SAADU ZUNGUR UNIVERSITY, BAUCHI STATE

DEPARTMENT OF BIOLOGICAL SCIENCES.

BIO102
GENERAL BIOLOGY II
LECTURE NOTE

INTRODUCTION

Classification is a system in which information on organisms are gathered and stored in an orderly manner for easy retrieval. There millions of different kinds of organisms; to study these organisms, they need to be separated into small, more manageable groups with common characteristics (closely related) and given names. Easily observable positive and negative characteristics are used as basis for classification while irrelevant characters are left out.

Classification of Organisms

All animals along with animal-like are classified into two (2) main groups, namely:

- Invertebrates - Animals (and animal-like organisms) without backbone and
- Vertebrates – Animals with backbone

The aspect of biology that deals classification of organisms is called **Taxonomy**. It includes the naming of organisms (nomenclature) and the systematic assignment of organisms to groups called taxa (this is referred to as systematics). Taxonomy and systematics are very often interchanged.

There are two main types of classification:

i. Artificial classification
ii. Natural classification

An artificial classification is based on one or more easily observable characteristics such as colour, mode of locomotion, habitat etc.

A natural classification may be phylogenetic and reflects possible evolutionary relationships based on ancestry and descent. In phylogenetic classification, organisms belonging to the same taxa are believed to have a common ancestor. This may be represented by a cladogram (family tree).

Phenetic classification is based on evidence from data compiled on morphological (structural), cytological (cellular) and biochemical similarities or differences between organisms.

Biological nomenclature is based on the binomial system, which was introduced by the Swedish naturalist Carl Von Linnaeus (1707-1778), who gave two Latin names to each organism. The first name is the generic name, which begins with an uppercase alphabet and the second is the specific name, which begins with a lowercase alphabet. Both names must be underlined or italicized e.g. Clarias gariepinus or Clarias gariepinus. Animals are named following rules set out in the International Code of Zoological

Nomenclature (ICZN). Following the rules of nomenclature, there can only be one *Clarias gariepinus*, etc.

Basic Characteristics, Identification, and Classification Viruses, Fungi and Bacteria

1.0 VIRUSES

Basic Characteristics, Identification, and Classification

1.1 Basic Characteristics

- **Non-living Entities**: Viruses are unique entities that are much simpler than cellular organisms. Major cause of disease
- They lack many of the components found in cells, such as organelles, ribosomes, and a plasma membrane.
- Here's a detailed look at the structure of a typical virus:
- Viruses cannot reproduce or carry out metabolic processes outside a host cell.
- They are considered obligate intracellular parasites.
- Their protein coats may be Icosahedral (polygon with 20 faces and corners), helical or complex in symmetry.
- The viruses may be enveloped or without an envelope, i.e. naked
- No metabolic activity (invade other cells and use their metabolic mechanism)
- Viruses can affect all type of cells of hosts which can be animal (infect animals), plant (Infect plants) or Bacteriophages (Infects bacteria)
- **Reproduction**:
  Viruses replicate by hijacking the host cell's machinery to produce new virus particles
  Distinct pattern of multiplication through replication strategy:
  Lytic Cycle: Virus replicates and lyses the host cell.
  Lysogenic Cycle: Viral DNA integrates into the host genome and replicates along with it.

1.2 **Structure**:

- **Genetic Material**: Either DNA or RNA, but not both.
- **Capsid**: A protein coat that encloses the genetic material.
- **Envelope**: Some viruses have an additional lipid envelope derived from the host cell membrane.
- **Size**: Typically 20-300 nanometers.
- **Viruses Stages** – Extracellular (No ability to divide) - a Virion
  - Intracellular (ability to divide)

1.3 Identification

- **Electron Microscopy**: Used to visualize virus particles due to their small size.
- **Molecular Techniques**:
  PCR (Polymerase Chain Reaction): Detects viral genetic material.
  Sequencing: Determines the genetic sequence of the virus.
  Serology: Detects antibodies or antigens related to the virus.

1.4 Classification

Genetic Material: **DNA Viruses**: e.g., Herpesviridae.
RNA Viruses: e.g., Coronaviridae.

1.5 Types of Viral Structures

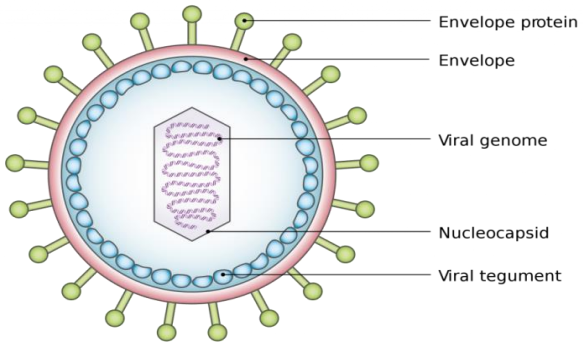
i. **Icosahedral Viruses**:
Shape: Spherical appearance but composed of 20 triangular faces.
Examples: Adenoviruses, Herpesviruses.

ii. **Helical Viruses**:
Shape: Rod-shaped or filamentous.
Examples: Tobacco Mosaic Virus, Influenza Virus.

iii. **Complex Viruses**:
Shape: Combination of icosahedral and helical structures, often with additional complex structures like tails.
Examples: Bacteriophages (viruses that infect bacteria).

iv. **Enveloped Viruses**:
Shape: Can be either icosahedral or helical but surrounded by a lipid envelope.
Examples: HIV, Herpes Simplex Virus.

v. **Non-enveloped (Naked) Viruses**:
Shape: Lacks a lipid envelope, can be icosahedral or helical.
Examples: Poliovirus, Norovirus.

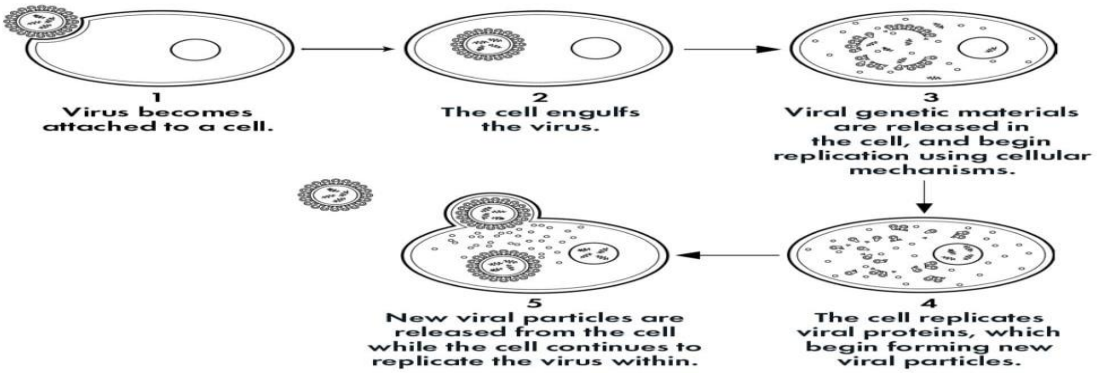


1.6 Viral Cell Structure and function

- **Genetic Material**:
  Composition: Either DNA or RNA, but not both.
  Function: Contains the genetic instructions for making new virus particles.

Types: Single-stranded or double-stranded, linear or circular.

- **Capsid**:
  Composition: Protein coat made up of subunits called capsomeres.
  Function: Protects the genetic material and aids in the transfer of the virus between host cells.
  Shapes: Can be icosahedral, helical, or complex.
- **Envelope (in some viruses)**:
  Composition: Lipid bilayer derived from the host cell membrane, embedded with viral proteins.
  Function: Helps the virus enter host cells and evade the host immune system.
  Presence: Not all viruses have an envelope; those without are called non-enveloped or naked viruses.
- **Spikes (Glycoproteins)**:
  Composition: Protein structures that protrude from the surface of the envelope.
  Function: Facilitate attachment and entry into host cells.
- **Tail (in bacteriophages**): Some viruses that infect bacteria, known as bacteriophages, have a tail structure that helps them inject their genetic material into bacterial cells



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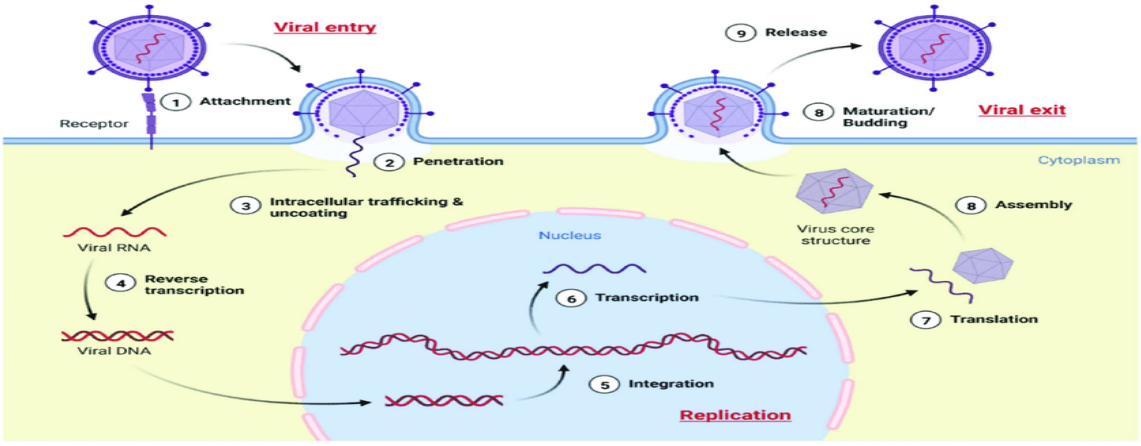


FUNGI
Basic Characteristics, Identification, and Classification

2.1 Basic Characteristics

- **Eukaryotic Cells**:
  Fungi have a true nucleus and membrane-bound organelles.
  Their cell walls are primarily composed of chitin.
- **Heterotrophic Nutrition**:
  Fungi obtain nutrients by absorbing organic matter from their environment.
  They can be saprophytic (decomposers), parasitic, or mutualistic.
- **Reproduction**:
  Fungi reproduce both sexually and asexually through spores.
  Common reproductive structures include sporangia, asci, and basidia.
- **Growth Forms**:
  Fungi can be unicellular (yeasts) or multicellular (molds and mushrooms).
  Multicellular fungi form networks of hyphae, which collectively make up the mycelium.

2.2 Identification

- **Microscopy**: Observing fungal structures such as hyphae, spores, and reproductive bodies under a microscope.
- **Culture Techniques**: Growing fungi on specific media to observe colony morphology and growth patterns.
- **Molecular Techniques**: PCR and sequencing to identify fungal DNA.
  Ribosomal RNA sequencing is commonly used for fungal identification.
- **Biochemical Tests**: Assessing metabolic and enzymatic activities to differentiate fungal species.

2.3 Classification

Fungi are classified into several phyla based on their reproductive structures and genetic data:

- **Chytridiomycota (Chytrids)**:
  Simplest and most primitive fungi
  Produce flagellated spores called zoospores
  Mostly aquatic and can be saprobes or parasites

- **Zygomycota (Conjugated Fungi)**:
  Produce zygospores during sexual reproduction
  Commonly found in soil and decaying organic matter
  Example: Rhizopus (bread mold)

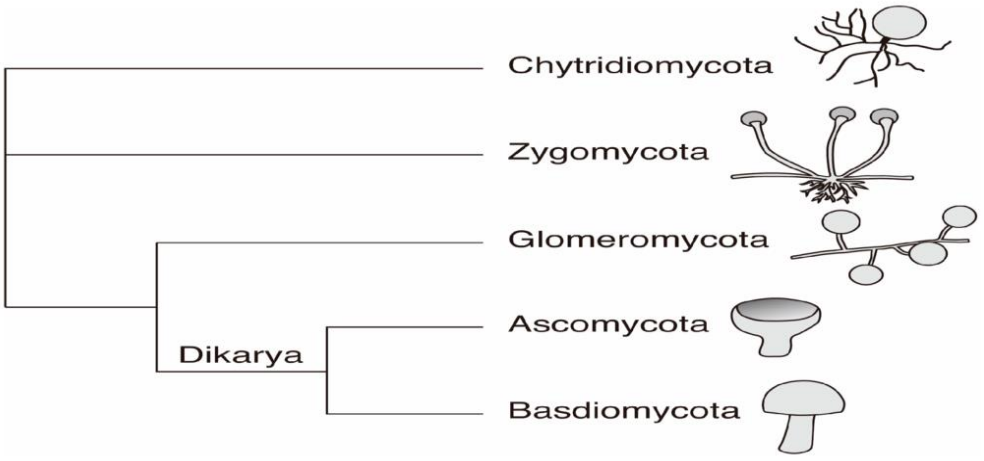
- **Ascomycota (Sac Fungi)**:
  Produce spores in sac-like structures called asci
  Includes yeasts, molds, and morels

Example: Saccharomyces (brewer's yeast)

- **Basidiomycota (Club Fungi)**:
  Produce spores on club-shaped structures called basidia
  Includes mushrooms, puffballs, and rusts
  Example: Agaricus (common mushroom)

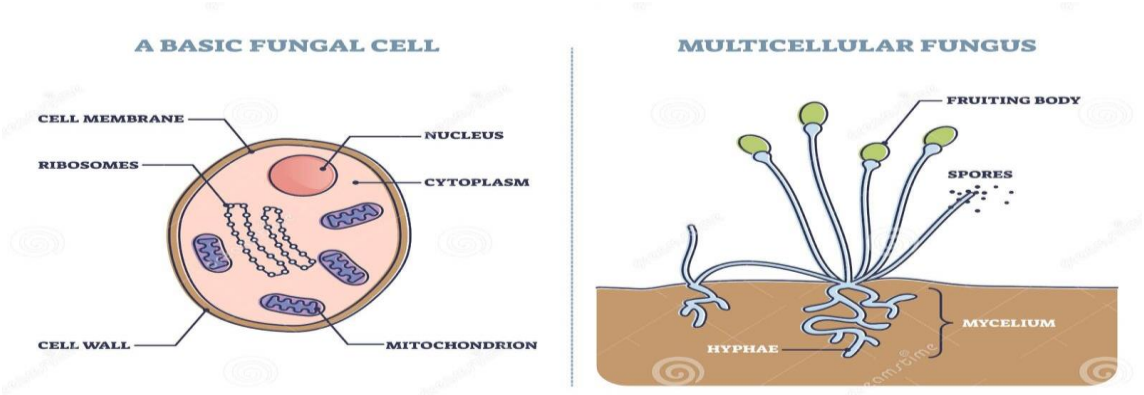
- **Glomeromycota**:
  Form symbiotic relationships with plant roots (mycorrhizae)
  Important for nutrient exchange between soil and plants

- **Deuteromycota (Imperfect Fungi)**:
  Fungi with no known sexual reproduction stage
  Often reclassified into other phyla as their sexual stages are discovered
  Example: Penicillium (source of penicillin)



2.4 Fungal Cell Structure

Fungi are eukaryotic organisms, meaning they have a complex cellular organization with membrane-bound organelles. Here's a detailed look at the structure of a fungal cell:



Key Components of Fungal Cells

No	Organelle	Function	Description
1	**Cell Wall**	Provides structural support and protection.	Primarily made of chitin, a strong and flexible polysaccharide, along with glucans and proteins.
2	**Cell Membrane**	Regulates the movement of substances in and out of the cell.	Contains ergosterol, a sterol unique to fungi, instead of cholesterol found in animal cells.
3	**Nucleus**	Controls cellular activities and reproduction.	Contains the cell's genetic material (DNA) wrapped around histone proteins.
4	**Cytoplasm**	Site of various metabolic activities.	Gel-like substance where cellular organelles are suspended.
5	**Mitochondria**	Powerhouse of the cell,	Responsible for energy production through cellular respiration.
6	**Endoplasmic Reticulum (ER)**:		
	i. Rough ER	Studded with ribosomes, involved in protein synthesis.	
	ii. Smooth ER	Involved in lipid synthesis and detoxification processes.	
7	**Golgi Apparatus**:	Modifies, sorts, and packages proteins and lipids for secretion or use within the cell.	
8	**Vacuoles**	Storage of nutrients, waste products, and helps maintain cell turgor.	
9	**Ribosomes**:	Sites of protein synthesis	
10	**Hyphae**:	Absorb nutrients from the environment.	Long, thread-like structures that form the mycelium.
11	**Septum**:	Allows for compartmentalization within the hyphae.	Cross-walls that divide hyphae into individual cells.

BACTERIA

Basic Characteristics, Identification, and Classification

3.1 Basic Characteristics

- **Prokaryotic Cells**:
  - Bacteria are unicellular organisms that lack a true nucleus and membrane-bound organelles.
  - Their genetic material is located in a nucleoid, an irregularly shaped region within the cell.

- **Cell Wall**:

- Most bacteria have a cell wall composed of peptidoglycan, which provides structural support and shape.
- The composition of the cell wall varies between Gram-positive and Gram-negative bacteria.

- **Reproduction**:
  - Bacteria reproduce asexually through binary fission, where a single cell divides into two identical daughter cells.
  - Some bacteria can exchange genetic material through processes like conjugation, transformation, and transduction.

- **Metabolism**:
  - Bacteria exhibit diverse metabolic pathways, including aerobic and anaerobic respiration, fermentation, and photosynthesis.
  - They can be autotrophic (producing their own food) or heterotrophic (obtaining food from external sources).

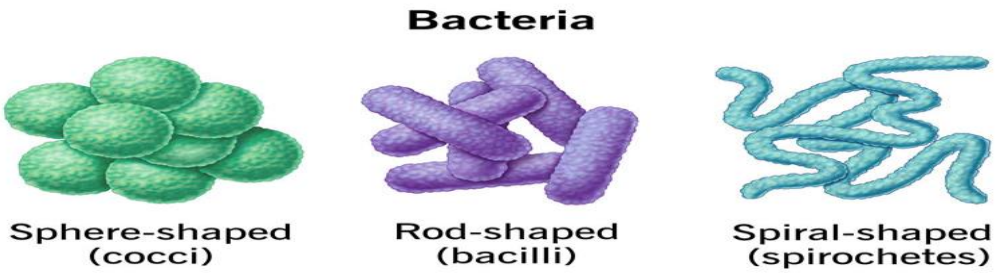
- **Shapes**:
  - Common shapes include cocci (spherical), bacilli (rod-shaped), and spirilla (spiral-shaped).

3.2 Identification

1. **Microscopy**:
   - **Gram Staining**: Differentiates bacteria into Gram-positive (purple) and Gram-negative (pink) based on cell wall composition.
   - **Morphology**: Observing the shape, size, and arrangement of bacterial cells.
2. **Culture Techniques**:
   - Growing bacteria on specific media to observe colony morphology and growth patterns.
3. **Biochemical Tests**:
   - Identifying metabolic and enzymatic activities, such as carbohydrate fermentation, catalase test, and oxidase test.
4. **Molecular Techniques**:
   - **PCR (Polymerase Chain Reaction)**: Detects bacterial DNA.
   - **Sequencing**: Determines the genetic sequence of bacteria.
5. **Serology**:
   - Detects specific antigens or antibodies related to bacterial infections.

3.3 Classification

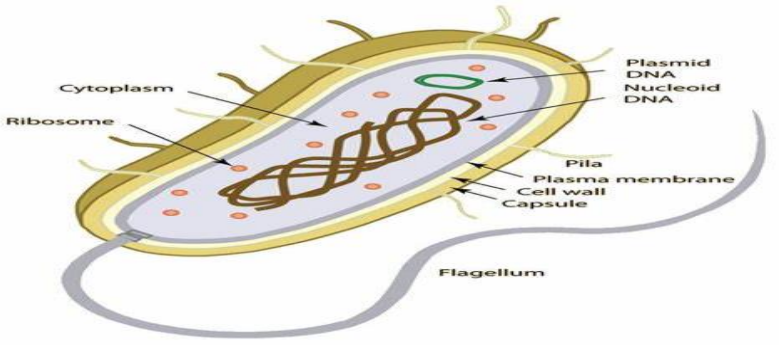
1. **Shape**:
   - **Cocci**: Spherical bacteria (e.g., Staphylococcus, Streptococcus).
   - **Bacilli**: Rod-shaped bacteria (e.g., Escherichia coli, Bacillus).
   - **Spirilla**: Spiral-shaped bacteria (e.g., Spirillum, Treponema).



2. **Gram Staining**:
   - **Gram-positive**: Thick peptidoglycan layer (e.g., Staphylococcus, Bacillus).
   - **Gram-negative**: Thin peptidoglycan layer and outer membrane (e.g., Escherichia coli, Salmonella).
3. **Oxygen Requirement**:
   - **Aerobic**: Require oxygen for growth (e.g., Mycobacterium tuberculosis).
   - **Anaerobic**: Grow in the absence of oxygen (e.g., Clostridium).
   - **Facultative Anaerobes**: Can grow with or without oxygen (e.g., Escherichia coli).
4. **Temperature Requirement**:
   - **Psychrophiles**: Thrive in cold temperatures.
   - **Mesophiles**: Grow best at moderate temperatures.
   - **Thermophiles**: Thrive in high temperatures.
5. **Nutritional Requirement**:
   - **Autotrophs**: Produce their own food (e.g., Cyanobacteria).
   - **Heterotrophs**: Obtain food from external sources (e.g., Escherichia coli).

3.4 Bacterial Cell Structure

Bacteria are prokaryotic organisms, meaning they lack a true nucleus and membrane-bound organelles. Here's a detailed look at the structure of a typical bacterial cell:



Key Components of Bacterial Cells

No	Organelle	Function	Description
1	**Cell Wall** **Gram-positive**: **Gram-negative**	Protects the cell from osmotic pressure and gives it shape. Thick peptidoglycan layer. Thin peptidoglycan layer and an outer membrane.	Primarily made of peptidoglycan, which provides structural support and shape.
2	**Cell Membrane (Plasma Membrane)**	Regulates the movement of substances in and out of the cell.	Phospholipid bilayer with embedded proteins.
3	**Nucleoid**:	Contains genetic material that controls cell activities.	Region containing the bacterial chromosome, which is a single, circular DNA molecule
4	**Cytoplasm**	Site of various metabolic activities.	Gel-like substance where cellular components are suspended.
5	**Endospores**:	Ensure survival in harsh conditions.	Highly resistant structures formed by some bacteria.
6	**Plasmids**:	Carry genes that may provide advantages, such as antibiotic resistance.	Small, circular DNA molecules separate from the chromosomal DNA.
7	**Pili (Fimbriae)**:	Help in attachment to surfaces and in conjugation (transfer of genetic material between bacteria).	Hair-like structures on the surface of the cell.
8	**Ribosomes**:	Contains genetic material that controls cell activities.	Made of RNA and proteins.
9	**Flagella**:	Enable motility	Long, whip-like structures made of protein.
10	**Capsule**:	Protects against desiccation and phagocytosis, and aids in adherence to surfaces	Polysaccharide layer outside the cell wall.

PLANTS KINGDOM

Kingdom Plantae include all plants. They are eukaryotic, multicellular and autotrophic organisms. The plant cell contains a rigid cell wall. Plants has chloroplast and chlorophyll pigment which is required for photosynthesis

Characteristics of Kingdom Plantae

The plant kingdom has the following characteristic features:

1. They are non-motile.
2. They make their own food and hence are called autotrophs.
3. They reproduce asexually by vegetative propagation or sexually.
4. These are multicellular eukaryotes. The plant cell contains the outer cell wall and a large central vacuole.
5. Plants contain photosynthetic pigments called chlorophyll present in the plastids.
6. They have different organelles for anchorage, reproduction, support and photosynthesis.

Classification of Kingdom Plantae

A plant kingdom is further classified into subgroups. Classification is based on the following criteria:

1. **Plant body**: Presence or absence of a well-differentiated plant body. E.g. Root, Stem and Leaves.
2. **Vascular system**: Presence or absence of a vascular system for the transportation of water and other substances. E.g. Phloem and Xylem.
3. **Seed formation**: Presence or absence of flowers and seeds and if the seeds are naked or enclosed in a fruit.

The plant kingdom has been classified into five subgroups according to the above-mentioned criteria:

1. Thallophyta
2. Bryophyta
3. Pteridophyta
4. Gymnosperms
5. Angiosperms

Thallophyta

Thallophytes lack a well-differentiated body structure and the plant body is thallus like.

Thallophyta includes plants with primitive and simple body structures. The plant body is thallus, they may be filamentous, colonial, branched or unbranched. Examples include green algae, red algae and brown algae. Common examples are *Volvox, Fucus, Spirogyra, Chara, Polysiphonia, Ulothrix*, etc.

Brayophyta

Bryophytes do not have vascular tissues. The plant body has root-like, stem-like and leaf-like structures. Bryophytes are terrestrial plants but are known as "amphibians of the plant kingdom" as they require water for sexual reproduction. They are present in moist and shady places. Bryophyta includes mosses, hornworts and liverworts. Some of the common examples are *Marchantia, Funaria, Sphagnum, Antheoceros,* etc.

Pteridophyta

Pteridophytes have a well-differentiated plant body into root, stem and leaves. They have a vascular system for the conduction of water and other substances. Some of the common examples are *Selaginella, Equisetum, Pteris*, etc.

Gymnosperms

The gymnosperms are a group of seed-producing plants that includes conifers, cycads, Ginkgo, and gnetophytes, forming the clade Gymnospermae. The term gymnosperm comes from the composite word in Greek: γυμνόσπερμος, literally meaning 'naked seeds'. The name is based on the unenclosed condition of their seeds. Or a plant of a group that comprises those that have seeds unprotected by an ovary or fruit, including the conifers, cycads, and ginkgo.

The word "Gymnosperm" comes from the Greek words "gymnos"(naked) and "sperma"(seed), hence known as "Naked seeds." Gymnosperms are the seed-producing plants, but unlike angiosperms, they produce seeds without fruits. These plants develop on the surface of scales or leaves, or at the end of stalks forming a cone-like structure.

Gymnosperms belong to kingdom 'Plantae'and sub-kingdom 'Embryophyta'. The fossil evidence suggested that they originated during the Paleozoic era, about 390 million years ago.

Basically, gymnosperms are plants in which the ovules are not enclosed within the ovary wall, unlike the angiosperms. It remains exposed before and after fertilisation and before developing into a seed. The stem of gymnosperms can be branched or unbranched. The thick cuticle, needle-like leaves, and sunken stomata reduce the rate of water loss in these plants.

The family of gymnosperms consist of conifers, the cycads, the gnetophytes and the species of Gynkgophyta division and Ginkgo biloba.

Characteristics of Gymnosperms

Following are the important characteristics of gymnosperms:

1. They do not produce flowers.
2. Seeds are not formed inside a fruit. They are naked.
3. They are found in colder regions where snowfall occurs.
4. They develop needle-like leaves.
5. They are perennial or woody, forming trees or bushes.
6. They are not differentiated into ovary, style and stigma.
7. Since stigma is absent, they are pollinated directly by the wind.
8. The male gametophytes produce two gametes, but only one of them is functional.
9. They form cones with reproductive structures.
10. The seeds contain endosperm that stores food for the growth and development of the plant.
11. These plants have vascular tissues which help in the transportation of nutrients and water.
12. Xylem does not have vessels and the phloem has no companion cells and sieve tubes.

Classification of Gymnosperms

Gymnosperms are classified into four types as given below –

Cycadophyta

Cycads are dioecious (meaning: individual plants are either all male or female). Cycads are seed-bearing plants where the majority of the members are now extinct. They had flourished during the Jurassic and late Triassic era. Nowadays, the plants are considered as relics from the past.

These plants usually have large compound leaves, thick trunks and small leaflets which are attached to a single central stem. They range in height anywhere between a few centimetres to several meters.

Cycads are usually found in the tropics and subtropics. Some members have adapted to dry arid conditions and some also have adapted to oxygen-poor swampy environments.

Ginkgophyta

Another class of Gymnosperms, Ginkgophyta, has only one living species. All other members of this class are now extinct.

The Ginkgo trees are characterised by their large size and their fan-like leaves. Also, Ginkgo trees have a large number of applications ranging from medicine to cooking. Ginkgo leaves are ingested as a remedy for memory-related disorders like Alzheimer's.

Ginkgo trees are also very resistant to pollution, and they are resilient against diseases and insect infestations. In fact, they are so resilient that after the nuclear bombs fell on Hiroshima, six Ginkgo trees were the only living things to survive within a kilometre or two of the blast radius.

Gnetophyta

Just like any other member of gymnosperms, Gnetophytes are also relics from the past. Today, only three members of this genus exist.

Gnetophytes usually consist of tropical plants, trees, and shrubs. They are characterised by flowery leaves that have a soft coating. This coating reveals an ancestral connection with the angiosperms.

Gnetophytes differ from other members of this class as they possess vessel elements in their xylem.

Coniferophyta

These are the most commonly known species among the gymnosperm family. They are evergreen; hence they do not shed their leaves in the winter. These are mainly characterised by male and female cones which form needle-like structures.

Coniferous trees are usually found in temperate zones where the average temperature is 10 ℃. Giant sequoia, pines, cedar and redwood are examples of Conifers.

Gymnosperms Examples

Following are some of the examples of gymnosperms:

- Cycas
- Pinus
- Araucaria
- Thuja
- Cedrus
- Picea
- Abies
- Juniperus
- Larix

Gymnosperms Life Cycle

The life cycle of gymnosperms is both haploid and diploid, i.e., they reproduce through the alternation of generations. They have a sporophyte-dominant cycle.

The gametophyte phase is relatively short. The reproductive organs are usually cones.

Male Cones– These have microsporophylls that contain microsporangia. Microsporangium produces haploid microspores. A few microspores develop into male gametes called pollen grains, and the rest degenerate.

Female Cones– The megasporophylls cluster together to form female cones. They possess ovules containing megasporangium. It produces haploid megaspores and a megaspore mother cell.

The pollen reaches the egg through wind or any other pollinating agent, and the pollen grain releases a sperm. The nuclei of male and female gametophytes fuse together to form a zygote. This is known as fertilisation.

The seed appears as scales which can be seen on the cones of the gymnosperm.

Angiosperms

Angiosperms are vascular plants with stems, roots, and leaves. The seeds of the angiosperm are found in a flower. These make up the majority of all plants on earth. The seeds develop inside the plant organs and form fruit. Hence, they are also known as flowering plants.

Angiosperms are the most advanced and beneficial group of plants. They can grow in various habitats as trees, herbs, shrubs, and bushes.

Characteristics of Angiosperms

Angiosperms have diverse characteristics. The important characteristics of angiosperms are mentioned below:

1. All plants have flowers at some stage in their life. The flowers are the reproductive organs for the plant, providing them with a means of exchanging genetic information.
2. The sporophyte is differentiated into stems, roots, and leaves.
3. The vascular system has true vessels in the xylem and companion cells in the phloem.
4. The stamens (microsporophyll) and the carpels (megasporophyll) are organized into a structure called the flower.
5. Each microsporophyll has four microsporangia.
6. The ovules are enclosed in the ovary at the base of the megasporophyll.
7. Angiosperms are heterosporous, i.e., produce two kinds of spores, microspore (pollen grains) and megaspores.
8. A single functional megaspore is permanently retained within the nucellus.
9. The pollen grains transfer from the anther to stigma and reproduction takes place by pollination. They are responsible for the transfer of genetic information from one flower to the other. The pollen grains are much smaller than the gametophytes or reproductive cells present in the non-flowering plants.
10. The sporophytes are diploid.
11. The root system is very complex and consists of cortex, xylem, phloem, and epidermis.
12. The flowers undergo double and triple fusion which leads to the formation of a diploid zygote and triploid endosperm.
13. Angiosperms can survive in a variety of habitats, including marine habitats.
14. The process of fertilization is quicker in angiosperms. The seeds are also produced quickly due to the smaller female reproductive parts.
15. All angiosperms are comprised of stamens which are the reproductive structures of the flowers. They produce the pollen grains that carry the hereditary information.
16. The carpels enclose developing seeds that may turn into a fruit.
17. The production of the endosperm is one of the greatest advantages of angiosperms. The endosperm is formed after fertilization and is a source of food for the developing seed and seedling.

Classification of Angiosperms

The classification of angiosperms is explained below:

Monocotyledons

- The seeds have a single cotyledon.
- The leaves are simples and the veins are parallel.
- This group contains adventitious roots.
- Each floral whorl has three members.
- It has closed vascular bundles and large in number.
- For eg., banana, sugarcane, lilies, etc.

Dicotyledons

- The seeds of these plants have two cotyledons.
- They contain tap roots, instead of adventitious roots.
- The leaves depict a reticulate venation.
- The flowers are tetramerous or pentamerous and the vascular bundles are organized in rings.
- For eg., grapes, sunflower, tomatoes, etc.

The angiosperms originated about 250 million years ago and comprise 80% of earth's plant life. They are also a major source of food for humans and animals.

INVERTEBRATES

Invertebrates are animals without a backbone. They make up a vast majority of animal species and can be found in various habitats around the world. The majority of animal species are invertebrates; one estimate puts the figure at 97%. Many invertebrate taxa have a greater number and variety of species than the entire subphylum of Vertebrata. Here are some of the major groups of invertebrates along with their characteristics:

1. Porifera (Sponges)

- **Characteristics:**
  - Simple, porous body structure.
  - Lack true tissues and organs.
  - Filter feeders, drawing water through their pores to trap food particles.
  - Mostly marine.

2. Cnidaria (Jellyfish, Corals, Sea Anemones)

- **Characteristics:**
  - Radial symmetry.
  - Possess specialized stinging cells called cnidocytes.
  - Have two main body forms: polyp and medusa.
  - Mostly marine.
- These are mostly marine and a few like hydra live in fresh water
- Many are colonial (Eg: Corals). Some are solitary (Eg: sea anemone)
- They are diploblastic and show tissue grade of organization

3. Platyhelminthes (Flatworms, tapeworm, flukes)

- **Characteristics:**
  - Bilateral symmetry.

- Flattened body.
- Lack specialized respiratory and circulatory systems.
- Some are free-living, while others are parasitic.
- They are heamophrodite
-

4. Nematoda (Roundworms,Hookworm, Ascaris, Filaria)

- **Characteristics:**
  - Bilateral symmetry.
  - Cylindrical, elongated body.
  - Complete digestive system with a mouth and anus.
  - Many are parasitic, while others are free-living in soil or water.
  - Play an important role in nutrient cycling
  - Have metameric segmentation
  -

5. Annelida (Segmented Worms)

- **Characteristics:**
  - Bilateral symmetry.
  - Segmented body.
  - They have a well-developed circulatory and digestive system
  - Their body contains haemoglobin, which gives them a red colour
  - Includes earthworms, leeches, and marine polychaetes.

6. Mollusca (Snails, Clams, Squids)

- **Characteristics:**
  - Bilateral symmetry.
  - Soft body, often protected by a hard shell.
  - Mantle secretes the shell.
  - Includes diverse classes such as Gastropoda (snails), Bivalvia (clams), and Cephalopoda (squids, octopuses).

7. Arthropoda (Insects, Crustaceans, Arachnids)

- **Characteristics:**
  - Bilateral symmetry.
  - Exoskeleton made of chitin.
  - Segmented body with specialized appendages.
  - Includes classes such as Insecta (insects), Crustacea (crabs, lobsters), Arachnida (spiders, scorpions), and Myriapoda (centipedes, millipedes).

8. Echinodermata (Starfish, Sea Urchins)

- **Characteristics:**
  - Radial symmetry in adults, bilateral symmetry in larvae.
  - Endoskeleton made of calcareous plates.
  - They are exclusively marine animals.
  - They have an open circulatory system.
  - Water vascular system for locomotion and feeding.

- Exclusively marine.
-

General Characteristics of Invertebrates:

1. **Lack of a Backbone:**
   - Invertebrates do not possess a vertebral column or backbone. This is the primary characteristic distinguishing them from vertebrates.
2. **Body Structure:**
   - Invertebrates display a wide range of body structures and complexities, from simple, single-celled organisms to complex multicellular forms.
   - They may have an exoskeleton (external skeleton) made of chitin or calcium carbonate, as seen in arthropods and mollusks, respectively.
3. **Symmetry:**
   - They exhibit various types of body symmetry, including radial symmetry (e.g., cnidarians like jellyfish), bilateral symmetry (e.g., arthropods like insects), and asymmetry (e.g., sponges).
4. **Diversity:**
   - Invertebrates comprise over 95% of all animal species. They are found in almost every habitat on Earth, including oceans, freshwater, terrestrial environments, and even extreme environments.
5. **Reproduction:**
   - Reproductive strategies among invertebrates are highly diverse. They can reproduce sexually, with separate male and female individuals, or asexually, through processes like budding, fission, or parthenogenesis.
6. **Nervous System:**
   - The complexity of the nervous system varies widely. Some invertebrates, like cnidarians, have a simple nerve net, while others, like cephalopods, have a highly developed nervous system and exhibit complex behaviors.
7. **Respiratory Systems:**
   - Respiratory mechanisms vary, including diffusion through the body surface (e.g., flatworms), gills (e.g., aquatic mollusks), tracheal systems (e.g., insects), and book lungs (e.g., spiders).
8. **Circulatory Systems:**
   - Many invertebrates have an open circulatory system, where blood flows freely within body cavities. Others, like annelids, have a closed circulatory system with vessels.
9. **Feeding and Digestion:**
   - Invertebrates exhibit various feeding mechanisms and digestive systems. They can be filter feeders (e.g., sponges), predators (e.g., spiders), scavengers (e.g., crustaceans), or parasites (e.g., tapeworms).
   - Digestive systems can be simple or complex, with specialized organs for digestion and nutrient absorption.
10. **Locomotion:**

- Modes of locomotion are diverse, including ciliary movement (e.g., ctenophores), muscular contraction (e.g., annelids), and jointed appendages (e.g., arthropods).

11. **Habitat:**
    - Invertebrates inhabit a wide range of environments, from deep ocean trenches to high mountain ranges. They are adapted to various ecological niches and play crucial roles in ecosystems as pollinators, decomposers, and part of the food web.

Chordates

Animals that belong to the phylum Chordata are also called **chordates** or **chordate animals** and derives their name from **notochord** (an elongate, flexible, rod-like, skeletal structure dorsal to the gut tube and ventral to the nerve cord) which is one of their characteristic features indicating their common ancestry. **Chordates** are animals possessing a **notochord**, a **hollow dorsal nerve cord**, **pharyngeal slits**, an **endostyle**, and **a post-anal tail** for at least some period of their life history.

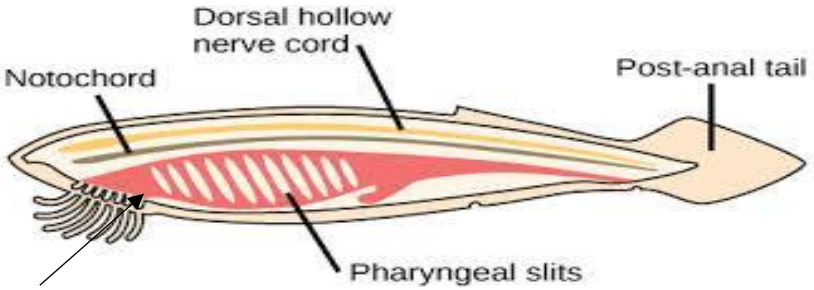
In those chordates which lack bone, muscles work against the notochord to move the animal. All chordates have a notochord at some stage in their lives, but in some (such as tunicates), the notochord is lost in the adult, whereas in others (such as the vertebrates) the notochord is present in the embryo, but in later stages is largely replaced and surrounded by the vertebrae, or backbones.

Five distinguish characteristics of chordates

- Notochord
- Hollow dorsal nerve cord
- Pharyngeal slits also called visceral clefts or arches
- Post-anal tail
- **Endostyle:** It is a longitudinal ciliated groove on the ventral wall of the pharynx which produces mucus to gather food particles and help in transporting food to the oesophagus found in urochordata and cephalochordate as well as larvae of lampreys.

General characteristics of chordates

- They have ventral heart
- They are Deuterostomes [i.e the first opening of the blastopore during the embryonic development becomes the anus]
- Central nervous system is hollow, dorsal and tubular
- Sexes are separate
- Have closed circulatory system
- They have endoskeleton



Classification of the phylum chordata:

The Phylum Chordata is divided into four [4] Sub-Phyla:

i. Hemichordata
ii. Urochordate [Tunicates] also called Tunicata
iii. Cephalochordata [Lancelets] also called Acraniata
iv. Vertebrata also called Craniata

The first three [3] sub-phyla [Hemichordata, Urochordata and Cephalochordata] are collectively known as **protochordate** and are entirely marine. They are invertebrates but share some attributes of chordates

Sub-Phylum Hemichordata

These are mostly marine worm-like organism unfamiliar to most people. The name is derived from having characteristics of chordates while lacking others. They play important role in the study of the evolution of the origin of vertebrates. They are the sister group to the true chordates and the echinoderms

Anatomically their body is divided into three (3) parts:

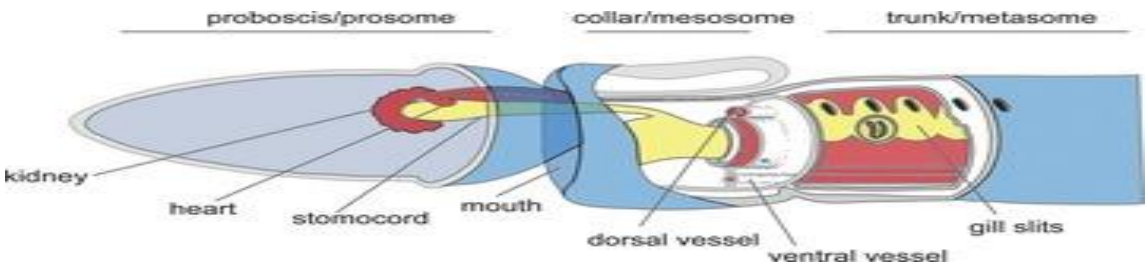
- Prosome[anterior] or proboscis
- Mesosome[intermediate] or collar
- Metasome [posterior] or trunk

General Characteristics of Hemichordata:

- They are worm-like marine animals e.g Acorn worm
- The body is divided into three [3]: Anterior prosome, Intermediate mesosome, and Posterior metasome
- They have stomochord i.e a more primitive type of notochord
- They are Deuterostomes
- The mouth is located between the proboscis and the collar [mesosome]
- They have perforated pharynx
- Reproduction is sexual

Hemichordata is classified into three classes

i. Class Enteropneusta e.g Acorn worm
ii. Class Ptebranchia
iii. Class Graptolithina [Graptolites]

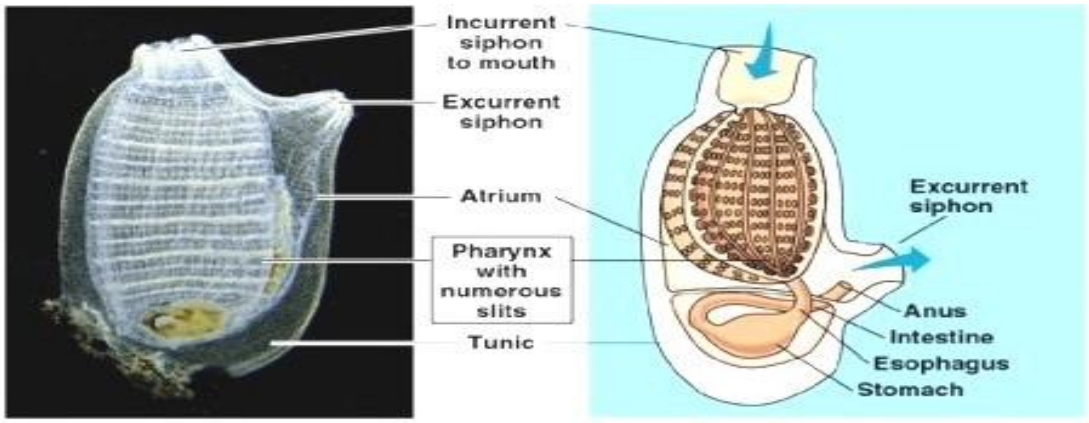


Sub-Phylum Urochordata [Tunicates]

The name is from Greek word, meaning tail and Latin word "chorda" = cord, because the organism possess notochord only in the tail. These are group of marine, filter feeding, sessile or pelagic animals, some are solitary some are colonial with well-developed pharynx. They are known as sea squirts or tunicates which possess notochord during the larval stage and loss it upon becoming adults.

General Characteristics of the Sub-Phylum Urochordata

- They have notochord, hallow nerve cord and posterior and tail
- They have triploblastic level of organism
- The adults have no tail and the body is unsegmented
- They are mostly marine
- The body is covered by a test [funic structure] formed by tunicate [animal cellulose] and hence the name tunicate
- They have U-shaped gut
- They are filters feeders
- Have open type of circulatory system
- Have ventral heart
- Reproduce both sexually and asexually
- Asexual reproduction by budding
- They are hermaphrodites but cross fertilization is favored
- Fertilization is external



Urochordata is divided into three [3] main classes, two [2] Sub-Classes and Six [6] Orders:

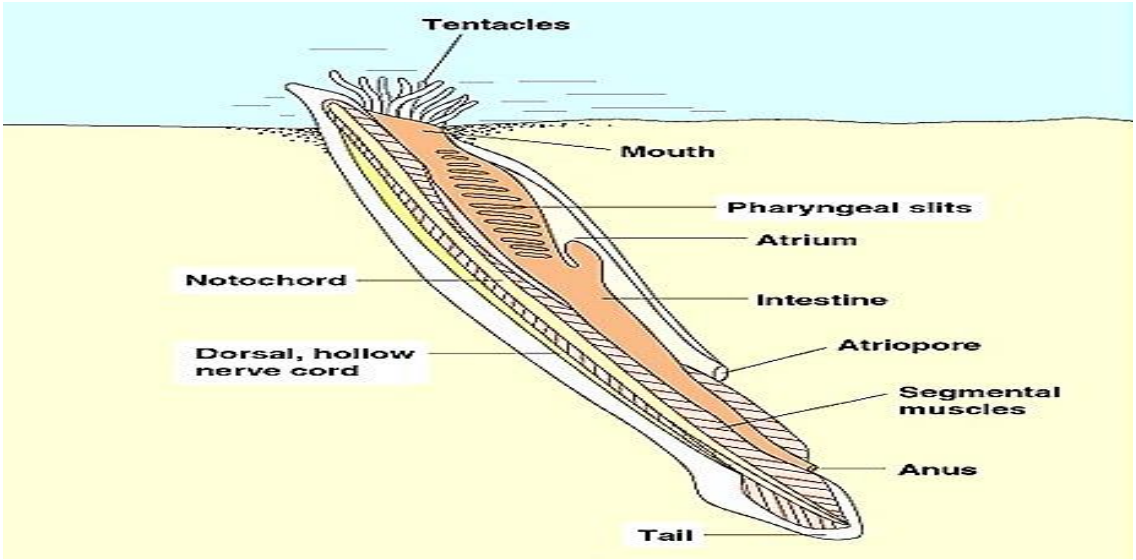
- Class Ascioliaceas e.g sea squirts
- Class Thaliacea e.g salps
- Class Appendicularia e.g larvacea and they resemble tadpole

SUB-PHYLUM CEPHALOCHORDATA [ACRANIATA]

The name is derived from two Greek word 'kephale' meaning head aid 'khorde' =chord i.e the notochord extends far forward into the head they are also called lancelets or Amphioxus because they have both ends pointed. They have notochord that persists throughout life the famous representative of their group is Branchiostoma lanceolatum

General Characteristics of Cephalochordata

- They are fish-like marine animal
- The body is segmented, elongated and pointed at both ends with distinct eyes, nose, head and ears
- They have hollow dorsal nerve cord, pharyngeal slits, notochord and post anal tail
- They have persistent notochord throughout life
- They are suspension feeders
- They lack brain case or cranium
- They have simple nervous system consisting of main and style hallow nerve chord which slightly swells at the frontal region and serve as brain
- They have unique excretory structure called **SOLENOCYTES**
- They have simple and closed circulatory system but lack heart, blood corpuscles pigment
- Reproduction is sexual
- Have separate sexes and fertilization is external



The Sub-Phylum Cephalochordata has Three Genera:

- Asymmetron
- Epigonicyths
- Branchiostoma

SUB-PHYLUM VERTEBRATE [CRANIATA]

The name vertebrate is derived from the presence of a vertebral column which is a derivation of the notochord. The notochord may persist throughout life as in certain fishes [lamprey] or may be replaced either partially or wholly in the adult animal by a cartilaginous or body vertebrate column [backbone].

Vertebrates are the most organized and advanced group of animals on the earth the prominent characteristics that make them special are the presence of spinal cord, vertebral column, and notochord These advanced and specialized organisms that have well developed nervous system, muscles and skeletons which help them move around efficiently and perform complex moves they also have a protective covering that covers and protect the brain called cranium [skull]

GENERAL CHARACTERISTICS OF THE SUB-PHYLUM VERTEBRATE:

- **Triploblastic level of organization**
- They are multicellular organisms derived from embryos having 3 tissue [germ] layer **Ectoderm, Mesoderm and Endoderm** living the gut
- The body cavity [coelom] has separate opening for mouth and anus
- The body is bilaterally symmetrical
- The body is divided into three [3] regions: Head with an internal skeletal cranium, Trunk and post anal tail
- The head bears the mouth and organs of special senses [olfactory organs, paired eyes, paired ears]
- They have well developed and complex brain enclosed inside a bony box known as Cranium [skull]
- The brain is associated with organs of special senses if formed
- Sense organs are concentrated on the head a phenomenon known as Cephalization
- The notochord terminates at the cranium
- The notochord is supported and in advanced forms and replaced by cartilaginous or bony element which constitute the vertebral column
- They have well developed nervous system which is divided into central and peripheral nervous system
- Have closed circulatory system with well-developed ventral heart divided into chambers [2-4]
- Sexes are separate with unsegmented gonads [testicles or ovary] and reproduction is sexually
- Fertilization may be internal [in higher forms] or external [as in lower forms]
- All vertebrates have two pairs of appendages

CLASSIFICATION OF THE SUB-PHYLUM VERTEBRATE

The sub-phylum vertebrata is divided into two [2] super classes [refer to the schematic classification earlier given]

SUPER CLASS AGNATHA [JAWLESS]

General Characteristics:

- They have a head with cranium, a brain and paired organ of sight [although incomplete compared to the standard of the vertebrates]
- Vertebrae [vertebral column] is in the form of cartilaginous element
- They lack jaws, true teeth, typical appendages
- The mouth is round
- They lack scales or exoskeleton
- Notochord is presence in both larvae and adult
- Absence of paired fin but possesses dorsal and caudal fins
- Possesses two chambered hearts
- They are mostly hermaphrodites
- Fertilization and developed are both external with no parental care

The superclass Agnatha is divided into two (2) classes:

1. **Class Ostracodermi** (extinct)
   - These were small fish-like animals that lived in the fresh water of several continents.
   - They evolved nearly 500 million years ago.

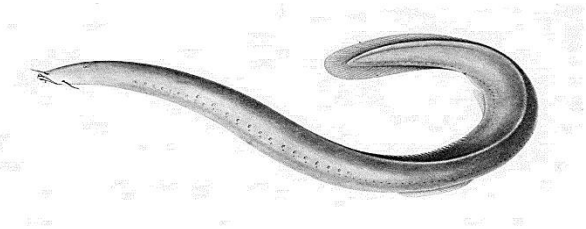
The class was divided into three (3) orders:

i. **Order Cephalaspidomorpha** e.g *Cephalaspis*
ii. **Order Anaspida** e.g *Birkenia*
iii. **Order Pteraspidomorpha** e.g *Pteraspis*

2. **Class Cyclostomata**
   - They are eel-like creatures, slippery and naked skin.
   - They are predatory or parasitic on fishes.
   - They lack jaws.
   - Notochord persist in adults.
   - They lack paired fins.
   - Possess median fins with cartilaginous fin rays.
   - Lack exoskeleton but possess cartilaginous endoskeleton.
   - Most have separate sexes except some species of hagfishes that are believed to be hermaphrodites.

The class is divided into two orders:

i. **Order Petromizontia** (Lampreys) e.g *Petromyzon marinus*
ii. **Order Myxinoidea** (Hagfishes) e.g *Maxine glutinosa*



SUPER CLASS GNATHOSTOMATA [JAW BEARING VERTEBRATES]

The term Gnathostomata is derived from two Greek words "gnathos" meaning jaw "stoma" meaning mouth. It is believed that the jaws evolved from anterior gill support arches that had acquired a new role, being modified to pump water over the gills by opening and closing the mouth more effectively (the buccal pump mechanism). The mouth could then grow bigger and wider, making it possible to capture larger prey. This close and open mechanism would, with time, become stronger and tougher, being transformed into real jaws. It is now assumed that Gnathostomata evolved from ancestors that already possessed a pair of both pectoral and pelvic fins. In addition to this, some placoderms were also shown to have a third pair of paired appendages, that in males had been modified to claspers and basal plates in females, a pattern not seen in any other vertebrate group.

In addition to opposing jaws, living gnathostomes are characterized by:

- Having teeth
- Paired appendages like paired pelvic fins.
- Horizontal semicircular canal of the inner ear.
- Interventrals and basiventrals in the backbone (These are the elements of the backbone which lie under the notochord, and match the basidorsals and interdorsals respectively).
- Gill arches which lie internally to the gills and branchial blood vessels contrary to the gill arches of all jawless craniates which are external to the gills and blood vessels.
- Paired nasal sacs which are independent from the hypophysial tube.
- There are numerous other characteristics of the soft anatomy and physiology e.g. myelinated nerve fibres, sperms passing through urinary ducts, etc., which are unique to the gnathostomes among living craniates, but cannot by observed in fossils.

Note: It is important to take notes that, in some text books, some taxonomists regard Gnathostomata as infraphylum rather than super class as regarded by other taxonomists and in this handout.

Advancements in the Evolution of Gnathostomes:

- The most important advancement common to this group was the enlargement and adaptation of the first gill arch to function as jaws, instead of gill support.
- The evolution of jaws permitted fishes and their descendants to utilize larger and harder food, and thus enabled them to become adapted to many new and diverse ways of living.
- Another advancement common to all jaw-bearing fishes is the presence of paired appendages (fins) which permitted them to expand from sedentary suspension feeding of jawless fishes and become mobile predators.

Gnathostomes are divided into two major groups, based on the diversity of habits, forms and structures:

1. Pisces (fishes).
2. Tetrapoda (tetrapods)

THE PISCES OR FISHES

The term "fish" most precisely describes any non-tetrapod craniate that has gills throughout life and whose limbs, if any, are in the shape of fins. These include hagfishes, lampreys, armoured fishes (placoderms), cartilaginous and bony fishes, sharks and rays, ray-finned fish, coelacanths and lungfish. However, a typical fish (true fish) is ectothermic (cold blooded), has a streamlined body for rapid swimming, extracts oxygen

from water using gills or uses an accessory breathing organ to breathe atmospheric oxygen, the eyes have a well-formed nictitating membrane, has two sets of paired fins, usually one or two (rarely three) dorsal fins, an anal fin, and a tail fin, has jaws, has skin that is usually covered with scales, External fertilization, Soft shelled eggs that must be laid in water. This strict biological definition of a fish is sometimes called a true fish. True fish are also referred to as fin fish to distinguish them from other aquatic animals harvested in fisheries or aquaculture.

Fish classification

There are three (3) major classes of fish:

i Class Placodermi*[Extinct]
ii Class Chondrichthyes (cartilaginous fishes)
iii Class Osteichthyes (bony fishes)

Class Placodermi* (Extinct armoured fishes)

- They are the earliest known gnathostomes.
- They were armoured fishes.
- They were rather strange fishes mostly heavy armoured, hence, the name with sharp spines in addition to the armour.
- They were mostly bottom-dwelling and dorso-ventrally flattened.
- They pioneered gas bladder that were ultimately to become lungs.
- Features of their gill structure, scales, digestive and sense organs were transitional between those of ostracoderms and higher fishes.
- They were diverse in structure.

The class has two (2) orders with worldwide distribution and abundant fossil records:

i. Order Antiarchi
ii. Order Arthrodira

The Class Chondrichthyes (cartilaginous fishes):

These are the only vertebrates that have gills on both side of the body in a common chamber covered by a movable opercula.

The general characteristics of chondrichthyes are as follows:

i. The skeleton is made up of cartilage rather than bone.
ii. They are jawed fishes that possess paired fins and paired nares.
iii. Their teeth, unlike other fishes, are anchored to the intergument and occur only at the margins of the jaws.
iv. Possesses hyomandibular which plays role in supporting the jaws.
v. They have placoid scales (tooth like scales called dermal dentricules).
vi. They are predacious (carnivorous) and hunting by smell while some are suspension feeders.
vii. The pectoral fin is anterior to pelvic fin and the latter usually bears claspers.
viii. Fertilization is internal.
ix. The tail is heterocercal.
x. Possesses a heart with its chambers in series.
xi. Have high concentration of urea in the blood.
xii. Have no operculum over the gills.

xiii. The first pair of gill slits modified into the spiracles.
xiv. No lungs or swim bladder.
xv. Most species are marine, few lives in fresh water habitat.

The class Chondrichthyes is divided into two subclasses:

1. **Subclass Elasmobranchii** (sharks, rays and skates):
    i. Order Pleuracanthodii (extinct):
    ii. Order Cladoselachii:
    iii. **Order selachii** (sharks and rays): Selachii The major order of the cartilaginous fishes containing the sharks, rays, skates, and similar but extinct forms.
2. Subclass Holocephali (complete heads): Chimaeriformes (chimaeras) sometimes called ghost sharks are the only surviving members of the subclass and are sometimes separated into their own separate class by taxonomists e.g Rat fishes, Rabbit fishes and Elephant fishes.

Class Osteichthyes (Bony Fishes):

Members of the clade Osteichthyes are also called bony fishes due to possession of bony skeleton. The vast majority of present-day fish belong to this group, which consists of approximately 30,000 species, making it the largest class of vertebrates in existence today. Osteichthyes is also the largest class of organisms that live in the ocean which account for 96% all the fish in the sea.

General characteristics of bony Fishes

The following are some of the characteristics bony fishes (Osteichthyes). There are exceptions of course, but the generally characteristics include:

i. Nearly all bony fish have an ossified skeleton with specialized bone cells (osteocytes) that produce and maintain a calcium phosphate matrix but few groups of Osteichthyes, such as sturgeons and paddlefish, have primarily cartilaginous skeletons, but retain some bony elements.
ii. The pectoral girdle is joined to the skull by a chain of bones.
iii. Bony fishes are the only vertebrates that have gill on each side of the body in a common chamber covered by movable bony opercula.
iv. The skin of bony fish is often covered by overlapping scales (which may be cycloid or ctenoid) and the Skin glands secrete mucus that reduces drag when swimming and aids the fish in osmoregulation.
v. Like sharks, bony fish have a lateral line system that detects vibrations in water.
vi. Osteichthyes also have a keen sense of smell, but unlike other keen smelling fish, they also have very good eyesight.
vii. Osteichthyes have a wide range of foods they eat, some are herbivores and some carnivores, and some can go long periods without any kind of food. The freshwater eel can go up to a year.
viii. A lung is usually present e.g the African and Australian lung fishes.
ix. Many bony fish also have a swim bladder, a gas-filled organ that helps to control the buoyancy of the fish.
x. The body is streamlined.
xi. Mouth is terminal.

xii. Tail may be homocercal, heterocercal or diphycercal.
xiii. Sexes are separate and fertilization is external.

Bony fishes are further divided into two extant subclasses:

1. **Subclass Actinopterygii** (ray-finned fish): These are ray-finned fish including many familiar fish, such as Tuna, Bass, Trout, and Salmon, among others. Ray-finned fish are named for their fins that are webs of skin supported by bony spines called rays.
2. **Subclass Sarcopterygii** (lobe-finned fish): These includes African lung Fish (*Protopterus annectens*), Australian Lung Fish (Dipnoi *spp*) and fringe-finned fish (**Crossopterygii)** e.g *Latimeria spp*

However, there is another extinct group fishes which is believed to the ancestors of bony fishes called

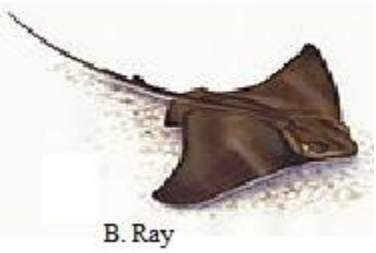
3. **Subclass Acanthodii**:

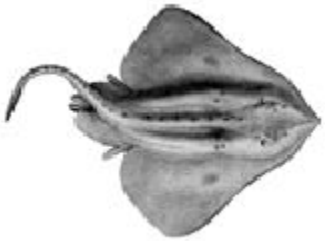
i. **Order Climatiiformes:** Had shoulder armor and many small sharp spines.
ii. **Order Ischnacanthiformes:** Had their teeth fused to the jaw.
iii. **Order Acanthodiformes:** They were filter feeders, with no teeth in the jaw, but long gill rakers

Differences between Cartilaginous fishes and Bony fishes

S/N	Cartilaginous fishes	Bony fishes
1	Cartilaginous endoskeleton.	Bony skeleton.
2	Gills are exposed to the outside.	Gills are covered by operculum.
3	Mouth is on the ventral side of the head.	Mouth is at terminal end of the head.
4	Lack swim bladder.	Swim bladder present.
5	Possesses placoid scales.	Possesses cycloid and ctenoid scales.
6	Fertilization is internal e.g Sharks, Rays and Skates	Fertilization is external e.g Salmon, Trout etc


A. Shark


B. Ray


C. Skate


D. Chimarae (Ratfish)

E. Actinopterygii Fish

F. Sercopterygii Fish

G. Holostei

H. Holostei

I. Dipnoi

A. Hammerhead Shark (*Shpyrna lewini*). **B**. Stingray (*Dasyatis pastinaca*). **C**. Arctic Skate fish (*Amblyraja hyperborean*). **D**. Spotted Ratfish (*Hydrolagus colliei*). **E**. Sockaye Salmon (*Oncorhynchus nerka*). **F**. Coelacanth (*Latimeria chalumnae*).**G**. Bowfin (*Amia calva*). **H**. Spotted gar (*Lepisosteus oculatus*). **I**. African lungfish (*Protopterus annectens*).

TETRAPODA

- Tetrapods are organisms with two pairs of pair appendages (tetrapod) ending in five digits (pentadactyl).
- Ears are specialized for sound reception.
- Where fins are present, lack rays.
- Have developed salivary glands.
- Have well developed nervous system.
- The nervous tissue in the forebrain forms the cerebral cortex.

Class Amphibia

The name Amphibia is from Greek: ***Amphi*** meaning **dual** and ***bio*** meaning **life**. Therefore, Amphibians can live in both aquatic and terrestrial habitats.

General Characteristics:

- They are poikilothermic (cold blooded).
- They have two pairs of pentadactyl limbs.
- The body is divided in head, trunk and tail in some animals.
- They have moist skin with no scales.
- The eyes have eyelids.
- They lack external ears and the ears are represented by a **tympanum.**
- They have internal nares.
- They have a cloaca which opens to the exterior. i.e a common chamber for the alimentary canal, urinary and reproductive tract.

- Respiration is through gills, lungs, skin and buccal cavity.
- They have well developed circulatory system with three chambered-heart with two auricles and one ventricle.
- Have well developed excretory system with urinary bladder and nitrogenous waste is in the form of urea.
- The upper jaw is fused to the skull
- Sexes are separate and fertilization is external.
- They may **viviparous** or ovoviparous.

All the living Amphibians belong to **Sub-class Lissamphibia** which contains three orders:

i. **Order Anura or Salientia** (frogs and Toads)
ii. **Order Urodela or Caudata** (Newts, Salamanders, Mudpuppies etc).
iii. **Order Apoda or Gymnopiona** (Caecilians)

Class Reptilia

The word Reptilia is from latin: **Repere** or **Reptum** meaning **Creep** or **Crawl**. Hence the class name refers to a type of locomotion which is creeping or crawling. Animals belonging to this group are regarded as the first successful colonizers of terrestrial habitat.

General Characteristics

- They are mostly terrestrial and the body is covered by dry and cornified skin, epidermal scales or **scutes** (shield)
- They are poikilothermic animals
- They have well developed sense organs
- Lack external ear opening but instead have **tympanum** which represent the ear.
- Limbs if present, are of two pairs ending in five digits with claws
- Have well developed respiratory system and respiration is exclusively by lung.
- Have well developed circulatory system with 3 or 4-chambered hearts.
- They excrete uric acid as main nitrogenous waste
- Some members like snakes and lizard do shed their skin.
- Sexes are separate and fertilization is internal.
- They are oviparous and development is direct.

The class Reptilia has three sub-classes:

Sub-Class Anapsida
Order Testidunata e.g Turtles and Totoises
Sub-Class Archosauria
Order Crocodilia e,g Crocodiles
Sub-Class Diapsida
Super order Lapidosauria
Order Squamata (Snakes, Lizards and scaly reptiles)
Sub-order Lasertilia e.g Lizards
Sub-order Amphisbaenia (worm Lizard) e.g *Amphisbaena sp.*

Sub-order Ophidia (Serpents) e.g Snakes

Order Rhyncocephalia

Sub-order Sphenodontia e.g Tuatara: Sphenodon puntatus

Note that: more than 95% of the approximately 600 living species of reptiles belong to the order squamata

Class Aves (Birds)

This class comprises of group of endothermic vertebrates called birds characterized by feathers, a beak with no teeth, laying of hard-shelled eggs, a high metabolic rate, a four chambered and a lightweight but strong skeleton.

General Characteristics

- They are worm blooded (endothermic) animals.
- They have lightweight but strong skeleton.
- The endoskeleton is bony and the bones are hollow with air cavities known as **pneumatic bones.**
- Presence of feathers is the unique feature of birds and most members can fly except the flightless birds.
- They combined flight with bipedalism (two footed locomotion).
- The forelimbs are modified into wings for flying while the hind limbs are modified for walking, swimming, clasping and generally have scales.
- The jaws are modified into beaks
- The skin is dry and does not have glands except an oil gland at the base of tail.
- Have no external ear
- Have well-developed nervous system.
- Well-developed circulatory system with four chambered heart.
- Well-developed respiratory system with lungs as an organ of respiration.
- Sexes are separate and fertilization is internal.
- They are oviparous and development is direct.

The class Ave is classified into two sub-classes:

1. **Sub-Class Archaeonithes** (Ancient birds): They extinct Mesozoic birds with only fossil records as representation.
2. **Sub-Class Neonithes** (Recent birds): This group comprises of all living birds and few extinct ones. They have three (3) super orders:

a) **Super-Order Odontognathae** (extinct): comprising flightless aquatic birds e.g *Hesperornia regalis*

b) **Super-Order Paleognathae** (Tinamous and Flightless Ratite) e.g Ostrich, Emu and Kiwi with many orders which include:

   i. Order Tinamiformes e.g Tinamous
   ii. Order Struthioniformes e.g Ostriches
   iii. Order Causariformes e.g Emu
   iv. Order Apterygiformes e.g Kiwi

c) **Super-Order Neognathae** (comprising all other surviving birds) e.g Chickens, Grauses, Doves, Pigeons, Turkeys, Ducks etc comprising of about 10,000 different species in nine (9) orders with the order

Passeriformes (perching birds) having the largest number of species which account for 60% of all the living birds.

i. **Order Galliformes** e.g Chicken Grouse, Turkey etc
ii. **Order Anseriformes** e.g Ducks, Geese, Swans etc
iii. Order Columbiformes e.g Pigeons and Doves
iv. Order Passeriformes (perching birds) e.g Songbirds
v. Order Strigiformes e.g Owls
vi. Order Accipitriformes e.g Hawks, Eagles, Old word Vultures etc
vii. Order Psittaciformes e.g Parrots

Class Mammalia (Mammals)

The word mammal is from Latin **Mamma** meaning **Teat or Pap.** Therefore, name mammal is due to the possession of mammary glands for nursing the younger ones.

General Characteristics

- All female mammals nurse their young with milk, which is secreted from special glands called the mammary glands.
- Except for the five species of monotremes (which lay eggs), all living mammals are viviparous i.e give birth to live young.
- They have sweat and sebaceous glands.
- Nearly all mammals are endothermic ("warm-blooded").
- The skin of most mammals is covered with hair (fur) which helps keep them warm.
- The majority of mammals have seven cervical vertebrae (bones in the neck), including bats, giraffes, whales, and humans. The exceptions are the manatee and the two-toed sloth, which have only six cervical vertebrae, and the three-toed sloth with nine cervical vertebrae.
- Their heart is four chambered, and have closed circulatory system.
- Respiration is by lungs.
- A complete diaphragm separates the lungs and heart from the abdominal cavity.
- The larynx has vocal cords.
- Mammals are **heterodonts** i.e have a variety of specialized teeth (incisors, canines, premolars, and molars) and strong jaws.
- They also have **diphyodont dentition** i.e having two sets of teeth in a life time.
- The male has copulatory organ.
- The brain is large which coordinates and regulates body temperature, the circulatory system including the four-chambered heart and most of the activities of the entire body.
- All mammalian brains possess a neocortex, a brain region unique to mammals.
- Have external ear lobes (pinna).
- Sexes are separate and fertilization is external.
- In most species, the embryos are nourished through a special connection to the female parent called placenta.

The class Mammalia is divided into two subclasses:

1. **Sub-Class Prototheria (**from Greek "protos" means first, and "ther" means wild animal).
2. **Sub-Class Theria** (from Greek "ther" meaning wild animal).

Sub-Class Prototheria: Majority of the members of this subclass are now extinct and the only surviving (extant) members belong to the order **Monotremata.** Members of the subclass Prototheria lay eggs like most non-mammalian vertebrates. However, they feed their newborn with mammary gland secretions like all other mammals. They lack nipples, but the skin over their mammary glands exudes milk for their babies. The Prototheria are also referred to as monotremes which literally mean that they have one opening for both excretion and reproduction. This is similar to birds and reptiles. There are only three surviving rare species groups of Prototheria. These are the Australian platypus and 2 echidna (spiny anteater) species of Australia and New Guinea i.e Duck-billed platypus (*Ornithorhynchus anatinus*), the short-nosed echidna (*Tachyglossus aculeatus*) and the New Guinean echidna a (*Zaglossus bruijni*).

The subclass prototheria has only one extant order and two suborders:

Order Monotremata:

- **Suborder Platypoda** e.g platypuses
  Family Ornithorhynchidae: e.g Duck-billed platypus (*Ornithorhynchus anatinus*)
- **Suborder Tachyglossa** e.g echidnas (spiny anteaters)
  Family Tachyglossidae: echidnas (*Tachyglossus aculeatus*)

Sub-Class Theria: All other living mammalian species, including humans, are in this subclass, generally characterized by giving birth to live young (viviparity). Therian mammals apparently did not evolve from the Prototheria.

The subclass Theria has two infraclasses:

i. Infraclass Metatheria (the marsupials).
ii. Infraclass Eutheria (the placental mammals)

Infraclass Metatheria (the marsupials)**:** These are the kangaroos, koalas, opossums, and many other similar animals. Marsupials have their young born very immature and cannot live without further development in the mother's pouch. The word marsupial comes from Latin word "marsupium" meaning Purse. Marsupials are native only to Australia and New Guinea.

Infraclass Eutheria (the placental mammals)**:** Most mammal species, including humans, are in the infraclass Eutheria. They are also referred to as placental mammals. Eutherian mothers carry their unborn children within the uterus where they are nourished and protected until an advanced stage is reached. This is made possible by the umbilical cord and placenta which connects the fetus to the uterus wall and enables nutrients and oxygen to get to the fetus as well as providing a means of eliminating its waste.

Giant pandas are an exception among the placental mammals. Their babies are born at only 1/4 the size predicted for the general placental mammal pattern.

Marsupial babies are born at an even more immature stage because their rudimentary placentas are comparatively inefficient in nurturing fetuses.

Placental mammals have been extremely successful in out-competing monotremes and marsupials for ecological niches. This is mostly due to the fact that their babies are born more mature, which increases their chances of survival.

Briefs on Physiology: Nutrition, Respiration, Circulatory Systems, Excretion, Reproduction, Growth and Development

Nutrition and Types of Nutrition

Nutrition is the process by which organisms obtain and utilize food to support their life functions. It involves the intake of nutrients, which are substances necessary for energy production, growth, repair, and maintenance of bodily functions.

Types of Nutrition:

1. **Autotrophic Nutrition:**
    - **Definition:** Organisms produce their own food using simple inorganic substances.
    - **Examples:**
        - **Photosynthesis:** Green plants, algae, and some bacteria use sunlight, carbon dioxide, and water to produce glucose and oxygen.
        - **Chemosynthesis:** Some bacteria use chemical energy from inorganic compounds to produce food in the absence of sunlight.
2. **Heterotrophic Nutrition:**
    - **Definition:** Organisms obtain food by consuming other organisms or organic matter.
    - **Types:**
        - **Herbivores:** Animals that eat plants (e.g., cows, rabbits).
        - **Carnivores:** Animals that eat other animals (e.g., lions, hawks).
        - **Omnivores:** Animals that eat both plants and animals (e.g., humans, bears).
        - **Detritivores:** Organisms that feed on dead organic matter (e.g., earthworms, vultures).
        - **Parasites:** Organisms that derive nutrients from a host, often harming it (e.g., tapeworms, fleas).
        - **Saprophytes:** Organisms that feed on decaying organic matter, often fungi and bacteria (e.g., mushrooms).

Respiration is the process by which organisms convert organic compounds into energy, usually in the form of ATP (adenosine triphosphate), which is used for cellular activities.

Types of Respiration:

1. **Direct Respiration:**
    - **Definition:** Oxygen and carbon dioxide exchange directly through the organism's body surface.
    - **Examples:** Simple organisms like flatworms and some aquatic invertebrates.
2. **Indirect Respiration:**
    - **Definition:** Oxygen and carbon dioxide exchange occurs through specialized respiratory structures like gills, tracheae, or lungs.
    - **Examples:** Insects (tracheal system), fish (gills), mammals (lungs).
3. **Aerobic Respiration:**
    - **Definition:** Respiration that requires oxygen to produce energy (ATP) from organic molecules.

- **Examples:** Most animals and plants perform aerobic respiration.

4. **Anaerobic Respiration:**
    - **Definition:** Respiration that occurs without oxygen, producing less energy than aerobic respiration.
    - **Examples:** Some bacteria, fungi, and certain animal tissues can perform anaerobic respiration in low oxygen environments.

Excretion is the process by which organisms remove metabolic wastes and excess substances from their bodies to maintain internal homeostasis. It involves the elimination of waste products that result from cellular metabolism and other physiological processes.

Processes of Excretion:

1. **Kidneys (Vertebrates):**
    - **Function:** Filter blood to remove metabolic wastes, excess ions, and water.
    - **Products:** Urine containing urea, creatinine, salts, and water.
    - **Regulation:** Hormonal control (e.g., antidiuretic hormone, aldosterone) maintains water and electrolyte balance.
2. **Malpighian Tubules (Insects and Arachnids):**
    - **Function:** Remove nitrogenous wastes (uric acid) and regulate ion balance in hemolymph (insect blood).
    - **Products:** Uric acid crystals excreted as semi-solid waste.
3. **Nephridia (Annelids and Some Invertebrates):**
    - **Function:** Filter coelomic fluid to remove metabolic wastes, excess water, and ions.
    - **Products:** Diluted urine or nitrogenous wastes excreted directly through body wall or specialized openings.
4. **Protonephridia (Flatworms):**
    - **Function:** Remove nitrogenous wastes (ammonia) and excess water.
    - **Products:** Excreted as dilute fluid through flame cells.

Importance of Excretion:

- **Maintains Homeostasis:** Eliminates toxic substances and maintains proper balance of water, ions, and pH in the body.
- **Regulation of Osmotic Pressure:** Helps regulate osmotic pressure to prevent dehydration or overhydration.
- **Removal of Nitrogenous Wastes:** Prevents accumulation of ammonia, urea, or uric acid, which can be harmful to tissues.

Reproduction is the biological process by which organisms produce offspring, ensuring the continuity of their species. It involves the transmission of genetic material from parent to offspring, contributing to genetic diversity and adaptation.

Types of Reproduction:

1. **Asexual Reproduction:**
    - **Definition:** Involves the production of offspring from a single parent without the fusion of gametes (sex cells).

- **Types:**
  - **Binary Fission:** Parent organism divides into two genetically identical daughter cells (e.g., bacteria).
  - **Budding:** New individuals develop as outgrowths from the parent organism (e.g., hydra).
  - **Fragmentation:** Parent organism breaks into fragments, each capable of growing into a new organism (e.g., starfish).
  - **Parthenogenesis:** Development of offspring from unfertilized eggs (e.g., some insects, reptiles).

2. **Sexual Reproduction:**
   - **Definition:** Involves the fusion of specialized sex cells (gametes) from two parents, leading to genetic variation in offspring.
   - **Process:**
     - **Gametogenesis:** Formation of haploid gametes (sperm and egg) through meiosis.
     - **Fertilization:** Fusion of sperm and egg to form a diploid zygote.
     - **Development:** Zygote undergoes mitotic cell divisions and differentiation to form a new organism.
   - **Advantages:** Increases genetic diversity, allowing populations to adapt to changing environments.

Reproductive Strategies:

- **R-Selected Species:** Produce large numbers of offspring with minimal parental care, suited for unstable or unpredictable environments (e.g., insects, small fish).
- **K-Selected Species:** Produce fewer offspring with extensive parental care, suited for stable environments with limited resources (e.g., mammals, birds).

Adaptations across Species:

- **External Fertilization:** Eggs and sperm are released into the environment, often in aquatic organisms (e.g., fish, amphibians).
- **Internal Fertilization:** Sperm is deposited directly into the female reproductive tract, common in terrestrial organisms (e.g., mammals, reptiles).

Growth and **development** are fundamental biological processes that occur throughout an organism's life cycle, encompassing physical changes, maturation, and functional adaptations.

Growth:

- **Definition:** Growth refers to an increase in size or mass of an organism, typically involving cell division and enlargement.
- **Process:**
  - **Cell Division:** Cells multiply through mitosis, increasing the number of cells.
  - **Cell Enlargement:** Cells expand in size, contributing to overall growth.
  - **Accumulation of Materials:** Organisms accumulate organic materials such as proteins, carbohydrates, and minerals.
- **Factors Influencing Growth:**
  - **Nutrition:** Adequate nutrients support growth and development.

- **Hormonal Regulation:** Growth hormones (e.g., human growth hormone) regulate growth processes.
- **Genetic Factors:** Genetic instructions determine growth potential and patterns.

Development:

- **Definition:** Development refers to changes in form, structure, and function during an organism's life cycle, encompassing differentiation and maturation.
- **Stages of Development:**
  - **Embryonic Development:** Formation of an organism from a fertilized egg (zygote) through successive cell divisions and differentiation.
  - **Post-Embryonic Development:** Growth and maturation after birth or hatching, involving tissue specialization and functional adaptation.
  - **Metamorphosis:** Transformational changes from larval to adult form in organisms like insects and amphibians.
- **Types of Developmental Processes:**
  - **Differentiation:** Cells become specialized for specific functions (e.g., nerve cells, muscle cells).
  - **Morphogenesis:** Organization of cells into tissues and organs, shaping the body's structure.
  - **Maturation:** Attainment of adult characteristics and functional abilities.