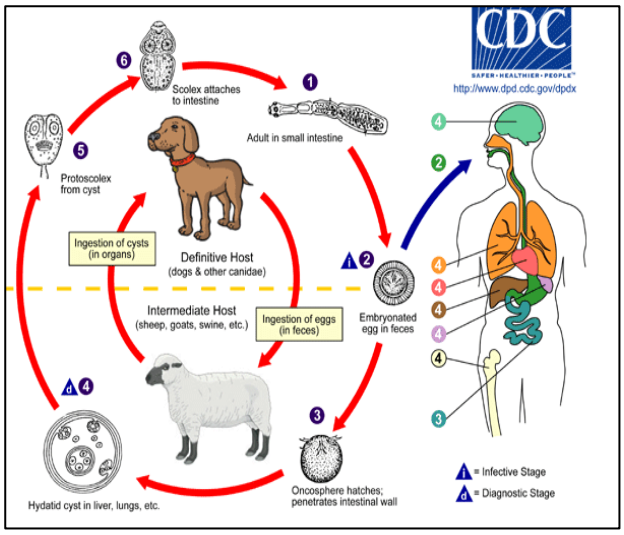
Life cycle of *Fasciola hepatica* **(a)**



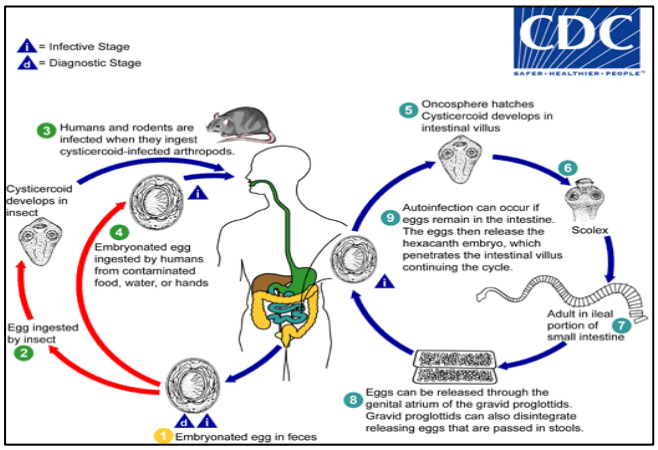
Life cycle of *Fasciola hepatica* **(b)**



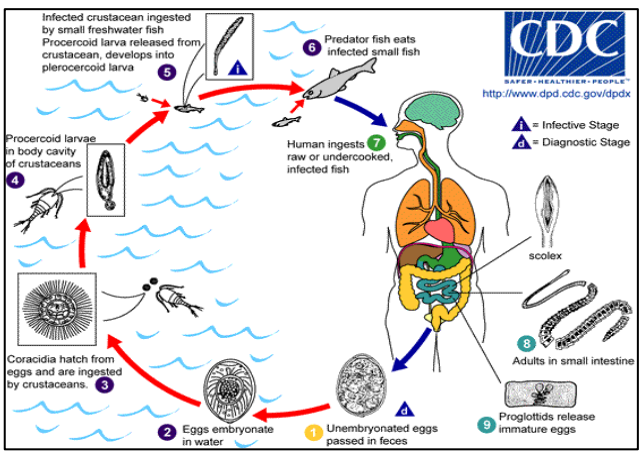
Life cycle of *Taenia solium* and *Taenia saginata* **(c) .**



Life cyc le of *Echinococcus granulosus* **(d).**



Life cycle of *Hymenolepis nana* **(e).**



Life cycle of *Diphyllobothrium latum* **(f).**

Figure 60 : Life cycle of a few species of Plathelminthes.

III-2- Phylum:

Nemathelminthes

2. Phylum Nemathelminthes or Aschelminthes

Nematodes (Gr., nema thread+ eidos, form) are commonly referred to as non-segmented roundworm, threadworm or pinworm, as distinct from flatworm and higher segmented annelids.

Nematodes are one of the most common phyla of animals, with over 20,000 different described species, out of which 15,000 are parasitic in nature.

Greek: Nema= thread + eidos=form; Helmins = Worms.

Greek: Ascus = Bladder, Helmins = Worms (Roundworms).

Greek words: askes - cavity + helmins –worm.

The body of the aschelminthes is circular in cross section, hence they are known as **roundworms**.

Characteristics of Nemathelminthes or Aschelminthes

- **External Features (Figure 61):**
  - ✓ **Shape:** Body mostly cylindrical, vermiform or flattened. It is tubular tapering at both ends and is covered with a thin cuticle.
  - ✓ **Body size:** Mostly small, some microscopic, while others few millimeters to over a meter or even more in length.
  - ✓ **Head:** Head not distinctily formed with well-defined sense organs.
  - ✓ **Segmentation:** Unsegmented.
- **Internal Anatomy (Figure 61):**
  - ✓ **Germ Layers:** They are triploblastic animals with three germ layers.
  - ✓ **Grade of organization:** Roundworms have organ system level of body organisation.
  - ✓ **Body cavity or Coelom:** Pseudocoelomates. Not lined by mesoderm (presence of a cavity, the pseudocoel, between the gut and body wall).
  - ✓ **Symmetry:** They are bilaterally symmetrical.
  - ✓ **Integumentary System:**
    - **Body wall:** Body wall with a syncytial or cellular epidermis externally covered with thick cuticle of scleroprotein.
    - **Epidermis** is multinucleated.
  - ✓ **Skeletal System:** Absent.
  - ✓ **Muscular system:** Musculature includes mostly longitudinal fibres.
  - ✓ **Digestive system:** They have a tubular straight and complete alimentary canal within their body consisting of mouth, muscular pharynx, straight non-muscular intestine and anus. The mouth may possess teeth to cut and pierce the tissues. The muscular pharynx is well developed which helps in sucking food from the host (**Figure 61**).

- ✓ **Digestion:** Extracellular.
- ✓ **Nervous system:** Simple and consists of a circumenteric nerve ring having anterior and posterior longitudinal nerves (**Figure 61**).
- ✓ **Sense organs:** Are pits, papillae, bristles and eye spots.
- ✓ **Circulatory system:** Absent.
- ✓ **Respiration system:** Absent Diffusion of gases through the skin. Respiration is aerobic in free-living forms and anaerobic in parasitic form.
- ✓ **Excretory system:** Includes a system of canals, protonephridia or glandular organs or both for osmoregulation (**Figure 61**).
- ✓ **Reproductive System** (**Figure 61**):
  - ➢ **Sexes:** They are **dioecious (Sexes are separate).**

    Sexual dimorphism present. The male is smaller than the female.

    Males have copulatory spicules which help in the process of copulation.

    Gonads and ducts single or double.

    Eggs with chitinous shell. Cleavage is determinate and spiral.
  - ➢ **Fertilization:** Is internal.
  - ➢ **Development:** May be direct (the young ones resemble the adult) or indirect.
  - ➢ **Life cycle:** May be direct or indirect (Life cycle has different stages) (**Figure 62**).
- ✓ **Habitat:** They may be free-living, aquatic and terrestrial or parasitic in plants and animals.

Examples: *Ascaris* (Round Worm), *Wuchereria* (Filarial worm), *Ancylostoma* (Hookworm).

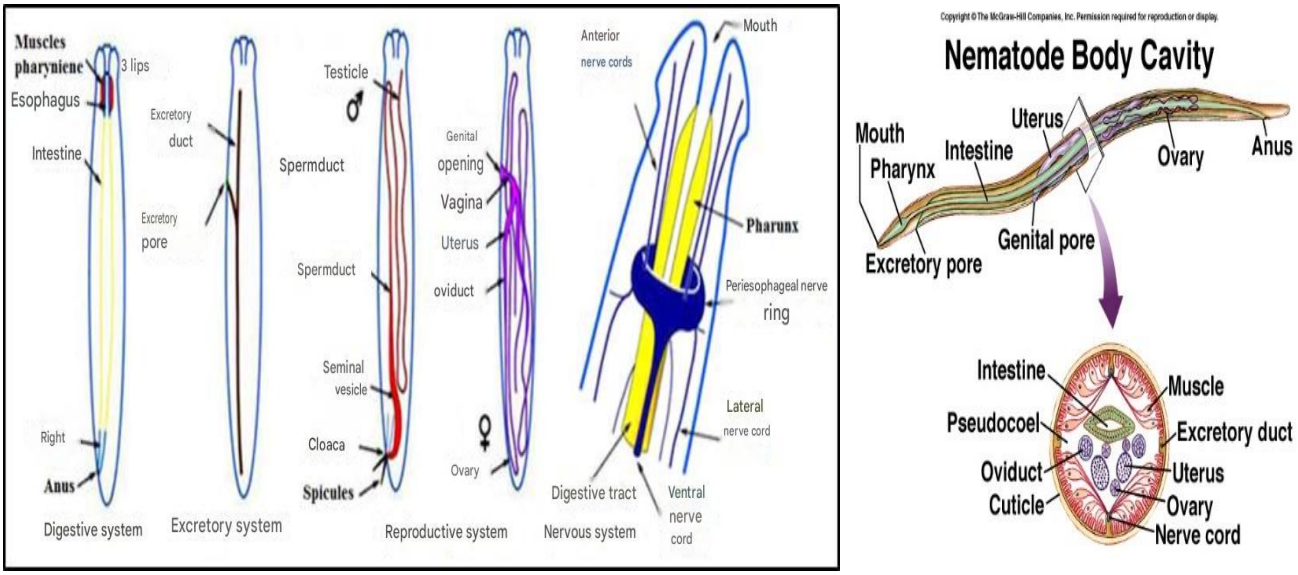


Figure 61 : Morphology and general anatomy of Nemathelminthes.

Classification of Phylum Nemathelminthes

Nematoda are among the most numerous of any phylum. About 15,000 species of nematodes are known at present. Due to much diversity in form and structures difficult to classify. Chitwood (1933) **divided them into two classes phasmidia and Aphasmidia on the basis of presence and absence of phasmids (sensory organ).**

2.1. Class 1 / Adenophorea or Aphasmidia

- ✓ Phasmid (causal sensory organs) absent.
- ✓ Amphids (anterior sense organs) of various types, rarely pore-like.
- ✓ Excretory system absent. If present poorly developed.
- ✓ Well-developed mesenterial tissue.
- ✓ Caudal adhesive glands present.
- ✓ Most species are free living and some are parasitic.
- ➢ Free living species include almost all marine forms, and some terrestrial and freshwater forms

A few **example**s *Xiphinema*, *Mermis* and *Enoplus*.

2.1.1. Order 1 / Trichuroidea/ Trichinelloidea

- ➢ Mouth without lips.
- ➢ Pharynx slender.
- ➢ Body filiform anteriorly.
- ➢ Female with 1 ovary and male with 1 or none spicule.
- ➢ Parasites of vertebrates.

Examples: *Trichinella spiralis*; *Trichuris trichiura.*

2.2. Class 2 / Phasmidia (secernentea)

- ✓ Phasmids are present which open through minute pore on each side near tip of tail.
- ✓ Amphids are pore-like and are present in the lateral lips.
- ✓ Well-developed excretory system.
- ✓ Weekly developed mesenterial tissue.
- ✓ No caudal adhesive glands.
- ✓ Most of the species are parasitic in nature.
- ✓ Free living species are soil inhabitants.

A few examples are Ascaris, Wuchereria, Oxyuris, Ancylostoma and Dracunculus Class nematoda divided into following eighteen orders.

2.2.1. Order 1/ Ascaridida/Ascaroidea

- Large-sized worm.
- Mouth surrounded by three prominent lips.
- Pharynx without posterior bulb.
- Buccal capsule absent.
- Tail of female blunt.
- Male with a ventrally coiled tail.
- Parasitic in the vertebrates.

Examples: *Ascaris lombricoïdes; Toxocara canis; Ascaris megalocephala*.

2.2.2. Order 2/ Oxyuroidea: (Oxyurus)

- Pin-shaped small worm.
- Mouth surrounded by 3-6 small lips.
- Pharynx with valvular posterior bulbs.
- Females with a long pointed tail.
- Male with one or two equal spicules.
- Parasitic in invertebrates and vertebrates.

Examples: *Oxyuris*, *Enterobius vermicularis*.

2.2.3. Order 3/ Strongylida/Strongyloidea

- Mouth without lips but leaf crown.
- Pharynx without bulb.
- Male with expanded copulatory brusa
- Female usually with ovijector.
- Parasites of vertebrates.

Examples: *Ancylostoma duodenale*, *Strongylus*, *Syngamus trachealis*,*Necator*.

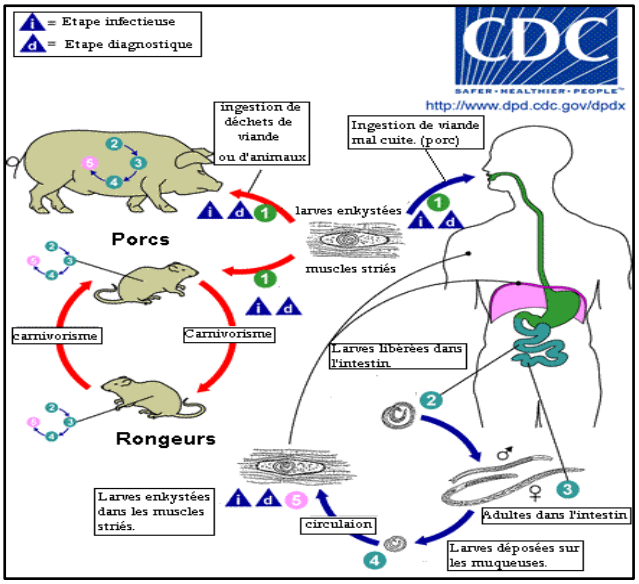
2.2.4. Order 4/ Filarioidea

- Filiform slender worm.
- Lips absent in filiform worms.
- Buccal capsule small.
- 6 labial papillae present.
- No pharyngeal bulb.
- Male small with a coiled tail.
- Vulva anterior in female.
- Microfilariae in blood or skin and developed in blood-sucking insects.

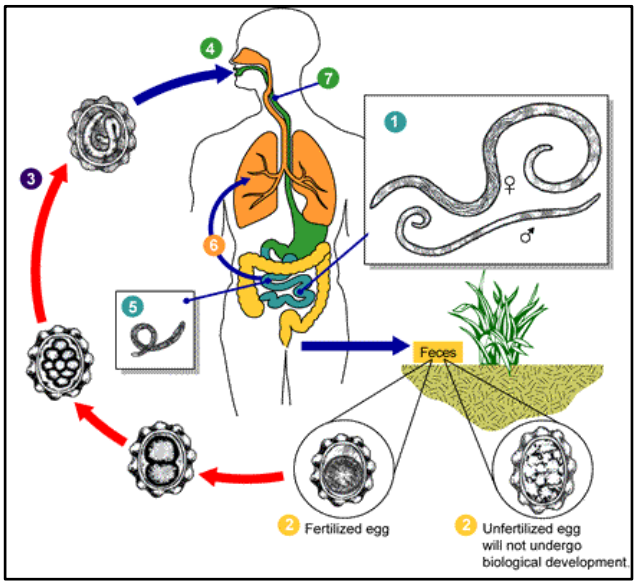
III-2- Phylum: Nemathelminthes

- Parasites of vertebrates.

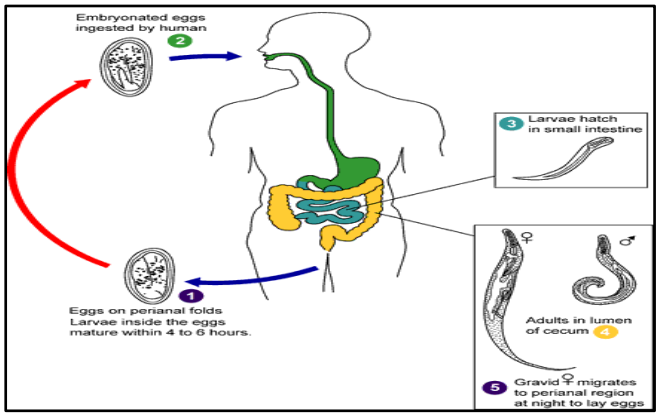
Examples: *Wuchereria bancrofti*, *Onchocerca volvulus*, *Loa*, *Microfilaria*.



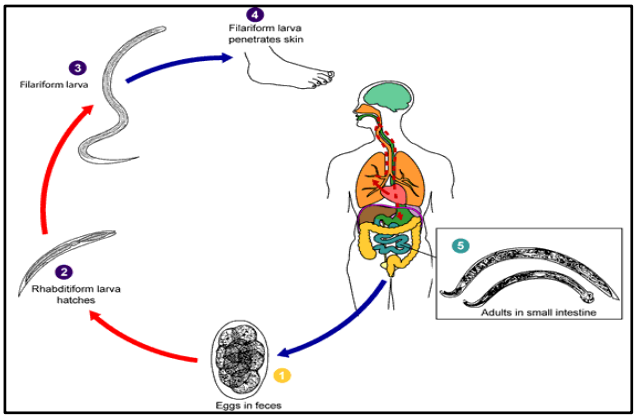
a : *Trichinella sp*



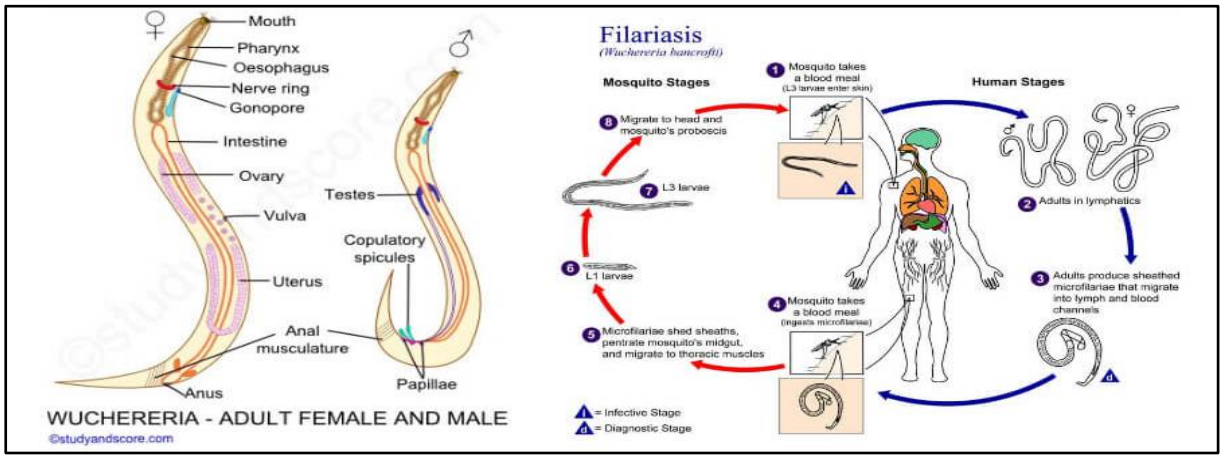
b : *Ascaris lumbricoides*



c : *Enterobius vermicularis*



d : *Ancylostoma duodenale*



e : *Wuchereria bancrofti*

Figure 62 : Life cycle of a few species of Nemathelminthes.

III-3- Phylum: Annelida

3. Phylum Annelida

Gr : Annulus - little ring + eidos – form.

Latin: Annulus = Ring, Eidos = Form (Segmented worms).

General Characters of Annelida:

- **External Features (Figure 63):**
  - ✓ **The body of an annelid usually consists of three parts:**
    - Head= Prosoma (prostomium and peristomium).
    - Soma= metameres.
    - Telson= pygidium (terminal segment).
  - ✓ **Metamerically segmented:** body is externally divided into segments called metameres.
  - ✓ Remarkable feature of annelids is the true segmentation.
- **Internal Anatomy (Figure 63):**
  - ✓ **Germ Layers:** They are triploblastic animals with three germ layers.
  - ✓ **Grade of organization:** They exhibit organ-system level of organisation.
  - ✓ **Body cavity or Coelom:** Coelomates or true coelomates.
  - ✓ **Symmetry:** They are bilaterally symmetrical.
  - ✓ **Protostomia:** the blastopore becomes the mouth-first, and anus second.
  - ✓ **The organs of locomotion:** Locomotory organs are segmentally repeated chitinous bristles, called setae or chaetae, embedded in skin. or unjointed lateral appendages called parapodia which helps swimming in aquatic annelids, **Eg:** *Nereis*.
  - ✓ **Integumentary System:** Body surface is covered by a thick cuticle. Body wall has both longitudinal and circular muscles.
  - ✓ **Muscular system:** Outer muscle fibres circular, longitudinal
  - ✓ **Digestive system:** It is complete and consists of pharynx, oesophagus, crop storage, gizzard, stomach, intestine, anus (straight).
  - ✓ **Digestion:** Digestion entirely extracellular.
  - ✓ **Nervous system:** It consists of a pair of cerebral ganglia (brain), segmented ganglia and a double ventral nerve cord (Hyponeurians) bearing ganglia and lateral nerves in each segment.
  - ✓ **Sense organs:** Sensory organs include tactile organs, taste buds, statocysts, photoreceptor cells and sometimes eyes with lenses in some.
  - ✓ **Circulatory system:** They are the first group of animals to have closed circulatory system. Blood flows through closed blood vessel. The blood colour is red due to the presence of haemoglobin.
  - ✓ **Respiration system:** They show skin respiration or some through parapodia, A few have gills.

- ✓ **Excretory system:** Excretory organs are paired segmentally arranged coiled tubes called **nephridia**. They also help in osmoregulation.
- ✓ **Reproductive System:**
  - ❖ **Reproduction:** Sexual reproduction occurs. Asexual reproduction occurs in some. Regeneration is common.
  - ❖ **Sexes:** Earthworms and leeches are monoecious (Hermaphroditic) but *Nereis*, an aquatic worm, is dioecious (sexes separate). cleavage pattern spiral and determinate (**Figure 63**)
  - ❖ Larva, when present, is a trochophore.
  - ➢ **Fertilization:** May be => Self-Fertilization.
    May be => Cross-Fertilization.
- ✓ **Development:** Their development is direct in monoecious form but indirect in dioecious form.
- ✓ **Habitat:** They may be aquatic (marine or fresh water) some terrestrial; free-living, and sometimes parasitic. Some commensal.

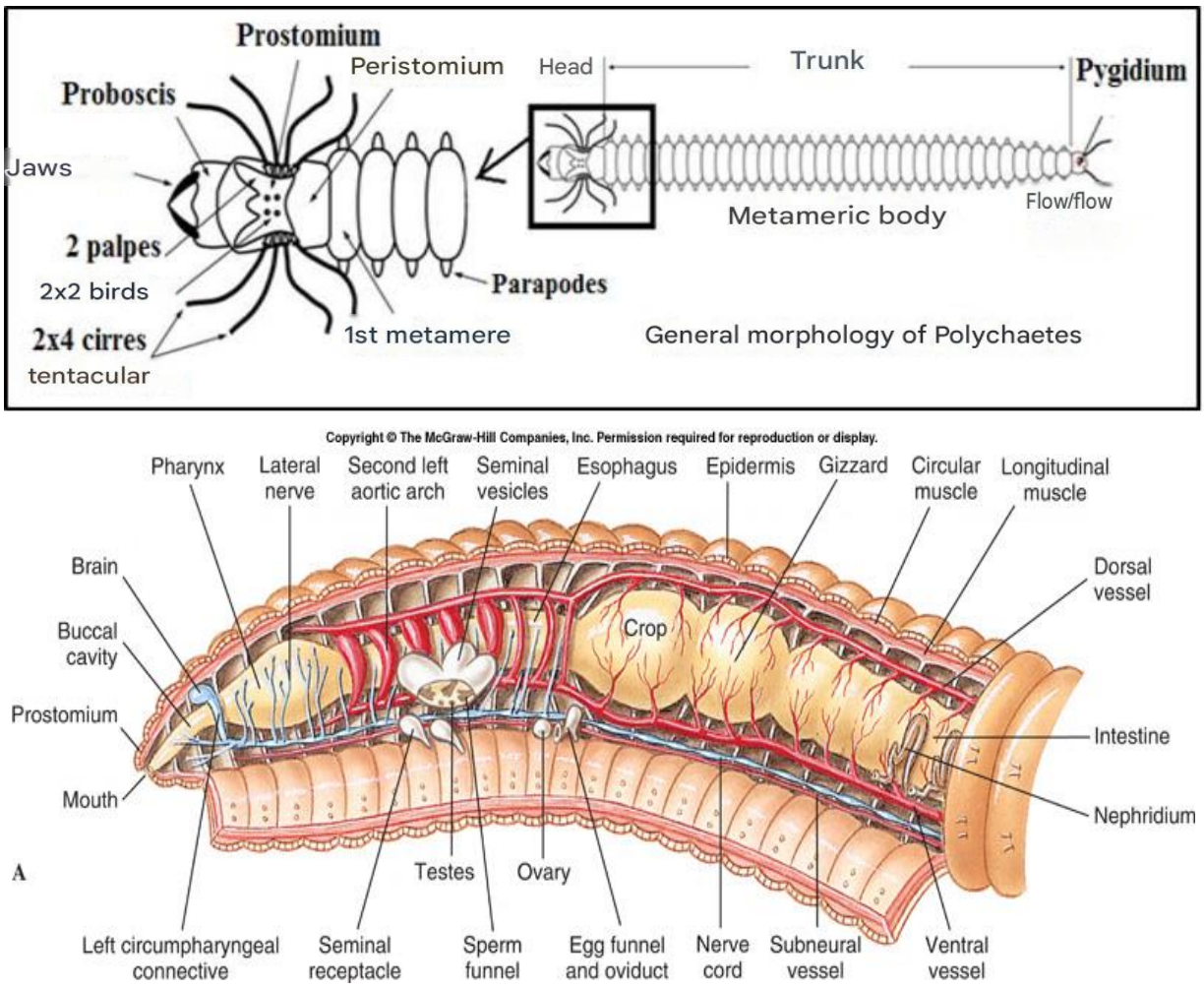


Figure 63: Morphology and general anatomy of annelids.

Classification of Phylum Annelida:

Modern classification of phylum Annelida was proposed by Fauchold (1977) and Parker (1980). About 8,700 known species of annelid are divided into four main classes, primarily on the basis of the presence or absence of parapodia, setae, metamers, and other morphological features.

Class Oligochaeta Class Polychaeta Class Achaeta (Hirudinea).

3.1. Class 1 / Polychaeta

(Gr., **Poly**=Many**, Chaeta**=Bristles/hair)

- ✓ Chiefly or Most marine, some in fresh water.
- ✓ Carnivorous.
- ✓ Body segmentation is internal and external (**Figure 64**).
- ✓ Head consists of prostomium and peristomium and bears eyes, tentacles cirri, and palps.
- ✓ Setae numerous on lateral parapodia.
- ✓ The excretory organ is segmentally paired nephridia.
- ✓ Cirri or branchiae or both may be present for respiration.
- ✓ Have paddle (parapodia) Aid in gas exchange and locomotion (**Figure 64**).
- ✓ The coelom is spacious usually divided by intersegmental septa.
- ✓ The alimentary canal provided with the eversible buccal region and protrusible pharynx.
- ✓ The clitellum is absent.
- ✓ Sexes separate.
- ✓ Fertilization external.
- ✓ Asexual reproduction by lateral budding.
- ✓ Trochophore larva present.

Polychaetes are divided into two subclasses**,** Erranitia and Sedentaria (Fauvel, 1959).

However, according to Dab (1963), this subdivision is artificial and not a natural one.

3.2.1.1. Subclass 1/ Errantia

- ➢ Free-swimming, crawling, burrowing or tube-dwelling and predatory polychaetes.
- ➢ Segmentation similar, except at anterior and posterior ends.
- ➢ The prostomium is distinct with sensory organs.
- ➢ Parapodia, provided with cirri, are equally developed throughout.
- ➢ Pharynx protrusible, enlarged and usually with jaws and teeth.

Examples*: Nereis diversicolor, Aphrodite*, *Polynoe*, *Phyllodoce*, *Tomopteris*, *Syllis*, *Eunice*, *Histriob della*, *Glycera*, *Diopatra*.

3.2.1.2. Subclass 2/ Sedentaria

- Sedentary polychaetes living in burrows or tubes.
- Body made of 2 or more regions, with unlike segments and parapodia.
- Head is small or much modified without eyes and tentacles, prostomium small.
- No acicula and compound setae.
- Pharynx non-protrusible without jaws and teeth.
- Gills, when present, localized to the anterior segments.
- Feeding on plankton or organic detritus.

Examples: *Chaetopterus*, *Arenicola*, *Owenia*, *Sabella*, *Sabellaria*, *Terebella*, *Amphitrite*, *Pomatoceros*, *Spirorbis*, *Serpula*, *Mercierella.*

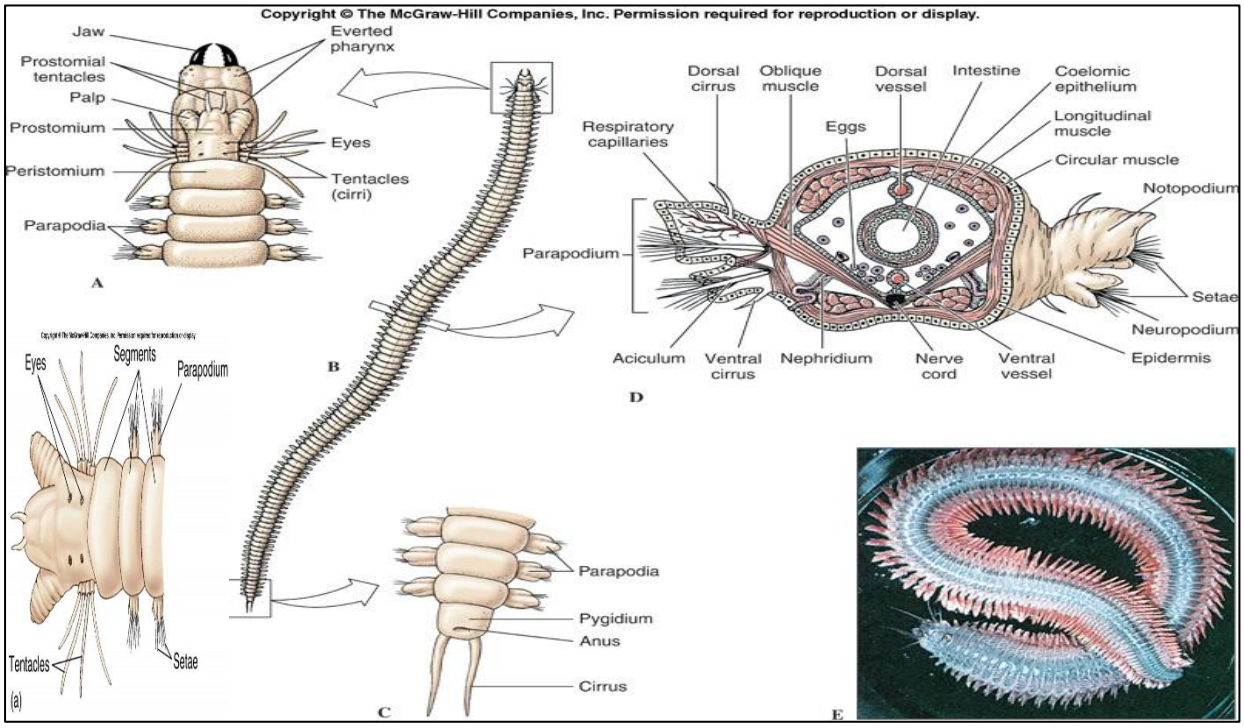


Figure 64: Morphology and general anatomy of Polychaeta

3.2.2. Class 2/ Oligochaeta

(Gr., **Oligos**=Few+ **Chaete**=hair)

- ✓ Include earthworms.
- ✓ Mostly terrestrial or some freshwater forms.
- ✓ Body with conspicuous external and internal segmentation (**Figure 65**).
- ✓ Head indistinct, without sensory organs.
- ✓ Setae few, embedded in the skin (**Figure 65**).
- ✓ Parapodia absent.
- ✓ The pharynx is not eversible and without jaws.

- ✓ Hermaphrodites (cross fertilization).
- ✓ Fertilization external (in cocoon); development direct, no larval stages (**Figure 66**).
- ✓ Testes anterior to ovaries.
- ✓ Development is direct. fertilization external (in cocoon); no larval stage.
- ✓ Glandular clitellum present for cocoon formation.
- ✓ Earthworms have five (aortic arches) hearts.
- ✓ The excretory: pair of nephridia (similar to our kidneys).
- ✓ Extremely beneficial to farming as they enrich and aerate soils (Friends of farmer).
- ✓ Food is brought in by a muscular pharynx.

Examples: *Lumbricus terrestris* (Earthworm).

3.2.2.1. Order 1/ Opisthopora

- ➢ Mostly terrestrial earthworms.
- ➢ Male gonopores some distance behind the testes-containing segments.

Examples: *Lumbricus Eisenia*, *Pheretima*, *Megascolex*, *Allolobophora*, *Dendrobaena*.

3.2.2.2. Order 2/ Prosopora

- ➢ Mostly aquatic.
- ➢ Male gonopores on the same segment containing testes, or on segment containing the second pair of testes.

Example: *Branchiobdella* (parasitic).

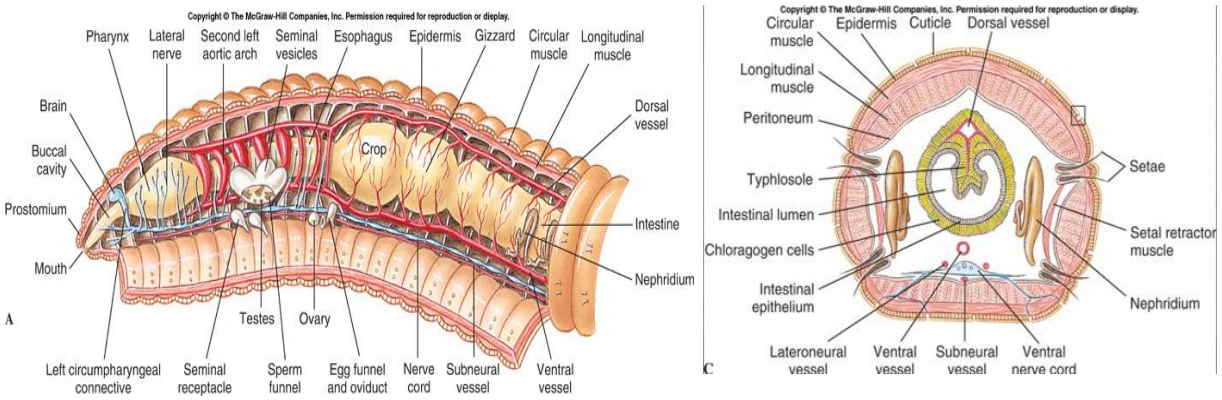


Figure 65: Morphology and general anatomy of Oligochaeta.

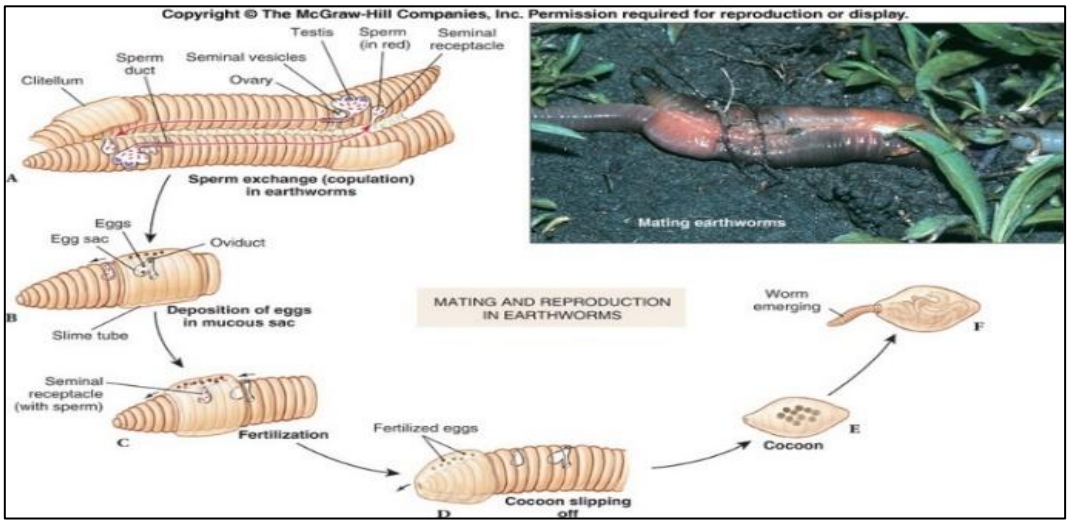


Figure 66: Life cycle of Earthworm.

3.2.3. Class 3/ Hirudinea Achaeta

(L., **hirudo**= a leech)

- ✓ Few are marine, freshwater or terrestrial.
- ✓ Generally, ectoparasitic, blood-sucking and/or carnivorous.
- ✓ The body is elongated and usually flattened and dorso-ventrally or cylindrical (**Figure 67**).
- ✓ The body consists of a fixed number of segments (33) (**Figure 67**).
- ✓ Each segment breaks up into 2 to 4 rings or annuli (**Figure 67**).
- ✓ Segmentation external without internal septa.
- ✓ Parapodia and setae absent.
- ✓ Both anterior and posterior ends of the body with ventrally situated suckers (**Figure 67**).
- ✓ The mouth opens on the ventral surface on anterior suckers, while anus opens dorsal to the posterior suckers (**Figure 67**).
- ✓ Coelom much reduced due to its filling by botryoidal tissue, and forms haemocoelomic sinuses.
- ✓ Hermaphroditic with one male and one female gonopore (**Figure 67**).
- ✓ Fertilization internal.
- ✓ Asexual reproduction is not known.
- ✓ Eggs are always laid in cocoons.
- ✓ Development is direct without a free-swimming larval stage.

3.2.3.1. Order 1/ Gnathobdellida

- ➢ Freshwater and terrestrial form.
- ➢ Ectoparasitic blood-sucking leeches.
- ➢ Each typical body segment consists of 5 rings or annuli.
- ➢ Anterior suckers with 3 jaws, 1 median dorsal and 2 ventrolateral.

- The proboscis is absent.
- Blood is red-colored.
- Botryoidal tissues present.

Examples: *Hirudo*, *Hirudinaria*, *Haemadipsa*, *Herpobdella*.

3.2.3.2. Order 2/ Acanthobdellida

- Mostly parasitic on the fins of salmon fishes.
- The body comprises 30 segments only.
- They are primitive, without anterior suckers, proboscis, and jaws.
- Double rows of setae are present in 5 anterior segments.
- The body cavity is spacious and incompletely divided by septa.
- The vascular system consists of the dorsal and ventral vessels.
- Nephridial opening situated on the surface between the segments.

Example: A single *Russian* genus and species (*Acanthobdella*) parasitic on salmon.

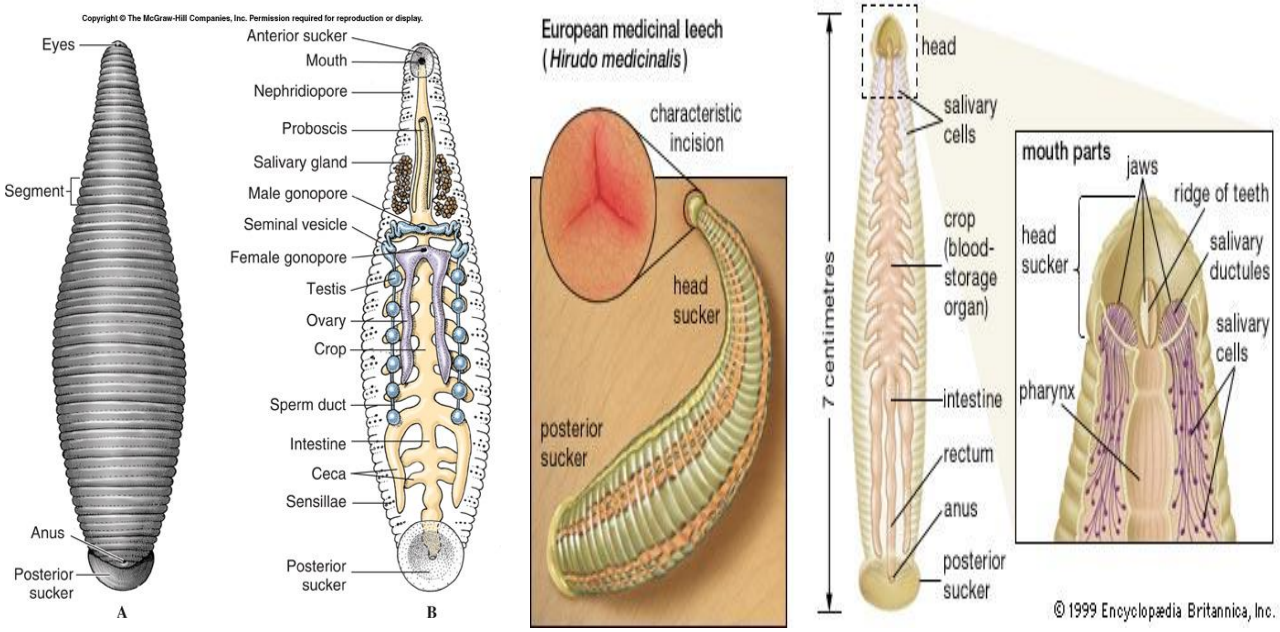


Figure 67: Morphology and anatomy of a leech.

III-4- Phylum:

Mollusca

4 Phylum : Mollusca

Molluscs (also know as mollusks) are soft-bodied, bilaterally symmetrical, unsegmented, coelomate animals; usually shelled having a mantle, ventral foot, anterior head, and a dorsal visceral mass.

Latin: Mollis = Soft (Soft bodied Animals).

This is the Second Largest Phylum in the animal kingdom.

The study of molluscs is called Malacology and the study of molluscans shells is called chonochology.

General Characters of Mollusca

Habitat: They are generally aquatic forms. Most of them are marine, some are found in fresh water, and a few are terrestrial. Grey slug is a terrestrial mollusc without a shell.

They may be found as hidden parasites in the interior of other animals.

They vary in size from giant squids and clams to little snails, a millimeter long.

➢ External Features:

Body Structure: The body is soft, unsegmented (except in Monoplacophora)

The body is commonly protected by an exoskeleton calcareous shell of one or more piece secreted by the mantle.

The shell: Is made up of calcium carbonate, and is of one piece (univalve) or two pieces (bivalve) or spirally. In some cases, the shell is internal or absent **(Figure 68, 69).**

Body consists of four parts: head, visceral hump, and foot, mantle.

The head: Head is distinct, bearing mouth, eyes, tentacles and other sense organs except in pelecypoda and scaphodoa **(Figure 68).**

The visceral hump contains the vital organs of the body in the compact form taking the form of dorsal humps or dome. It is covered by a soft and spongy layer of skin called the mantle or pallium.

The foot is ventral, broad, soft, flat and muscular forming the creeping sole and often bearing dorsally a hard piece, the operculum on its posterior end. It is the locomotory organ. The foot which is variously modified for creeping, burrowing and swimming.

The mantle or pallium: Is a fold of a body wall that leaves between itself the main body, mantle cavity. Mantle secretes shell. Mantle cavity has gills **(Figure 68, 69).**

A soft and spongy layer of skin forms a mantle over the visceral hump.

The anterior head region has sensory tentacles.

The mouth contains a file-like rasping organ for feeding, called radula.

➢ Internal Anatomy:

✓ **Germ Layers:** They are triploblastic animals with three germ layers.

✓ **Coelom:** They are true coelomates but the coelom is reduced in adults. The body cavity is a haemocoel.

✓ **Organisation:** They possess organ system level of body organisation.

✓ **Protostomia:** the blastopore becomes the mouth-first, and anus second.

✓ **Symmetry:** They are bilaterally symmetrical.

✓ **Digestive system:** The digestive tract is simple with anterior mouth and posterior anus but in gastropods, scaphodos, and cephalopods the intestine becomes U-shaped bringing anus to anterior part.

✓ **Circulatory System:** It is open type except in cephalopods. Blood colour is blue due to the presence of copper containing Haemocyanin **(Figure 68, 69).**

✓ **Respiratory organs:** Respiration by gills (ctenidia) in aquatic forms, through the wall of the mantle cavity in some forms and in many by Pulmonary sacs in terrestrial form or both. Haemocyanin is their respiratory pigments **(Figure 68, 69).**

- ❖ The space between the hump and the mantle is called the mantle cavity in which feather like gills are present. They have respiratory and excretory functions **(Figure 68, 69).**

✓ **Excretory system:** It has Nephridia. Excretion is by paired metanephridia (kidney).

✓ **Nervous system:** The nervous system consists of paired cerebral, pleural, pedal and visceral ganglia joined by longitudinal and transverse connections and nerves. Ganglia usually form a circumenteric ring.

✓ **Sense organs:** Sense organs consist of eyes, statocysts, and receptors for touch, smell, and taste.

✓ **Reproductive system:**

- ❖ **Sexes**: Are usually separate (dioecious) but some are monoecious (hermaphroditic).
- ❖ **Fertilization:** Is external or internal, mostly oviparous and a few viviparous.
- ❖ **The larval forms**: Are Glochidium, Trocophere and Veliger.
- ❖ **Development**: Is direct or indirect with metamorphosis through the trochophore stage called veliger larva.

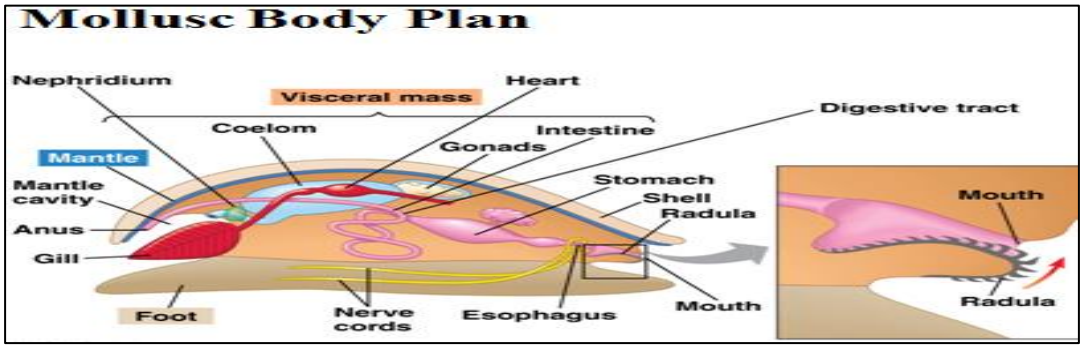


Figure 68: Molluska body plan.

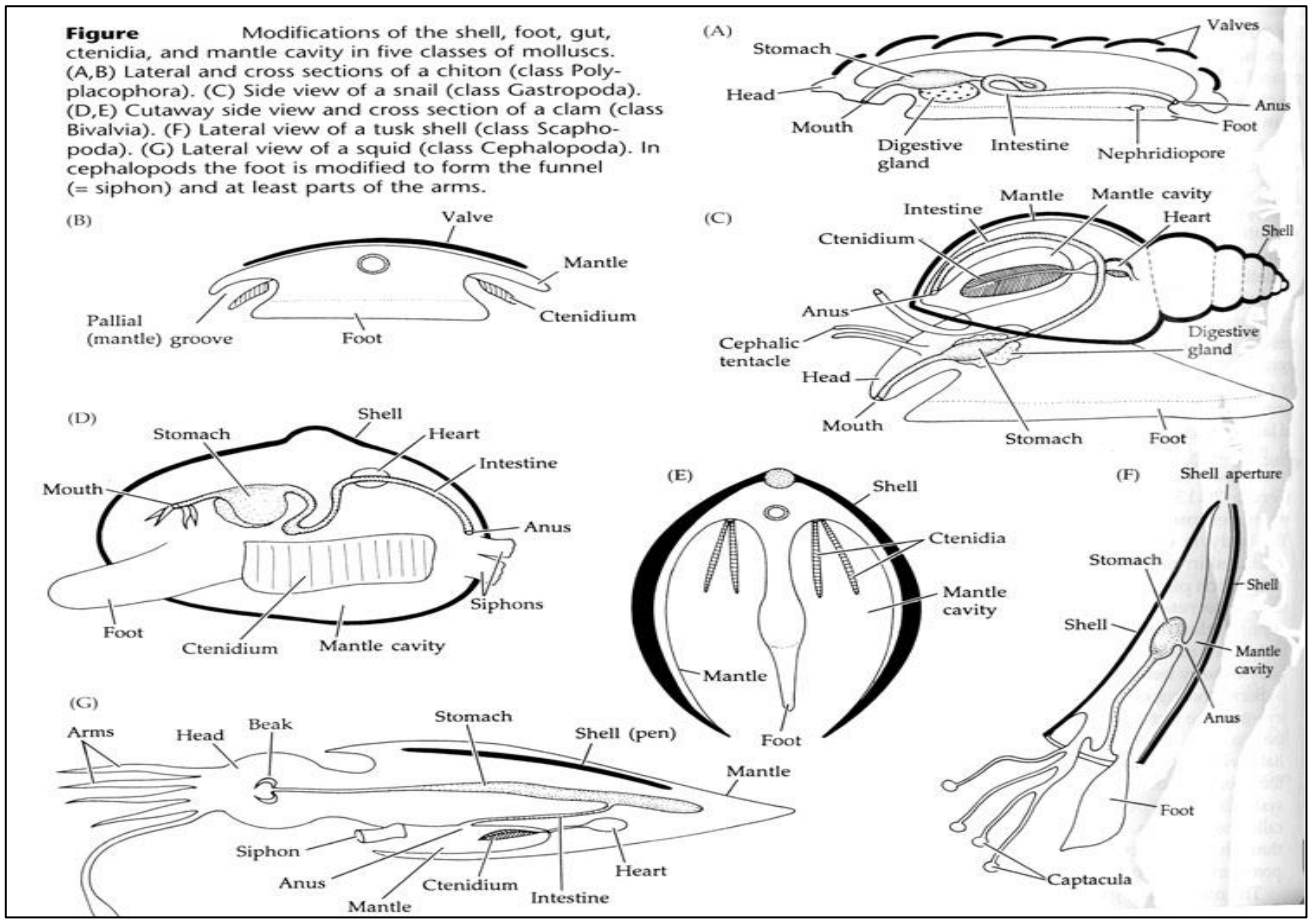


Figure 69: In summary the key characteristics of mollusks

Classification of Phylum Mollusca:

Molluscs (mollusks) are classified into seven classes according to their symmetry and also according to their food habits, shell, mantle, gill, nervous system, muscles and radula **(Figure 70).**

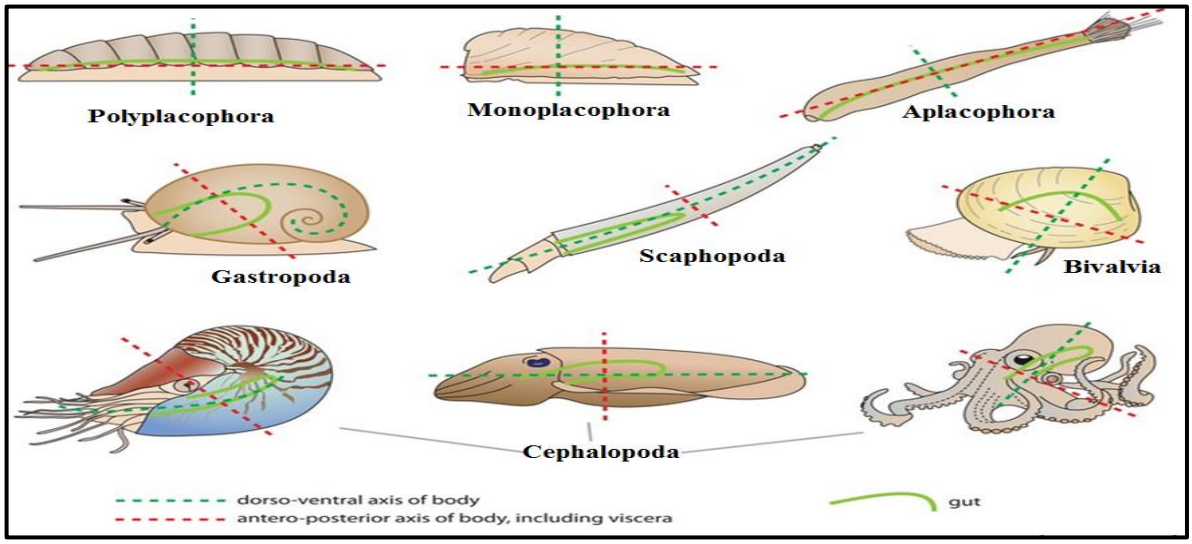


Figure 70: The classes of molluscs

4.1. Class 1/ Aplacophora

- ✓ Worm-like body with mantle **(Figure 71).**
- ✓ No shell and foot.
- ✓ Radula is simple.
- ✓ Calcareous spicules buried in cuticle.
- ✓ Some with a pair of bipectinate ctenidia.

Examples: *Neomenia*, *Nematomein*, *Chaetoderma*.

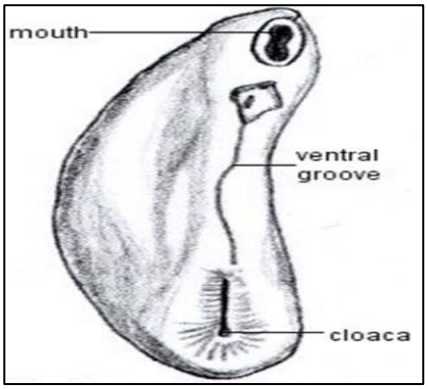
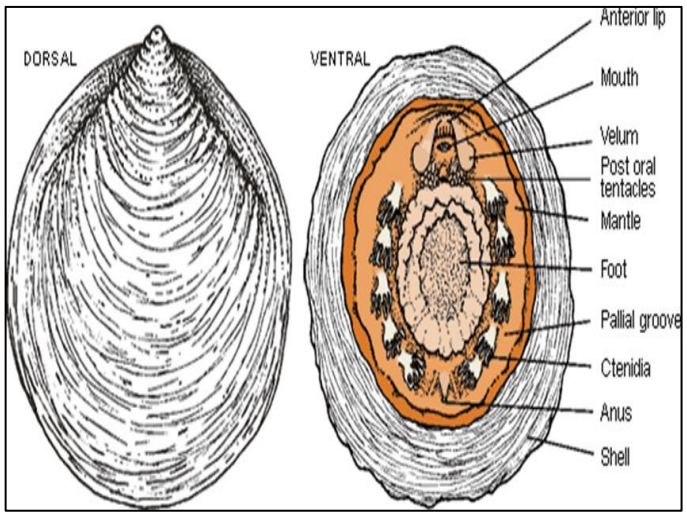


Figure 71 : Internal anatomy *of Neomenia.*

4. 2. Class 2/ Monoplacophora

(Gr., monos = one + plax = plate + pherein = bearing)

- ✓ Body is bilaterally symmetrical and segmented **(Figure 72).**
- ✓ Head without eyes and tentacles.
- ✓ Mantle is dome shaped.
- ✓ Mantle encircles the body as a circular fold of the body.
- ✓ The shell comprises a single piece or valve **(Figure 72).**
- ✓ Shell is flattened and limpet-shaped with spirally coiled protoconch.
- ✓ Foot broad and flat, with 8 pairs of pedal retractor muscles.
- ✓ Gills external. Five pairs of gills in pallial grooves.
- ✓ There are six pairs of nephridia out of which two are modified into gonoducts.
- ✓ Nervous system with longitudinal, pallial and pedal cords.
- ✓ Heart consists of two pairs of auricles and a single ventricle.
- ✓ Radula present in radular sac; intestine much coiled.
- ✓ Sexes separate (dioecious).



Examples: *Neopilina galatheae*.

Figure 72 : Morohology and Internal anatomy of *Neopilina.*

4. 3. Class 3/ Polyplacophora

- ✓ Body is dorso-ventrally flattened.
- ✓ Head small and without eyes and tentacles.
- ✓ Radulla, mantle, foot and external gills present.
- ✓ 2. Mantle cavity is present towards the back side.
- ✓ Shell as 8 calcareous dorsal plates **(Figure 73).**

Examples: *Chiton*, *Lepidopleurus*, *Chaetopleura*, *Ischnochiton*.

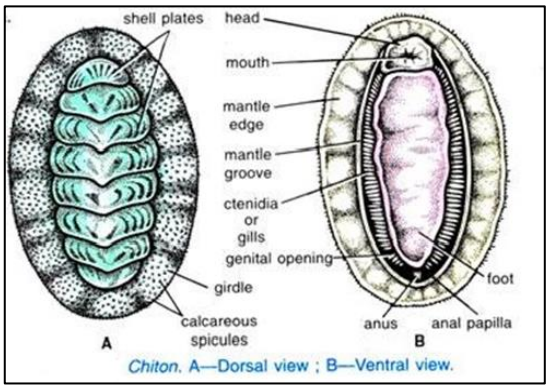


Figure 73 : Internal anatomy of *Chiton.*

4. 4. Class 4/ Scaphopoda

(Gr., scapha = boat + podos = foot)

- ✓ Exclusively marine.
- ✓ The body is bilaterally symmetrical, elongated and enclosed in a tusk-shell opens at both ends.
- ✓ Mantle tubular completely enclosing the body.
- ✓ Head and eyes absent; mouth with tentacles.
- ✓ Radula present.
- ✓ Foot conical **(Figure 74).**
- ✓ No gills.
- ✓ Kidneys are paired.
- ✓ Gonad is single.
- ✓ Heart rudimentary.
- ✓ Sexes separate (dioecious).
- ✓ Development includes trochophore larva.

Examples: *Dentalium*, *Pulsellum*, *Cadulus.*

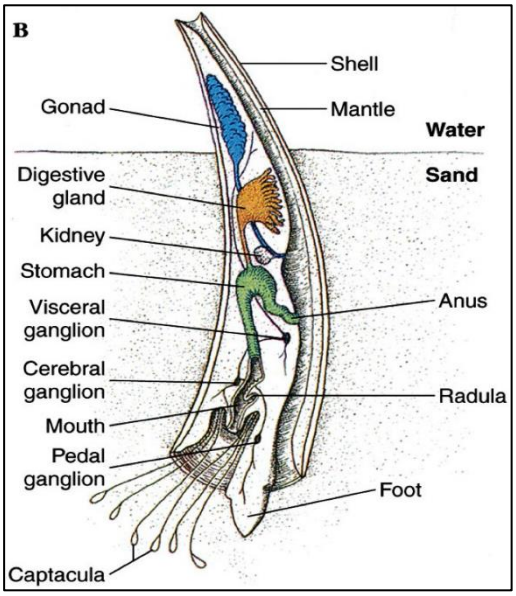


Figure 74 : Internal anatomy of *Dentalium.*

4. 5. Class 5/ Gastropoda – Stomach Footed

(Gr., gaster = belly + podos = foot)

- ✓ Mostly marine, some freshwater, terrestrial, and few parasitic on echinoderms.
- ✓ Body unsegmented, asymmetrical and typically with a univalve, spirally coiled shell.
- ✓ Head well developed and possesses eyes and tentacles and mouth **(Figure 75).**
- ✓ The foot is ventral, broad, flat and muscular forming the creeping sole and often bearing dorsally a hard piece, the operculum on its posterior end **(Figure 75).**
- ✓ The buccal cavity contains an odontophore with a radula bearing rows of chitinous teeth.

- ✓ Respiration by gills (ctenidia) in most forms, through the wall of the mantle cavity in some forms and in many by lungs **(Figure 75).**
- ✓ The digestive system comprises muscular pharynx, long esophagus, stomach, long coiled intestine, and anteriorly placed anus **(Figure 75).**
- ✓ The open circulatory system and heart is enclosed in a pericardium.
- ✓ The excretory system comprises metanephridia which are paired in primitive forms and reduced to a single nephridium in most forms.
- ✓ The nervous system comprises distinct cerebral and pleural besides buccal, pedal, parietal and visceral ganglia.
- ✓ Sexes separate (dioecious) in most forms while in some forms united.
- ✓ The development includes trochophore and veliger.

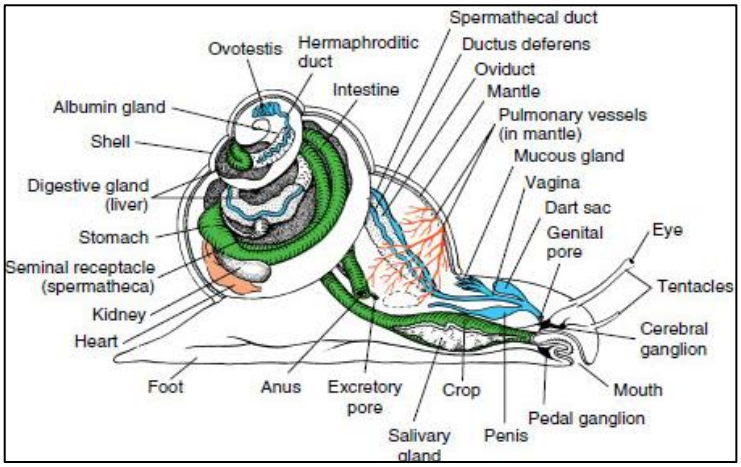


Figure 75 : Anatomy of a pulmonate snail.

The class Gastropoda comprises three subclasses: Based on the presence and arrangement of gills.

4.5.1. Subclass 1/ Prosobranchia / Streptoneura

- ➢ Mostly marine, few freshwater and terrestrial.
- ➢ Body mass torted; head with a single pair of tentacles.
- ➢ Shell closed by operculum.
- ➢ Head distinct with snout bearing a pair of tentacles and a pair of eyes.
- ➢ Foot is muscular and forms ventral part of the body.
- ➢ Sexes are separate, gonad single, larva trochophore or veliger.

4.5.1.1. Order 1/ Archaeogastropoda / Diotocardia

Examples: *Patella* (limpet), Trochus (top shell), *Fissurella* (key-hole limpet). *Haliotis sp.*

4.5.1.2. Order 2/ Mesogastropoda /Monotocardia

Examples: *Pila* (apple snail), *Crepidula* (slipper shell), *Natica* (star shell), *Cypraea* (cowrie). *Littorina.*

4.5.1.3. Order 3/ Neogastropoda / Heterocardia

Examples: *Murex*, *Magilus*, *Buccinum*, *Melongena*, *Conus*, *Oliva*. *Patella rustica*.

4.5.2. Subclass 2/ Opisthobranchia

- Exclusively marine gastropods.
- Shell small, without operculum or no shell.
- Shell when present covered with mantle or pedal cord.
- Body mass torted or detorted.
- Gills posterior to heart.
- Heart with one auricle posterior to the ventricle, one kidney and one gonad.
- The nervous system concentrated due to detorsion.
- Hermaphrodite (Monoecious), i.e., sexes united; larva veliger.

Examples: *Acteon*, *Hydatina*, *Bulla*, *Aplysia*, *Akera*, *Doris*, *Eolis*, *Tritonia*, *Armina*.

4.5.3. Subclass 3 / Pulmonata

- Mostly freshwater or terrestrial, a few are marine.
- Detorted body mass.
- Shell typically spiral or reduced or absent, if present partly or completely concealed by the mantle.
- Mantle cavity transformed into a pulmonary sac with a narrow pore on the right side.
- Gills absent.
- Heart with one auricle anterior to the ventricles.
- Nervous system secondarily symmetrical owing to the shortening or connectives and concentration of ganglionic complex.

4.5.3.1. Order 1/ Basommatophora

Examples: *Lymnaea*, *Siphonaria*, *Planorbis*. *Bulinus ; Lymnaea cailliaudi ; Lymnaea truncatula*.

4.5.3.2. Order 2/ Stylommatophora

Examples: *Limax*, *Partula*, *Helix* (land snail), *Retinella*. *Helix aspersa Milax gagates.*

4. 6. Class Bivalvia/ Pelecypoda / Lamellibranchia

(Gr., **pelekus** = batchet + podos = foot)

- ✓ Aquatic, mostly marine, some freshwater forms.
- ✓ The body is bilaterally symmetrical and laterally compressed **(Figure 76).**
- ✓ Mantle bilobed, consisting of paired, right and left lobes.
- ✓ Head, tentacles, eyes, jaws as well as radulla absent **(Figure 76).**
- ✓ Foot hatchet-shaped and extending between mantle lobes.
- ✓ Gills or ctenidia are paired, one on each side **(Figure 76).**
- ✓ The coelom is reduced to a dorsally placed pericardium.

- ✓ The alimentary canal is coiled with large paired digestive glands.
- ✓ The heart is contained within the pericardium and comprises a median ventricle and two auricles.
- ✓ The excretory organ is paired nephridia or kidneys opens at one end into pericardium at the other end to the exterior.
- ✓ The nervous system consists typically of 4 pairs of ganglia i.e. cerebral, pleural, pedal and visceral. Cerebral and pleural of each side usually fused into a single Cerebro-pleural ganglion.
- ✓ Sense organs are statocyst and osphradia.
- ✓ Sexes are separate or united (Dioecious).
- ✓ Development is accompanied by metamorphosis which usually includes a trochophore larva.
- ✓ Mostly filter-feeding.

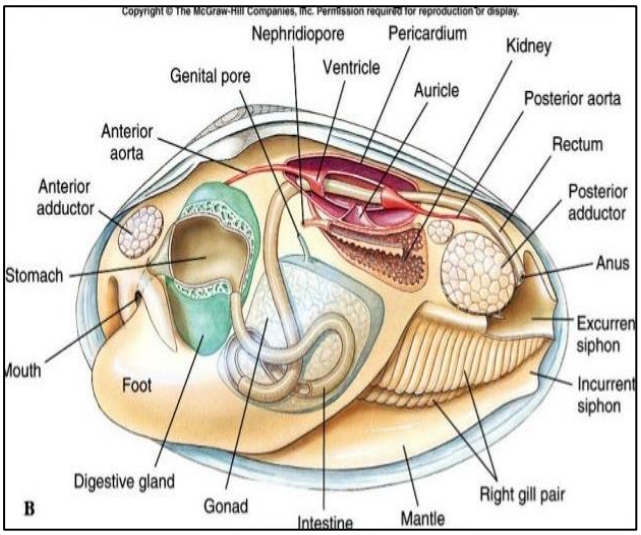


Figure 76 : Internal anatomy of Bivalve.

The class Bivalve comprises four orders:

4.6.1. Order 1/ Protobranchia

Examples: *Nuculina*, *Nucula*, *Yoldia*, *Malletia*, Solenomya.

4.6.2. Order 2/ Filibranchia

Examples: Arca, *Mytilus edulis* (mussel), *Ostrea edulis*, *Pecten* (scallop), *Spondylus* (edible oyster).

4.6.3. Order 3/ Eulamellibranchia

Examples: *Unio*, *Venus*, *Teredo* (ship-worm), *Anodonta*, *Lamellidens*, *Enis*, *Cardium edule* ; *Mya arenaria.*

4.6.4. Order 4/ Septibranchia

Examples: *Poromya*, *Cuspidaria*.

4. 7. Cephalopoda (Gr., kephale = head + podos = foot)

- ✓ Exclusively marine and free-swimming.
- ✓ Body elongated dorso-ventrally.
- ✓ The body is bilaterally symmetrical with head and trunk.
- ✓ Shell external, internal or absent.
- ✓ Head distinct and large with well-developed eyes and mouth.
- ✓ Foot altered into a series of suckers bearing arms or tentacles encircling the mouth.

- ✓ Mantle encloses posteriorly and ventrally a large mantle cavity.
- ✓ Moth bears jaws and radula.
- ✓ 2 or 4 pairs of bipectinate gills.
- ✓ Circulatory system closed, heart with 2 or 4 auricles.
- ✓ The excretory system comprises 2 or 4 pairs of nephridia.
- ✓ The nervous system is highly developed and the principal ganglia are concentrated around the esophagus.
- ✓ Sexes separate (Dioecious).
- ✓ Development meroblastic without metamorphosis.

4.7.1. Subclass 1/ Nautiloidea

- ➢ Shell external, coiled or straight**(Figure 77).**
- ➢ The main part of the foot encircling the mouth, divided into lobes bearing numerous tentacles **(Figure 76).**
- ➢ Tentacles without suckers.
- ➢ Two pair ctenidia or gills, two pair kidneys and two pair auricles present.
- ➢ Ink glands and chromatophores are absent.
- ➢ Eyes are simple.

Examples: *Nautilus*.

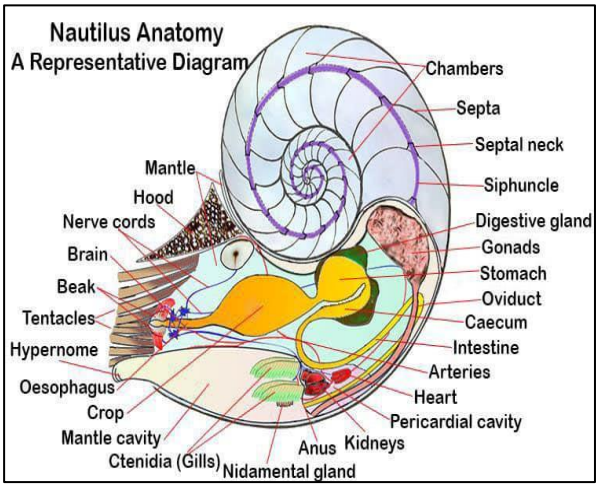


Figure 77 : The Anatomy of a *Nautilus* Shell.

4.7.2. Subclass 2/ Dibranchiata

- ➢ Shell usually internal and reduced, enveloped by mantle, when external its cavity is not divided by septa or absent.
- ➢ The main part of the foot is modified into 8 or 10 suckers bearing arms encircling moth.
- ➢ The funnel forms a complete tube.
- ➢ One pair ctenidia or gills, One pair kidney, One pair c auricle, and One pair branchial heart present.
- ➢ Ink gland duct and chromophores present.
- ➢ Eyes are complex in structures.

The major divisions within Dibranchiata dea are based upon the number of arms or tentacles and their structure.

4.7.2.1. Order 1/Decapoda

- Body elongated often with lateral fins.
- Ten arms-Two elongated and called tentacles bearing suckers at their distal ends and 8 short arms bear stalked suckers provided with horny rims **(Figure 78).**
- Shell is internal and well-developed.
- Nidamental glands are usually present.
- Herat enclosed in the well-developed coelom.

Examples: *Sepia officinalis* (cuttle-fish), *Loligo vulgaris* (squid) Calamar, Spirula (spiral shell).

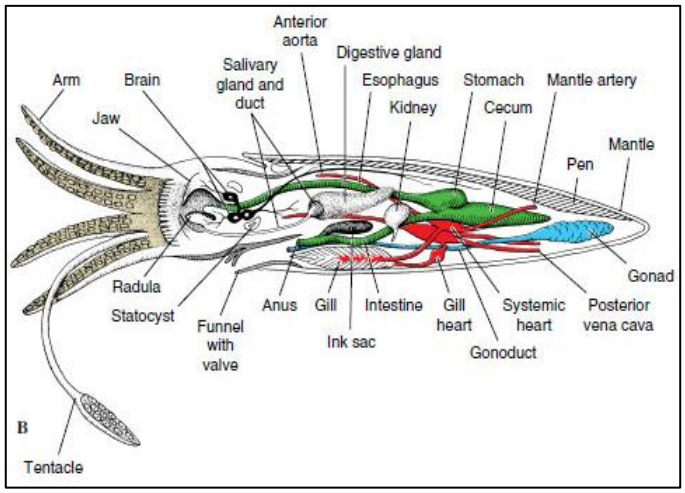


Figure 78 : Internal anatomy of squid.

4.7.2.2. Order 2/Octopoda

- Body globular and without fins.
- Eight equal arms with sessile suckers and devoid of horny rims **(Figure 79).**
- Shell absent except in female Argonauta.
- Nidamental glands absent.
- The heart does not lie in the reduced coelom.

Examples: *Octopus vulgaris*, *Argonauta*.

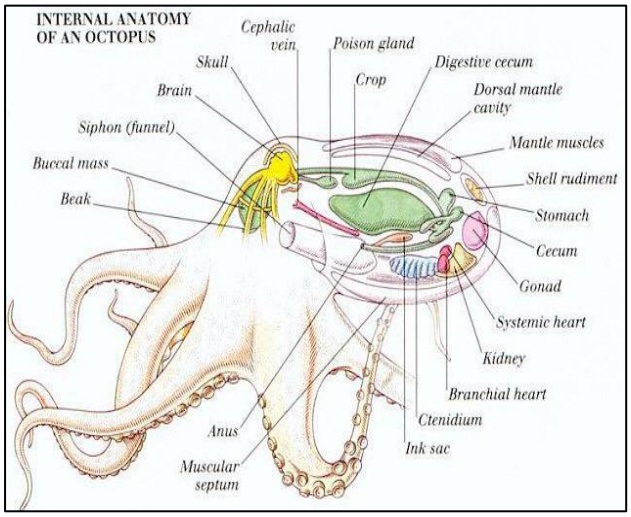


Figure 79 : Internal anatomy of *Octopus*.

III-5- Phylum: Arthropoda

5. Phylum : Arthropoda

The arthropods are by far the most successful phylum of animals, both – in diversity of distribution and – in numbers of species and individuals. They have adapted successfully to life in water, on land and in the air.Relative abundance. – 3/4 (About 80%) of all known species of animals are arthropods. More known species of arthropods than known species of plants and animals combined. About 800,000 species have been described, and recent estimates put the total number of species in the phylum at about 6 million.

Greek: Arthros = Joint, **Podos** = Feet Jointed Feet

This is the largest phylum of kingdom Animalia which includes insects.

General characteristics

Habitat: They are mostly terrestrial. Some are aquatic.

➢ External Features (Figure 80):

✓ **Body Structure:** The body of arthropods is segmented and covered by chitinous exoskeleton.

✓ Rigid, chitinous exoskeleton that is periodically molted as the animal grows.

✓ **Body Plan:** Usually has three major parts or three tagmata: head, thorax, abdomen; head and thorax are often fused to form Cephalothorax.

✓ **Head:** Has sensory/food manipulation appendages.

✓ **Thorax:** Section with jointed limbs and/wings for movement.

✓ **Abdomen :** Contains vital organs (heart, reproductive organs, digestive organs…….).

✓ They have jointed appendages.

✓ **Jointed appendages:** each segment may have one pair of appendages, such as:

- ❖ Legs
- ❖ Wings
- ❖ Mouthpart

➢ Internal Anatomy (Figure 80):

✓ **Organisation:** They have organ system level of organisation.

✓ **Germ Layers and Coelom:** They are triploblastic animals and coelomates.

✓ **Protostomia:** the blastopore becomes the mouth-first, and anus second.

✓ **Symmetry:** They are bilaterally symmetrical.

✓ **Digestive system:** Alimentary canal completing consisting of foregut, midgut and hindgut.

- ❖ **Specialized mouthparts** piercing, sucking or sponging, chewing, lapping.
- ❖ **Feeding** Herbivores, carnivores, omnivores, bloodsuckers, parasites, detrivores, and filter feeders.First group to show advanced mouthparts: Pincers, fangs, and jaws.

✓ **Respiratory system:** Respiratory organs are gills, book gills, book lungs or tracheal system.

III-5- Phylum: Arthropoda

✓ **Circulatory system:** It has open circulatory system. Blood is colourless without haemoglobin and called haemolymph.

- ❖ Heart is dorsal to the alimentary canal with lateral openings in the abdominal region.

✓ **Excretory system:** Are coxal glands, green glands (antennal gland) or maxillary (in aquatic forms) and Malpighian tubules (in terrestrial forms).

✓ **Muscles:** are mostly striated, usually capable of rapid contraction.

✓ **Nervous system** ventral nerve cord Hyponeurians or **(**ventral to the alimentary canal**)**. Cerebral ganglia/brain.

✓ **Sense Organs:** Sensory organs like antennae and simple eyes, compound eyes, statocysts or balance organs, chemoreceptors and taste receptors.

- ❖ Arthropods have compound eyes made of several visual units called ommatidia. Each ommatidium transmits visual information through the optic nerve to the brain, which interprets the image. These ommatidia are round and numerous, and their external surfaces point in different directions creating independent images.
- ❖ Some insect have one or more simple eye in addition to their pair of compound eyes.

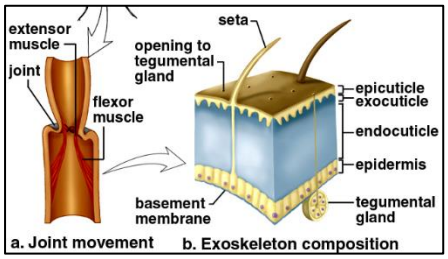
✓ **Reproduction:** They are mostly dioecious and majority are oviparous, few like Scorpios are ovoviviparous.

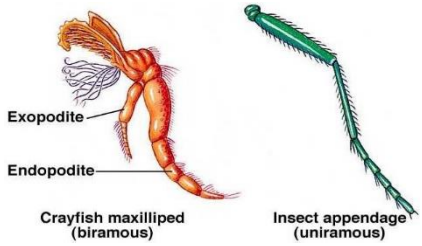
- ❖ **Fertilisation:** May be external or internal in aquatic arthropods; always internal in terrestrial species.
- ❖ **Development** may be direct or indirect, one to many larval stages.
- ❖ Some species reproduce through parthenogenesis **E.g.** Bees ,wasps ,ants and aphids a form of asexual reproduction in which a new individual develops from an unfertilized egg.
- ❖ In bees, drones are developed from unfertilized eggs.
- ❖ Undergo **metamorphosis Complete** egg – larva – pupa – adut
- ❖ **metamorphosis Incomplete** egg – nymph – adult

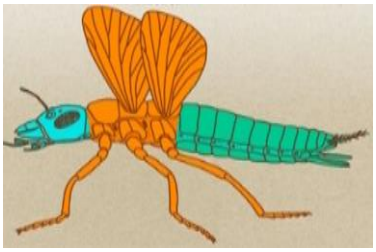
✓ **Structure of the Exoskeleton**

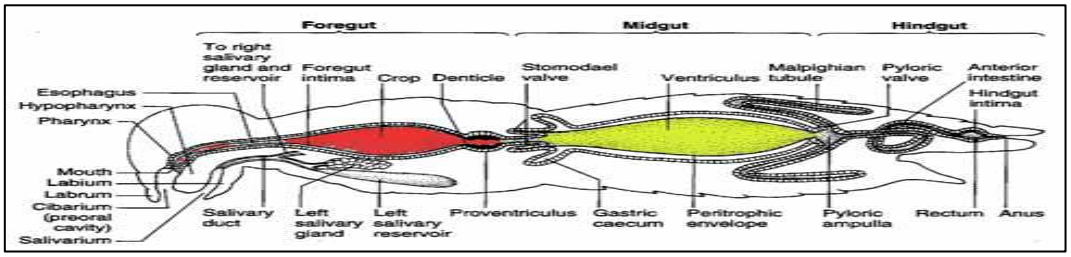
- ❖ Composed of the polysaccharide *chitin* and protein – glycoprotein.
- ❖ Outer surface called the epicuticle; contains waxes.
- ❖ The thicker portion is called the procuticle:
  - exocuticle
  - endocuticle
- ❖ In the exocuticle, the glycoprotein chains are cross linked; process is called tanning
- ❖ Molting
- ❖ In order to grow the arthropod must shed its exoskeleton, and secrete a new and larger one - molting or ecdysis.

III-5- Phylum: Arthropoda

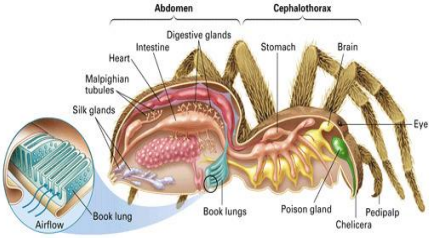


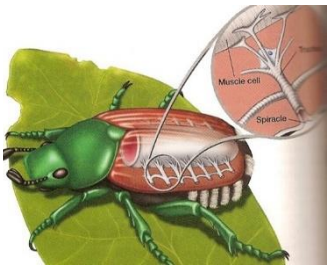


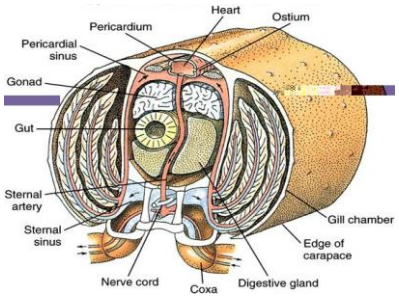




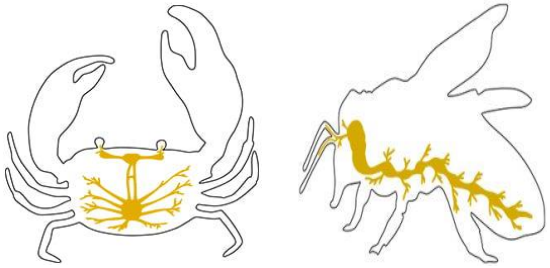
Digestive system



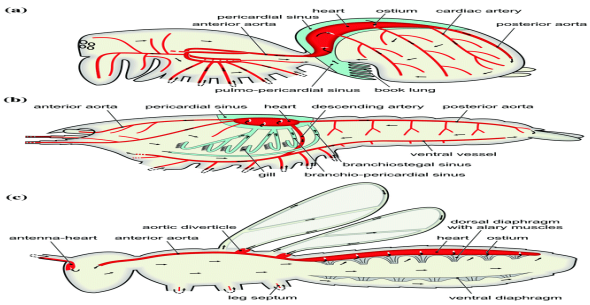




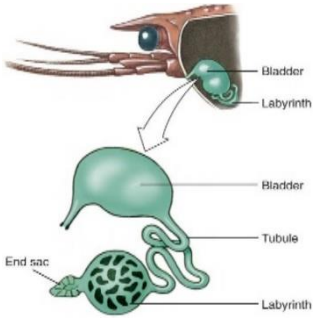
Respiratory system

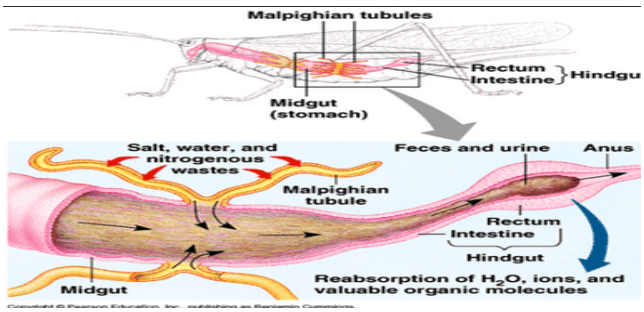


Nervous system



Circulatory system





Excretory system

Figure 80 : General characteristics of Arthropoda.

Classification of Phylum Arthropoda:

Arthropoda is a heterogenous group including a wide variety of animals. Since there are divergent views concerning their phylogeny, therefore there is no definitive system for classifying this phylum. However, we can simply classify it under following (**Figure 81**):

Arthropoda is divided into four main modern subphyla: Chelicerata, Crustacea, Hexapoda, and Myriapoda, alongside the extinct subphylum Trilobitomorpha (**Figure 81**).

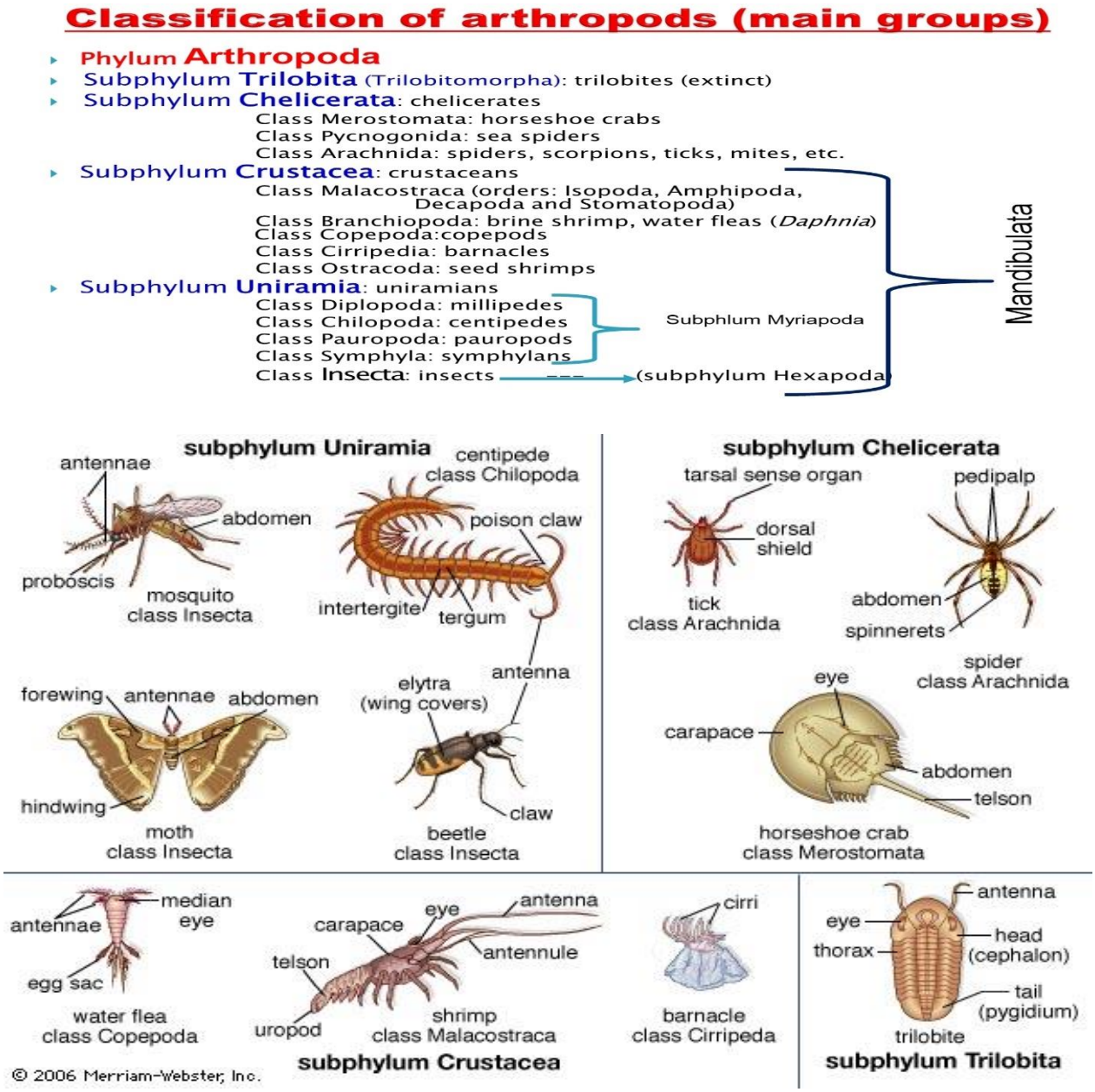


Figure 81 : Classification of Phylum Arthropoda.

5-1-Subphylum

Trilobitomorpha

5.1. Subphylum 1: Trilobitomorpha

(Gr., tria=three + lobos= lobe+morphe= form)

- ✓ Mostly marine and bottom dwellers arthropods.
- ✓ Fossil trilobites.
- ✓ Body can be divided into 3 lobes by 2 longitudinal furrows (**Figure 82**).
  - ➢ Cephalon (head), a single plate made up of several fused segments. Head bears a pair of antenna and eye
  - ➢ Thorax, consists of a number of segments hinged together
  - ➢ Pygidium (tail), also segmented, but like the head, fused together into a single plate.
- ✓ Biramous appendages are there on all segments except the last one.
- ✓ Ranged in size from a few millimeters up to 75 centimeters.

Examples: *Triarthrus*, *Dalmanites.*

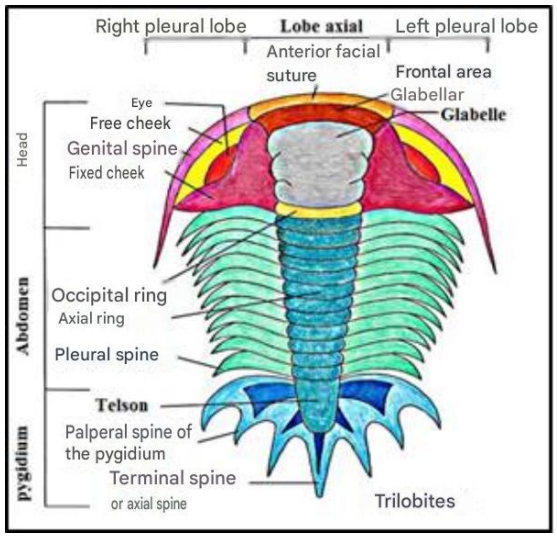


Figure 82 : The morphology of trilobites.

5-2-Subphylum

Chelicerata

5.2. Subphylum 2: Chelicerata

(Gr., **Chele**= claw+ **Keros** = horn **+ata** =group)

General characteristics of Subphylum Chelicerata

- ✓ Body divided into 2 tagmata (Prosoma + Opisthostoma).
- ✓ Body differentiated into an anterior prosoma (cephalothorax) and an opisthosoma (abdomen).
- ✓ There are six pairs of appendages. First pair is of preoral chelicerae with claws (pincer, fang-like (chelicerae)), one pair of pedipalps and four pairs are of walking legs.
- ✓ Antennae and jaws are absent.
- ✓ Respiratory systems vary by habitat: marine species (horseshoe crabs) have book gills, while terrestrial forms use book lungs and/or tracheae (airways).
- ✓ separate sexes - female often larger than male ; Internal fertilization.

Classification of Subphylum Chelicerata

Chelicerates are divided into three classes: Merostomata, Pycnogonida, Arachnida.

5.2.1. Class Merostomata

(Gr., **Meros** = thigh + **Stoma** = mouth).

- ➢ Marine and aquatic chelicerates.
- ➢ Body divided into an anterior cephalothorax covered by carapace and a posterior abdomen
- ➢ Median, simple and lateral compound eyes.
- ➢ Possess chelicerae, pedipalps, and 4 pair of walking legs (all but the last pair are **chelate**
- ➢ Abdomen with 5 or 6 pair of appendages.
- ➢ Abdomen terminates in a long tail called the **telson.**
- ➢ Possess a series of gill plates called **book gills**.

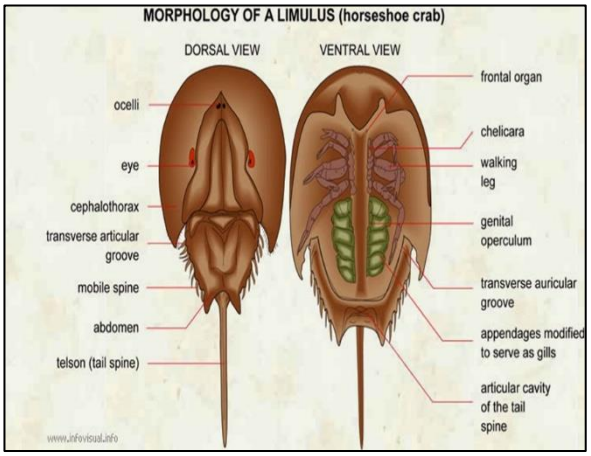


Figure 83 : Morphology and Internal anatomy of *Limulus*.

5.2.1.1. Subclass 1/ Xiphosura

(Gr., xiphos = sword + aura = tail)

- ❖ Cephalothorax with a broad, horse-shoe shaped carapace (**Figure 83**).
- ❖ Abdomen is unsegmented and ends in a long telson.

Examples: *Limulus* (king crab or horseshoe), *Xiphosura polyphemus*.

5.2.1.2- Subclass 2/ Eurypterida

(eurys = broad + pteryx = wing)

- ❖ Extinct, marine and giant water scorpion.
- ❖ Abdomen has twelve segments.
- ❖ Cephalothorax is small.

Examples: *Eurypterus* and *Pterygotus*.

5.2.2. Class 2/Arachnida

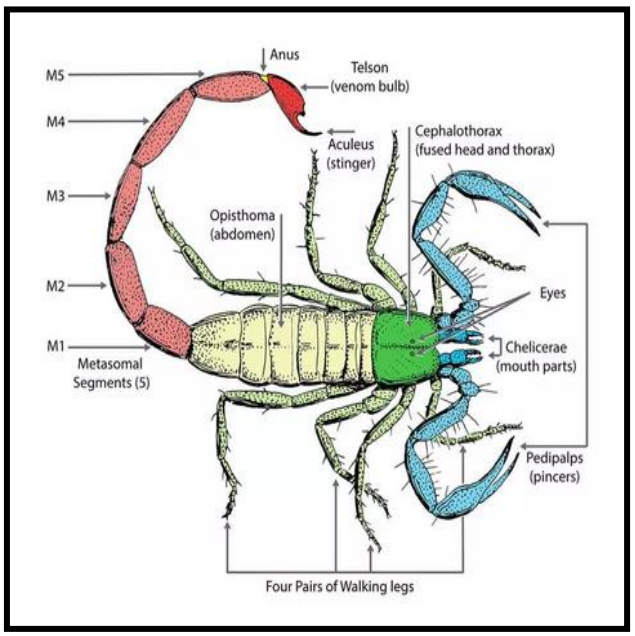
(Gr. arachne = spider)

- ➢ Mostly terrestrial, some aquatic.
- ➢ Body divided into two regions: Cephalothorax (prosoma) with 2 chelicerae, 2 pedipalps and 4 pairs of walking legs. Abdomen without appendages.
- ➢ It has simple and non-compound eyes.
- ➢ Respiration by tracheae, book lungs or both.
- ➢ Excretory organs: Excretion by malpighian tubules and/ coxal glands.
- ➢ Dioecious, Viviparous, oviparous, courtship before mating.

Arachnida has been divided into following 10 orders.

5.2.2.1. Order 1/ Scorpionida (True Scorpions)

- ➢ Cephalothorax covered with carapace.
- ➢ Prosoma covered by a carapace.
- ➢ Opisthosoma differentiated into an anterior, broad, 7-segmented pre-abdomen and a posterior, narrow, 5-segmented post-abdomen with a terminal poison sting.
- ➢ Second abdominal segment with two ventral sensory pectines.
- ➢ Respiration by four pairs of book-lungs.
- ➢ Chelicerae small, 3-jointed and with claws.
- ➢ Pedipalps large, 6-jointed and with pincers.



Examples: *Palamnaeus*, *Buthus occitanus*, *Androctonus*.

Figure 84: Morphology of Scorpionida.

5.2.2.2. Order 2/ Pseudoscorpionida (False scorpions)

- Tiny sized.
- Cephalothorax covered with carapace, abdomen 11 segmented; sting and telson absent.

Examples: *Chelifer*, *Microcreagris*.

5.2.2.3. Order 3/ Araneae (True Spiders)

- Prosoma and opisthosoma are joined by a narrow pedicel.
- Opisthosoma with 3 pairs of spinnerets. The Telson is absent.
- Typically have eight eyes.
- Chelicerae possess fangs and poison glands.
- Distal tips of male pedipalps are knoblike and modified for sperm transfer.
- Four pairs of walking legs that terminate in either two (cursorial or three (web building) claws.
- Gonopore and book lung spiracles located ventrally.
- Tracheal spiracle located posteriorl , near spinnerets.

Examples: Achaearanea (House spider), *Lycosa* (wolf spider), *Argiope* (writing spider), *Agelena* (funnelweb spider).

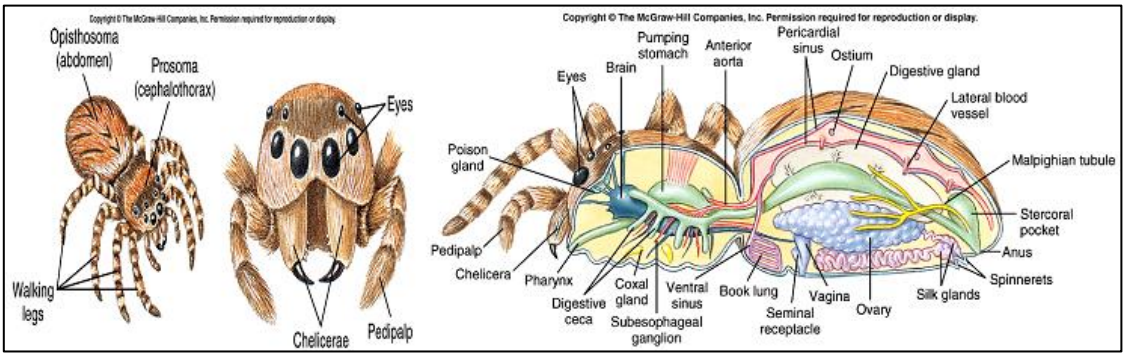


Figure 85 : Morphology and Internal anatomy of Araneae.

5.2.2.4. Order 4/ Solifugida

- False Spiders, Sun Spiders or Wind Spiders.
- Prosoma is divided into a large anterior and a small posterior part.
- Opisthosoma has 10 or 11-segments.
- Chelicerae large form pincers; male with flagellum for sperm transfer.

Examples: *Galeodes* (Sun Spiders).

5.2.2.5. Order 5/ Opioliones

- Spider-like harvest-men.
- Body is elliptical.
- Prosoma is broadly joined to opisthosoma.

Examples: *Phalangium*, *Leiobunum*.

5.2.2.6. Order 6/ Acarina

- Most mites are free-living, but some are parasites of people, animals, and crops
- Body is small, oval and unsegmented.
- Lack segmentation; cephalothorax is fused with abdomen.
- Prosoma and opisthosoma are not differentiated.
- Chelicerae and pedipalps are small.
- Some can inhabit the tracheae of honeybees.
- Some live in human hair follicles.
- The largest mites (called ticks) can reach 3 cm when engorged with blood.
- Can be internal or external parasites.
- Larvae of Trombicula are referred to as chiggers
- Mange mite burrows under skin, lays eggs, and causes a skin condition known as scabies.
- Can also be vectors of diseases.

Examples: *Sarcoptes* (Itchomite), *Ixodes* (sheep tick), *Dermacentor* (dog tick).

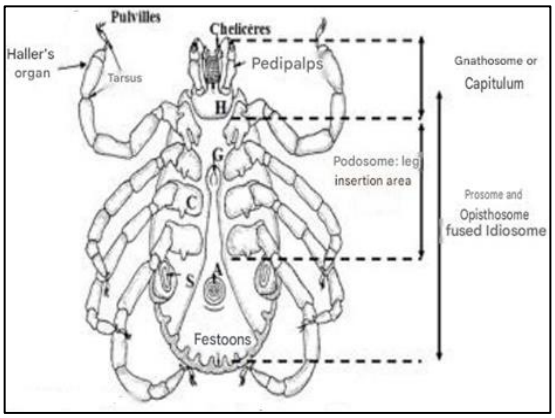


Figure 86: Morphology of Acarina.

5.2.3. Class 3 / Pycnogonida

(From the Greek pykno = 'lots of' or 'thick' and gónу = “knees”).

- ✓ Pycnogonids are small, slender-looking marine animals (often less than one centimetre in length).
- ✓ They have a flat, segmented body and four pairs of legs.
- ✓ The opisthosoma is rudimentary.
- ✓ They lack respiratory and excretory systems.
- ✓ They are equipped with a proboscis, sometimes supplemented by a pair of chelicerae.
- ✓ The larvae are parasites of Cnidarians.
- ✓ They live near the coast, usually on bryozoans (microscopic invertebrates), hydraids (small animals) or red algae.

Example: Sea spider.

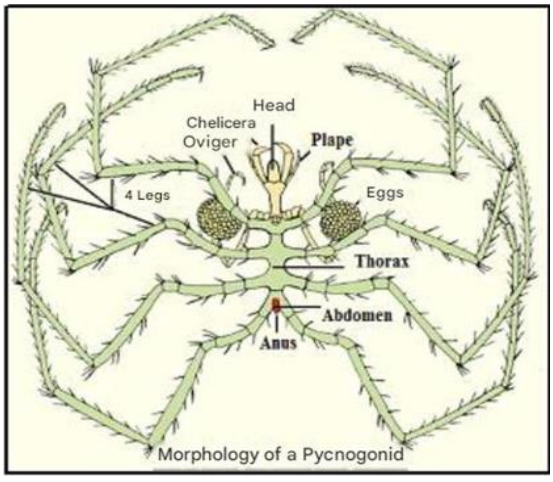


Figure 87: Morphology of Pycnogonida.

5-3-Subphylum

Crustacea

5.3. Subphylum: Crustacea

(Gr. Cursta = hard shell)

General characteristics of Subphylum Crustacea

✓ Crustacea are mainly aquatic (mostly marine, few freshwater) and few live in moist places on land.

✓ Generally free living but some are parasitic.

✓ Body divided into 2 Tagmata cephalothorax and abdomen **(Figure 88)**.

✓ Head joined with thorax to form cephalothorax.

✓ **The head** bears :

2 pair of compound eyes.

2 pair of antennae: First pair is homologous to those of insects; second pair is unique to the crustaceans, Second antennae have various functions, including sensory, locomotion or feeding.

3 pairs of mouthparts: a pair of **mandibles**, and 2 pairs of **maxillae;** used for food handling.

✓ Head (Cephalothorax) has 5-segmented: 2 pairs of antennae, 2 pairs of maxillae and 1 pair of mandibles and 5 pairs of walking legs **(Figure 88)**.

- ✓ Trunk varies considerably among classes.
- ✓ Primitively, the first three pairs of thoracic segments are **maxillipeds;** function in handling food
- ✓ Also, there are usually 5 pairs of appendages strengthened for walking (walking legs) and protection **(chelipeds,** pincer-like claws).

✓ Three pairs of thoracic appendages are called maxillipeds; the first pair of walking legs are called chelipeds, and the last pair of appendages are called uropods.

✓ Abdomen is also highly variable, but it is primitively large.

✓ Groups with a well-developed abdomen usually possess six pairs of appendages: Five pairs of structures called **swimmerets (=pleopods);** one pair of structures called **uropods.**

✓ Abdominal swimmerets are used in locomotion, the first pair are named gonopods.

✓ Gonopods in males are modified for copulation; females attach eggs and young to them.

✓ Uropods together with the terminal **telson** form a tail fan than can serve as rudders during locomotion.

✓ The telson also protects eggs and young on the swimmerets.

✓ Appendages: All appendages, except perhaps the first antennae, are biramous with two main branches.

✓ Primitively many of the appendages of the crustaceans are **biramous:** there is an outer **exopod** and an inner **endopod**

✓ They usually have an extremely hardened exoskeleton, which is impregnated with calcium carbonate - **carapace**

Internal anatomy of crustaceans (Figure 88)

- ✓ Respiration takes place through general body surface or gills.
- ✓ Excretion by antennal glands called green glands.
  - ✓ There is a brain with a double ventral nerve cord.
  - ✓ A median eye and compound eyes are present.
  - ✓ The median eye consists of three pigment cups, retinal cells, and possible a lens.
  - ✓ Crustacean compound eyes are similar to insect eyes.
  - ✓ Attached to moveable stalks, compound eyes detect motion and analyze polarized lights.
  - ✓ Statocysts, tactile setae, and chemosensitive setae are also present.
- ✓ Sexes are separate or united and, external fertilization; development with nauplius stage.
- ✓ Almost all barnacles are monecious but generally cross-fertilize.
- ✓ In some ostracods, males are scarce and reproduction is by parthenogenesis.
  - ✓ Most crustaceans have a larva unlike the adult in form, and under metamorphis.
  - ✓ The Nauplius is a common larval form.
- ✓ Exoskleton is chitinous, hard and calcareous.
- ✓ Crustaceans Grow by molting, shedding their exoskeleton to allow for growth.

The molting process of crustacean

- ❖ Molting is necessary for a crustacean to increase in size; the exoskeleton does not grow.
- ❖ The physiology of molting affects reproduction, behavior and many metabolic processes.
- ❖ Inorganic salts are withdrawn from the old cuticle during premolt.
- ❖ The underlying epidermis secretes the cuticle.
- ❖ Enzymes released into the area above the new epicuticle dissolve the old endocuticle.
- ❖ The animal then swallows water or air to expand and burst the old cuticle.
- ❖ The new soft cuticle stretches and then hardens with the deposition of inorganic salts during postmolt.
- ❖ Molting occurs often in young animals and may cease in adults **(Figure 89)**.
- ❖ Temperature or day length may trigger molting.

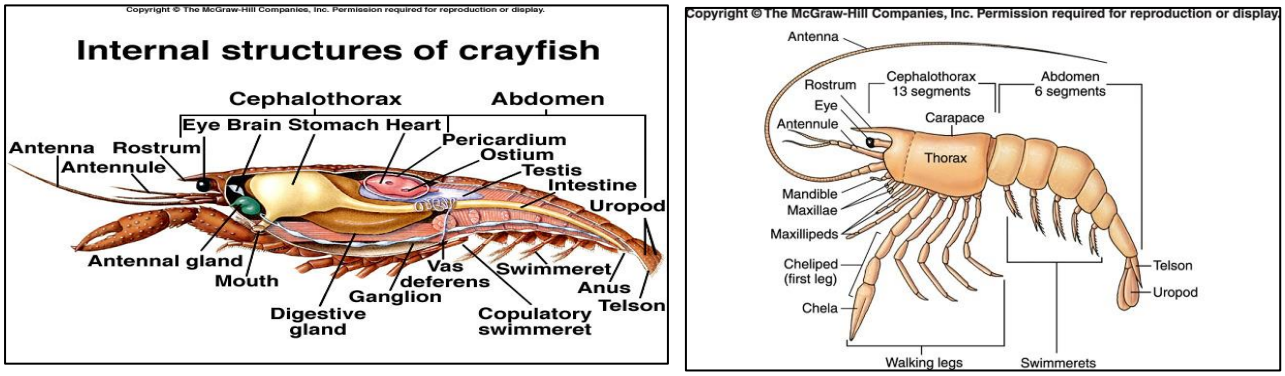


Figure 88: Morphology and general anatomy of Crustacea.

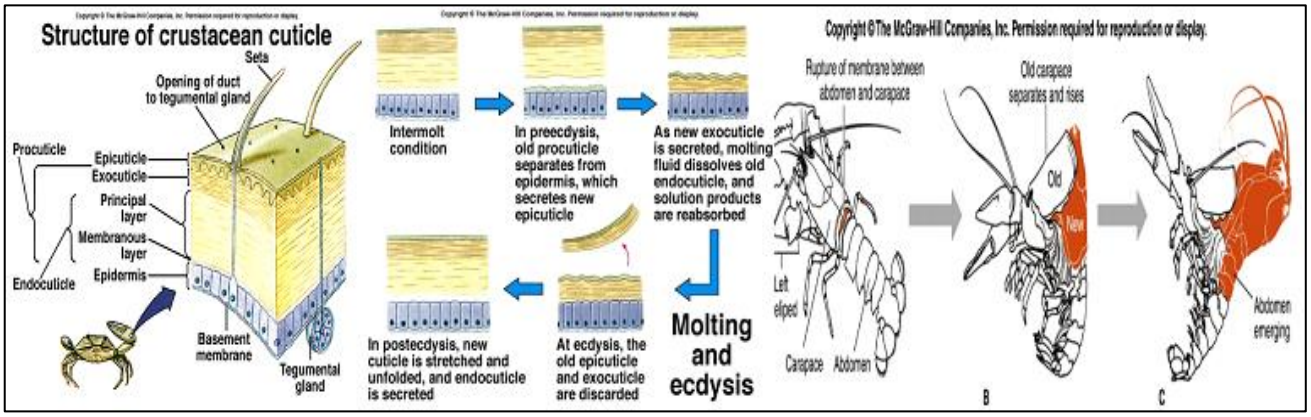


Figure 89: Structure of crustacean cuticle and Ecdysis or Molting.

Classification of crustacea

The traditional classification of Crustacea based on morphology recognised four to **six classes.**

5.3.1. Subclass 1/ Cephalocarida

- Body made of a horseshoe-shaped head and 19 trunk segments.
- Eyes absent. Antennae short.
- Hermaphrodite; life-histroy completes in a metanauplius larva.

Examples: *Hutchinsoniella*.

5.3.2. Subclass 2/ Branchiopoda

- Primitive, small-sized and mostly freshwater.
- Trunk appendages leaf-like and serve for locomotion, respiration and feeding.

- Antennules and 2nd maxillae reduced or absent.
- Abdomen ends in a pair of jointed or unjointed caudal styles.

Examples: *Artemia*, *Eubranchipus*, *Lepidurus*, *Apus*, *Daphnia pulex*, *Cyzicus*.

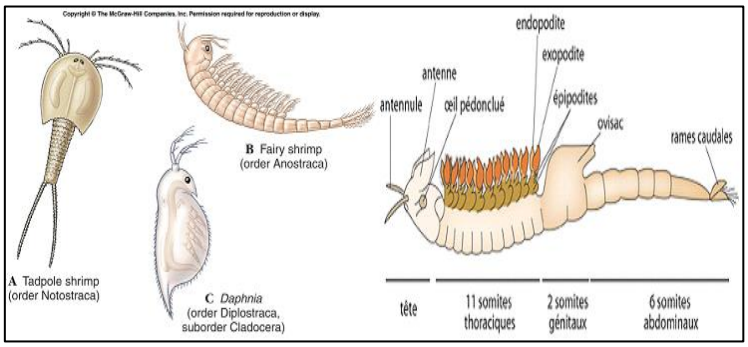


Figure 90: Types of Branchiopoda.

5.3.3. Subclass 3/ Ostracoda

- Seed shrimps and small-sized mussel with poorly segmented body.
- Trunk appendages 2 pairs and leg-like.
- Antennae and antennules and large, used in swimming.

Exemple : *Darwinula sp* ; *Cythereis bicarinata* ; *Cypridopsis vidua, Cypridina*, *Cypris*, *Cytherella*, *Polycope*.

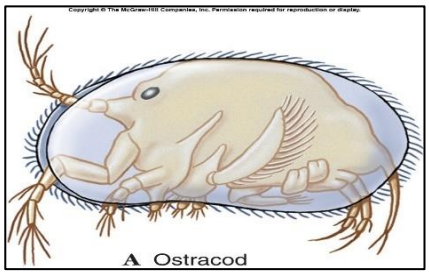


Figure 91: Ostracoda.

5.3.4. Subclass 4/ Mystacocarida

- Primitive and microscopic body.
- Antennae and antennules prominent.
- A single median eye present. Compound eyes absent.
- Abdomen limbless and a pair of caudal styles.

Examples: *Derocheilocaris*.

5.3.5. Subclass 5/ Copepoda / Maxillopoda

- Body small, divisible into head, thorax and abdomen.
- Compound eyes absent and median eye present.
- Antennae smaller and antennules long.
- They lack a carapace.
- They have four pairs of flattened, biramous, thoracic swimming appendages.

Examples: *Cyclops*, *Ergasilus*, *Caligus*, *Argulus foliaceus, Balanus sp.*

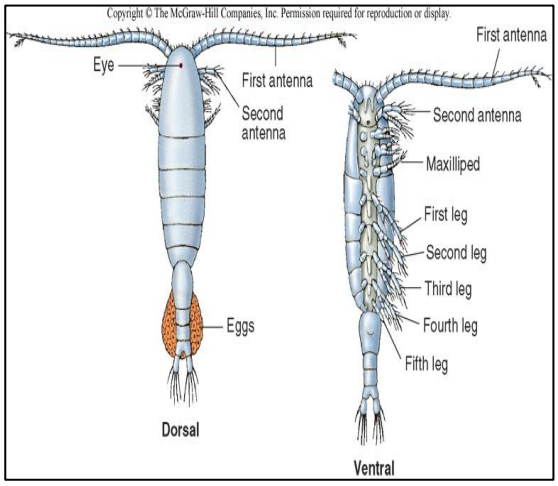


Figure 92: Morphology and general anatomy of Copepoda.

5.3.6. Subclass 6/ Cirripedia

- Barnacles as adults are sessile and attach directly or by a stalk to the substrate.
- parasitic.
- Carapace forms two folds of mantle and covered externally by calcareous plates.
- Head is reduced.
- Thoracic limbs 6 pairs, cirriform and biramous.
- Antennae and compound eyes are absent in adult.
- Antennules become cement glands for attachment.
- Abdomen rudimentary with caudal styles.
- The many-jointed cirri that bear the setae are extended from the plates to feed on small particles.

Examples: *Lepas*, *Balanus*, *Alcippe*, *Cryptophialus*, *Synagoga*, *Dendrogaster*, *Proteolepis*, *Sacculina*.

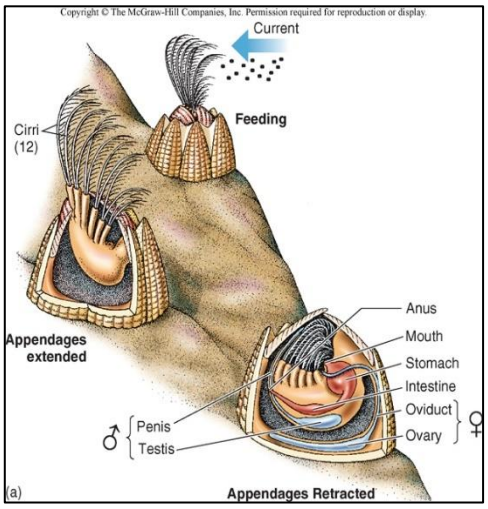


Figure 93: Morphology and general anatomy of Cirripedia.

5.3.7. Subclass 7/ Branchiura

- Fish lice; ectoparasites of skin and gill chambers of fishes and some amphibians.
- Body dorso-ventrally flattened.
- Head and thorax covered with carapace.
- One pair of compound eyes present.
- Antennae and antennules reduced.
- First maxillae modified into suckers.
- Abdomen unsegmented and bilobed.

Examples: *Argulus*, *Dolops*.

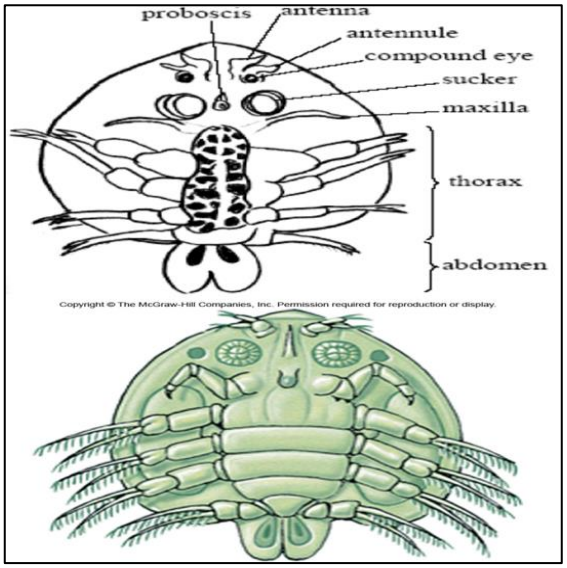


Figure 95: Morphology and general anatomy of Branchiura.

5.3.8. Subclass 8/ Malacostraca

- Largest class of Crustacea (23,000 species = Great diversity).
- Marine, freshwater, terrestrial.
- Body large-sized and made of 19 segments **(Figure 95)**.
- Cephalothorax made of head and one or more thoracic segments.
- Carapace well formed and absent.

- Compound eyes sessile or paired.
- Abdomen ends into telson; caudal styles absent.

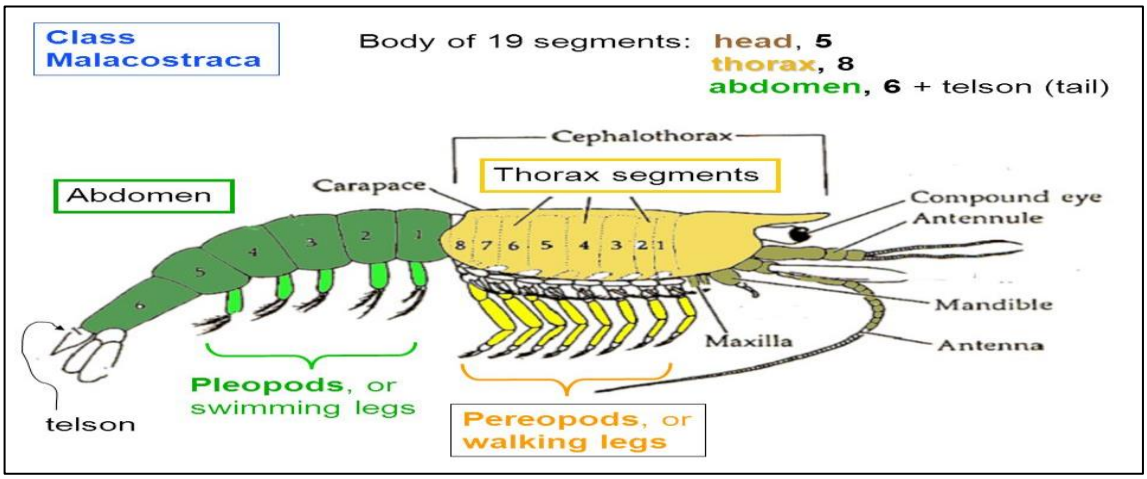


Figure 96: Morphology of Malacostraca.

5.3.8.1. Order 2/ Isopoda

- Body dorso-ventrally flattened.
- Head and 1 or 2 thoracic segments form cephalothorax.
- Carapace absent.
- Abdomen is usually short.
- The abdominal appendages bear gills.
- Common land forms include the sow bugs and pill bugs.
- Some isopods are highly modified as parasites of fish or crustaceans.

Examples: *Asellus*, *Oniscus*.

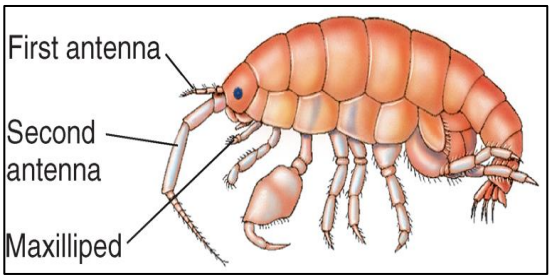


Figure 96: Morphology of Isopoda.

5.3.8.2. Order 2/ Decapoda

- Decapods have five pairs of walking legs, the first forming pincers or chelae.
- They range from a few millimeters to the larges arthropod, a Japanese crab with a 12 foot leg-span.
- They are true crabs with a broader cephalothorax and reduce abdomen, compared to crayfish or lobsters.
- Carapace well developed.

- First 3 pairs of thoracic limbs form maxillipedes.
- Gills in 3 series present on thorax.

Examples: *Palaemon*, *Penaeus*, *Leucifer*, *Astacus*, *Hippa*, *corcinus*, Cancer, *Eupagurus*.

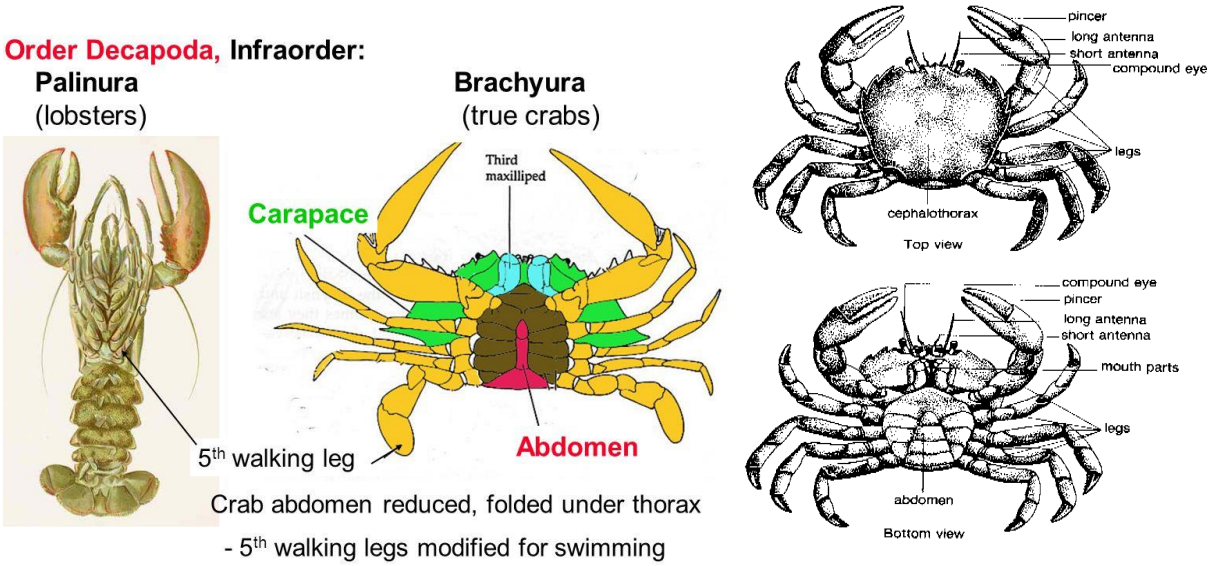


Figure 97: Morphology and general anatomy Decapoda.

III-5-4 Subphylum: Myriapoda

5.4. Subphylum: Myriapoda

- Includes the centipedes, millipedes, pauropods and symphylans.
- Several classes have two tagmata – a head and trunk with paired appendages on the trunk.
- Myriapods only have one pair of antennae, mandibles, and There are one or 2 pairs of maxillae.
- Legs are always uniramous unbranched.
- Respiration occurs through the body surface, trachea, or gills in juveniles.

5.4.1. Class Chilopoda (Centipedes)

(Gr., **Cheilos** = lip + **pou**s = foot).

- ✓ Body dorso-ventrally flattened and divisible into head and trunk (bodies have up to 177 segments) (**Figure 98**).
- ✓ Head with 1 pair of long antennae, 1 pair of mandibles (chewing) and 2 pairs of maxillae. pair of eyes (groups of ocelli) (**Figure 98**).
- ✓ First pair of legs modified into poison claws (**Figure 98**).
- ✓ Body long, worm-like, somewhat dorso ventrally flattened and regionated into head and trunk.
- ✓ Body elongated with numerous segments each bearing one pairs of legs (**Figure 98**).
- ✓ First pair of legs clawlike and each contains a poison gland.
- ✓ Carnivorous.
- ✓ Respiration by tracheae.
- ✓ Excretion by malpighian tubules.
- ✓ Unisexual; females oviparous or viviparous. Genital openings midventral on last but one segment.

Examples: *Scolopendra sp* ; *Lithobius forficatus*.

5-4-1-1- Subclass1/ Epimorpha

- Development epimorphic.
- Adults with 21 or more pairs of legs.

Examples: *Geophilus*, *Scolopendra*.

5-4-1-2- Subclass2/ Anamorpha

- Adults with fifteen pairs of legs.
- Development anamorphic, i.e. less number of segments in young than adults.

Examples: *Lithobius*, *Scutigera*

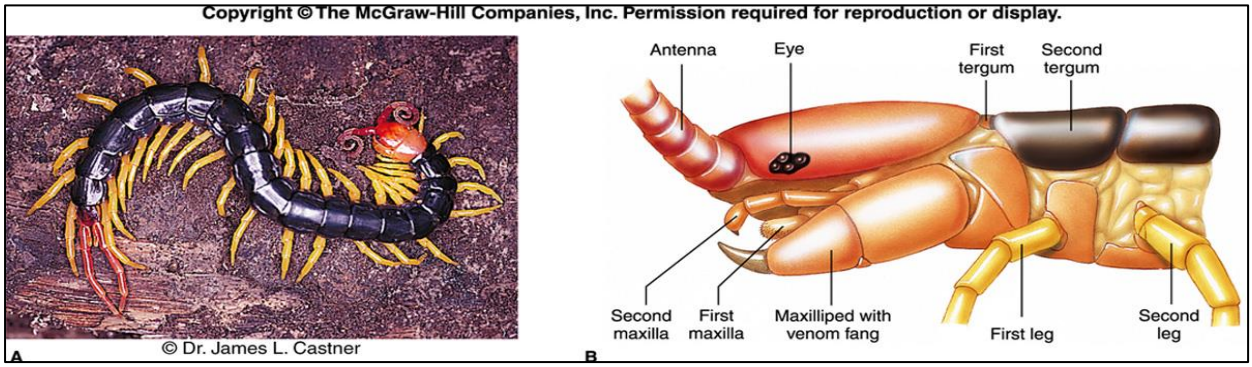


Figure 98: General morphology of Chilopoda.

5.4.2. Class Diplopoda (Millipedes)

(Gr., diplos = double + pous = foot).

- ✓ Body long, cylindrical, worm-like (bodies have from 25 to 100 segments).
- ✓ Head with 1 pair each of short antennae, mandibles and maxillae (**Figure 99**).
- ✓ Thorax of 4 segments, each except the first with a pair of jointed legs (**Figure 99**).
- ✓ Abdomen of 9 to 100 or more segments, but each apparent segment formed by fusion of two and, hence, bears 2 pairs of legs per segment (**Figure 99**).
- ✓ Respiration by tracheae.
- ✓ Excretion by malpighian tubules.
- ✓ Unisexual; gonad single; females oviparous.
- ✓ Herbivorous.

Examples: *Julus*, *Spirobolus*.

5.4.2.1. Sub-class 1/ Pselaphrognatha

- ➢ Minute millepedes with soft skin bearing rows of scale-like setae.
- ➢ Trunk with 13 to 17 pairs of legs.

Examples: *Lophoproctus*, *Polyxenus*.

5.4.2.2.Sub-class 2/Pentazonia

- ➢ Last two pairs of legs modified for clasping.

Examples: *Desmus*, *Glomeris* and *Glomeria*.

5.4.2.3.Sub-class 3/ Helminthomorpha

- ➢ Body flattened or cylindrical.
- ➢ One pair of legs of the 7th segment in the male.

Examples: *Julus*, *Polyzonium*, *Apheloria*, *Polydesmus*.

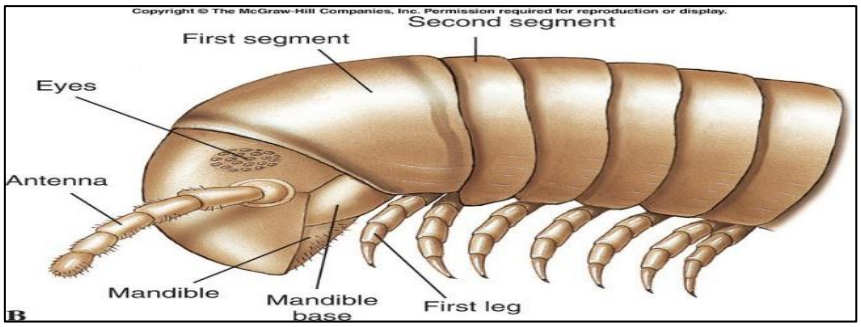


Figure 99: General morphology of Diplopoda.

5.4.3. Class 3/ Symphyla

(Gr., syn = together + phylon = tribe)

- ✓ Body is slender and made of head and 15 to 22 trunk segments.
- ✓ Head like that of insects, but without eyes.
- ✓ Genital pores located ventrally on the 4th trunk segment, beween legs of 4 th pair.
- ✓ Bears 10 to 12 pairs of legs.

Examples: *Hanseniella*, *Scutigerella*.

5.4.4. Class 4/ Pauropoda

(Gr., pauros = small + pous = foot)

- ✓ Minute, soft and cylindrical, worm-like body divisible into head and trunk.
- ✓ Less than 2 mm long; eyes are absent.
- ✓ Body divisible into head and 11-12 trunk segments.
- ✓ Head with one pair each of branched antennae and unbranched mandibles and maxillae; no eyes.
- ✓ Genital pores ventral on 3 trunk segment.
- ✓ Legs 9 to 10 pairs.

Examples: *Pauropus*.

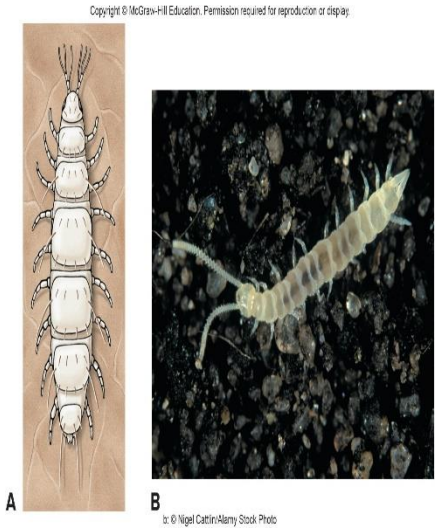


Figure 100: A) Pauropod. (B) *Scutigerella* sp., a symphylan

III-5-5- Subphylum: Hexapoda /Insecta

5.5. Subphylum: Hexapoda /Insecta

General characteristics

Insecta (L., insectus = cut or divided)

Insecta (L., insectus = cut or divided) Largest group of phylum Arthropoda.

✓ **Body** divided into 3 tagmata head and thorax and abdomen (different parts of the insect's anatomy (**Figures 101, 102).**

✓ **Head :** Structures on the Head include: Mouthparts, Antenna, Eyes**.**

- **Antenna:** has one pair (1 pair) of antennae (Different types of insect antennae are shown in **Figures 103).**
- **Eyes:** a pair (1pair) of compound eyes and several sets of simple eyes **(Figures 104).**
- **Mouthparts:** Insects have much variation in mouthparts, depending upon food habits and include: a pair (1 pair) of mandibles, and two pairs (2 pairs) of maxillae, one pair (1 pair) labium, one pair (1 pair) labrum **(Figures 105).**
  - **Mouthparts orientation:** The orientation of the mouthparts on the head may differ, and they may be described as **(Figures 106)**:
    - ⇒ **Prognathous**: projecting forward (horizontal).
    - ⇒ **Hypognathous**: projecting downward.
    - ⇒ **Opisthognathous**: projecting obliquely or posteriorly.

✓ **Thorax:** Is composed of 3 segments : Prothorax, Mesothorax, Metathorax (**Figure 101).** each one has a pair of legs; the last two segments also have one or two pairs of wings.

- **Legs:** are found on all three (pro- meso- and meta-) thoracic segments (**Figure 102).**

Leg segments include (**Figure 107).:**

- Coxa: attached to body.
- Femur: largest segment of leg.
- Tibia.
- Tarsus.
- Tarsal claws.

The structure of legs of insects vary depending upon use, but all have the same basic parts. Different types of insect legs can be found in **Figure 107).**

- **Wings:** In winged insects, the meso- and metathoracic segments each bear a pair of wings Called forewings and hindwings (never on the Prothorax) (**Figures 101, 102).**

Note: Some insects are wingless (Silverfish).

Abdomen does not have appendages; terminal portions do harbor the reproductive structures There are various modifications of insect wings, some with special functions.

These include (**Figure 108, 109)**:

- ❖ Membrane Wings.
- ❖ Scale Wings.
- ❖ Haltares.
- ❖ Elytra.
- ❖ Hemi-elytra.

✓ **Abdomen:** is comprised of 6 to 10 segments.

Abdomen does not have appendages; terminal portions do harbor the reproductive structures and excretion. Terminal structures include (**Figure 110)**:

- ❖ **Cerci:** Paired sensory projections from the terminal abdominal segment.
- ❖ **Ovipositor:** Egg-laying apparatus (may be modified for other purposes).
- ❖ **Aedeagus:** Male copulatory organ, analogous to the penis in vertebrates.

Internal Anatomy (Figure 111)

✓ **Respiration** by tracheae. Spiracles lateral.

✓ **Circulatory system :** The open circulatory system is a system in which a fluid in a cavity called the hemocoel bathes the organs directly with oxygen and nutrients and there is no distinction between blood and interstitial fluid; this combined fluid is called hemolymph or haemolymph.

✓ Haemolymph, is a fluid, analogous to the blood in higher phyla, that circulates in the interior of the arthropod body remaining in direct contact with the animal's tissues.

✓ **Nervous System :** Ventral nerve cord.

✓ **Digestive system:** Complete digestive system.

✓ **Excretion** by Malpighian tubules.

✓ Most insects have separate sexes (Unisexual) with complex reproductive systems.

✓ Fertilisation is internal.

✓ In many insects, the female has a spermatheca in which sperm is stored during copulation.

Structure of the Exoskeleton (Figure 112)

- ❖ Composed of the polysaccharide chitin and protein – glycoprotein.
- ❖ Outer surface called the epicuticle; contains waxes.
- ❖ The thicker portion is called the procuticle:
  - ➢ Exocuticle.
  - ➢ endocuticle.
  - ➢ In the exocuticle, the glycoprotein chains are cross linked; process is called tanning.

✓ **Metamorphosis**

Most insects undergo metamorphosis

It is the change in growth and development of an insect undergoes during its life cycle from birth to maturity

There are three basic types of metamorphosis in insects (**Figure 113)**:

- **Ametabola** (No metamorphosis).
- **Complete metamorphosis** (Holometabolous Development or Holometabola).

Insects with complete metamorphosis pass through four stages of development --- egg, larva, pupa, and adult. The immature stage is called a "larva", and it is quite different in form than the adult. Larvae in this group are usually soft-bodied and have such names as "caterpillars", "worms", "grubs" or "maggots". Adults are usually winged and quite mobile. The resting stage between the mature larva (last instar) and the adult is called the "pupa" **(Figure 113).** Within the pupa, which may be protected by a cocoon, capsule or soil, the larval body undergoes a radical transformation to the adult stage. Sometime later, the new adult emerges and rests until its wings fully expand and its body hardens.

Examples of insect orders that have complete metamorphosis are Coleoptera (Beetles), Diptera (Flies), Hymenoptera (Bees and Wasps), Lepidoptera (Butterflies and Moths) and Neuroptera (Lacewings and Antlions).

- **Incomplete metamorphosis** (Heterometaboa) =>

Hemimetabolous ; Paurometabolous.

Gradual Metamorphosis (Paurometabolous Development).

In gradual metamorphosis, the immature stages (nymphs) and adults closely resemble each other, except for size **(Figure 113).** Wings pads develop and grow longer as the nymphs reach full maturity (fifth instar). With insects that have gradual metamorphosis, both nymphs and adults live in the same habitat and feed on the same kinds of foods or plants. Examples include the orders Blattodea (Cockroaches), Isoptera (Termites), Mantodea (Mantids), Dermaptera (Earwigs), Orthoptera (Grasshoppers and Crickets), and Hemiptera (True Bugs, Aphids, Leafhoppers, etc.).

✓ **Molting**

In order to grow the arthropod must shed its exoskeleton, and secrete a new and larger one - molting or ecdysis).

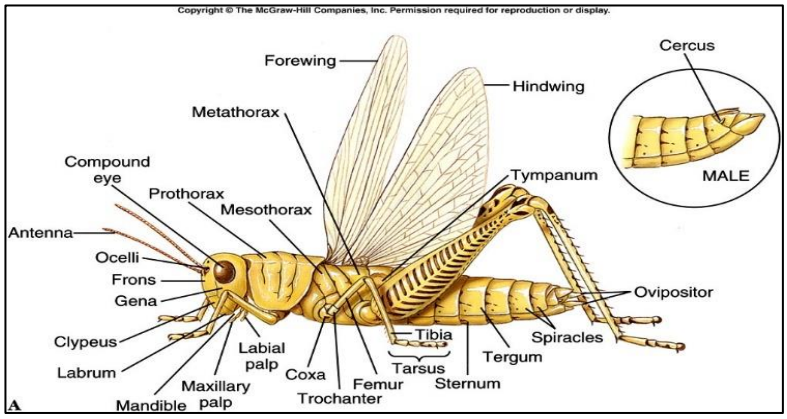


Figure 101: General morphology of Insecta

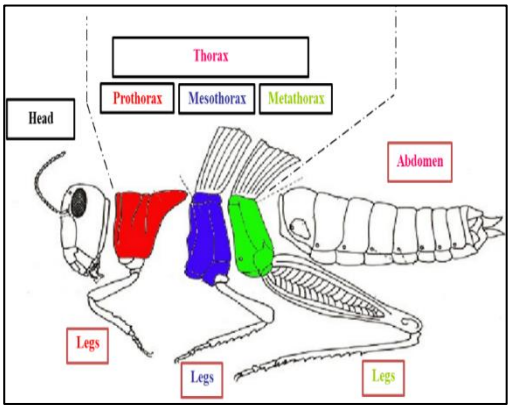


Figure 102: Tagmata of Insecta.

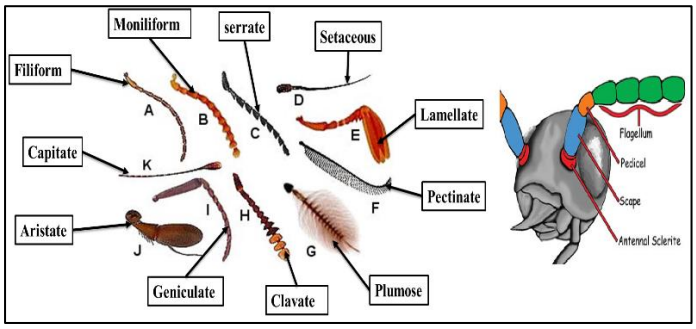


Figure 103: Types of Insect Antenna.

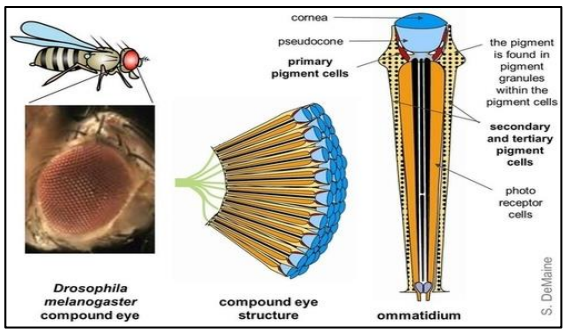


Figure 104: Insect Eyes.

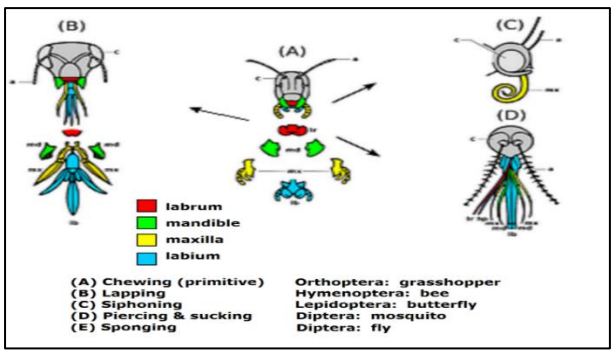


Figure 105: Mouth Parts in Insects

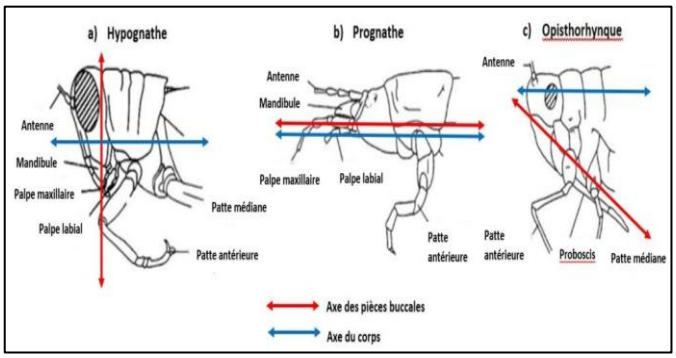


Figure 106: Mouthparts orientation.

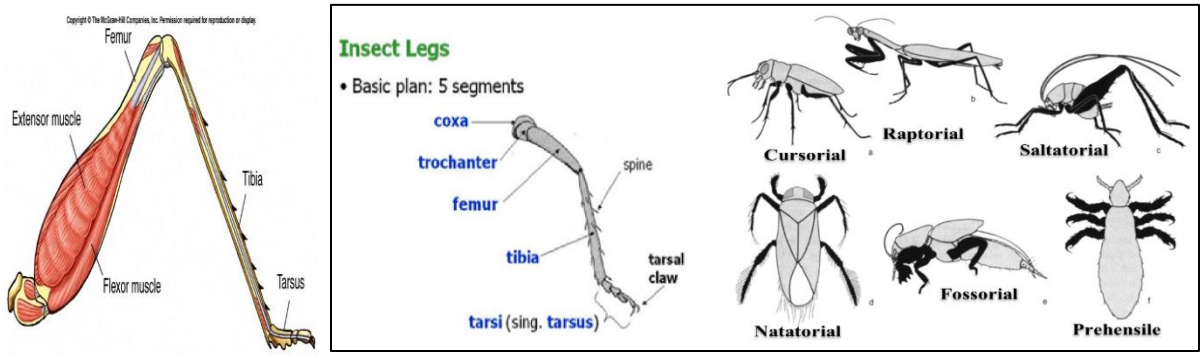


Figure 107: Insect legs modifications.

III-5- Phylum: Arthropoda

III-5-5- Subphylum: Hexapoda /Insecta

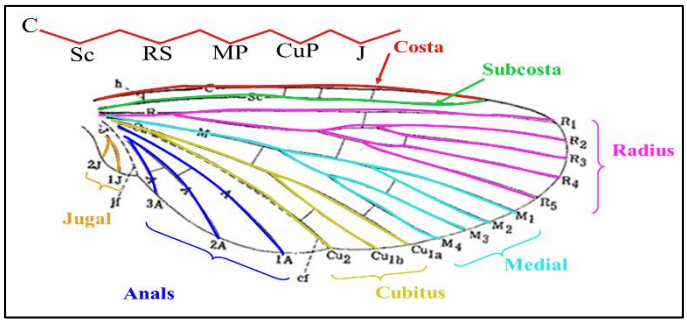


Figure 108: Typical insect wing venation.

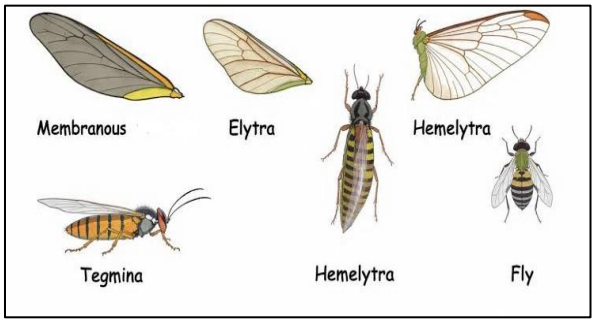


Figure 109: Wing modifications in Insects.

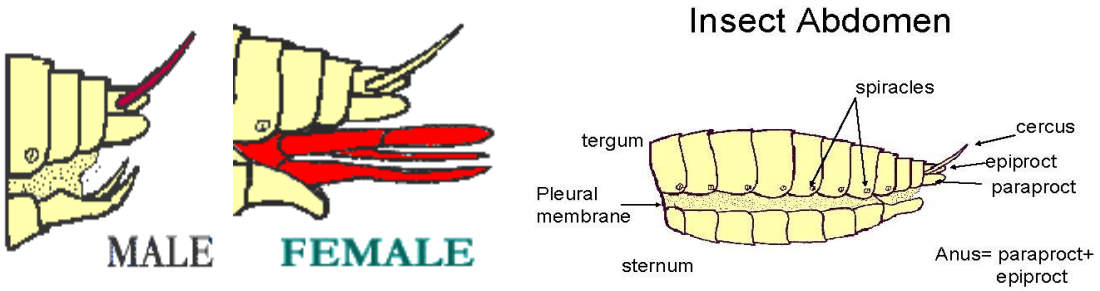


Figure 110: Insect abdomen

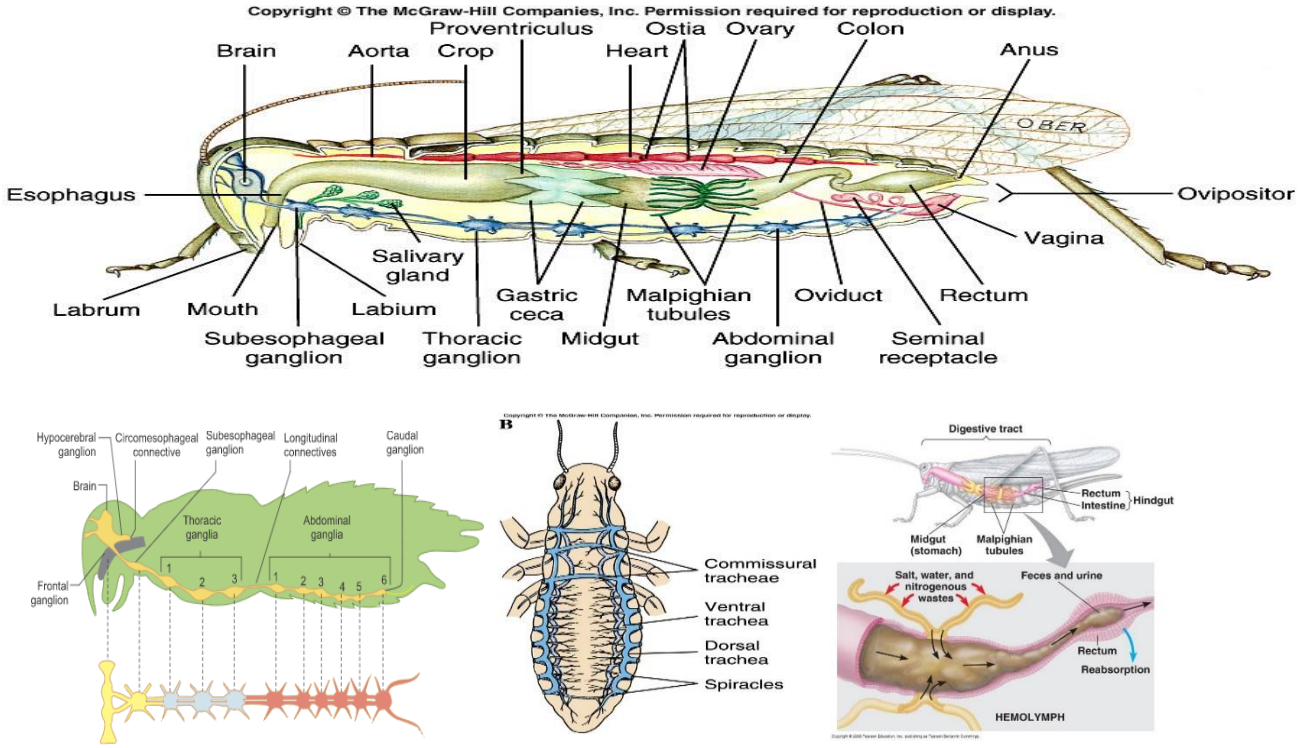


Figure 111: Internal Anatomy of Insects

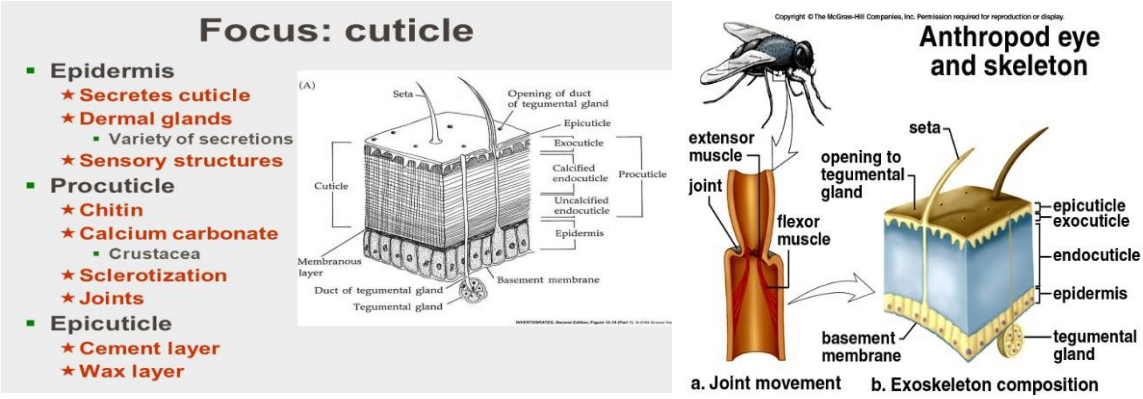


Figure 112: Structure of the Exoskeleton

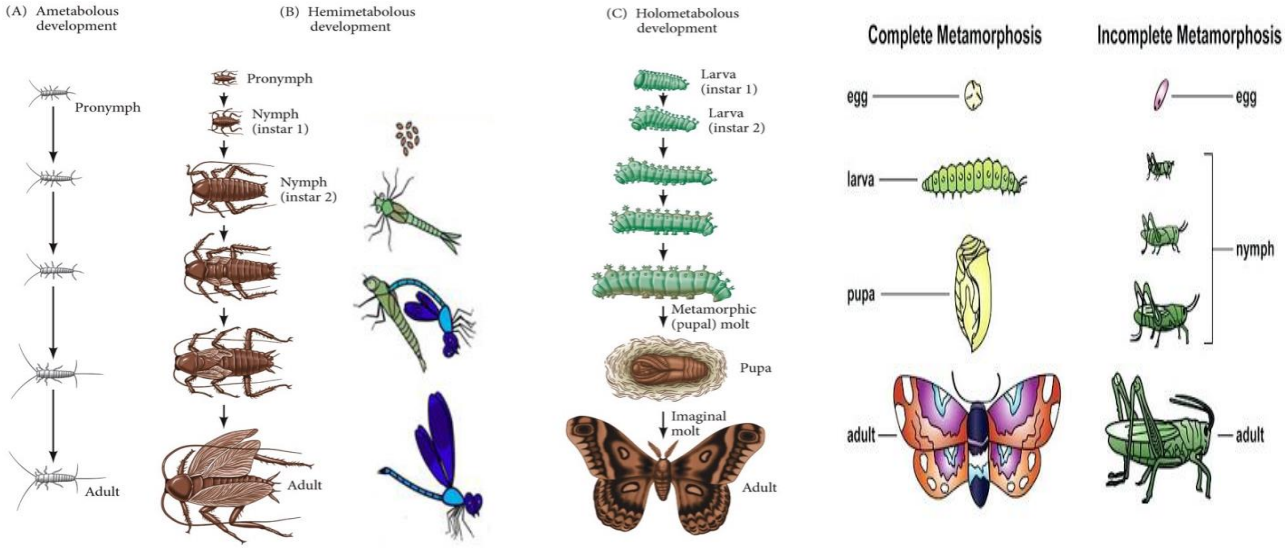


Figure 113: Post-embryonic development in insects.

Classification of class insecta

Insects are classified based on various structural and functional characteristics, such as wings, mouthparts, metamorphosis, feeding habits, reproduction, and economic impact. These bases help in understanding their diversity, roles in ecosystems, and their relationships with humans. Below are the key bases for insect classification:

- ❖ Presence or Absence of Wings.
- ❖ Types of Mouthparts.
- ❖ Types of Metamorphosis.
- ❖ On the Basis of Feeding Habits.
- ❖ On the Basis of Reproduction.

Insects, the only winged invertebrates, are classified based on various characteristics like the presence or absence of wings, their texture, shape, and size.

A widely accepted classification was proposed by A. D. Imms, which helps in organizing insects based on their evolutionary traits and functions.

- ❖ Class Insecta is categorized into two sub-classes based on the presence or absence of wings:

Class Insecta is categorized into two sub-classes based on the presence or absence of wings:

5-5-2-1- Subclass 1/ Apterygota

- ➢ These are primitve wingless insects.
- ➢ Abdomen with cerci and style-like appendages.
- ➢ One pair or more than one pair of appendages present in front of genital opening.
- ➢ Metamorphosis primitive or no that is called Ametabola.
- ➢ Nymphs develop with little or no metamorphosis and resemble adults.
- ➢ Mandible is attached into a specific position of head capsule.
- ➢ The head is prognathous with the mouthparts generally concealed.
- ➢ Moulting continuous after sexual maturity.
- ➢ They are all land animals, though a few live near the ocean and are occasionally found in tide pools.

1. Order1/ Protura

- ❖ Insects without wings.
- ❖ No antennae, true eyes and metamorphosis.

Examples: *Acerantulus*.

2. Order 2/ Collembola

- ❖ No eyes, tracheae, Malpighian tubules.
- ❖ Mouthparts chewing or sucking type.
- ❖ Abdomen 6-segmented.
- ❖ Metamorphosis absent.

Examples: *Achoruted*, *Sminthurus*, *Springtails*.

3. Order 3/ Thysanura

- ❖ Body covered with minute silvery scales.
- ❖ Antennae long; mouthparts chewing.
- ❖ Abdomen 11-segmented; telson long.

Examples: *Lepisma* (silver fish).

5.5.2.2. Subclass 2/ Pterygota

- Winged (alate) or secondarily wingless insects.
- Metamorphosis incomplete or complete.
- Abdominal appendages absent but cerci present.
- Head structure can vary: prognathous, opisthognathous, or hypognathous.
- Mouthparts are ectognathous, with dicondylic mandibles (attached at two points).
- No appendage present in front of genital opening
- Mandible is attached into two specific position of head capsule.
- Immature stages undergo metamorphic development, which can be incomplete or complete.
- Sexually matured adults do not moult.

The subclass Pterygota comprises a total of twenty-five orders. Out of these, 16 orders containing hemimetabolous insects are kept under the Division Exopterygota and 9 orders including holometabolous insects are placed under the Division Endopterygota.

2.a. Division (a) Exopterygota

⇒ Metamorphosis incomplete or simple that is called Hemimetabola (3 developmental stages include egg, nymph and adult).

⇒ Wings develop externally as buds.

⇒ Pupal instar absent or rare.

⇒ Young generalized as nymph.

⇒ Immature insects similar with adults.

a.1. Order 1/ Orthoptera

- Orthoptera (Gr., ortho= straight; ptera = wing).
- Very long bodies / Rear legs modified for jumping.
- Grasshoppers can impact crops positively and negatively.
- Wings 2 pairs. Forewings straight and leathery. Hindwings membranous and folded at rest.
- Mouth parts chewing.
- Prothorax large.

Examples: *Periplaneta* (Cockroach), *Poecilocercus* (Grasshoppers), *Schistocerca* (Locust), *Gryllus* (Cricket), *Mantis* (Praying mantis), *Carausius* (Stick insect) and *Phyllium* (Leaf insect).

a.2. Order 2/ Isoptera

- Wings 2 pairs. Held flat on back.
- Mouthparts chewing.

- ❖ Social insects with well developed caste-system.

Examples: *Termites* or white ants.

a.3. Order 3/ Dermaptera

- ❖ Dermaptera (Gr., derma= skin; ptera = wing).
- ❖ Called earwigs / Long, flat bodies.
- ❖ Large jaws (mandibles).
- ❖ Short, hard forewings (membranous wings).
- ❖ Forelibs small, leahery; hindwings large and semicircular.
- ❖ Mouthparts chewing.

Examples: *Forficula* (Earwig).

a.4. Order 4/ Odonata

- ❖ Wings 2 pairs and membranous.
- ❖ Eyes very large.
- ❖ Mouthparts chewing. Predaceous.

Examples: Dragon flies, Damsal flies.

a-5- Order 5/ Mallophaga

- ❖ Wings absent; body small; head large; eye degenerate; legs clasping.
- ❖ Mouth parts of chewing type.

Examples: Bitings lice of mammals, bird lice.

a-6- Order 6/ Hemiptera

- ❖ Hemiptera (Gr., hemi= one-half; ptera = wing)
- ❖ Wingsless or wings 2 pairs. Forewings thickened at base, membranous at tip.
- ❖ Mouth parts of piercing-sucking type forming beak.
- ❖ Some species use Parthenogenesis for reproduction.
- ❖ Parthenogenesis is a form of asexual reproduction in which an organism develops from an unfertilized egg ex : True bugs, Scale insects, Aphids, White flies

Examples: *Belostoma* (Giant water bug), *Cimex* (bedbug) and *Ranatra* (water scorpion).

a.7. Order 7 Homoptera

- ❖ Wingless or 2 pairs of membranous wings.
- ❖ Mouth parts form a piercing and sucking beak.

Examples: Aphids, Cicadas ans Scale insects.

2.b. Division (b) Endopterygota

⇒ Metamorphosis complete or complex that is called holometabola

⇒ [4 developmental stages such as egg, larva, pupa and adult].

⇒ Wings developed from the internal portion of the body.

⇒ Always accompanied by larval and pupal instar.

⇒ Young generalized as larva.

⇒ Immature insects externally differ with adults.

b.1. Order 1/ Coleoptera

- Forewings leathery and hindwings membranous.
- Antennae modified. Mouth parts chewing type.

Examples: Beetles.

b.2. Order 2/ Lepidoptera

- . Wings membranous, covered with overlapping scales.
- 2. Mouth-parts of sucking type.
- 3. Life-cycle includes caterpillar larva.

Examples: Butterflies, Moths.

b.3. Order 3/ Diptera

- One pair of wings; hindwings knob-like.
- Mouth-parts of piercing-sucking type or sponging type.
- Larva limbless and worm-like called maggot.

Examples: *Musca* (House fly), *Drosophilla* (Fruit fly), *Culex* (Mosquito).

b.4. Order 4/ Hymenoptera

- Two pair of wings that are membranous and hooked together during flight.
- Mouth parts sucking or chewing type.
- Some show social behavior.

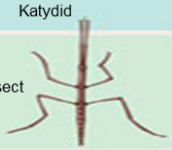
Examples: *Apis* (Honey bee), ants, *Vespa* (Wasp).

III-5- Phylum: Arthropoda

III-5-5- Subphylum: Hexapoda /Insecta

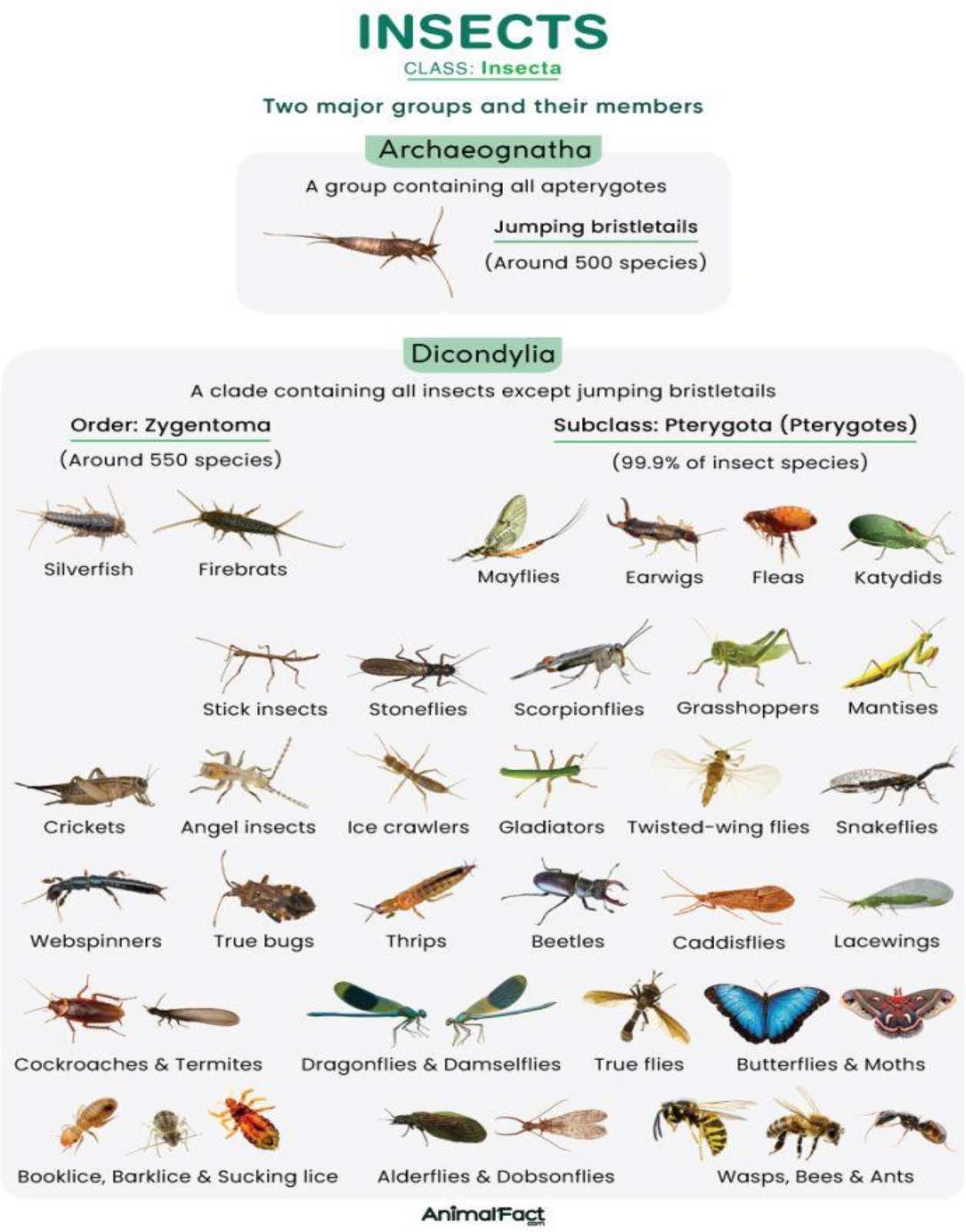
Table 4: Main characteristic of Insecta order

ORDER	APPROXIMATE NUMBER OF SPECIES	MAIN CHARACTERISTICS	EXAMPLES
Blattodea	4,000	Cockroaches have a dorsoventrally flattened body, with legs modified for rapid running. Forewings, when present, are leathery, whereas hind wings are fanlike. Fewer than 40 cockroach species live in houses; the rest exploit habitats ranging from tropical forest floors to caves and deserts.	German cockroach 
Coleoptera	350,000	Beetles comprise the most species-rich order of insects. They have two pairs of wings, one of which is thick and leathery, the other membranous. They have an armored exoskeleton and mouthparts adapted for biting and chewing. Beetles undergo complete metamorphosis.	Japanese beetle 
Dermaptera	1,200	Earwigs are generally nocturnal scavengers. While some species are wingless, others have two pairs of wings, one of which is thick and leathery, the other membranous. Earwigs have biting mouthparts and large posterior pincers. They undergo incomplete metamorphosis.	 Earwig
Diptera	151,000	Dipterans have one pair of wings; the second pair has become modified into balancing organs called halteres. Their head is large and mobile; their mouthparts are adapted for sucking, piercing, or lapping. Dipterans undergo complete metamorphosis. Flies and mosquitoes are among the best-known dipterans, which live as scavengers, predators, and parasites.	Horsefly 
Hemiptera	85,000	Hemipterans are so-called "true bugs," including bed bugs, assassin bugs, and chinch bugs. (Insects in other orders are sometimes erroneously called bugs.) Hemipterans have two pairs of wings, one pair partly leathery, the other membranous. They have piercing or sucking mouthparts and undergo incomplete metamorphosis.	Leaf-Footed bug 
Hymenoptera	125,000	Ants, bees, and wasps are generally highly social insects. They have two pairs of membranous wings, a mobile head, and chewing or sucking mouthparts. The females of many species have a posterior stinging organ. Hymenopterans undergo complete metamorphosis.	 Cicada-killer wasp
Isoptera	2,000	Termites are widespread social insects that produce enormous colonies. It has been estimated that there are 700 kg of termites for every person on Earth! Some termites have two pairs of membranous wings, while others are wingless. They feed on wood with the aid of microbial symbionts carried in specialized chambers in their hindgut.	 Termite

ORDER	APPROXIMATE NUMBER OF SPECIES	MAIN CHARACTERISTICS	EXAMPLE
Lepidoptera	120,000	Butterflies and moths are among the best-known insects. They have two pairs of wings covered with tiny scales. To feed, they uncoil a long proboscis. Most feed on nectar, but some species feed on other substances, including animal blood or tears.	Swallowtail butterfly 
Odonata	5,000	Dragonflies and damselflies have two pairs of large, membranous wings. They have an elongated abdomen, large, compound eyes, and chewing mouthparts. They undergo incomplete metamorphosis and are active predators.	 Dragonfly
Orthoptera	13,000	Grasshoppers, crickets, and their relatives are mostly herbivorous. They have large hind legs adapted for jumping, two pairs of wings (one leathery, one membranous), and biting or chewing mouthparts. Males commonly make courtship sounds by rubbing together body parts, such as a ridge on their hind leg. Orthopterans undergo incomplete metamorphosis.	 Katydid
Phasmida	2,600	Stick insects and leaf insects are exquisite mimics of plants. The eggs of some species even mimic seeds of the plants on which the Insects live. Their body is cylindrical or flattened dorsoventrally. They lack forewings but have fanlike hind wings. Their mouthparts are adapted for biting or chewing.	Stick insect 
Phthiraptera	2,400	Commonly called sucking lice, these insects spend their entire life as an ectoparasite feeding on the hair or feathers of a single host. Their legs, equipped with clawlike tarsi, are adapted for clinging to their hosts. They lack wings and have reduced eyes. Sucking lice undergo incomplete metamorphosis.	Human Body louse 
Siphonaptera	2,400	Fleas are bloodsucking ectoparasites on birds and mammals. Their body is wingless and laterally compressed. Their legs are modified for clinging to their hosts and for long-distance jumping. They undergo complete metamorphosis.	 Flea
Thysanura	450	Silverfish are small, wingless insects with a flattened body and reduced eyes. They live in leaf litter or under bark. They can also infest buildings, where they can become pests.	 Silverfish
Trichoptera	7,100	The larvae of caddisflies live in streams, where they make houses from sand grains, wood fragments, or other material held together by silk. Adults have two pairs of hairy wings and chewing or lapping mouthparts. They undergo complete metamorphosis.	 Caddisfly

III-5- Phylum: Arthropoda

III-5-5- Subphylum: Hexapoda /Insecta



6- Phylum

Echinodermata

6. Phylum : Echinodermata

Echinos = spiny; derma = skin; ata = to bear.

Greek: Echinos = Spines; derma = Skin (Spiny Skinned Organisms).

These animals have an endoskeleton of calcareous ossicles or spiny skin; hence they are named Echinodermata (Spiny skinned Organisms).

General characteristics

✓ **Habitat:** Echinoderms are exclusively marine, free living and mostly bottom-dwellers.

✓ **Body surface:** Body surface with five radial areas, the ambulacra, with tube feet and five inter-radial areas, the inter-ambulacra.

✓ **Cephalization:** No Cephalization (No head).

✓ **Skeleton:** Endoskeleton is made up of spines and calcareous spicules.

✓ **Organisation:** They have organ-system level of organisation.

✓ **Germ Layers and Coelom:** They are triploblastic and coelomate animals. Coelom is a large cavity lined by ciliated peristomium, coelomic fluid with coelomaocytes.

✓ **Symmetry:** The adult echinoderms are radially symmetrical but larvae are bilaterally symmetrical or pentamerous **(Figure 114).**

✓ **Circulatory:** Water vascular system or ambulacral system present, usually with a madreporite.

✓ **Water Vascular System:** The most distinct feature of echinoderms is the presence of water vascular system which helps in locomotion, capture and transport of food and respiration **(Figure 115).**

✓ **Digestive/ Feeding:** carnivores tube feet.

✓ Alimentary canal straight or coiled.

✓ **Nervous:** Nervous system without brain but with a circum-oral ring and radial nerves (Epithelioneurians).

✓ **Sense organs:** Sense organs are poorly developed.

✓ **Excretory system** is absent.

✓ Have an anus, but undigested food is expelled back through the mouth.

✓ **Respiratory:** Respiratory organs include dermal branchiae and skin gills, Tube feet/ water vascular system, respiratory tree and bursae.

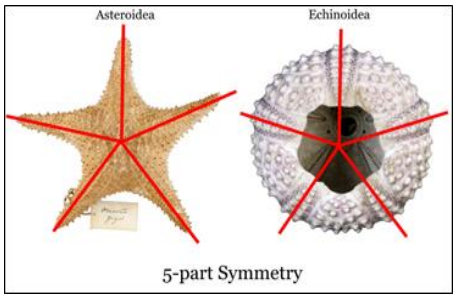
✓ **Reproductive:** Reproduction is usually sexual but few reproduce asexually or by regeneration.

✓ **Sexes:** They are dioecious (Sexes are separate). Sexual reproduction occurs.

✓ **Fertilisation** is external.

✓ **Development** is indirect with free-living larva.

✓ **Movement:** The water vascular system of echinoderms is responsible for their movement and ability to clean (Ecological role).



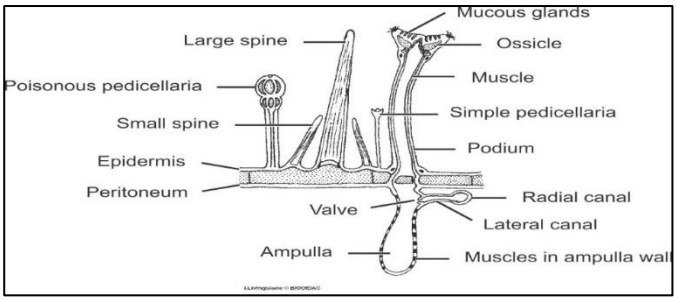


Figure 114: Symmetry of Echinodermata

Figure 115 : Structure of tube foot in section.

Classification of Echinodermata

6.1. Subphylum 1/ Eleutherozoa

Gr: eleutheros= free + zoios = animal.

6.1.1. Class 1/ Asteroidea/ Stelleroidea

Gr: eleutheros = star + eidos = form.

- ✓ Body includes 5 arms (or rays) radiating from central disk.
- ✓ Tube feet with suckers.
- ✓ Anus and madreporite are present on the aboral surface.
- ✓ Pedicellariae present.
- ✓ Free-living, predaceous, slow creeping and scavengerous.
- ✓ Found on rocks along coasts.

Examples: *Sea stars* (Starfish).

Examples 1: *Astropecten*, *Goniaster*, *Luidia*, *Oreaster*.

Examples 2: *Echinaster*, Solaster, *Asterina*, *Pteraster*.

Examples 3: *Asterias rubens*, *Heliaster*.

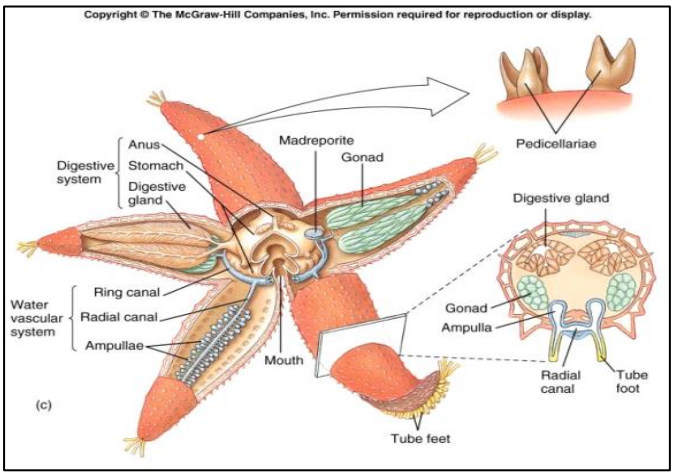


Figure 116 : Internal anatomy of a starfish.

6.1.2. Class 2/ Ophiuroidea

Gr: ophis = snake + oura = tail + eidos = form.

- ✓ Includes brittle stars and allies.
- ✓ Body flattened with a pentamerous and has rounded central disc.
- ✓ Arms usually five, rarely six or seven, and are long, slender, smooth or spiny.

- ✓ Pedicellariae absent.
- ✓ Madreporite on the oral surface.
- ✓ Stomach sac like; anus absent.
- ✓ Ambulacral grooves absent or covered by ossicles.
- ✓ Tube feet without suckers.
- ✓ More mobile than brittle stars

Examples 1: *Ophioderma*, *Ophiothrix*, *Ophiura lacertosa*, *Ophiopholis*.

Examples 2: *Asteronyx*, *Gorgonocephalus* (Basket star).

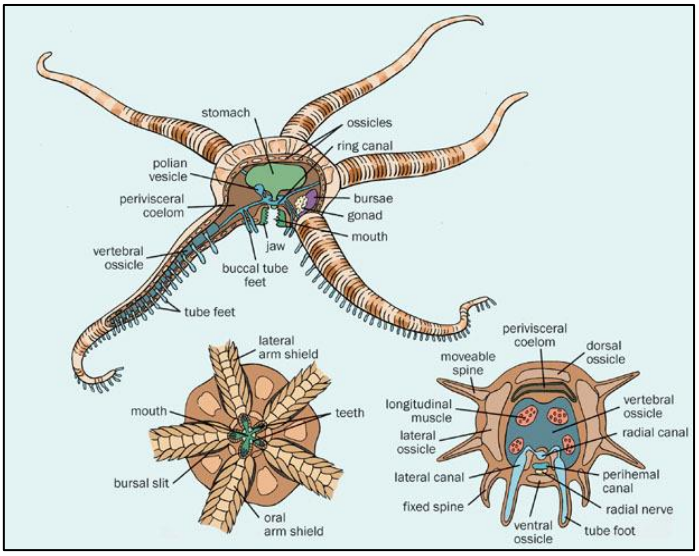


Figure 117 : Ophiuroidean anatomy.

6.1.3. Class 3/ Echinoidea

Gr: echinos = hedgehog + eidos = form.

- ✓ Sea urchins and dollars.
- ✓ Body spherical, disc-like, oval or heart-shaped.
- ✓ Skeleton with movable spines and three-jawed pedicellariae.
- ✓ Chewing apparatus or Aristotle's lantern with teeth.
- ✓ Ambulacral grooves covered by ossicles.
- ✓ Sexes separate. Gonads pentamerous.

Examples 1: *Single extinct Ordovician* genus *Bothriocidaris*.

Example 2: *Palaeodiscus*; *Melonechinus*; *Histocidaris*; *Goniocidaris*; *Echinus*; *Diadema*;*Arbacia*.

Examples 3: *Echinoneus*; Holectypus; *Cassidulus*; *Clypeaster*; *Echinocyamus*; *Echinarachinus*; *Heart urchins*;*Spatangus*;*Hemipneustes*; *Echinocardium lovenia*.

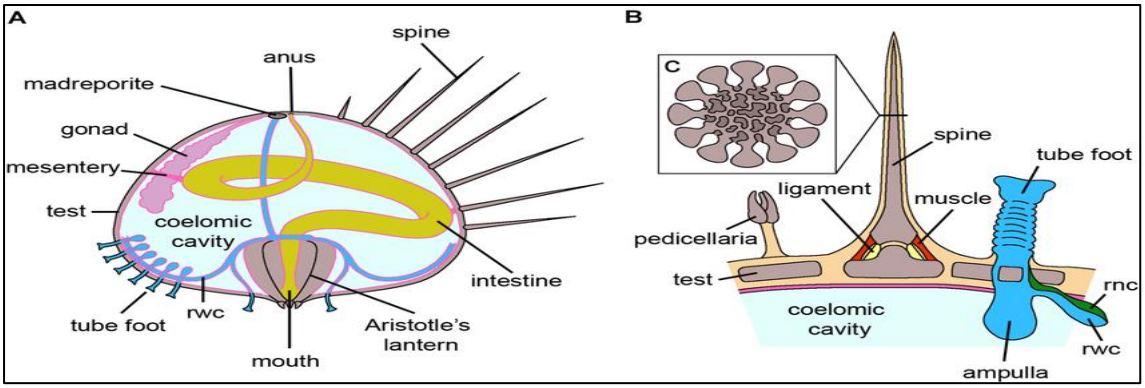


Figure 118 : Echinoidea anatomy.

6.1.4. Class 4/ Holothuroidea

Gr: holothurion = sea cucumber + eidos = form.

- ✓ Sea cucumbers.
- ✓ Body bilaterally symmetrical, elongated on oral-aboral axis having mouth at or near one end and anus at or near the other end body wall leathery.
- ✓ Cucumberlike shape (Soft body).
- ✓ Arms and spines absent.
- ✓ Mouth anterior, surrounded by tentacles.
- ✓ Ambulacral grooves concealed; tube feet with suckers.
- ✓ Respiratory tree for respiration.
- ✓ Found on the sea bottom.

Examples 1: *Cucumaria*, *Thyone*.

Examples 2: *Holothuria*, *Actinopyga*.

Examples 3: *Pelagothuria*.

Examples 4: *Caudina*, *Molpadia*.

Examples 5: *Synapta*, *Leptosynapta*.

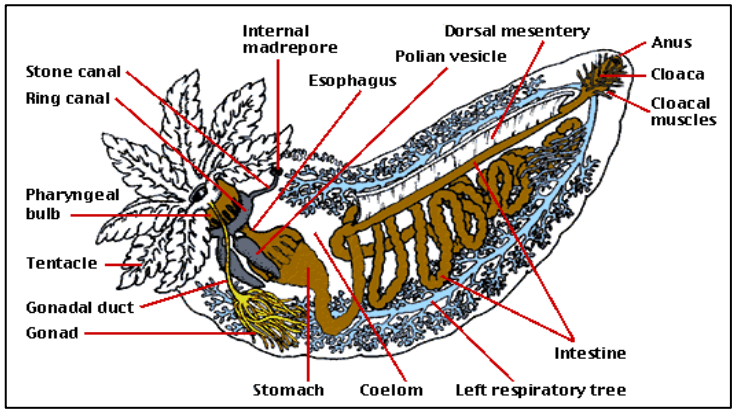
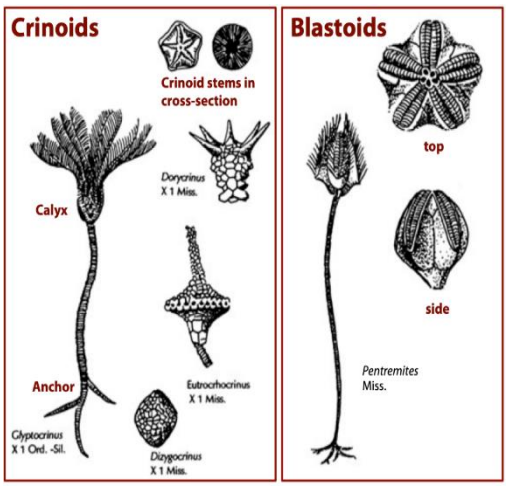


Figure 119 : Holothuroidea anatomy

6.2. Subphylum 2/ Pelmatazoa

Gr: pelmatos = stalk + zooios = animal

Stalked, sedentary echinoderms.



6.2.1. Class 1/ Crinoidea

Gr: crinon = lily + eidos = form

- ✓ Sea lilies.
- ✓ Body attached during part or whole life by an aboral stalk.
- ✓ Mouth and anus on oral surface.
- ✓ Arms with pinnules.
- ✓ Tube feet without suckers; madreporite, spines and pedicellariae absent.
- ✓ Found on the sea bottom filter feeders, using their arms to capture plankton and small particles.

Examples: *Antedon* (sea lily), *Neometra* (feather star). *Annacrinus.*

Chaptre III

Subkingdom Metazoa

Part 2. Vertebrates (Chordata)

Triploblastic

2.7. Phylum Chordata

2.7.1. Sub-phylum Urochordata (Tunicata)

2.7.2. Sub- phylum Cephalochordata

2.7.3. Sub-phylum Vertebrata

2.7.3.1. Super Classe Fishes

2.7.3.1.1. Classe of Chondrichtyens

2.7.3.1.2. Classe of Osteichtyens

2.7.3.2. Super Classe Tetrapoda

2.7.3.2.1. Classe Amphibians

2.7.3.2.2. Classe Reptiles

2.7.3.2.3. Classe Aves

2.7.3.2.4. Classe Mammalia

III-7- Phylum: Cordata

7. Phylum : Cordata

General characteristics

Animals, Metazoans, Triploblastic, Coelomate, Bilateral symmetry, Deuterostomia , Epineurians, Endoskeleton, organ-system level of organisation

All the chordates possess four diagnostic characters either in the embryonic or adult stage **(Figure 120)**.

- **Notochord**

It is a solid un-jointed, stiff but flexible rod-like structure situated on the dorsal side between the dorsal hollow nerve cord and the alimentary canal.

- **Nerve cord**

The nerve cord of chordates is always hollow and lies dorsal to the notochord.

- **Pharyngeal Gill Slits**

All the chordates have at some stage of life, a series of paired narrow openings, the gill slits on the lateral sides of the pharynx.

- **Postanal tail**

Tail and musculature provide motility

It is a post-anal part of the body. Which is reduced or absent in many adult chordates.

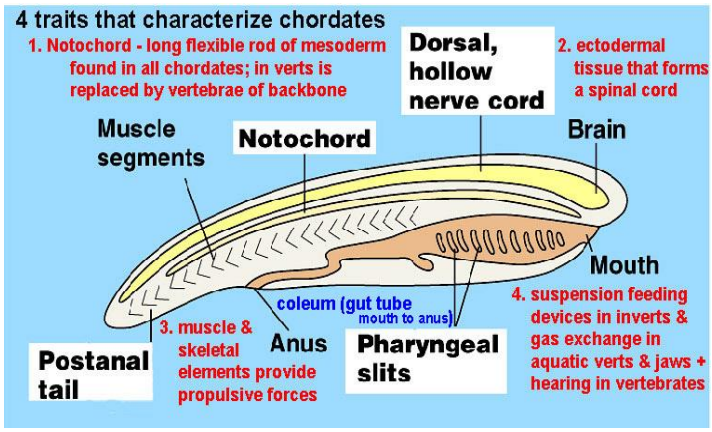
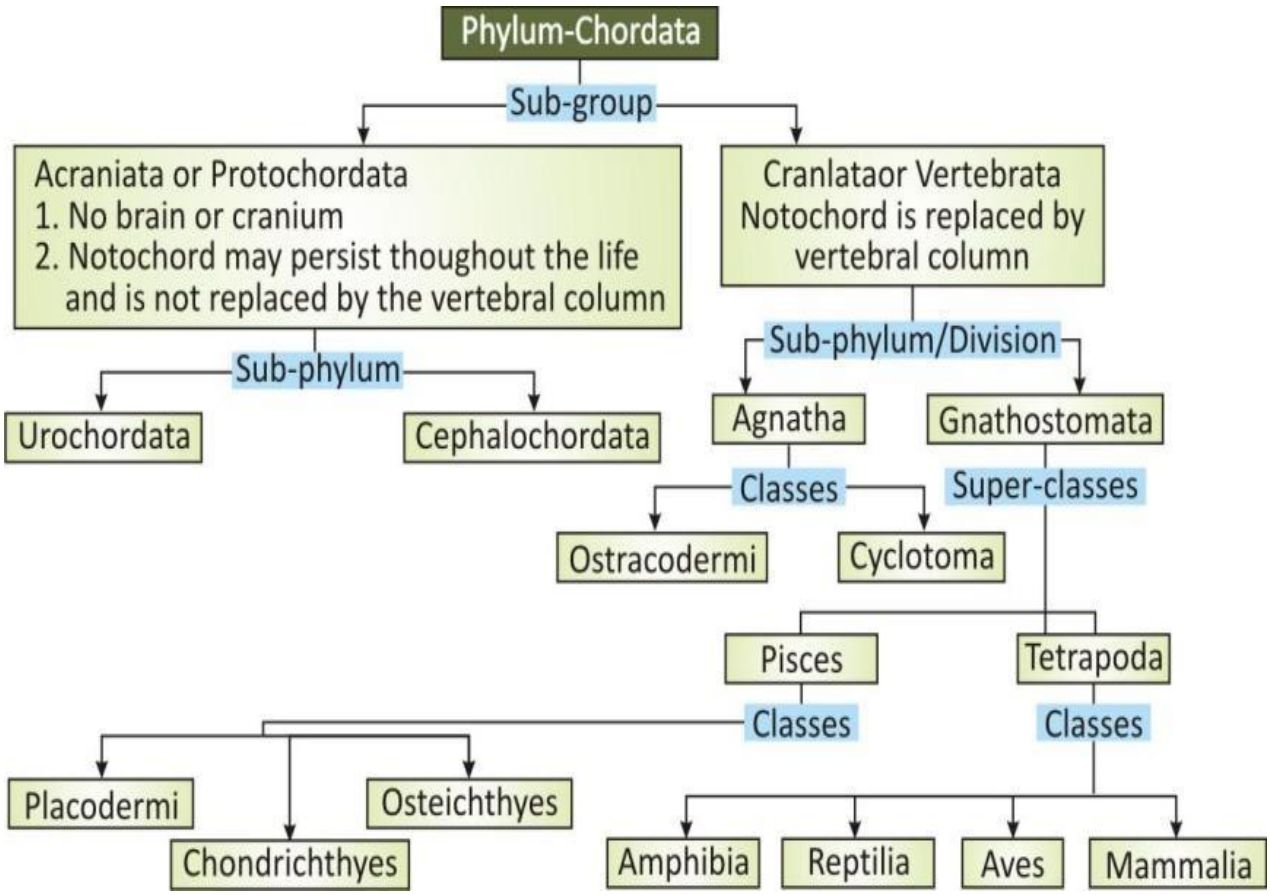


Figure 120 : Four key characteristic of chordata

Classification of Phylum Cordata



III-7- Phylum: Cordata

III-7-1- Subphylum Urochordata

7.1. Subphylum Urochordata

Urochordata (Greek : Uro – tail ; chorde – cord).

General characteristics

✓ Considered as the invertebrate chordata (Gelatinous body).

✓ They are also known as tunicates because their body is surrounded by a leathery sheath composed of tunicin (cellulose) often transparent (**Figure 121**).

✓ Possess a notochord during the larval stage, in adults, the notochord is reduced or absent.

✓ The neural tube in the larva is replaced by a dorsal ganglion in the adults (**Figure 121**).

✓ No definite head.

✓ Respiration performs by gaseous exchange across the tunic or the pharyngeal slits.

✓ They have an open circulatory system where the heart is tubular in shape and has either none or one chamber with no endocardium.

✓ No coelom, segmentation or nephridia.

✓ The digestive tract is complete with an anus and can be in the form of a U shaped tube or straight.

✓ Adult forms are typically sessile (attached to a substrate), while larval forms are free-swimming.

✓ They are found in the marine environment.

✓ They can be solitary or in colonies.

✓ Development is mostly indirect (**Figure 121**). But a few species exhibit direct development.

✓ Sexes are separate.

✓ Reproduction is mostly sexual reproduction.

✓ Fertilization is external.

Examples: *Herdmania, Selpa, Molgula.*

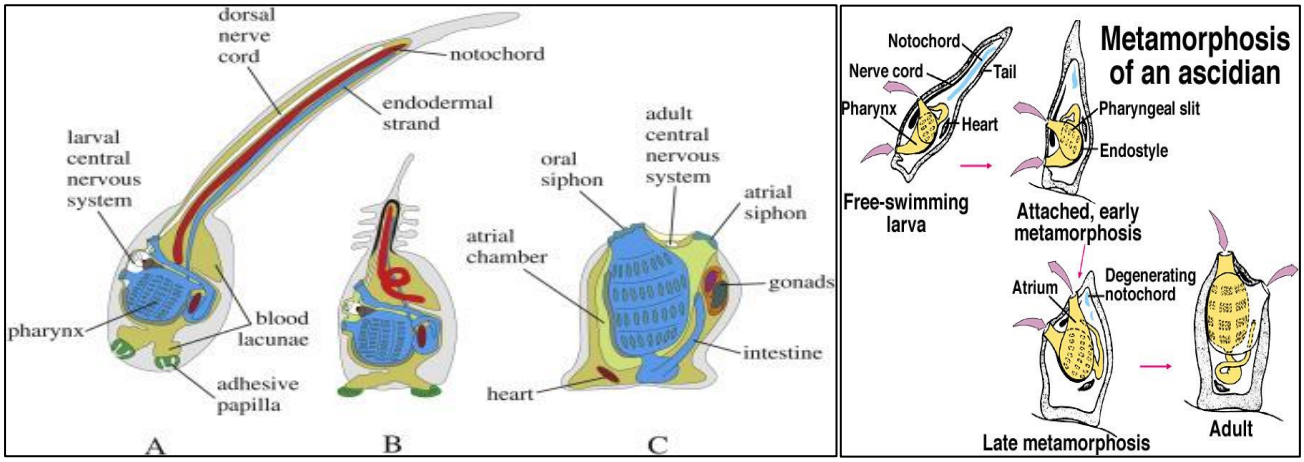


Figure 121 : Anatomy of a sea squirt: (C) the adult, (A) the larva.

III-7- Phylum: Cordata
III-7-2- Subphylum Cephalochordata

4.2. Subphylum Cephalochordata

General characteristics

✓ Also a invertebrate chordata-only 29 species (All are marine).

✓ The notochords remain throughout life and extend up to the head region (**Figure 122**).

✓ The nerve cord and the tail also remain throughout life.

✓ Body-wall shows one- cell thick, non-ciliated epidermis, dermis, connective tissue, striated muscle and parietal peritoneum.

✓ It has no exoskeleton.

✓ Alimentary canal is long. It includes a large pharynx with many gill-slits.

✓ Excretory system shows paired protonephridia with solenocytes (Solenocytes are the excretory organs).

✓ They respire through gills which open in the atrium.

✓ Reproduce sexually, with external fertilization (Separate sexes).

✓ Motile adult and larval stage.

✓ Dorsal, caudal and ventral fins are present.

Exemples : *Amphioxus.*

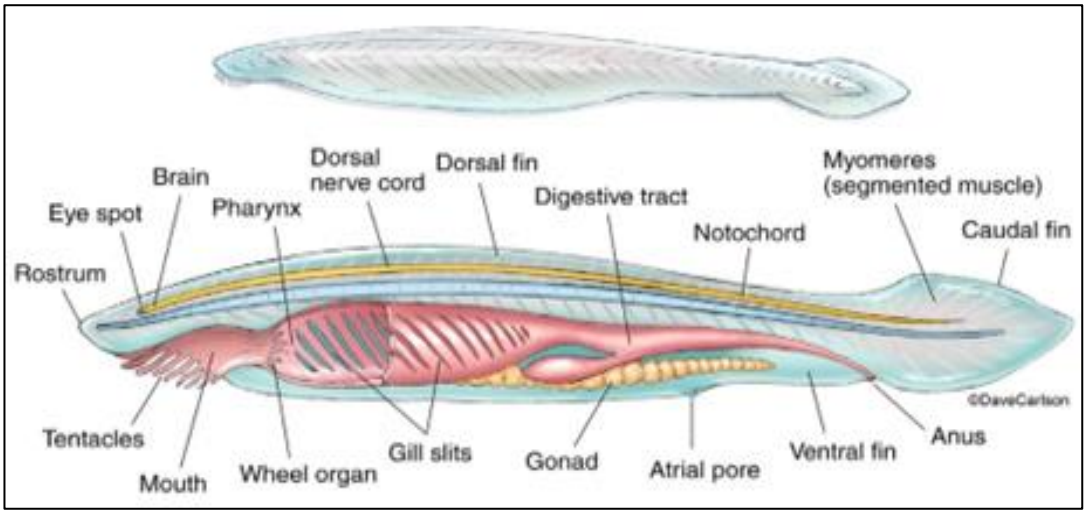


Figure 122 : Anatomy of an *Amphioxus*.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)

7.3. Subphylum Vertebrata (Craniata)

General characteristics

The characteristic features of vertebrates include (**Figure 123a, b**):

✓ These are advanced chordates and have cranium (brain box) around the brain.

✓ The notochord is replaced by a vertebral column in adults.

✓ This is why it is said that 'all vertebrates are chordates but all chordates are not vertebrates'.

✓ A high degree of cephalization is observed.

✓ **Body plan:** Consisting typically of head, trunk, and postanal tail; neck present in some, especially terrestrial forms; usually two pairs of appendages, although entirely absent in some; coelom divided into a pericardial space and a general body cavity; mammals with a thoracic cavity.

✓ **Integument:** Basically of two divisions, an outer epidermis of stratified epithelium from ectoderm and an inner dermis of connective tissue derived from mesoderm; many modifications of skin among the various classes, such as glands, scales, feathers, claws, horns, and hair.

✓ Epidermis having many cells, it may bear an exoskeleton of scales, feathers or hair.

✓ **Musculer system:** They consist of three types of muscles-striped, unstriped and cardiac.

✓ They have a well-developed coelom.

✓ **The alimentary cana:** Is complete.

✓ **Circulatory system:** Consisting of a ventral muscular heart with two or three or four-chambered; a closed blood vessel system of arteries, veins, and capillaries; blood fluid containing ed corpuscles with hemoglobin and white corpuscles.

✓ **Excretory system:** Consisting of paired kidneys (mesonephric or metanephric types in adults) provided with ducts to drain waste to the cloaca or anal region.

✓ **Respiratory organs:** May include gills, skin or lungs.

✓ **Sense organs:** Like eyes, ear, skin, tongue and nasal chamber.

✓ **Endocrine system:** Endocrine glands are present in all.

✓ **Neve system:** Highly differentiated brain; 10 or 12 pairs of cranial nerves usually with both motor and sensory functions; a pair of spinal nerves for each primitive myotome; an autonomic nervous system in control of involuntary functions of internal organs; paired special sense organs.

✓ They are unisexual and reproduce sexually, hagfish being an exception.

Classification of Subphylum Vertebrata

On the basis of presence or absence of jaw the subphylum Vertebrata is further divided into **two sub-groups:**

III-7- Phylum: Cordata

III-7-3- Subphylum Vertebrata (Craniata)

Sub-groups 1 Agnatha- The Jawless Vertebrates.

(Gr., a = not; gnathos = jaw). lawless fish-like vertebrates without true jaws and paired limbs

Sub-groups 2 Gnathostomata- The Jawed Vertebrates.

(Gr., gnathos = jaw; stoma = mouth). Jawed vertebrates having true jaws and paired limbs.

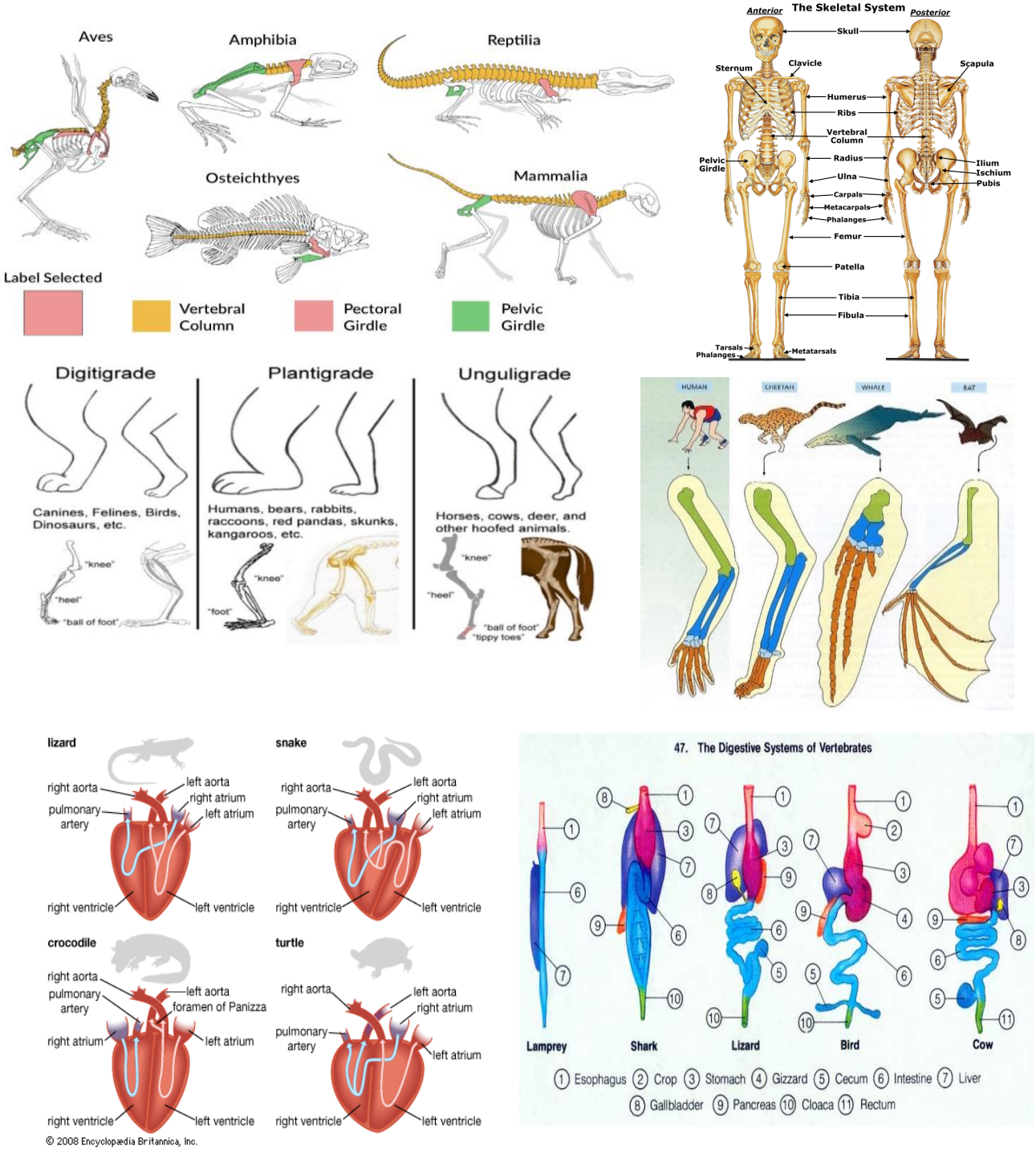
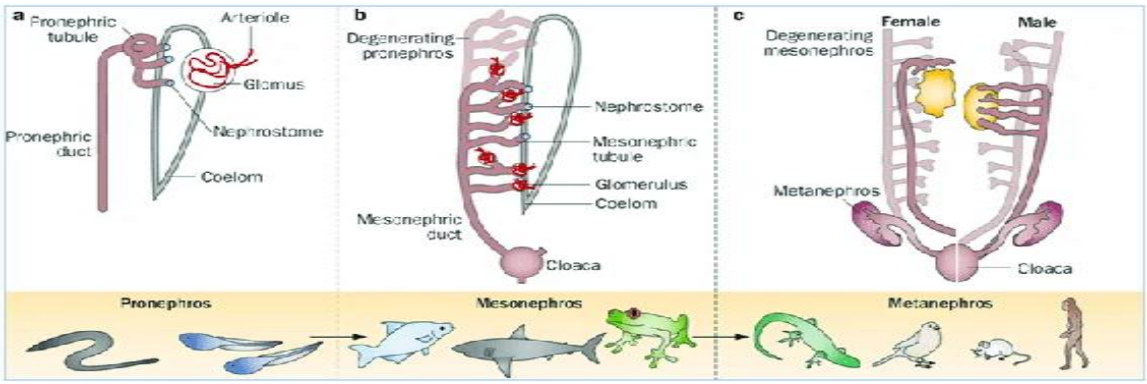
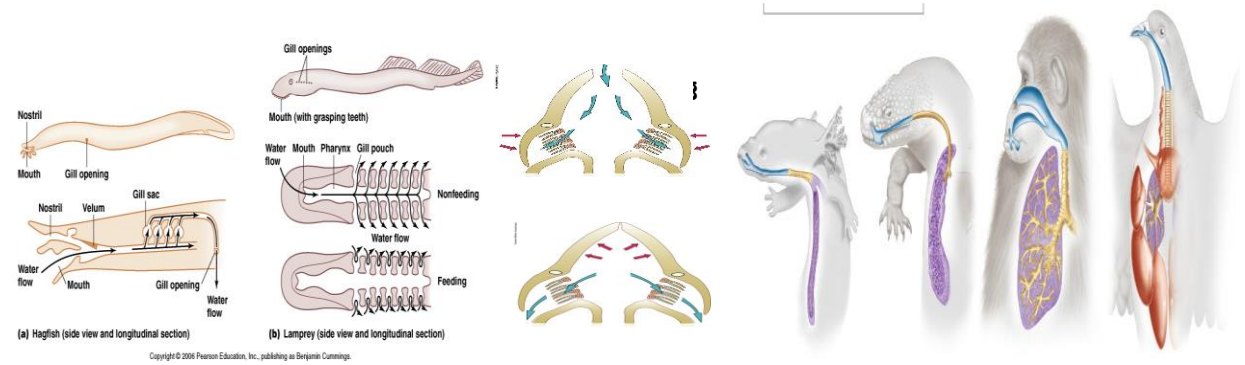


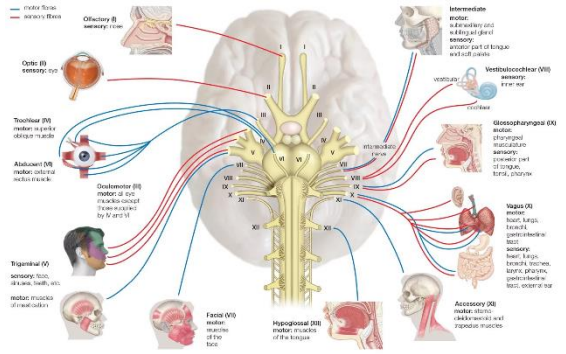
Figure 123 a : Morphology and general anatomy of Vertebrata.

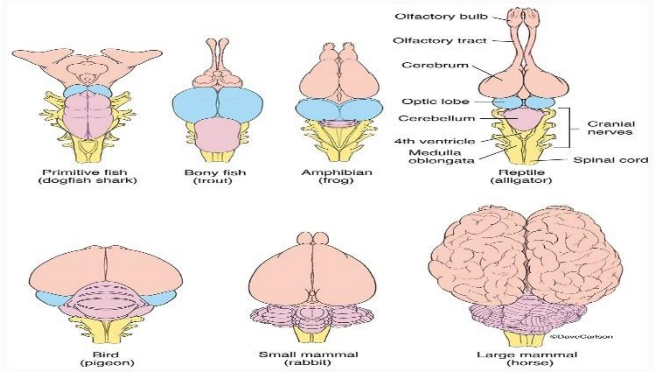
III-7- Phylum: Cordata

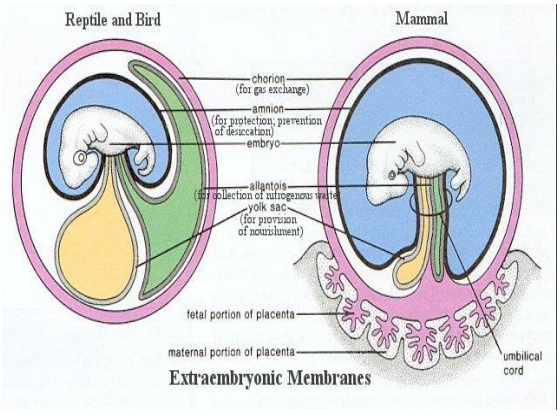
III-7-3- Subphylum Vertebrata (Craniata)











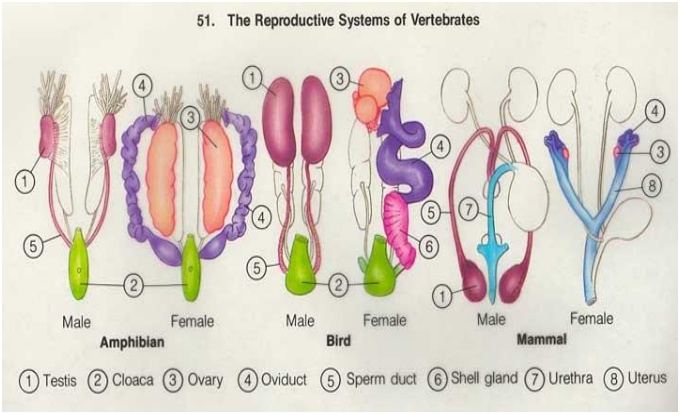


Figure 123 b : Morphology and general anatomy of Vertebrata.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Sub-groups 1 Agnatha /Cyclostomes/ Cyclostomata

7.3.A. Groups A/ Agnatha / Cyclostomata

Agnatha- The Jawless Vertebrates (Cyclostomata);
(Gr., a = not; gnathos = jaw). lawless fish-like vertebrates without true jaws and paired limbs;
(Gr., Cyclos = circular; stoma = mouth).

General characteristics

- ✓ Slender, eel-like body.
- ✓ Median fins but no paired appendages.
- ✓ Fibrous and cartilaginous skeleton; notochord persistent; no vertebrae.
- ✓ Biting mouth with two rows of eversible teeth in hagfishes; suckerlike oral disc with well-developed teeth in lampreys.
- ✓ Heart with one atrium and one ventricle; hagfishes with three accessory hearts; aortic arches in gill region.
- ✓ Five to 16 pairs of gills and a single pair of gill apertures in hagfishes; 7 pairs of gills in lampreys.
- ✓ Pronephric kidney anteriorly and mesonephric kidney posteriorly in hagfishes; mesonephric kidney only in lampreys.
- ✓ Dorsal nerve cord with differentiated brain; 8 to 10 pairs of cranial nerves.
- ✓ Digestive system without stomach; intestine with spiral valve and cilia in lampreys; both lacking in intestine of hagfishes.
- ✓ Sense organs of taste, smell, hearing; eyes poorly developed in hagfishes but moderately well developed in lampreys; one pair of semicircular canals (hagfishes) or two pairs (lampreys).

Classification of Cyclostomata

The class Cyclostomata is divided into two orders:

Order 1. Petromyzontiformes

(Gr., petros-stone+ myzon-suck)

- ➢ In most cases the skeleton is cartilaginous.
- ➢ The embryonic notochord persists in the adult.
- ➢ Buccal funnel lined with horny dentricles.
- ➢ 3 pairs of barbels around the nostril and mouth used as tactile organs.
- ➢ Have a dorsal fin.
- ➢ Presence of vertebral elements in the trunk.
- ➢ Sides of body have 1–14 gill openings.

- Seven pairs of gill pouches open separately to the exterior via pore-like gill slits that conduct water into as well as out of the pouches.
- free living or parasitic; adapted for sucking blood and body fluids of other fish.
- Adults live in sea (saltwater), but migrate upstream (freshwater) to lay eggs.
- Lamprey eggs develop into sedentary filter- feeding larvae.
- Skull is more complex and includes true cartilagenous braincase.
- The digestive system lacks a stomach.

Exemples : *Lamprey* (Petromyzon) **(Figure 124).**

Order 2. Myxiniformes

(Gr., myxa-slime+ oidea-type of)

- Lack rasping dentricles; funnel surrounded by a ring of stubby finger-like papillae.
- Chiefly bottom-feeding scavengers.
- Use 6 short tentacles surrounding the mouth to find its food.
- Eyes are vestigial and covered by opaque skin.
- 1 semicircular duct.
- No dorsal fin.
- No larval stage.
- Incomplete braincase (skull).
- The digestive system lacks a stomach.
- Hagfish: External fertilization; both ovaries and testes present in individual but gonads of only one sex functional.
- Lamprey – External fertilization; separate sexes and a long larval stage in lampreys.

Exemples : *Myxine* (Hagfishes) **(Figure 124).**

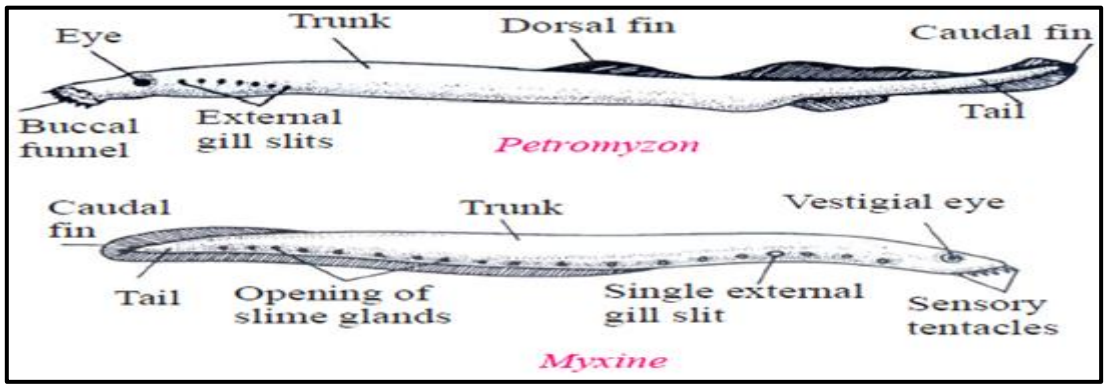


Figure 124 : Morphology of a representative of the lampreys and hagfish.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Group 2 / Gnathostomata
Super classes Pisces

7.2.B. Group B. Gnathostomata

Advanced Vertebrates with following features like embryonic notochord is usually replaced by vertebral column, Paired fins or limbs are present.

Gnathostomata are divided into two super classes as **Pisces** and **Tetrapoda**.

B.1. Superclass 1. Pisces

Pisces in Latin and ichthys in Greek.

General characteristics of Fish

- ✓ Fishes are aquatic cold blooded vertebrates.
- ➢ It has a spindle shaped body.
- ➢ Their body is divisible into head, trunk and tail. Neck is absent.
- ✓ The body is covered by scales. They are placoid scales, cycloid scales, ctenoid scales, ganoid scales etc.
- ➢ The body shows paired and unpaired fins. Pelvic and pectoral fins are paired. Dorsal and ventral fins are unpaired. They maintain balance in water. They are useful for locomotion.
- ➢ Respiration is by gills.
- ➢ Heart – 2 chambered.
- ➢ On the lateral sides of the body Lateral line sense organs are present. They detect the pressure changes of water.
- ➢ The nervous system contains brain and spinal cord. Brain is small Ten pairs of cranial nerves are present.
- ➢ Kidneys are mesonephrlc.
- ➢ Urinary bladder is absent.
- ➢ Fins- help the fish move steer, stop, and balance
- ➢ scales- protect the body.
- ➢ Well-developed sense of vision, hearing, taste, and smell.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Group B /Gnathostomes/ Gnathostomata
Superclass 1. Pisces

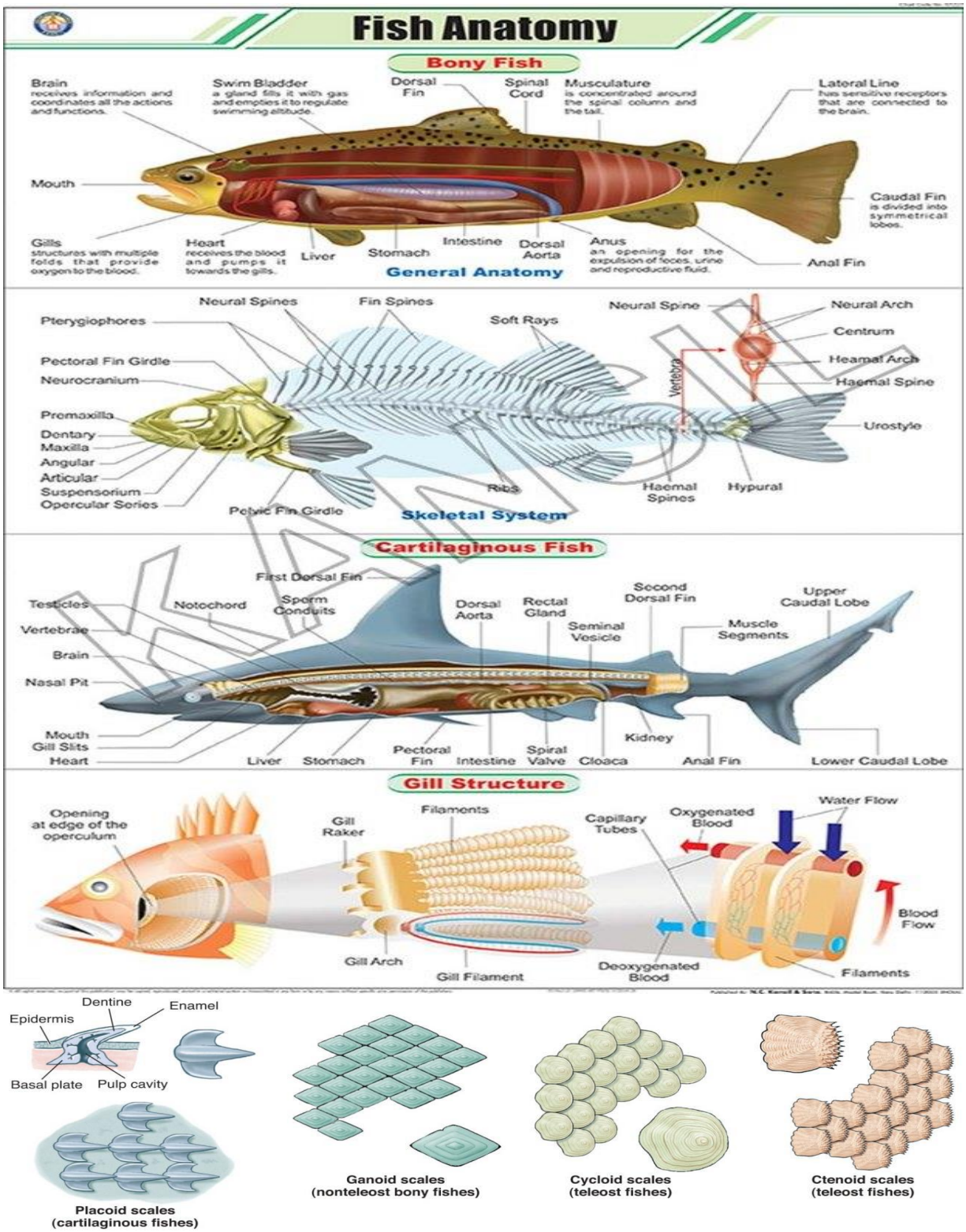


Figure 125 : Fish anatomy

Classification of Pisces

These are divided into two **classes** : **Chondrichthyes, Osteichthyes (Figure 126).**

B.1.1. Class 1/ Chondrichthyes / (Cartilaginous fish)

In Greek, “chondros” means cartilage and “icthyes” means fish, hence they are called cartilagenous fishes.

✓ They are marine animals with streamlined body and have cartilaginous endoskeleton **(Figure 126).**
✓ Notochord is persistent throughout life.
✓ The skin is tough, containing minute placoid scales.
✓ Mouth is located ventrally **(Figure 126).**
✓ Their jaws are very powerful or strong jaws.
✓ Gill slits are separate and without operculum) gill cover) or Gills not protected.
✓ Heterocercal caudal fin.
✓ Reproduction – Sexes-separate, Fertilisation-internal, oviparous or ovoviviparous
✓ Due to the absence of air bladder, they have to swim constantly to avoid sinking.
✓ Some of them have electric organs (e.g., Torpedo) and some possess poison sting (e.g.,Trygon).
✓ Possess a variety of sensory systems, including senses of smell, vision, hearing and sensory lateral line lthat allows them to detect sound, vibration, and pressure changes.
✓ Reproduction – Sexes-separate.
✓ They have internal fertilisation and many of them are viviparous.
✓ In males, pelvic fins bear claspers which are used for copulation.
✓ Most of them are predators.

Examples: Carcharodon (Great white shark), Scoliodon (Dog fish), Torpedo (electric ray), Trygon (sting ray), Chimaera (rabbit- or rat-fish).

Classification of Chondrichthyes

Today, they are represented by two groups: Elasmobranchii and Holocephali **(Figure 126).**

B.1.1.1. Subclass 1 / Selachians or elasmobranchs / Elasmobranchii

These are sharks and rays **(Figure 126).**

Example 1: Sharks.

Order Orectolobiformes: Whale shark; Leopard shark; Sleeper shark.

Order Carcharhiniformes: Sharks in the strict sense; Hammerhead shark.

Example 2: Rays have ventral fins (hypotremes).

*Presence of electric organs: pectoral (torpedes) Torpedo or caudal (rays) Raja radiata.

Order Myliobatiformes: stingray; eagle ray; manta ray.

Order Torpediniformes: Torpedo ray.

Order Rajiformes: Guitar ray.

B.1.1.2. Subclass 2/ Holocephali

Example: Chimaeridae => *Chimaera*.

B.1.2. Classe 2/ Osteichthyens/ Osteichthyes

Characteristics of bony fishes (osteichthyes)

In Greek, "osteon" means bone and "icthyes" means fish, hence they are called bony fishes.

✓ It includes both marine and fresh water fishes with bony endoskeleton **(Figure 126).**

✓ Skeleton more or less bony, vertebrae numerous; tail usually homocercal or Homocercal caudal fin

✓ Their body is streamlined.

✓ Skin with mucous glands and embedded dermal.

✓ Skin is covered with: ganoid, cycloid, or ctenoid; some without scales, no placoid scales.

✓ Fins both median and paired with fin rays of cartilage or bone **(Figure 126).**

✓ Mouth terminal with many teeth (some toothless); jaws present.

✓ Respiration by gills supported by bony gill arches and covered or protected by a common operculum (Have four pairs of gills on each side).

✓ Swim bladder often present (Swim bladder- balloon like organ filled with oxygen and other gases that gives the fish buoyancy).

✓ Sexes separate (some hermaphroditic), gonads paired; fertilization usually external; larval forms may differ greatly from adults.

✓ Oviparous (some fishes exhibit parental care).

Examples: *Exocoetus* (flying fish), *Hippocampus* (sea horse) are marine; *Labeo* (rohu), *Catla* (carp), *Clarias* (cat fish or magur) are fresh water forms.

Classification of Osteichthyes

They are divided into two sub-classes:

B.1.2.1. Subclass 1/ Acanthodians (fossils)

B.1.2.2. Subclass 2/ Actinopterygians/ Actinopterygii

This subclass is in turn divided into several groups or superorders **(Figure 127).**

B.1.2.1.1. Superorder 1/ Palaeoniscoids

Two extant groups are of Palaeoniscoid descent: the Chondrosteans and the Brachyopterygian.

B.1.2.1.2. Superorder 2/ Chondrosteans

B.1.2.1.3. Superorder 3/ Brachyopterygian

They are currently represented by two genera found in tropical and equatorial freshwater habitats: Polypters and the reedfish: *Erpetoichthys calabaricus.*

B.1.2.1.4. Superorder 4/ Holosteans

Currently, they are represented by only two freshwater genera:

Lepisosteus and *Amia calva*.

B.1.2.1.5. Superorder 5/ Teleosteans

They are divided into around thirty orders **(Figure 127).**

Examples: Anguilliformes (eels and moray eels); Clupeiformes (anchovies, herrings, sardines); Salmoniformes (pike, trout and salmon); Cypriniformes (carp, goldfish); the Characiformes (piranhas, 'neon' tetras found in aquariums); the Siluriformes (catfish); the Gadiformes (cod); the Lophiiformes. The Perciformes, comprising the families of groupers, butterflyfish, wrasse, parrotfish, blennies, surgeonfish, gobies, etc…

B.1.2.3. Subclass 3 / The Sarcopterygia

There are only 6 species belonging to 3 genera **(Figure 127)**:

Neoceratodus in Australia, which has only one lung.

Lepidosiren in the Amazon basin in South America.

Protopterus in intertropical Africa.

The Actinistia

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Group B /Gnathostomes/ Gnathostomata
Superclass 1. Pisces

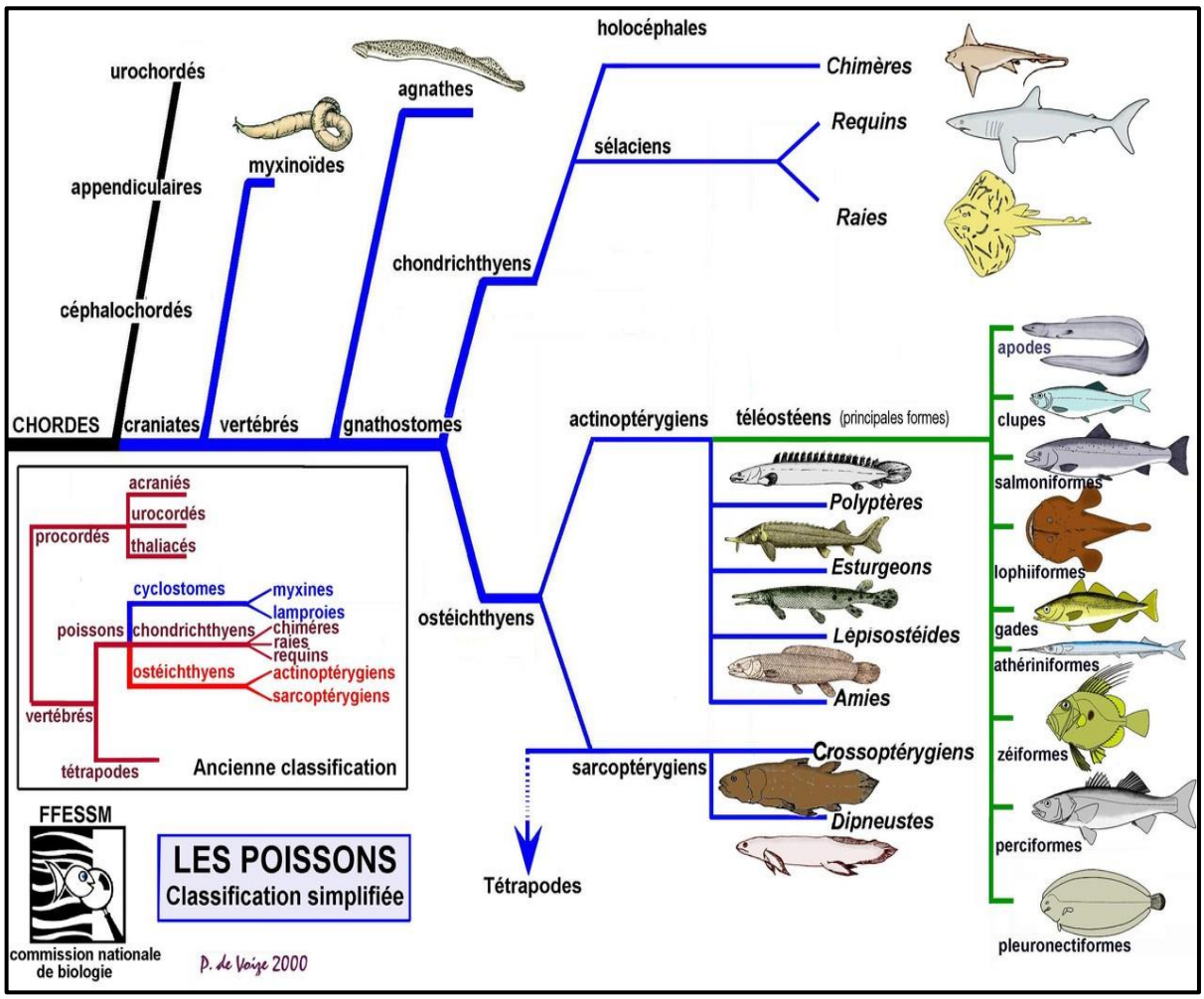


Figure 127 : Fish family tree.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 1. Amphibia

B.2. Superclass 2. Tetrapoda

(Gr., tetra = four; podos = foot).

Land vertebrates with two pairs of pentadactyle limbs, comified skin with lungs.

Tetrapoda are divided into Amniota and Anamniota based on the presence and absence of the amniotic membrane respectively

Anamniotes => Cl 1/ Amphibia

Amniotes => Cl 2/ Reptilia, Cl 3/ Aves, Cl 4/ Mammalia

B.2.1. Class 1. Amphibia

General characteristics of Amphibia

✓ The amphibian class is the smallest of the vertebrate classes and includes about 4,000 species.

✓ Amphibian means “double life” because they live in water and on land.

✓ **Habitat:** Amphibians can live in aquatic as well as terrestrial habitats. They live in fresh water and moist soil. **(Figures 128 and 129).**

- ❖ **Adult:** live on land near water.
- ❖ **Larva:** live in water.

✓ **Skeleton:** Mostly bony, with varying numbers of vertebrae; ribs present in some, absent or fused to vertebrae in others.

✓ **Circulatory system:**

- ❖ **Adult:** 3 chambered heart, closed-double loop.
- ❖ **Larva:** 2 chambered heart.

✓ **Respiratory system:**

- ❖ **Adult:** through lungs, skin, & lining of the mouth.
- ❖ **Larva:** through skin and gills.

✓ **Nervous system:**

✓ Brain; eyes w/ nictitating membrane. Ten pairs of cranial nerves

✓ tympanic membrane (like a drum) for hearing; lateral lines.

✓ Eyes have eyelids.

✓ A tympanum represents the ear.

✓ **Digestive system:** Complete digestive system (mouth --> anus).

✓ **Excretory system:** Kidneys filter wastes from blood, urine travels through ureters to urinary bladder and out through cloaca.

- **Adult:** carnivore.
- **Larva:** herbivore or filter feeder.

✓ **Body Temperature**: Ectothermic (cold blooded, find heat from an outside source like the sun).

✓ Body forms vary greatly from an elongated trunk with distinct head, neck, and tail to a compact, depressed body with fused head and trunk and no intervening neck.

✓ Body is divisible into head and trunk. Tail may be present in some **(Figures 128 and 129).**

✓ Body with fused head and trunk and no intervening neck.

✓ Limbs usually four (tetrapod) or two pairs of limbs, although some are legless; forelimbs of some much smaller than hindlimbs, in others all limbs small and inadequate; webbed feet often present; no true nails or claws; forelimb usually with four digits but sometimes five and sometimes fewer **(Figures 128 and 129).**

Classification of Amphibians

B.2.1.1. order 1/ Anura Frogs and toads

- ✓ They lack tails in adult **(Figure 128).**
- ✓ have 4 legs or limbs; Hindlimbs larger, stout, highly muscular adopted for leaping, jumping and swimming.
- ✓ well-developed ears for hearing, sticky tongues, and vocal cords for calling; Eye lids well developed.

Example: *Alytes, Xenopus, Hyla*, etc

- **Pipidae =>** *Pipa americana*.
- **Bufonidae =>** *Bufo vulgaris* ; *Bufo viridis*.
- **R anidae =>** *Rana temporaria*.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 1. Amphibia

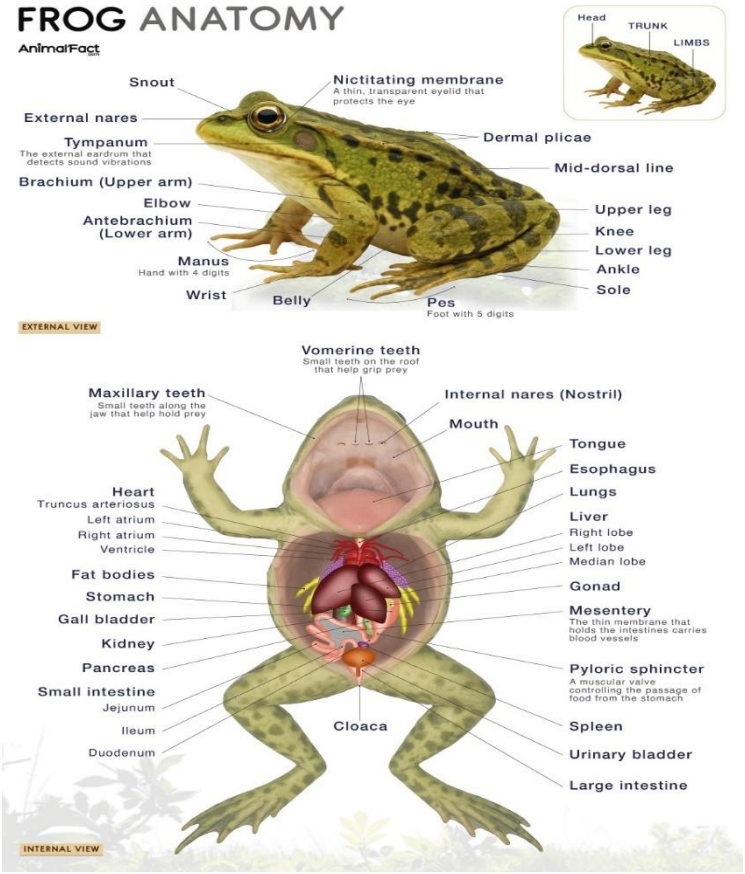


Figure 128 : Frog anatomy

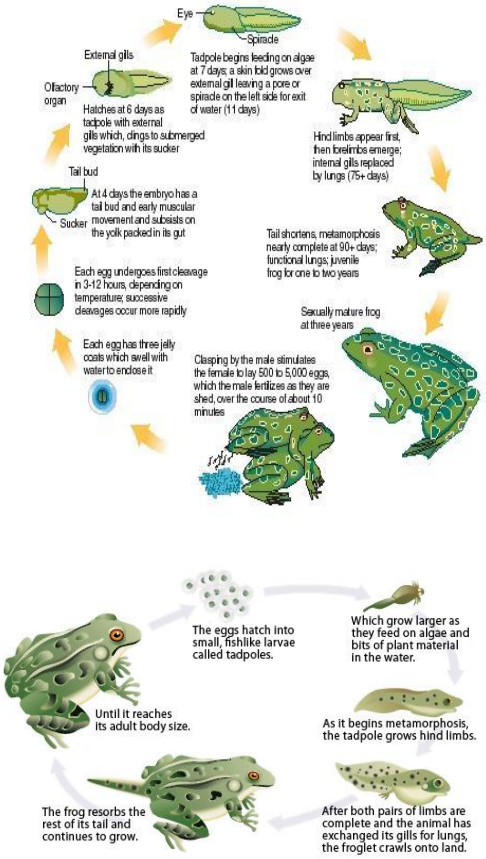


Figure 129 : Frog Life Cycle and Metamorphosis

B.2.1.2. Orde 2/ Urodela / or Caudata: Salamanders

- ✓ Lizard-like amphibians with distinct tail **(Figure 130).**
- ✓ 2 pairs of equal limbs.
- ✓ Teeth present in both jaws.
- ✓ Body with distinct head, trunk & tail.
- ✓ live under stones or logs in damp woods

Example: *Ambystoma*

Salamandridae => *Salamandra* ; *Tritons*

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 1. Amphibia

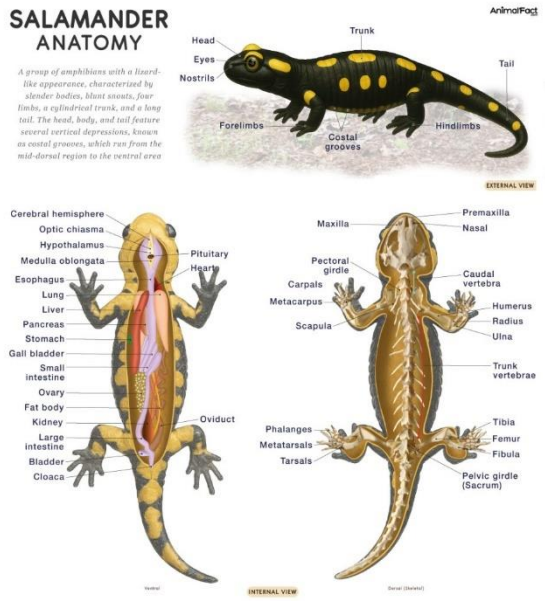


Figure 130 : *Salamandra* anatomy

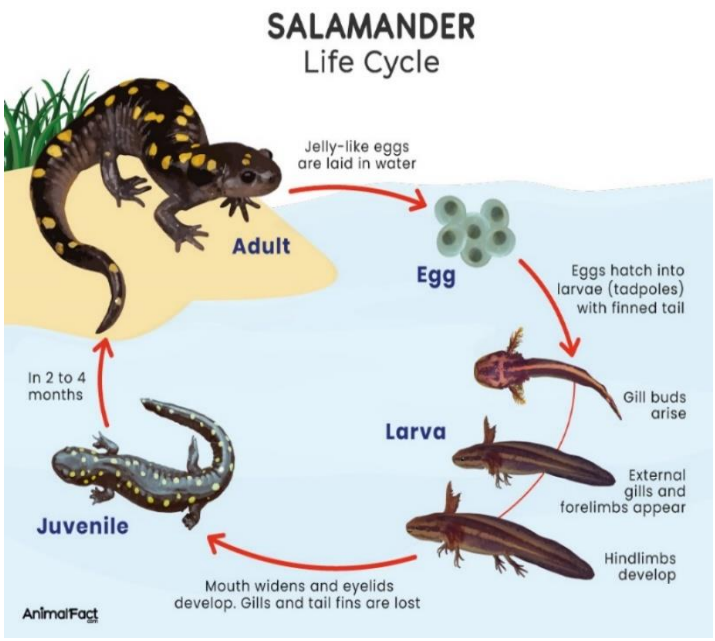


Figure 131 : *Salamandra* Life Cycle and Metamorphosis

B.2.1.3. Order 3/ Apoda Caecilians/ Gymnophiona

- ✓ Shaped like worms or snakes, they have no legs. They live in tropical areas.

Example: Order /Gymnophiona => Fam/ Indotyphlidae => *Hypogeophis*.

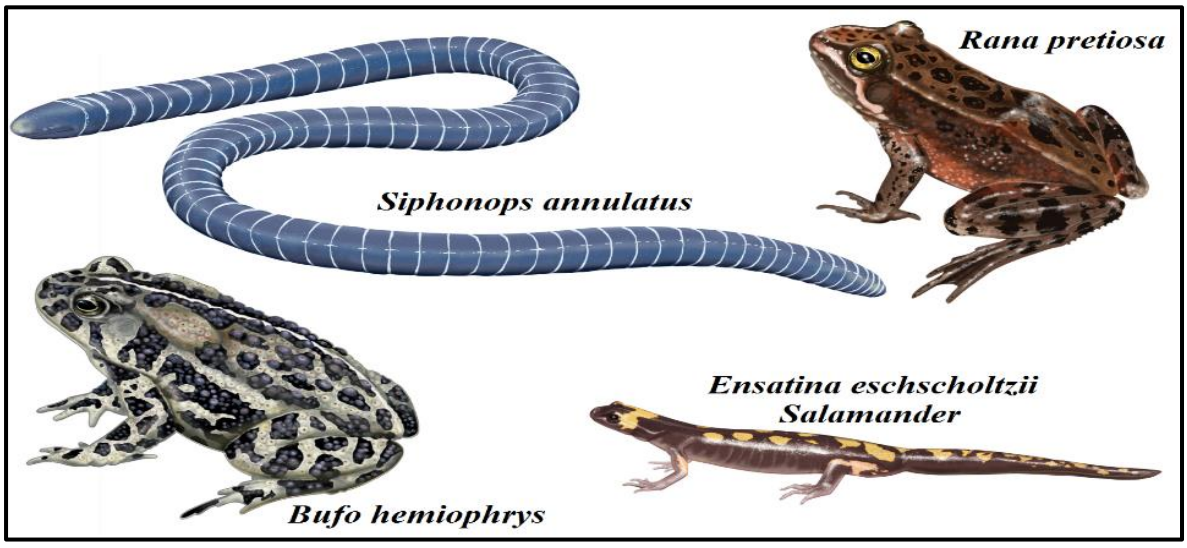


Figure 132 : The orders of amphibians.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 2. Reptilia

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 2. Reptilia

B.2.2. Class 2. / Reptiles / Reptilia

Latin: Reptare = To creep = Creeping Vertebrates.

The animals of this class are often referred to "creeping vertebrates" due to their creeping or crawling mode of locomotion.

General characteristics

- ✓ They are mostly terrestrial, creeping animals.
- ✓ Poikilotherms Ectothermic; many thermoregulate behaviorally.
- ✓ Body divided into head, neck, trunk and tail **(Figure 133).**
- ✓ Body varied in shape, compact in some, elongated in others.
- ✓ Body covered with an exoskeleton of horny epidermal scales or scutes with the addition sometimes of bony dermal plates; Skin is dry, cornified and without glands.
- ✓ They have thick, dry skin that protected them from water loss.
- ✓ Limbs – 2 pairs, usually with five toes with claws, adapted for climbing, running or paddling; limbs absent in snakes and some lizards **(Figure 133).**

Skeletal System: Skeleton well ossified; ribs with sternum except in snakes, forming a complete thoracic basket; skull with single occipital condyle.

Respiratory System: Respiration by lungs.

Circulatory system: Heart is usually three-chambered, but four-chambered in crocodiles; usually one pair of aortic arches; systemic and pulmonary circuits functionally separated.

Nervous system with primitive brain, spinal cord dominant. There are 12 pairs of cranial nerves.

Senses.

Vision is the main sense in most reptiles.

Some reptiles have tympanic membranes and others detect vibrations through their jaw bones.

In snakes, Jacobson's organs in the mouth are used to sense odors.

Excretory Systems: Metanephric kidney; uric acid is the main nitrogenous waste.

Exhibit moulting (snakes and lizards).

Reproductive System: Reproduction – Sexual, sexes separate, internal fertilisation and external, hemipenis as copulatory organ.

Direct development**,** no larval stages.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 2. Reptilia

Eggs macrolecithal and covered with calcareous or leathery shells. Extra embryonic membranes, amnion, chorion, yolk sac and allantois are present during embryonic life.

✓ Snakes and lizards shed their scales as skin cast (molting).

Generally, carnivores or insectivores, except the tortoise which feeds on vegetation.

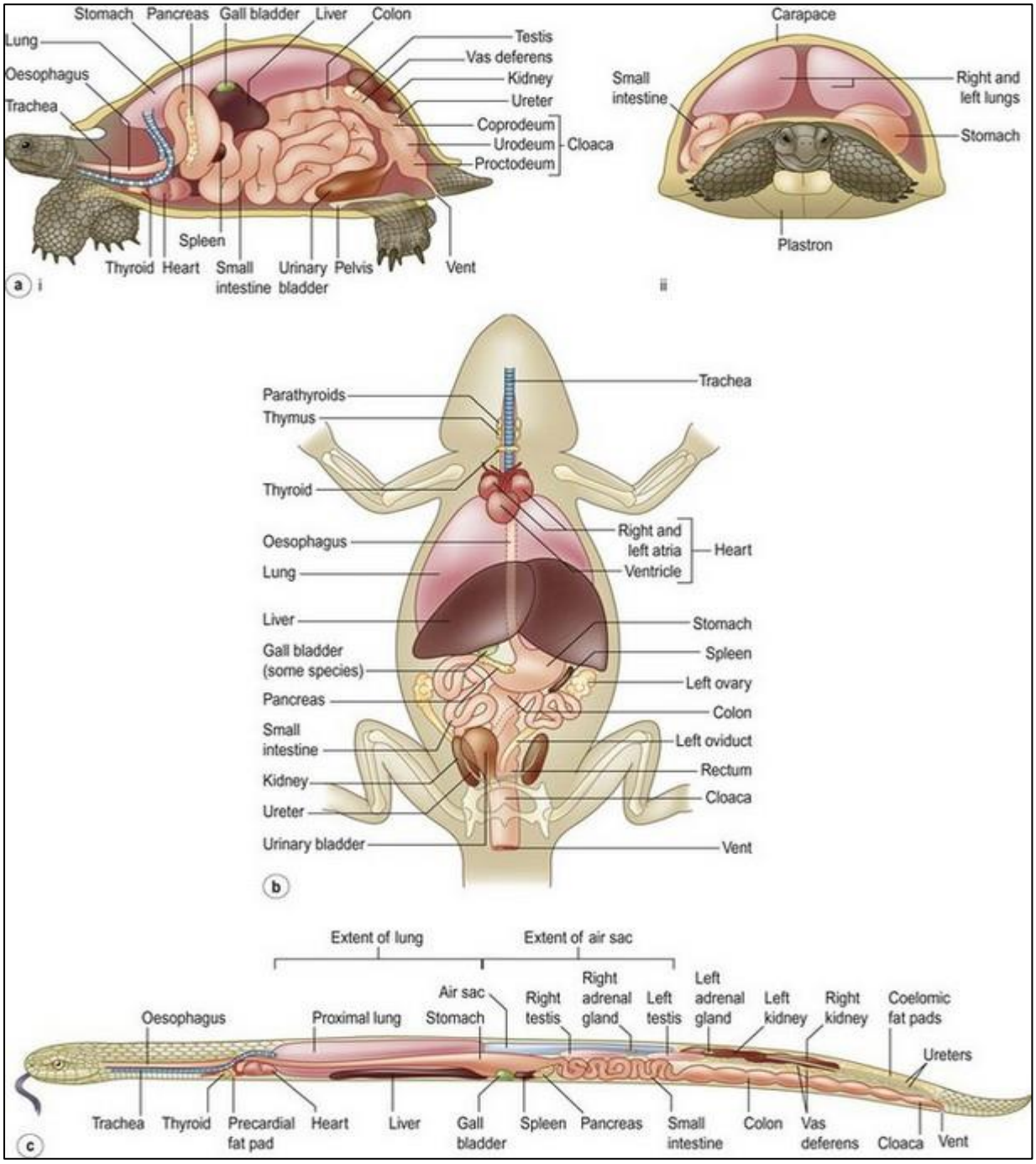


Figure 133: Basic internal anatomy for (a) chelonia, (b) lizards, (c) snakes.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 2. Reptilia

Classification of Reptilia

Chelonia, Rhynchocéphales, Squamat, Crocodilia **(Figure 134).**

B.2.2.1. Ordre 1 / Chelonia/ Testudines: Turtles and Tortoises.

- Tortoises and turtles do not have teeth but possess horny beaks.
- Tortoises are usually herbivorous while sea and fresh water turtles are omnivorous.
- Body is covered with a shell consisting of two parts– the dorsal carapace and the ventral plastron, which are connected by bridges between front and hind legs.
- Turtles are adapted to various habitats, including both aquatic and terrestrial environments.
- They have a unique bony or cartilaginous shell that provides protection.
- The ribs and backbone are fused with the carapace.

Example: *Testudo graeca; Chelonia myda.s*

B.2.2.2. Ordre 2 / Rhynchocephalia /Sphenodontia

Example: *Sphenodon.*

B.2.2.3. Ordre 3 / Squamates/ Squamates / Squamata

which are creepers and inhabit a variety of habitats.

Some characteristics that distinguish snakes from lizards are:

- ✓ Snakes are carnivorous but lizards eat a variety of foods including plants and insects, elongated body.
- ✓ Snakes do not have eyelids but lizards have.
- ✓ Snakes usually have one row of scales on the belly; lizards have many.
- ✓ Snakes do not have legs or limbs and ribs are absent. ; most lizards have legs (short limbs).
- ✓ Snakes have jaw bones that disarticulate allowing them to swallow large objects. Lizard jaw bones do not disarticulate.

Example: *Chamaeleo chamaeleon* (Tree lizard), Calotes (Garden lizard), *Hemidactylus* (Wall lizard), *Cerastes cerastes*, Poisonous snakes *Naja* (Cobra), *Vipera* (Viper), *colubra*.

The order includes Sub-order Sauriens (Lizards) and Sub-order Ophidiens (Snakes).

B.2.2.3.1. Sub-order 1/ Sauriens (Lizards) / Lacertilia

Exemples : *Chamaeleo vulgaris*.

B.2.2.3.2. Sub-order 2/ Ophidiens (Snakes)

Fam1 / Boidae => Exemples : *Boa constrictor.*

Fam2 / Colubridae => Exemples : *Natrix natrix.*

Fam3 / Viperidae / Vipères => Exemples : *Naja naja.*

B.2.2.4. Order 4 / Crocodilia

This order includes alligators, caimans, crocodiles and gharials that are found in and near water in warmer areas of the world. Known for their ambush hunting behavior. They eat fish, birds, turtles, and mammals. Members of the crocodile group have legs and feet designed for walking on land and a strong flattened tail used for swimming. Powerful build, strong jaws. The three groups are distinguished from one another by the shape of their heads. Alligators have a broad, rounded snout; while the crocodiles have a triangular head with a more pointed snout and gharials have a very long and narrow snout.

Fam1 / Crocodylidae

=> *Crocodylus niloticus*.

Fam2 / Alligatoridae

=> *Alligator mississippiensis*.

Fam3 / Gavialidae

=> *Gavialis gangeticus*.

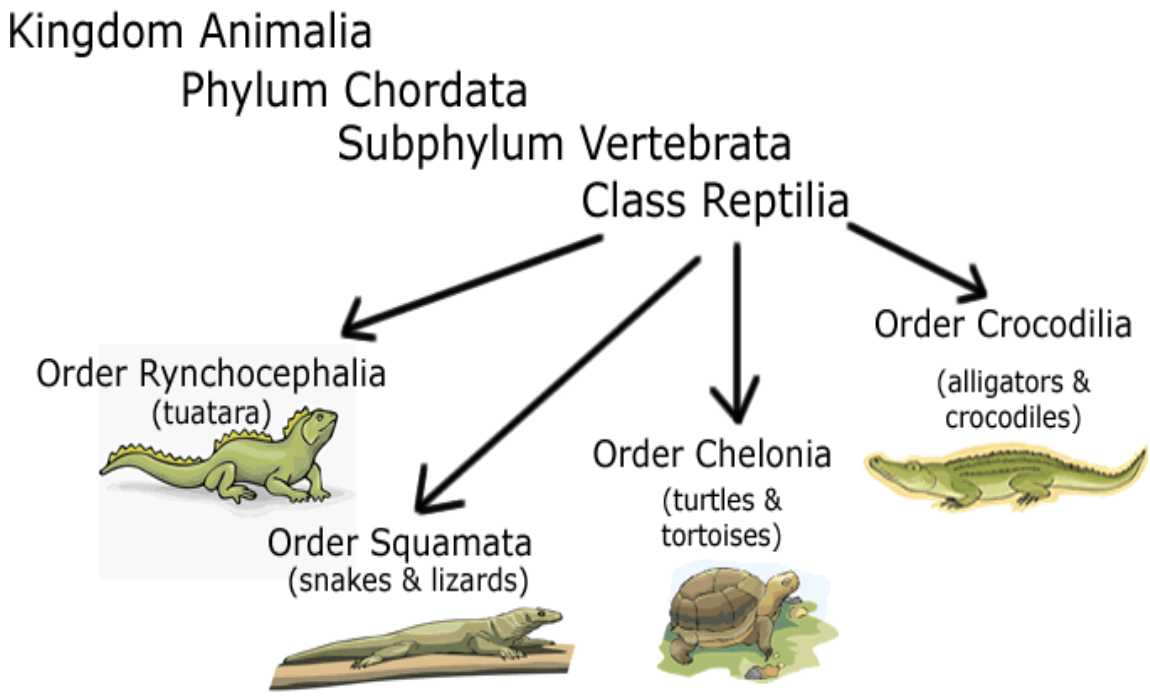


Figure 134 : Classification of Class Reptilia.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 3. Aves

B.3.Classe 3/ Aves

Greek: Avis = Birds.

In **Latin**, "avis" means bird.

The characteristic features of Aves (birds) are

✓ Presence of feathers **(Figure 135).**

⇒ Feathers fall into following broad categories based on their structure and location on the bird's body:

- Vaned feathers (Contour feathers, Wing feathers, Tail feathers), Semiplume, Filoplume, Down, Bristle.

✓ Most of them can fly except flightless birds (e.g., Ostrich).

✓ They are warm-blooded (homoiothermous) animals, i.e., they are able to maintain a constant body temperature.

✓ Upper and lower jaws are modified into beak. They lack teeth.

✓ **Body and limbs (Figure 135).**

- **Body** – streamlined, divisible into head, neck, trunk and tail
- Skin –Skin is dry without glands except the oil gland at the base of the tail.
- **Limbs** – 2 pairs, forelimbs and hindlimbs.
- **Hindlimbs** have scales and are modified for walking, swimming or clasping the tree branches. Foot with four toes (two or three toes in some).
- **Forelimbs** modified into wings, there are four general wing shapes that are common in birds : Passive soaring, active soaring, elliptical wings, and high-speed wings.

✓ **Skeleton System :** Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (pneumatic). ribs with strengthening processes; tail not elongate; sternum well developed with keel or reduced with no keel.

✓ **Circulatory system:** Heart is completely four- chambered.

✓ **Nervous system:** The peripheral nervous system consists of 12 pairs of cranial nerves and 38 pairs of spinal nerves radiating out to the body along the spinal cord.

✓ Sharp eyesight, but poor sense of smell.

✓ **Respiratory System**: Respiration by slightly expansible lungs, with thin air sacs among the visceral organs and skeleton; syrinx (voice box) near junction of trachea and bronchi.

✓ **Digestive System**: Digestive tract of birds has additional chambers, the crop and gizzard. Crop stores and softens the food and gizzard helps in crushing and churning the food.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 3. Aves

✓ **Urinogenital system :** Excretory system of metanephric kidney ; ureters open into cloaca ; no bladder ; semisolid urine; uric acid main nitrogenous waste

✓ **Reproductive System**: Sexes separate; Fertilization is internal.

✓ They are oviparous and development is direct.

✓ Lay amniotic, cleidoic egg.

✓ Many of them show sexual dimorphism.

They show courtship, nest making, migration, parental care and territorial behaviour.

✓ **Diversity :** Class Aves has about 9000 species.

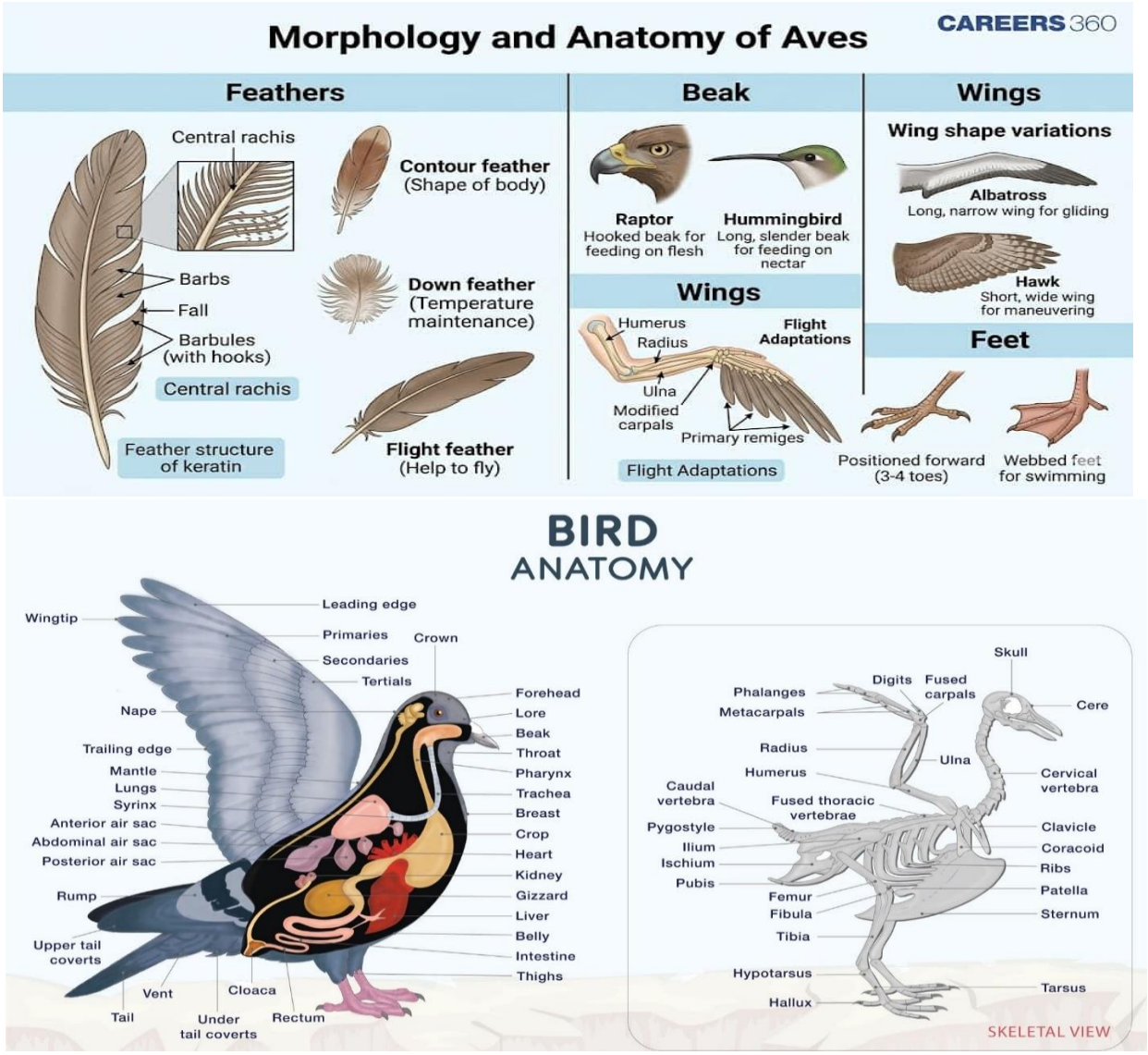


Figure 135 : Morphology and Anatomy of Aves.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 3. Aves

Cassification of Birds

The class Aves is divided into two subclasses: Paleognathae and Neognathae.

✓ These subclasses are based on differences in the structure of the palate and the keel (Carina) of the sternum (breastbone).

✓ **Subclass Paleognathae:** Includes flightless birds. The name "Paleognathae" means "old jaws," referring to the relatively simple structure of their jaw bones. They do not have a keel.

Ex: ostriches, emus, kiwis, rheas, and cassowaries.

✓ **Subclass Neognathae:** Includes the vast majority of bird species. The name "Neognathae" means "new jaws," reflecting the more advanced structure of their jaw bones. Neognath birds have a keeled sternum, which provides an anchor for flight muscles.

B.3.1. Subclass Paleognathae

B.3.2. Subclass Neognathae: There are 25 orders: **(Figures 136 and Table 5).**

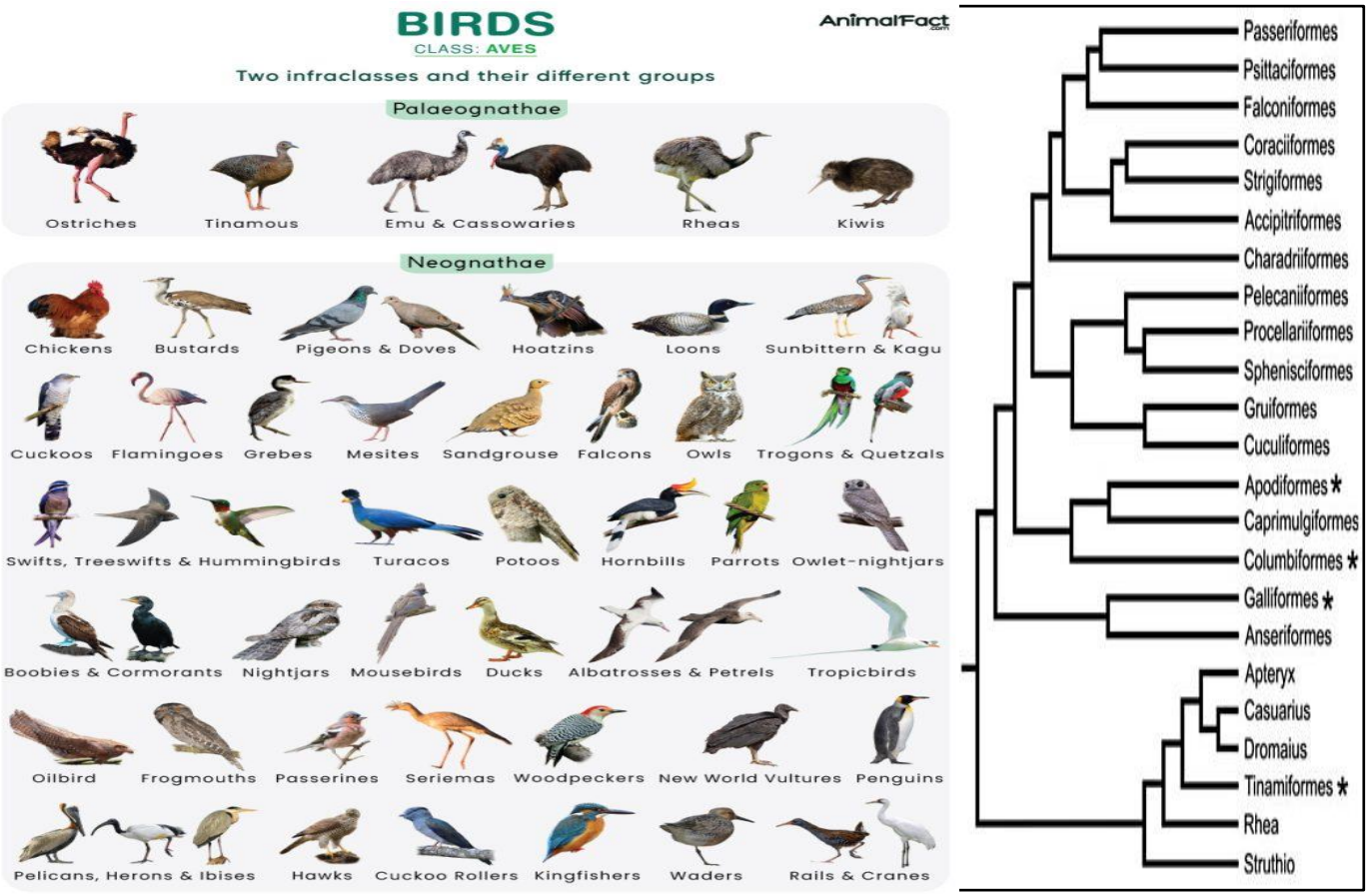


Figure 136 : Classification and orders of birds.

Table 5 : Main characteristic of birds order .

Order	Approximate Number of Living Species	Main Characteristics	Examples
Passeriformes	5,276	Songbirds; perching feet; well-developed vocal organs; dependent young; largest bird order, containing 60 percent of all bird species	Sparrows, robins, warblers, crows, starlings, mockingbirds,
Apodiformes	428	Small bodies, short legs, rapid wing beat; hummingbirds are the smallest birds	Hummingbirds, swifts
Piciformes	383	Sharp, chisel-like bills for pounding through wood in search of insects; grasping feet	Woodpeckers, toucans, honeyguides
Psittaciformes	340	Well-developed vocal organs; large powerful bills for crushing seeds	Parrots, cockatoos
Charadriiformes	331	Shorebirds; typically with long, slender, probing bills and long, stiltlike legs	Gulls, terns, plovers, auks, sandpipers
Columbiformes	303	Stout bodies; perching feet	Pigeons, doves
Falconiformes	288	Birds of prey; day-active carnivores; sharp pointed beaks for tearing flesh; keen vision; strong fliers	Eagles, hawks, falcons, vultures
Galliformes	268	Rounded bodies; often limited flying ability	Chickens, quail, grouse, pheasants

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 4. Mammalia

B.4. Classe 4/ Mammalia

✓ They are found in a variety of habitats polar ice caps, deserts, mountains, forests, grasslands and dark caves. Some of them have adapted to fly or live in water.

✓ They are homoiothermous.

✓ The most unique mammalian characteristic is the presence of milk producing glands (mammary glands) by which the young ones are nourished.

✓ The skin of mammals is unique in possessing hair with oil glands (sebaceous glands) and sweat glands (sudoriferous glands).

✓ **Skeleton System :** Endoskeleton-bony ; Skull-dicondylic **(Figure 137).**

✓ The diaphragm is a muscle that separates the thoracic cavity from the abdominal cavity.

✓ The mammals respire through lungs.

✓ They have two pairs of limbs, adapted for walking, running, climbing, burrowing, swimming or flying **(Figure 137).**

Circulatory system: Heart is four- chambered.

Nervous system: Brain has large cerebrum and cerebellum, 12 pair of cranial nerves.

Respiratory System: The mammals respire through lungs.

Digestive System; Digestion – Starts in the buccal cavity itself, Alimentary canal opens outside by anus.

✓ Different types of teeth are present in the jaw; Thecodont, Diphyodont, Heterodont.

Excretory Systems: Excretion – By kidneys, Ureotelic.

Reproductive System: Sexes-separate, Fertilisation – Internal, Viviparous (exceptions monotremes which are egg laying), Development – direct. An extended gestation period uterine development is common in most placental mammals.

✓ Parental care well developed.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 4. Mammalia

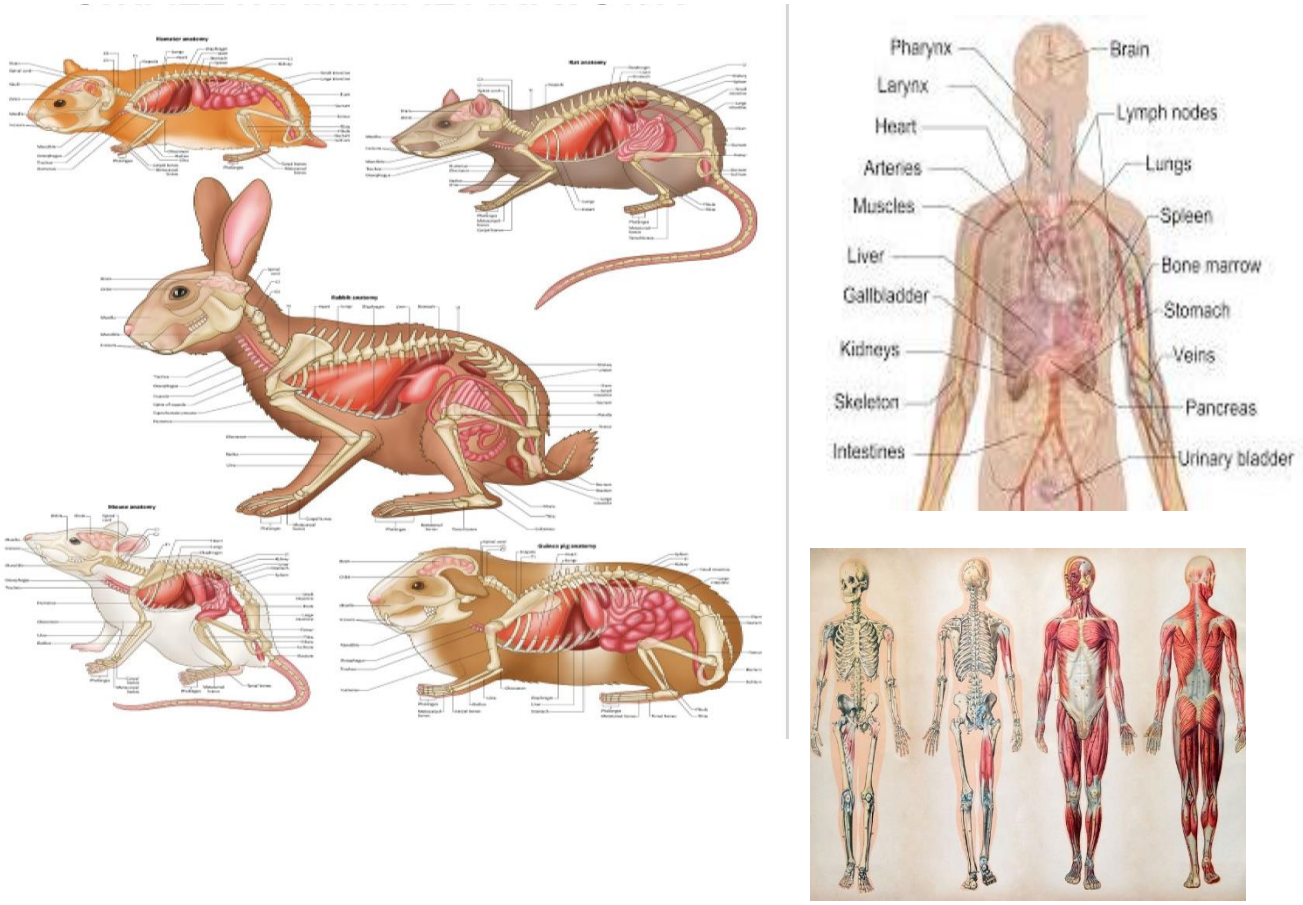
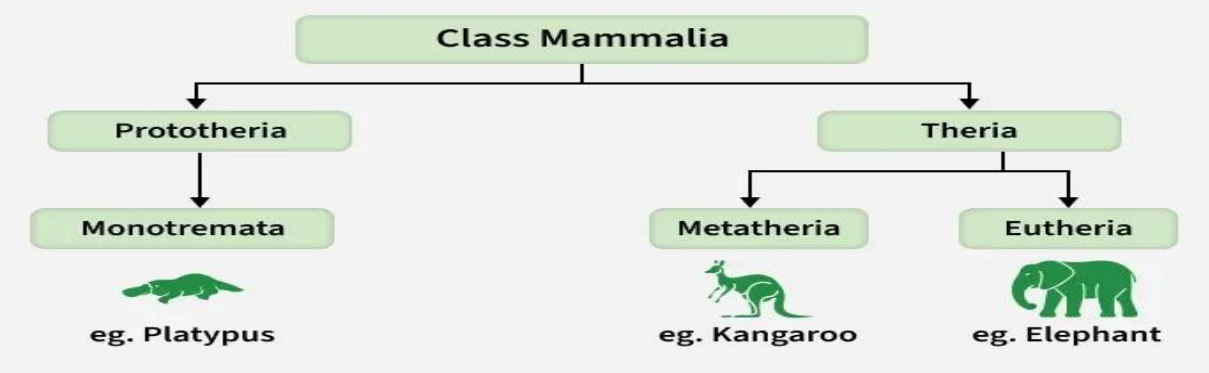


Figure 137 : Mammalian anatomy.

Classification of Mammals

Mammalia has the largest class in the animal kingdom. Based on their reproduction, they are classified into three subclasses:



B.4.1. Sub Class 1 / Prototheria (Monotremes)

- ✓ Primitive, reptile-like
- ✓ Egg-laying mammals
- ✓ They are found in specific regions of Australia and New Guinea
- ✓ Have mammary glands
- ✓ They have a cloaca, which is a single opening for excretion and reproduction, similar to reptiles and birds

Example: *Duck-billed Platypus*, *Echidna* (spiny ant eater)

B.4.2. Sub-class 2 / Metatheria (Marsupials)- mammals with pouches

- ✓ Mother has marsupium (brood pouch) on her belly
- ✓ Pouch Development: Marsupials have a short gestation period, and the underdeveloped young, are born in an immature state. They crawl into the mother's pouch, where they continue their development by attaching to a teat for further nourishment.
- ✓ Short-lived placenta that provides limited transfer of nutrients during gestation. The majority of nutrient exchange occurs after birth, during the pouch phase.
- ✓ Most live in Australia, except Possums live in Australia, New Zealand, and North America
- ✓ **Example:** Macropus (Kangaroo), Opossums, koalas and Tasmanian devils.

B.4.3. Sub-class 3 / Eutheria (Placentals)

✓ Eutherians, also known as placental mammals, are the largest and most diverse group of mammals within the subclass eutheria. 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 mammals **(Figure 138)**:

B.4.3.1. Orders of Eutheria (Placentals)

Rodentia: Rodents are characterized by continuously growing incisors that they must gnaw to keep from overgrowing. Examples include mice, rats, squirrels, and beavers.

Chiroptera: Bats are the only mammals capable of sustained flight. They are characterized by their elongated fingers and thin membranes of skin that form wings.

Carnivora: Carnivores are adapted for hunting and eating other animals. This order includes cats, dogs, bears, and seals.

Cetacea: Cetaceans are marine mammals, including whales, dolphins, and porpoises.

Artiodactyla: Even-toed ungulates have an even number of toes on each foot and include animals like deer, cattle, pigs, and giraffes.

Perissodactyla: Odd-toed ungulates have an odd number of toes on each foot. include horses, zebras, and rhinoceroses.

Proboscidea: Elephants are the only living members of this order. They are known for their long trunks and large tusks.

Lagomorpha: Lagomorphs include rabbits, hares, and pikas. They are characterized by their continuously growing incisors and hind limb adaptations for hopping.

Insectivora: Small insectivorous mammals, such as shrews, Hedghogs and moles, are part of this order.

Primates: Primates, including, monkeys, and apes, are characterized by advanced cognitive abilities, forward-facing eyes, and grasping hands.

III-7- Phylum: Cordata
III-7-3- Subphylum Vertebrata (Craniata)
Gnathostomes/ Gnathostomata
Superclass 2. Tetrapoda
Class 4. Mammalia

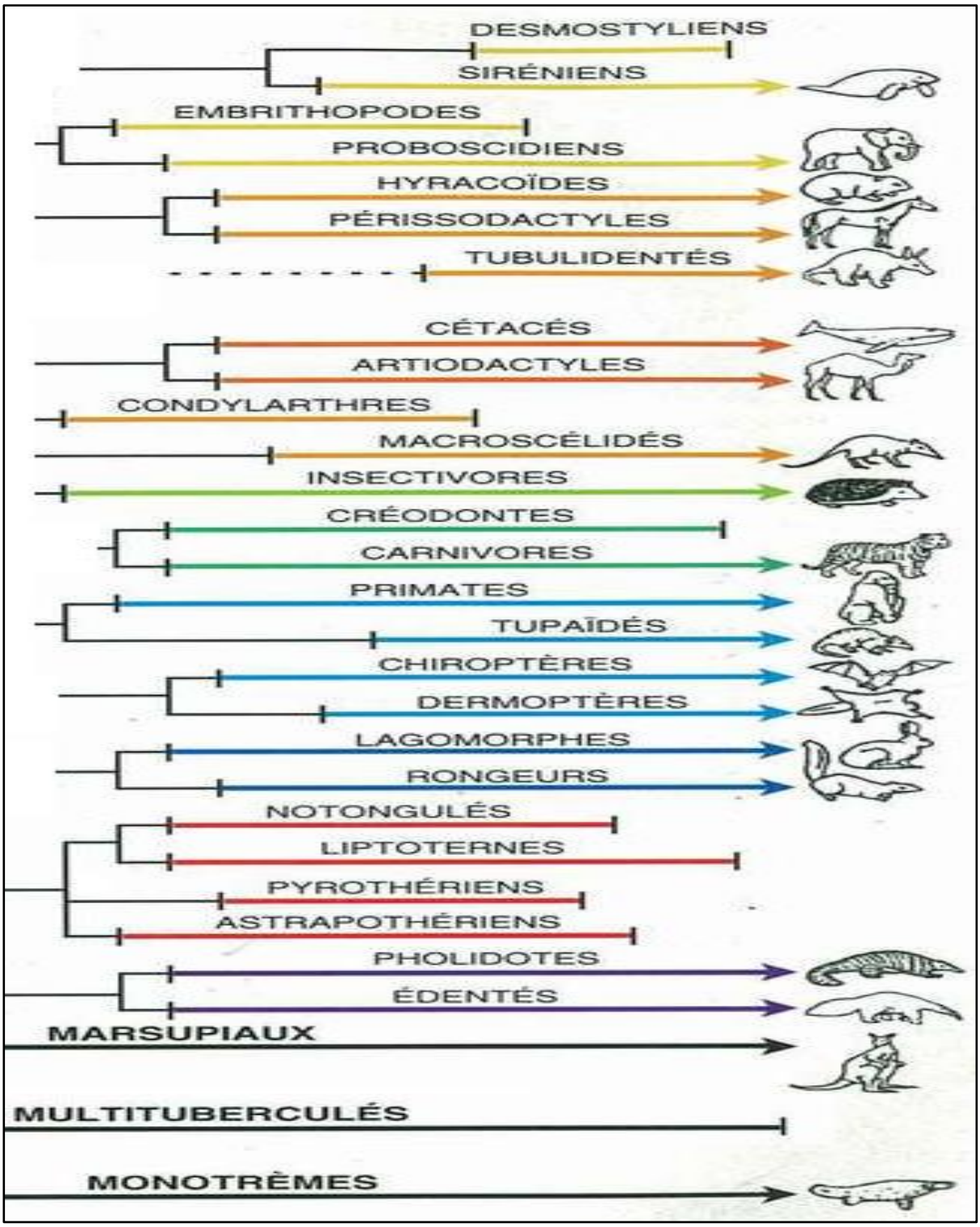
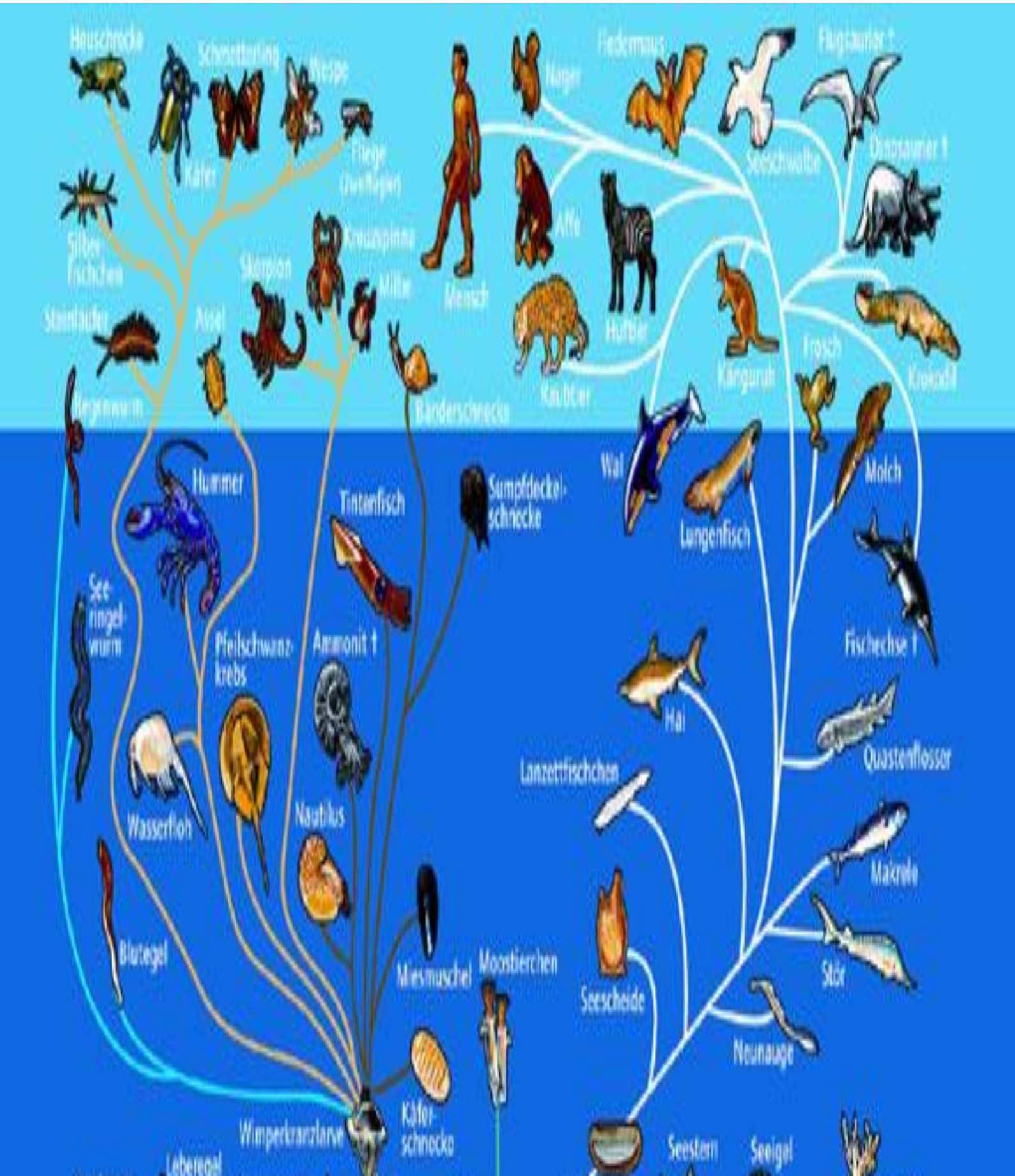


Figure 138 : Classification of Mammals.

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Heuschrecke
Schmetterling
Wespe
Käfer
Fliege
Zweiflügler
Silberfischchen
Skorpion
Spinne
Milbe
Steinläufer
Assel
Regenwurm
Hummer
Tintenfisch
Sumpfdeckelschnecke
Bänderschnecke
Seeringelwurm
Pfeilschwanzkrebs
Ammonit †
Wasserfloh
Nautilus
Blutegel
Miesmuschel
Moostierchen
Wimperkranzlarve
Käferschnecke
Leberegel
Mensch
Nager
Affe
Huftier
Kaubär
Fledermaus
Flugsaurier †
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Frosch
Krokodil
Wal
Lungenfisch
Molch
Fischechse †
Hai
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