

ZOOLOGY COURSE

2nd year Common Core Biological Sciences

Semestre: 3ème Semestre

UE : Unité d'Enseignement Fondamentale 1

Matière: Zoologie

Objectifs d'enseignement :

Connaître les principaux groupes d'organismes vivants aux plans : Architecture générale, Caractéristiques (Systématique, Morphologie, Anatomie, reproduction, Ecologie), contraintes, adaptations, et évolution. Une importance particulière sera accordée à l'actualisation de la classification et aux groupes zoologiques ayant un intérêt agricole, médical, vétérinaire, halieutique ou environnemental.

L'étudiant doit avoir une idée sur les différentes classes du règne animal.

Contenu de la matière

1. Présentation du règne animal

- 1.1. Bases de la classification
- 1.2. Nomenclature zoologique
- 1.3. Evolution et phylogénie
- 1.4. Importance numérique du règne Animal

2. Sous-règne des Protozoaires

- 2.1. Généralités sur les protozoaires.
- 2.2. Classification
 - 2.2.1. Embranchement Sarcomastigophora
 - 2.2.2. Embranchement Ciliophora
 - 2.2.3. Embranchement Apicomplexa
 - 2.2.4. Embranchement Cnidosporidies

3. Sous-règne des Métazoaires

- 3.1. Embranchement Spongiaires
- 3.2. Embranchement Cnidaires

- 3.3. Embranchement Cténaires
- 3.4. Embranchement Plathelminthes :
- 3.5. Embranchement Nématelminthes.
- 3.6. Embranchement Annélides
- 3.7. Embranchement Mollusques
- 3.8. Embranchement Arthropodes
- 3.9. Embranchement Echinodermes 3.10. Embranchement Chordés

Travaux pratiques

TP N°1 : Etude de quelques espèces types de Protozoaires : Trypanosoma rhodesiense, Leishmania major, Leishmania infantum, Trypanosoma gambiense, Entamoeba histolytica, Paramecium sp.

TP N°2 : Etude de quelques espèces types Plathelminthes : Moniezia expansa, Taenia hydatigena, Taenia pisiformis, Fasciola hepatica.

TP N°3 : Etude de quelques espèces types Annélides : Lumbricus terrestris, Hirudo officinalis.

TP N°4 : Etude de quelques espèces types d'Arthropodes : Crustacés (Crevette royale, Squille, morphologie et appendices biramés), Chélicérates (Scorpion), Insectes (Criquet, Abeille).

TP N°5 : Etude des pièces buccales des Insectes : Les différents appareils buccaux et adaptation aux régimes alimentaires, les pièces buccales du type broyeur (Orthoptères, Criquet).

TP N°6 : Etude de quelques espèces types d'Echinodermes : Echinides (Oursin), Astérides (Etoile de mer).

TP N°7 : Etude de quelques espèces types de Vertébrés : Poissons (Carpe), Oiseaux (Pigeon), Mammifères (Rat, Souris)

Projection de films

Préambule :

La zoologie est la branche de la biologie qui se consacre à l'étude des animaux. Elle englobe divers aspects de la vie animale, tels que l'anatomie, la physiologie, la génétique, l'écologie, l'évolution, ainsi que le comportement des animaux. Les zoologistes étudient non seulement les espèces animales modernes mais aussi les fossiles pour comprendre l'évolution des animaux au fil du temps. Ils peuvent se spécialiser dans un groupe d'animaux particulier, comme les insectes

(entomologie), les oiseaux (ornithologie), les mammifères (mammalogie) ou les reptiles et amphibiens (herpétologie). La zoologie joue également un rôle clé dans la conservation de la biodiversité et la gestion des écosystèmes, en étudiant les interactions entre les animaux et leur environnement.

Semester: 3rd Semester

UE: Core Teaching Unit 1

Subject: Zoology

Teaching Objectives:

Understand the main groups of living organisms in terms of:

- General structure,
- Characteristics (taxonomy, morphology, anatomy, reproduction, ecology),
- Constraints, adaptations, and evolution.

A particular emphasis will be placed on updating classification and focusing on zoological groups with agricultural, medical, veterinary, fishery, or environmental significance.

Students should develop an understanding of the different classes of the animal kingdom.

Course Content:

1. Introduction to the Animal Kingdom

- 1.1. Foundations of Classification
- 1.2. Zoological Nomenclature
- 1.3. Evolution and Phylogeny
- 1.4. Numerical Importance of the Animal Kingdom

2. Subkingdom Protozoa

- 2.1. Overview of Protozoa
- 2.2. Classification
 - 2.2.1. Phylum Sarcomastigophora
 - 2.2.2. Phylum Ciliophora
 - 2.2.3. Phylum Apicomplexa
 - 2.2.4. Phylum Cnidosporidia

3. Subkingdom Metazoa

- 3.1. Phylum Porifera
- 3.2. Phylum Cnidaria
- 3.3. Phylum Ctenophora
- 3.4. Phylum Platyhelminthes
- 3.5. Phylum Nemathelminthes
- 3.6. Phylum Annelida
- 3.7. Phylum Mollusca
- 3.8. Phylum Arthropoda
- 3.9. Phylum Echinodermata
- 3.10. Phylum Chordata

Practical Work:

- **TP 1:** Study of Protozoa: *Trypanosoma rhodesiense*, *Leishmania major*, *Leishmania infantum*, *Trypanosoma gambiense*, *Entamoeba histolytica*, *Paramecium sp.*
- **TP 2:** Study of Platyhelminthes: *Moniezia expansa*, *Taenia hydatigena*, *Taenia pisiformis*, *Fasciola hepatica*
- **TP 3:** Study of Annelids: *Lumbricus terrestris*, *Hirudo officinalis*
- **TP 4:** Study of Arthropods: Crustaceans (royal shrimp, mantis shrimp, morphology, and biramous appendages), Chelicerates (scorpion), Insects (locust, bee)
- **TP 5:** Study of Insect Mouthparts: Different types of mouthparts and their adaptation to diet, with a focus on biting (Orthoptera, locust)
- **TP 6:** Study of Echinoderms: Echinoids (sea urchin), Asterooids (starfish)
- **TP 7:** Study of Vertebrates: Fish (carp), Birds (pigeon), Mammals (rat, mouse)

Preamble:

Zoology is a branch of biology that focuses on the study of animals. It covers various aspects of animal life, such as anatomy, physiology, genetics, ecology, evolution, and animal behavior. Zoologists study not only modern animal species but also fossils to understand the evolution of animals over time. They may specialize in particular groups of animals, such as insects (entomology), birds (ornithology), mammals (mammalogy), or reptiles and amphibians (herpetology). Zoology also

plays a key role in biodiversity conservation and ecosystem management by studying the interactions between animals and their environment.

Chapter 01: Introduction to the Animal Kingdom

Zoology (from Zoon = animal, Logos = study) is the science dedicated to studying the animal kingdom. It draws from various disciplines, such as anatomy, histology, physiology, embryology, paleontology, ecology, and genetics, to assign animals their place in the grand tree of life (classification).

The animal kingdom, or Animalia, encompasses all multicellular eukaryotic organisms that can move voluntarily, feed on organic matter, and respond to their environment. Animals differ from plants, fungi, and protists in several fundamental ways:

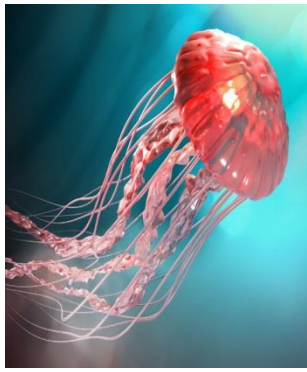
A. **Multicellularity:** Animals consist of multiple cells organized into tissues and organs.

B. **Heterotrophy:** Unlike plants, which produce their own food through photosynthesis, animals rely on other organisms for nutrition.

C. **Mobility:** Most animals have the ability to move at some point in their life cycle, whether to find food, escape predators, or reproduce.

D. **Sexual Reproduction:** Although some animals can reproduce asexually, sexual reproduction is more common, with a life cycle that often includes complex developmental stages.

The animal kingdom is incredibly diverse, with over a million known species, ranging from simple organisms like sponges and jellyfish to more complex ones like birds, fish, and mammals. It is divided into several phyla, including arthropods, mollusks, chordates (which include vertebrates), and cnidarians.



Jellyfish



Sponges



Mollusks

1. History of Zoology

The history of zoology dates back thousands of years and can be divided into several key periods that highlight its evolution as a scientific discipline:

A/ Ancient Period :

- **Prehistoric Era:** Early humans had a rudimentary knowledge of animal behavior and classification due to their need for hunting, gathering, and understanding nature. Evidence of animal studies and classification can be found in prehistoric cave paintings, which indicate a basic understanding of animal forms and behaviors.
- **Ancient Civilizations: Egyptians:** Ancient Egyptians depicted numerous animals in art and hieroglyphs and practiced animal mummification, which indicates a fascination with animals and their anatomy.
- **Greeks:** The foundation of systematic zoology began with the Greeks. Philosophers such as **Aristotle (384–322 BC)** are considered the "Father of Zoology." He wrote extensively about animals in his works like *Historia Animalium*, categorizing over 500 species based on their habitats, morphology, and behaviors.

B/ Medieval Period (5th–15th Century):

During the Middle Ages, zoology did not advance significantly due to the dominance of religious and mystical interpretations of nature. However, knowledge from ancient texts was preserved by scholars in the Islamic world and later translated back into Latin during the European Renaissance.

- **Islamic Scholars:** Notable scholars like **Al-Jahiz (776–868)**, who wrote *The Book of Animals*, and **Avicenna (Ibn Sina)** contributed to zoology by classifying animals and describing their anatomy and behavior.

C/ Renaissance and Early Modern Period (14th–18th Century):

The Renaissance brought a revival of interest in science and nature. The printing press facilitated the widespread dissemination of knowledge, and naturalists began to describe and classify animals more systematically.

- **Andreas Vesalius (1514–1564):** Known as the founder of modern anatomy, Vesalius' work provided a more accurate understanding of the internal structure of animals and humans.
- **Conrad Gessner (1516–1565):** His work, *Historiae Animalium*, is considered one of the first comprehensive compilations of animal descriptions, based on direct observation.
- **Carl Linnaeus (1707–1778):** Linnaeus revolutionized taxonomy by introducing the binomial nomenclature (genus and species) system still used today. His work, *Systema Naturae*, categorized thousands of species and laid the foundation for modern classification.

D/ 19th Century: Evolutionary and Comparative Zoology:

The 19th century saw significant advances in zoology, influenced by the development of evolutionary theory and comparative anatomy:

- **Jean-Baptiste Lamarck (1744–1829):** Proposed one of the first theories of evolution, suggesting that species could adapt to their environment over generations.
- **Charles Darwin (1809–1882):** Darwin's seminal work, *On the Origin of Species* (1859), introduced the theory of natural selection, explaining how species evolve over time through the survival and reproduction of the fittest individuals.
- **Gregor Mendel (1822–1884):** Mendel's experiments with pea plants laid the groundwork for genetics, providing an understanding of how traits are inherited in animals.

- **Louis Pasteur (1822–1895):** Pasteur's discoveries in microbiology and germ theory revolutionized the study of infectious diseases in animals and humans.

E/ 20th Century: Modern Zoology :

Modern zoology diversified into numerous sub-disciplines, such as genetics, ethology (study of animal behavior), ecology, and conservation biology. Important developments include:

1. **Genetics and Molecular Biology:** Advances in genetics, such as the discovery of DNA's structure by James Watson and Francis Crick in 1953, provided insights into the molecular basis of evolution and development.
2. **Ethology:** Pioneers like **Konrad Lorenz**, **Niko Tinbergen**, and **Karl von Frisch** advanced the understanding of animal behavior and communication, earning a Nobel Prize in 1973.
3. **Conservation Biology:** In response to growing concerns about biodiversity loss, zoologists began focusing on conservation and the protection of endangered species.

F/ 21st Century: Integration and Technological Advances :

With the rise of new technologies such as genetic engineering, satellite tracking, and computer modeling, zoology has entered an era of interdisciplinary integration:

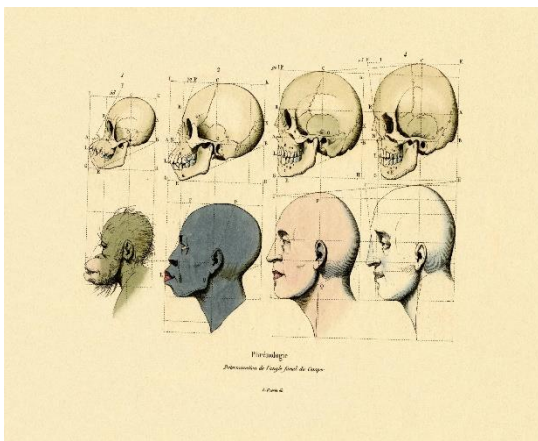
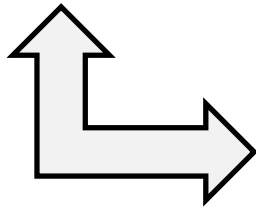
1. **Genomics and Biotechnology:** Genomic technologies allow zoologists to study the genetic basis of animal behavior, adaptation, and evolution.
2. **Behavioral Ecology:** The use of GPS tracking and digital modeling helps in studying animal migration, social structures, and habitat use.
3. **Conservation and Climate Change:** Zoologists are increasingly involved in assessing the impact of climate change on animal populations and developing strategies for habitat preservation and species conservation.

2. Foundations and bases of Animal Kingdom Classification:

The classification of the animal kingdom, also known as animal taxonomy, is based on several criteria. Below are the main levels of classification and the criteria used to organize animals into taxonomic groups:

- ✓ **Kingdom:** The broadest category. All animals belong to the kingdom Animalia.
- ✓ **Phylum:** Groups animals that share common morphological and embryological traits. For example, the Chordata phylum includes animals that possess a vertebral column or notochord at some point in their development.
- ✓ **Class:** Further groups animals within a phylum based on more specific characteristics. For example, Mammalia (mammals) in the phylum Chordata are distinguished by their ability to produce milk to nourish their offspring.
- ✓ **Order:** Groups classes based on specific features like diet or reproduction. For instance, the Carnivora order consists of animals that primarily feed on meat.
- ✓ **Family:** A more restricted group within an order, consisting of animals with closer morphological and behavioral similarities. For example, the family Felidae includes cats, lions, tigers, etc.
- ✓ **Genus:** A subgroup within a family where members share a recent common ancestor. For example, the genus Panthera includes large felines like lions and tigers.
- ✓ **Species:** The basic unit of classification. Members of a species can reproduce with each other and produce fertile offspring. For example, Homo sapiens refers to humans.

Humans Classification



Domain:	Eukaryota
Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Primates
Suborder:	Haplorhini
Infraorder:	Simiiformes
Family:	Hominidae
Subfamily:	Homininae
Tribe:	Hominini
Genus:	Homo
Species:	<i>H. sapiens</i>

Binomial name

Homo sapiens

[Linnaeus, 1758](#)

2.1. Classification Criteria:

- **Body Structure:** This includes the number of cells (unicellular or multicellular), presence or absence of a vertebral column, and body symmetry (radial, bilateral).
- **Embryonic Development:** How the embryo develops, including the presence of embryonic layers such as the endoderm, ectoderm, and mesoderm.
- **Mode of Nutrition:** Animals are heterotrophic (feeding on other organisms), and they can be carnivores, herbivores, or omnivores.
- **Reproductive Modes:** This includes whether animals reproduce sexually or asexually, and the type of fertilization (internal or external).
- **Habitat:** Animals can live in terrestrial, aquatic, or aerial environments, among others.

These criteria help group animals in a logical and scientific manner to better understand their evolution and relationships with each other.

3. Zoological nomenclature :

Zoological nomenclature is the system used for naming animals, which allows the classification and universal naming of animal species.

A **species** is the fundamental unit of biological classification. It is generally defined as a group of individuals capable of interbreeding and producing fertile offspring. However, the exact definition can vary depending on the field of study, especially in contexts such as evolutionary biology or taxonomy.

Other characteristics include: interbreeding capability, reproductive isolation, morphological and genetic similarities, and adaptation to a specific environment

Zoological nomenclature is governed by a set of rules formalized in the International Code of Zoological Nomenclature (ICZN). Here are the basic principles of zoological nomenclature:

- **Scientific Binomial**

Each animal species is named using a binomial system (two-part name) developed by Carl von Linné:

- **Genus name** (with a capital letter): designates the genus to which the species belongs.

- **Species name** (in lowercase): designates the specific species within the genus.

For example, for the human species: *Homo sapiens* (*Homo* = genus; *sapiens* = species).

- **Priority**

The principle of priority states that the first published scientific name for a species has precedence over others. If a species is rediscovered or renamed, the first correctly published name is retained.

- **Uniqueness**

Each species must have a unique name worldwide. There cannot be two different species with the same scientific name.

- **Latin or Latinization**

Scientific names are generally in Latin or "Latinized," even if the original language of the name is different.

- **Authors and Dates**

The name of the author who first described the species, along with the date of this description, is sometimes added after the scientific name. Example:

Panthera leo (Linnaeus, 1758).

- **Subgenera and Subspecies**

- **Subgenus:** It is sometimes placed in parentheses between the genus and species names to indicate an additional subdivision. Example: *Panthera (Leo) leo*.
- **Subspecies:** Some animals are divided into subspecies. Example: *Canis lupus lupus* (the European wolf) and *Canis lupus arctos* (the Arctic wolf).

- **Synonyms**

When multiple names are attributed to the same species, these are called synonyms. The valid name is the one assigned according to the rules of priority.

- **Homonyms**

If two species belonging to different groups (usually genera) receive the same species name, they are called homonyms. These names are generally corrected later to avoid confusion.

- **Types**

When a species is described for the first time, specimens called types are

preserved in collections for reference. This provides a reference model of the species for future studies.

Zoological nomenclature thus ensures that each animal species has a universally recognized name, facilitating communication and scientific research on a global scale

4. Evolution and Phylogeny

1.1. Evolution:

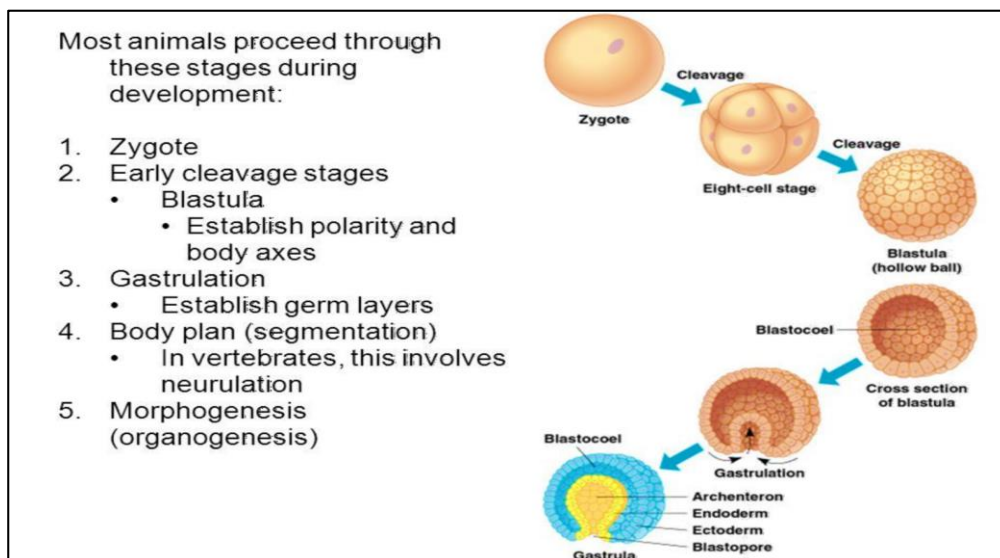
First Stage: Over geological time, different organizational types emerged in a hierarchical order, with the simplest forms appearing first (unicellular eukaryotes, known as protozoa). The evolution towards animal life occurred through the acquisition of heterotrophy, which is characterized by the organism's inability to produce its own food from inorganic sources.

- **Unicellular Eukaryotes (Protozoa):** This group includes both autotrophic (organisms that produce their own food) and heterotrophic protozoa.

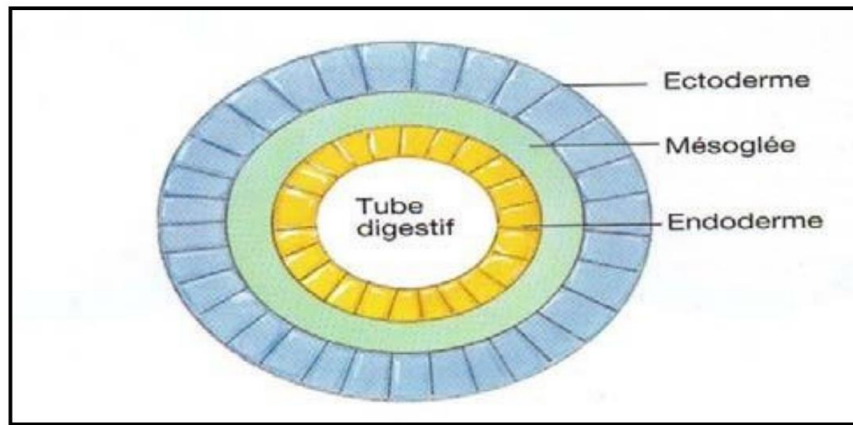
Second Stage: The emergence of increasingly complex forms (multicellular organisms, also known as metazoans). The fertilized egg first forms an aggregation of cells that need to be structured and organized into different stages: morula, blastula, and gastrula. The final stage (gastrula) results in the formation of embryonic layers, distinguishing two main groups:

- **Diploblastic or Didermic Metazoans:** Composed of two embryonic layers—ectoderm and endoderm—separated by the mesoglea. These animals are represented by three marine phyla: **Sponges, Cnidarians, and Ctenophores.**
- **Triploblastic or Tridermic Metazoans:** Characterized by the presence of a third embryonic layer, the mesoderm (situated between the ectoderm and endoderm). This third layer gives rise to skeletal tissue, connective tissue, rapidly contracting muscles, blood, excretory and reproductive organs, and contributes to the formation of a body cavity. The development of the mesoderm can lead to three forms of triploblastic animals:

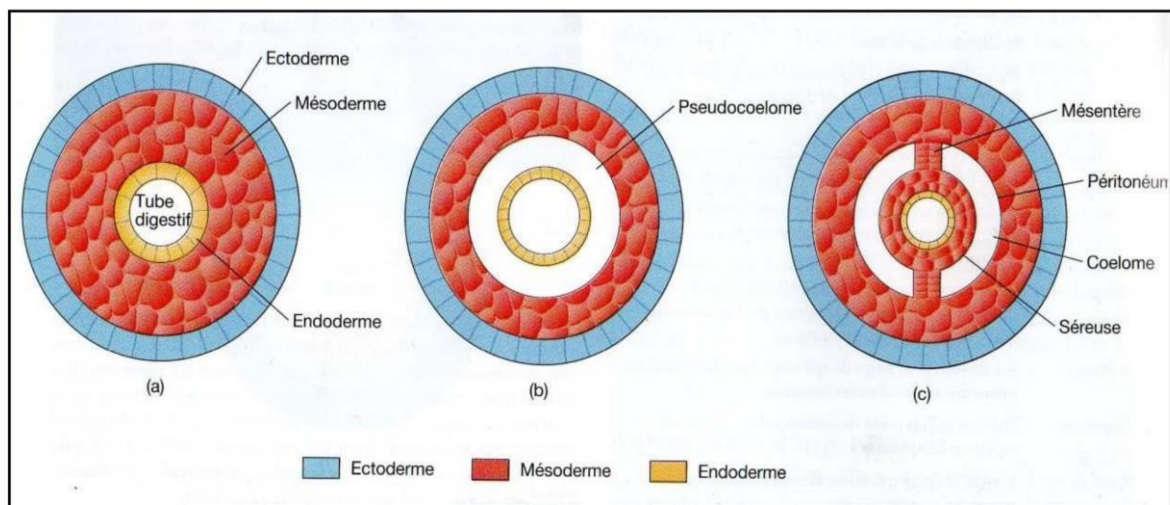
1. **Acoelomates:** Lack a true coelom (body cavity). The mesoderm remains compact and forms a solid tissue (parenchyma) between the body wall and the digestive tube. Example: flatworms, phylum **Platyhelminthes**.
2. **Pseudocoelomates:** The mesoderm does not form a solid parenchyma, and a large general cavity (pseudocoelom) that is only partially lined by mesodermal tissue appears, containing muscular masses, genital organs, and excretory structures. Example: phylum **Nematoda**.
3. **Coelomates:** The mesoderm forms a parenchyma that hollows out to create coeloms (true body cavities), where internal organs (viscera) develop. These are the **Triploblastic Coelomates**. The evolution of coelomates led to the formation of two distinct lineages:
 - **Protostomes:** Include **Annelids, Mollusks, and Arthropods**. In these animals, the blastopore develops into the mouth. They are characterized as hyponeurians (having a ventral nerve cord) with Ventral nervous system.
 - **Deuterostomes:** Include **Echinoderms and Chordates**. In these animals, the blastopore becomes the anus, while the mouth forms secondarily. They are further divided into two branches:
 - **Epithelioneurians:** The nervous system is not completely separated from the ectoderm (e.g., echinoderms such as sea urchins).
 - **Epineurium :** an organism that has a nervous system in a dorsal position (above the digestive tract)



Développement embryonnaire chez les métazoaires



Diploblastic organisation forme



Triploblastic organisation forme

Tableau. Simplified comaparaison between Protozoaires ans Métazoaires.

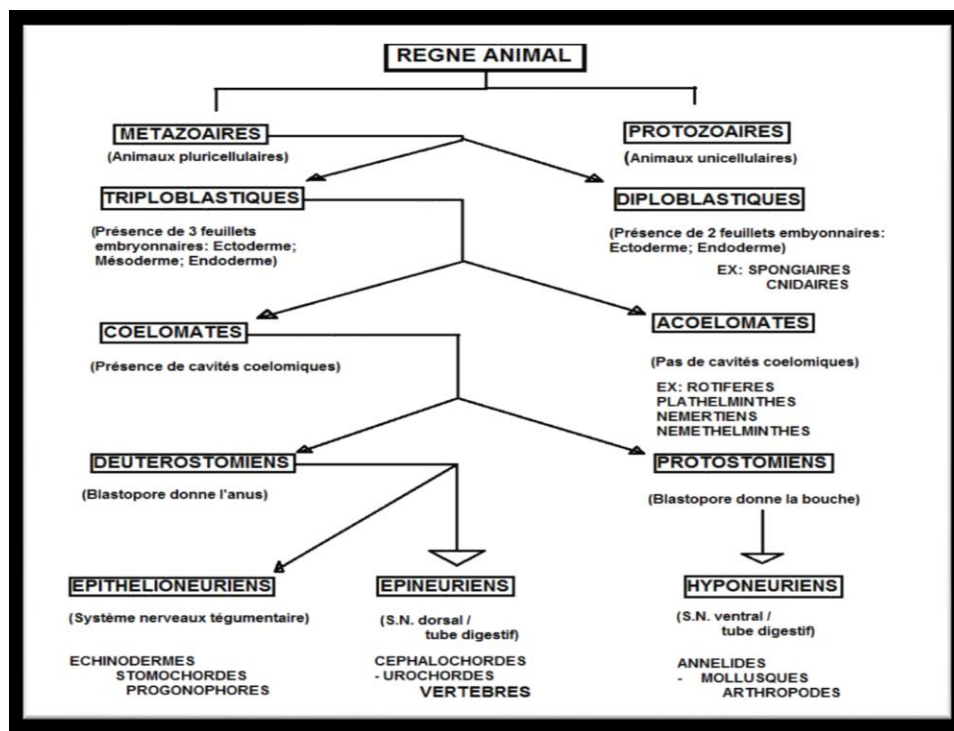
Criteria	Protozoaires	Mutazoaires
Cells type	Eucaryotes	Eucaryotes
Cellularity	Unicellulair	Pluri/multicellulair
Différencied tissu	No	YES
Nnutrition Mode	Heterotroph	Heterotroph
Mobility	yes	Yes (others are immobiles/sessiles)
Reproduction	asexuee	sexuee

Phases of Zoological Evolution:

- **Appearance of Multicellular Animals:** Around 600 million years ago, the first multicellular animals emerged, including sponges and jellyfish.
- **Cambrian Explosion (540 million years ago):** A period marked by a rapid diversification of animal life forms, resulting in the appearance of nearly all major animal phyla.
- **Colonization of Land:** The first animals to colonize land were likely arthropods, followed by amphibians around 400 million years ago.
- **Diversification of Vertebrates:** Vertebrates diversified into various groups, including fish, amphibians, reptiles, birds, and mammals, each adapting to different environments over time.

Phylogenesis

Phylogenesis is the study of the evolutionary relationships between different animal species (and more broadly, between all living organisms). It aims to trace the history of evolution, that is, to understand how species diverged from common ancestors. Phylogeny relies primarily on morphological, genetic, and biochemical data to establish kinship links.



Arbre Généalogique du règne animale

Evolution

Evolution is the process by which organisms change over time due to natural selection, mutations, gene flow, and genetic drift. Species evolve from common ancestors, leading to the biodiversity we observe today.

Phylogenetic Tree

A phylogenetic tree represents the evolutionary relationships between different species or groups of species. Each branch of the tree symbolizes an evolutionary lineage, while the points of divergence (nodes) represent common ancestors.

Example: The phylogenetic tree of vertebrates shows the divergence of fish, amphibians, reptiles, birds, and mammals from common ancestors.

Natural Selection

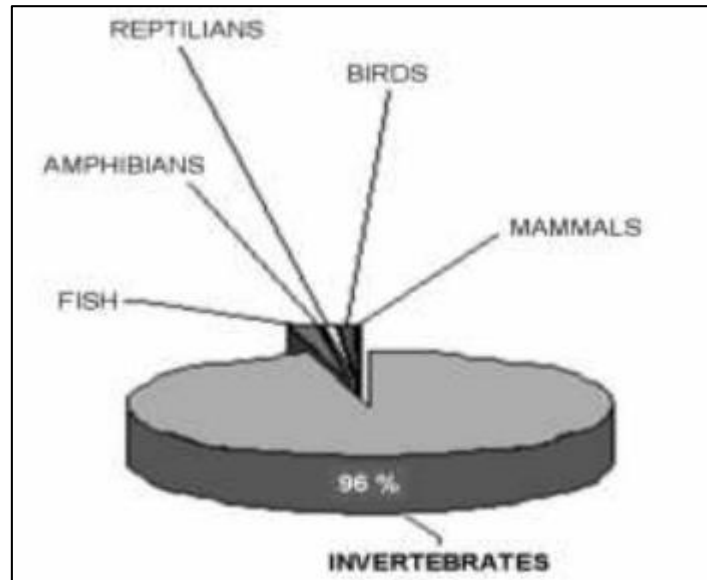
Proposed by Charles Darwin, the theory of natural selection explains how certain traits that enhance survival or reproduction are more likely to be passed on through generations. Organisms better adapted to their environment tend to survive and reproduce, passing on their genes.

Importance of Phylogeny in Zoology:

- **Biological Classification:** Phylogeny helps classify species based on their evolutionary relationships, leading to a more natural classification than one based solely on morphological traits.
- **Understanding Evolutionary Mechanisms:** It explains how current species evolved and the factors influencing their development (environmental pressure, genetic drift, geographical isolation).
- **Conservation of Biodiversity:** Phylogeny is crucial for conservation efforts, as it helps identify the oldest or most vulnerable species at risk of extinction.

5. Numerical Importance of the Animal Kingdom

The **numerical importance of the animal kingdom** refers to the vast diversity and abundance of animal species, which play crucial roles in ecosystems and human life. Here are some key points highlighting this importance:



✓ Biodiversity

- The animal kingdom is incredibly diverse, with an estimated **1.5 million described species** and possibly up to **10 million total species** when including those not yet discovered.
- Animals are classified into various groups, including:
 - **Invertebrates** (e.g., insects, mollusks, crustaceans)
 - **Vertebrates** (e.g., mammals, birds, reptiles, amphibians, fish)

✓ Ecosystem Roles

- ✓ Animals contribute significantly to ecosystem functions:
 - **Pollination:** Many animals, especially insects like bees, play a critical role in pollinating plants, which is vital for food production and maintaining plant diversity.
 - **Decomposition:** Decomposers, such as certain insects and worms, help break down dead organic matter, recycling nutrients back into the ecosystem.

- **Food Webs:** Animals occupy various trophic levels, forming intricate food webs that sustain ecosystem balance.

✓ **Economic Importance**

- Animals provide essential resources for humans:
 - **Food:** Livestock (cows, pigs, chickens) and fish contribute significantly to the global food supply.
 - **Materials:** Animals provide materials such as wool, leather, and silk.
 - **Medicinal Resources:** Many pharmaceuticals are derived from animal products or inspired by animal biology.

✓ **Cultural Significance**

- Animals hold cultural and spiritual significance in many societies, influencing art, folklore, and traditions.
- Pets, such as dogs and cats, contribute to human well-being and companionship.

✓ **Conservation and Threats**

- Many animal species face threats from habitat loss, climate change, pollution, and overexploitation, leading to declines in biodiversity.
- Conservation efforts are essential to protect endangered species and preserve ecosystem health.

✓ **Research and Education**

- Animals serve as important subjects for scientific research, providing insights into genetics, behavior, ecology, and evolution.
- Understanding animal biology and ecology is crucial for addressing environmental challenges and promoting sustainability.

Number importance of Animal Phylum

Embranchements	Nombre d'espèce	Exemples
Arthropodes (Arthropoda)	~ 1,2 Million species	Insects, Spiders, and Crustaceans
Mollusques (Mollusca)	~ 85000-100000 species	Snails, Mussels, and Octopuses
Chordés (Chordata)	~ 65 000 species	Mammals, Birds, Fish, and Amphibians
Nématodes (Nematoda)	~ 25 000 à 40 000 species	Roundworms (Nematodes): Parasitic and Free-living
Cnidaires (Cnidaria)	~ 10 000 species	Jellyfish, Corals, and Sea Anemones
Annélides (Annelida)	~ 17 000 species	Earthworms, Leeches, and Polychaetes
Échinodermes (Echinodermata)	~ 7 000 species	Sea Stars, Sea Urchins, and Sea Cucumbers
Platyhelminthes (Platyhelminthes)	~ 20 000 species	Flatworms: Planarians, Flukes, and Tapeworms
Porifères (Porifera)	~ 8 000 species	Sponges
Rotifères (Rotifera)	~ 2000 species	Rotifers: The Phylum Rotifera
Bryozoaires (Bryozoa)	~ 5000 species	Colonial Aquatic Organisms

CHAPTER 2: Sub-Kingdom Protozoa

1. Generalities on Protozoa:

Proto=first=primitive, Zoon= Animal

Protozoa are unicellular, eukaryotic, heterotrophic organisms. They are either free-living or parasites. There are around 65000 species of protozoans categorised in different groups. They lack a cell wall. There are many different cell organelles that perform various tasks performed by different organs in higher animals, e.g. mouth, anus, intestinal tract, etc. There are many protozoa, that cause various diseases in animals and humans, e.g. Plasmodium (malarial parasite), Trypanosoma (sleeping sickness), Trichomonas (trichomoniasis), etc.

The protozoa have many stages in their life cycle. Some of the stages of the life cycle are infectious. The cyst stage is dormant and resistant to environmental stress, the trophozoite stage is reproductive and causes disease.

A/General Characteristics of Protozoa

✓ Habitat:

Protozoa are found in the aquatic environment. They live in freshwater or oceans. Some are free-living and some are parasitic in plants and animals. Mostly they are aerobic but some are anaerobic and present in the rumen or human intestine. Some of the species are found in extreme environments like hot springs. Some of them form resting cyst to overcome dry environments.

✓ Size and Shape:

The size and shape of Protozoa vary greatly, from microbial (1µm) to large enough and can be seen by the naked eye. The shell of unicellular foraminifera can have a diameter of 20 cm.

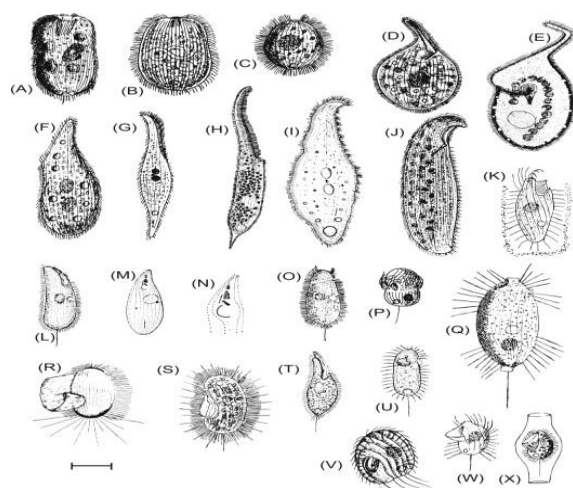
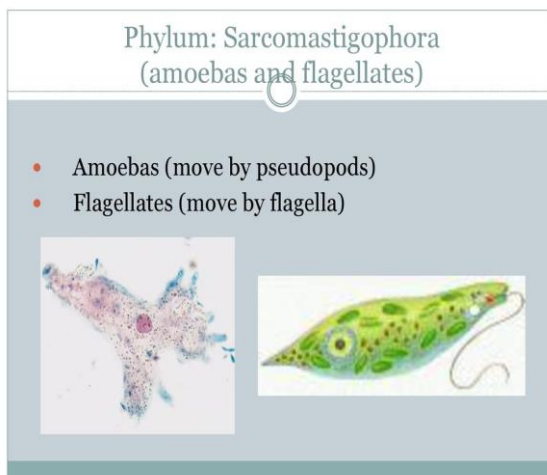
They lack a rigid cell wall, so they are flexible and found in various shapes. Cells are enclosed in a thin plasma membrane. Some of the species have a hard shell on the outer surface. In some of the protozoans especially in ciliates, the cell is supported by **Pellicle**, which may be flexible or rigid and give organisms the definite shape and help in locomotion.

✓ Cellular Structure:

They are unicellular having a eukaryotic cell. The metabolic functions are performed by some specialised internal structures.

- ✓ They mostly have one membrane-bound nucleus in the cell
- ✓ The nucleus has diffused appearance due to scattered chromatin, the vesicular nucleus contains a central body called endosome or nucleoli. Nucleoli of apicomplexans have DNA, whereas amoeboids lack DNA in their endosome
- ✓ Ciliates have micronucleus and macronucleus
- ✓ The plasma membrane encloses the cytoplasm and other locomotory projections like flagella, pseudopodia and cilia
- ✓ Some of the genera have a membranous envelope called pellicle, which gives a definite shape to the cell. In some of the protozoans, epibiotic bacteria attach to the pellicle by their fimbriae
- ✓ The cytoplasm is differentiated into outer ectoplasm and inner endoplasm, ectoplasm is transparent and endoplasm contains cell organelles
- ✓ Some of the protozoa have cytostome for ingesting food. Food vacuoles are present, where ingested food comes. Ciliates have a gullet, a body cavity which opens outside
- ✓ The central vacuole is present for osmoregulation, that removes excess water
- ✓ Membrane-bound cell organelles, like mitochondria, Golgi bodies, lysosomes and other specialised structure.

Ciliophora

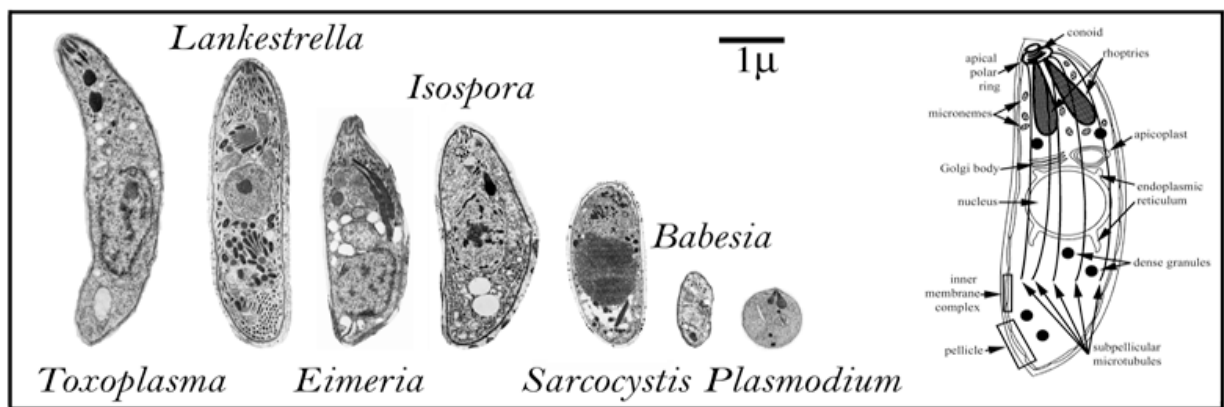


✓ **Nutrition:**

Protozoa are heterotrophic and have holozoic nutrition. They ingest their food by phagocytosis. Some of the protozoan groups have a specialised structure called **cytostome** for phagocytosis. The pseudopodia of amoeboids help in catching the prey. Thousands of cilia present in ciliates drive the food-laden water into the gullet. The ingested food comes to the food vacuole and gets acted on by lysosomal enzymes. The digested food gets distributed throughout the cell.

✓ **Locomotion:**

Most of the protozoa species have flagella, cilia or pseudopodia. Sporozoa, which don't have any locomotory structure, have subpellicular microtubules, which help in the slow movement.



✓ **Life Cycle:**

The life cycle of most of the protozoa alternates between dormant cyst stage and proliferating vegetative stage, e.g. Trophozoites. The cyst stage can survive harsh conditions without water and nutrients. It can remain outside the host for a longer duration and get transmitted. The trophozoite stage is infectious, and they feed and multiply during this stage.

The life stages of protozoa vary depending on the species and their environmental conditions. However, many protozoa have a complex life cycle that includes both active and dormant stages. The general life stages of protozoa are:

1. **Trophozoite Stage:**

- **Description:** The active, feeding, and motile stage of the protozoa.

- **Function:** During this stage, the protozoa absorb nutrients and reproduce, usually by binary fission or other asexual means.
- **Characteristics:** Protozoa are metabolically active and can move freely.

2. Cyst Stage:

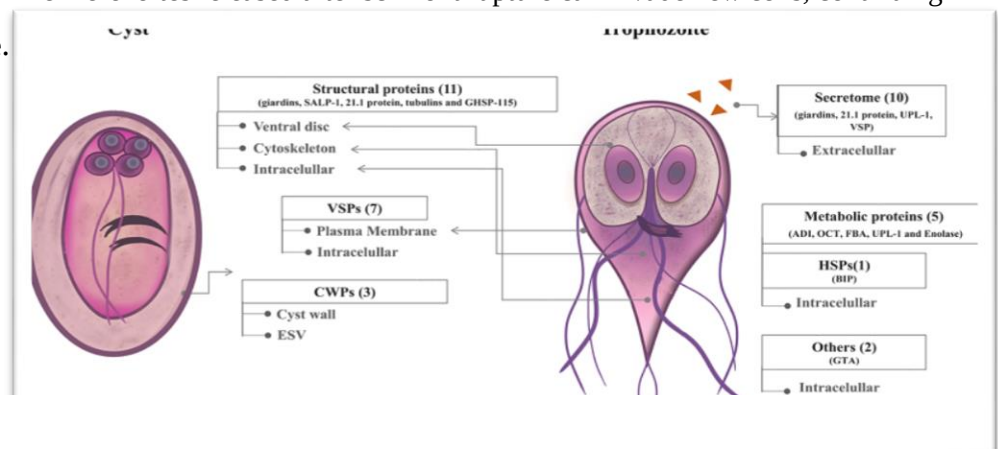
- **Description:** The dormant, resistant, and non-motile stage of protozoa.
- **Function:** This stage allows the organism to survive in harsh environmental conditions, such as extreme temperatures, dehydration, or nutrient deficiency.
- **Characteristics:** The cyst has a protective wall that helps it resist unfavorable conditions and facilitates transmission to new hosts.

3. Spore Stage (Some Species)

- **Description:** A reproductive stage found in certain parasitic protozoa, especially those in the phylum Apicomplexa (e.g., *Plasmodium*, *Eimeria*).
- **Function:** Sporozoites (spores) are typically infective stages that allow the protozoa to enter a new host.
- **Characteristics:** These spores are often formed after sexual reproduction and are designed to ensure the spread of the organism to new environments or hosts.

4. Schizont Stage (Apicomplexa)

- **Description:** Found in protozoa like *Plasmodium* (the malaria parasite), where the organism undergoes asexual multiplication.
- **Function:** The schizont divides multiple times to produce many merozoites.
- **Characteristics:** The merozoites released after schizont rupture can invade new cells, continuing the infection cycle.



Reproduction:

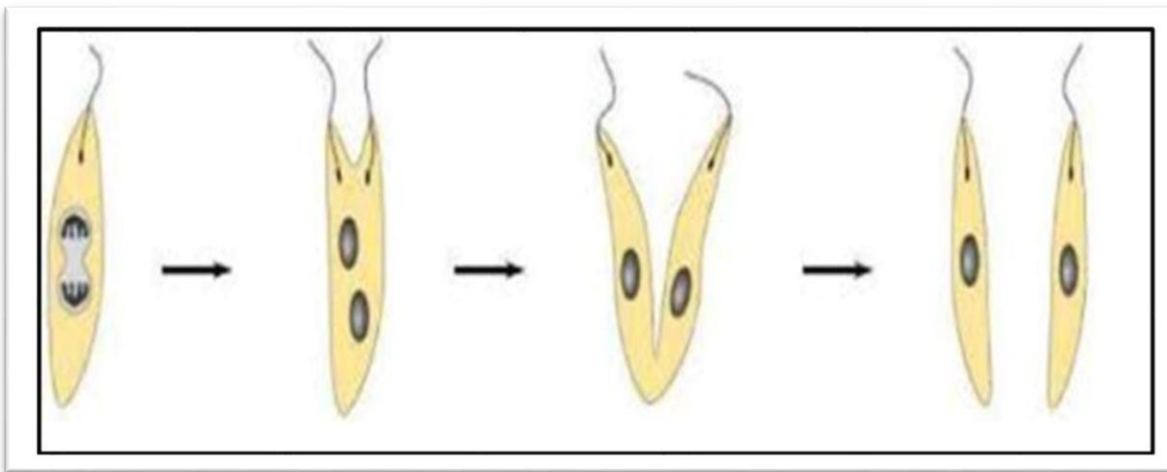
Mostly they reproduce by asexual means. They multiply by binary fission, longitudinal fission, transverse fission or budding (bourgeonnement). In some of the species, sexual reproduction is present. The sexual reproduction is by conjugation, syngamy or by gametocytes formation.

1. Asexual Reproduction:

This is the most common mode of reproduction in protozoa, where a single organism produces offspring without genetic exchange. There are several types of asexual reproduction:

a) *Binary Fission:*

- **Description:** The parent cell divides into two identical daughter cells.
- **Process:** The nucleus first undergoes mitotic division, followed by cytoplasmic division (cytokinesis).
- **Examples:** *Amoeba*, *Paramecium*, and many other free-living protozoa reproduce this way.

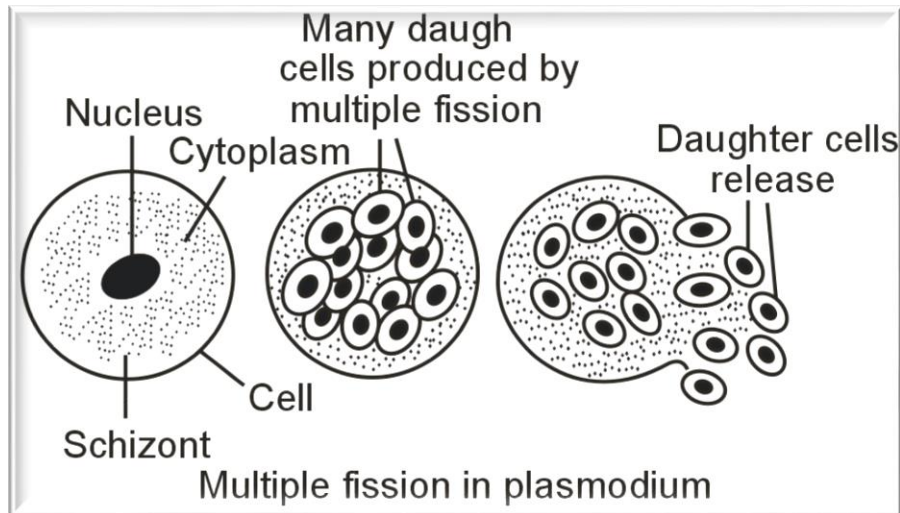


Longitudinal Binary Fission

b) Multiple Fission (Schizogony):

- **Description:** The parent cell divides multiple times to form many daughter cells simultaneously.

- **Process:** The nucleus divides repeatedly before the cytoplasm divides, forming numerous new cells.
- **Examples:** *Plasmodium* (the malaria parasite) undergoes multiple fission within red blood cells or liver cells.



c) Budding:

- **Description:** A small outgrowth (bud) forms on the parent cell, eventually detaching to become an independent organism.
- **Process:** The bud develops into a new organism, often differing slightly in size from the parent.
- **Examples:** Some ciliates and flagellates may reproduce via budding.

d) Endodyogeny:

- **Description:** A form of internal budding where two daughter cells are produced within the parent cell and then released upon the disintegration of the parent.
- **Examples:** Some Apicomplexans, like *Toxoplasma gondii*, reproduce by endodyogeny.

2. Sexual Reproduction:

Sexual reproduction in protozoa involves the exchange of genetic material, leading to increased genetic diversity. There are several forms of sexual reproduction:

a) Conjugation:

- **Description:** A temporary fusion of two protozoan cells (usually ciliates) to exchange genetic material.
- **Process:** Two cells attach and exchange micronuclei, which then fuse with the macronucleus to create a new genetic combination.
- **Examples:** *Paramecium* species commonly undergo conjugation.

b) Syngamy:

- **Description:** The fusion of two gametes (haploid cells) to form a zygote (diploid cell).
- **Process:** Gametes are produced through meiosis and fuse during fertilization to create a zygote, which develops into a new organism.
- **Examples:** Many parasitic protozoa, such as *Plasmodium*, undergo syngamy as part of their life cycle.

c) Autogamy:

- **Description:** Self-fertilization that occurs within a single individual.
- **Process:** The nucleus of a single organism divides and undergoes recombination to produce new genetic material without the need for another individual.
- **Examples:** Some ciliates can perform autogamy under specific conditions.

3. Alternation of Generations:

- **Description:** Some protozoa, especially parasitic species, have complex life cycles that alternate between asexual and sexual reproduction.
- **Examples:** *Plasmodium*, the malaria-causing protozoa, alternates between asexual reproduction in human hosts and sexual reproduction in mosquito hosts.

B/ Protozoa Classification and Examples

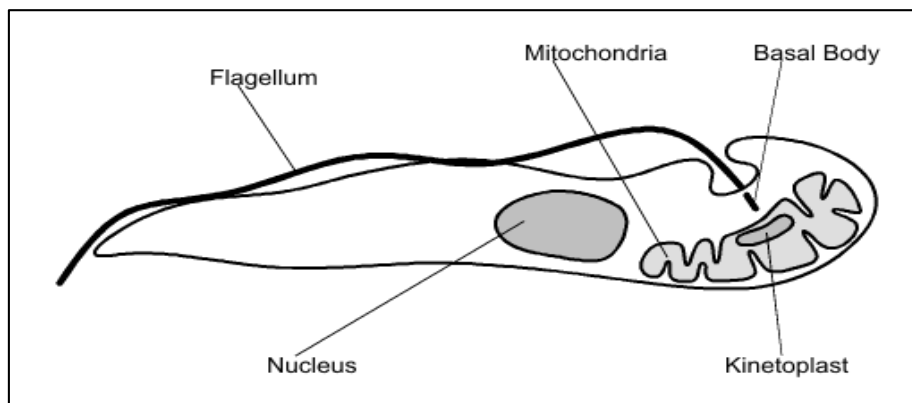
Protozoa is a phylum having unicellular heterotrophs. It comes under Kingdom Protista.

Protozoa are divided into four major groups based on the structure and the part involved in the locomotion:

1. Mastigophora or Flagellated protozoans:

Sarcos = Flesh; **Mastix** = Whip; **Phorein** = To carry. The **phylum Sarcomastigophora** is divided into two subphyla:

- **Subphylum Mastigophora:** Movement occurs through one or more **flagella**.
- **Subphylum Sarcodina:** Movement occurs through **pseudopodia**, which can take on different shapes. They are parasites or free-living.
 - ✓ They have flagella for locomotion
 - ✓ Their body is covered by a cuticle or pellicle
 - ✓ Freshwater forms have a contractile vacuole
 - ✓ Reproduction is by binary fission (longitudinal division)
 - ✓ Examples: *Trypanosoma*, *Trichomonas*, *Giardia*, *Leishmania*, etc.



Sarcomastigophora is a former taxonomic group within the **protozoa** that encompassed single-celled organisms capable of moving using flagella or pseudopodia. This group has been historically important for studying protozoans but is no longer valid in modern taxonomy due to advances in molecular biology.

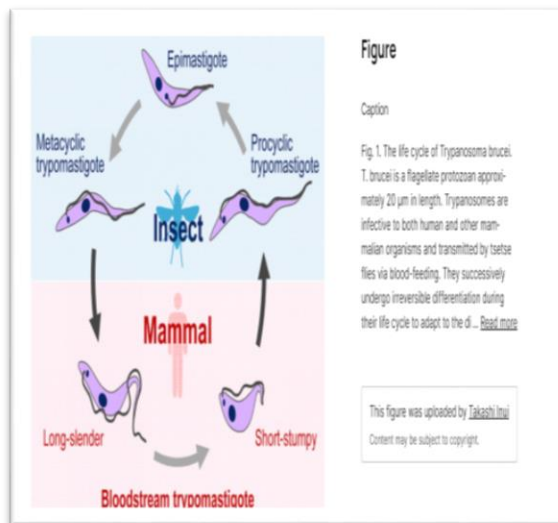
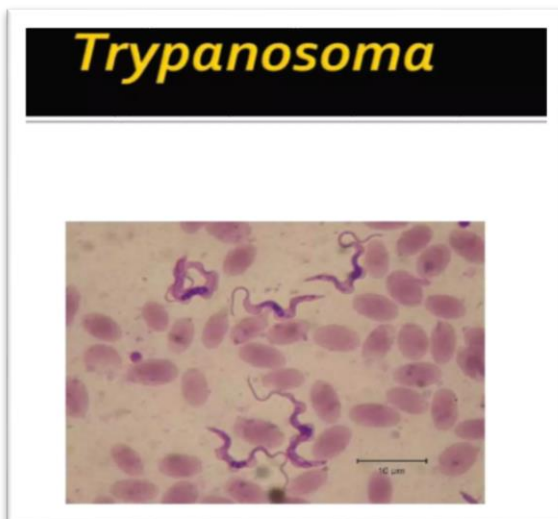
Main Characteristics:

- **Unicellular** organisms.
- **Locomotion:** By either **flagella** (in the case of mastigophorans) or **pseudopodia** (in the case of sarcodines).
- **Nutrition:** Can be autotrophic (produce their own food) or heterotrophic (feed on other organisms).
- **Habitat:** Found in aquatic environments, soil, or as parasites within host organisms.

Divisions within Sarcomastigophora:

A. Mastigophora (Flagellates):

- Move with the help of **flagella**, which are long, whip-like appendages.
- Some are **photosynthetic** (e.g., *Euglena*), while others are **heterotrophic** (e.g., *Trypanosoma*).
- Many are parasitic and cause diseases, such as:
 - *Trypanosoma* (causes sleeping sickness).
 - *Giardia* (causes giardiasis).



B. Sarcodina (Amoeboids):

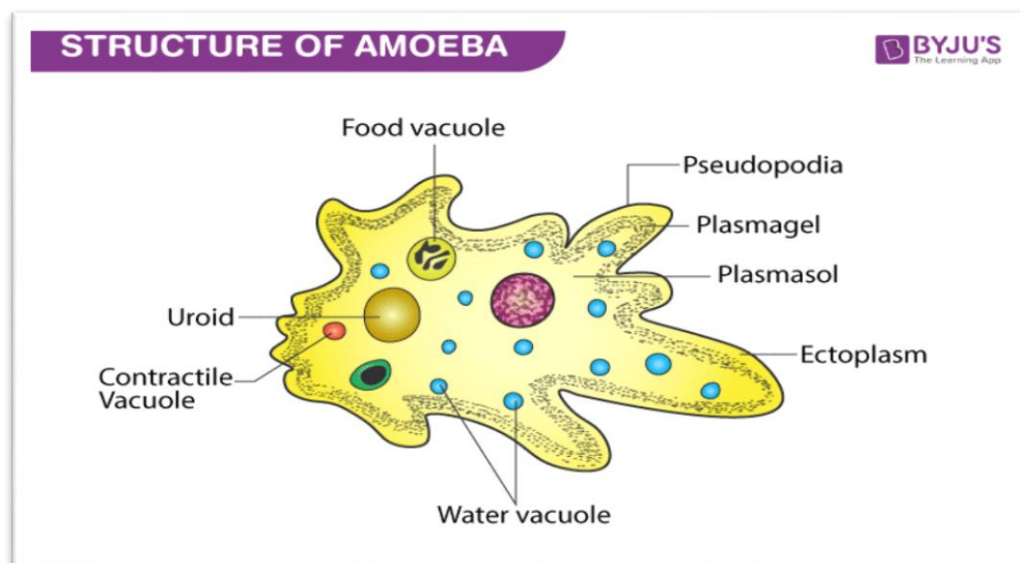
- Move using **pseudopodia**, which are temporary extensions of the cell membrane.
- Characterized by their amorphous, shape-shifting bodies.
- Many are free-living, but some are parasitic, such as: *Entamoeba histolytica* (causes amoebic dysentery). Foraminifera (marine organisms with shells).

Examples:

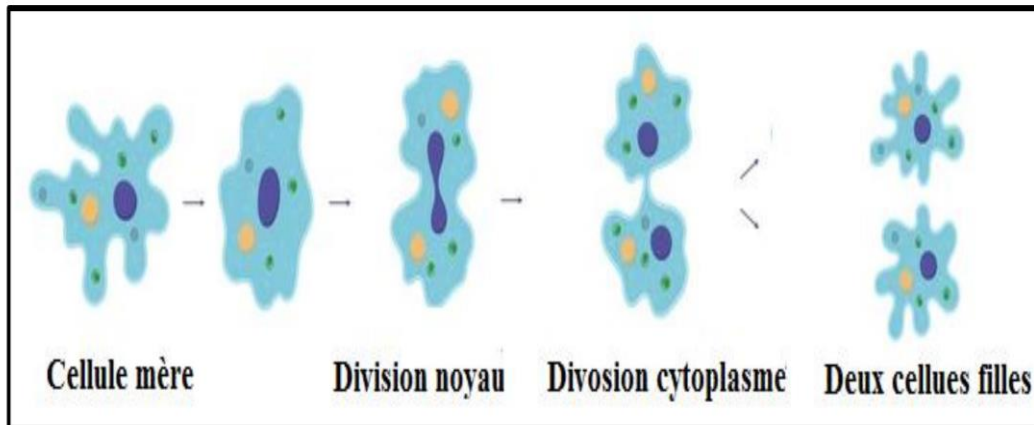
- *Euglena*: A flagellate that is mixotrophic (can both photosynthesize and feed on other organisms).
- *Amoeba proteus*: A classic free-living amoeboid that moves and feeds with pseudopodia.
- *Trypanosoma*: A parasitic flagellate that causes African sleeping sickness.

Foraminifera: Marine amoeboids with calcium carbonate shells, important in paleontology for fossil records. They constitute a small group (200 species). The body constantly changes shape (amoebas). They can be:

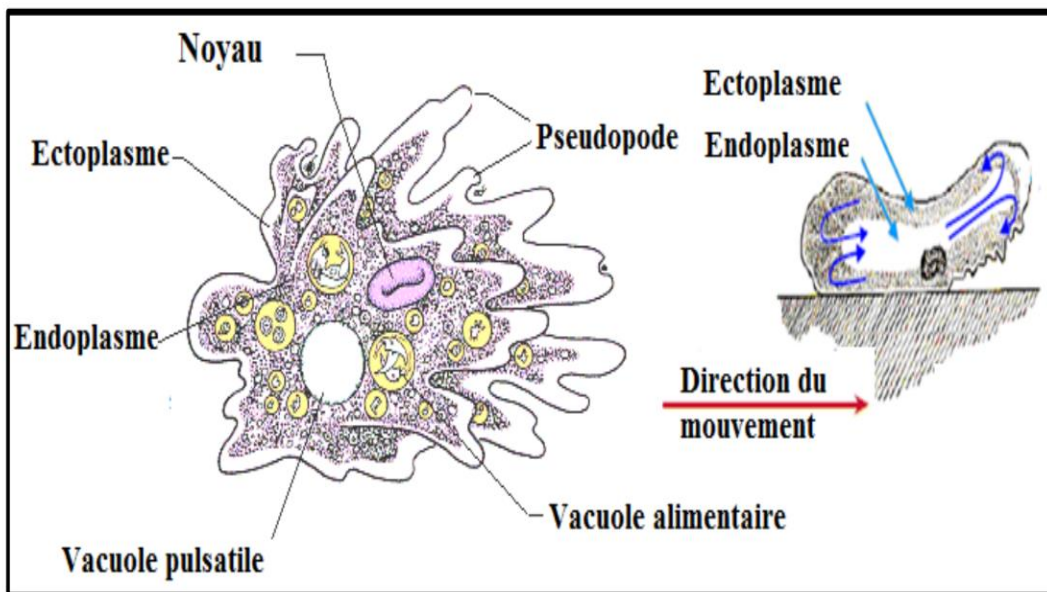
- Free-living → Ex: *Amoeba proteus*
- Parasitic → Ex: *Entamoeba histolytica*, *Entamoeba gingivalis*
- Symbiotic → Ex: *Entamoeba coli*



- ✓ **Habitat and Distribution:** Generally free-living organisms that inhabit seas, freshwater, and moist soil.
- ✓ **Reproduction:** Most reproduce by **binary fission** (transversal)



- **Locomotion:** They are capable of forming **pseudopodia** to move or capture their prey, which involves the extension of the cytoplasm in the direction of movement.



The classification of Sarcodina is based on the presence or absence of an external shell and the morphology of their pseudopodia (lobed, digitate, filiform, or anastomosed). The Rhizopods are divided into two superclasses: Rhizopoda and Actinopoda

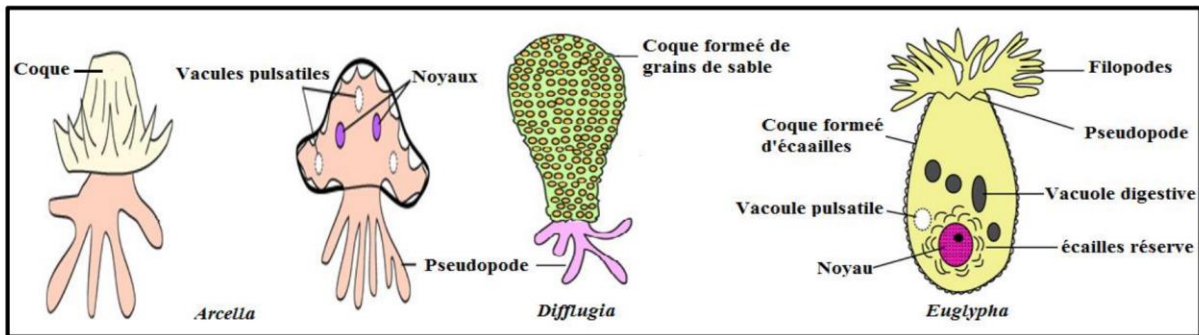


Figure 13 : Différents forme thèque et pseudopodes chez Rhizopodes testacés.

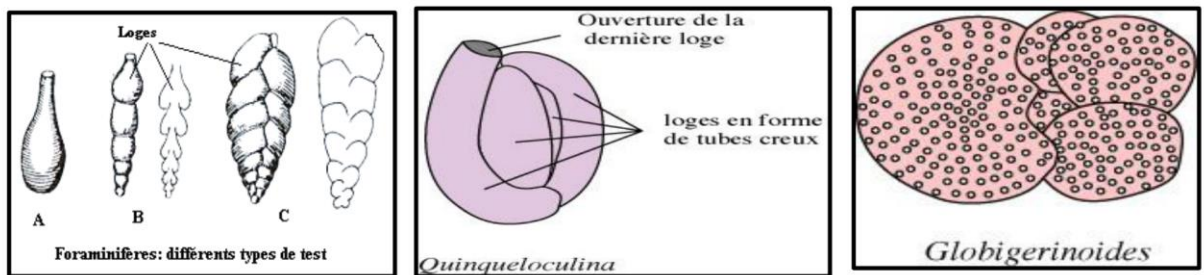


Figure 14 : Structure et différents types de tests chez Foraminifères.

Exemples : *Acanthocystis aculeata* ; *Actinolphus pedunculatus*.

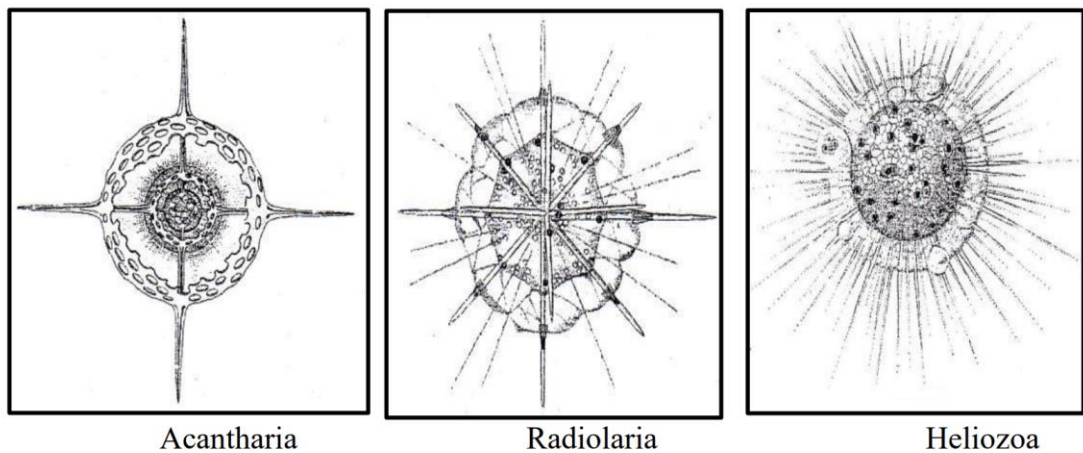


Figure 15 : Différentes formes des Actinopodes.

2. Ciliophora or Ciliated protozoans:

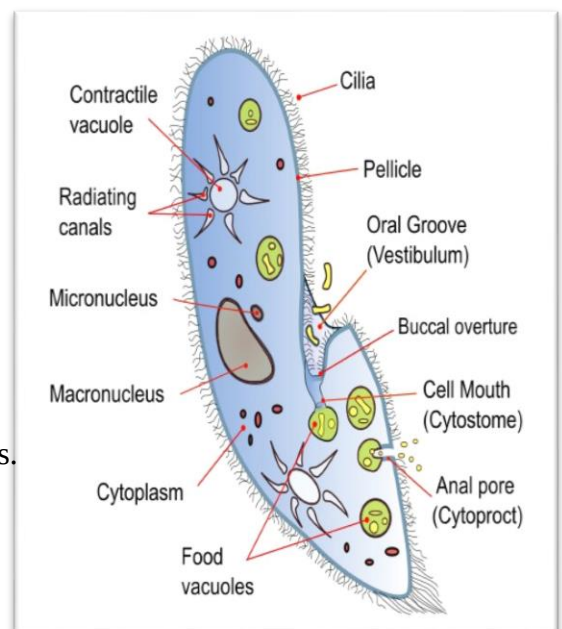
Ciliophora is a phylum of **protozoan organisms** that are distinguished by the presence of hair-like structures called **cilia**. These structures are used for **locomotion** and **feeding**, giving the group its name. Ciliophora species can be found in a wide variety of environments, including **freshwater**, **marine**, and even **terrestrial** habitats, where they play important ecological roles as **predators**, **decomposers**, and sometimes **symbionts** or **parasites**.

General Characteristics of Ciliophora:

1. **Cilia:** Ciliophorans possess **cilia** on their body surface, which are essential for movement and feeding. The coordinated beating of cilia propels the organism through water.
2. **Nuclear Dimorphism:** They have two types of nuclei:
 - **Macronucleus:** Controls everyday cellular functions like metabolism and growth.
 - **Micronucleus:** Involved in sexual reproduction processes like **conjugation**.
3. **Feeding:** They are mostly **heterotrophic**, meaning they consume other microorganisms such as bacteria, algae, or smaller protozoans. Some species are mixotrophic, combining autotrophic and heterotrophic feeding.
4. **Complexity:** Ciliates are among the most complex unicellular organisms, with specialized structures such as **contractile vacuoles** for osmoregulation and **trichocysts** for defense.
5. **Reproduction:** They reproduce asexually by **binary fission** and sexually through **conjugation**, a process where two individuals exchange genetic material.

Examples of Ciliophora:

1. **Paramecium:**
 - A well-known freshwater ciliate.
 - Moves using cilia and feeds by sweeping food into its oral groove.
 - Often used as a model organism in cell biology studies.

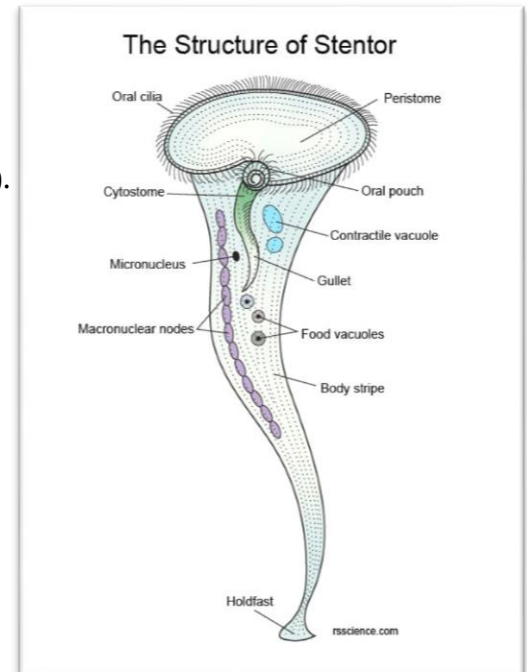


2. **Vorticella:**

- A sessile (attached) ciliate with a stalk.
- Common in ponds, attaches to surfaces (plants or stones).
- Known for its bell-shaped body and retractable stalk.

3. **Stentor:**

- Another large ciliate, often trumpet-shaped.
- Notable for its regenerative ability; it can reform into a complete organism from just a fragment of its body.



4. **Balantidium coli:**

- A parasitic ciliate that can infect humans and other animals, causing the disease **balantidiasis**. It mainly infects the colon and can lead to diarrhea or dysentery.

Ecological Roles:

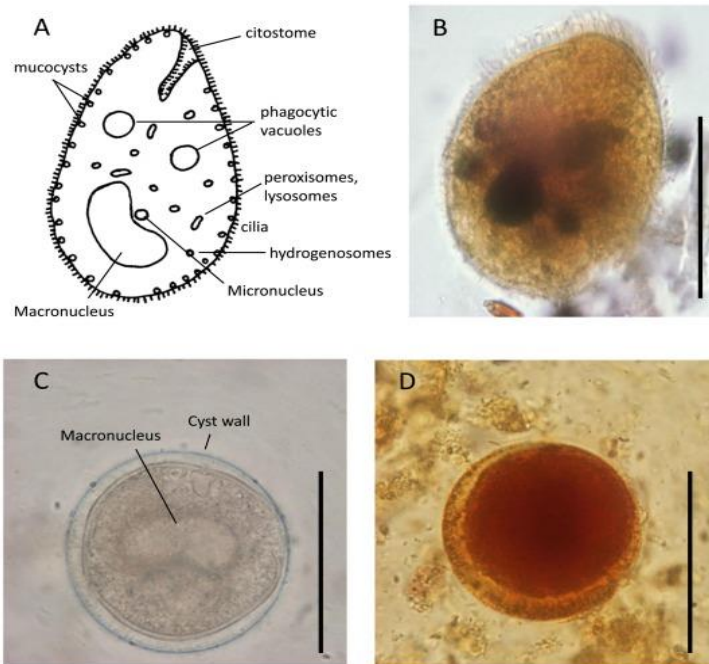
- **Decomposers:** Many ciliates play a crucial role in breaking down organic material, helping recycle nutrients in aquatic ecosystems.
- **Predators:** They are important predators of bacteria, controlling bacterial populations and maintaining ecological balance.
- **Symbionts:** Some species live in symbiosis with other organisms, such as ciliates that live in the digestive tracts of ruminants and help digest cellulose.

Examples of Notable Ciliophora Species:

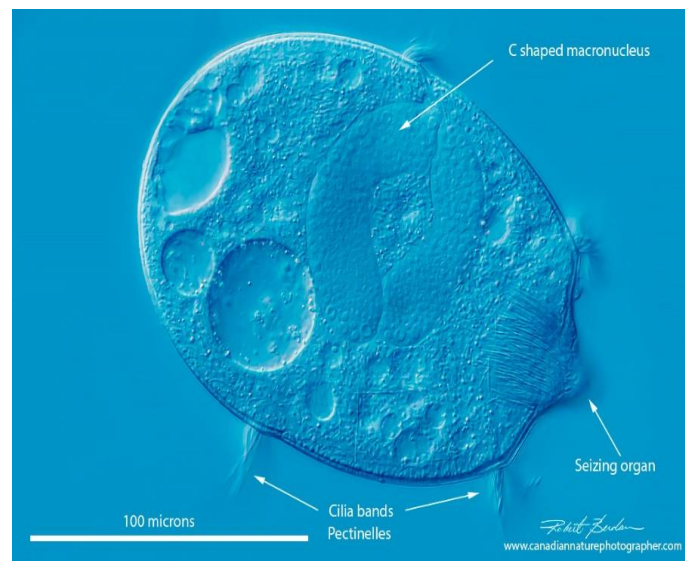
- Paramecium (**Class Oligohymenophorea**): A widely studied free-living ciliate known for its distinctive slipper shape and rapid movement.
- Stentor (**Class Heterotrichea**): Large, trumpet-shaped ciliates known for their size and regenerative abilities.

•

- Vorticella (**Class Oligohymenophorea**): A sessile ciliate that uses its cilia to create water currents to bring food particles into its oral groove.
-
- *Balantidium coli* (**Class Litostomatea**): The largest protozoan parasite in humans, causing balantidiasis.



- Didinium (**Class Litostomatea**): A predatory ciliate known for its ability to capture and consume other ciliates like Paramecium.



- This classification system provides a framework for understanding the diversity and complexity of the Ciliophora, from free-living species to parasitic forms, all playing crucial roles in their respective ecosystems.

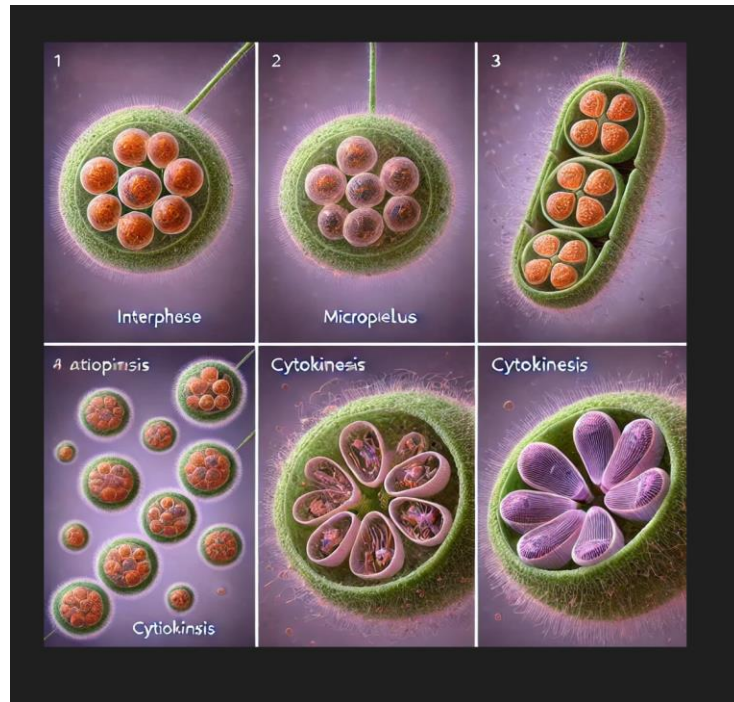
Reproduction in Ciliophora:

- **Asexual reproduction:** Through **binary fission**, where one cell divides into two identical offspring.
- **Sexual reproduction:** Through **conjugation**, where two ciliates exchange micronuclear material to promote genetic diversity.

Steps of Asexual Reproduction in Ciliophora:

1. **Interphase (Preparation for Division):** The cell grows and increases in size. The macronucleus and micronucleus of the ciliate prepare for division. The cell begins to replicate its genetic material in preparation for nuclear division.
2. **Micronuclear Division (Mitosis):** The micronucleus undergoes mitosis, a process that ensures each daughter cell will receive a complete set of chromosomes. During mitosis, the nuclear envelope around the micronucleus dissolves, and the chromosomes condense and align in the center of the cell. The chromosomes are then pulled apart to opposite poles of the cell, resulting in two sets of identical chromosomes.
3. **Macronuclear Division (Amitosis):** The macronucleus, which controls the cell's metabolic activities, divides through a process called amitosis (direct division). Amitosis is a simpler form of nuclear division, where the macronucleus elongates and is pinched into two parts without undergoing the complex processes of mitosis.
4. **Cytokinesis (Cytoplasmic Division):** Following nuclear division, the cytoplasm of the ciliate begins to divide. The cell membrane constricts in the middle, creating two distinct halves. Organelles such as vacuoles, mitochondria, and the cytoskeleton are distributed between the two daughter cells. The division occurs along the transverse axis of the cell, with the posterior end of the parent cell becoming the anterior end of one daughter cell and the anterior end of the parent cell becoming the posterior end of the other.
5. **Formation of Two Daughter Cells:** As the division completes, the cytokinesis concludes, and two genetically identical daughter cells are formed. Each daughter cell has one

macronucleus, one micronucleus, and its own set of organelles. The daughter cells grow to full size, becoming capable of reproducing on their own.



Steps of Sexual Reproduction (Conjugation) in Ciliophora:

Sexual reproduction in Ciliophora primarily occurs through a process called **conjugation**. During conjugation, two ciliates of the same species exchange genetic material without increasing in number. Here are the steps involved in the process:

1. **Pairing (Conjugation):**

- Two ciliates come into close contact and align side by side, connected by their oral regions. A cytoplasmic bridge forms between them.
- The micronucleus of each organism undergoes meiosis, producing four haploid micronuclei.

2. **Nuclear Exchange:**

- Three of the four micronuclei in each ciliate disintegrate, leaving one.
- The remaining micronucleus divides by mitosis, forming two haploid nuclei. One nucleus from each ciliate migrates to the partner (this is the exchange of genetic material).

3. **Fusion of Nuclei:**

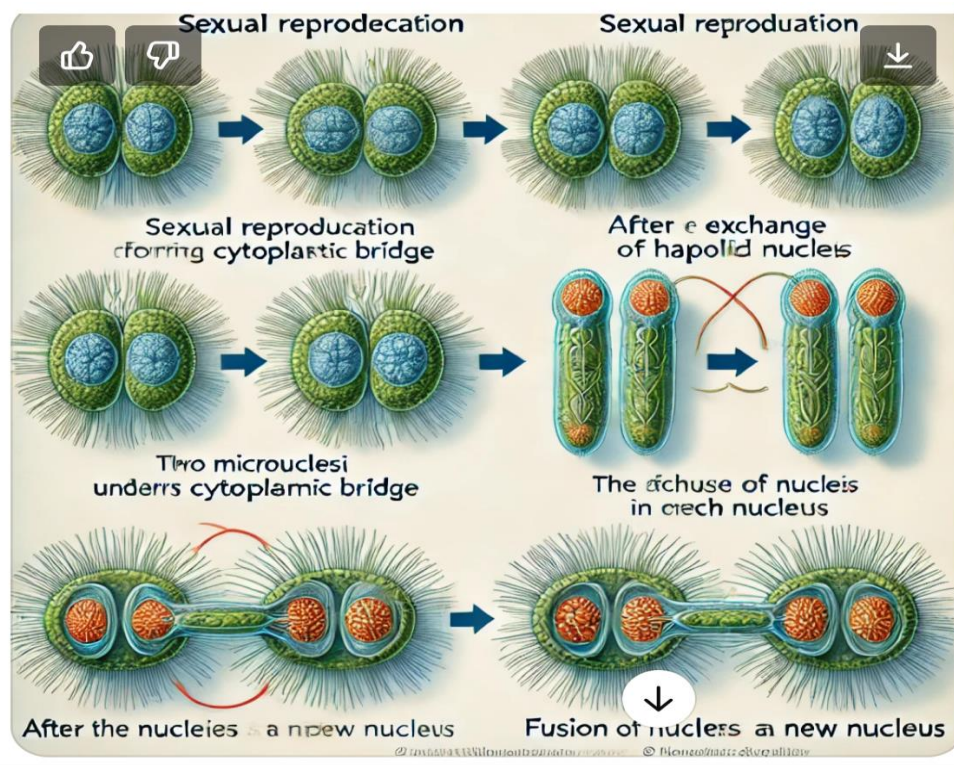
- After the exchange, the haploid micronuclei from each ciliate fuse with the retained micronucleus of their partner to form a new diploid nucleus.

4. Separation:

- The two ciliates separate after the exchange of genetic material.
- The new diploid nucleus in each ciliate undergoes mitosis to restore the number of nuclei.

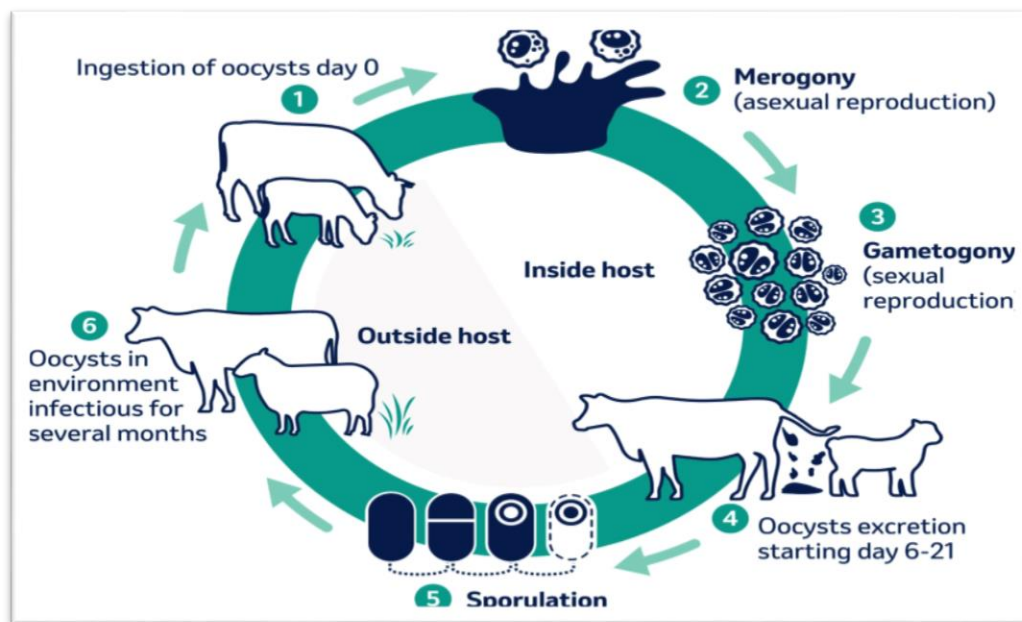
5. Reorganization:

- The macronucleus disintegrates and is replaced by a new macronucleus derived from the micronucleus.
- The new micronucleus and macronucleus are fully restored, and both ciliates now have a new genetic makeup.



3. Phylum Apicomplexa

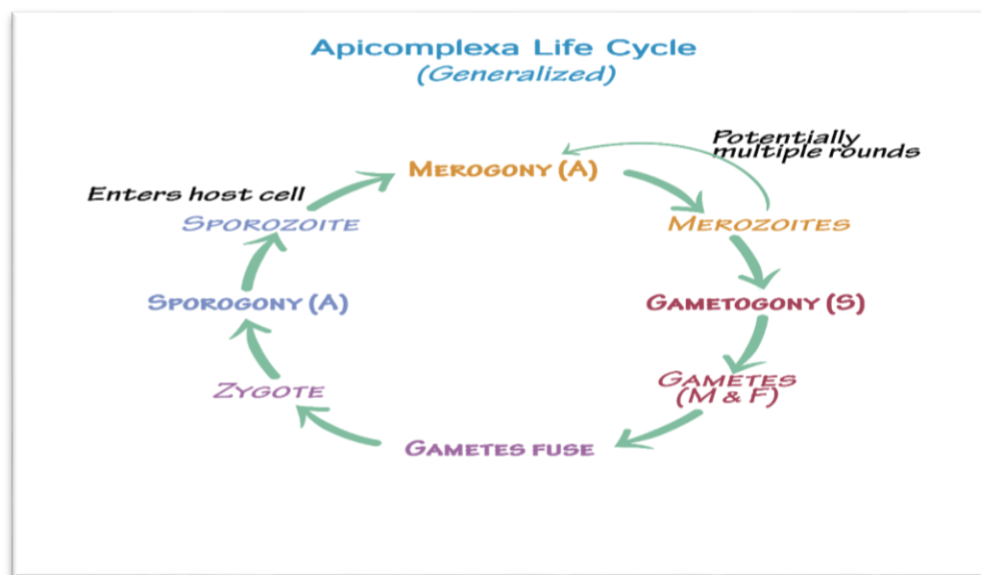
Phylum Apicomplexa is a large group of parasitic protozoans, most of which possess a unique structure called the **apical complex** at some stage in their lifecycle. This structure helps them penetrate the host's cells. They are obligate parasites, meaning they cannot live independently and must infect a host to complete their life cycle. Many of the Apicomplexa are responsible for serious diseases in humans and animals, including **malaria**, **toxoplasmosis**, and **coccidiosis**.



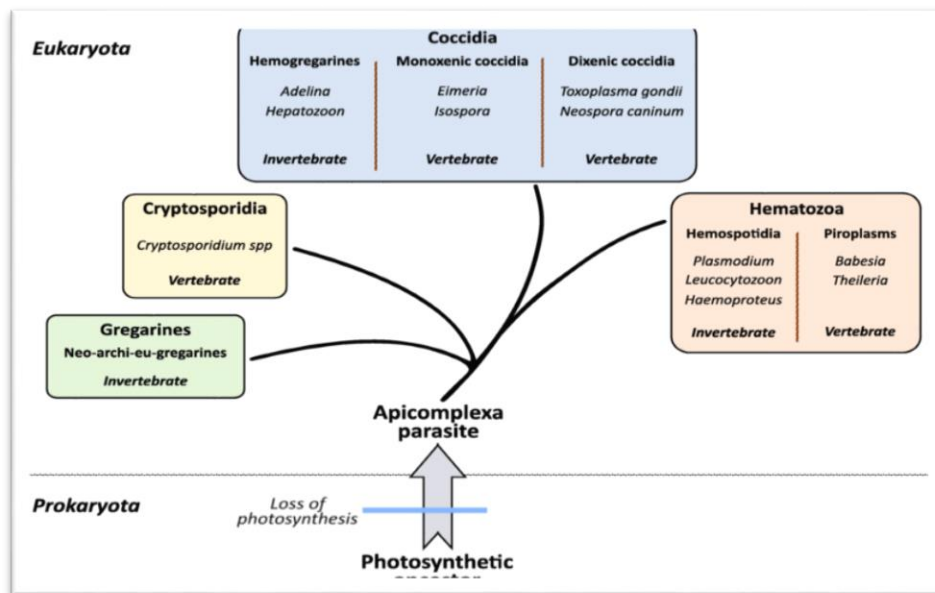
General Characteristics of Apicomplexa:

- 1. Apical Complex:** A collection of organelles and structures found at the apex (tip) of the parasite that aids in host cell invasion.
 - This complex includes structures like **rhoptries**, **micronemes**, and **conoids**.
- 2. Parasitism:** All members of this phylum are parasitic, often infecting vertebrates and invertebrates.
- 3. No Locomotory Organelles:** Unlike many protozoa, Apicomplexans do not have cilia or flagella (except for the flagellated gametes in some species). They move via a process called **gliding motility**.

4. **Complex Life Cycles:** Apicomplexa generally have a life cycle that includes both **sexual** and **asexual** reproduction, often involving multiple hosts. Their life cycle typically includes three stages:
- **Sporogony:** Formation of sporozoites after meiosis.
 - **Schizogony:** Asexual reproduction in the host, resulting in the production of merozoites.
 - **Gametogony:** Sexual reproduction leading to the formation of gametes.
5. **Oocysts Formation:** The infectious stage often forms **oocysts**, which are usually excreted by the host and facilitate the spread of the parasite to new hosts.

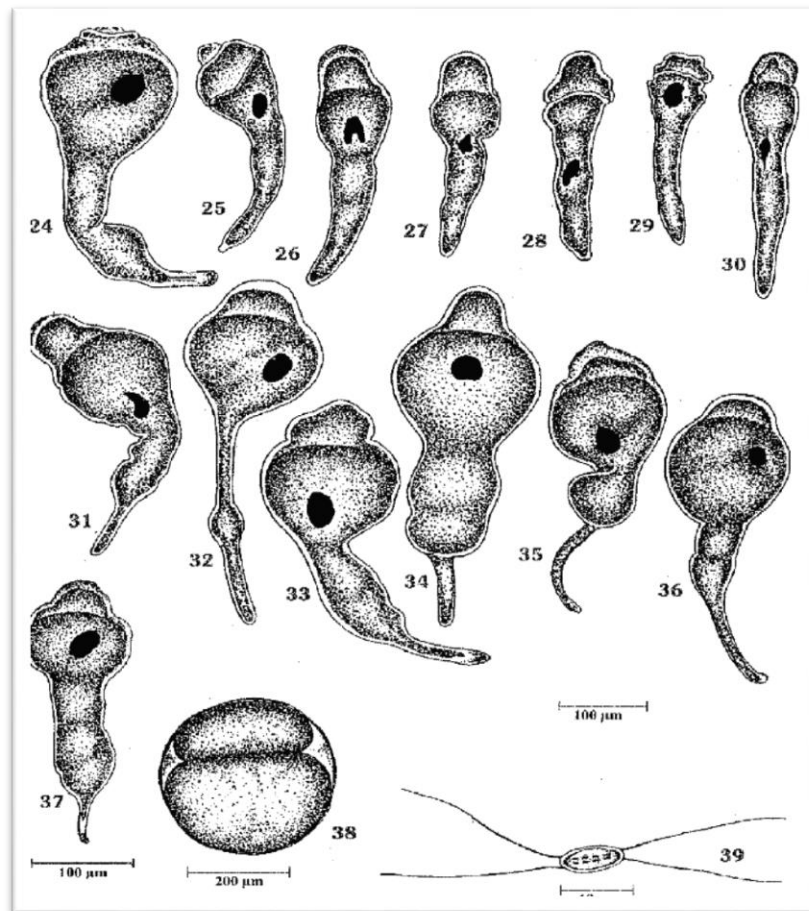


Classification of Phylum Apicomplexa:



1. Class Conoidasida

- Members of this class possess a **conoid** in the apical complex throughout their lifecycle.
- Includes well-known parasites responsible for diseases in both humans and animals.



A. Subclass Coccidia

- These are primarily **intracellular parasites** of vertebrates and invertebrates, often infecting the digestive tract and other organs.
- **Important Orders:**
 1. **Order Eucoccidiorida**
 - **Example: Plasmodium** (causative agent of malaria), **Toxoplasma gondii** (causative agent of toxoplasmosis), **Cryptosporidium** (causative agent of cryptosporidiosis), and **Eimeria** (causative agent of coccidiosis).
 2. **Order Haemosporida**
 - Includes **Plasmodium** species that infect vertebrates, including humans, birds, and reptiles.

B. Subclass Gregarinasina (Gregarinia)

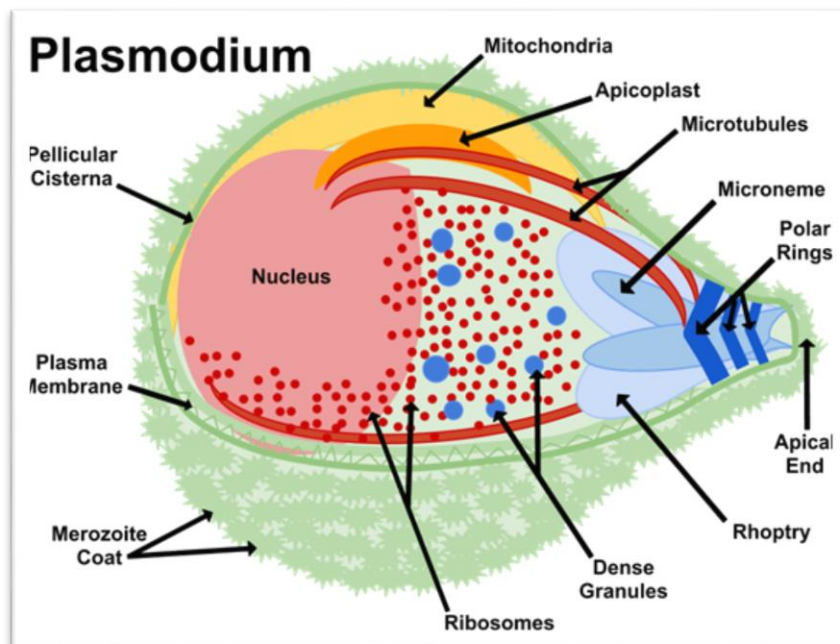
- These are parasites of invertebrates, often infecting the body cavities or the digestive tract of arthropods and annelids.
- **Examples: Gregarina**, which infects invertebrate hosts such as insects and worms.

2. Class Aconoidasida

- Members of this class lack the **conoid** in the apical complex in the mature stage, although it may be present in other life stages.

A. Order Haemosporida

- These are blood parasites that are transmitted by blood-sucking insect vectors.
- **Example: Plasmodium** (causative agents of malaria in humans and animals).



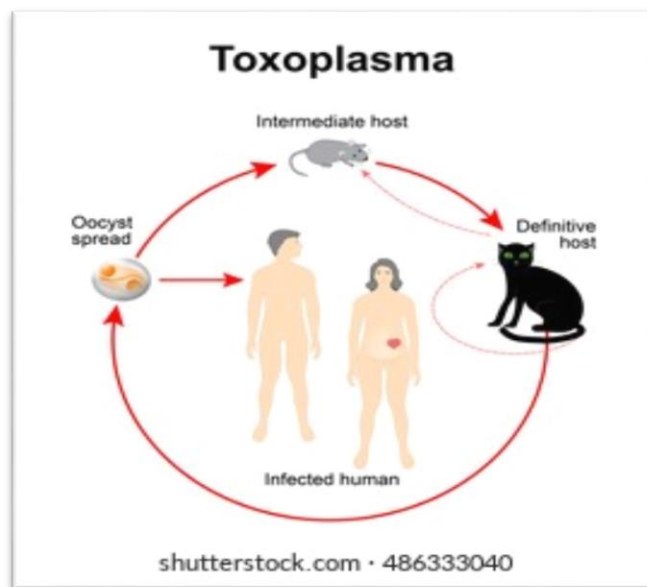
B. Order Piroplasmida

- These parasites infect red blood cells and are transmitted by ticks.

- **Examples: Babesia** (causative agent of babesiosis in animals and humans), **Theileria** (causative agent of theileriosis in livestock).

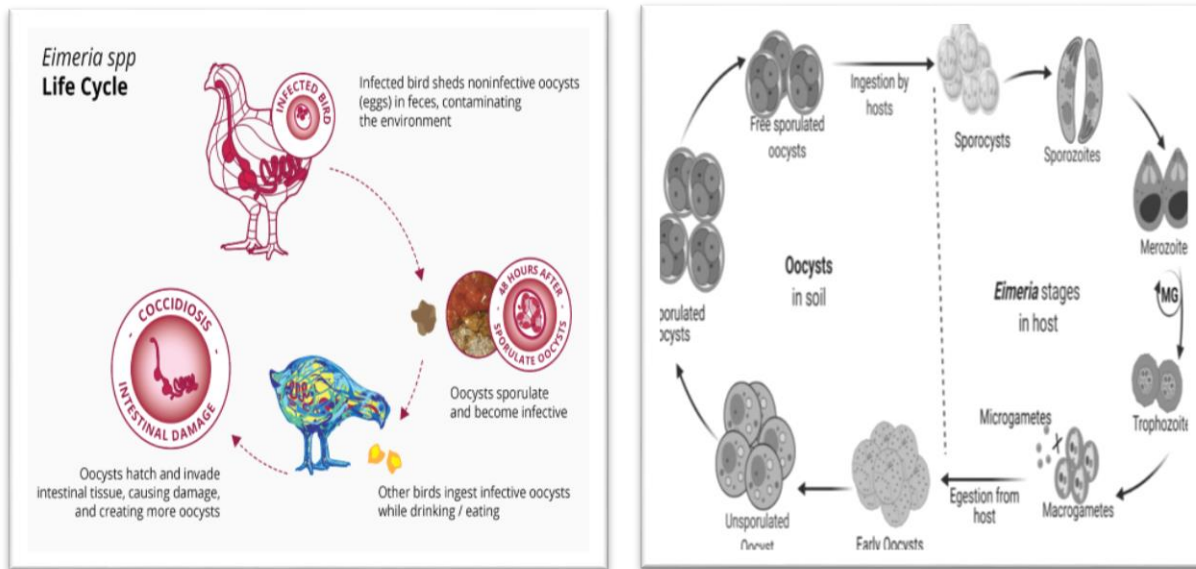
Examples of Notable Apicomplexan Parasites:

1. **Plasmodium** (Class Aconoidasida, Order Haemosporida)
 - Responsible for malaria in humans, with species like *Plasmodium falciparum* (the deadliest), *P. vivax*, *P. ovale*, and *P. malariae*.
 - Lifecycle involves two hosts: a mosquito (vector) and a vertebrate (human).
2. **Toxoplasma gondii** (Class Conoidasida, Order Eucoccidiorida)
 - Causes **toxoplasmosis**, a disease that can have serious consequences for immunocompromised individuals and during pregnancy.
 - Cats are the definitive host, while many mammals and birds can act as intermediate hosts.



3. **Cryptosporidium** (Class Conoidasida, Order Eucoccidiorida)
 - Causes **cryptosporidiosis**, a diarrheal disease that can be severe in immunocompromised individuals.
 - Transmission occurs via ingestion of oocysts in contaminated water or food.
4. **Eimeria** (Class Conoidasida, Order Eucoccidiorida)
 - Causes **coccidiosis** in livestock and poultry, leading to significant economic losses.

- The parasite invades the intestinal cells, causing severe diarrhea and dehydration.



5. **Babesia** (Class Aconoidasida, Order Piroplasmida)

- Responsible for **babesiosis**, a malaria-like illness that infects red blood cells, typically transmitted by ticks.

6. **Theileria** (Class Aconoidasida, Order Piroplasmida)

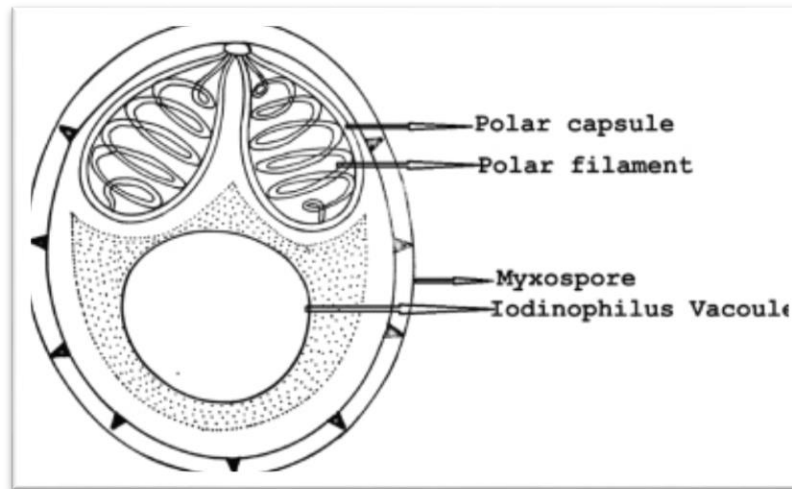
- Causes **theileriosis** in cattle, transmitted by ticks. Some species, like **Theileria parva**, can be deadly.

Lifecycle Overview (Example: Plasmodium)

1. **Sporogony** (in the mosquito): Sporozoites are formed and transmitted to a new host during a mosquito bite.
2. **Schizogony** (in the vertebrate host): Sporozoites infect liver cells and multiply, producing **merozoites**, which then invade red blood cells.
3. **Gametogony**: Infected red blood cells produce male and female gametocytes, which are taken up by another mosquito. Inside the mosquito, they form zygotes, restarting the cycle.

4. **Phylum Cnidosporidia**

The **Phylum Cnidosporidia** is a group of microscopic, parasitic protozoa that are primarily known for infecting aquatic organisms, particularly fish. These protozoans are characterized by the presence of unique **spore-like structures** that assist in their transmission and survival outside the host. They are part of the broader group of **spore-forming parasites** and belong to the supergroup **Amoebozoa** within the Protozoa. The phylum is divided into several important groups, including **Myxosporea** and **Microsporidia**.



Spore structure

General Characteristics of Cnidosporidia:

1. Parasitic Nature:

- All Cnidosporidia species are obligate parasites, meaning they require a host organism to complete their life cycle.
- They infect a wide range of aquatic animals, including fish, amphibians, and invertebrates.

2. Spore Formation:

- These organisms produce **spores**, which are highly resistant, thick-walled cells that allow them to survive in harsh environmental conditions outside the host. The spores are used to infect new hosts.
- The spores typically contain one or more **polar filaments** that act as a mechanism for injecting infectious material into host cells.

3. Complex Life Cycles:

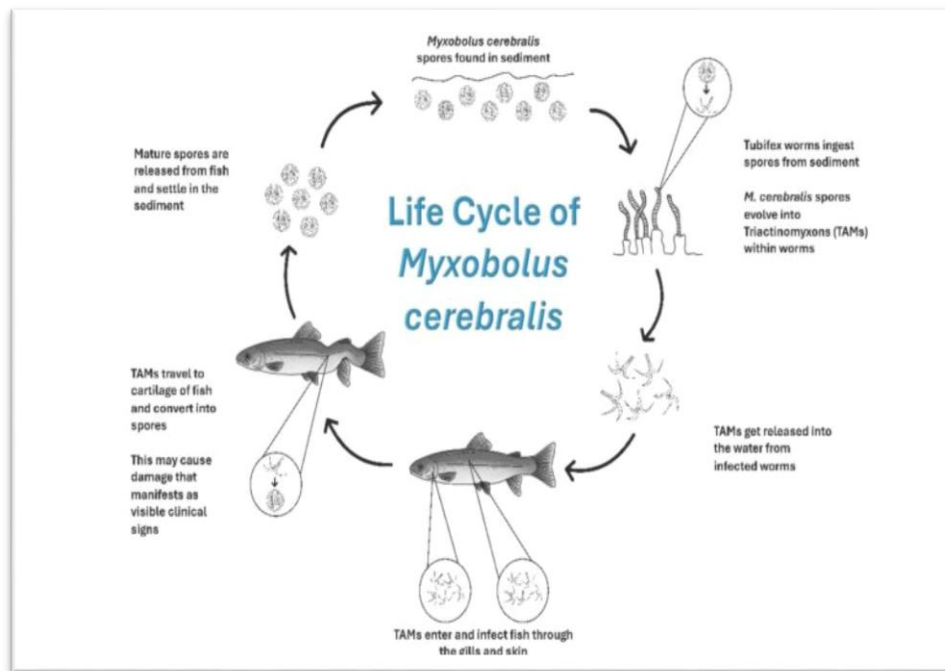
- The life cycles of Cnidosporidia typically involve multiple stages, with both sexual and asexual reproduction. In many cases, different life stages occur in different hosts.
- The cycle often involves a host-to-host transmission through the release of spores in the environment.

4. Host Specificity:

- Many species of Cnidosporidia exhibit a high degree of host specificity, meaning that they infect specific species or groups of organisms.
- Some species are economically important due to their impact on fisheries and aquaculture.

5. Polar Capsules and Polar Filaments:

- One of the most distinctive features of Cnidosporidia is the presence of **polar capsules**, which are unique, specialized organelles inside the spores. These capsules contain **polar filaments** that can be extruded to penetrate host cells and inject the infectious stages of the parasite.



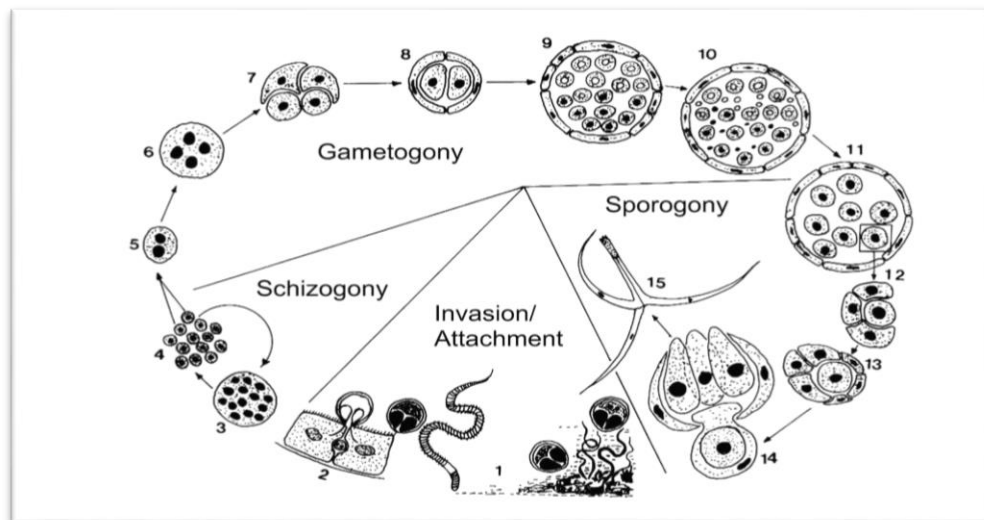
Classification of Phylum Cnidosporidia:

1. Class Myxosporea:

- **Myxosporea** is a class of microscopic parasites that primarily infect fish and other aquatic vertebrates. Some species are known to cause significant diseases in aquaculture.
- These parasites have complex life cycles that often involve two hosts: a fish and an annelid worm (as a secondary host).
- The life cycle includes the production of resistant **myxospores**, which are released when the host dies or sheds them into the environment.

Example of Myxosporean parasites:

- **Myxobolus cerebralis**: The causative agent of **whirling disease** in fish, particularly trout and salmon.



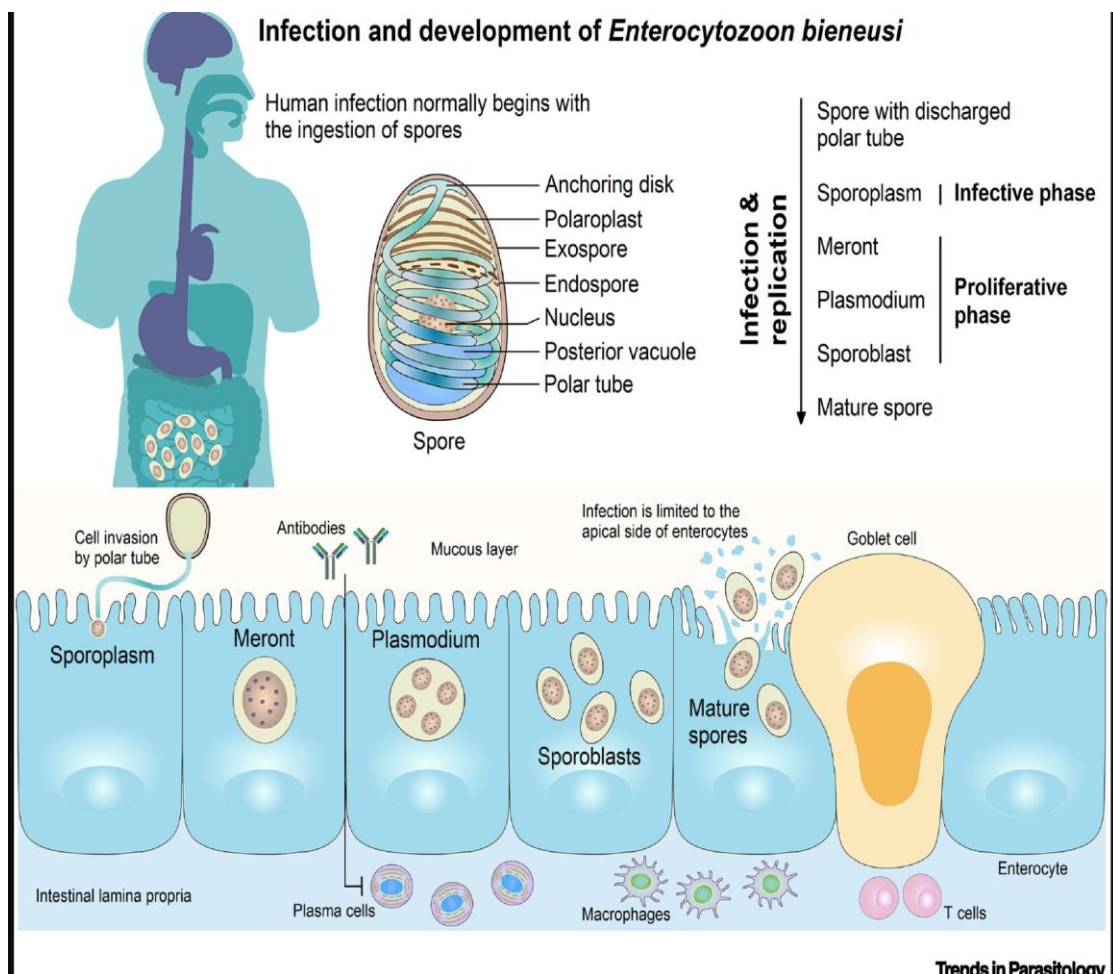
- **Kudoa spp.:** Known to infect the muscles of fish, causing soft flesh syndrome.

2. Class Microsporidia:

- **Microsporidia** are obligate intracellular parasites that infect a wide range of hosts, including fish, insects, and mammals (even humans). These parasites are highly adapted to live inside host cells.
- They are known for their extreme reduction in cellular structures and small genome size, making them highly specialized for parasitism.
- Microsporidia produce highly resistant spores that are capable of surviving outside the host for long periods, making them highly effective in transmission.

Example of Microsporidian parasites:

- **Nosema spp.:** Parasites of insects, particularly honeybees, causing **nosema disease**.
- **Enterocytozoon bienersi:** A microsporidian parasite that can infect humans and is particularly problematic in immunocompromised individuals.

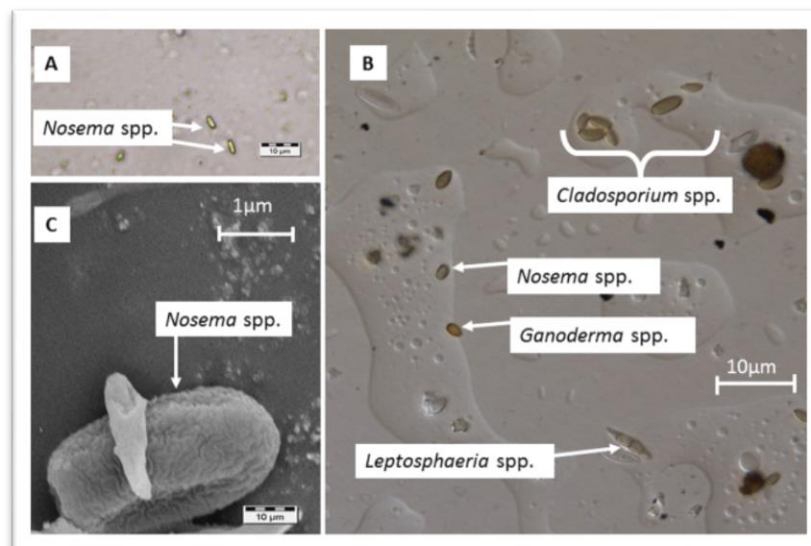


Life Cycle:

- Cnidosporidians have complex life cycles that typically include both **asexual reproduction** (schizogony) and **sexual reproduction**.
- The life cycle often begins with the release of spores into the environment, where they are ingested or come into contact with a new host.
- Inside the host, the spores germinate, releasing the infectious material into the host cells. The parasite then undergoes various developmental stages, often resulting in the production of new spores.
- In some species, the life cycle involves an intermediate host, making the infection process more complex.

Economic and Ecological Importance:

- **Fisheries and Aquaculture:** Cnidosporidia parasites, particularly those from the Myxosporea class, are significant pathogens in aquaculture, leading to economic losses due to fish mortality, reduced growth, and compromised fish quality.
- **Impact on Biodiversity:** In natural ecosystems, Cnidosporidia can impact fish populations, leading to changes in biodiversity and ecosystem health.



Differences between Protozoa Phylums

Feature	Sarcomastigophora	Apicomplexa	Ciliophora	Cnidosporidia
Locomotion	Pseudopodia or flagella	No distinct locomotion structures	Cilia	Axopods or polar filaments
Reproduction	Asexual (binary fission), some sexual forms	Complex life cycle, sexual & asexual phases	Asexual (binary fission) and sexual (conjugation)	Asexual (binary fission), sporogony and gamogony
Feeding Mechanism	Phagocytosis or ingestion through cytostome	Absorbs nutrients through host ↓ Ils	Phagocytosis, cytostome present	Parasitic absorption from host
Habitat	Free-living or parasitic	Mostly parasitic (inside hosts)	Free-living in aquatic environments	Mostly parasitic
Examples	Amoeba, Trypanosoma	Plasmodium (causes malaria)	Paramecium, Stentor	Myxobolus, Microsporidia
Special Structures	Flagella or pseudopods for movement	Apical complex for host cell penetration	Cilia for movement and feeding	Spore-forming structures
Skeletal Structures	Usually absent	None	Pellicle	Spore walls, polar capsules

Sub-kingdom of Metazoa

The sub-kingdom **Metazoa** (also known as **Animalia**) includes multicellular organisms that exhibit tissue differentiation and complex body structures. Metazoa is broadly classified into two major subgroups:

1. Parazoa

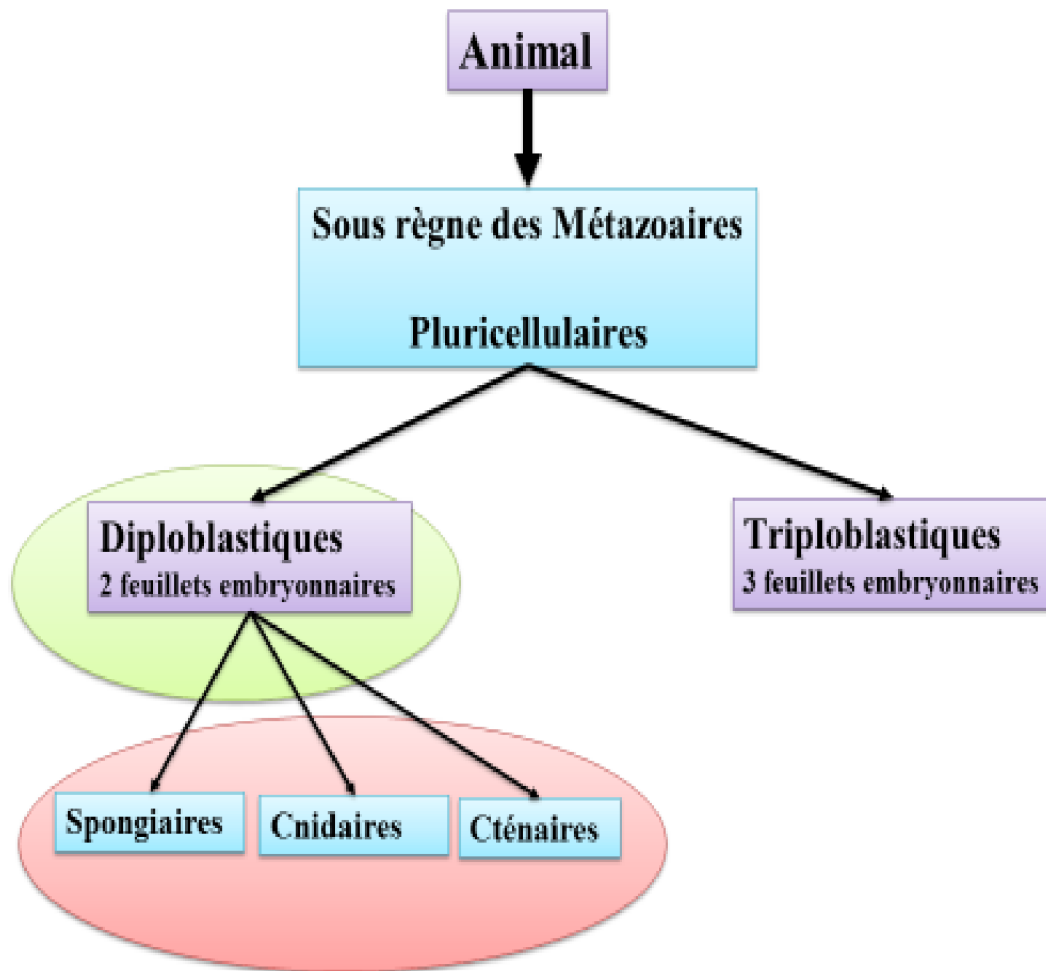
- **Defining Feature:** Lack of true tissues and organs.
- **Phyla Included:**
 - **Porifera (Sponges):** The only phylum in this group. These are simple animals with porous bodies, lacking true tissues, and typically marine.
- **Characteristics:**
 - No distinct tissues or organs.
 - Cellular level of organization.
 - Mostly sessile and filter feeders.

2. Eumetazoa

- **Defining Feature:** Presence of true tissues and organs, more complex organization.
- **Further Classification:**
 - **Radiata** (Animals with radial symmetry) and **Bilateria** (Animals with bilateral symmetry).
- **Phyla Included:**
 - **Radiata:**
 - **Cnidaria** (jellyfish, corals, sea anemones).
 - **Ctenophora** (comb jellies).
 - **Bilateria** (divided into three major groups):
 - **Acoelomates:** No body cavity (e.g., Platyhelminthes – flatworms).
 - **Pseudocoelomates:** Body cavity not completely lined by mesoderm (e.g., Nematoda – roundworms).

- **Coelomates:** True body cavity (e.g., Annelida, Arthropoda, Mollusca, Chordata).

Eumetazoa is far more diverse, with a complex structure and includes all animals from jellyfish to humans.

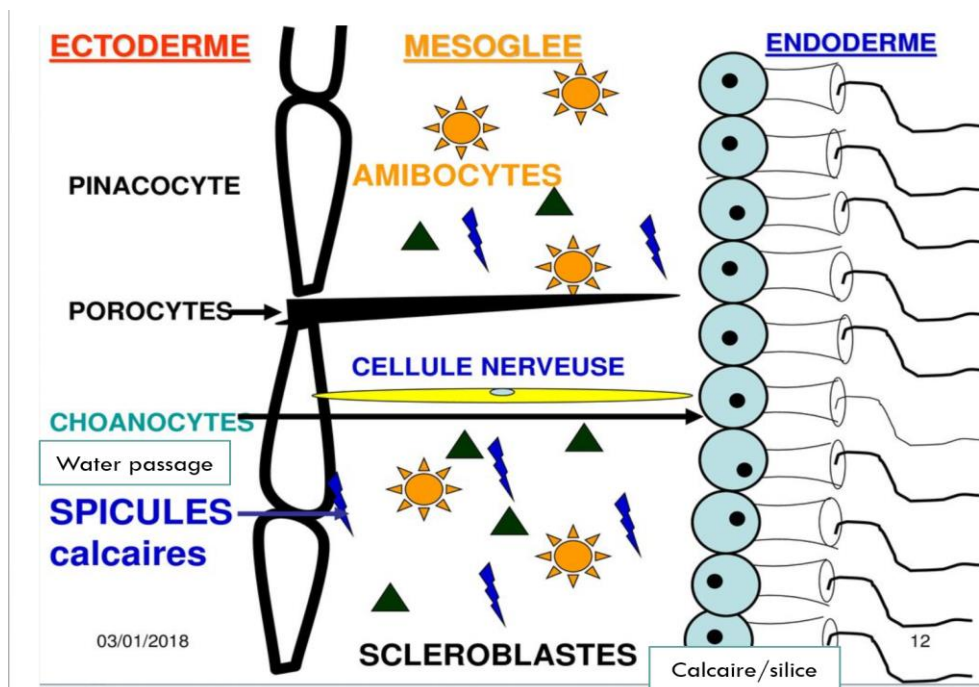


I. The phylum Spongia (Porifera)

The **phylum Porifera**, commonly known as **sponges**, is a group of simple, multicellular organisms that are primarily aquatic, mostly marine, but a few live in freshwater environments. Sponges are among the most primitive animals and are known for their porous bodies, through which water circulates. They lack true tissues, organs, and body symmetry.

Key Characteristics of Phylum Porifera (Sponges):

1. **Body Structure:** Sponges have a porous body with numerous holes (pores) called **ostia** for water inflow and a larger opening called the **osculum** for water outflow. They possess a simple, loose aggregation of cells.
2. **Cell Types:**
 - **Choanocytes** (collar cells): Responsible for creating water currents and capturing food particles.
 - **Amoebocytes:** Distribute nutrients and help in producing the sponge's skeleton.
 - **Pinacocytes:** Flat cells that form the outer layer of the sponge.



3. **Skeleton:** The skeleton of sponges is made of spicules (composed of silica or calcium carbonate) or spongin (a fibrous protein).
4. **Reproduction:**
 - **Asexual:** By budding, fragmentation, or producing **gemmules** (dormant structures for surviving harsh conditions).
 - **Sexual:** Most sponges are hermaphroditic, producing both eggs and sperm.
5. **Feeding:** Sponges are filter feeders. They draw water in through their pores, filter out small particles like plankton and bacteria, and expel the water through the osculum.
6. **Habitat:** Primarily marine, sponges are found attached to rocks, corals, or other submerged surfaces in oceans, though some species live in freshwater.

Life cycle of Spongia

The **life cycle of sponges (Phylum Porifera)** is relatively simple compared to other animals, and it primarily involves both **sexual and asexual reproduction**. Here's an outline of the sponge's life cycle:

1. Asexual Reproduction

- Sponges can reproduce **asexually** by:
 - **Budding:** Small buds form on the parent sponge, which eventually detach and grow into new sponges.
 - **Fragmentation:** Pieces of the sponge break off and can develop into new individuals.
 - **Gemmules:** In unfavorable conditions (e.g., drought), sponges produce **gemmules**—clusters of cells that can survive harsh conditions and later grow into new sponges.

2. Sexual Reproduction

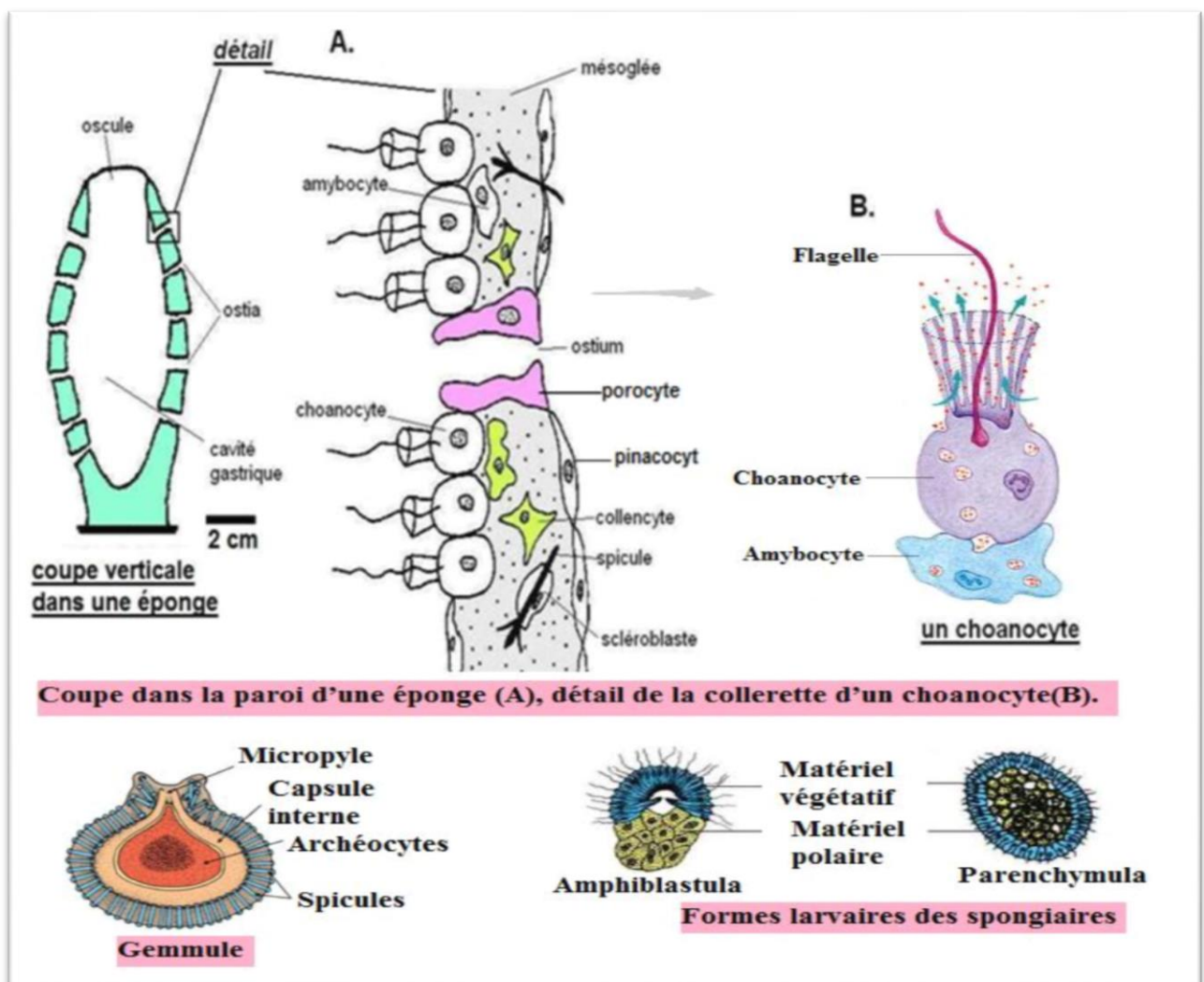
- Most sponges are **hermaphrodites**, meaning they can produce both **eggs and sperm**.
- Sperm is released into the water by one sponge and taken in by another through their **pores**.

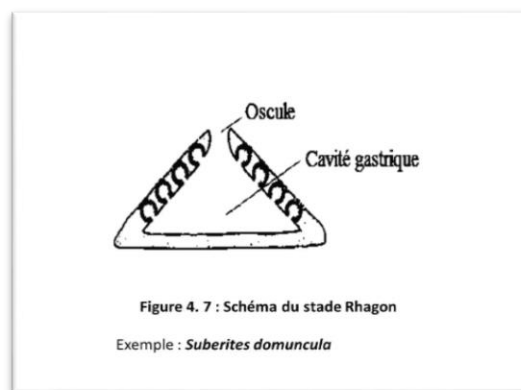
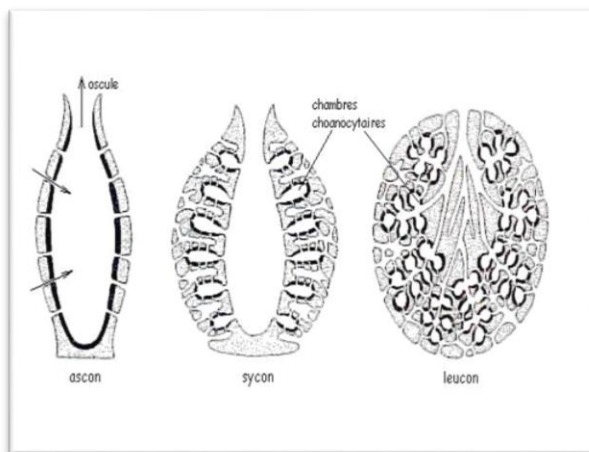
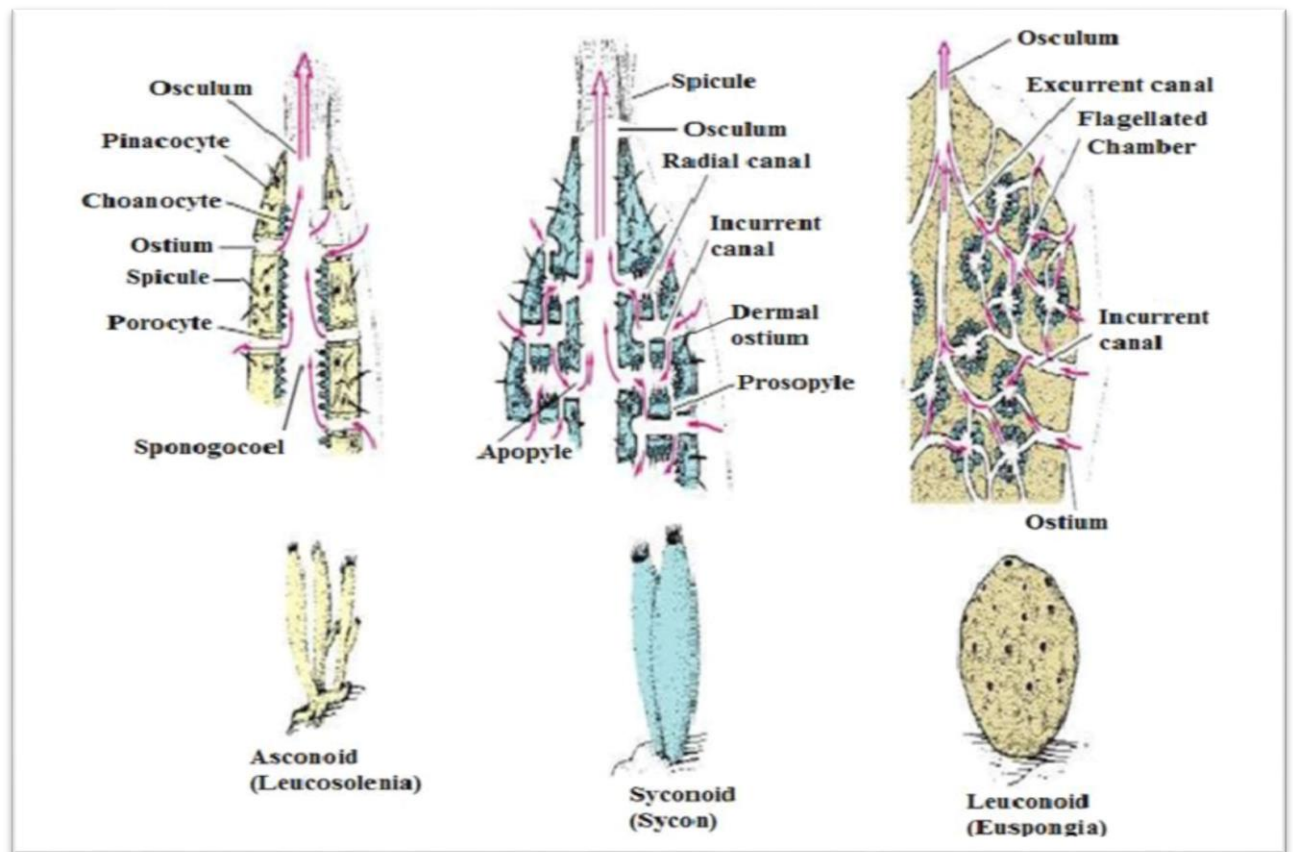
3. Fertilization

- **Internal fertilization** occurs inside the sponge after sperm is captured by specialized cells called **choanocytes**.
- The sperm travels to an egg located in the sponge's body, resulting in the formation of a **zygote**.

4. Larval Stage

- The zygote develops into a free-swimming, ciliated larva called a **parenchymula** or **amphiblastula**.
- This larval stage swims in the water for a short time before settling on a suitable substrate.





5. Metamorphosis

- The larva attaches to a substrate and undergoes **metamorphosis** into a **juvenile sponge**.
- It then develops into an adult sponge, growing in size and forming its characteristic porous structure.

6. Adult Sponge

- The adult sponge is typically **sessile** (non-motile), attached to a solid surface, filtering water for food particles and continuing the reproductive cycle.

Examples of Classes in Phylum Porifera:

1. **Class Calcarea:** Sponges with calcium carbonate spicules.

Skeletal Composition: Composed of calcium carbonate spicules.

Body Forms: May have asconoid, syconoid, or leuconoid structures.

Habitat: Mostly found in shallow marine waters

(zone creuse). **Examples:** *Leucosolenia*, *Clathrina*, olynthus



Clathrina

2. **Class Hexactinellida** (Glass sponges): Sponges with silica spicules.
- Example: *Euplectella* (Venus flower basket).



Euplectella

3. **Class Demospongiae**: The largest class, with skeletons made of spongin and/or silica.
- Example: *Spongia officinalis* (bath sponge).



Spongia officinalis

II. The phylum of Cnidaria.

The **phylum of Cnidaria** includes a variety of aquatic, mostly marine organisms known for their stinging cells called **cnidocytes**, which they use for prey capture and defense, examples of Cnidarians: **Jellyfish, Sea anemones, Corals, Hydras.**



Jellyfish



Sea anemones



Corals



Hydras

Characteristics of Phylum Cnidaria:

1. Radial Symmetry:

- Cnidarians exhibit radial symmetry, meaning their body parts are arranged around a central axis. This allows them to interact with the environment from all directions.

2. **Diploblastic:**

- Cnidarians have two primary germ layers, **ectoderm** and **endoderm**, with a non-cellular jelly-like layer called **mesoglea** in between.

3. **Cnidocytes (Stinging Cells):**

- They possess specialized cells called **cnidocytes**, which contain organelles called **nematocysts**. These stinging cells are used for capturing prey and defense.

4. **Body Forms:**

- Cnidarians have two distinct body forms:
 - **Polyp:** A sessile (attached) form, like sea anemones and corals.
 - **Medusa:** A free-swimming, umbrella-shaped form, like jellyfish.

5. **Gastrovascular Cavity:**

- They have a central body cavity, called the **gastrovascular cavity**, which functions as both the digestive and circulatory system. There is a single opening that serves as both the mouth and anus.

6. **Nervous System:**

- Cnidarians have a simple **nerve net** instead of a centralized brain, allowing for basic responses to stimuli.

7. **Reproduction:**

- **Asexual reproduction** usually occurs through budding in the polyp form.
- **Sexual reproduction** typically involves medusae, where gametes are released into the water for external fertilization. Some species can alternate between sexual and asexual reproduction (alternation of generations).

8. **Tentacles:**

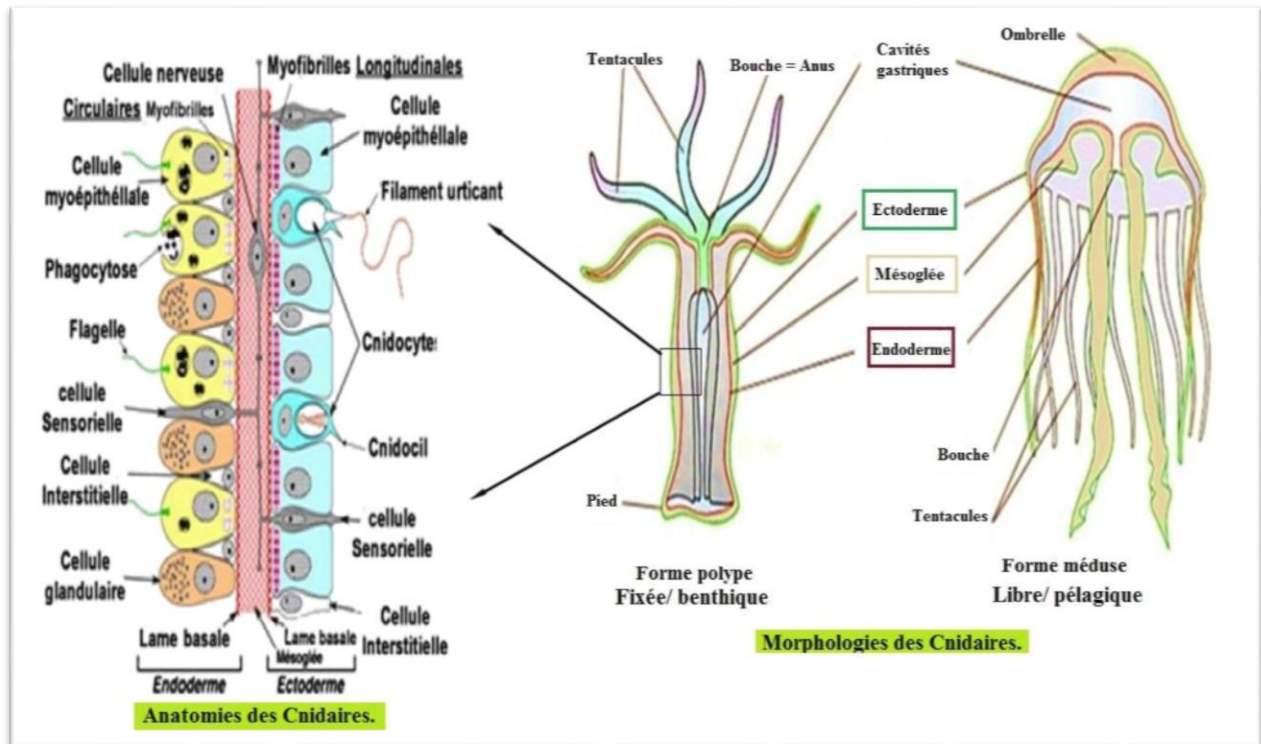
- They have tentacles surrounding the mouth, which are equipped with cnidocytes to capture prey.

9. **Aquatic Habitat:**

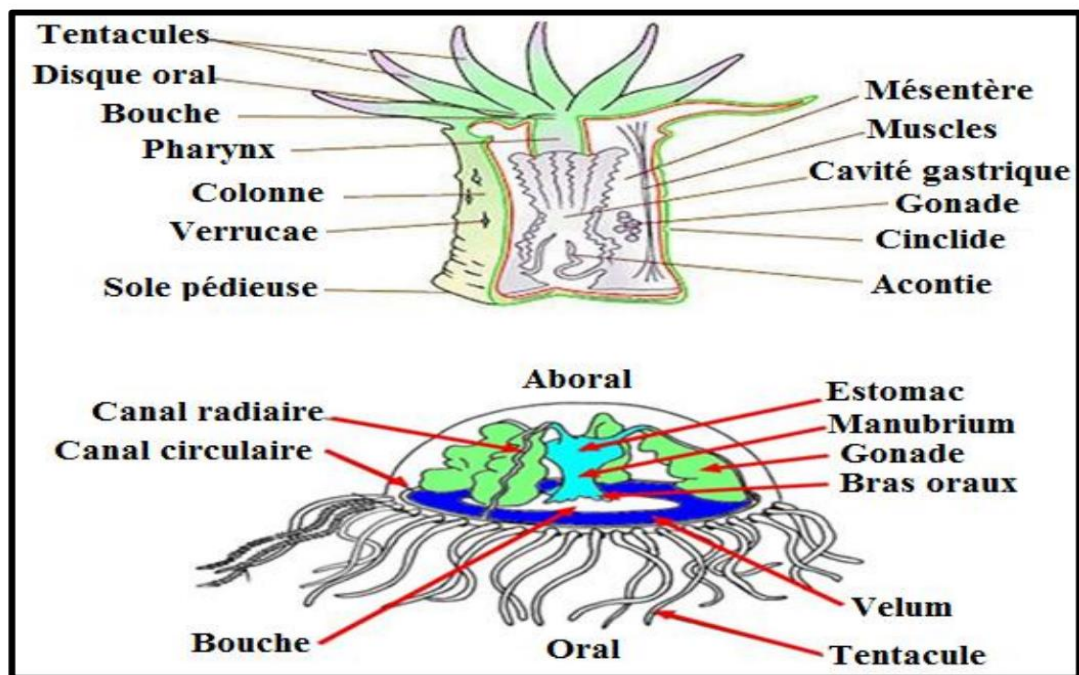
- Cnidarians are mostly marine, but some, like hydras, are found in freshwater environments.

10. **No Excretory or Respiratory Systems:**

- They lack specialized systems for excretion and respiration; exchange of gases and waste removal occurs through diffusion across the body surface.



Morphology of Cnidaria



Anatomy of Cnidaria

Life cycle of Cnidaria

The **life cycle of Cnidaria** is fascinating, as it can involve both sexual and asexual reproduction, with two distinct body forms: the **polyp** and the **medusa**. The cycle varies depending on the class, but here is a general outline of the life cycle seen in many cnidarians, especially **Hydrozoa** and **Scyphozoa**.

1. Polyp Stage

- The polyp is typically a **sessile** (non-moving) form that attaches to a substrate.
- It reproduces **asexually** by budding, forming new polyps or **medusae**.
- Polyps can exist singly or in colonies.

2. Asexual Reproduction (Budding)

- Polyps can reproduce asexually by **budding**, where new individuals are produced as outgrowths of the parent polyp.
- In some cnidarians, polyps can also produce medusae asexually through a process called **strobilation**, where segments of the polyp break off and develop into medusae.

3. Medusa Stage

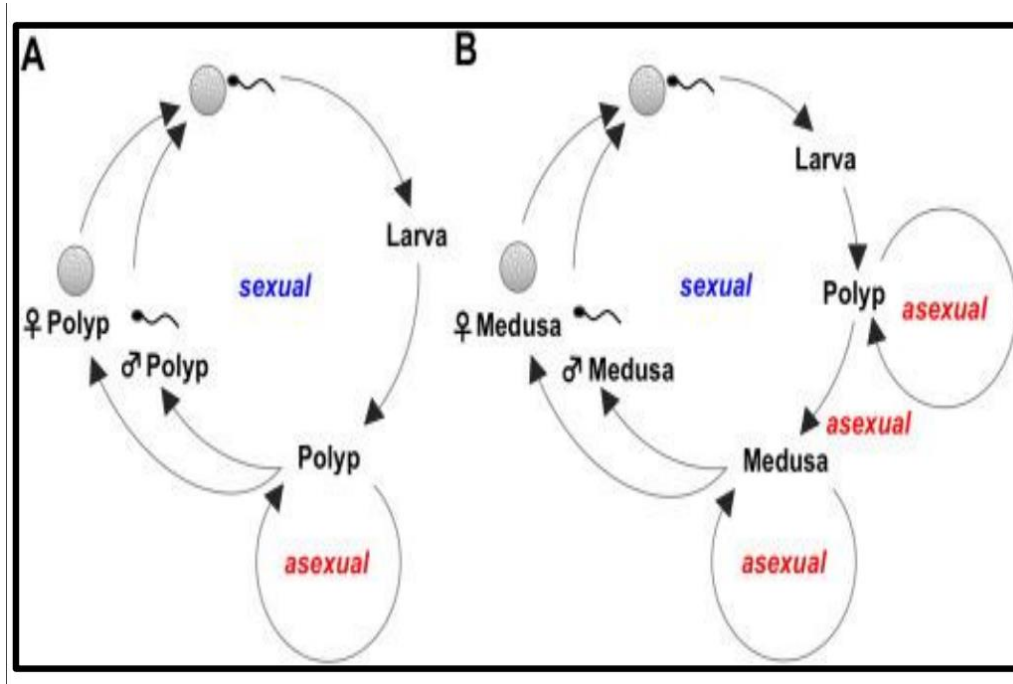
- The **medusa** is the free-swimming, sexual stage of the life cycle.
- Medusae are **motile** and resemble jellyfish, floating through the water with tentacles.
- In species where medusae are present, they reproduce **sexually** by producing eggs and sperm.

4. Sexual Reproduction

- **Medusae** release **eggs** and **sperm** into the water (external fertilization).
- Fertilization results in the formation of a **zygote**, which develops into a **planula larva**.

5. Planula Larva

- The **planula** is a free-swimming, ciliated larva that swims through the water for a short period.
- Eventually, the planula settles on a substrate and develops into a new **polyp**, starting the cycle again.



Classification of Cnidaria

The classification of the phylum **Cnidaria** is based on body structure, life cycle, and other biological characteristics. Here is a simple classification of Cnidaria: Cnidarians are aquatic, mostly marine organisms, characterized by the presence of cnidocytes, specialized cells for capturing prey.

1. Class *Hydrozoa*

- These organisms are generally small and colonial.
- Most have both polyp and medusa stages in their life cycle.
- **Examples:** *Hydra*, *Obelia*, *Portuguese man o' war* (*Physalia physalis*).

2. Class Scyphozoa

- Also known as the "true jellyfish."
- Medusa is the dominant stage, and the polyp is reduced or absent.
- **Examples:** *Aurelia* (moon jellyfish), *Cyanea*.

3. Class Cubozoa

- Box-shaped medusae.
- Known for their highly potent venom.
- **Examples:** *Chironex fleckeri* (box jellyfish), *Carukia barnesi* (Irukandji jellyfish).

4. Class Anthozoa

- Polyps only, no medusa stage.
- Includes corals and sea anemones.
- **Examples:** *Actinia* (sea anemone), *Acropora* (stony coral).

Subclasses in Anthozoa:

- **Hexacorallia:** Includes hard corals and sea anemones.
- **Octocorallia:** Includes soft corals and gorgonians (sea fans)

III. **Phylum Ctenophora** الهلاميات

The **Phylum Ctenophora**, commonly known as **comb jellies**, includes marine organisms that are mostly planktonic and bear a superficial resemblance to jellyfish. However, they belong to a distinct phylum and are characterized by several unique features. Here's an overview:

Key Characteristics of Ctenophora

1. Body Structure:

- Ctenophores have soft, **gelatinous**, and nearly transparent bodies, often bi-radially symmetrical.
- Their size varies from a few millimeters to over a meter in length.

2. Comb Rows (Ctenes):

- The name "Ctenophora" comes from the Greek words for "comb" and "bearing." Their bodies are lined with **rows of ciliary plates called ctenes** that beat in coordinated waves, propelling the animal through the water.
- These rows give them a characteristic shimmering or rainbow effect when they swim.

3. Tentacles:

- Many ctenophores have two tentacles, although some species are tentacle-less.
- Unlike jellyfish, they lack stinging cells (cnidocytes) and instead capture prey using specialized sticky cells called **colloblasts** found on their tentacles.

4. Locomotion and Feeding:

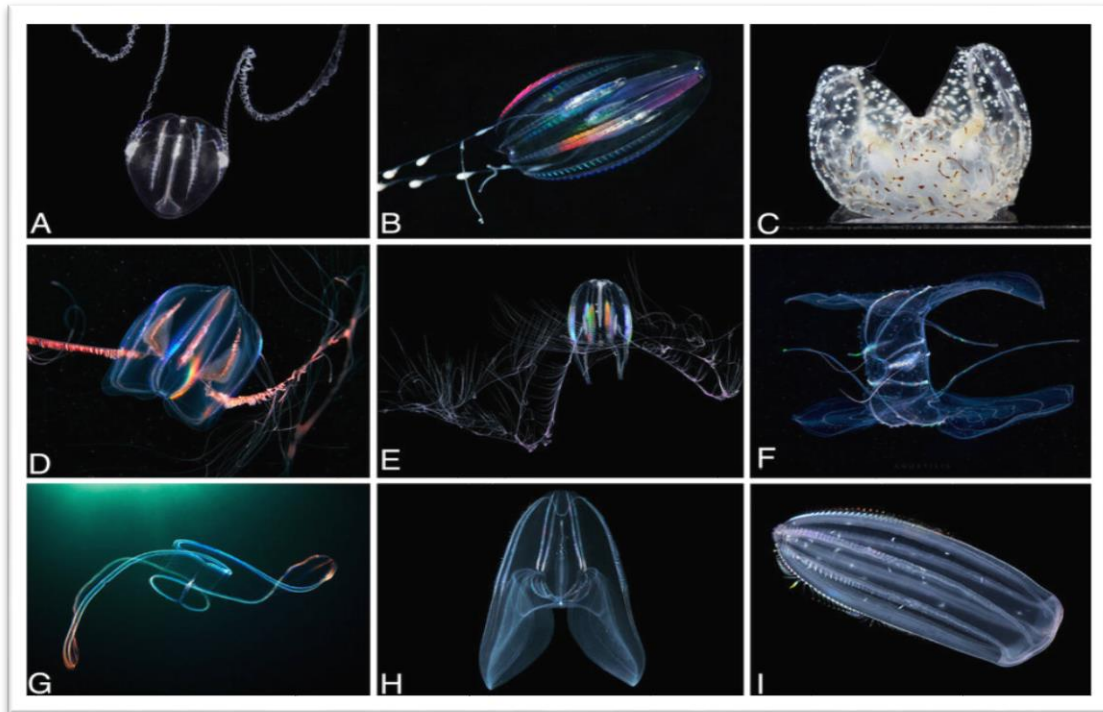
- Ctenophores are propelled by ciliary movement rather than muscular contraction.
- They are carnivorous, feeding on small plankton, larval fish, and other tiny marine animals.

5. Reproduction:

- Most are hermaphroditic, possessing both male and female reproductive organs.
- They typically reproduce sexually, with some species also capable of asexual reproduction through fragmentation.

6. Bioluminescence:

- Many ctenophores produce light, an adaptation that may help them in predator evasion or communication.



Classification of Ctenophora

The Phylum **Ctenophora** is divided into two main classes **based on morphology and the presence or absence of tentacles**. Here is the classification of Ctenophora:

1. Class Tentaculata (with tentacles)

- **Characteristics:**

- Members of this class have tentacles that contain *colloblasts*, specialized cells that release a sticky substance to capture prey.
- Tentacles can retract into sheaths when not in use.

- **Orders within Tentaculata:**

1. **Cydingpida:** Globular or oval-shaped; long tentacles. Example: *Pleurobrachia* (sea gooseberry).

2. **Lobata:** Features lobes on either side of the body that assist in prey capture. Example: *Mnemiopsis*.
3. **Cestida:** Ribbon-like, flattened body; unique for its elongated shape. Example: *Cestum* (Venus' girdle).
4. **Platyctenida:** Flattened body; mostly benthic, meaning they live near or on the seabed. Example: *Coeloplana*.
5. **Ganeshida:** Less common, recently described group with unique anatomical features. Example: *Ganeshia*.

2. Class Nuda (without tentacles)

- **Characteristics:**
 - Lack tentacles in adulthood.
 - They have large mouths and are specialized for engulfing other ctenophores.
- **Order within Nuda:**
 - **Beroida:** The only order within Nuda, characterized by a large mouth that opens wide to consume prey whole. Example: *Beroe*.

Summary of Classification

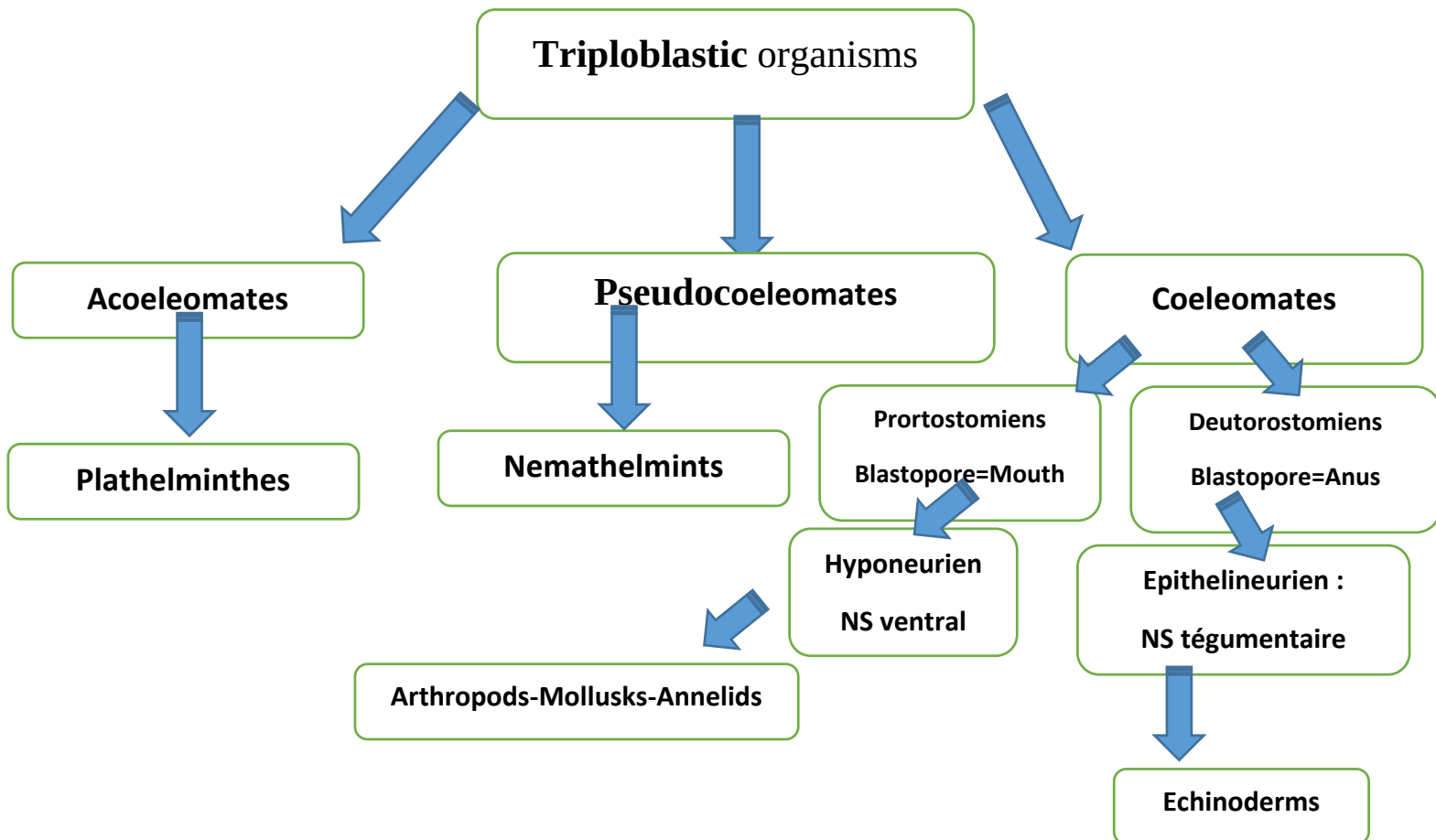
Class	Order	Example	Key Features
Tentaculata	Cydippida	<i>Pleurobrachia</i>	Globular, long tentacles
	Lobata	<i>Mnemiopsis</i>	Lobes for prey capture, bi-radial symmetry
	Cestida	<i>Cestum</i>	Ribbon-like, elongated body
	Platyctenida	<i>Coeloplana</i>	Flattened, benthic
	Ganeshida	<i>Ganeshia</i>	Recently described, unique features
Nuda	Beroida	<i>Beroe</i>	No tentacles, large mouth for engulfing prey

Feature	Spongia (Porifera)	Cnidaria	Ctenophora
Body Symmetry	Asymmetrical or radial symmetry	Radial or biradial symmetry	Biradial symmetry
Body Structure	No true tissues or organs; porous body	Diploblastic with tissues, simple organs, no complex organs	Diploblastic with simple tissue layers
Body Layers	Outer pinacoderm, inner choanoderm, mesohyl in between	Epidermis, gastrodermis, and mesoglea	Epidermis, gastrodermis, and mesoglea
Germ Layers	None (parazoa, lack true tissues)	Diploblastic (two germ layers: ectoderm and endoderm)	Diploblastic
Feature	Spongia (Porifera)	Cnidaria	Ctenophora
Body Symmetry	Asymmetrical or radial symmetry	Radial or biradial symmetry	Biradial symmetry
Germ Layers	None (parazoa, lack true tissues)	Diploblastic (two germ layers: ectoderm and endoderm)	Diploblastic
Nervous System	Absent	Nerve net with sensory cells	Nerve net with more advanced sensory structures
Locomotion	Sessile (fixed)	Free-swimming or sessile; some medusae have tentacles	Free-swimming with ciliary rows called comb plates
Feeding Method	Filter feeding via choanocytes	Predatory, using nematocysts (stinging cells)	Predatory, using sticky cells (colloblasts)
Digestive System	Intracellular digestion, no true digestive cavity	Gastrovascular cavity (incomplete digestive system)	Gastrovascular cavity (branched, incomplete)
Reproduction	Asexual (budding, fragmentation), sexual	Asexual (budding, polyp division), sexual (gametes)	Primarily sexual; some asexual reproduction
Respiratory System	Diffusion	Diffusion	Diffusion

Triploblastics (Tridermic) animals

Triploblastic organisms are animals whose embryonic development forms three distinct germ layers:

1. **Ectoderm**: the outer layer, which typically forms the skin, nervous system, and parts of the sensory system.
2. **Mesoderm**: the middle layer, which gives rise to muscles, the circulatory system, bones, and other connective tissues.
3. **Endoderm**: the inner layer, developing internal organs like the lungs, liver, and digestive system.



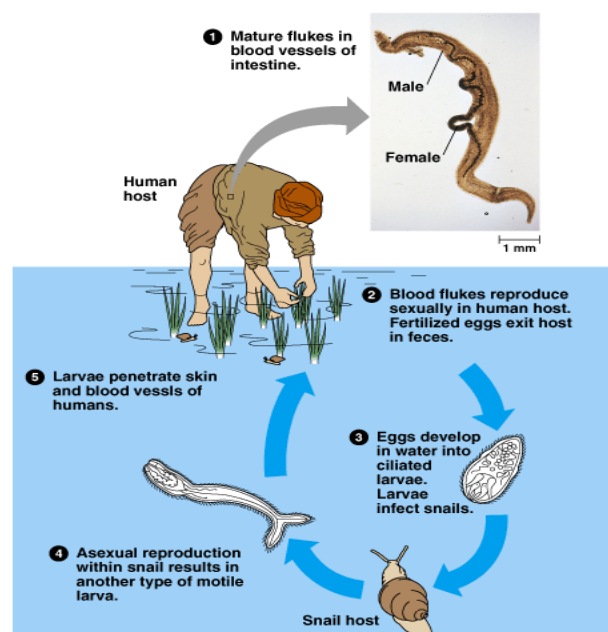
IV. Phylum Platyhelminthes (Flatworms) ديدان مسطحة

The Phylum of Platyhelminthes belongs to kingdom Animalia. This phylum includes 13,000 species. The organisms are also known as flatworms. These are acoelomates and they include many free-living and parasitic life forms. Members of this phylum range in size from a single-celled organism to around 2-3 feet long. This group includes several distinct types:

- ✓ Free-living flatworms - These include species such as planarians, which are often found in aquatic environments and have the ability to regenerate lost body parts.
- ✓ Parasitic flatworms - A significant number of flatworms are parasitic, and they can infect various hosts, including humans and animals. Key parasitic groups include: **Trematodes** (flukes), which can live inside the organs of host animals. **Cestodes** (tapeworms), which live in the intestines of vertebrates and absorb nutrients directly from their host.
- ✓ Dorsoventrally Flattened Body: This allows them to efficiently exchange gases and nutrients directly through their body surface, as they lack specialized respiratory and circulatory systems.
- ✓ Simple Digestive System: Many have an incomplete digestive system with only one opening, while others absorb nutrients directly from the host's body.
- ✓ Hermaphroditism: Most flatworms are hermaphroditic, possessing both male and female reproductive organs.

Unique Characteristics of Platyhelminthes

Some of the characteristics that distinguish the organisms belonging to phylum Platyhelminthes from others are: Presence of flame cells, Ladder-like nervous system, Presence of parenchyma in the body cavity, Self-fertilization



Classification of Platyhelminthes:

The Phylum Platyhelminthes (flatworms) is classified into four main classes based on their morphology, habitat, and life cycle:

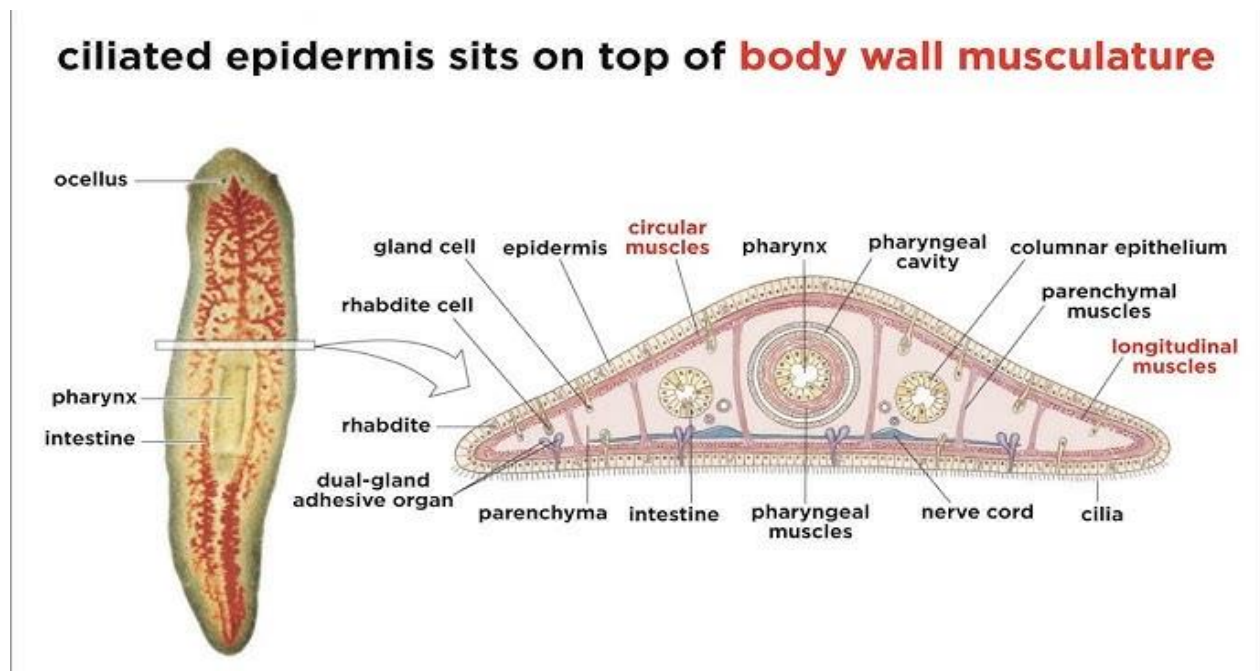
1. Class Turbellaria

Characteristics: Mostly free-living, non-parasitic flatworms with a ciliated epidermis.

Habitat: Commonly found in freshwater and marine environments, as well as moist terrestrial habitats.

Digestive System: Typically have a simple or branched gut with a mouth but no anus.

Examples: Planaria (often studied in regeneration experiments) and other small, predatory flatworms.



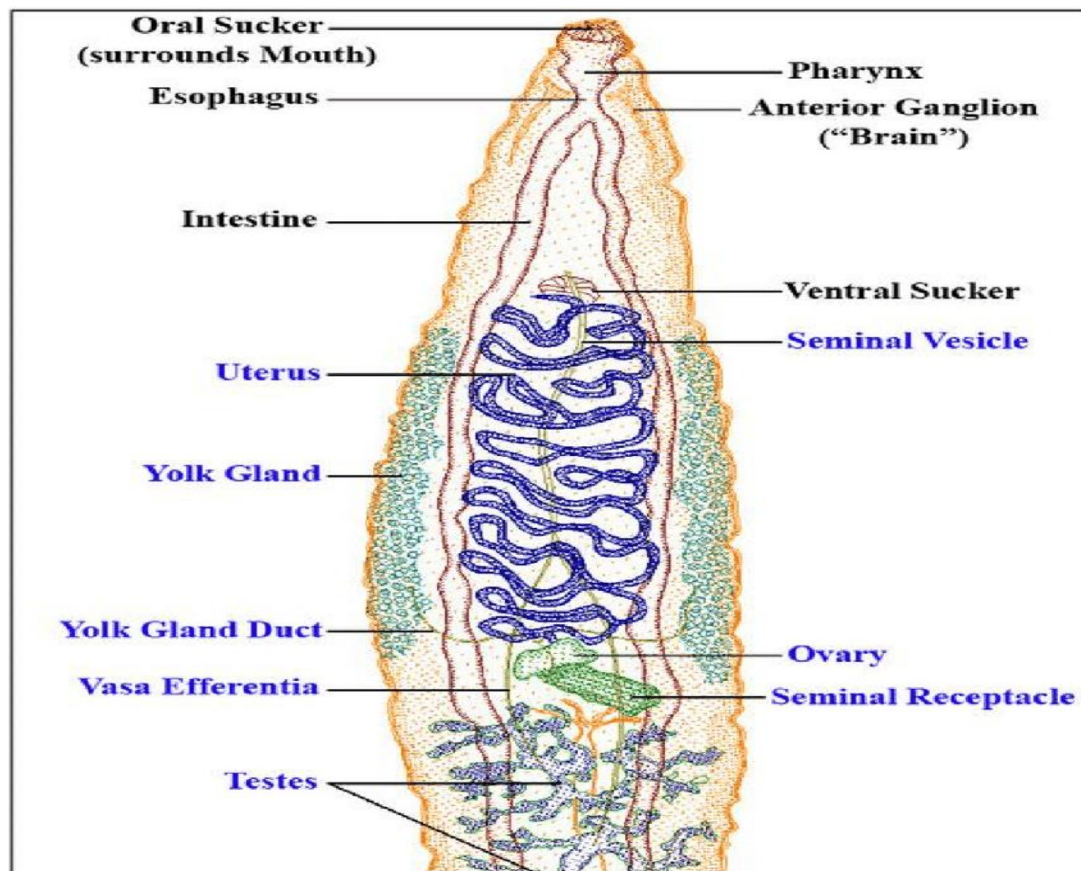
2. Class Trematoda (Flukes)

Characteristics: Parasitic, with a thick, non-ciliated epidermis and often complex life cycles involving multiple hosts.

Habitat: Endoparasites in vertebrate hosts, living in organs like the liver, lungs, and blood vessels.

Digestive System: Typically have a sucker around the mouth for attachment and feeding.

Examples: *Schistosoma* (blood fluke), *Fasciola hepatica* (liver fluke).



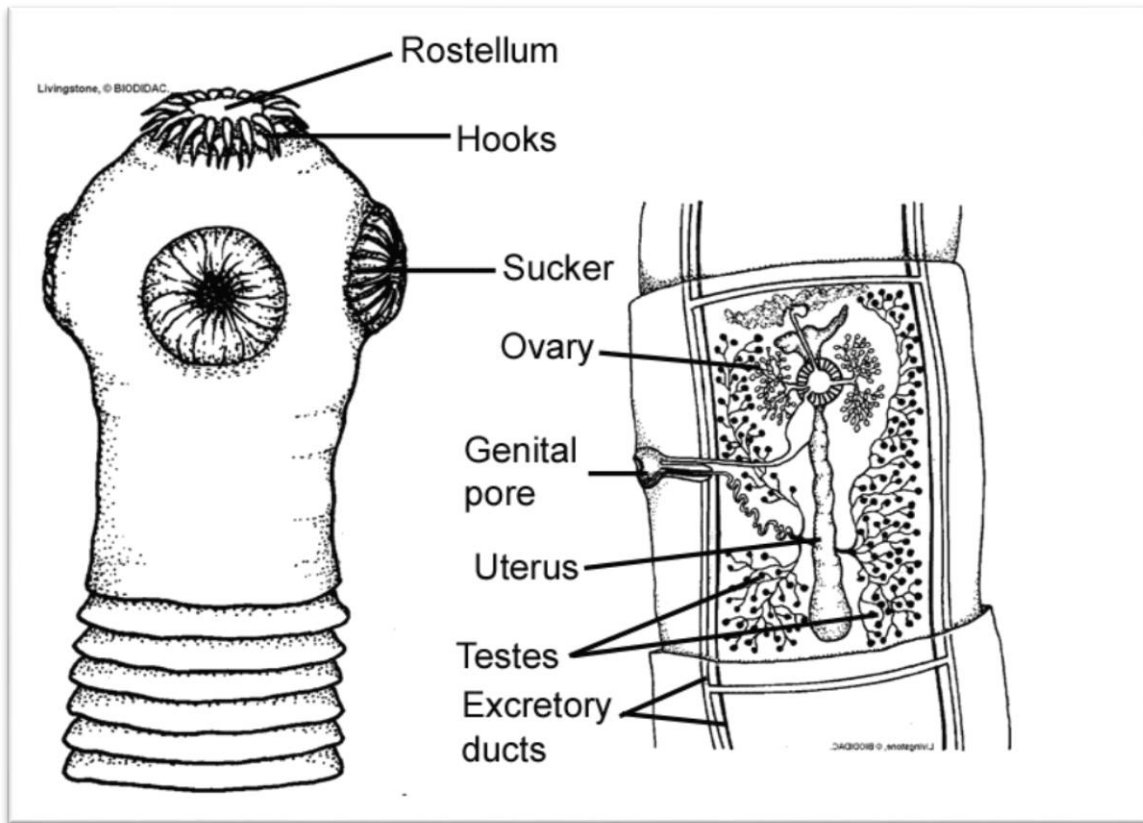
3. Class Cestoda (Tapeworms)

Characteristics: Parasitic, with long, segmented bodies and no digestive system (they absorb nutrients directly from the host).

Habitat: Endoparasites in the intestines of vertebrates.

Structure: Consist of a scolex (head) for attachment, and proglottids (body segments) that contain reproductive organs.

Examples: *Taenia solium* (pork tapeworm), *Diphyllobothrium latum* (fish tapeworm).



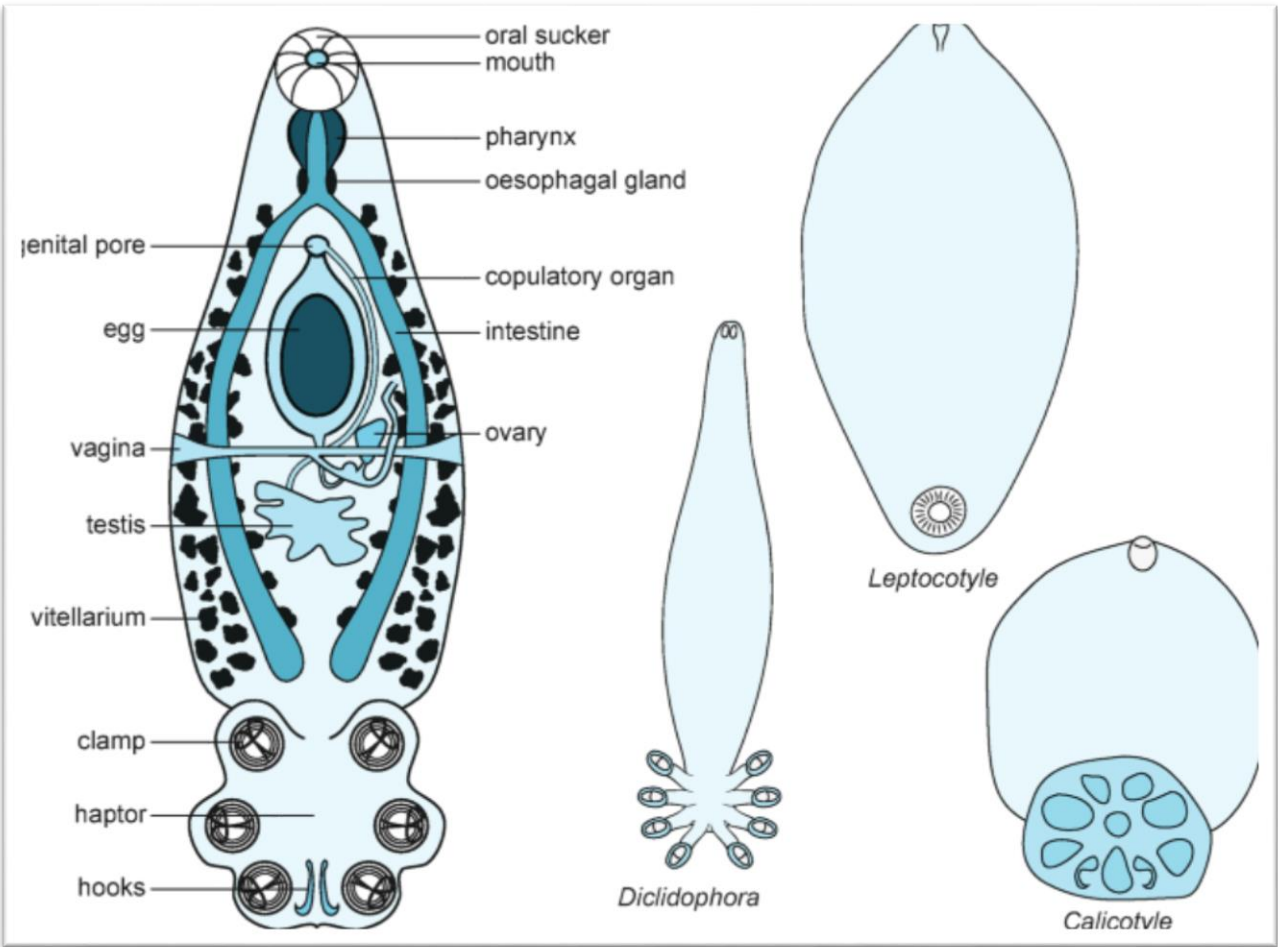
4. Class Monogenea

Characteristics: Primarily ectoparasitic flatworms with a single host, usually on fish.

Habitat: Found on the skin, gills, or external surfaces of aquatic animals, especially fish.

Life Cycle: Simple, with a single host and direct development without intermediate stages.

Examples: *Dactylogyrus* and *Gyrodactylus*, which are parasitic on fish.



Class	Type	Habitat	Life Cycle	Key Examples
Turbellaria	Free-living	Aquatic, moist terrestrial	Simple	<i>Planaria</i>
Trematoda	Parasitic	Vertebrate hosts	Complex, often multi-host	<i>Schistosoma</i> , <i>Fasciola</i>
Cestoda	Parasitic	Intestines of vertebrates	Complex, multi-host	<i>Taenia</i> , <i>Diphyllobothrium</i>
Monogenea	Ectoparasitic	External surfaces of fish	Simple, single-host	<i>Dactylogyrus</i> , <i>Gyrodactylus</i>

Reproduction of Platyhelminthes:

The reproduction in Platyhelminthes (flatworms) varies across different classes, and they display both sexual and asexual reproductive modes. Here's an overview of their reproductive strategies:

1. Asexual Reproduction

Fragmentation and Regeneration: Some free-living flatworms, particularly in the Turbellaria class, can reproduce asexually through fragmentation. The body splits, and each fragment regenerates into a complete individual.

Fission: Turbellarians like Planaria undergo a process called binary fission, where the flatworm splits into two parts, each regenerating missing structures to form two complete individuals.

2. Sexual Reproduction

Hermaphroditism: Most flatworms are hermaphroditic, meaning each individual has both male and female reproductive organs. This adaptation increases the likelihood of successful reproduction, as any two individuals can mate.

Internal Fertilization: Sexual reproduction typically involves internal fertilization, where sperm from one flatworm fertilizes the eggs of another, although self-fertilization can occur in some species.

Egg Production and Development:

Turbellaria: Eggs are often laid in protected cocoons and hatch into small versions of the adult.

Trematoda (Flukes): These parasitic flatworms have complex life cycles involving multiple hosts. They produce large numbers of eggs, which are released from the host and pass through intermediate hosts, often including mollusks.

Cestoda (Tapeworms): Tapeworms produce eggs within their proglottids (body segments), which are released with the host's feces. These eggs are then ingested by intermediate hosts, where larvae develop until they reach a vertebrate host.

3. Parasitic Reproduction Cycles

Complex Life Cycles: Parasitic flatworms, especially in Trematoda and Cestoda, often have complex life cycles with both asexual and sexual stages. For example, Schistosoma (blood flukes) require snails as intermediate hosts, where asexual reproduction occurs before moving into the definitive host for sexual reproduction.

Adaptation for Prolific Egg Production: Many parasitic flatworms are highly prolific, producing thousands to millions of eggs over their lifetimes, maximizing the chances of transmission between hosts.

Feature	<i>Turbellaria</i>	<i>Trematoda</i> (Flukes)	<i>Cestoda</i> (Tapeworms)	<i>Monogenea</i>
Common Name	Free-living flatworms	Flukes	Tapeworms	Monogeneans
Habitat	Mostly aquatic, some terrestrial	Endoparasitic in animals	Endoparasitic in intestines of vertebrates	Mostly ectoparasitic on fish and amphibians
Body Shape	Soft, flat, unsegmented	Leaf-shaped, unsegmented	Long, ribbon-like, segmented	Small, leaf-like or cylindrical
Reproductive System	Mostly hermaphroditic	Hermaphroditic	Hermaphroditic	Hermaphroditic
Life Cycle	Direct, no intermediate host	Complex, involves multiple hosts	Complex, involves intermediate hosts (usually arthropods)	Direct, single host
Development	Free-living larval stages	Multiple larval stages in hosts	Larval stages in intermediate hosts	Free-living
Digestive System	Complete or incomplete	Incomplete, has oral and ventral suckers	None (absorbs nutrients through skin)	Incomplete, with a single opening
Locomotion	Cilia on ventral surface	No cilia, relies on host	No locomotion; attaches via scolex (head with suckers/hooks)	Attaches to host with hooks or suckers
Reproductive System	Mostly hermaphroditic	Hermaphroditic	Hermaphroditic	Hermaphroditic

V. Phylum Nemathelminthes (Roundworms) ديدان خيطية

The term **Nemathelminthes** (or **phylum Nemathelminthes**) is an outdated classification that grouped roundworms, primarily **nematodes** (Nematoda) and sometimes **nematomorphs** (Nematomorpha). Although this classification has been replaced in modern taxonomy, the term is occasionally used to describe these cylindrical, unsegmented worms. Today, nematodes and nematomorphs are recognized as distinct phyla due to significant biological differences.

General Characteristics of Nemathelminthes

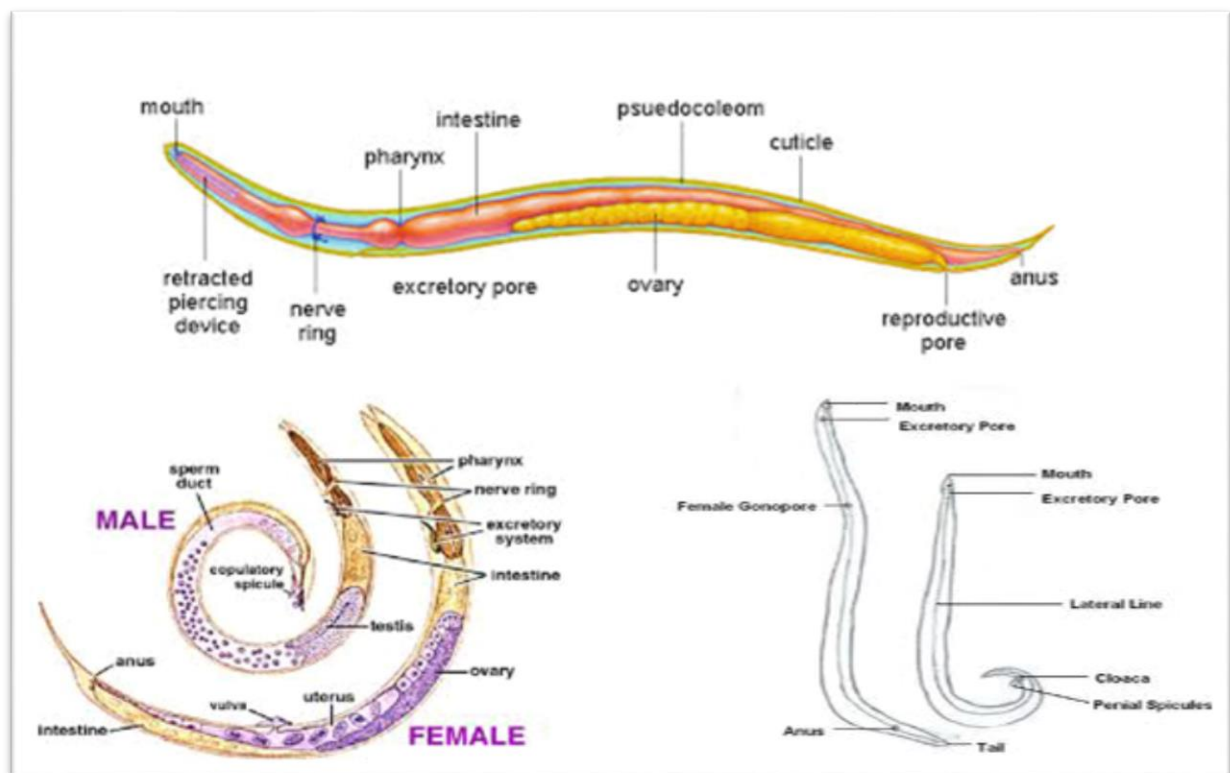
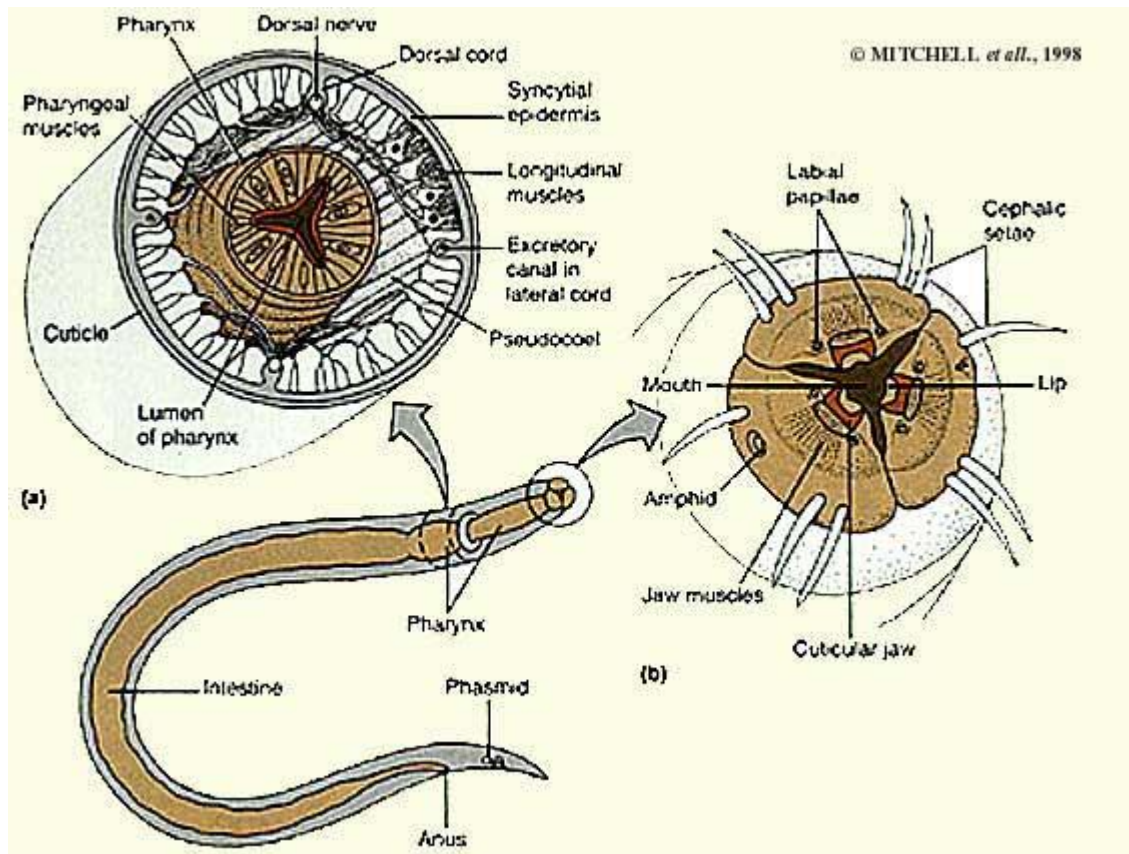
- **Cylindrical, unsegmented body:** These worms have elongated, worm-like bodies covered by a tough cuticle, providing resistance and protection.
- **Digestive system:** They possess a complete digestive tract, with a mouth, intestine, and anus.
- **Reproduction:** Most reproduce sexually, and sexes are typically separate (male and female).
- **Nervous system:** Consists of a nerve ring around the pharynx and longitudinal nerve cords.
- **Lack of circulatory and respiratory systems:** They rely on diffusion for gas exchange and nutrient distribution, as they lack complex circulatory systems.

Importance of Nematodes and Nematomorphs

- **Nematodes:** They are highly diverse and found in various habitats, including soil and aquatic ecosystems. Many are free-living, but some are parasites that affect plants, animals, and humans (e.g., *Ascaris lumbricoides* in humans, *Meloidogyne spp.* in plants).
- **Nematomorphs:** Commonly known as "horsehair worms," they are mostly parasitic on insects in their larval stage but are free-living as adults.

Ecological and Health Roles

Nematodes, in particular, play a crucial role in ecosystems by decomposing organic matter and contributing to nutrient cycles. However, some pathogenic species cause diseases in humans and animals, such as onchocerciasis, lymphatic filariasis, and other parasitic infections.



Classification of Nematelminthes

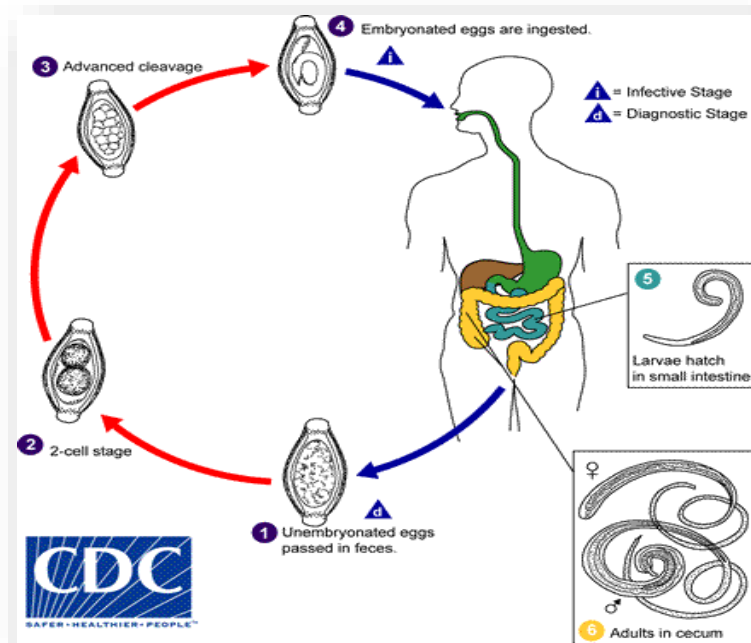
The term **Nematelminthes** is an older classification used to refer to a group of roundworms with elongated, cylindrical, and unsegmented bodies, primarily including the phyla **Nematoda** and **Nematomorpha**. In modern taxonomy, these organisms are treated as separate phyla because they are not closely related, despite their similar body shapes. Here's a breakdown of the classification of each phylum previously included under Nematelminthes:

1. Phyla Nematoda (Nematodes)

The **Nematoda** are diverse and include both free-living and parasitic roundworms. They are found in a variety of habitats, from soil to freshwater and marine environments, as well as within other organisms as parasites.

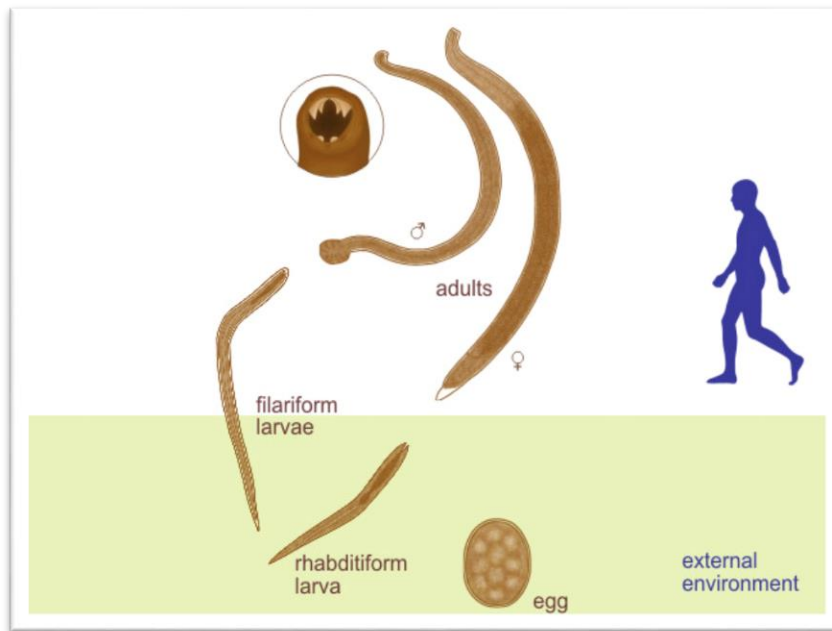
Classes:

- **Adenophorea (or Enoplea)**: Includes primarily free-living species found in soil and marine environments, with some parasitic species.
 - **Examples:** *Trichuris trichiura* (whipworm), various marine nematodes.



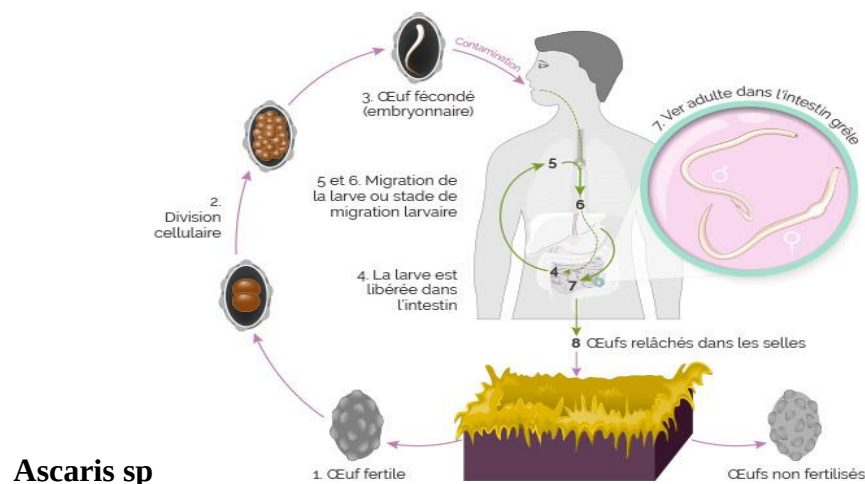
- **Secernentea (or Chromadorea):** Contains many of the parasitic nematodes that infect humans, animals, and plants.

- **Examples:** *Ascaris lumbricoides* (human roundworm), *Ancylostoma duodenale* (hookworm), *Caenorhabditis elegans* (a model organism in genetics).



Ancylostoma duodenale

Each of these classes includes several orders, each containing species with distinct ecological roles or parasitic behaviors. For instance: **Order Ascaridida:** Includes large intestinal parasites like *Ascaris*. **Order Rhabditida:** Includes both free-living species and parasites like *C. elegans*.



2. Phyla Nematomorpha (Horsehair Worms)

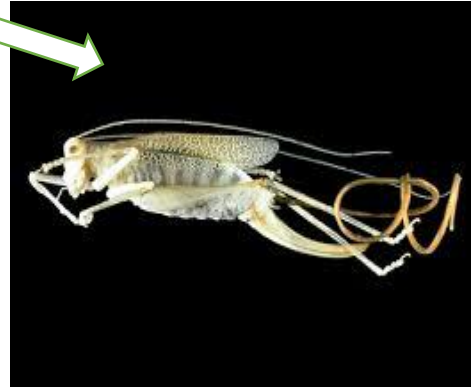
Nematomorpha are commonly known as "horsehair worms" and are typically parasites of arthropods during their larval stage but are free-living in water as adults, there is two **classes**.

- **Gordioida:** Mostly freshwater species, which parasitize insects (e.g., grasshoppers, crickets) during their larval stage and are free-living as adults.

- **Example:** *Paragordius tricuspidatus*

- **Nectonematoida:** A small group of marine nematomorphs that parasitize crustaceans.

- **Example:** *Nectonema agile*



Phylum	Class	Key Characteristics	Examples
Nematoda	Adenophorea, Secernentea	Cylindrical, complete digestive system, free-living or parasitic	<i>Ascaris lumbricoides</i> , <i>Trichuris trichiura</i>
Nematomorpha	Gordioida, Nectonematoida	Parasitic in larval stages, simpler anatomy, mostly aquatic	<i>Paragordius tricuspidatus</i> , <i>Nectonema agile</i>

Reproduction of Nemathelminthes

Phylum	Reproductive Strategy	Characteristics
Nematoda	Primarily sexual, some hermaphroditic/parthenogenetic	Internal fertilization, egg-laying, multiple larval molts
Nematomorpha	Sexual, with parasitic larval stage	External fertilization, free-living adults, larvae parasitize arthropods

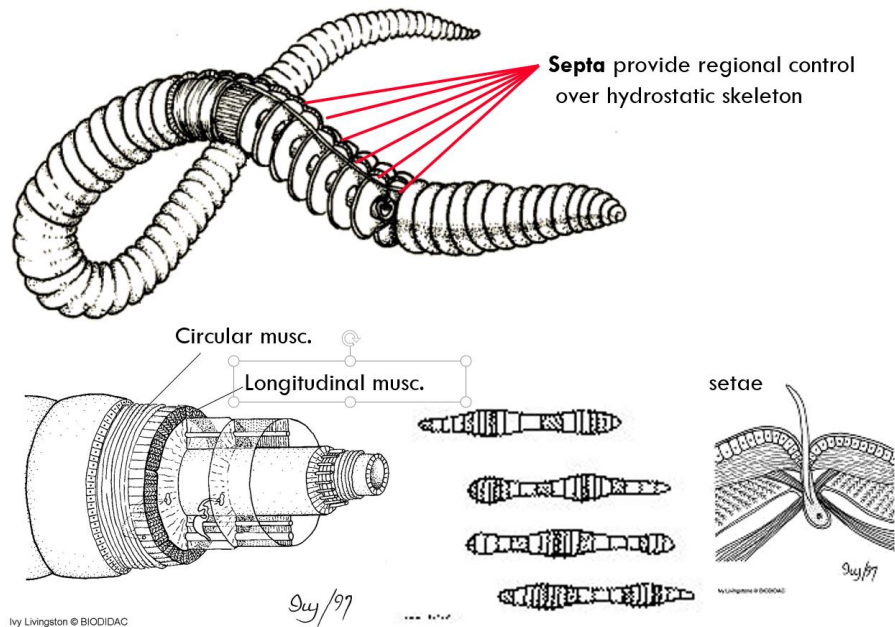
VI. Phylum Annelida (Segmented Worms) ديدان حلقيه

The **Phylum Annelida** comprises segmented worms, known for their distinctive, ring-like body segmentation. Annelids are found in a wide variety of habitats, including marine, freshwater, and terrestrial environments. This group includes **earthworms**, leeches, and marine polychaetes, each with specialized adaptations to their habitats.

Key Characteristics of Annelida

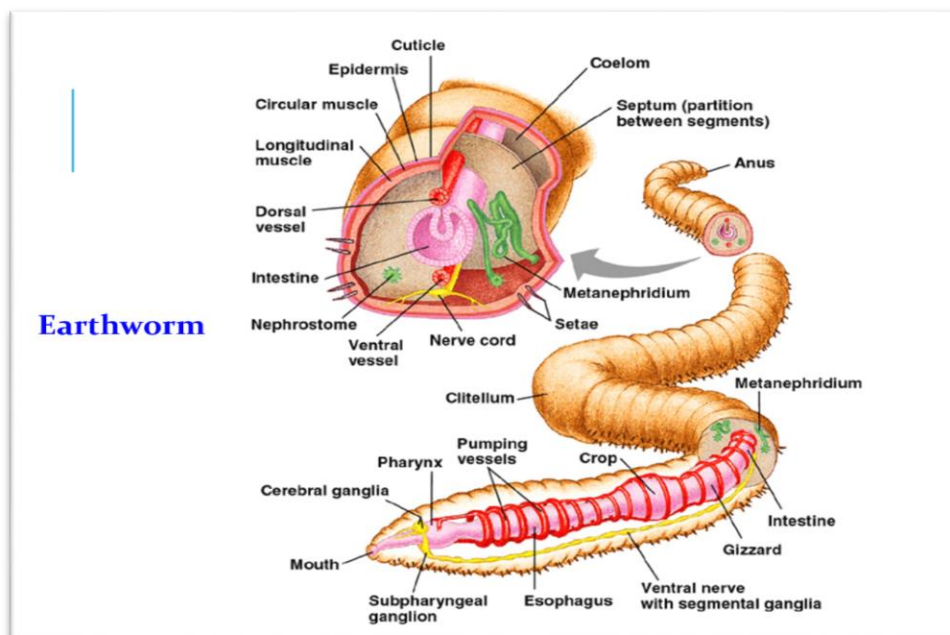
- **Segmented Body:** Annelids have bodies divided into repeated segments, each containing similar sets of organs. This segmentation provides flexibility and allows for efficient movement.
- **True Coelom:** Annelids possess a true coelom (body cavity), which is divided by septa. The coelom provides a hydrostatic skeleton, helping with locomotion.
- **Chaetae (Setae):** Most annelids have bristle-like structures called chaetae (or setae) on each segment that aid in movement.
- **Closed Circulatory System:** They have a closed circulatory system, where blood is contained within vessels and pumped by muscular structures.
- **Complete Digestive System:** Annelids have a complete digestive tract, with a mouth and anus, and specialized regions for digestion and nutrient absorption.
- **Nervous System:** Annelids have a ventral nerve cord and a simple brain, allowing them to respond to environmental stimuli.

METAMERISM



Reproduction of annelids

The **reproduction of annelids** varies widely among the different classes, but generally includes both sexual and asexual methods. Annelids can be either dioecious (separate sexes) or hermaphroditic (both male and female organs in one individual), with some capable of asexual reproduction. Here's a breakdown of their reproductive methods across the major classes.



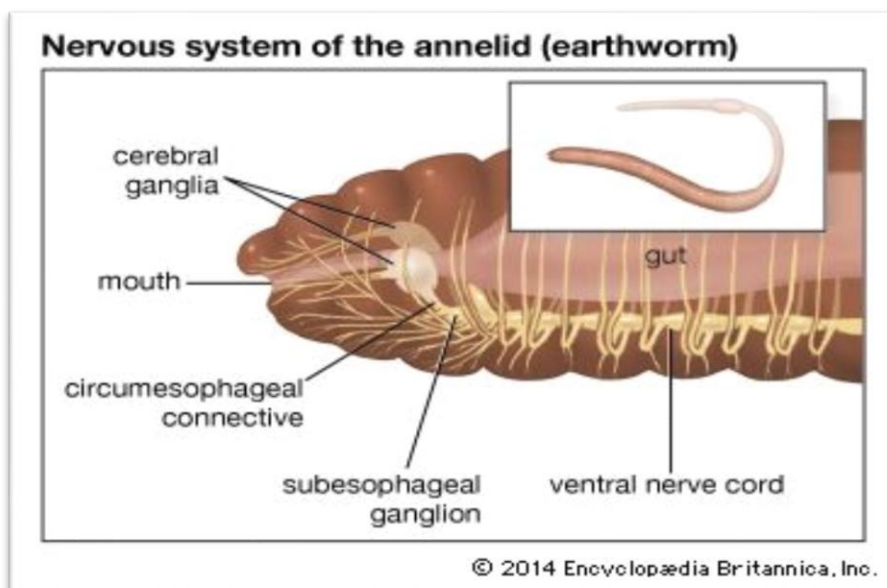
Annelid Classes

1. Class Polychaeta:

- **Habitat:** Primarily marine environments.
- **Characteristics:** Polychaetes possess numerous bristles (chaetae) on parapodia (fleshy appendages) that aid in swimming or crawling. They have well-developed heads with eyes, antennae, and specialized mouthparts.
- **Ecological Role:** Polychaetes play important roles in marine ecosystems, contributing to sediment mixing and serving as a food source for other marine organisms.

2. Class Clitellata:

- **Subclasses:**
 - **Oligochaeta:** Includes earthworms and freshwater worms. They have fewer chaetae and lack parapodia. Earthworms are important soil aerators and decomposers.
 - **Hirudinea:** Includes leeches, which are mostly freshwater or terrestrial. Leeches are either parasitic (feeding on blood) or predatory. Some species are used in medicine for therapeutic purposes.
- **Characteristics:** Members of Clitellata possess a clitellum, a specialized reproductive structure used to produce a mucus cocoon for eggs. Most are hermaphroditic.



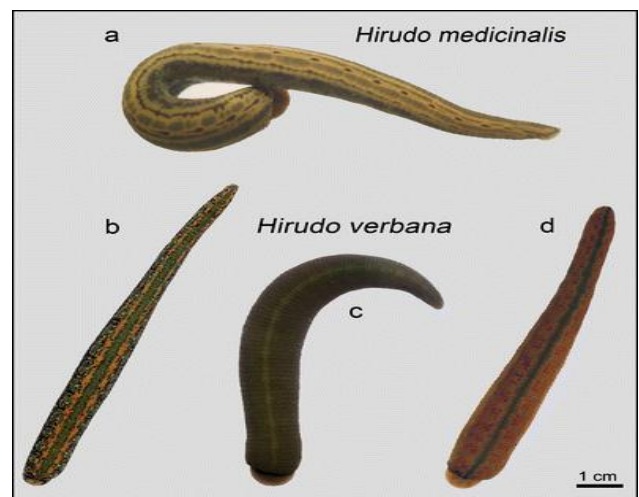
3. Class Sipuncula (Peanut Worms):

- **Characteristics:** Unlike other annelids, peanut worms are unsegmented and have a retractable introvert with tentacles. They are generally burrowers and contribute to sediment turnover in marine habitats.
- **Habitat:** Marine, found in shallow waters and burrowed in sand or mud.



Ecological and Economic Importance of Annelids

- **Soil Fertility:** Earthworms are essential for soil aeration, mixing, and nutrient cycling, which enhances soil health.
- **Medical Uses:** Leeches (e.g., *Hirudo medicinalis*) are used in medicine for bloodletting and to reduce blood coagulation in certain surgeries.



- **Marine Ecosystems:** Polychaetes and sipunculans play key roles in marine ecosystems as detritivores and prey for other marine organisms.

Differences between classes of Annelids

Feature	Class Polychaeta	Class Oligochaeta	Class Hirudinea	Class Sipuncula
Habitat	Marine	Terrestrial or freshwater	Freshwater, terrestrial, or marine	Marine
Segmentation	Well-segmented with parapodia	Well-segmented, no parapodia	Segmented but reduced externally	Unsegmented
Chaetae (Setae)	Numerous chaetae on parapodia	Few chaetae per segment, no parapodia	Absent	Absent
Body Shape	Cylindrical	Cylindrical	Dorsoventrally flattened	Cylindrical with retractable introvert
Locomotion	Parapodia and chaetae for crawling/swimming	Peristaltic movement via longitudinal/circular muscles	Use of suckers for attachment/movement	Burrowing or crawling
Feeding	Filter-feeders, scavengers, or predators	Decomposers, feed on organic matter	Blood-sucking parasites or predators	Deposit or suspension feeders
Sensory Organs	Well-developed (antennae, eyes, palps)	Poorly developed	Reduced	Absent or minimal
Reproductive Mode	Mostly sexual, dioecious	Hermaphroditic	Hermaphroditic	Sexual, dioecious
Fertilization	External	Internal	Internal	External

Development	Trochophore larvae	Direct (no larval stage)	Direct (no larval stage)	Trochophore larvae
Special Structures	Parapodia for movement and gas exchange	Clitellum for reproduction	Suckers for feeding and attachment	Retractable introvert with tentacles
Ecological Role	Sediment mixing, prey in marine food webs	Soil aeration and nutrient recycling	Parasites or predators in ecosystems	Sediment turnover in marine environments
Examples	<i>Nereis</i> , <i>Aphrodita</i> , <i>Sabella</i>	<i>Lumbricus terrestris</i> , <i>Tubifex</i>	<i>Hirudo medicinalis</i> , <i>Haemopsis</i>	<i>Sipunculus nudus</i>

VII. Phylum Mollusca الرخويات

Mollusca (Mollusk) are animals, Metazoans, Triploblastic, Coelomate, Protostomes, Hyponeurian. **Symmetry:** Bilateral or spiral symmetry. **Body:** Soft, unsegmented body (not metamerized) consisting of three parts: Head, Foot, and Visceral Mass protected by a shell (coquille).

Mollusk, any soft-bodied invertebrate of the phylum Mollusca, usually wholly or partly enclosed in a calcium carbonate shell secreted by a soft mantle covering the body. Along with the insects and vertebrates, it is one of the most diverse groups in the animal kingdom, with nearly 100,000 (possibly as many as 150,000) described species. Each group includes an ecologically and structurally immense variety of forms: the shell-less Caudofoveata; the narrow-footed gliders (Solenogastres); the serially valved chitons (Placophora or Polyplacophora); the cap-shaped neopilinids (Monoplacophora); the limpets, snails, and slugs (Gastropoda); the clams, mussels, scallops, oysters, shipworms, and cockles (Bivalvia); the tubiform to barrel-shaped tusk shells (Scaphopoda); and the nautilus, cuttlefishes, squids, and octopuses (Cephalopoda).

Key Characteristics of Mollusca

1. Body Structure:

- **Head-Foot:** For locomotion and sensory functions.
- **Visceral Mass:** Contains internal organs (digestive, excretory, and reproductive systems).
- **Mantle:** Secretes the shell and forms a mantle cavity that may house gills or lungs.

2. Shell:

- External, internal, or absent.
- Made of calcium carbonate (e.g., clams, snails).

3. Nervous System:

- Varies from simple nerve nets to complex brains in cephalopods (octopuses).

4. Circulatory System:

- Open circulatory system in most (e.g., snails, clams).
- Closed circulatory system in cephalopods (e.g., squids, octopuses).

-

5. Reproduction:

- Mostly sexual.
- Dioecious (separate sexes) or hermaphroditic.
- Fertilization can be external or internal.

6. Larval Stages:

- Trochophore larvae (shared with annelids).
- Some develop into veliger larvae.

Importance of Mollusks

1. Ecological Roles:

- Filter-feeding (e.g., clams, oysters) maintains water quality.
- Predators (e.g., octopuses) regulate prey populations.
- Food source for many marine animals and humans.

2. Economic Importance:

- Source of food (e.g., mussels, clams).
- Pearls and shells used in jewelry.
- Research models (e.g., squid in neuroscience).

3. Environmental Indicators:

- Sensitive to pollution, making them bioindicators for monitoring ecosystem health.

Classification of Mollusks

1. Polyplacophora (Chitons)

- Body covered by overlapping plates for protection.
- Found clinging to rocks in tidal zones.
- Herbivores, scraping algae with their radula.

2. Monoplacophora

- Cap-like shell resembles ancestral mollusks.
- Unique segmentation of internal organs (e.g., gills, kidneys).

- Rare and found in the deep sea.

3. *Gastropoda (Snails and Slugs)*

- Includes terrestrial, freshwater, and marine species.
- Undergo torsion: a 180° twist of the visceral mass.
- Highly diverse feeding strategies and habitats.

4. *Bivalvia (Clams, Mussels, Oysters)*

- Two shells hinged together.
- Lack a radula; filter feeders using gills.
- Important ecologically (water filtration) and economically (food, pearls).

5. *Cephalopoda (Octopus, Squid, Cuttlefish, Nautilus)*

- Agile predators with tentacles and suckers.
- Use ink for defense, jet propulsion for escape.
- Highly intelligent with complex behaviors.

6. *Scaphopoda (Tusk Shells)*

- Shells shaped like tiny tusks.
- Burrow into marine sediments.
- Use tentacle-like structures (captacula) to capture microscopic prey.

7. *Aplacophora*

- Worm-like mollusks without shells.
- Covered with calcareous spicules for protection.
- Found in the deep sea, burrowing in sediment or living on coral

Class	Locomotion	Feeding Mode	Examples
Polyplacophora	Crawling (foot)	Herbivores (radula)	<i>Chiton</i>
Monoplacophora	Crawling (foot)	Scavengers	<i>Neopilina</i>
Gastropoda	Crawling (foot), swimming	Herbivores, carnivores, scavengers	Snails, Slugs
Bivalvia	Sedentary	Filter feeding	Clams, Oysters
Cephalopoda	Jet propulsion (siphon)	Carnivores	Squid, Octopus
Scaphopoda	Burrowing	Deposit feeding	<i>Dentalium</i>
Aplacophora	Burrowing	Predators or scavengers	<i>Chaetoderma</i>

MOLLUSKS

PHYLUM: **MOLLUSCA**

Seven extant classes and their major groups

Gastropods
(Large-footed with flat soles)



Snails

Slugs

Aplacophorans
(Worm-like appearance)



Cauofoveates

Solenogasters

Polyplacophorans
(With eight-plated shells)



Chitons

Monoplacophorans
(With cap-like shells)



Tergomya

Scaphopods
(With curved, tooth-like shells)



Tusk shells

Cephalopods
(Having merged head and foot)



Cuttlefish Squid Nautilus Octopuses

Bivalves
(With two-part, hinged shells)



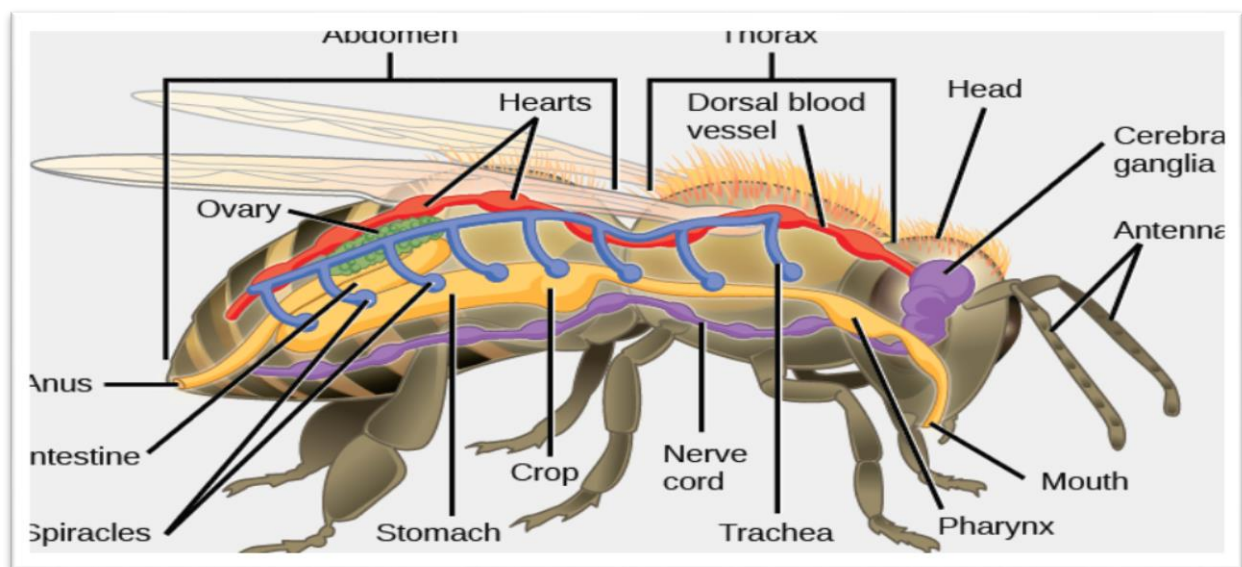
Clams Oysters Geoducks Scallops Mussels

AnimalFact

Phylum of Arthropods

Arthropod, (phylum Arthropoda), any member of the phylum Arthropoda, the largest phylum in the animal kingdom, which includes such familiar forms as lobsters, crabs, spiders, mites, insects, centipedes, and millipedes. About **84 percent** of all known species of animals are members of this phylum. Arthropods are represented in every habitat on Earth and show a great variety of adaptations. Several types live in aquatic environments, and others reside in terrestrial ones; some groups are even adapted for flight.

The distinguishing feature of arthropods is the presence of a jointed skeletal covering composed of **chitin** (a complex sugar) bound to protein. This nonliving exoskeleton is secreted by the underlying **epidermis** (which corresponds to the skin of other animals). Arthropods lack locomotory cilia, even in the larval stages, probably because of the presence of the exoskeleton. The body is usually **segmented**, and the segments bear paired jointed appendages, from which the name arthropod (“jointed feet”) is derived. About one million arthropod species have been described, of which **most are insects**. This number, however, may be only a fraction of the total. Based on the number of undescribed species collected from the treetops of tropical forests, zoologists have estimated the total number of insect species alone to be as high as 5.5 million. The more than 48,000 described species of mites may also represent only a fraction of the existing number.



Key Characteristics of Arthropods

1. Exoskeleton:

- Made of chitin, often reinforced with calcium carbonate.
- Provides protection and support.
- Periodically shed during growth (molting or ecdysis).

2. Body Segmentation:

- Body is divided into distinct segments, often grouped into regions (tagmata): head, thorax, and abdomen.
- Segments may have specialized functions.

3. Jointed Appendages:

- Legs, antennae, and other structures are articulated, providing flexibility and a wide range of motion.

4. Nervous System:

- Centralized brain and ventral nerve cord.
- Compound eyes and sensory organs for detecting light, sound, and chemicals.

5. Circulatory System:

- Open circulatory system with hemolymph (blood-equivalent) flowing through sinuses.

6. Reproductive System:

- Mostly sexual reproduction.
- Dioecious (separate sexes) with internal or external fertilization.

7. Diverse Respiratory Structures:

- Gills (in aquatic forms), tracheae, or book lungs (in terrestrial forms)

Importance of Arthropods

1. Ecological Roles:

- Pollinators (e.g., bees and butterflies).
- Decomposers (e.g., dung beetles, millipedes).
- Predators and prey in ecosystems.

2. Economic Significance:

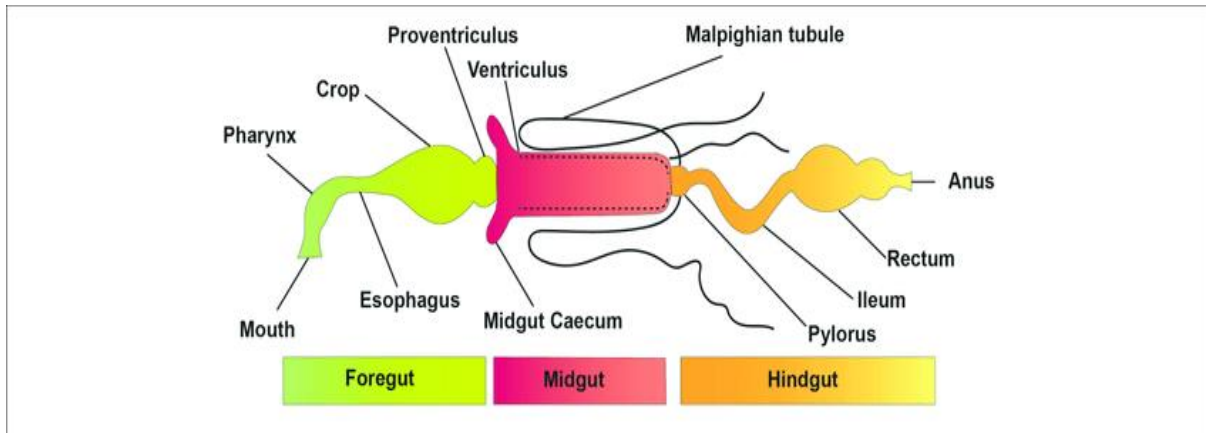
- Source of food (crabs, lobsters).

- Harmful pests (crop-destroying insects).
- Vectors of diseases (e.g., mosquitoes, ticks).

3. Scientific Study:

- Model organisms for genetics and behavior (e.g., *Drosophila melanogaster*).

Digestive system of Arthropods



Nervous system of Arthropods

The nervous system of arthropods is well-developed and highly adapted to their diverse lifestyles. It consists of a combination of central and peripheral components, with unique adaptations in various groups such as insects, crustaceans, and arachnids.

Structure of the Nervous System in Arthropods

1. Central Nervous System (CNS):

- **Brain (Cerebral Ganglion):** Located in the head, the brain consists of fused ganglia and is divided into three main regions:
 - **Protocerebrum:** Associated with the eyes and vision.
 - **Deutocerebrum:** Processes sensory input from the antennae.
 - **Tritocerebrum:** Controls the labrum (upper lip) and connects the brain to the ventral nerve cord.
- **Ventral Nerve Cord:** A double chain of ganglia running along the body. Each body segment has paired ganglia, which control localized functions.

2. **Peripheral Nervous System (PNS):**

- Includes nerves extending from the CNS to the body, supplying the muscles and sensory organs.

3. **Sympathetic Nervous System:**

- Regulates involuntary functions, such as digestion and heartbeat.

Variations Across Arthropod Groups

1. **Insects:**

- Highly developed CNS with fused thoracic ganglia for coordination of wing and leg movements.
- Antennae and compound eyes are linked to advanced sensory processing.

2. **Crustaceans:**

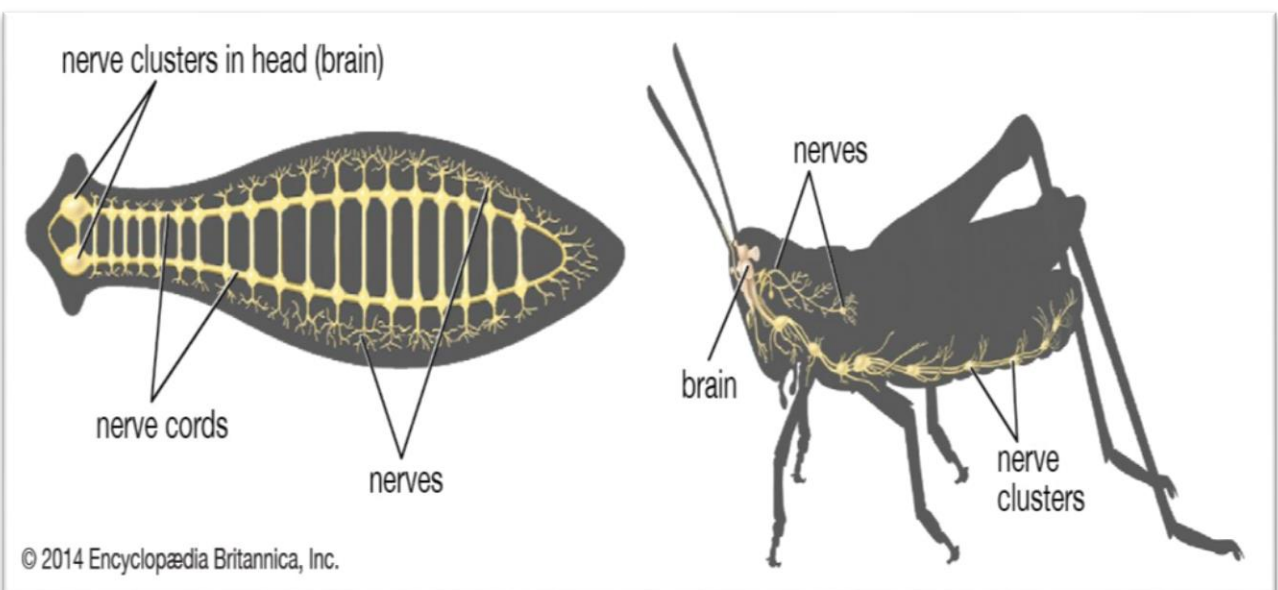
- Large, well-developed brain and ganglia in the thorax and abdomen for control of complex behaviors, such as swimming and feeding.

3. **Arachnids:**

- Fused brain and subesophageal ganglia to control their eight legs and specialized appendages (e.g., chelicerae).

4. **Myriapods:**

- A simpler nervous system with repeated ganglia along their elongated body.



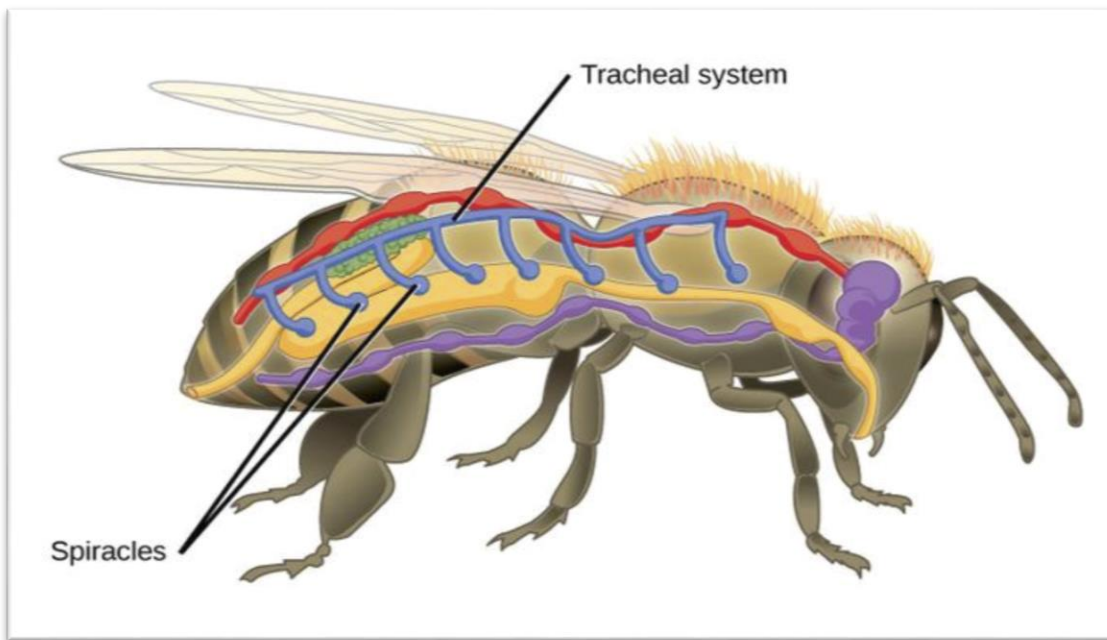
Respiratory system of Arthropods

The respiratory system of arthropods is highly diverse, reflecting their adaptation to various environments, such as aquatic and terrestrial habitats. Here's an overview:

Key Respiratory Structures in Arthropods

1. Tracheal System (Insects, Myriapods):

- A network of air-filled tubes (tracheae) delivers oxygen directly to tissues.
- Air enters through openings called **spiracles** on the body surface.
- Smaller tubes, or **tracheoles**, extend to individual cells for efficient gas exchange.
- Example: Grasshoppers and centipedes.



2. Book Lungs (Arachnids):

- Flattened, leaf-like structures stacked within a chamber to increase surface area for gas exchange.
- Air flows through these "pages," allowing oxygen to diffuse into the blood.
- Example: Spiders and scorpions.

Book lungs

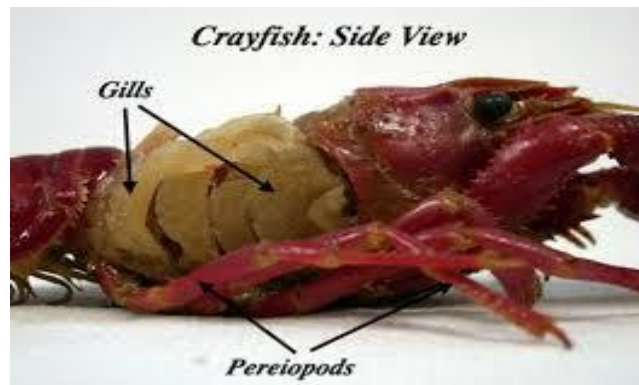
Book lungs are respiratory organs of certain arachnids.

The diagram on the left illustrates the internal anatomy of a book lung, showing the trachea, book lung, and associated structures. A large blue arrow points from the book lung to a magnified view on the right. The magnified view shows the book lung's structure, which consists of multiple layers of tissue, with the central part labeled 'BOOK LUNGS'.

The diagram on the left illustrates the human respiratory system with various components labeled: Brain, Trachea, Larynx, Esophagus, Diaphragm, Ribs, Intercostal muscles, Pleural cavity, Pleural fluid, Lung, and Blood vessels. A large blue arrow points from the trachea towards the lungs. To the right, a detailed view of the lungs is shown, with a label 'BOOK LUNGS' pointing to the branching structure of the bronchi. A small blue circular logo is visible in the bottom right corner.

3. Gills (Aquatic Crustaceans):

- Thin, feathery structures that extract dissolved oxygen from water.
- Located near the appendages or within the carapace, facilitating water flow over the gills.
- Example: Crabs, lobsters, and shrimp.



4. Body Surface Diffusion (Some Arthropods):

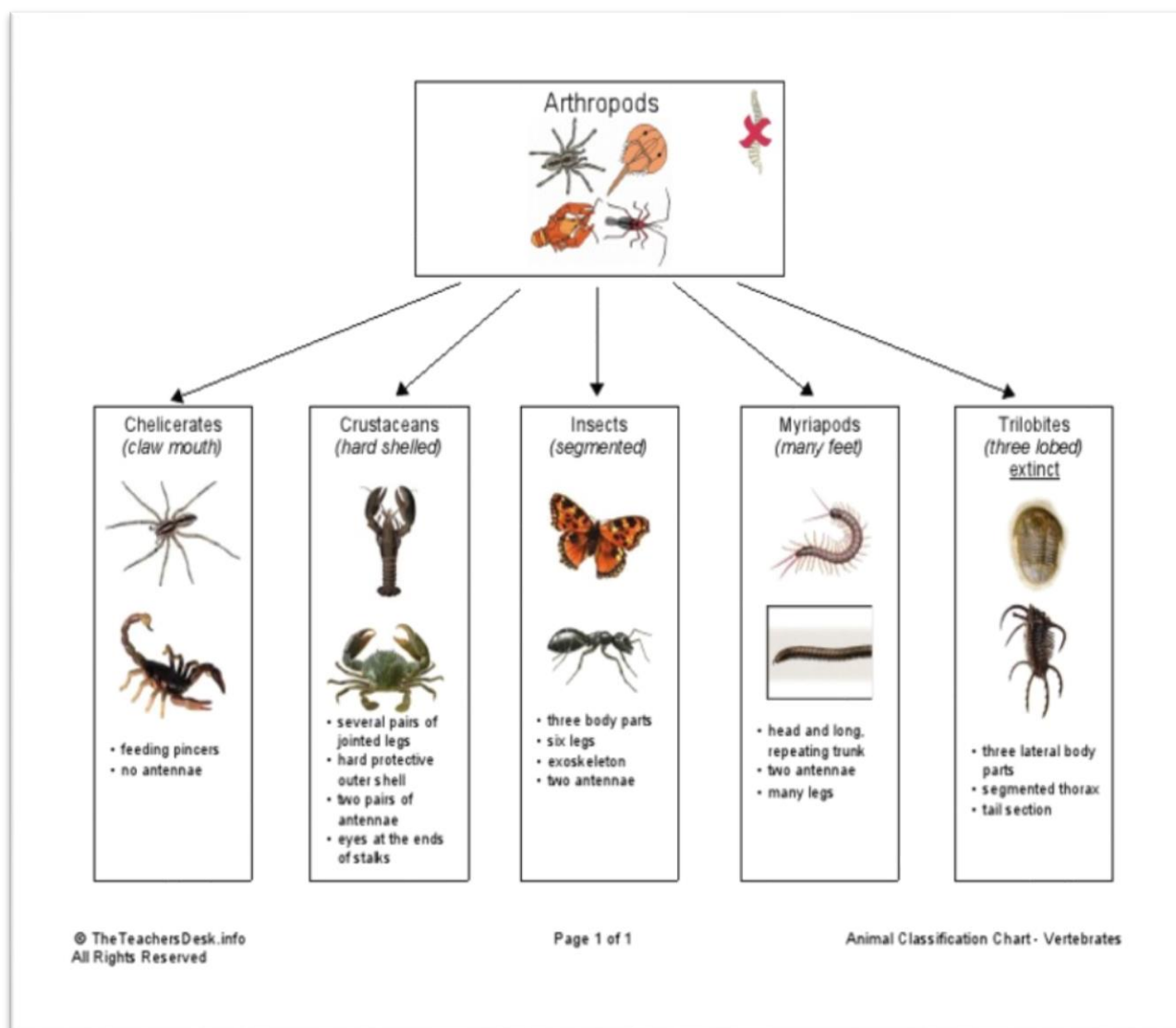
- In smaller arthropods, oxygen diffuses directly through the moist body surface.
- Common in tiny or parasitic species.

5. Respiratory Pigments:

- Some arthropods have pigments like **hemocyanin** (in crustaceans) to transport oxygen in the blood.

Classification of Arthropods:

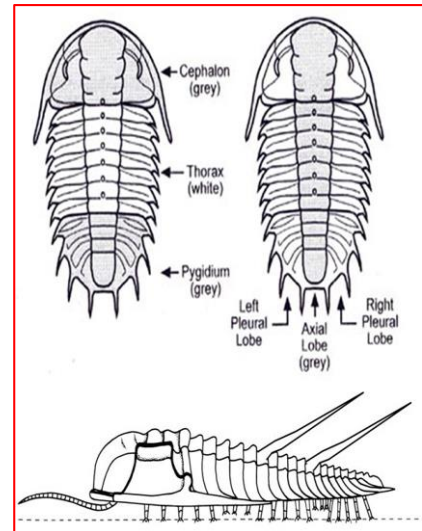
The Phylum Arthropoda is the most diverse phylum in the animal kingdom, comprising organisms with jointed appendages and segmented bodies. Below is a detailed classification of arthropods:



Details of Subphyla

1. Trilobita (Extinct)

- ✓ Early marine arthropods.
- ✓ Body divided into three lobes: a central lobe and two lateral lobes.
- ✓ Had compound eyes and numerous body segments.
- ✓ Extinct at the end of the Permian period (~250 million years ago).



2. Chelicerata

- No antennae.
- Two main body regions: cephalothorax and abdomen.
- First pair of appendages modified into chelicerae (specialized mouthparts).
- Classes:
 1. **Arachnida:** Includes spiders, scorpions, ticks, and mites. Predominantly terrestrial, with four pairs of legs and book lungs or tracheae.
 2. **Merostomata:** Includes horseshoe crabs, which are marine with book gills and a hard carapace.
 3. **Pycnogonida:** Sea spiders, found in marine environments with long legs and a small body.



CHELICERATES

SUBPHYLUM
Chelicerata

AnimalFact

Class : Arachnida

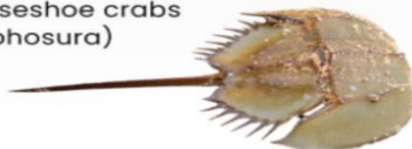
Includes 2 superorders and 10 extant orders



Class : Merostomata

Includes 1 extant order

Horseshoe crabs
(Xiphosura)



Class : Pycnogonida

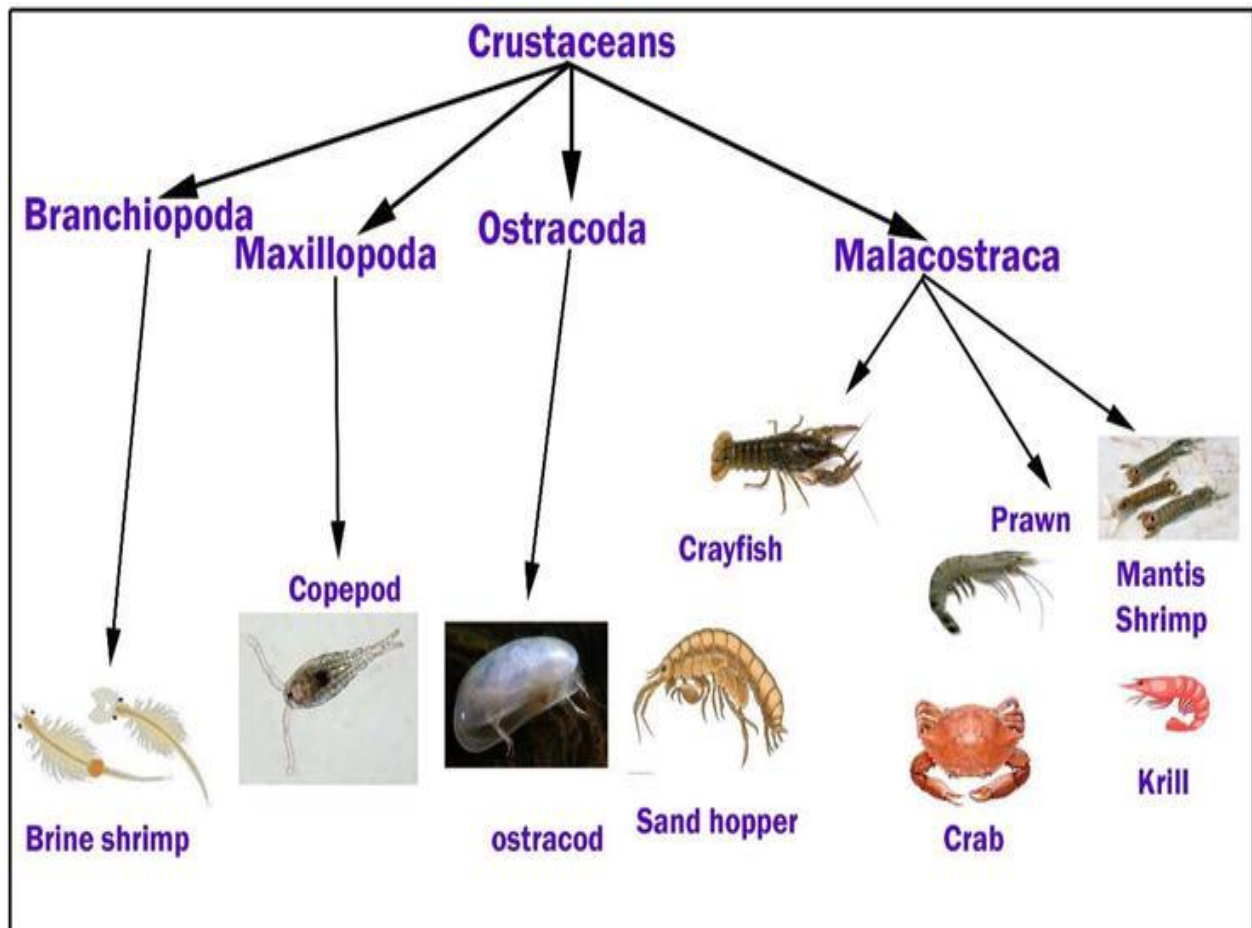
Includes 1 extant order

Sea spiders
(Pantopoda)



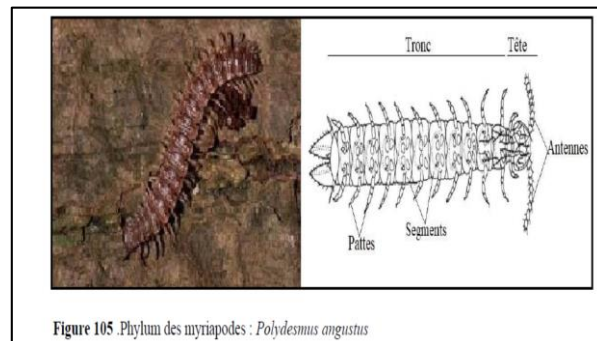
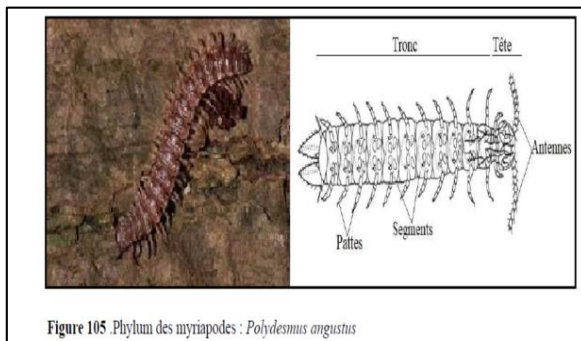
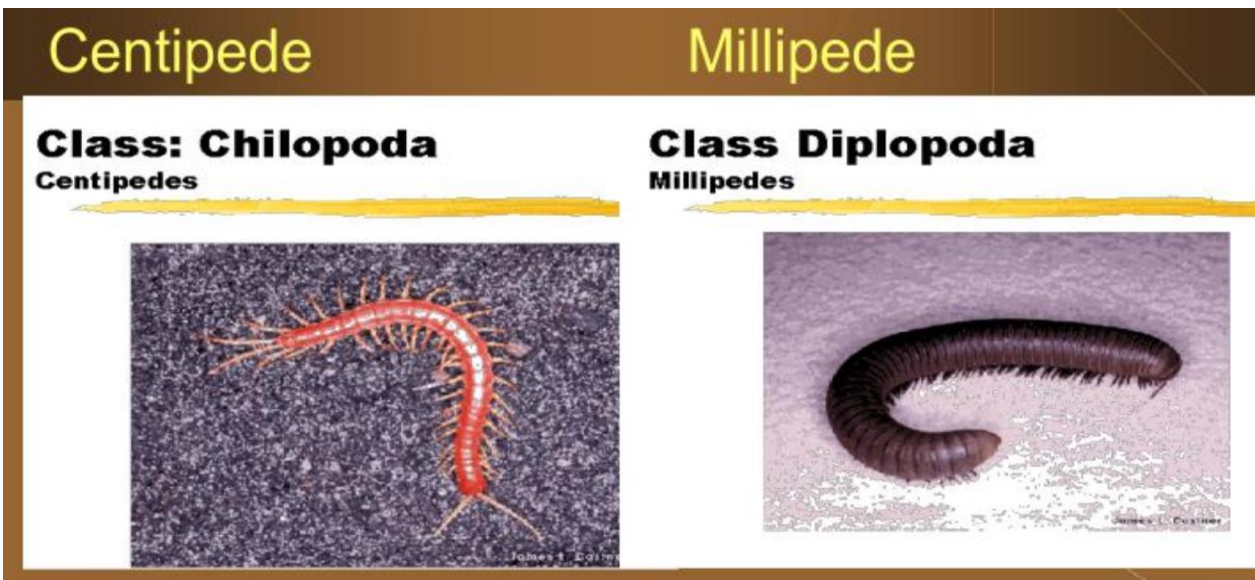
3. Crustacea

- Primarily aquatic, with a few terrestrial species.
- Two pairs of antennae.
- Biramous appendages (branched).
- Classes:
 1. **Malacostraca**: Includes crabs, lobsters, shrimp, and krill.
 2. **Branchiopoda**: Includes water fleas (*Daphnia*) and brine shrimp.
 3. **Maxillopoda**: Includes barnacles and copepods, many of which are planktonic.
 4. **Ostracoda**: Seed shrimp with a bivalve-like shell.
 5. **Remipedia**: Primitive crustaceans found in coastal caves.
 6. **Cephalocarida**: Small, marine crustaceans with simple body structures.



4. Myriapoda

- Terrestrial arthropods with long, segmented bodies.
- One pair of antennae.
- Classes:
 1. **Chilopoda**: Centipedes, with one pair of legs per body segment; carnivorous.
 2. **Diplopoda**: Millipedes, with two pairs of legs per body segment; herbivorous or detritivorous.
 3. **Paupoda**: Small, soft-bodied arthropods found in soil; have fewer legs and are detritivorous.
 4. **Symphyla**: Small, whitish myriapods living in leaf litter and soil.



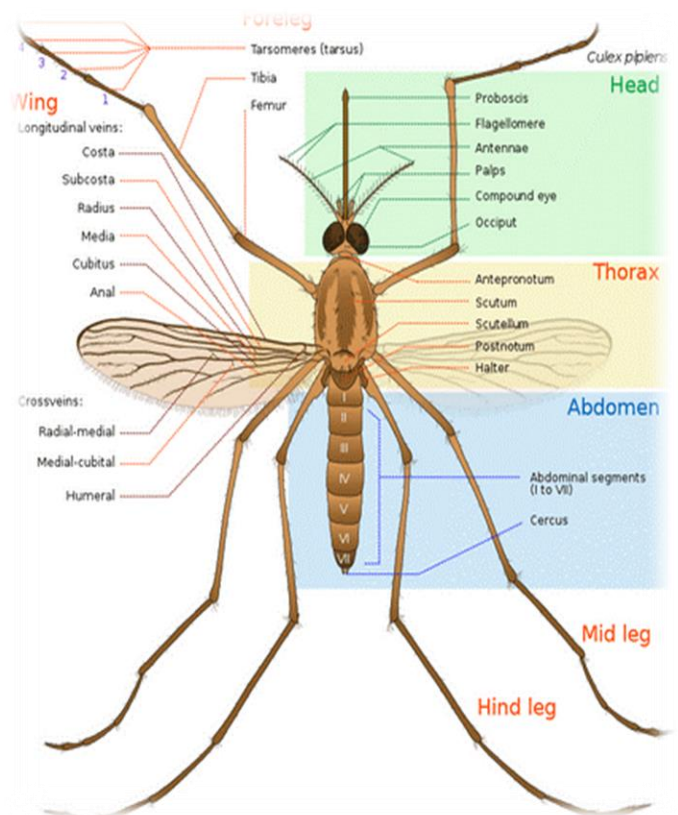
5. Hexapoda

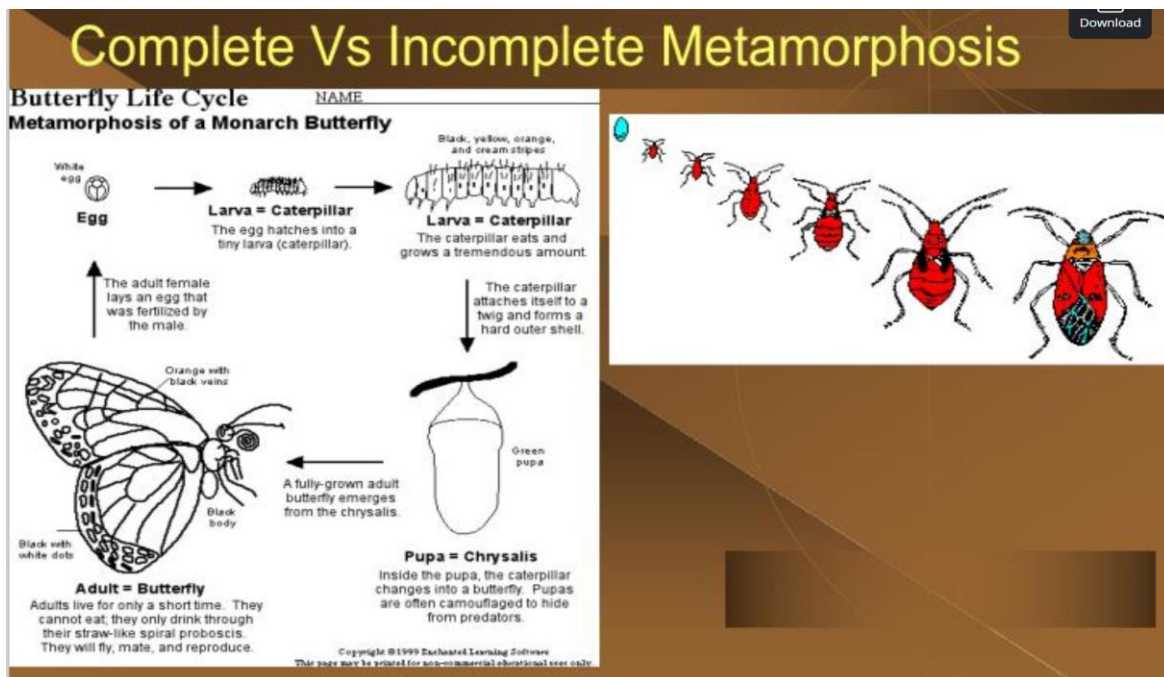
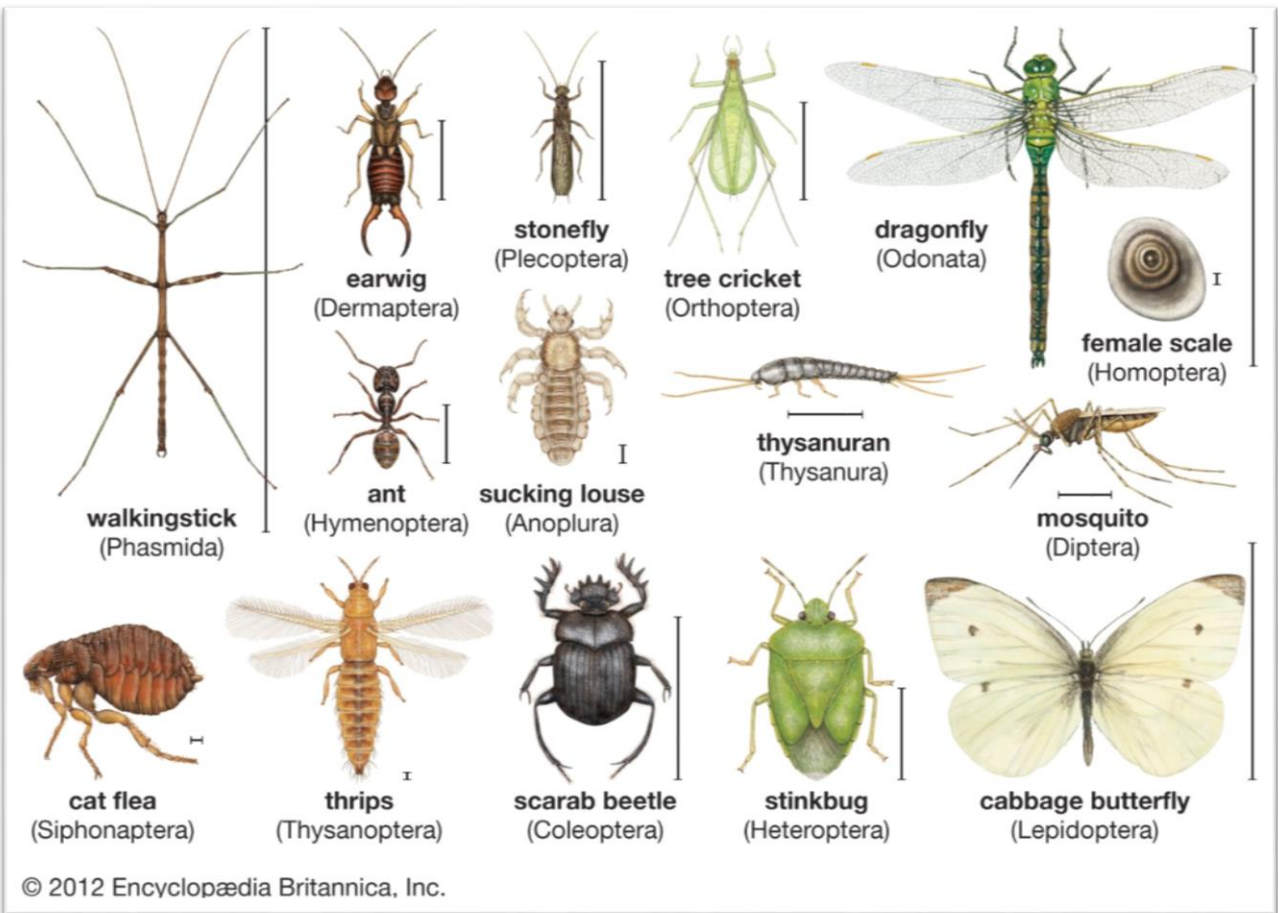
- The most diverse and abundant arthropods.
- Three main body regions: head, thorax, and abdomen.
- One pair of antennae.
- Three pairs of legs on the thorax.
- Classes:
 1. **Insecta**: Includes all insects such as bees, butterflies, ants, and grasshoppers. Many have wings and show great diversity in morphology and ecology.
 2. **Entognatha**: Primitive, wingless arthropods with enclosed mouthparts. Includes springtails (*Collembola*), proturans (*Protura*), and diplurans (*Diplura*).

The insects have proved to be the most successful arthropods. There are far more species in the class Insecta than in any other group of animals. These amazingly diverse animals have conquered all the environments on earth except for the frozen polar environments at the highest altitudes and in the immediate vicinity of active volcanoes.

Insects are the only invertebrates (animals without backbones) with wings. Much of their success results from their ability to fly and colonise new habitats. The study of insects is called entomology and entomologists are scientists who study insects.

Insects play a very important role in the web of life, in every environment. Some of their jobs include pollinating flowering plants, being a source of food for insectivorous animals and assisting in the decomposition of plants and animals.





Commercial significance of insects:

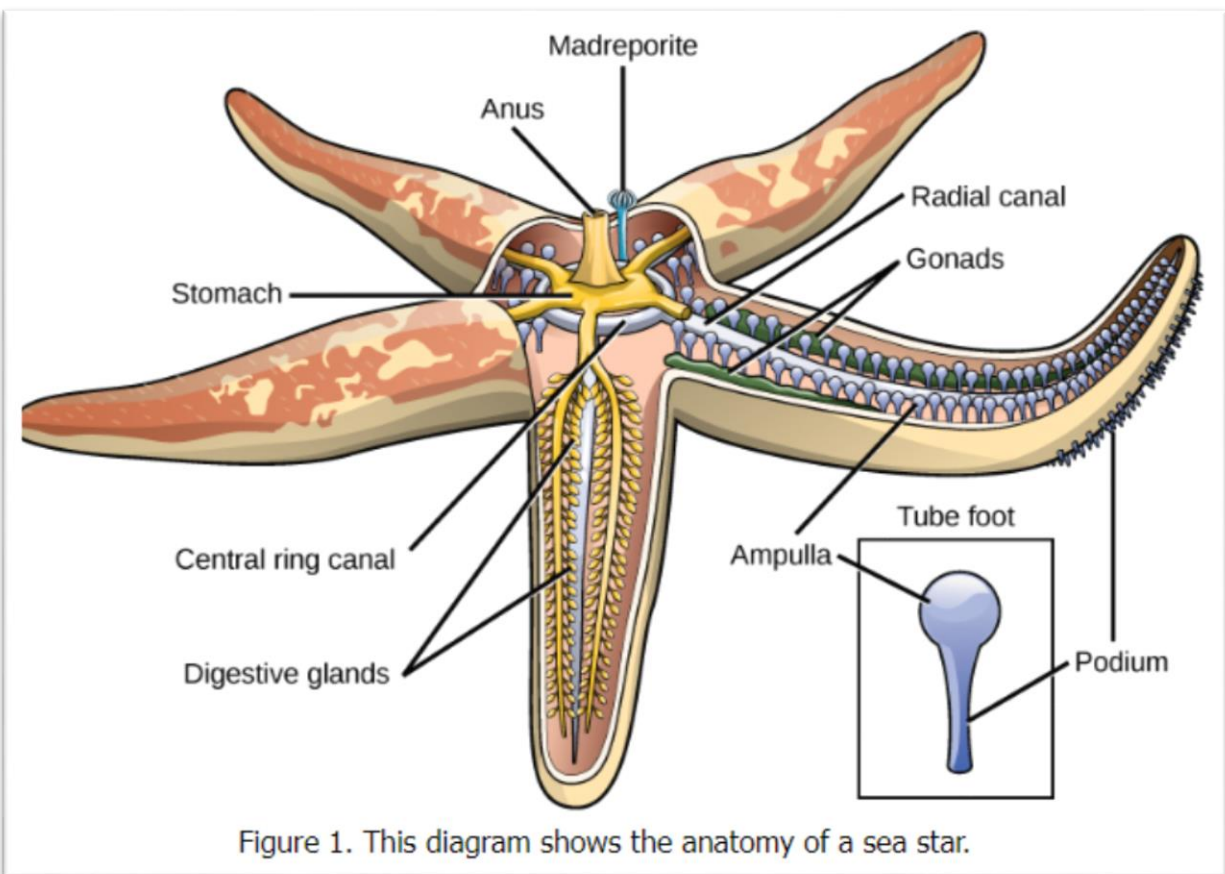
Certain insects provide sources of commercially important products such as honey, silk, wax, dyes, or pigments, all of which can be of direct benefit to humans. Because they feed on many types of organic matter, insects can cause considerable agricultural damage. Insect pests devour crops of food or timber, either in the field or in storage, and convey infective microorganisms to crops, farm animals, and humans. The technology for combatting such pests constitutes the applied sciences of agricultural and forest entomology, stored product entomology, medical and veterinary entomology, and urban entomology.

Table of some differences between Arthropods sub-phylum and classes:

Feature	Insects	Arachnids	Crustaceans	Myriapods
Examples	Beetles, butterflies, ants	Spiders, scorpions, ticks	Crabs, lobsters, shrimp	Centipedes, millipedes
Body Segments	3: Head, thorax, abdomen	2: Cephalothorax, abdomen	2 or more: Head, thorax, abdomen	2: Head, trunk
Number of Legs	6 legs	8 legs	Varies (usually 10 or more pairs)	Centipedes: 1 pair/segment Millipedes: 2 pairs/segment
Antennae	1 pair	None	2 pairs	1 pair
Wings	May have wings (e.g., flies, bees)	None	None	None
Eyes	Compound and simple eyes	Simple eyes	Compound and stalked eyes	Simple eyes
Respiration	Tracheae	Book lungs or tracheae	Gills	Tracheae
Habitat	Terrestrial (mostly)	Terrestrial	Aquatic (mostly)	Terrestrial
Exoskeleton	Chitinous exoskeleton	Chitinous exoskeleton	Chitin and calcium carbonate	Chitinous exoskeleton
Reproduction	Oviparous (lay eggs)	Oviparous or ovoviparous	Mostly oviparous	Oviparous

شوكيات الجلد Phylum of Echinodermata

Echinodermata are so named owing to their spiny skin (from the Greek “echinos” meaning “spiny” and “dermos” meaning “skin”), and this phylum is a collection of about 7,000 described living species. Echinodermata are exclusively marine organisms. Sea stars (Figure 1), sea cucumbers, sea urchins, sand dollars, and brittle stars are all examples of echinoderms. To date, no freshwater or terrestrial echinoderms are known. Echinoderms belong to the superphylum **Deuterostomia**, along with chordates and hemichordates. They evolved around 540 million years ago and have a rich fossil record due to their calcareous skeleton.



Zoological Definition:

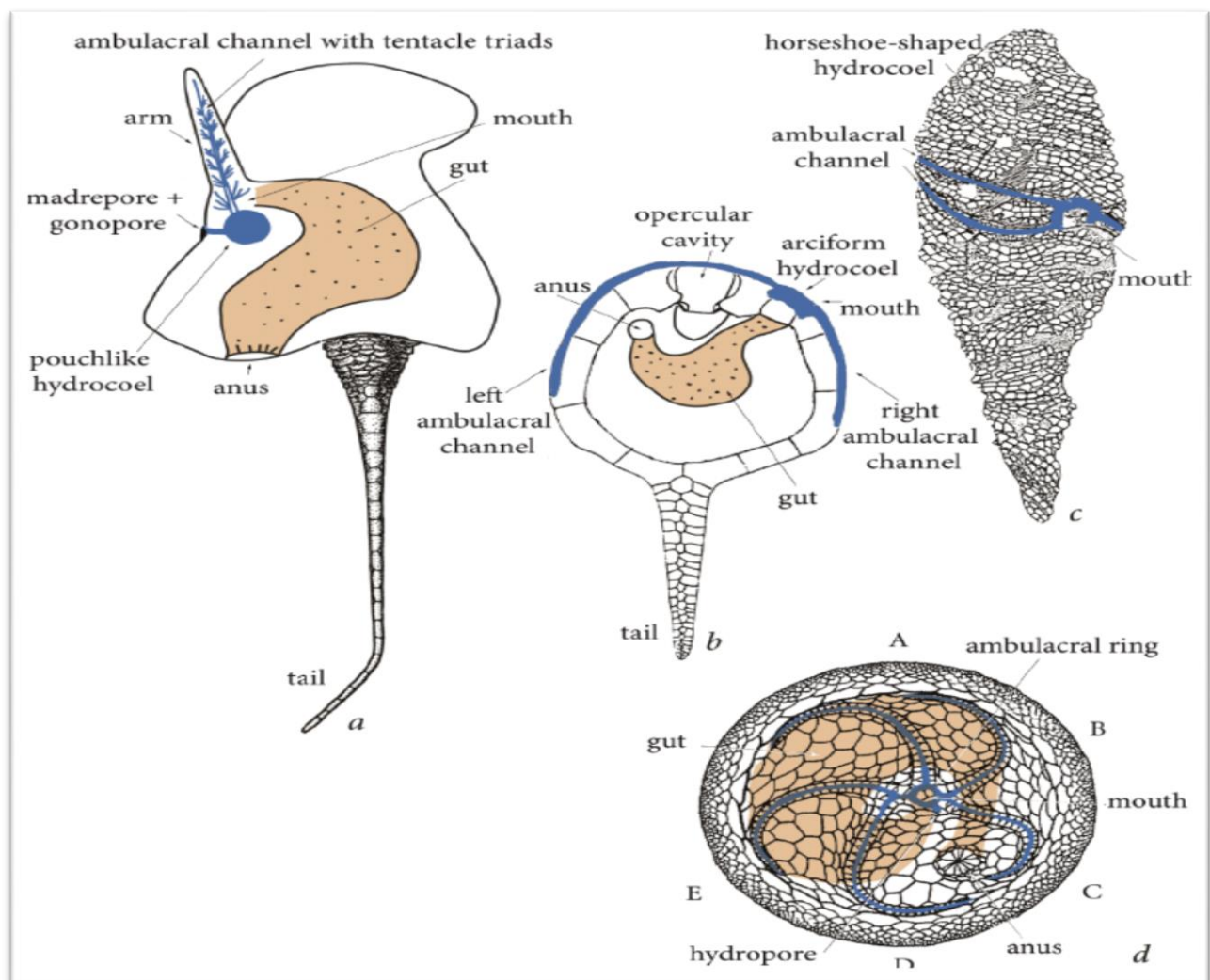
Echinoderms are marine invertebrates characterized by:

- A calcareous endoskeleton.
- A water vascular system used for movement, feeding, and respiration.

- Pentaradial symmetry in adults, though their larvae show bilateral symmetry.
- The ability to regenerate lost body parts.

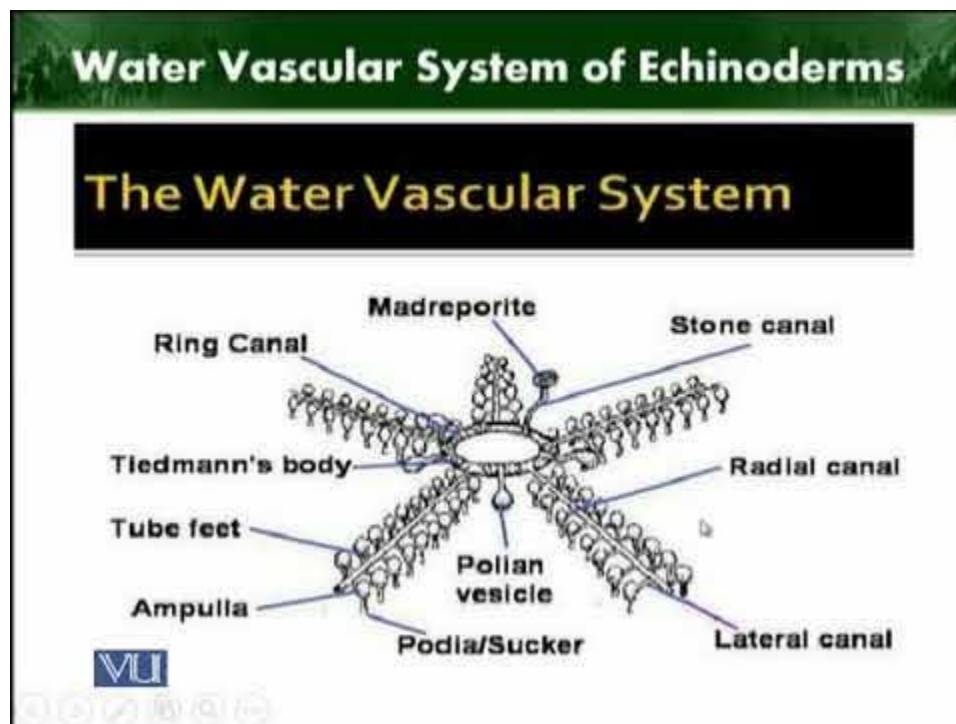
Morphology and Anatomy

Adult echinoderms exhibit pentaradial symmetry and have a calcareous endoskeleton made of ossicles, although the early larval stages of all echinoderms have bilateral symmetry. The endoskeleton is developed by epidermal cells and may possess pigment cells, giving vivid colors to these animals, as well as cells laden with toxins. Gonads are present in each arm. In echinoderms like sea stars, every arm bears two rows of tube feet on the oral side. These tube feet help in attachment to the substratum. These animals possess a true coelom that is modified into a unique circulatory system called a water vascular system. An interesting feature of these animals is their power to regenerate, even when over 75 percent of their body mass is lost.



Water Vascular System

Echinoderms possess a unique ambulacral or water vascular system, consisting of a central ring canal and radial canals that extend along each arm. Water circulates through these structures and facilitates gaseous exchange as well as nutrition, predation, and locomotion. The water vascular system also projects from holes in the skeleton in the form of tube feet. These tube feet can expand or contract based on the volume of water present in the system of that arm. By using hydrostatic pressure, the animal can either protrude or retract the tube feet. Water enters the madreporite on the aboral side of the echinoderm. From there, it passes into the stone canal, which moves water into the ring canal. The ring canal connects the radial canals (there are five in a pentaradial animal), and the radial canals move water into the ampullae, which have tube feet through which the water moves. By moving water through the unique water vascular system, the echinoderm can move and force open mollusk shells during feeding.

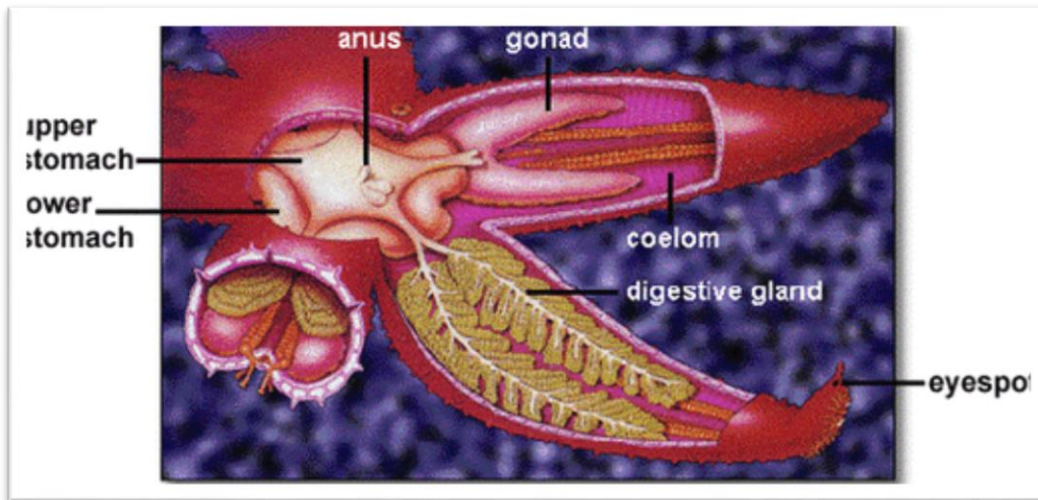


Nervous System

The nervous system in these animals is a relatively simple structure with a nerve ring at the center and five radial nerves extending outward along the arms. Structures analogous to a brain or derived from fusion of ganglia are not present in these animals.

Excretory System

Podocytes, cells specialized for ultrafiltration of bodily fluids, are present near the center of echinoderms. These podocytes are connected by an internal system of canals to an opening called the madreporite.



Reproduction

Echinoderms are sexually dimorphic and release their eggs and sperm cells into water; fertilization is external. In some species, the larvae divide asexually and multiply before they reach sexual maturity. Echinoderms may also reproduce asexually, as well as regenerate body parts lost in trauma.

Classes of Echinoderms

Echinodermata is divided into **five main extant classes**, with some extinct classes as well.

1. Class Asterozoidea

- Common name: **Sea stars (starfish)**
- Characteristics:
 - Central disc with five or more radiating arms.
 - Predators or scavengers.

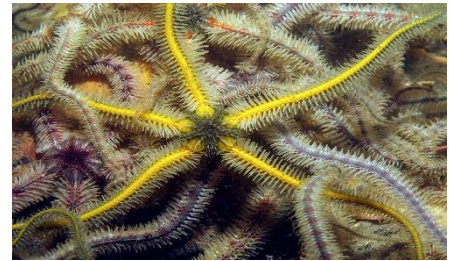


- Locomotion through tube feet on the underside of their arms.

Example: *Asterias rubens*.

2. Class Ophiuroidea

- Common name: **Brittle stars and basket stars**
- Characteristics:
 - Slender, flexible arms distinct from the central disc.
 - Locomotion by arm movement rather than tube feet.
 - Often found in deep-sea habitats.
- Example: *Ophiothrix fragilis*.



3. Class Echinoidea

- Common name: **Sea urchins and sand dollars**
- Characteristics:
 - Globular or flattened body covered with spines.
 - Lack arms but have movable spines and a hard test (shell).
 - Feeding mechanism: Aristotle's lantern (a complex jaw system).
- Example: *Strongylocentrotus purpuratus*.



4. Class Holothuroidea

- Common name: **Sea cucumbers**
- Characteristics:
 - Elongated, soft-bodied echinoderms.
 - Reduced endoskeleton with leathery skin.
 - Some species can eviscerate internal organs as a defense mechanism.
- Example: *Holothuria scabra*.

5. Class Crinoidea

- Common name: **Feather stars and sea lilies**
- Characteristics:
 - Filter feeders with long, feathery arms.
 - Sea lilies are stalked and sessile, while feather stars are free-moving.

- Example: *Antedon mediterranea*.

Extinct Classes

Fossils reveal additional classes of echinoderms that thrived in ancient seas:

1. Class Blastoidea

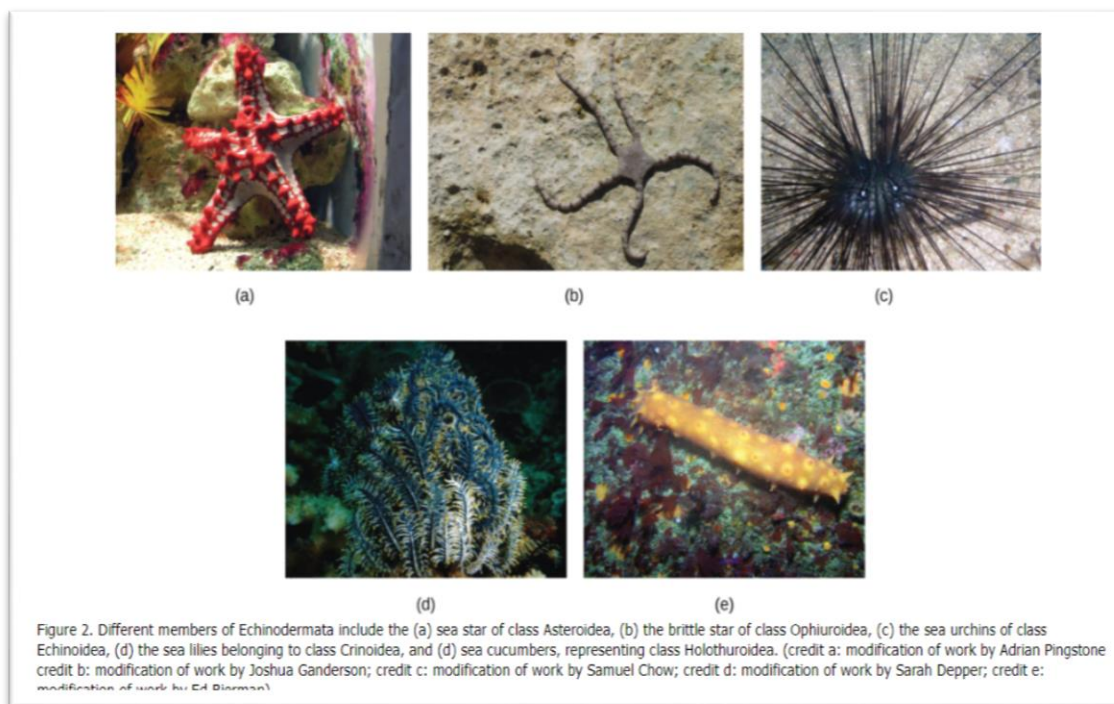
- Extinct echinoderms with a flower-like structure.

2. Class Cystoidea

- Primitive, sac-like echinoderms.

3. Class Edrioasteroidea

- Disc-shaped, sessile echinoderms.

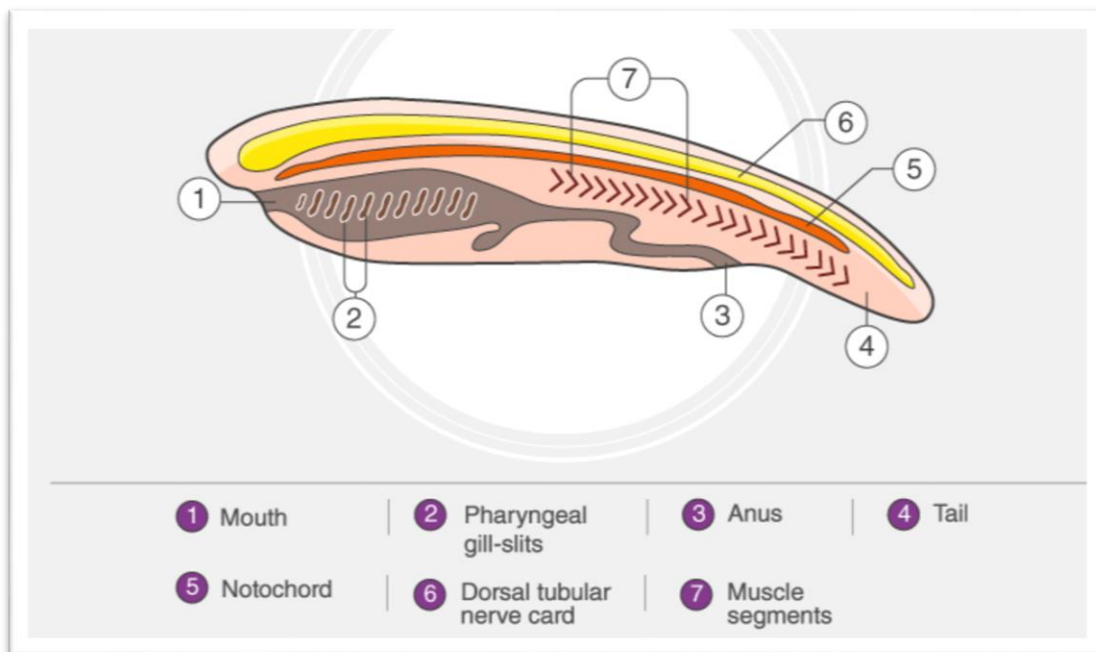


Zoological Significance:

- Ecological Role: They are key players in marine ecosystems, controlling populations of algae and invertebrates.
- Evolutionary Significance: Echinoderms are part of the Deuterostomia, a group that also includes vertebrates, showing evolutionary links between invertebrates and vertebrates.

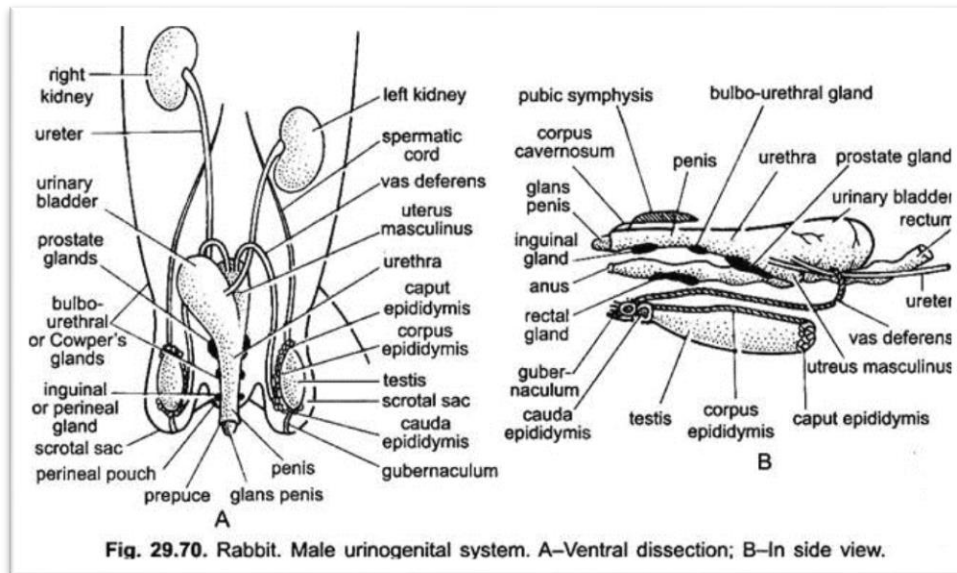
الحبليات Phylum of Chordata

The Phylum Chordata includes organisms with advanced anatomical structures, characterized by unique features. This phylum comprises species such as fish, amphibians, reptiles, birds, mammals, and some invertebrate chordates. Phylum Chordata belongs to the Kingdom Animalia and includes all the vertebrates, i.e., animals **with a backbone**, and several invertebrates, i.e., organisms **without a backbone**. They possess a bilaterally symmetrical body and are divided into three different sub-phyla.



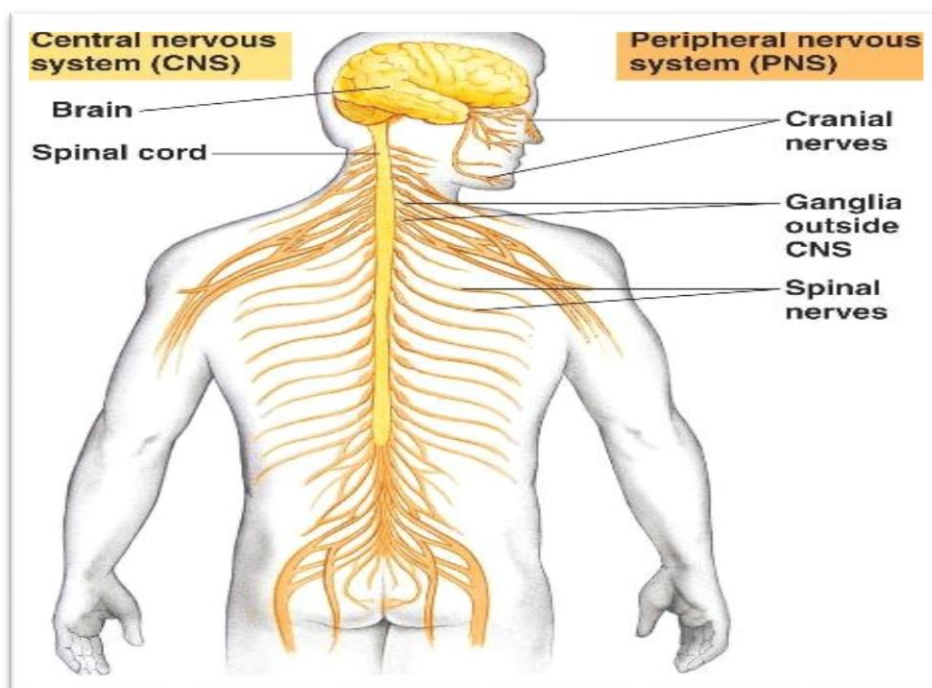
Reproduction and life cycle

The chordate life cycle begins with fertilization (the union of sperm and egg). In its primitive form, fertilization occurs externally, in the water. Asexual reproduction takes place in tunicates and in some vertebrates (females of some fish and lizards can reproduce without fertilization). Hermaphroditism (possessing both male and female reproductive organs) is found in tunicates and some fishes, but otherwise the sexes are separate. Larvae (very young forms that differ considerably from the juveniles and adults), when they do occur, differ in structure from the [larvae](#) of nonchordates. Internal fertilization, viviparity (giving birth to young that have undergone embryological development), and parental care are common in tunicates and vertebrates.



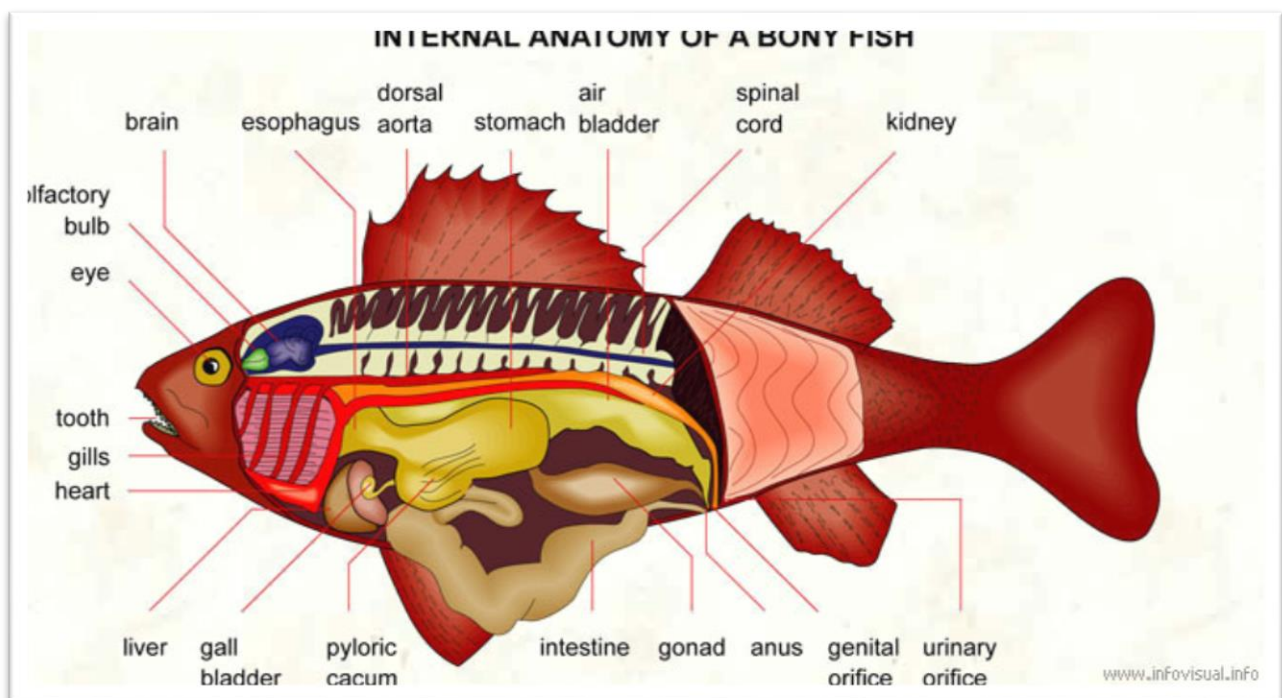
Nervous system and sense organs

The [anterior](#) end of the main nerve cord in chordates is enlarged to form at least the suggestion of a brain, but a brain is well developed only in vertebrates. Tunicate [larvae](#) have visual organs sensitive to light and sense organs responsive to the direction of gravity. Pigment spots and light receptors in the nerve cord of lancelets detect sudden changes in [light intensity](#). The eyes and other sense organs of vertebrates are more elaborate and complex.



Digestion and nutrition

Both tunicates and cephalochordates are filter feeders of small particles of food suspended in the water. Beating [cilia](#) (hairlike cellular extensions) on the [gill](#) slits draw a current of water into the mouth and through the [pharynx](#), where a sheet of [mucus](#), [secreted](#) by the [endostyle](#) (a glandular organ lying below the two rows of gill slits), filters suspended food particles from the water. Cilia lining the pharynx move the food-rich sheet of mucus upward over the gill slits, and it is then rolled up and transported to the posterior part of the gut. The water current passes into the atrium and exits through the atrial opening.



Ecology and habitats

Chordates are common in all major habitats. Tunicate larvae either seek out a place where they can attach and metamorphose into an adult or develop into adults that float in the open water. Cephalochordates develop in the open water, but as adults they lie partially or entirely buried in sand and gravel. In either case, they are filter feeders with simple behaviour. Vertebrates are much more complex and, in keeping with their more active manner of obtaining food, highly varied in their [ecology](#) and habits.

Locomotion

Chordates are capable of locomotion by means of muscular movements at some stage in life. In tunicate larvae, this is accomplished using a tail; in cephalochordates, by undulations of the body; and in vertebrates, by general body movements (as in eels and snakes) and by the action of fins and limbs, which in birds and some mammals are modified into wings.

Key Characteristics of Phylum Chordata

1. Notochord:

- A flexible rod running along the dorsal side of the body.
- Present during embryonic development or throughout life.
- Replaced by the vertebral column in vertebrates.

2. Dorsal Hollow Nerve Cord:

- A tubular nerve cord located dorsally, above the notochord.
- Develops into the brain and spinal cord in vertebrates.

3. Pharyngeal Slits:

- Openings in the pharynx used for respiration or feeding.
- May be modified or disappear in adults of some species.

4. Post-anal Tail:

- A tail extending beyond the anus, functional in some species or vestigial in others.

5. Closed Circulatory System:

- A well-developed circulatory system with a heart typically located on the ventral side.

Main Subphyla of Chordata

- Urochordates (Urochordata), which have a notochord only in the free larval stage

- Cephalochordates (Cephalochordata), with a permanent notochord

- Vertebrates (Vertebrata), which have a vertebral column and a cranium that protects the brain. In addition, the neural tube evolves to **become** the spinal cord (moëlle épinière).

1. **Subphylum Urochordata (Tunicates):**

- Marine organisms like *sea squirts* and *salps*.
- The notochord appears only in the larval stage.

2. **Subphylum Cephalochordata (Lancelets):**

- Simple marine organisms such as *lancelets* (*Amphioxus*).
- The notochord and nerve cord persist throughout life.

3. **Subphylum Vertebrata (Craniata):**

- Organisms with a vertebral column.
- Includes fishes, amphibians, reptiles, birds, and mammals.

