ALGERIAN DEMOCRATIC AND PEOPLE'S REPUBLIC
Ministry of Higher Education and Scientific Research

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Zoology

Intended for students of Earth and Universe Sciences

1st year

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Preamble

THIS ZOOLOGY HANDOUT IS INTENDED FOR FIRST-YEAR UNDERGRADUATE STUDENTS •LMD• EARTH AND UNIVERSE SCIENCE AND FOR ANYONE INTERESTED IN THE SCIENTIFIC STUDY OF LIVING BEINGS (TEACHERS, DOCTOR, BIOLOGY RESEARCHER, ETC.). IT PRESENTS A NECESSITY FROM THE BEGINNING OF A UNIVERSITY STUDENT'S CAREER IN THE SCIENTIFIC FIELD IN GENERAL: SCIENCE OF NATURE AND LIFE, DOCTOR, VETERINARIAN, PHARMACY...ETC. TO FULLY UNDERSTAND THE CONCEPTS OF ZOOLOGY, THE STUDENT MUST HAVE PREREQUISITES IN THE ^{2ND} AND ^{3RD} SNV SECONDARY YEAR (BACCALAUREATE).

THIS HANDOUT PROVIDES THE STUDENT WITH THE BASIC KNOWLEDGE OF ZOOLOGY, WHICH IS A NECESSARY AND INDISPENSABLE TOOL FOR CONTINUING THE MODULES OFFERED IN THE SECOND SEMESTER.

THE GOALS OF THE SESSION ARE THE FOLLOWING:

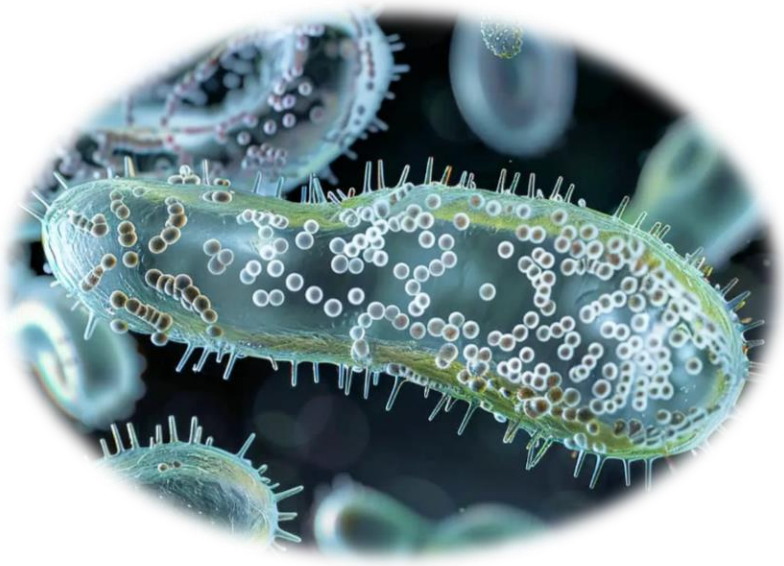
- Develop basic knowledge of animal classification (systematic) and taxonomy to understand diversity and evolutionary relationships between species.
- Identify and understand major biological functions in animals, such as nutrition, respiration, reproduction, and shedding.
- Learn to observe and identify the main morphological characteristics of animals and relate them to their lifestyles and adaptation.
- Use microscopic observation techniques to examine samples, understand the cellular and tissue structure of animals, and distinguish between different groups of organisms.

This module is accompanied by a teaching of practical and directed work (TP/TD) which focuses on the methods used in animal biology, observation and interpretation of experimental results. Mastery of the concepts acquired in the context of TDs and TPs is necessary for a good understanding of most of the chapters of this module.

This handout consists of four chapters:

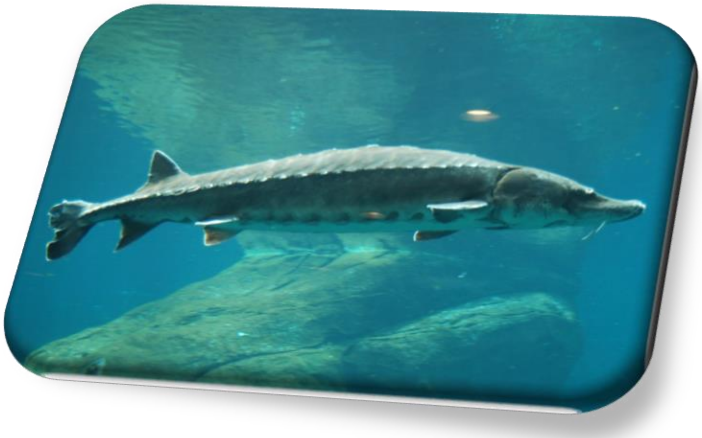
The first chapter deals with the animal kingdom, exploring its classification, its main characteristics and the diversity of the species that compose it. This chapter provides an understanding of the basics of animal taxonomy, large groups (phyla).

The second chapter is devoted to protozoa, a group of eukaryotic single-celled organisms belonging to the reign of the Protists. This chapter explores their classification, biological characteristics, and varied lifestyles. It also addresses their cellular structure, their mechanisms of nutrition, reproduction, as well as their methods of locomotion (flagella, eyelashes, pseudopods).



The third chapter is devoted to metazoans, or multicellular animals, which are a large group of complex organisms characterized by the presence of several cells organized into tissues and organs. This chapter explores the different classes and phyla of metazoans, focusing on their bodily organization, embryonic development, and the biological systems that provide their vital functions, such as the nervous, digestive, circulatory, and reproductive systems.

The fourth chapter is devoted to vertebrates, a subgroup of metazoans characterized by the presence of a spine and an internal skeleton. This chapter explores vertebrate diversity by addressing the five main classes: fish, amphibians, reptiles, birds, and mammals. Each of these classes is studied in detail, with a focus on their distinctive characteristics, their anatomical structure, and their adaptation to different living environments.



Chapter I: Presentation of the Animal Kingdom

Chapter II: Generalities on the Protozoan Sub-Kingdom

Chapter III: Metazoa Sub-Kingdom

Chapter IV: Vertebrate Class

Chapter 1: Presentation of the animal kingdom

1. Classification and Zoological Nomenclature:

Zoological classification and nomenclature are essential pillars of modern biology, making it possible to organize and describe the diversity of animal species that inhabit our planet. Through these systems, biologists can identify, name, and study the relationships between different species.

a) The Zoological Classification:

Zoological classification is based on a systematic hierarchy that groups organisms into categories, based on their common characteristics. The main categories of the classification, from the most general to the most specific, are:

- **Reign**: The highest level, which includes all living organisms, for example, the Animalia reign for animals.

- **Phylum**: Groups large groups of animals sharing common characteristics, such as Chordates (which include vertebrates).

- **Class**: A further subdivision of phyla. For instance, within *Chordata*, there are classes like *Mammalia* (mammals), *Aves* (birds), and *Reptilia* (reptiles).

- **Order**: Groups families with common traits, such as Carnivores.

- **Family**: Groups genders with similarities, for example, the Felidae family for cats.

- **Genus**: Groups closely related species, such as the genus *Panthera*.

- **Species**: Basic unit of classification, representing a group of individuals capable of reproducing among themselves, such as *Panthera leo* for the lion.

Fig 01: Hierarchy of biological classification

This hierarchy relies heavily on taxonomy, a science that studies the evolutionary relationships between different species. Modern taxonomy uses molecular and genetic methods to establish phylogenetic links, providing a more accurate understanding of the evolution of organisms.

b) Zoological nomenclature:

Zoological nomenclature is a set of rules and conventions that defines how organisms should be named in a standardized way. The most common nomenclature system is the binomial system, established by Carl von Linné in the 18th century. Each species is designated by two Latin names:

A. **Gender**: A name that starts with a capital letter.

B. **Species**: A specific epithet that begins with a lowercase letter.

For example, the dog's scientific name is *Canis lupus familiaris*, where '*Canis*' is the genus and 'lupus familiaris' the epithet.

Nomenclature:

The rules of nomenclature are governed by the International Code of Zoological Nomenclature (CINZ), which establishes principles such as:

- Priority: The first valid name assigned to a species must be used, except in exceptional cases.

- Stability and University: Names should be as stable and standardized as possible, facilitating global science communication.

- Validity: Species descriptions must be published in recognized scientific journals and meet rigorous criteria.

c) **Conclusion**:

Zoological classification and nomenclature play a crucial role in understanding biodiversity. They make it possible not only to identify and classify species, but also to study evolutionary relationships and ecological interactions among different life forms. By following established rules, scientists can communicate effectively about their research and contribute to the protection of biodiversity

2. Evolution and Phylogeny:

Evolution and phylogeny are fundamental concepts in biology that make it possible to understand the history of life on Earth. By examining how species have developed, diversified, and interacted over time, scientists can trace the roots of our current biodiversity.

- **The Foundations of Evolution:**

Evolution is the process by which species change over generations through mechanisms like natural selection, mutations, genetic drift, and migration. Charles Darwin, with his theory of natural selection, laid the foundation for our modern understanding of this process. “It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change”.

Darwin's model of evolution has since been enriched by discoveries in genetics and molecular biology. It is now known that genetic variations are essential for the adaptation of species to their environment.

- **Phylogeny**: A Tree of Life

While evolution deals with species change, phylogeny focuses on the relationships between them. She uses tools like genetic analysis and morphology to build phylogenetic trees. These trees represent the evolutionary links between species, indicating how they diverged from common ancestors.

Phylogeny is based on the idea that all forms of life are related. As biologist Ernst Mayr pointed out, 'The length of the chain of life rests on the unity of the tree of life.' The concept of a common ancestor for all species has been solidified by modern genetics, revealing surprising connections between seemingly very different organisms.

- **The Importance of Evolution and Phylogeny:**

  Understanding evolution and phylogeny is crucial not only for biology, but also for fields such as medicine, conservation and agriculture. By studying evolutionary relationships between species, researchers can better understand disease resistance mechanisms, ecosystem dynamics, and the impacts of environmental change.

For example, in the area of conservation, setting priorities for the protection of endangered species can be guided by their place in the phylogenetic tree. By preserving species that appear in critical places on this tree, we can protect biodiversity more effectively.

3. Numerical Importance of the Animal Kingdom:

The animal kingdom, rich in diversity and complexity, plays an essential role in the functioning of terrestrial and aquatic ecosystems. From pollination to the regulation of prey populations, animals that contribute to biodiversity are crucial to the health of our planet. Each species, no matter how small, plays a role in the wide range of interactions that maintain this fragile dynamic. Awareness of the numerical importance of this kingdom is necessary to work towards its preservation.

- **Biodiversity**:

Animal biodiversity is often measured in terms of species abundance and diversity. According to scientist E.O. Wilson, 'Biodiversity is the treasure of biology. Life is our greatest gift, and nature is our greatest wealth.' This wealth translates into resilient ecosystems that are able to adapt to environmental change and provide essential resources for humanity, such as water, clean air, and food.

- **The Ecosystem Services Offered by the Animal Kingdom:**

Animals provide many ecosystem services that support life on Earth. For example:

- pollinators such as bees and butterflies play a fundamental role in food production. According to the Food and Agriculture Organization of the United Nations (FAO), '75% of food crops depend on pollination'. Without these species, global food security would be severely compromised.
- In addition, predators regulate populations of other species, preventing imbalances that can lead to ecosystem collapse. Wolves in North American national parks are a good example: their presence helps control elk populations, allowing plants to thrive and promoting biodiversity.

- **A Growing Threat:** Human Dependence on the Animal Kingdom

However, human pressure on these valuable resources is constantly increasing. Habitat destruction, climate change, pollution and excessive exploitation of resources threaten not only the survival of animal species, but also the very balance of our planet. The UN Biodiversity Report states that 'virtually all animal and plant species are in decline', highlighting the urgency of taking action to protect our environment.

- **Digital technology:**

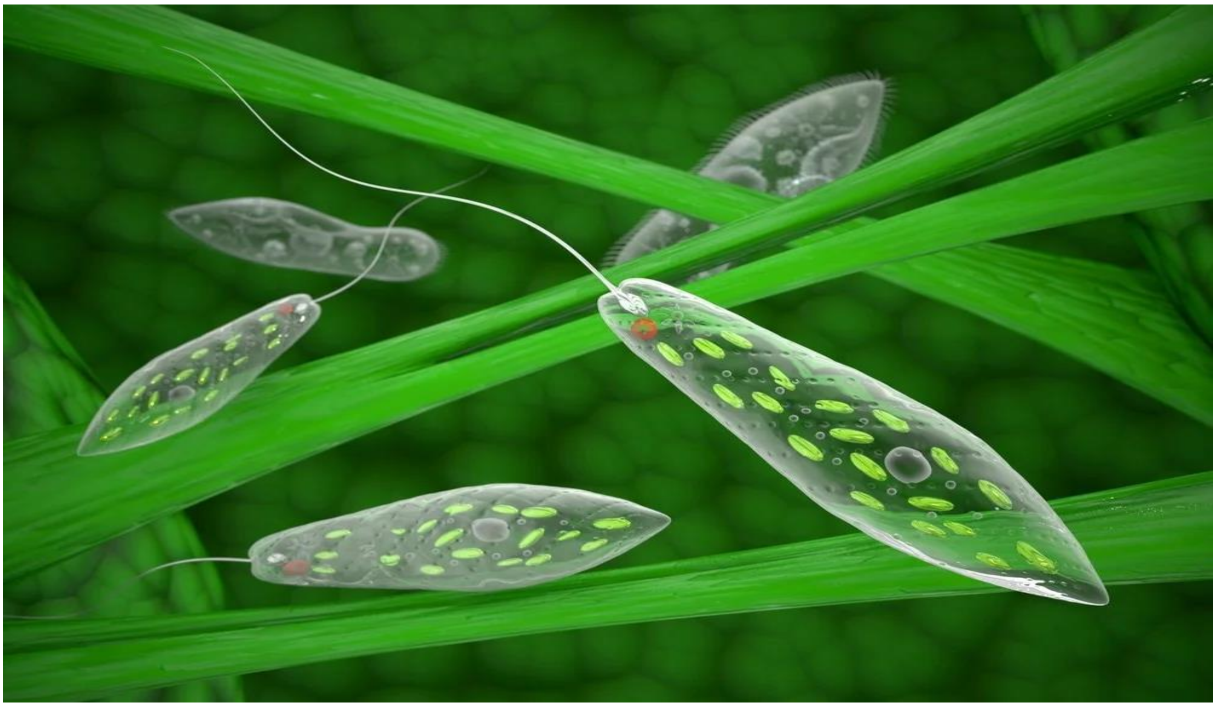
Digital technology can play a vital role in conserving the animal kingdom. Modern tools such as satellite tracking, drones and online databases provide valuable information about animal populations and status. These technologies make it possible to develop more effective conservation strategies to protect endangered species.

- **Conclusion**:

The digital wealth of the animal kingdom is not limited to a number or a statistic. It represents a legacy that must be preserved for future generations. As the famous biologist David Suzuki points out, 'we are not owners of the planet, but guardians of the future.' The preservation of the animal kingdom is therefore both an ethical duty and a necessity for our collective survival.

To preserve this fragile balance, it is crucial that governments, organizations and each individual become aware of the numerical importance of animals and take action. By investing in conservation, supporting sustainable policies, and increasing our awareness of environmental issues, we can help protect the animal kingdom and, therefore, our own future

Chapter 2: Generalities on the Protozoa sub-kingdom



Introduction:

Protozoa are a diverse group of single-celled organisms belonging to the reign of the Protists. They are characterized by a eukaryotic cell, that is, a cell that has a nucleus surrounded by a membrane. Although some protozoa are considered parasites to humans, animals and plants, others play essential ecological roles in food webs as primary or secondary consumers.

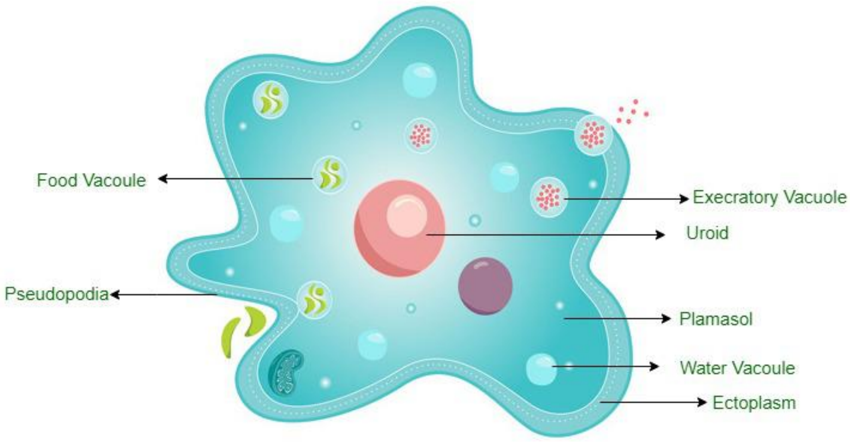


Fig 02: Protozoa

1 . General characteristics :

- Unicellular: Protozoa consist of a single cell, but they perform all vital functions, such as reproduction, nutrition, and locomotion, autonomously.
- Eukaryotes: Protozoan cells have a distinct nucleus containing DNA, as well as specialized organelles like mitochondria.
- Heterotrophs: The majority of protozoa obtain their food by ingesting organic particles or other organisms. Some protozoa, such as *Euglena*, can perform photosynthesis in the presence of light, but become heterotrophic in its absence.

- Locomotion: They use different structures to move, such as flagella, cilium, or pseudopods.
- Reproduction: Protozoa reproduce mainly asexually by binary division. Some species can also reproduce sexually.

2. Classification of protozoa

The classification of protozoa is mainly based on their mode of locomotion. They can be grouped into four main groups:

A. The Flagellates (Mastigophora)

- Locomotion: Movement by flagella, which are filamentous structures.
- Examples: *Trypanosoma* (responsible for sleeping sickness), *Giardia* (causes intestinal infections).
- Habitat: Aquatic and often parasitic in host organisms.

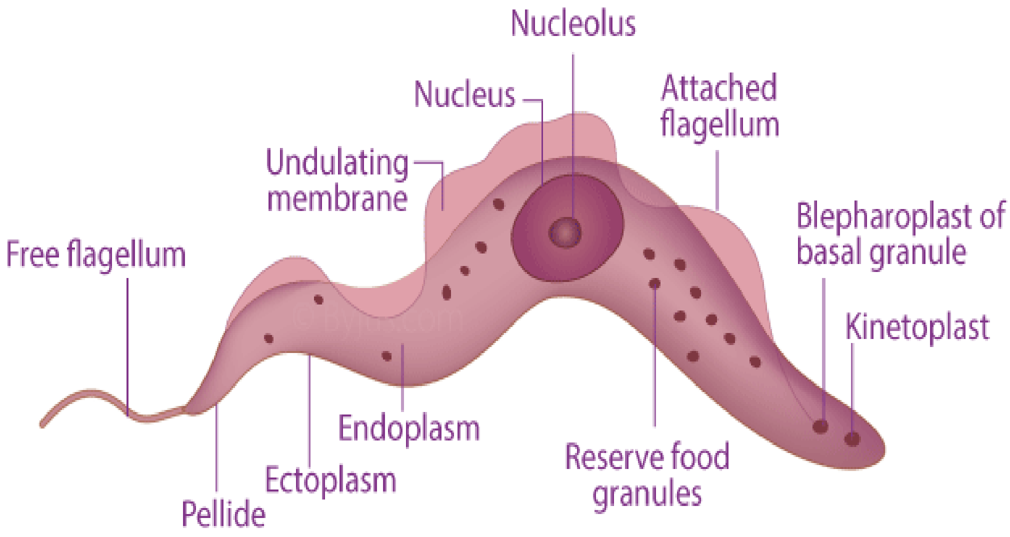


Fig 03: Structure of *Trypanosoma*

B. **The Ciliates** (Ciliophora) :

- Locomotion: Use short, numerous lashes that cover their surface to move around and capture food.
- Examples: *Paramecium* (paramecia), *Balantidium coli* (human parasite).
- Habitat: Freshwater and marine, sometimes in symbiosis or parasitism.

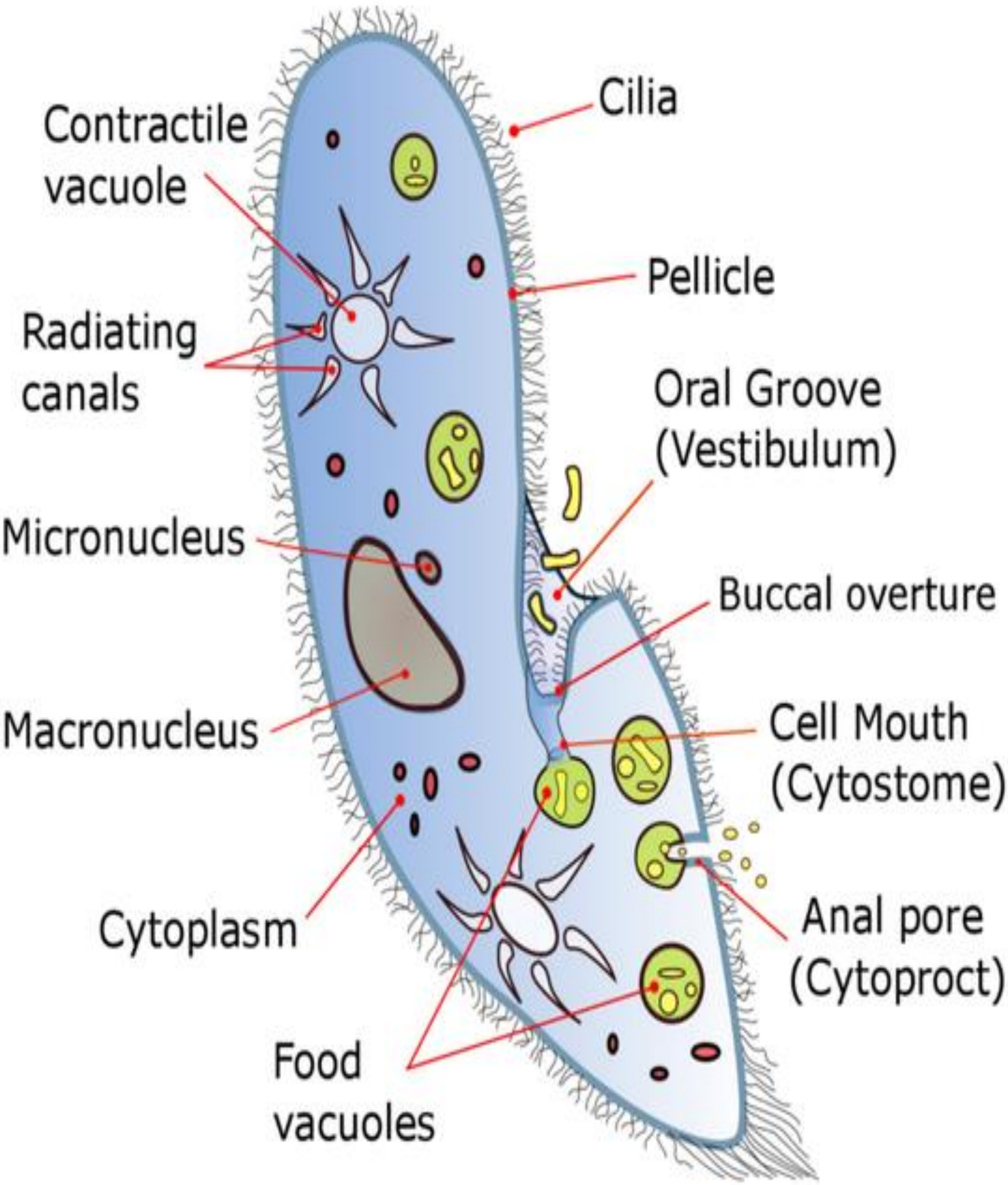


Fig 04: Structure of *Paramecium*

C. **Rhizopods** (Sarcodina)

- Locomotion: Use pseudopods (cell membrane extensions) to move around and phagocytose food.
- Examples: *Amoeba proteus* (amoeba), *Entamoeba histolytica* (agent of amoebic dysentery).
- Habitat: Especially in aquatic environments, wet soils, and host intestines.

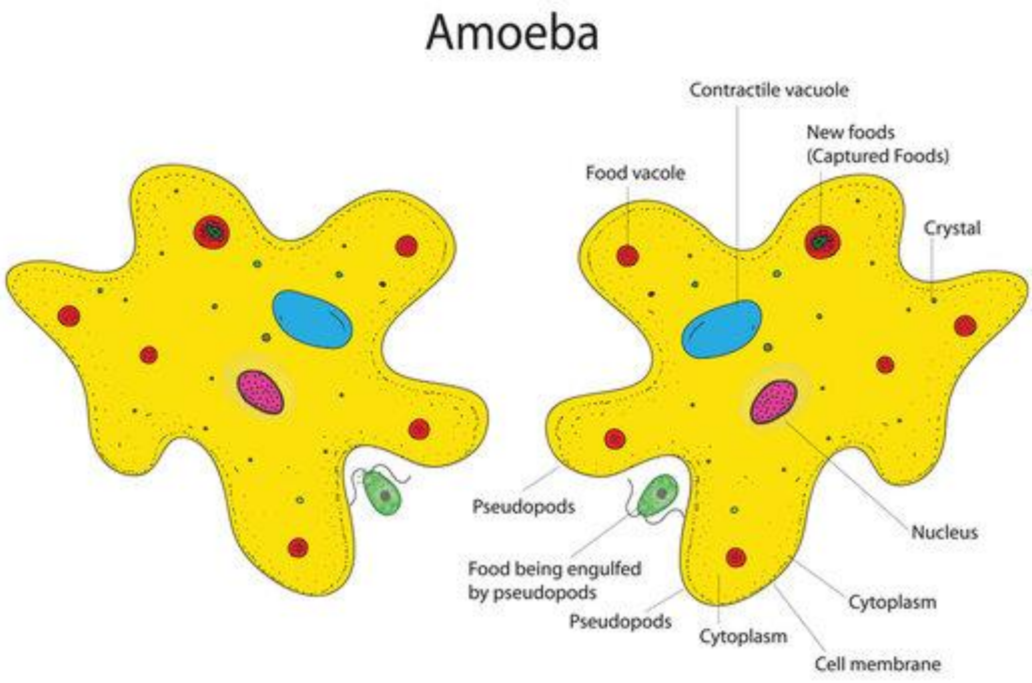


Fig 05: Structure of *Amoeba*

D. **Sporozoa** (Apicomplexa)

- Locomotion: Absence of specific locomotion structures in the adult state. They are often motionless and parasitic.
- Examples: *Plasmodium* (responsible for malaria), *Toxoplasma gondii* (toxoplasmosis).
- Habitat: Live exclusively as parasites in other organisms.

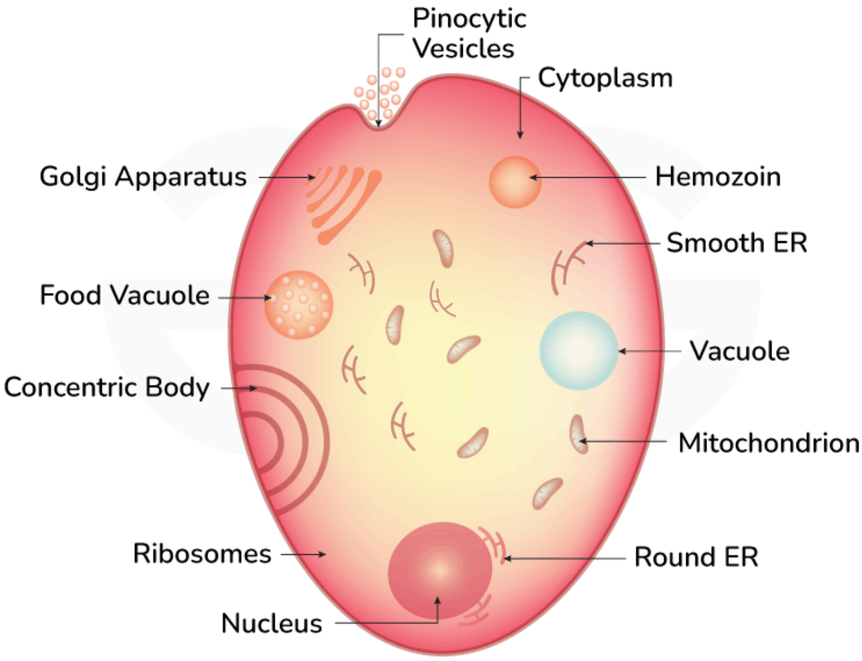


Fig 06: Structure of *Plasmodium*

3.Life cycle and reproduction

- Asexual reproduction: By binary division, scissiparity, or budding. In binary division, the cell divides into two identical daughter cells.
- Sexual reproduction: Some protozoa undergo sexual reproduction by conjugation or fusion of gametes. For example, *Paramecium* performs a conjugation where two individuals exchange genetic material.
- Complex life cycle: Many parasitic protozoa, like *Plasmodium,* have complex life cycles involving several different stages and hosts.

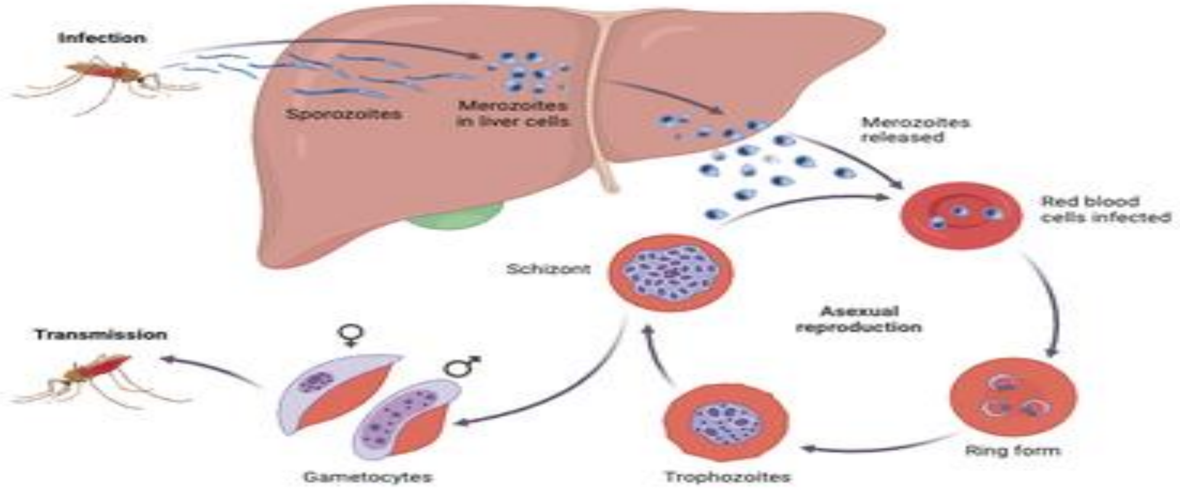


Fig 07: Malaria Transmission Cycle

4. Protozoan nutrition and respiration

Protozoans are single-celled eukaryotic organisms that can be found in a variety of environments, from aquatic ecosystems to soil, and some even inside other organisms. They are diverse in terms of their nutrition and respiration processes, depending on the species. Here's an overview of how protozoans manage nutrition and respiration:

- **Protozoan Nutrition**

Protozoa are a diverse group of unicellular eukaryotic organisms that exhibit a variety of nutritional strategies. They are primarily heterotrophic, meaning they obtain their nutrients from organic sources, but some can also exhibit mixotrophic or autotrophic behaviors. Below is a detailed explanation of protozoan nutrition:

1. Modes of Nutrition in Protozoa:

Protozoa can be classified based on their nutritional strategies into the following categories:

a. Holozoic Nutrition (Phagotrophic Nutrition)

- Protozoa ingest solid food particles, such as bacteria, algae, or other small organisms, through phagocytosis.
- Process:
  - Ingestion: The food particle is engulfed by the cell membrane, forming a food vacuole.
  - Digestion: Enzymes are secreted into the food vacuole to break down the food.
  - Absorption: Nutrients are absorbed into the cytoplasm.
  - Egestion: Undigested waste is expelled from the cell.
- Examples: *Amoeba* (engulfs prey using pseudopodia), *Paramecium* (uses cilia to direct food into the oral groove).

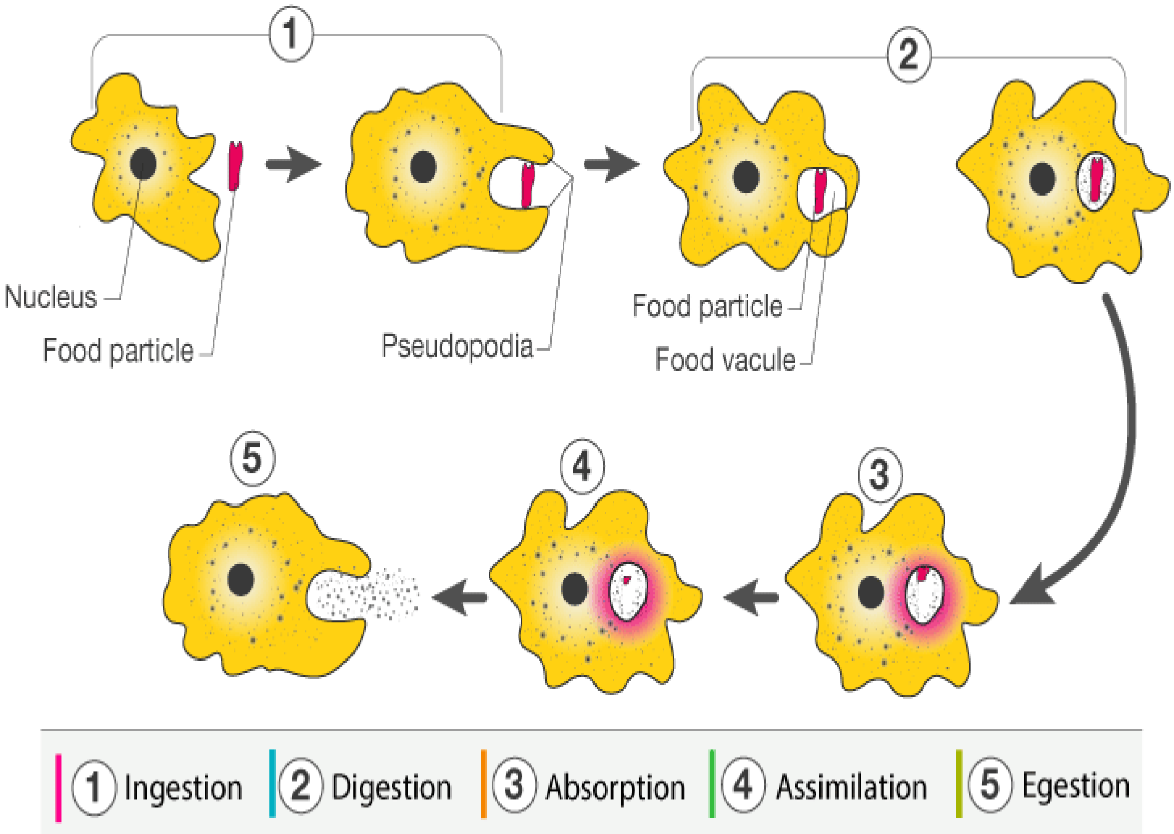


Fig 08: Nutrition in *Amoeba*

b. Saprozoic Nutrition (Osmotrophic Nutrition)

    - Protozoa absorb dissolved organic nutrients directly through their cell membrane.
    - Process:
    - Nutrients are absorbed from the surrounding environment, often decaying organic matter.
    - Examples: Some parasitic protozoa, such as *Trypanosoma*.

c. Mixotrophic Nutrition

- Protozoa combine autotrophic and heterotrophic nutrition. They can perform photosynthesis while also ingesting organic matter.
- Process:
    - They contain chloroplasts or symbiotic algae for photosynthesis.
    - They can also ingest food particles when light or nutrients are limited.
- Examples: *Euglena* (has chloroplasts but can also ingest food in the absence of light).

d. Autotrophic Nutrition

- Some protozoa can synthesize their own food using light energy (photosynthesis) or chemical energy (chemosynthesis).
- Process:
    - Photosynthetic protozoa contain chloroplasts and produce glucose using sunlight.
    - Chemosynthetic protozoa use inorganic compounds (e.g., sulfur, ammonia) to produce energy.
- Examples: *Chlamydomonas* (photosynthetic), certain sulfur bacteria-like protozoa.

2- Feeding Mechanisms in Protozoa:

Protozoa have evolved various structures and mechanisms to capture and ingest food:

a. Pseudopodia (False Feet)

- **Function**: Extensions of the cytoplasm used to engulf food particles.
- **Examples**: *Amoeba*.

b. Cilia

- **Function**: Hair-like structures that create water currents to direct food toward the oral groove.
- **Examples**: *Paramecium*.

c. Flagella

- Function: Whip-like structures used for locomotion and to draw food toward the cell.
- **Examples**: *Euglena*.

d. Cytostome (Cell Mouth)

- **Function**: A specialized structure for ingesting food particles.
- **Examples**: *Paramecium*.

3- **Digestive Processes in Protozoa**

- **Food Vacuoles**: Once food is ingested, it is enclosed in a food vacuole where digestive enzymes break it down.
- **Intracellular Digestion**: Digestion occurs inside the cell, and nutrients are absorbed directly into the cytoplasm.

- **Waste Elimination**: Undigested material is expelled through exocytosis or a specialized structure called the cytopyge (anal pore).

4. Examples of Protozoan Nutrition

A- **Amoeba**:

- **Nutrition Mode**: Holozoic.
- **Feeding Mechanism**: Uses pseudopodia to engulf prey.
- **Digestion**: Food is digested in food vacuoles.

B- **Paramecium**:

- **Nutrition Mode**: Holozoic.
- **Feeding Mechanism**: Uses cilia to direct food into the oral groove.
- **Digestion**: Food is digested in food vacuoles.

C- **Euglena**:

- **Nutrition Mode**: Mixotrophic.
- **Feeding Mechanism**: Can perform photosynthesis or ingest food particles.
- **Digestion**: Absorbs nutrients directly or through food vacuoles.

D- **Plasmodium** (Malaria Parasite):

- **Nutrition Mode**: Saprozoic.
- **Feeding Mechanism**: Absorbs nutrients from the host's blood.
- **Digestion**: Nutrients are absorbed directly through the cell membrane.

- **Respiration in Protozoans**

Protozoan respiration refers to the process by which these single-celled organisms obtain energy through the breakdown of nutrients. Like other eukaryotic organisms, protozoans can utilize different pathways for respiration depending on the presence of oxygen and the environmental conditions. Here's a breakdown of how protozoans manage their respiration:

1. Aerobic Respiration (Oxygen-Dependent)

Most protozoans rely on aerobic respiration when oxygen is available. In this process, oxygen is used to break down organic compounds (such as glucose) to produce ATP (adenosine triphosphate), which is the primary energy carrier used by the cell. The byproducts of this reaction are carbon dioxide (CO_2) and water (H_2O). Aerobic respiration takes place in the mitochondria, similar to other eukaryotes.

The chemical equation for aerobic respiration in protozoans is:

$$C_6H_{12}O_6+O_2 \rightarrow CO_2+H_2O+ATP$$

2. Anaerobic Respiration (Oxygen-Independent)

In environments where oxygen is absent (anaerobic conditions), some protozoans can perform anaerobic respiration. This process does not require oxygen and uses other molecules to break down nutrients, such as sugars or proteins. The byproducts of anaerobic respiration can vary but often include lactic acid or ethanol.

Certain protozoans, such as *Giardia* and *Entamoeba histolytica*, live in anaerobic environments like the intestines of their hosts and rely on anaerobic respiration for energy production. These protozoans use enzymes and pathways that allow them to survive and thrive in oxygen-free conditions.

The types of anaerobic respiration or fermentation can include:

- Lactic acid fermentation: Produces lactic acid as a byproduct.
- Alcoholic fermentation: Produces ethanol and carbon dioxide as byproducts.

3. Factors Influencing Respiration

- Oxygen availability: Protozoans in oxygen-rich environments will primarily rely on aerobic respiration, while those in low-oxygen environments will utilize anaerobic pathways.
- Type of protozoan: Different species of protozoans are adapted to specific environments. For example, paramecia and amoebas are aerobic, while Giardia and Trichomonas are anaerobic.

4. Examples of Protozoans and Their Respiration

- *Amoeba*: Generally relies on aerobic respiration in oxygen-rich environments.
- *Paramecium*: Uses oxygen for aerobic respiration but can survive in low-oxygen environments for a short time by shifting to anaerobic pathways.
- *Giardia*: An anaerobic protozoan that lives in the intestines of humans and animals, relying on fermentation to obtain energy.
- *Trichomonas*: Another anaerobic protozoan that resides in the human urogenital tract and uses anaerobic pathways to generate ATP.
- **Reproduction :**

Sexual reproduction in protozoa involves the fusion of genetic material from two different individuals to produce offspring, ensuring genetic diversity. While some protozoans reproduce asexually, many species also undergo sexual reproduction, often involving complex life cycles. Here's an overview of the sexual reproduction cycle in protozoa:

1. **Types of Sexual Reproduction in Protozoa**

Protozoans can reproduce sexually through syngamy or conjugation, depending on the species:

A. **Syngamy (Gametic Fusion)**

This is the most common form of sexual reproduction in protozoa, where two gametes (reproductive cells) fuse to form a zygote. The process involves several steps:

1. Gamete Formation: Each parent produces specialized reproductive cells called gametes (usually haploid), which contain half of the genetic material. These gametes are typically of two types: male gametes (microgametes) and female gametes (macrogametes).
2. Fertilization: The male and female gametes meet, either by direct fusion or by the sperm moving to the egg. This fusion results in a zygote, which is a diploid cell (containing two sets of chromosomes, one from each parent).
3. Zygote Development: The zygote undergoes meiosis or other forms of genetic recombination, eventually forming new individuals, which will later divide asexually.

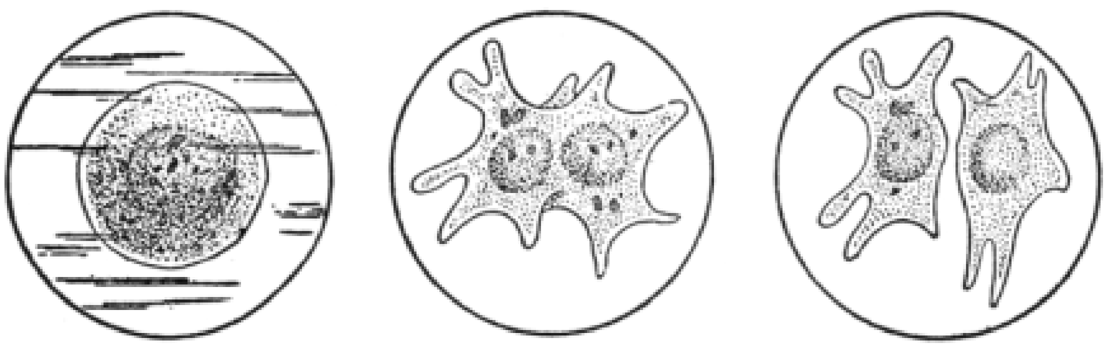


Fig 09: The sexual reproduction in protozoa

Example:

- Plasmodium (the causative agent of malaria) undergoes sexual reproduction in the mosquito host. The male and female gametes fuse in the mosquito's stomach, forming a zygote that develops into a sporozoite.

B. **Conjugation (Genetic Exchange)**

Conjugation is a form of sexual reproduction in which two protozoans of the same species temporarily join together to exchange genetic material, rather than forming gametes.

Steps of conjugation:

1. Pairing: Two individuals come together and align, forming a temporary connection.
2. Nuclear Exchange: Each protozoan undergoes nuclear division, where part of their genetic material (nucleus) is exchanged. This allows for genetic recombination.
3. Separation and Division: After the exchange, the two individuals separate and divide into two new cells. The new cells will have a mix of genetic material from both parent protozoans, ensuring genetic diversity.

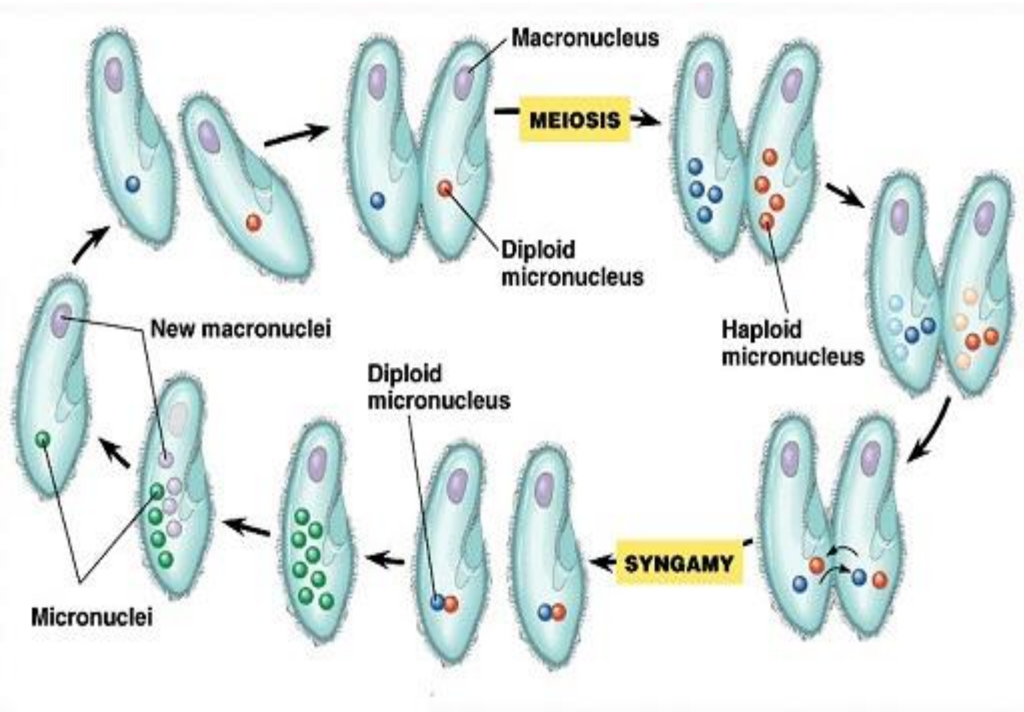


Fig 10: Paramecium – Conjugation

Example:

- Paramecium undergoes conjugation, where two individuals exchange nuclear material, resulting in genetically diverse offspring.

2. **Life Cycle Stages Involved in Sexual Reproduction**

The sexual life cycle of a protozoan typically involves the following stages:

A. **Gametogenesis**

- The process of forming male and female gametes from haploid cells. In some protozoans, the gametes are morphologically distinct (e.g., smaller, motile sperm and larger, non-motile eggs).

B. **Fertilization**

- Fusion of gametes (syngamy) or exchange of genetic material (conjugation).

C. **Zygote Formation**

- After fertilization, a diploid zygote is formed. In some species, the zygote can undergo a series of developmental changes, such as encystment (forming a protective cyst) to survive harsh environmental conditions.

D. **Meiosis**

- After the zygote forms, it may undergo meiosis, reducing the chromosome number to restore the haploid state in the offspring, enabling them to undergo further development.

E. **New Generation**

- The offspring resulting from sexual reproduction may undergo asexual division (binary fission or other forms) to proliferate in favorable environments.

3. **Examples of Protozoa with Sexual Reproduction**

- **Plasmodium**: In the mosquito host, sexual reproduction occurs with the fusion of male and female gametes, leading to the formation of sporozoites that later infect humans.
- **Paramecium**: Undergoes conjugation, where two individuals exchange nuclear material, leading to the creation of genetically diverse offspring.
- **Amoeba**: Some species may also exhibit a form of sexual reproduction involving gamete fusion, though asexual reproduction is more common.

4. Importance of Sexual Reproduction

- **Genetic Diversity**: Sexual reproduction introduces genetic variation, which enhances the adaptability and survival of protozoans in changing environments.
- **Adaptation**: The mixing of genetic material ensures that the population can adapt to new conditions or resist diseases.
- **Formation of Resistant Stages**: In some species, the zygote may form a cyst that can survive unfavorable environmental conditions, allowing the organism to persist until conditions improve.

5. Ecological role and importance of protozoa

- Role in food chains: Protozoa are an important food source for small aquatic organisms. They play critical roles in ecosystems, serving as primary producers, decomposers, and important links in food chains. Many species are autotrophic, capable of producing their own food through photosynthesis. For example, the phylum Euglenozoa includes photosynthetic organisms called Euglenoids, which possess chloroplasts and can produce their own energy from sunlight.

Furthermore, protozoa serve as essential decomposers, breaking down organic matter and recycling nutrients in the environment. By consuming bacteria, algae, and other organic material, protozoa release nutrients that can be utilized by other organisms, promoting a balanced ecosystem.

- Symbiosis: Some protozoa live in symbiosis in the intestines of animals, such as ruminants, helping to digest cellulose.
- Pathogens: Some protozoa are responsible for serious diseases in humans and animals, such as malaria (Plasmodium), sleeping sickness (Trypanosoma), and amoebic dysentery (Entamoeba histolytica).

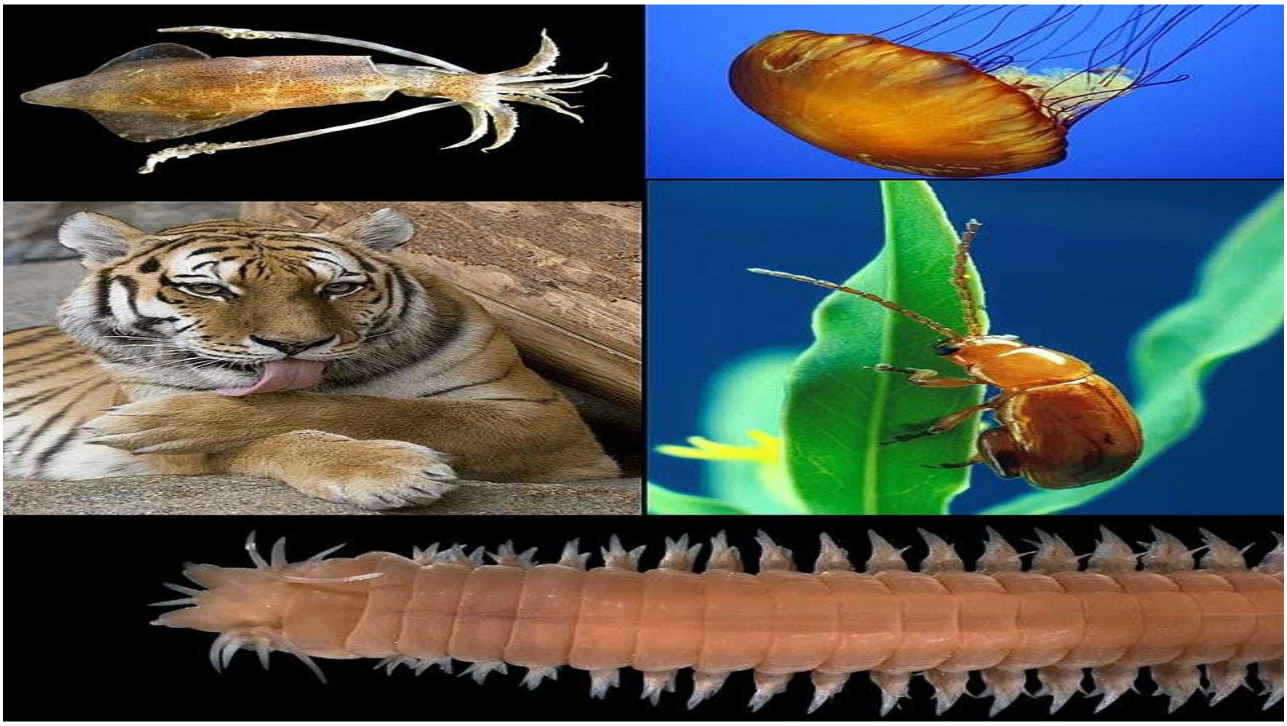
6. Examples of pathogenic protozoa and associated diseases

- Plasmodium spp.: Protozoa responsible for malaria. Transmitted by mosquitoes of the genus *Anopheles*.
- Trypanosoma brucei: Causes sleeping sickness, transmitted by the tsetse fly.
- Giardia lamblia: Causes giardiasis, an intestinal infection.
- Toxoplasma gondii: Responsible for toxoplasmosis, which can be dangerous for pregnant women.
- Entamoeba histolytica: Agent of amoebic dysentery.

7. **Conclusion:**

Protozoa are a diverse and fascinating group of single-celled organisms, playing important ecological and medical roles. Despite their small size, they are essential in aquatic and terrestrial ecosystems and directly influence human and animal health through their roles as parasites. The study of protozoa remains an important branch of microbiology and parasitology.

Chapter 3: Metazoa sub-kingdom



I. Introduction

Understanding the complexity of life on Earth necessitates a thorough exploration of its biological classifications. Among these classifications, the subphylum of Metazoans is particularly significant, encompassing a vast diversity of multicellular organisms. This subphylum includes everything from simple sponges to highly advanced mammals, illustrating the remarkable evolutionary adaptations that have occurred over millions of years. By examining the characteristics that define Metazoans—such as cellular organization and developmental biology—one can appreciate the fundamental differences that set these organisms apart from unicellular life forms. Furthermore, the study of Metazoans not only enhances our comprehension of biological structures and functions but also sheds light on the ecological roles these organisms play in their environments. Thus, delving into the intricacies of this subphylum serves as a vital gateway to the broader understanding of life and its myriad forms on our planet.

- ## Overview of Metazoans and their significance in the animal kingdom

Metazoans, a diverse group characterized by multicellularity and complex cellular differentiation, form a significant portion of the animal kingdom and highlight essential evolutionary adaptations. Their emergence marks a pivotal moment in biological history, showcasing innovations such as specialized tissues and organ systems, which facilitate intricate interactions with the environment.

This diversification allowed for the development of distinct body plans and ecological roles, illustrating the adaptability of metazoans in various habitats. For instance, octocorals like Eunicella not only represent the significance of metazoans as biodiversity indicators but also as ecosystem engineers that support other marine life. Furthermore, understanding the evolutionary relationships among metazoans, including insights gathered through genomic analyses, elucidates patterns of gene loss and novelty that are integral to their evolutionary success. Thus, metazoans serve not only as a foundation for complex life forms but also play a vital role in maintaining ecological balance within their respective environments.

II. Classification of Metazoans

Diverse organisms within the animal kingdom have prompted biologists to categorize Metazoans into several subphyla, each representing different evolutionary adaptations and complexities. Among these, the Pezizomycotina subphylum exemplifies how molecular markers like gene fusions can signify evolutionary relationships. The presence of a unique fusion gene, combining the α and β subunits of succinyl-CoA synthetase, serves as a definitive identifier for this group, linking them to a shared lineage that showcases their distinct biochemical pathways. Additionally, the classification of metazoans is heavily informed by genetic studies, particularly within the Sox transcription factor family. Research indicates that dramatic expansions in Sox group B occurred specifically in arthropods, contributing to their complexity and diversity, distinct from vertebrate genome duplications. Ultimately, these classifications not only enhance our understanding of evolutionary biology but also illustrate the intricate web of relationships that defines the Metazoan subphyla.

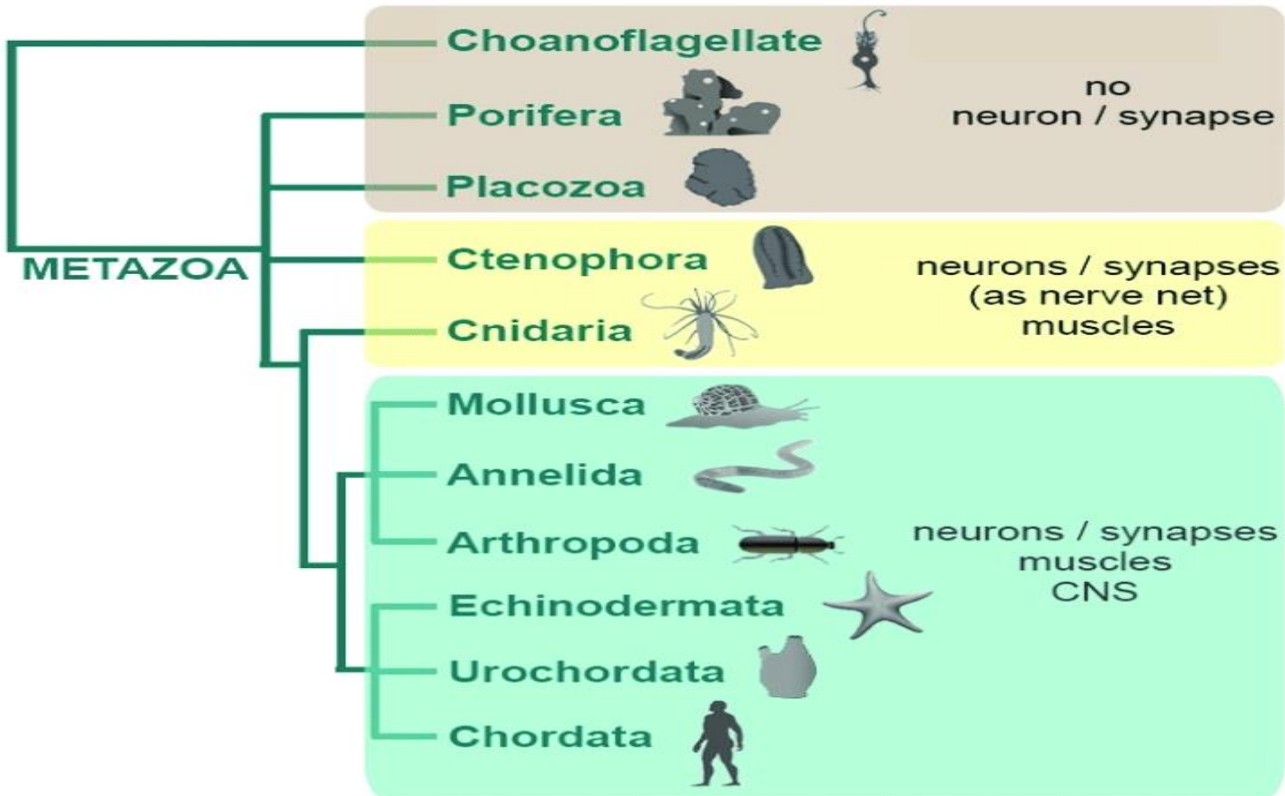


Fig 11: Phylogenetic tree of Metazoa

- **Explanation of the major subphyla within Metazoans**

  Metazoans, or multicellular animals, are classified into several major subphyla based on their evolutionary relationships and anatomical features. Among these subphyla, Chordata, which includes vertebrates, is particularly significant due to the presence of traits such as a notochord and a dorsal nerve cord, crucial for the development of complex organisms. In contrast, the subphylum Porifera encompasses sponges, which exhibit a unique tissue organization, featuring a syncytial structure known as the trabecular reticulum. This complex arrangement allows hexactinellid sponges, for instance, to efficiently filter water through their bodies and engage in nutrient absorption. The distinct characteristics of these subphyla highlight the diversity within Metazoans and underscore the evolutionary adaptations that have enabled various life strategies, emphasizing the intricate relationships among different animal groups in the broader biological context.

III. Evolutionary Adaptations of Metazoans

The evolutionary adaptations of metazoans illustrate a remarkable journey shaped by environmental pressures and ecological niches. With over 500 million years of diversification, metazoans have developed various physiological and structural traits to enhance survival and reproduction. Innovations such as flight, metamorphosis, and social structures have emerged alongside shifts in genomic content, evidenced by the findings of a recent study that explored the genomic evolution across 76 arthropod species, highlighting changes in gene families linked to significant phenotypic adaptations. Additionally, the advancements in DNA methylation patterns illustrate how these molecular changes can influence developmental processes across species, affecting everything from morphology to behavior. The comprehensive understanding of metazoan evolution hinges not only on these genetic insights but also on the ongoing curation of taxonomic information, which ensures accurate classifications and enriches our comprehension of the evolutionary tree. Overall, these adaptations underscore the intricate connections between genetics and the broad tapestry of life.

- **Discussion of key evolutionary traits that distinguish Metazoans from other life forms**

  An array of key evolutionary traits set Metazoans apart from other life forms, signifying their complex biological architecture and adaptation strategies. One notable feature is the specialized cellular organization that allows for the differentiation of tissues and organs, enabling Metazoans to perform various physiological functions efficiently. This tissue differentiation supports advanced systems, such as the respiratory and circulatory systems, enhancing their ability to adapt to diverse environments. Additionally, Metazoans exhibit a unique developmental process, including gastrulation, which establishes the basic body plan and leads to the formation of complex structures. The role of mitochondrial genomes further underscores this complexity; they are essential for energy production, adapting to evolutionary pressures and influencing fitness within various environments. Collectively, these traits highlight the innovative evolutionary strategies that define Metazoans, distinguishing them from simpler life forms and underscoring their evolutionary success.

IV. Conclusion

The exploration of metazoan subphylum relationships highlights the complex evolutionary paths these organisms have traversed. Understanding the genetic and phylogenetic links among various metazoans, such as brachiopods and phoronids, helps elucidate their shared ancestry and divergence over geological time. Recent studies have provided insights into this genetic diversification, confirming that crucial divergence between phyla likely occurred well before the Cambrian period, suggesting significant evolutionary advancement in the Proterozoic era (Cohen et al.). Furthermore, the in-depth evolutionary analysis of the catenin gene family underscores the essential roles these proteins play in cellular adhesion and signaling among multicellular organisms, further illustrating the adaptive significance and evolutionary pressures metazoans have faced throughout their history. Collectively, this evidence supports a nuanced understanding of the metazoan phylogeny, emphasizing the intertwined evolution of form and function that characterizes this diverse group.

Sponge Branch

A. Introduction

The Spongiaria, or Porifera, is a fascinating branch of the animal kingdom, distinguished by its morphological simplicity and adaptation to various aquatic environments. These organisms, often referred to as' sponges' in English, are mainly marine, although they can be found in freshwater.

Fig 12: Tubular branching vase sponge (*Callyspongia vaginalis*) with pink color variation

B. Characteristics of Sponges

Sponges are characterized by their porous body, which allows them to effectively filter water. They have a unique body architecture, made of specialized cells, some of which (choanocytes) are responsible for the circulation of water through the animal's body. This filtration process is essential for their feeding, as they feed mainly on phytoplankton and suspended organic particles.

One of the most interesting aspects of Sponges is how they reproduce. They can reproduce asexually by budding or fragmentation, but also sexually by producing gametes. This ability to reproduce in different ways allows them to adapt quickly to variations in their environment.

C. Classification and Diversity

The Spongee branch is divided into several classes, the main ones being Demasponge, Limestones and Hexactinellids. Demasponge, for example, are the most diverse, with about 90% of known species. They are distinguished by the presence of spicules composed of silica, while Limestones, as their name suggests, have spicules made of calcium carbonate.

This diversity within Sponges is also reflected in their habitats. They are found in a multitude of ecological niches, ranging from shallow coastal areas to abyssal depths, where they play a crucial role in the ecosystem by serving as a filter and habitat for many other marine species.

Sponges are highly diverse, with over 9,000 known species found in various marine and freshwater environments. They vary in size, shape, color, and skeletal composition :

1. Class Calcarea (Calcareous Sponges)

- Found in **shallow marine waters**.
- Skeleton made of **calcium carbonate** spicules.
- Generally **small in size** (up to 10 cm).
- Example species: *Sycon, Leucosolenia*.

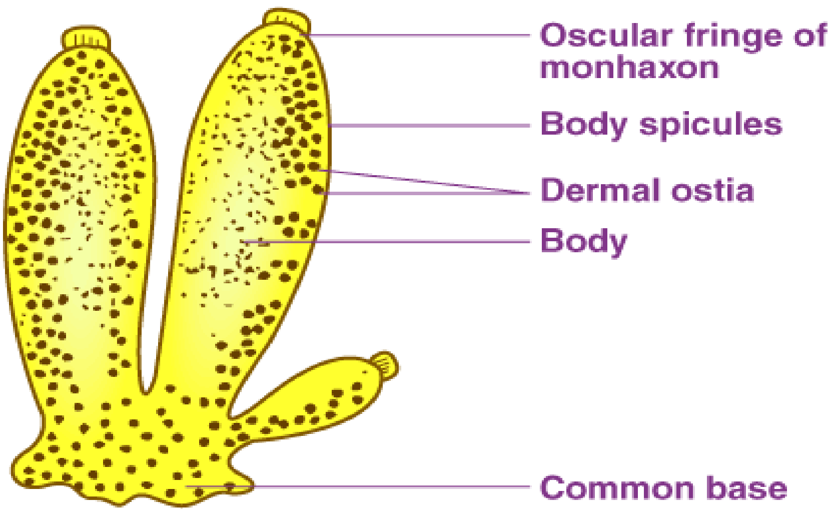


Fig 13: Structure of *Sycon*.

2. Class Hexactinellida (Glass Sponges)

- Found in **deep ocean waters**.
- Skeleton made of **silica** spicules with a **glass-like appearance**.
- Often **cylindrical or cup-shaped**.
- Example species: *Euplectella aspergillum* (Venus' flower basket).

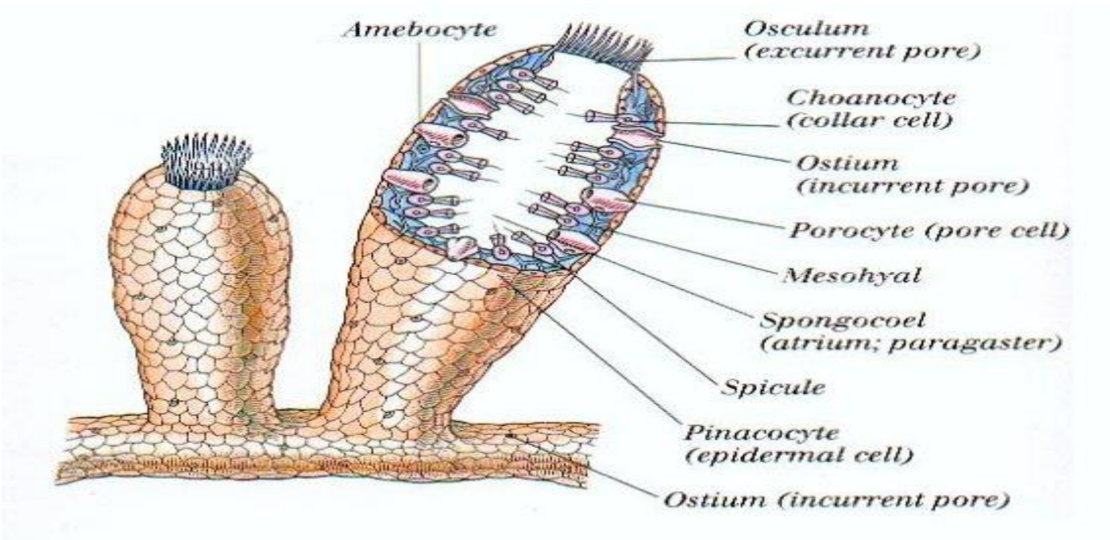


Fig 14: Structure of *Euplectella aspergillum*

3. Class Demospongiae (Largest and Most Diverse)

- Comprises **90% of all sponge species**.
- Found in **both freshwater and marine environments**.
- Skeleton made of **spongin fibers** or **silica spicules**.
- Includes **commercial sponges** used for bathing.
- Example species: *Spongilla* (freshwater sponge), *Cliona* (boring sponge).

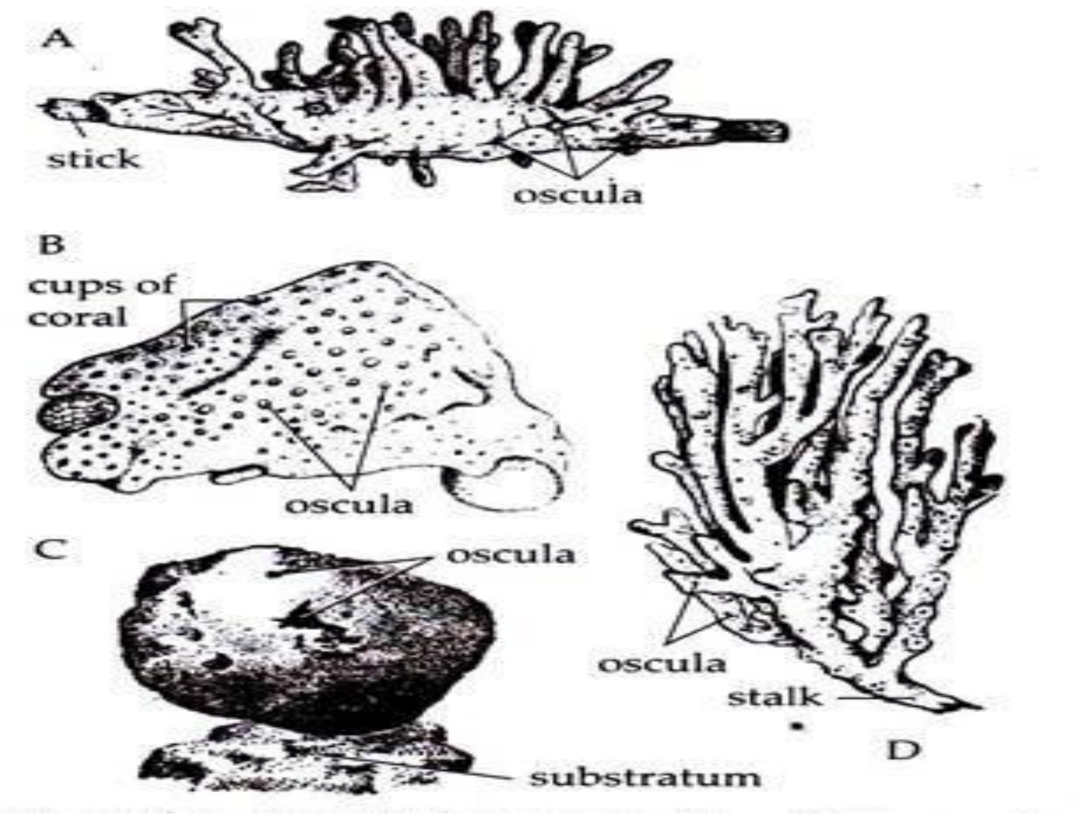


Fig 15: A. Spongilla locustris, B. Cliona, C. Euspongia officinalis, D. Chalina oculate.

4. Class Homoscleromorpha (Encrusting Sponges)

- Found in **shallow marine waters**, often near coral reefs.
- Body shape is usually **flat or encrusting**.
- Lack true spicules or have very simple silica spicules.
- Example species: *Oscarella lobularis*.

D. Ecological and Economic Importance

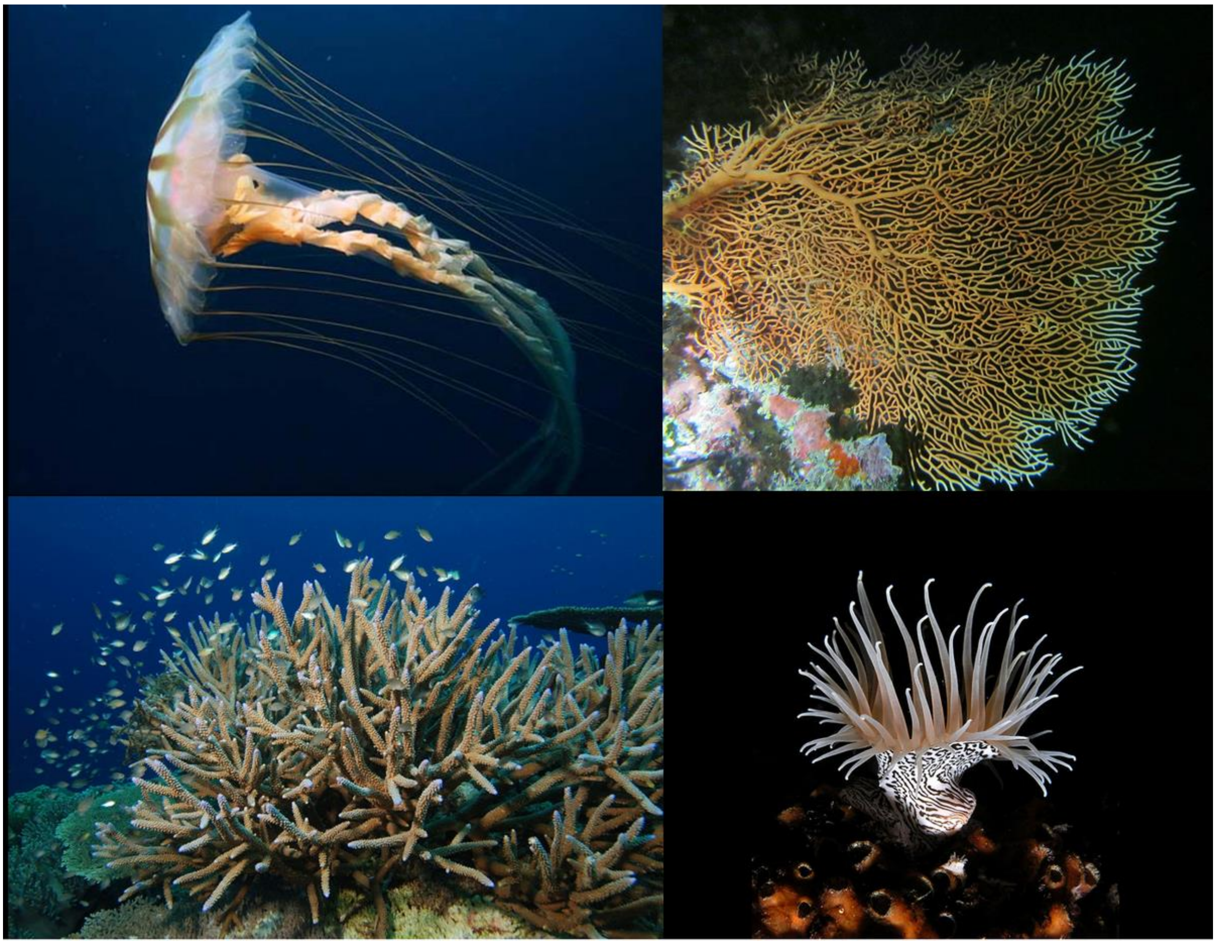
Sponges play a fundamental role in marine ecosystems, including contributing to water quality and supporting other forms of marine life. Their ability to filter massive amounts of water makes them key players in ecosystem health.

In addition, some species of sponges are exploited for their medicinal properties and their applications in biotechnology. For example, sponge-derived compounds have been studied for their antibacterial and anticancer effects.

E. Conclusion

The Spongiariae branch reminds us of the incredible diversity and complexity of marine life, even among the simplest organisms. Their study is not only crucial to understanding aquatic ecosystems, but it also offers exciting perspectives for the future of biology and medicine. As Paul A. Smith states, 'Spongies, pivots of marine ecosystems, deserve special attention both for their unique biology and for their invaluable contributions to biodiversity' (Smith, 2021).

Branching Cnidarians



A. Introduction:

Cnidarians represent a fascinating and essential branch of marine life. Composed of about 11,000 species, they are distinguished by their morphological diversity and ecological importance. This article explores the characteristics, classification, and role of cnidarians in marine ecosystems.

B. Characteristics of Cnidarians

Cnidarians are characterized by their radial body, often in the shape of a dome or cylinder, and their bilateral or radical symmetry. They have a diffuse nervous system, without a central nervous system, and are endowed with specialized cells called cnidocytes. These cells contain structures called nematocysts, which allow cnidarians to capture their prey with great efficiency. play a crucial role in the predation and defence of these organisms.

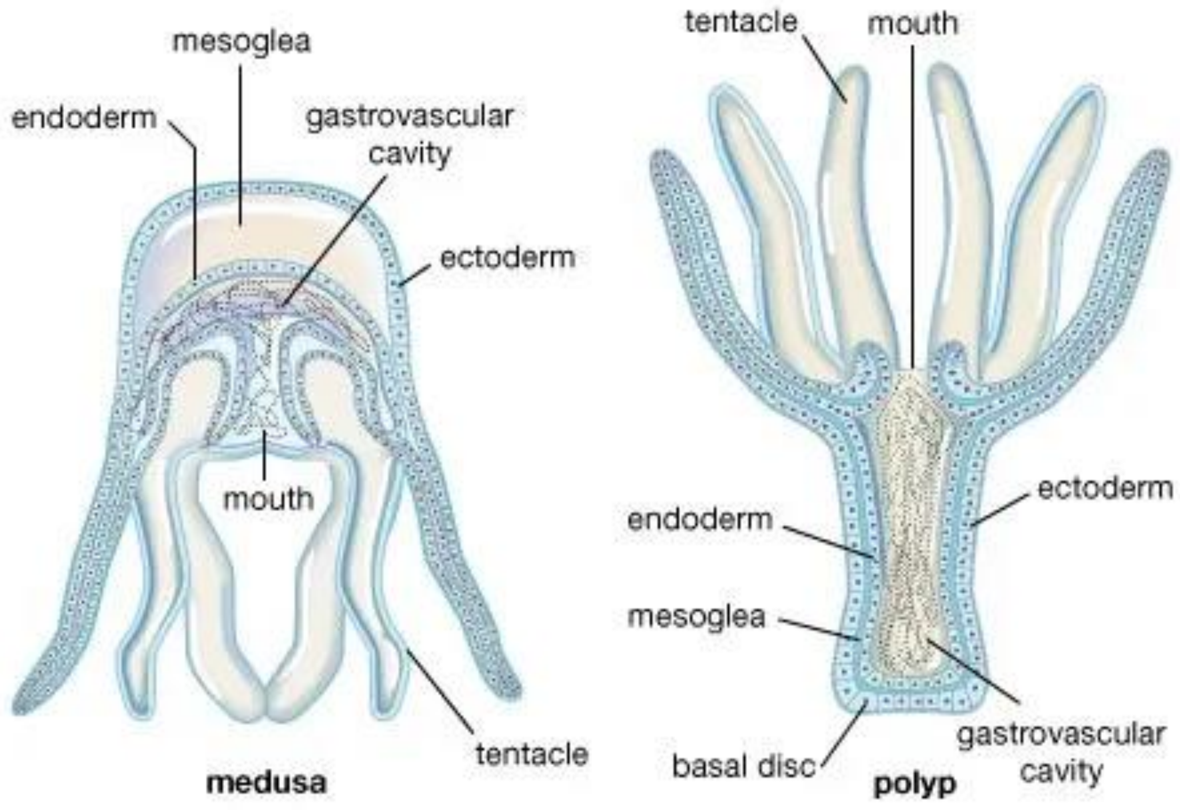


Fig 16: Anatomy of cnidarians

C. Classification of Cnidarians

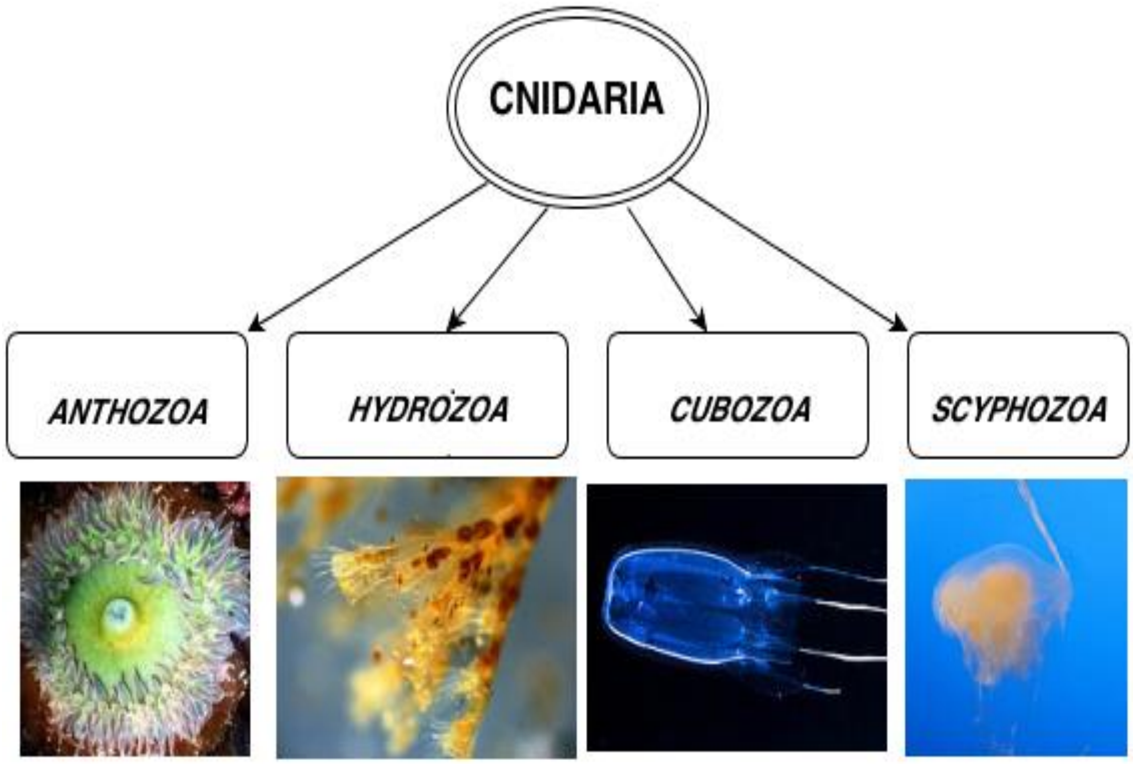


Fig 17: Classification of Cnidarians

Cnidarians are classified into four main classes:

1**. Hydrozoans**: Including polyps such as hydras and jellyfish. They are often found in fresh or marine water.

2. Scyphozoa: Genuine jellyfish, which have a dominant jellyfish form in their life cycle. They are mainly marine and can reach impressive sizes.

3. Cubozoa : Renowned for their cube-shaped jellyfish, some species in this class are known for their dangerous potential due to their powerful venom.

4. Anthozoa: Including corals and sea anemones, this class is mostly fundamentally benthic, meaning that it lives anchored to the seabed .

D. Feeding Mechanisms in Cnidarians

1. **Predation and Capture Mechanism**

   Most cnidarians are carnivorous, capturing prey using specialized cells called cnidocytes, which contain nematocysts. These nematocysts discharge toxins that immobilize prey, allowing the tentacles to bring it into the gastrovascular cavity for digestion.

   - Example: Chrysaora quinquecirrha (Atlantic sea nettle) actively captures small fish and zooplankton using its tentacles .

2. **Digestion Process**

   Digestion occurs in two phases:

   - Extracellular digestion: Enzymes break down food in the gastrovascular cavity.
   - Intracellular digestion: Nutrients are further processed within gastrodermal cells.
   - Example: Aurelia aurita (moon jellyfish) relies on enzymatic breakdown before phagocytosis of smaller particles .

3. **Symbiotic Relationships**

   Some cnidarians, particularly reef-building corals, rely on mutualistic relationships with photosynthetic algae called zooxanthellae (Symbiodinium spp.). These algae provide organic compounds via photosynthesis, enhancing coral growth.

   - Example: Acropora spp. corals derive up to 90% of their energy from zooxanthellae.

4. **Suspension and Filter Feeding**

   Some cnidarians, such as certain hydrozoans and soft corals, utilize cilia to capture suspended organic matter from the water column.

   - Example: Eudendrium spp. hydrozoans filter small planktonic organisms using tentacular cilia .

Adaptations for Nutrition

- **Radial symmetry**: Facilitates omnidirectional feeding.
- **Cnidocytes**: Enable prey immobilization.
- **Gastrovascular cavity**: Functions in both digestion and nutrient distribution.
- **Symbiosis**: Enhances survival in nutrient-poor waters.

E.Ecological Role of Cnidarians

Cnidarians play a crucial role in marine ecosystems. For example, corals formed by anthozoans are reef builders, providing habitats for many marine species. They are often considered indicators of the health of marine ecosystems, as their sensitivity to environmental changes, such as ocean acidification, can affect all biodiversity. According to Hughes et al. (2018), 'loss of coral reef biodiversity could have catastrophic consequences for marine ecosystems' (p. 162).

F. Conclusion

The branching of cnidarians is a vital element of the oceans, contributing to the biological diversity and health of marine ecosystems. Their study is not only important for marine biology, but also for the conservation of our seas. The complexity of their life cycle and their ability to adapt to environmental changes remind us of the importance of preserving these unique organisms for future generations. Ultimately, understanding and protecting cnidarians is key to ensuring an ecological balance in our oceans.

Branching Annelids

A. Introduction

Annelids, commonly known as ringworms, are a fascinating branch of the animal kingdom. Their name derives from the Latin 'annellus', meaning 'small ring', in reference to their body segmented into distinct rings or metamers. This branch brings together various organisms that play crucial ecological roles and have interesting anatomical characteristics.

B. Classification of Annelids

Annelids are mainly divided into three classes:

- **Polychaeta**: These marine annelids have parapods, locomotor structures that allow them to swim or move on the seabed. They also have bristles (chaetae) that help with locomotion. Polychetes play an essential role in marine ecosystems as decomposers and food sources for other organisms.

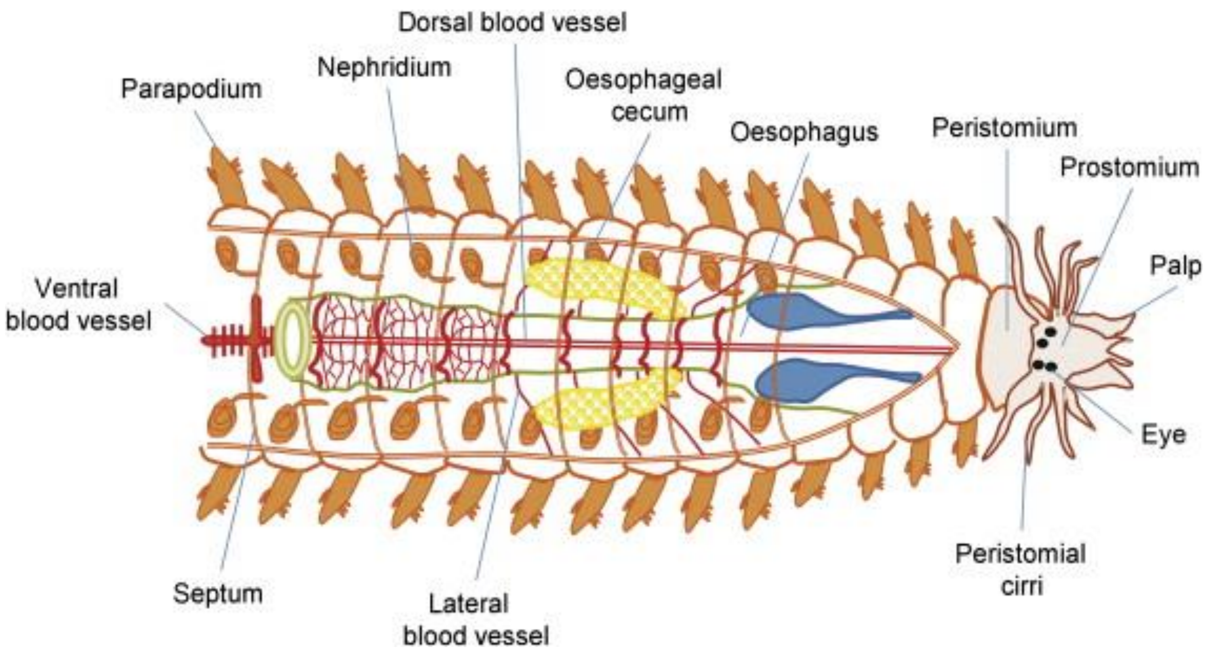


Fig 18: Polychaeta anatomy

- **Clitellata**: This class includes earthworms (Oligochaeta) and leeches (Hirudinea). Earthworms are key players in soil aeration and nutrient recycling, while leeches, although often poorly understood, have important medical and ecological applications. 'It is the earthworms that transform the soil into a fertile resource through their burrowing activity'.

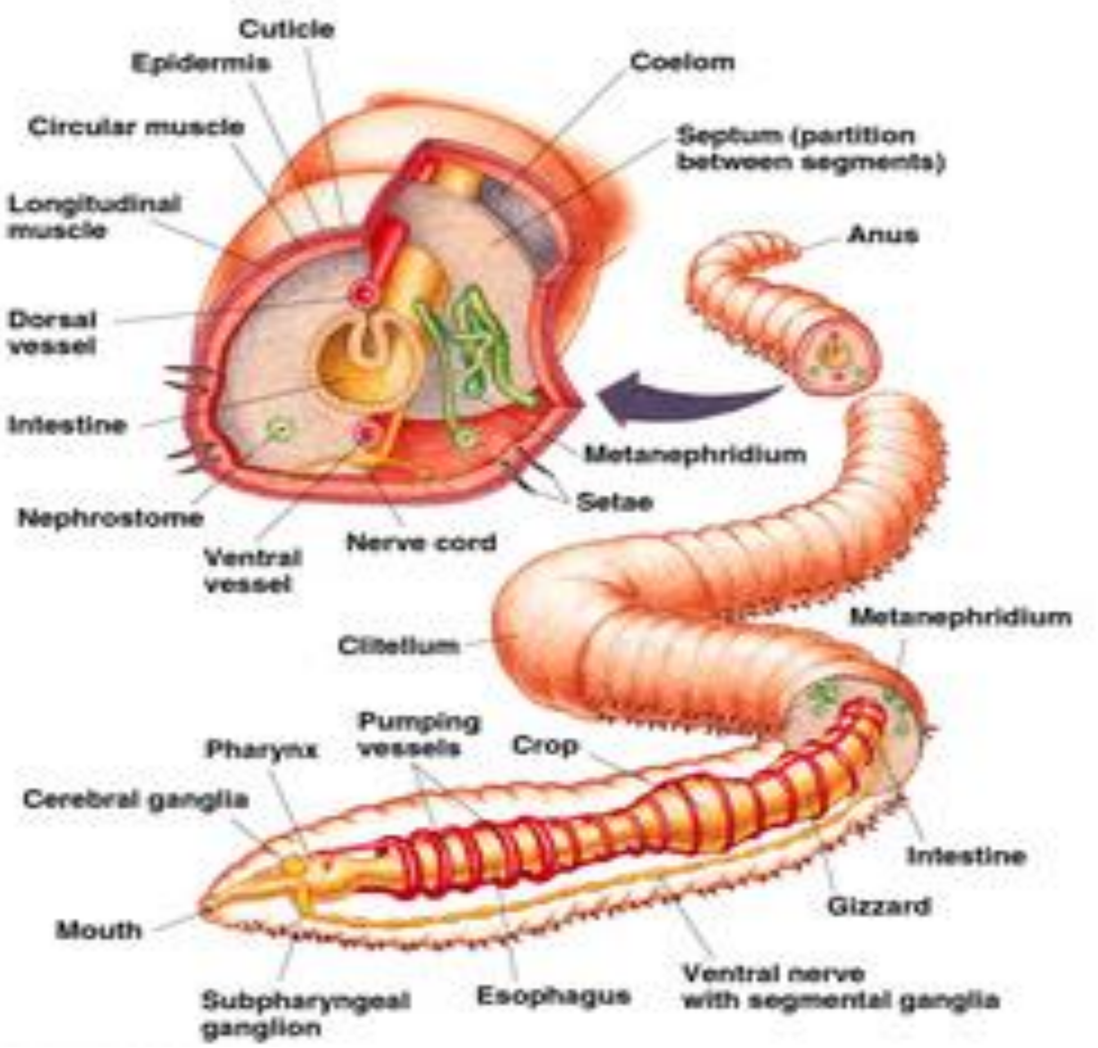


Fig 19: Clitellata anatomy

- **Echiura**: Less known, these annelids are similar to benthic marine worms that have a unique morphology and are often associated with nutrient-rich marine habitats.

C. Anatomy and Physiology

Annelids are characterized by their segmented body, an adaptation that has several advantages, including the specialization of segments for different functions. For example, in polychaetes, some segments are specialized for reproduction, while others are suitable for locomotion.

Their circulatory system is closed, which means that blood circulates in blood vessels, allowing efficient distribution of oxygen and nutrients. In addition, their nervous system is well developed, with a brain node that plays a central role in coordinating movements

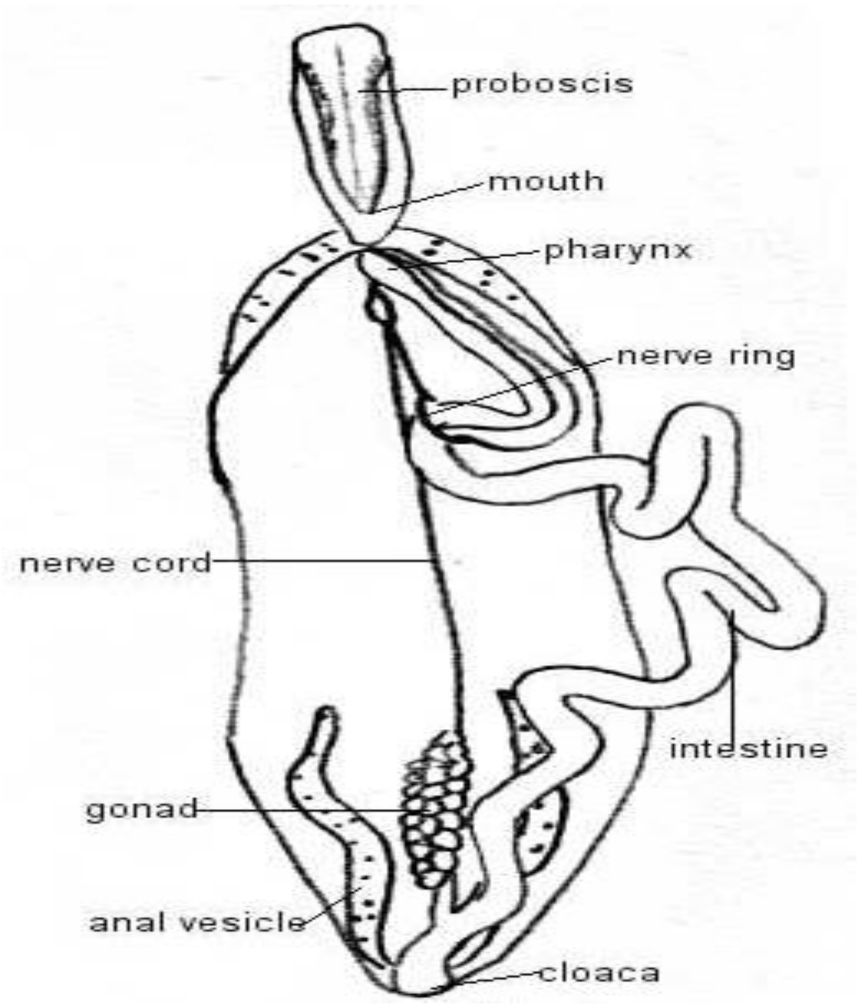


Fig 20: Echiura anatomy

D. Lifestyles & Habitat

Annelids occupy a range of diverse habitats, from deep oceans to rich, moist forest soils. Their lifestyle varies by class:

- Polychaeta: These marine worms feed mainly on decomposing organic substances and are often present in marine sediments or among corals.

- Clitellata: Earthworms, for example, feed on decomposing organic matter, playing a vital role in soil fertility. Leeches, on the other hand, feed on animal blood, and some species have developed remarkable adaptations to their parasitic lifestyle.

E. Ecological Importance and Human Use

Annelids play an indispensable ecological role. Earthworms are often referred to as "ecosystem engineers" because of their ability to aerate the soil, improve its structure, and promote water circulation. In addition, their activity contributes to the decomposition of organic matter, thus enriching the soil with nutrients.

In medicine, leeches are used for their anticoagulant properties, especially in surgical procedures and to treat certain conditions such as venous congestion syndrome.

F.Conclusion

Annelids, with their morphological and behavioural diversity, perfectly illustrate the adaptability and importance of invertebrates in ecosystems. Whether they are digging tunnels in the ground or floating in the water, their presence is crucial to maintain the balance and health of natural environments. By better understanding these organisms, we can better appreciate their invisible but invaluable role in our environment.

Branching of Molluscs

A. Introduction

Molluscs, a fascinating branch of the animal kingdom, play a crucial role in the terrestrial and aquatic ecosystem.With over 85,000 species described, and an estimated number of millions of species yet to be identified, molluscs represent one of the most diverse groups of animals on the planet. This group includes various organisms such as snails, mussels, octopuses, and squid, testifying to the richness of marine and terrestrial biodiversity.

B. General Characteristics of Molluscs

The term "mollusc" comes from the Latin "mollis", meaning "soft". Molluscs share several distinctive characteristics:

1. **Mollusc Body** : Their body is usually divided into three parts: the head, the muscular foot and the mantle. The mantle plays a crucial role as it secretes the shell in many species.

2. **Shell**: Although not all molluscs have a shell (like octopuses), the majority of species are protected by a limestone shell, which can be a determining factor in their classification.

3. **Respiratory and Circulatory System** : Most breathe through gills, and their circulatory system is generally open, except in cephalopods, which have a more complex closed circulatory system.

4. **Radula :** Many molluscs have a radula, a toothed tongue-like structure used for feeding. This sets them apart from other groups of animals.

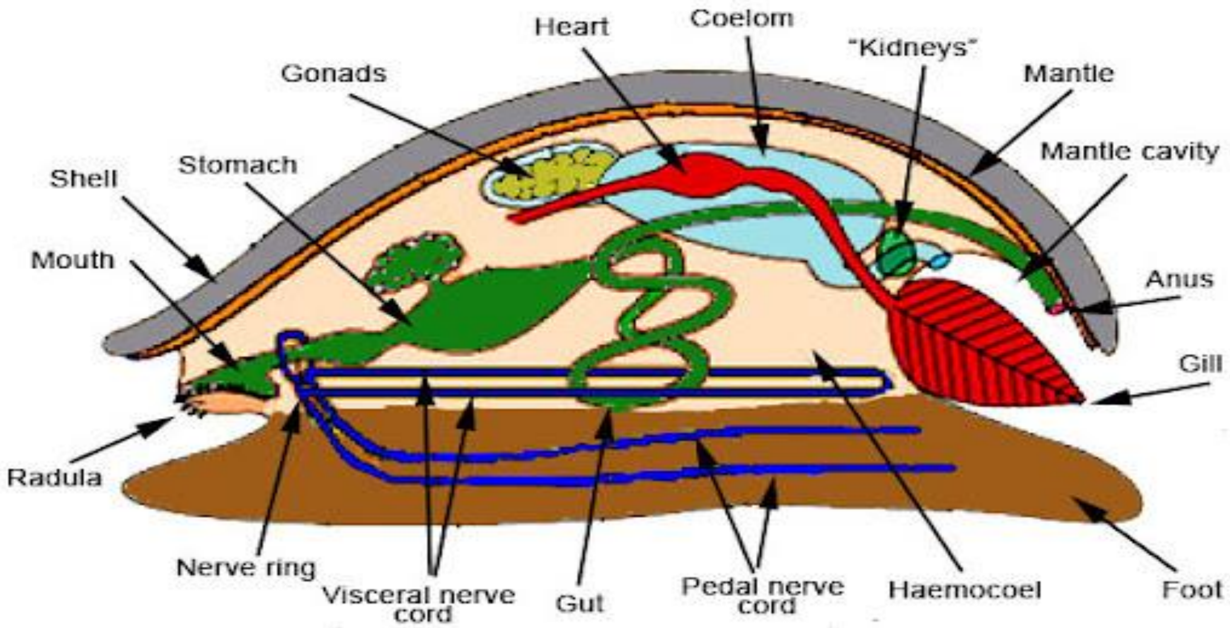


Fig 21: Molluscs anatomy

C. Classification of Molluscs

Molluscs are classified into several main classes:

- **Gastropods:** This class includes animals like snails and slugs. Gastropods are characterized by body torsion and a generally herbivorous lifestyle.

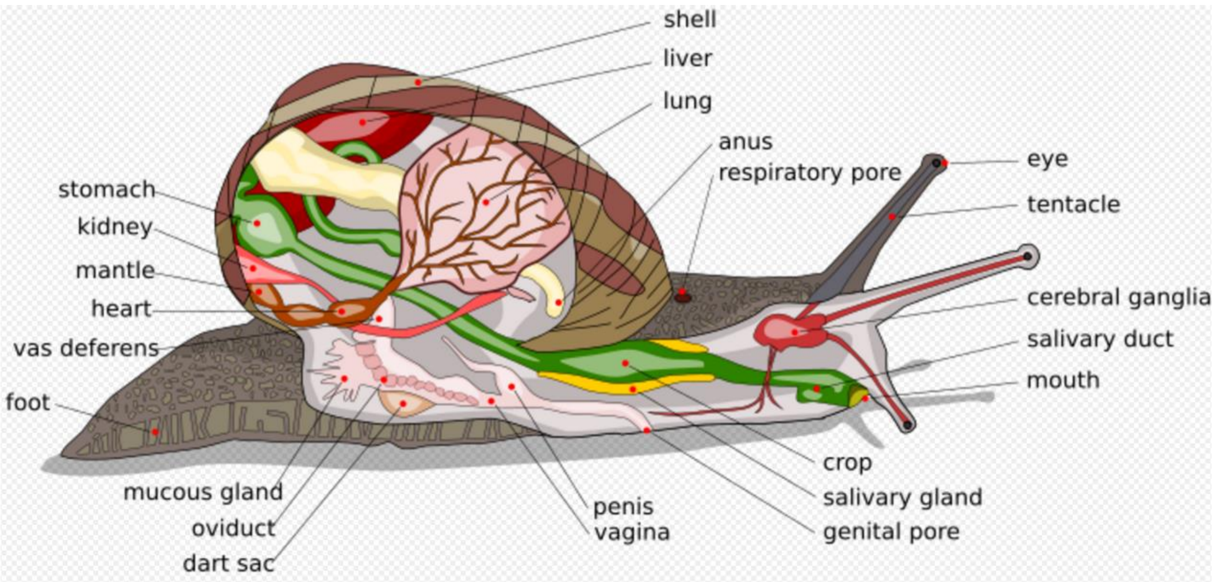


Fig 22: Gastropods anatomy

- **Bivalves**: Comprising organisms such as mussels and oysters, bivalves have two shell valves and are primarily filterers.

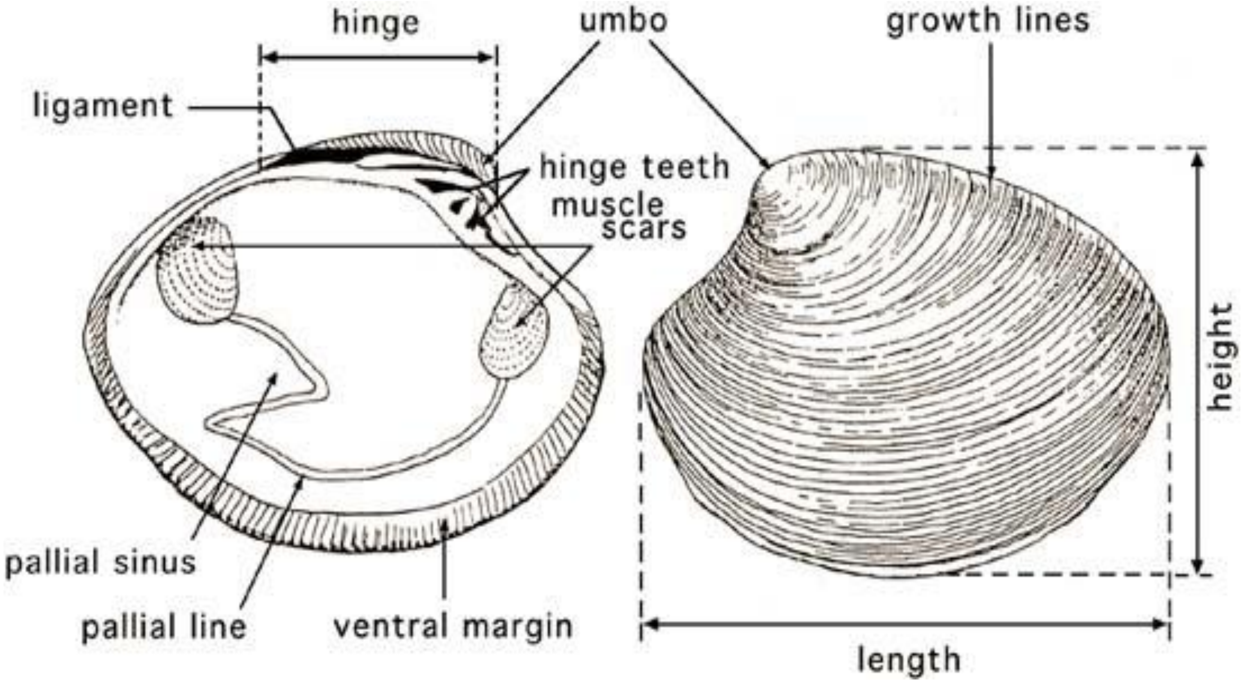


Fig23: External and internal features of the shell valves of the hard shell clam, *Mercenaria mercenaria*.

- **Cephalopods** : Including octopuses, squid, and cuttlefish, cephalopods are renowned for their intelligence, camouflage ability, and rapid propulsion locomotion.

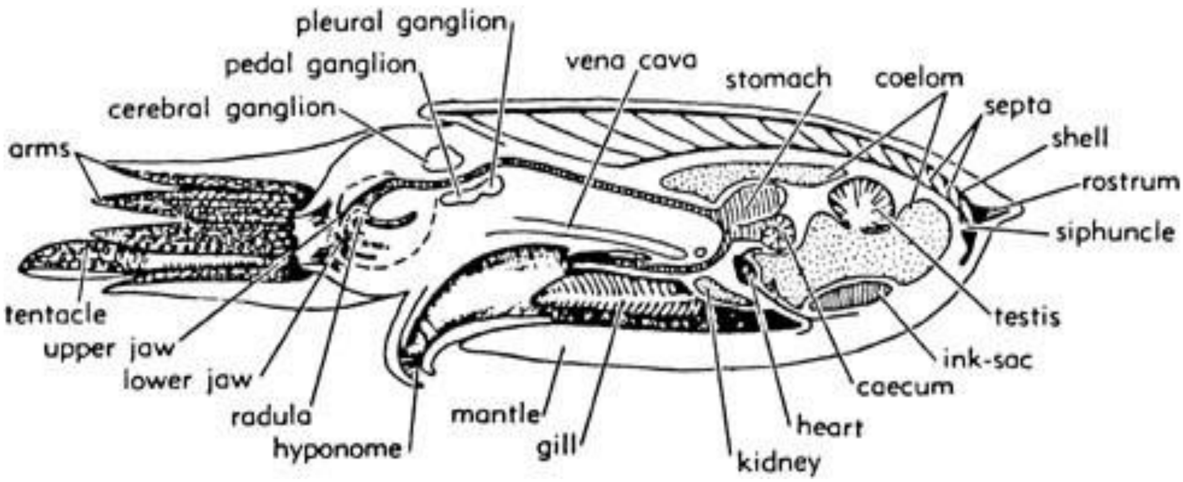


Fig 24: Cephalopods anatomy

* **Polypods :** Less known, polypods (or scaphopods) have an elongated shell and usually live buried in sand.

* **Monoplacophores:** Considered as living fossils, monoplacophores have a unique and rounded shell.

D. Ecological and economical

Shellfish play an essential role in ecosystems. They are primary consumers in marine food chains, and their presence is an indicator of the health of aquatic ecosystems. In addition, molluscs like mussels and oysters contribute to water filtration, helping to maintain ecological balance.

Economically, molluscs are of great value. They are a food source for millions of people around the world, and products like pearls and mother-of-pearl come from certain bivalve species.

E. Threats and Conservation

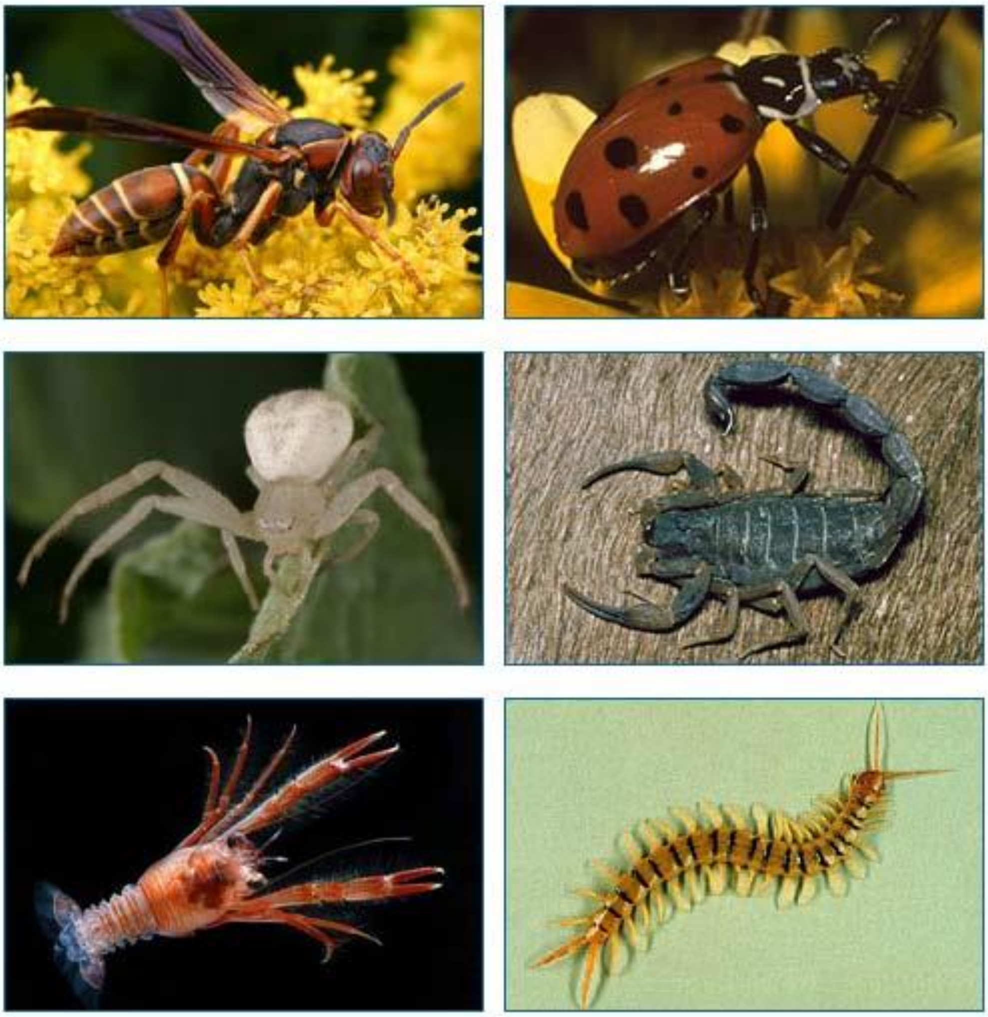
However, shellfish populations are threatened by various human activities such as pollution, overfishing and habitat destruction. The World Bank highlights the importance of shellfish biodiversity to assess the state of marine ecosystems and strengthen the sustainable management of fisheries resources.

To preserve this essential biodiversity, conservation efforts are underway, including responses to marine pollution and the establishment of marine reserves. Public awareness and protection policies are crucial to ensure the survival of these fascinating organisms.

Conclusion

The mollusc branch is a true showcase of animal diversity, encapsulating millions of years of evolution and adaptation. Understanding their biology and ecology is of paramount importance for science and the preservation of our environment. As the French biologist and writer Henri Laborit wrote, “The real journey of discovery is not to look for new landscapes, but to have new eyes." By studying molluscs, we discover not only their beauty, but also the importance of protecting our planet and all the life forms that inhabit it.

Arthropod Branching



A. Introduction

The arthropod branch represents one of the most diverse and adaptive groups in the animal kingdom.Composed of insects, arachnids, crustaceans, and other lesser-known classes, arthropods are distinguished by their segmented body, chitin exoskeleton, and articulated appendages.

B. Characteristics of Arthropods

Arthropods are defined by several distinctive anatomical traits:

1. Exoskeleton: Arthropods have a rigid chitin exoskeleton that provides protection and structural support. This exoskeleton is periodically renewed by a process called moulting, allowing the animal to grow.

2. Segmentation: The body of arthropods is usually segmented into three main parts: the head, thorax, and abdomen. This segmentation allows functional specialization of segments, such as antennas for the sense of touch and mouthpieces adapted to different types of food.

3. Articulated appendages : The limbs of arthropods are articulated, which gives them great mobility. These appendages are often specialized for specific functions, such as locomotion, object manipulation, or reproduction.

4. Complex nervous system : Arthropods have a more sophisticated nervous system than other invertebrates, with a dorsal brain and segmental nerve nodes.

5. Reproduction : Most arthropods reproduce sexually, but some also possess means of asexual reproduction. Their high reproductive potential contributes to their evolutionary success.

C. The Main Classes of Arthropods

Arthropods comprise several major classes:

- **Insects:** With over a million species described, insects are the most diverse group of arthropods. They play a crucial role in ecosystems as pollinators, decomposers and prey for other animals.

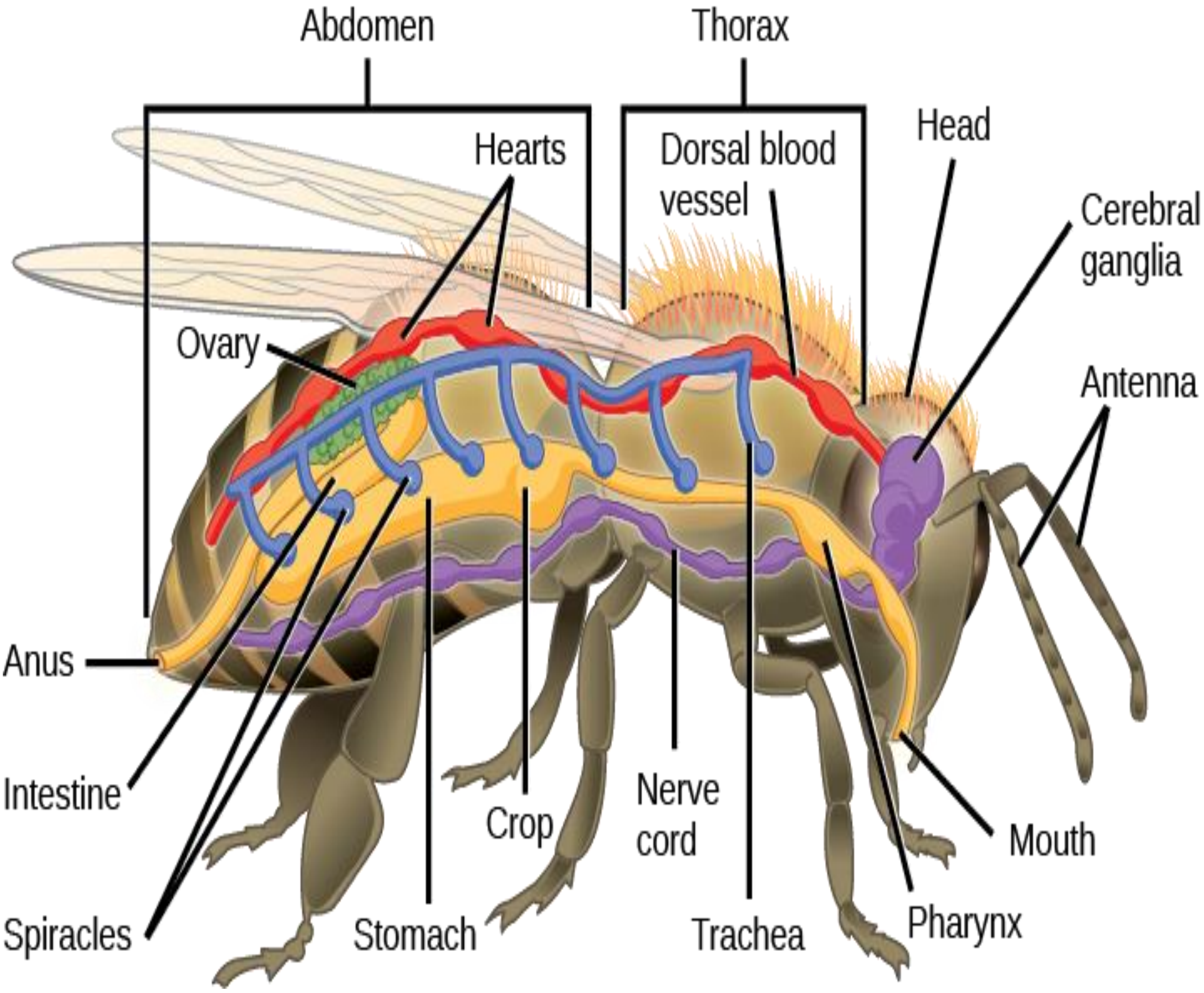


Fig 25: Insect anatomy

- **Arachnids :** Including spiders, scorpions and mites, arachnids are often effective predators. Their adaptation to varied habitats makes them vital for the control of insect populations.

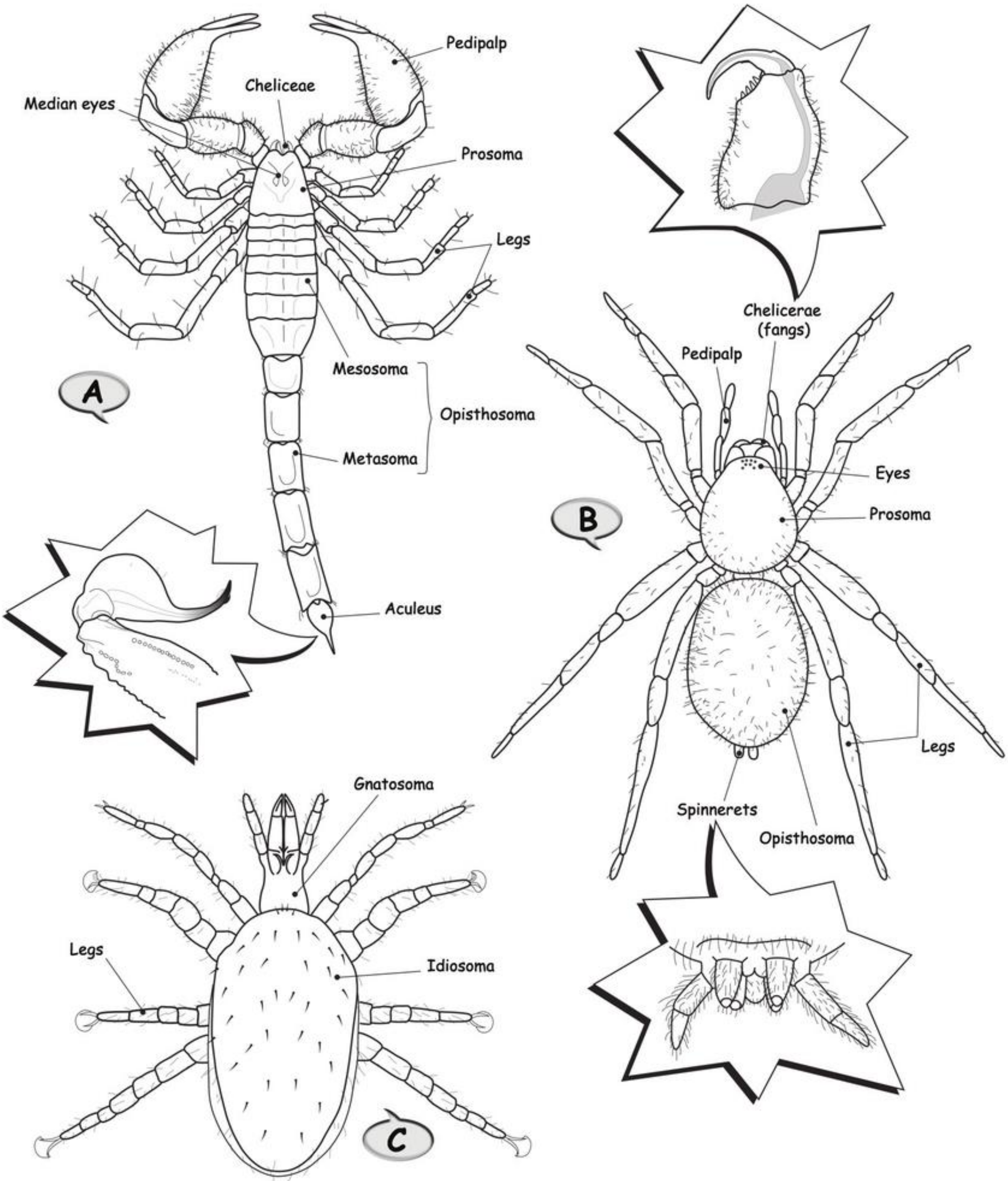


Fig 26: Drawings of generalized arachnids

- **Crustaceans:** This group includes crabs, shrimps and lobsters. Crustaceans play a key role in aquatic ecosystems and are of considerable economic importance in fisheries.

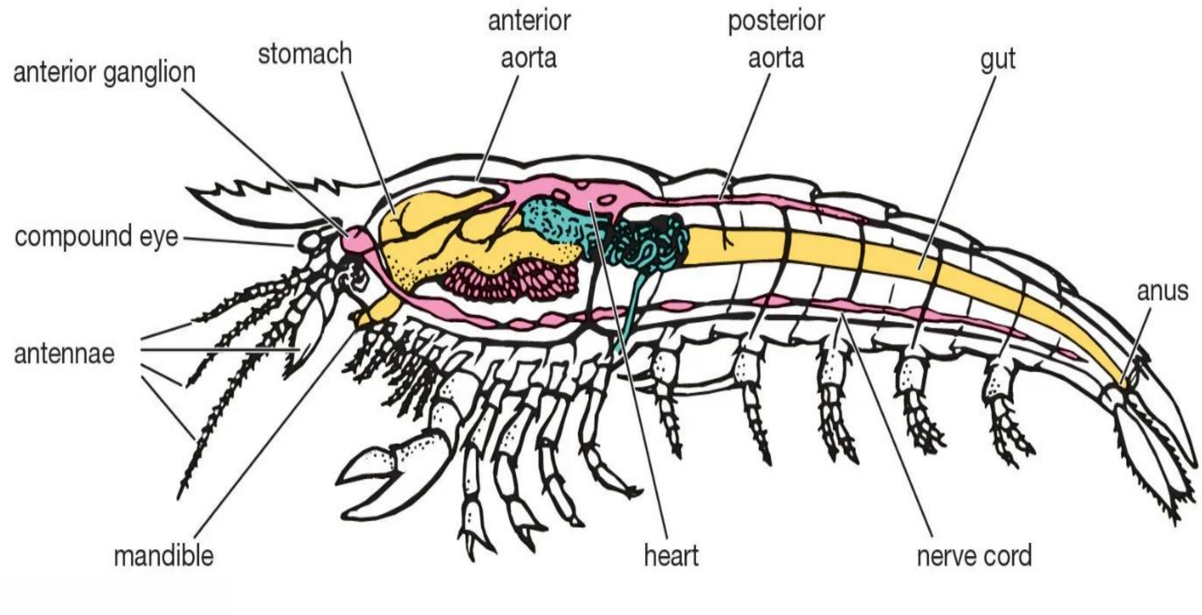


Fig 27: anatomy of a crustacean

- **Myriapods:** Including millipedes and centipedes, these arthropods are less known but play a crucial role in the recycling of organic matter on the ground.

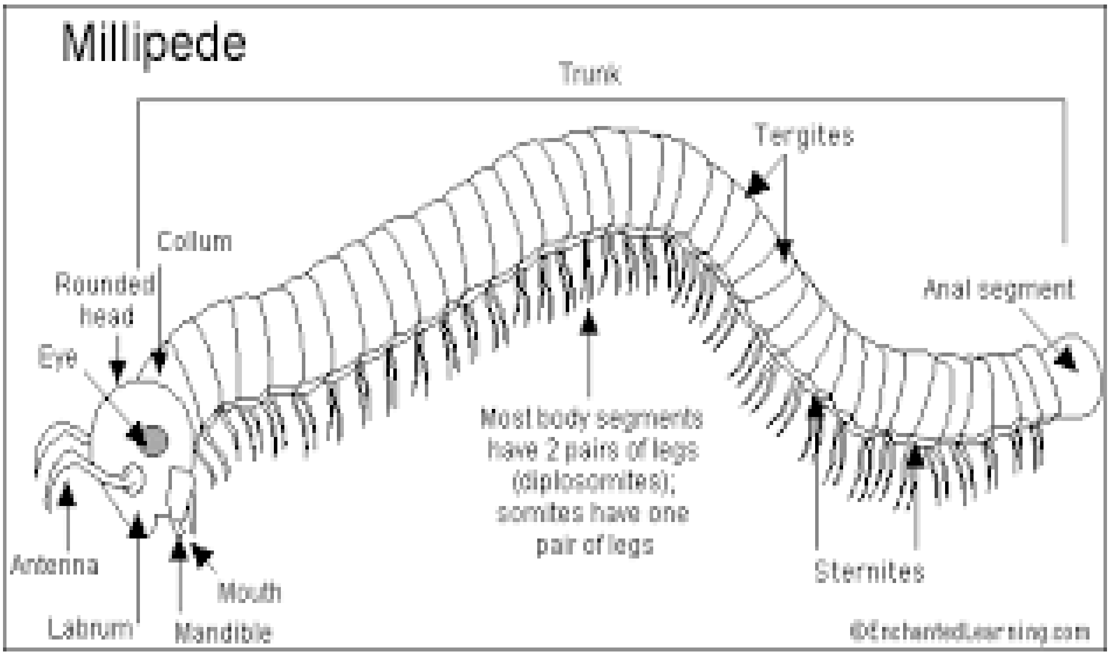


Fig 28: Myriapoda anatomy

D.Ecological and economical

Arthropods play essential roles in nature:

- Food webs: They are integrated into food chains, serving as prey for many animals, while also being predators of diseases and parasites.

- Pollination : Many insects, especially bees, are key pollinators for crops and wild plants, thus contributing to biodiversity.

- Decomposition : Arthropods, like springtails and manure beetles, help break down organic matter, enriching soils.

From an economic point of view, arthropods are of paramount importance in several industries. For example, crustaceans are at the heart of the fishing and seafood industry, while insects are often used in agriculture for pollination and biological pest control.

Conclusion

The branching of arthropods is a striking example of the diversity and adaptability of life on Earth. Their role in ecosystems, as well as their economic value, make them indispensable subjects of study for biology and ecology. Understanding arthropods and how they work is therefore essential for biodiversity conservation and natural resource management.

Branching Echinoderms

A. Introduction

The Echinoderms Fork is a fascinating and diverse group of marine animals that have captured the attention of biologists and naturalists for centuries. Composed of iconic organisms such as starfish, sea urchins, sea cucumbers and sea lilies, echinoderms play a crucial role in marine ecosystems and possess unique characteristics that set them apart from other groups of animals.

B. Morphological and Physiological Characteristics

Echinoderms are distinguished by their radial symmetry, which is often observed as pentameric symmetry (five parts). This feature is particularly evident in starfish, which typically have five arms. Echinoderms also have an endoskeleton composed of calcareous plates, giving them a rigid structure. This allows them to protect themselves from predators while offering them support.

In addition, these animals have an aquifer vascular system, a unique network of canals filled with seawater that allows them to move their arms and adhere to surfaces. This system also plays an essential role in their nutrition and breathing. As marine biologist Robert W. H. McNeill explains, “Echinoderms demonstrate remarkable adaptability through their unique marine physiology, which allows them to inhabit diverse underwater environments”.

C. Diversity and Ecology

The branching of echinoderms is composed of five main classes: Asterids (starfish), Echinoids (sea urchins), Holothurids (sea cucumbers), Ophiuroids (brigues) and Crinoids (sea lilies). Each group has particular adaptations that allow them to thrive in different ecological niches.

starfishes

Starfish are often considered the emblems of echinoderms. They play a vital role in regulating populations of other marine species, including mussels and sea snails. Some species of starfish, such as the famous *Pisaster ochraceus*, are key predators in their habitat, helping to maintain ecological balance.

Sea Urchins and Sea Cucumbers

Sea urchins, meanwhile, are herbivores that feed on algae, while sea cucumbers play a crucial role as decomposers, recycling nutrients into marine sediments. In this sense, echinoderms participate in a complex food chain and in the general health of marine ecosystems.

Threats and Conservation

Unfortunately, echinoderms face many threats, including climate change, pollution, and overfishing. Rising water temperatures and ocean acidification are disrupting marine habitats and affecting their ability to reproduce and survive. As a result, some species of echinoderms are experiencing alarming declines in their population.

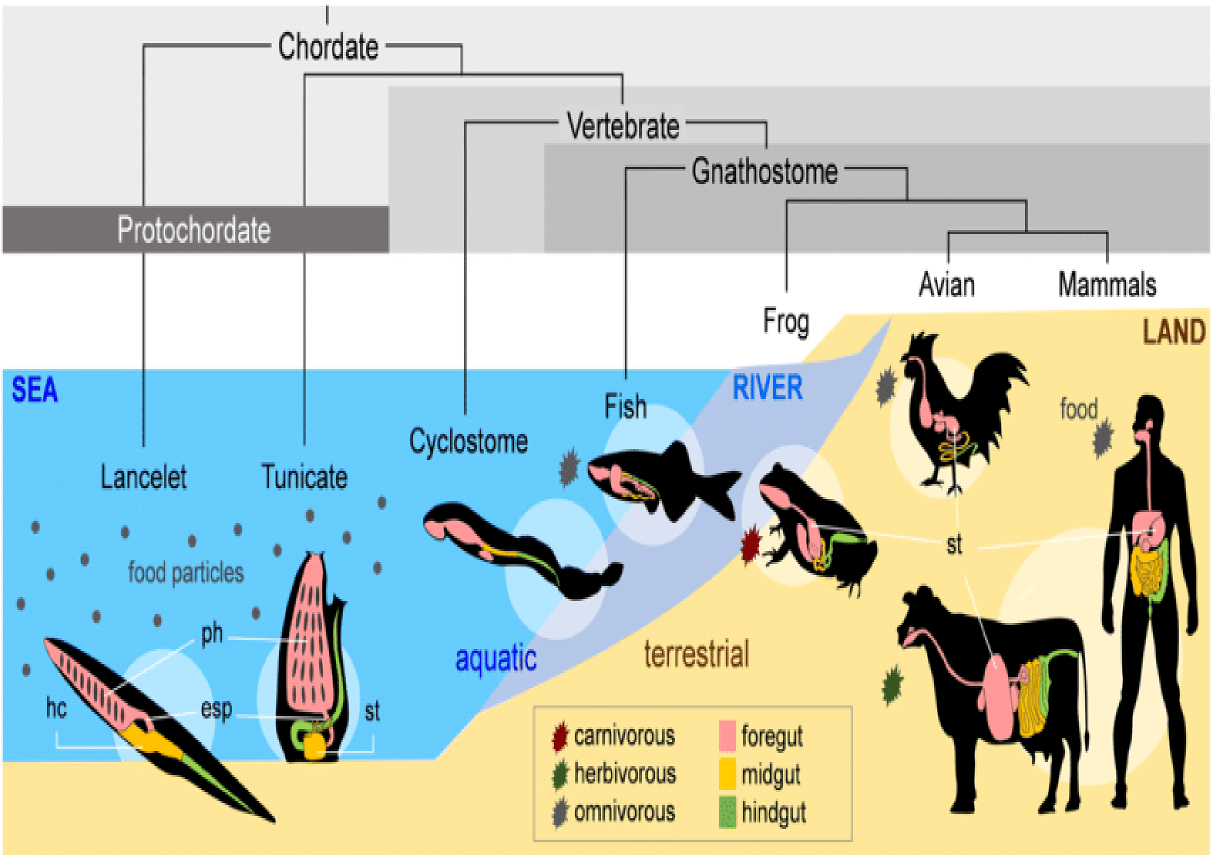
Conservation efforts are crucial to preserve these unique sea creatures. Scientific research and awareness-raising are essential to understand their role in marine ecosystems and to develop effective protection strategies.

Conclusion

The branching of echinoderms, with its incredible diversity and ecological importance, remains a primary subject of study for marine biologists. Understanding and protecting these fascinating organisms is not only a matter of scientific interest, but also a necessity to maintain the balance of our marine ecosystems. As marine biologist Dr. Sarah Johnson, “The preservation of echinoderms is essential not only for their survival, but also for the health of the oceans and, by extension, for humanity".

By continuing our research and strengthening our conservation efforts, we can hope to ensure a bright future for this extraordinary group of marine animals.

Branching of the Chordates



A. Introduction

The Chordates Branch, or Chordata, is one of the most fascinating and diverse groups in the animal kingdom. It includes organisms that exhibit, at different stages of their development, four distinctive anatomical characteristics: a notochord, a dorsal neural tube, gill slits and a post-anus. These traits make the Chordates a central group in the study of evolution and zoology.

B. Characteristics of Chordates

Chordates are distinguished by four main characteristics, which are present at different stages of their embryonic development:

1. Notochord: A flexible cartilage shaft that provides support and structure to the body. In vertebrates, the spine often develops to replace the notochord during development.

2. The dorsal neural tube : A structure that develops into a central nervous system, including the brain and spinal cord.

3. Gill slits: Initially present in embryos, these structures can evolve into different respiratory characteristics or atrophy during development.

4. Post-anus: A digestive extension that extends beyond the anus, a characteristic seen in some groups of Chordates.

C. Classification of Chordates

The Chordés branch is generally subdivided into three main subgroups:

1. Cephalocordata: Small marine organisms such as sandeels, which retain the notochord throughout their lives. They illustrate primitive features of the common ancestor of the Chordates.

2. Urochordates: Including tunicates, these aquatic animals are distinguished by their bag-like bodies and sessile lifestyle. Their phylum demonstrates a

remarkable diversity, with larval forms that display the typical characteristics of Chordates.

3. Vertebrates: The most complex and diverse group, including fish, amphibians, reptiles, birds and mammals. Vertebrates are characterized by the presence of a spine derived from the notochord. Their circulatory system is usually closed, and they show great morphological and functional diversity.

D. Evolution of the Chordates

The origin of the Chordates dates back to about 500 million years ago, during the Cambrian period. Researchers believe that the earliest forms of Chordates were marine animals similar to modern sandeels. Over time, evolution has given rise to an incredible diversity of forms and adaptations, allowing this group to conquer almost every habitat on the planet.

According to Charles Darwin, 'There is great harmony in all living things; they are all connected by some bond, and the study of biological parentage is essential to understanding this relationship' (Darwin, 1859). The Chordés illustrate this thesis by their diversity and their adaptation to varied environments, while sharing a common ancestor.

Conclusion

The Chordés branch is a rich and dynamic field of study, which continues to evolve with the discovery of new species and the application of modern technologies in biology and genetics. Understanding Chordates is not only about classifying organisms, but also about systematics and evolution, which contributes to our knowledge of ecological and evolutionary relationships in the natural world. By exploring this fascinating fork, we can better appreciate the connections that exist between all life forms on our planet.

Chapter IV:

Vertebrate Class

A. Introduction

The vertebrate class is one of the most fascinating and diverse in the animal kingdom.Comprising organisms ranging from fish to mammals, this class is distinguished by the presence of a spine – a fundamental criterion that distinguishes vertebrates from invertebrates. we will explore the generalities of this class as well as its general systematics.

B. General information on vertebrates

Vertebrates belong to the phylum of chordates, characterized by the presence of a notochord, a dorsal neural tube, and, for the most evolved, a spine. The latter is formed by vertebrae that protect the spinal cord, a key component of the central nervous system. In addition to their skeletal structure, vertebrates typically have a skull that protects their complex brains, allowing them to behave more sophisticatedly than invertebrates .

Vertebrates are divided into five main classes: fish, amphibians, reptiles, birds, and mammals. Each of these classes has unique characteristics in terms of reproduction, development and environmental adaptations.

C. General Systematics of Vertebrates

Vertebrate systematics are based on morphological, genetic and ecological criteria. According to the work of Nelson , each vertebrate class can be subdivided into several orders and families, allowing a more detailed classification.

1. **Fish:**

   fish are the earliest group of vertebrates, having appeared more than 500 million years ago. They have adapted to diverse aquatic environments, evolving into a wide range of species with varying anatomical and physiological characteristics.

Fish are broadly classified into two major groups:

A. Bony fish (Osteichthyes) – These fish possess a skeleton made of bone, giving them greater structural support. They exhibit remarkable morphological diversity, allowing them to thrive in both freshwater and marine habitats. This group includes species such as salmon, tuna, and goldfish.

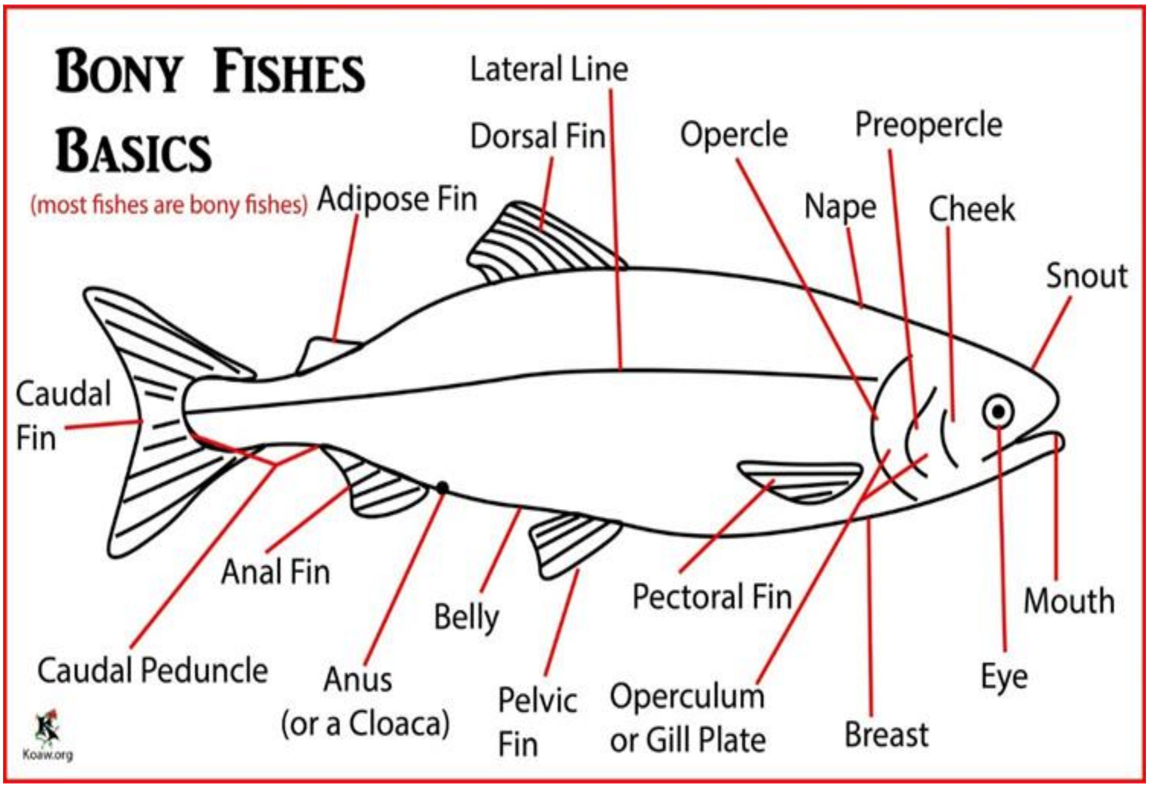


Fig 29: Osteichthyes -bony fish-

B. Cartilaginous fish (Chondrichthyes) – Unlike bony fish, these species have a skeleton composed mainly of cartilage, making them lighter and more flexible. This group includes sharks, rays, and skates, which are known for their highly developed sensory systems, such as electroreception and keen olfaction, helping them detect prey from great distances.

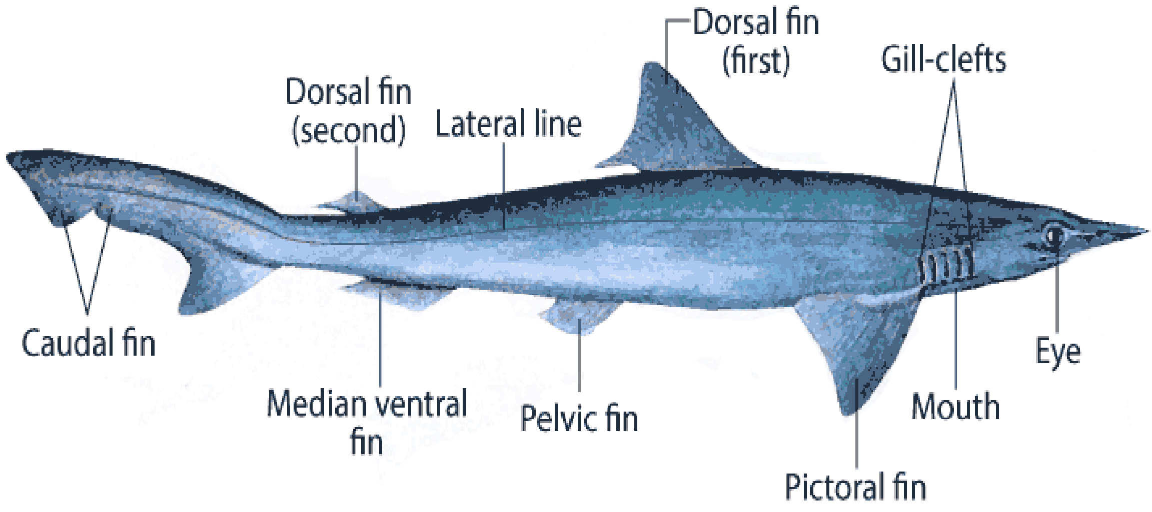


Fig 30: Cartilaginous fish

Fish play a vital role in aquatic ecosystems, serving as both predators and prey in food chains. Additionally, they are of great economic and ecological importance, providing a major source of food and supporting global fisheries. However, overfishing, habitat destruction, and climate change pose significant threats to fish populations, necessitating conservation efforts to ensure their sustainability.

With their evolutionary success and adaptability, fish continue to dominate aquatic environments, showcasing a fascinating blend of ancient survival traits and modern adaptations.

2. **amphibians**:

Amphibians, such as frogs, salamanders, and caecilians, are unique vertebrates characterized by their dual lifestyle, spending their early life stages in aquatic environments and transitioning to a terrestrial existence as adults. This remarkable adaptation allows them to thrive in both water and land, making them a crucial evolutionary link between fish and reptiles.

During the larval stage, amphibians typically have gills and a fully aquatic lifestyle, as seen in tadpoles. As they undergo metamorphosis, they develop lungs, limbs, and specialized skin that enable them to survive on land. However, most amphibians retain a strong dependence on moist environments, as their permeable skin plays a key role in respiration and water balance.

This class of vertebrates demonstrates the evolutionary transition from aquatic to terrestrial life, showcasing adaptations such as lungs for breathing air, limbs for movement on land, and complex reproductive behaviors. Amphibians also serve as ecological indicators, as their sensitive skin makes them highly susceptible to environmental changes, pollution, and climate fluctuations.

Despite their adaptability, many amphibian species face significant threats, including habitat loss, pollution, climate change, and disease outbreaks like chytridiomycosis. Conservation efforts are essential to protect these vital organisms, which play an integral role in maintaining ecosystem balance by controlling insect populations and serving as prey for larger species.

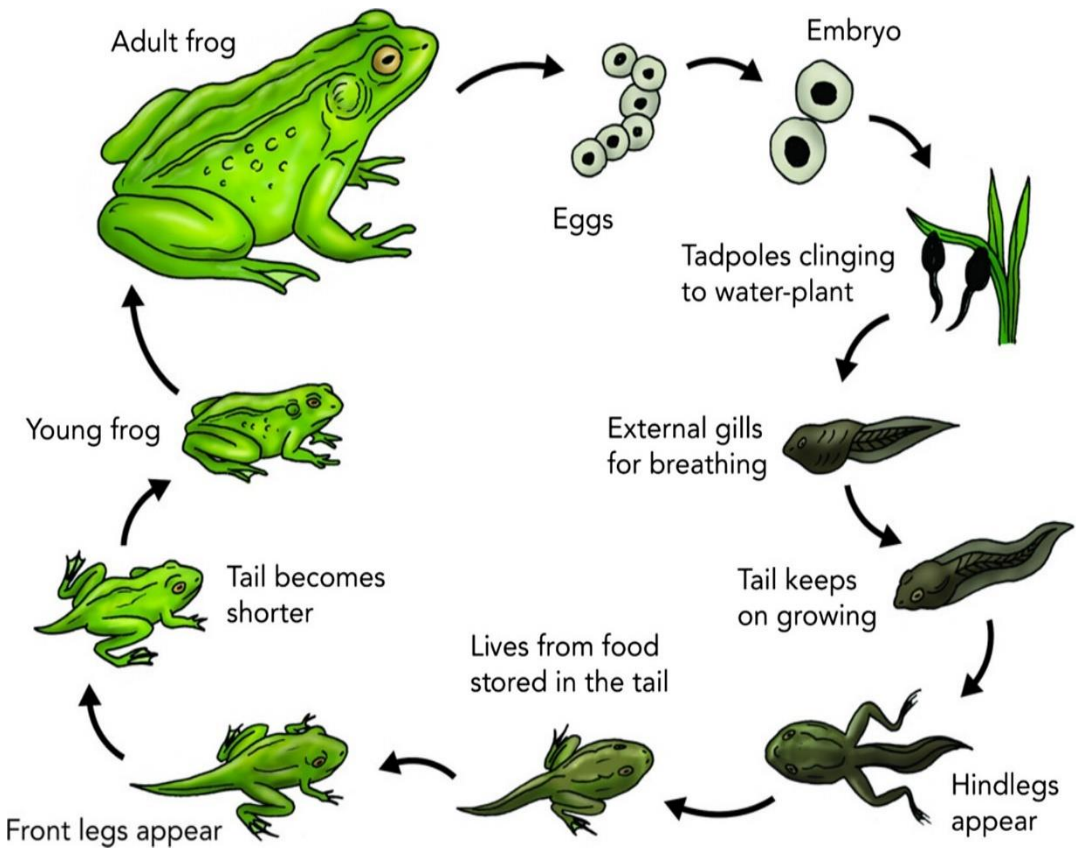


Fig 31: the life cycle of an amphibian

3. **Reptiles:**

Reptiles, which include lizards, snakes, turtles and crocodiles, are characterized by their scaly skin and oviparous reproduction (although there are exceptions). They have evolved to adapt to varied living conditions, from water to arid environments. As pointed out by Hedges . reptiles are also the direct ancestors of birds, which underlines the importance of their study in understanding evolution.

4. **The Birds:**

Birds are descended from a group of theropod dinosaurs and are distinguished by their feathers, flying ability and high metabolism.

According to phylogenetic analysis, they belong to a monophyletic group, Archosauria, which also includes crocodiles.

5. **Mammals:**

Mammals are a highly diverse and adaptable class of vertebrates, distinguished by their mammary glands, which produce milk to nourish their young, and their ability to regulate body temperature through endothermy. These adaptations have allowed them to thrive in nearly every habitat on Earth, from the icy Arctic tundra to dense rainforests, vast oceans, and arid deserts.

Mammals are classified into three major groups based on their reproductive strategies:

A. Monotremes (Egg-Laying Mammals) – These are the most primitive mammals, laying eggs instead of giving birth to live young. Examples include the platypus and echidnas, which are found in Australia and New Guinea. Despite their reptilian-like reproduction, they still produce milk and have fur, key mammalian traits.
B. Marsupials (Pouched Mammals) – These mammals give birth to underdeveloped offspring, which continue to grow and develop inside a protective pouch (marsupium). Common examples include kangaroos, koalas, and opossums. Marsupials are particularly diverse in Australia, though some species exist in the Americas.
C. Placental Mammals (Intrauterine Development) – The largest and most diverse group of mammals, placentals carry their young inside the womb for an extended period, where they receive nourishment through the placenta. This allows for longer fetal development, resulting in more developed offspring at birth. Examples include humans, elephants, whales, and lions.

Mammals exhibit a vast range of adaptations, including specialized teeth for different diets, advanced brains supporting complex behaviors, and efficient respiratory and circulatory systems. Their ability to socialize, communicate, and use tools makes them one of the most intelligent groups of animals.

Despite their success, many mammal species face threats from habitat destruction, climate change, and human activities. Conservation efforts are crucial to protect endangered species and maintain ecosystem balance, as mammals play essential roles as predators, prey, pollinators, and ecosystem engineers.

With their remarkable diversity, advanced physiological traits, and wide-ranging adaptations, mammals continue to dominate terrestrial, aerial, and aquatic environments, shaping ecosystems and coexisting with humans in complex ways.

Conclusion

The vertebrate class is not only fascinating in its diversity, but it also plays a crucial role in the ecosystem and the evolution of life on Earth. By understanding their systematics and general characteristics, we can better appreciate the importance of vertebrates in the food chain, ecological interactions, and ultimately the preservation of our planet.


Glossary

Glossary

A

- **Evolutionary adaptation**: The process by which organisms develop characteristics that promote their survival and reproduction in a given environment.
- **Amphibians**: Class of vertebrates that spend part of their lives in aquatic environments and another in terrestrial environments (e.g. frogs, salamanders).
- **Annelides**: Branch of segmented invertebrates, including earthworms, leeches and polychaetes.

B

- **Biodiversity**: Variety of living species in a given environment, playing a key role in the balance of ecosystems.
- **Bivalves**: Class of shell molluscs composed of two articulated valves (e.g. mussels, oysters).

C

- **Carnivores**: An order of mammals characterized by a diet based primarily on meat.
- **Chordates (Chordata)**: Branch of animals characterized by the presence of a notochord at a stage of their development.
- **Cnidaria**: Group of marine animals characterized by the presence of stinging cells (e.g. jellyfish, corals, sea anemones).
- **Crustaceans**: Subbranching of arthropods including species such as crabs, shrimps and lobsters.

D

- **Dorsal**: Relating to the back or upper face of an organism.

E

- **Echinoderms**: Branch of marine invertebrates characterized by radial symmetry (e.g. starfish, sea urchins, sea cucumbers).
- **Ecosystem**: A community of living things interacting with their physical environment.
- **Endoskeleton**: Internal support structure present in some animals, including vertebrates.
- **Evolution**: Process of changing the characteristics of living organisms over generations, under the influence of natural selection and other mechanisms.

F

- **Filtration**: Mechanism used by some marine organisms (e.g. sponges, bivalves) to feed by capturing particles suspended in the water.

G

- **Gastropods**: Class of molluscs including snails and slugs, characterized by a unique shell and muscular foot.
- **Gene**: Fundamental unit of heredity encoding a specific biological characteristic.

H

- **Herbivores**: Organisms that mainly feed on plants.

I

- **Invertebrates**: Animals without a spine, including arthropods, molluscs, cnidarians, etc.

L

- **Locomotion**: The ability of an organism to move in its environment.

M

- **Mammals**: A class of vertebrates characterized by the presence of milk-producing mammary glands to feed their young.
- **Molluscs**: Branch of soft-bodied invertebrates, often protected by a limestone shell (e.g. oysters, octopuses, snails).

N

- **Binomial nomenclature**: Scientific naming system of species in two words (genus + species), developed by Linnaeus (e.g. *Homo sapiens*).

O

- **Omnivores**: Organisms that can feed on both plant and animal matter.
- **Order**: Level of taxonomic classification between class and family.

P

- **Phylogeny**: Study of evolutionary relationships between organisms.
- **Plankton**: All aquatic microorganisms drifting passively in water.
- **Polychaetes**: Class of marine annelids characterized by parapods carrying bristles.

R

- **Radula**: Oral organ in the shape of a tongue, used by some molluscs to grate food.
- **Asexual reproduction**: A mode of reproduction that does not involve gamete fusion (e.g. budding in sponges).

S

- **Segmentation**: Division of the body into repetitive segments observed in some invertebrates (e.g. annelids, arthropods).
- **Spicules**: Rigid skeletal structures present in some sponges.

T

- **Taxonomy**: The science of classifying living things.
- **Tunicate**: A marine organism belonging to urochordates, often attached to a substrate.

V

- **Vertebrates**: A group of chordates characterized by a spine.

Exercises

Chapter I: Presentation of the Animal Kingdom

Question 1: What is the fundamental unit of zoological classification?

A) Kingdom

B) Phylum

C) Species

D) Family

✅ **Answer:** C) Species

Question 2: Which of the following best describes phylogeny?

A) The study of animal behavior

B) The evolutionary history of organisms

C) The classification of extinct species

D) The naming of species

✅ **Answer:** B) The evolutionary history of organisms

Chapter II: Generalities on the Protozoa Sub-Kingdom

Question 3: Which structure is responsible for movement in Paramecium?

A) Flagella

B) Pseudopodia

C) Cilia

D) Nematocysts

✅ **Answer:** C) Cilia

Question 4: Protozoans reproduce mainly through:

A) Budding

B) Binary fission

C) Fragmentation

D) Spore formation

✅ **Answer:** B) Binary fission

Chapter III: Metazoa Sub-Kingdom

Question 5: What is the main difference between Protozoa and Metazoa?

A) Protozoa are multicellular, Metazoa are unicellular

B) Metazoa are multicellular, Protozoa are unicellular

C) Protozoa are photosynthetic

D) Metazoa lack specialized tissues

✅ **Answer:** B) Metazoa are multicellular, Protozoa are unicellular

Question 6: Which of the following is an example of a metazoan?

A) Amoeba

B) Plasmodium

C) Earthworm

D) Paramecium

✅ **Answer:** C) Earthworm

Question 7: What is the primary feeding method of sponges?

A) Active predation

B) Filter feeding

C) Absorbing sunlight

D) Symbiotic feeding

✅ **Answer:** B) Filter feeding

Question 8: What is the name of the specialized cells in sponges that generate water currents?

A) Amoebocytes

B) Choanocytes

C) Nematocysts

D) Cnidocytes

✅ **Answer:** B) Choanocytes

Question 9: Cnidarians are characterized by the presence of:

A) Spicules

B) Nematocysts

C) Radula

D) Jointed appendages

✅ **Answer:** B) Nematocysts

Question 10: Which of the following is a polyp-form cnidarian?

A) Jellyfish

B) Hydra

C) Squid

D) Sea star

✅ **Answer:** B) Hydra

Question 11: Which class of annelids includes earthworms?

A) Polychaeta

B) Hirudinea

C) Oligochaeta

D) Trematoda

✅ **Answer:** C) Oligochaeta

Question 12: The circulatory system of annelids is:

A) Open

B) Closed

C) Absent

D) Mixed

✅ **Answer:** B) Closed

Question 13: What is the function of the radula in mollusks?

A) Movement

B) Digestion

C) Locomotion

D) Respiration

✅ **Answer:** B) Digestion

Question 14: Which of the following mollusks belongs to the class Cephalopoda?

A) Snail

B) Oyster

C) Squid

D) Clam

✅ **Answer:** C) Squid

Question 15: The exoskeleton of arthropods is made of:

A) Keratin

B) Calcium carbonate

C) Chitin

D) Silica

✅ **Answer:** C) Chitin

Question 16: Which arthropod class includes insects?

A) Crustacea

B) Arachnida

C) Myriapoda

D) Hexapoda

✅ **Answer:** D) Hexapoda

Question 17: What type of symmetry do echinoderms exhibit as adults?

A) Bilateral

B) Radial

C) Asymmetrical

D) Spiral

✅ **Answer:** B) Radial

Question 18: What structure helps echinoderms move and feed?

A) Tentacles

B) Water vascular system

C) Cnidocytes

D) Trachea

✅ **Answer:** B) Water vascular system

Question 19: Which of the following is a key characteristic of chordates?

A) Exoskeleton

B) Notochord

C) Radial symmetry

D) Segmentation

✅ **Answer:** B) Notochord

Question 20: What structure in chordates develops into the spinal cord?

A) Pharyngeal slits

B) Post-anal tail

C) Dorsal nerve cord

D) Notochord

✅ **Answer:** C) Dorsal nerve cord

Chapter IV: Vertebrate Class

Question 21: What distinguishes mammals from other vertebrates?

A) They lay eggs

B) They have mammary glands

C) They lack a backbone

D) They have gills

✅ **Answer:** B) They have mammary glands

Question 22: Which vertebrate group is characterized by having a cartilaginous skeleton?

A) Amphibians

B) Reptiles

C) Chondrichthyes (cartilaginous fish)

D) Osteichthyes (bony fish)

✅ **Answer:** C) Chondrichthyes (cartilaginous fish)

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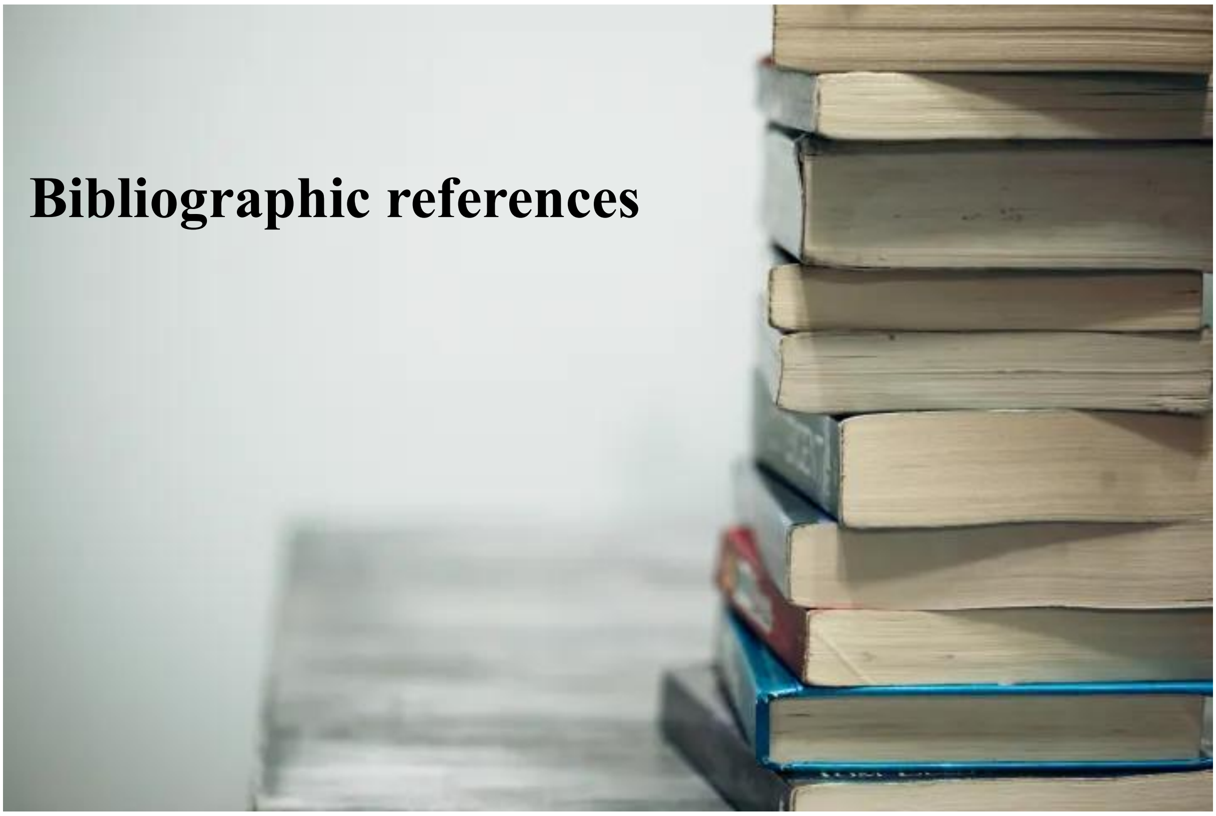

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