بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

(In the Name of Allah, the Most Compassionate, the Most Merciful.)

Biology

11

Punjab Education, Curriculum, Training and Assessment Authority

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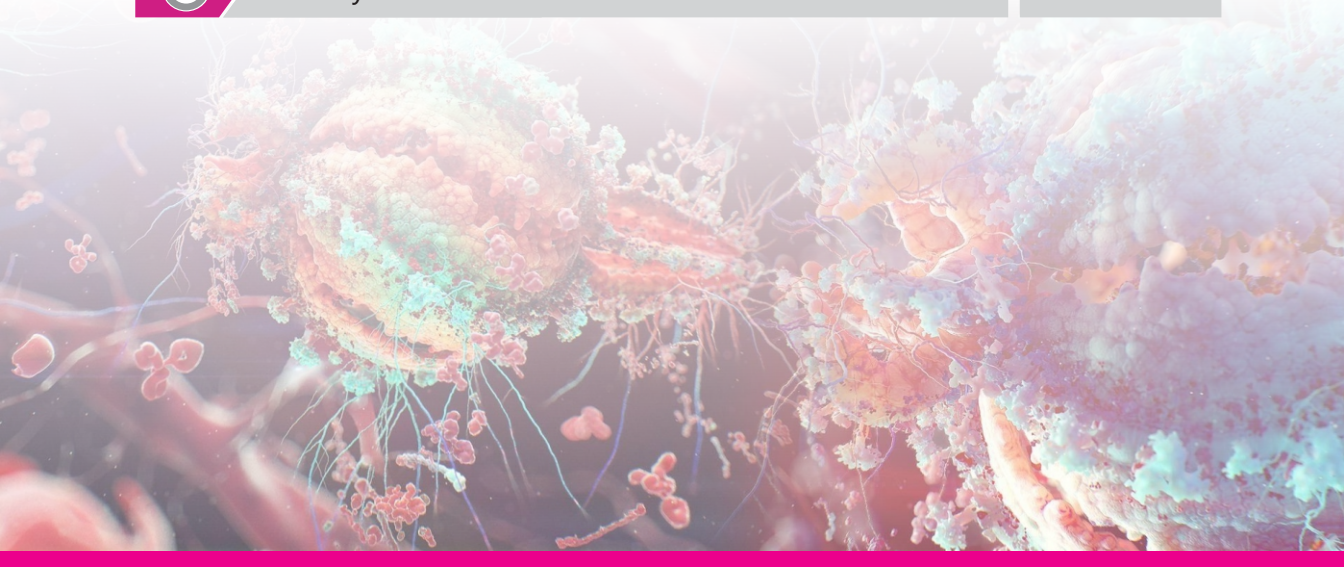

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Chapter 1

BIODIVERSITY & CLASSIFICATION

STUDENTS' LEARNING OUTCOMES

After studying this chapter, the students will be able to:

- Discuss the meaning of the terms species and speciation.
- Describe the classification of organisms into three domains: Archaea, Bacteria and Eukarya.
- Describe the classification of organisms in the Eukarya domain into the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species.
- Outline the characteristic features of the kingdoms Monera, Protoctista, Fungi, Plantae and Animalia.
- Outline how viruses are classified.
- Define the terms ecosystem and niche.
- Explain the different levels at which biodiversity can be assessed.
- Explain the importance of random sampling in determining the biodiversity of an area.
- Describe and use suitable methods to assess the distribution and abundance of organisms in an area.

Biodiversity and classification are fundamental concepts in biology that provide insight into the vast array of life forms on Earth and their evolutionary relationships. In this chapter, we will study the biodiversity, highlighting the variety of life at genetic, species, and ecosystem levels. We will also explore the principles and methods of biological classification, which scientists use to organize and categorize organisms.

1.1- THREE-DOMAIN SYSTEM OF CLASSIFICATION

According to the five-kingdom classification system, proposed by American ecologists **Rebert Whittaker** in 1969, all organisms were divided into five kingdoms i.e., Monera, Protista, Fungi, Plantae, and Animalia. According to this system, the kingdom Monera included prokaryotes while all the other four kingdoms included eukaryotes. In 1990, American microbiologist **Carl Woese** suggested that there are two separate groups of prokaryotes i.e., Archaea and Bacteria. On the basis, he classified living organisms into three domains i.e., domain Archaea, domain Bacteria and domain Eukarya. According to his three-domain

The evolutionary relationship among organisms is called **phylogeny**. The diagram to show phylogeny, is called phylogenetic or evolutionary tree.

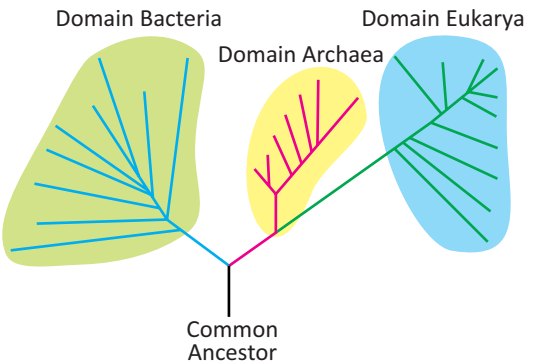


Figure 1.1: Evolutionary tree of the three domains

system, domain Archaea and domain Bacteria contain prokaryotes but they differ in a number of features.

Now biologists believe that Archaea and Bacteria evolved independently from some common ancestor. Molecular evidence suggests that archaea are more closely related to eukaryotes than to bacteria. In other words, Eukarya evolved from Archaea, after archaea split off from the Bacteria (Figure 1.1).

Domain Archaea

In the five-kingdom system, this domain was included in kingdom Monera. The name Archaea comes from the Greek *archaios* ("ancient"). They are prokaryotes which diverged from bacteria in very ancient times. Individual archaeans range from 0.1 µm to over 15 µm in diameter. Some form aggregates or filaments up to 200 µm in length. They occur in various shapes, such as spherical, rod-shape, spiral, lobed, or rectangular. Archaea reproduce asexually by binary or multiple fission, fragmentation, or budding. Mitosis and meiosis do not occur in archaea.

Archaea were initially classified as a group of bacteria, and were called archaebacteria.

How are Archaea unique?

Cell Membrane:

Their cell membrane contains lipids with ether-linkage between glycerol and fatty acid chains. The fatty acid chains are branched. That's why their cell membranes are more resistant to extreme conditions.

On the other hand, bacteria and Eukarya have membrane lipids with fatty acids attached to glycerol by ester linkages. The fatty acid chains are unbranched.

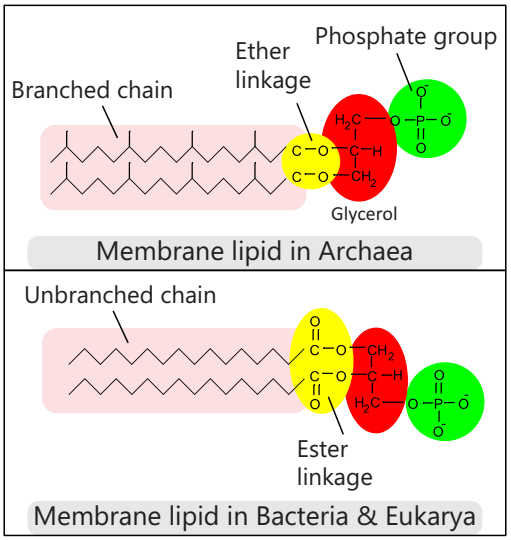


Figure 1.2: Difference in membrane lipids of Archaea and other organisms

Cell Wall Composition:

The cell walls of archaea lack cellulose and peptidoglycan. Instead, they contain distinct polysaccharides and proteins. Some archaea have pseudopeptidoglycan.

On the other hand, bacterial cell walls contain peptidoglycan, a polymer consisting of sugars and amino acids that provides structural support. In Eukarya, the cell walls, if present, are composed of cellulose (in plants) or chitin (in fungi).

Genetic Differences:

Archaea share several genetic sequences and regulatory features with eukaryotes, highlighting their closer evolutionary relationship.

Significance of Archaea

The archaeans which live in high acidity and alkalinity are a source of enzymes that can function under harsh conditions. For example, the enzymes of DNA replication have been extracted from such archaeans. These enzymes can work best at high temperatures and allow rapid cloning of DNA in laboratory. Similarly, the methanogen archaeans are a vital part of sewage treatment. They carry out anaerobic digestion and produce biogas. Acidophillic Archaea are used to extract metals such as gold, cobalt and copper from ores in mineral processing.

Metabolism:

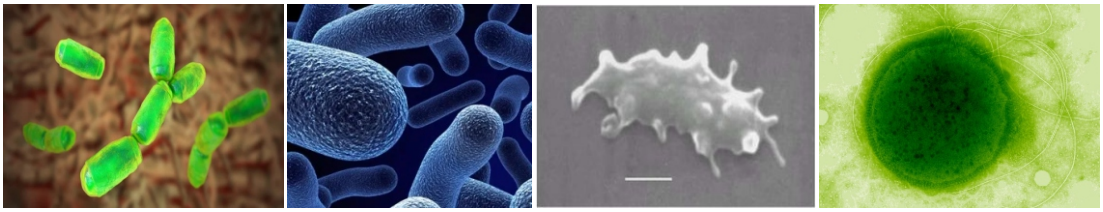
Archaea have unique metabolic processes like methanogenesis (production of methane), which is not found in bacteria or Eukarya.

On the other hand, bacteria exhibit metabolic pathways, including photosynthesis, nitrogen fixation, and fermentation. In Eukarya, the metabolic processes are often more complex and include cellular respiration, photosynthesis (in plants and algae), and various forms of fermentation.

Major Groups of Archaea

The major groups of Archaea include Methanogens (produce methane as a metabolic by-product), Halobacteria (live in extremely saline environments), Thermococci (found in hot environments), and Thaumarchaeota (involved in nitrogen cycle).

In humans, intestinal gas is largely the result of the metabolism of methanogens.



Methanogens Halobacteria Thermoplasmata Thermococci

Figure 1.3: Major groups of Archaea

Domain Bacteria

In the five-kingdom system, this domain was included in kingdom Monera. They are the true bacteria. They possess several distinct characteristics that differentiate them from other domains i.e., Archaea and Eukarya. Here are the general characteristics of the domain Bacteria:

1. Cell Structure: Like archaea, bacterial possess prokaryotic cell i.e., lack a true nucleus and membrane-bound organelles.

2. Cell Wall Composition: Bacteria have a cell wall composed of peptidoglycan, a unique polymer that provides structural support and shape.

3. Genetic Material: Like Archaea bacteria possess a single, circular chromosome composed of DNA, located in the nucleoid region.
4. Plasmids: Most bacteria have small, circular DNA molecules that can be transferred between bacteria, aiding in genetic diversity and adaptation.
5. Reproduction: Bacteria primarily reproduce asexually through binary fission, a process where a single cell divides into two identical daughter cells.
6. Nutritional Modes : Include autotrophs (self-feeding, e.g., photosynthetic bacteria) and heterotrophs (feeding on organic matter, e.g., decomposers).
7. Morphology : Bacteria exhibit a variety of shapes, such as cocci (spherical), bacilli (rod-shaped), spirilla (spiral-shaped), and vibrios (comma-shaped).
8. Arrangement: Cells may be found singly, in pairs (diplococci), chains (streptococci), clusters (staphylococci), or other arrangements based on species-specific characteristics.
9. Flagella: Many bacteria have one or more flagella, whip-like structures that enable movement.
10. Pili and Fimbriae: These are hair-like structures in some bacteria. They help in attachment to surfaces and in exchange of genetic material with other bacteria.
11. Respiration: Bacteria can be obligate aerobes, obligate anaerobes, facultative anaerobes, microaerophiles, or aerotolerant anaerobes. Some bacteria perform fermentation to produce energy in the absence of oxygen.
12. Extremophiles: Some bacteria thrive in extreme conditions, such as high temperatures (thermophiles), high salinity (halophiles), and low pH (acidophiles).
13. Pathogenicity: Some bacteria cause diseases in humans, animals, and plants, producing toxins or other virulence factors.
14. Symbiosis Many bacteria live in symbiotic relationships with other organisms, including mutualism (both benefit) and commensalism (one benefits, the other is not harmed).

Figure 1.4: Different forms of Bacteria

Major Groups of Bacteria

The domain Bacteria is divided into numerous groups. For example;

- Proteobacteria e.g., *Escherichia coli*, *Rhizobium*, *Helicobacter pylori*.
- Firmicutes e.g., *Bacillus subtilis*, *Lactobacillus*, *Clostridium botulinum*.

- Actinobacteria e.g., *Streptomyces*, *Mycobacterium tuberculosis*
- Cyanobacteria e.g., *Anabaena*, *Spirulina*.
- Spirochaetes e.g., *Treponema pallidum*,
- Acidobacteria e.g., *Acidobacterium*.
- Aquificae e.g., *Aquifex pyrophilus*.

Domain Eukarya

The domain Eukarya encompasses all organisms with eukaryotic cells, which are fundamentally different from the prokaryotic cells of Bacteria and Archaea. Here are the general characteristics of the domain Eukarya that justify its classification as a separate domain:

1. Cell Structure: They possess eukaryotic cells - with true nucleus enclosed by a nuclear membrane. Cells have membrane-bounded organelles e.g., mitochondria, chloroplasts (in plants and algae), endoplasmic reticulum, Golgi apparatus, lysosomes, and peroxisomes. Cells also have cytoskeleton i.e., a complex network of microtubules, microfilaments, and intermediate filaments that provides structural support, enables cell movement, and facilitates intracellular transport.

2. Genetic Material: Their DNA is organized into multiple linear chromosomes within the nucleus. DNA is associated with histone proteins, which help in the organization and regulation of genetic material.

3. Reproduction: Most eukaryotes undergo sexual reproduction involving meiosis and fertilization, leading to genetic diversity. Some eukaryotes can also reproduce asexually through mitosis, producing genetically identical offspring.

5. Complex Cellular Organization: In multicellular eukaryotes, cells differentiate into specialized types forming tissues and organs with specific functions.

6. Evolutionary Relationships: Eukaryotes are believed to have originated through endosymbiosis, where certain prokaryotic cells (such as mitochondria and chloroplasts) were engulfed by a host cell, leading to a symbiotic relationship.

1.2- Taxonomic Hierarchy

The classification of living organisms is organized into a hierarchical system that allows scientists to categorize and understand the relationships between different forms of life. This system includes several levels, known as **taxa** (singular: taxon), each representing a rank in the biological classification system. The primary levels of this hierarchy are: kingdom, phylum, class, order, family, genus, and species. Below is a detailed description of each level.

1. Domain

It is the highest level of classification. Currently, there are three domains: Archaea, Bacteria, and Eukarya.

2. Kingdom

The kingdom is one of the highest taxonomic ranks, just below domain. It groups together all forms of life that share fundamental characteristics.

- Example: In the domain Eukarya, there are several kingdoms, such as Animalia (animals), Plantae (plants), Fungi (fungi), and Protista (protists).

3. Phylum

Phylum is the next level of classification below kingdom. Organisms within a phylum share a basic body plan and significant structural features.

- **Example:** In the kingdom Animalia, the phylum Chordata includes all animals with a notochord, such as mammals, birds, reptiles, amphibians, and fish.

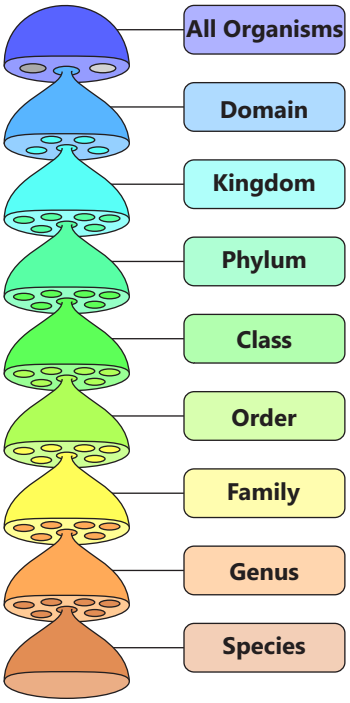


Figure 1.5: Taxonomic hierarchy

4. Class

Class further divides organisms within a phylum based on more specific common traits.

- **Example:** Within the phylum Chordata, the class Mammalia includes all mammals, which are characterized by having hair and mammary glands.

5. Order

Order categorizes organisms within a class based on additional shared characteristics and evolutionary history.

- **Example:** Within the class Mammalia, the order Primates includes humans, monkeys, and apes, characterized by their large brains and opposable thumbs.

6. Family

Family groups organisms within an order that are even more closely related, sharing more precise common attributes.

- **Example:** Within the order Primates, the family Hominidae includes great apes and humans.

7. Genus

Genus is a more specific rank within a family, grouping species that are very closely related and often visually similar.

- **Example:** Within the family Hominidae, the genus Homo includes humans and our closest extinct relatives.

8. Species

Species is the most specific level of classification, representing a single type of organism. Members of a species can interbreed and produce fertile offspring.

- **Example:** Within the genus Homo, the species Homo sapiens refers to modern humans.

Taxonomic Rank	Human (*Homo sapiens*)	Sparrow (*Passer domesticus*)	Onion (*Allium cepa*)
Domain	Eukarya	Eukarya	Eukarya
Kingdom	Animalia	Animalia	Plantae
Phylum	Chordata	Chordata	Angiosperms
Class	Mammalia	Aves	Monocots
Order	Primates	Passeriformes	Asparagales
Family	Hominidae	Passeridae	Amaryllidaceae
Genus	Homo	Passer	Allium
Species	*Homo sapiens*	*Passer domesticus*	*Allium cepa*

1.3- Salient Features of Kingdoms of Domain Eukarya

Eukarya consists of kingdoms protista, fungi, plantae and animalia. It includes all eukaryotes which consist of complex, eukaryotic cells containing nucleus and other membrane-bound organelles.

1. Kingdom Protista

Kingdom Protista includes eukaryote which are unicellular or colonial or filamentous or simple multicellular. Simple multicellular means that they do not have multicellular sex organs. There are three types of protists.

Certain protists are parasitic and cause diseases like malaria (Plasmodium), amoebic dysentery (Entamoeba histolytica), and sleeping sickness (Trypanosoma).

Major Groups or Protists

- The group Protozoa includes animal-like protists. They are unicellular and are heterotrophic. Examples are Paramecium, Amoeba, .Plasmodium, and Trypanosoma.
- The group Algae includes plant-like protists. They have cell walls made of cellulose. They have chlorophyll and are autotrophs. Examples include *Euglena*, diatoms.
- The groups Myxomycota and Oomycota include Fungi-like protists. They have hyphae-like structure and are saprophytic e.g., slime molds and water molds.

Figure 1.6: Common protists

2. Kingdom Fungi

Fungi are eukaryotic, heterotrophic organisms that are unicellular or multicellular. Their cells are covered by cell wall made of chitin (a polysaccharide). Fungi get nutrients in a unique way. They do not ingest food like animals and some protists. They absorb food from surroundings. Examples are mushrooms, rusts, smuts and molds.

Some fungi are used in the production of bread, cheese and beer. Others have medicinal properties, such as penicillin, an antibiotic derived from the fungus *Penicillium*.

Makro Groups of Fungi

There following are the major groups of fungi:

- Zygomycota includes the fungi which lack septa in their hyphae. Examples are Rhizopus (bread molds), which grow on moist bread, fruits etc.
- Ascomycota includes the largest groups of fungi. They have septate hyphae. Examples include common molds, morels, truffles, cup fungi, Neurospora and yeasts.
- Basidiomycota includes the fungi with septate hyphae. Examples are mushrooms, toadstools, puffballs, jelly fungi and bracket/shelf fungi, rusts and smuts.

There are about 100,000 known species of fungi. Most of the Ascomycetes are found in lichens and some are found in mycorrhizae.

Figure 1.7: Common fungi

3. Kingdom Plantae

It includes plants which are eukaryotic, multicellular organisms with cell walls made of cellulose.They are autotrophic and prepare food through photosynthesis. All

plants develop from embryos. Examples are mosses, ferns, conifers and flowering plants.

Major Groups of Plants

Plants are divided into two major groups:

- Nonvascular plants or bryophytes lack conducting tissues (xylem and phloem). Examples include liverworts, hornworts, and mosses.
- Vascular plants have conducting tissues. Vascular plants are of two types i.e., seedless plants (e.g., ferns) and seed plants (e.g., conifers and flowering plants).

Moss

Liverwort

Hornwort

Nonvascular plants

Sago palm

Pine

Cedrus

Ginkgo biloba

Seedless vasculaplants

Capsicum

Mustard

Seed plants

Figure 1.8: major groups of Kingdom Plantae

Table: Distinguishing Characteristics of the kingdoms of three domains						
Domain	**Bacteria**	**Archaea**	**Eukarya**			
Kingdom	**Monera**		**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell Type	Prokaryotic	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Nuclear Envelope	Absent	Absent	Present	Present	Present	Present
Presence of Cell Wall	In all	In all	In some	In All	In all	Absent
Composition of Cell Wall	Peptidoglycan	Various chemicals	Various chemicals	Chitin	Cellulose and other polysaccharides	No Cell wall
Mode of Nutrition	Autotroph or heterotroph	Autotroph or heterotroph	Photosynthetic or heterotroph, or combination	Absorptive heterotroph	Photosynthetic autotrophs	Ingestive heterotroph
Multi - cellularity	Absent	Absent	Absent in most forms	Present in most forms	Present in all forms	Present in all forms

4. Kingdom Animalia

This kingdom of eukaryotes includes animals which are eukaryotic, multicellular and heterotrophic. They develop from embryos. They ingest food and digest it within their bodies.

1.4- CLASSIFICATION OF KINGDOM ANIMALIA

The kingdom Animalia is broadly divided into the following phyla.

1- Phylum Porifera

This phylum contains sponges. Most of them are marine while some live in freshwaters. *Leucosolenia* and *Euplectella* (Venus' flower basket) are marine sponges. *Spongilla* is a common freshwater sponge.

A commercial sponge is prepared by drying, beating, and washing a sponge until all cells are removed.

Sponges do not have tissue level organization. Most sponges are asymmetrical but some have radially symmetry. They do not have nervous system. There are numerous pores in body wall called ostia. Through ostia, water enters the body. The larger pore through which water leaves the body is called osculum. The outer layer of body is made of thin, flat cells called pinacocytes. The second layer is jelly-like and is called mesohyle. It contains amoeboid cells. The third layer, which lines the spongocoel, is made of choanocytes or collar cells. They have skeleton in the form of minute needles of calcium carbonate or silica. Most sponges reproduce asexually by budding or regeneration. Some sponges form resistant capsules, called gemmules. When parent sponge dies, it releases its gemmules. In favourable environment, amoeboid cells come out of the gemmules and form a new sponge.

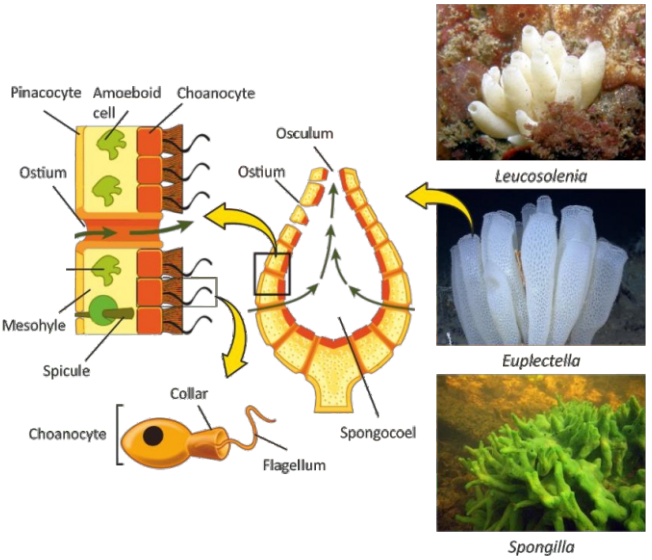


Figure 1.9: Representative sponges and general structure

2- Phylum Cnidaria

Almost all cnidarians are marine, although a few are found in freshwater e.g., *hydra* and jellyfish. Most cnidarians are colonial e.g., *obelia*, corals, sea fans etc. Most of them are sessile e.g., *hydra*, coral, *obelia* etc. Some cnidarians are motile e.g., jellyfish.

They are radially symmetrical animals and are diploblastic. It means that the adult body contains two tissue layers i.e., the epidermis and the gastrodermis, derived from ectoderm and endoderm respectively. Between the epidermis and gastrodermis, a jelly-like mesoglea is present. It contains amoeboid cells that have originated either from ectoderm or endoderm. They possess special cells, called cnidocytes. A cnidocyte contains a special organelle, called nematocyst. Nematocysts defend the body and captures prey. Cnidarians have a blind-ending cavity, called gastrovascular cavity or enteron. It opens outside by a single opening, the mouth. Mouth also acts as anus for the removal of undigested material. Mouth is surrounded by a series of projections, called tentacles. This types of digestive system in which there is a single opening for the entry of food and removal of undigested matter, is called **sac- like** digestive system.

Corals are colonial cnidarians. They produce hard exoskeleton of Calcium carbonate. The skeleton makes coral islands and coral reefs.

Coral reef

The nervous system is in the form of a network of neurons in the body wall. There is no central nervous system (brain and spinal cord). They do not have respiratory,

excretory and transport systems. There are two body forms in cnidarians i.e., polyps and medusae. **Polyps** are cylindrical and are attached to a substrate at the aboral end. They reproduce asexually. **Medusae** are umbrella-like and are free-swimming. They reproduce sexually.

Figure 1.10: Representative cnidarians

3- Phylum Platyhelminthes

They are called "flatworms". They are unsegmented and body is soft and dorsoventrally compressed. Most of them are free-living e.g., planaria. Some are endoparasites of humans and other animals e.g., liver fluke, tapeworm, and blood-fluke.

They are triploblastic i.e., the tissues of the body are derived from three embryonic layers; ectoderm, mesoderm and endoderm. They are acoelomates. A loose connective tissue called parenchyma fills space between the body wall and body organs. They have bilateral symmetry with distinct left and right sides as well as dorsal and ventral sides. They do not have respiratory and circulatory (transport) systems. They have a network of tubular protonephridia. These tubules have numerous branches. Each branch ends in a bulb-like cell called flame cell. The cilia of flame cells beat to suck surrounding fluid into the tubules. The tubules filter the waste materials from fluid and release them out of body wall through a small opening called a nephridiopore. They have a network of neurons. There are cerebral ganglia in the anterior end (head). These ganglia are attached to longitudinal nerve cords that are interconnected across the body by transverse branches. Most free-living flatworms have two simple eyespots at their anterior end. Flatworms reproduce asexually by "fission" in which the animal constricts in the middle and then divides into two pieces. Each piece then regenerates the missing part. The sexually-reproducing flatworms are hermaphrodites (bisexual).

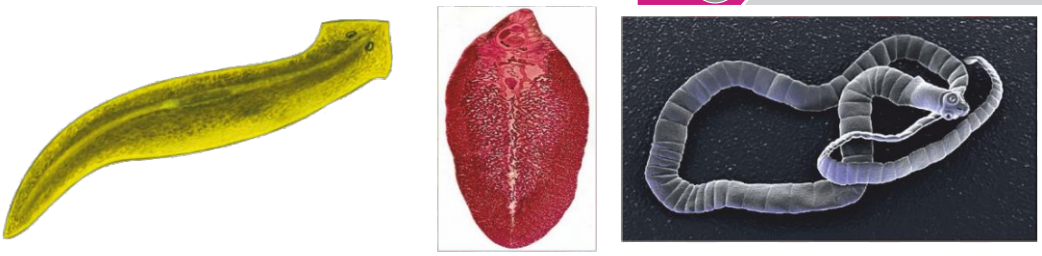


Figure 1.11 : Representative flatworms

4- Phylum Nematoda

The pseudocoelomates are classified in seven phyla. These phyla are grouped as a unit called Aschelminths. Phylum Nematoda is the representative phylum of this group.

They are roundworms with elongated worm-like (round) body with pointed ends. Some roundworms are free-living (in water and soil) e.g., *Caenorhabditis elegans.* Many are parasites e.g., *ascaris,* hookworm, pinworm, and whipworm.

They are triploblastic, bilateral symmetrical, and possess unsegmented body. They are pseudocoelomates because they possess a false body cavity called pseudocoelom filled with fluid. They possess tube-like digestive system. It consists of an alimentary canal with two openings; mouth at anterior end and anus at posterior end. The parasitic roundworms have simplified digestive systems. Their excretory system consists of protonephridia and two excretory canals, which unite at the anterior end to form a single canal. The single canal then opens outside through a nephridiopore on the ventral surface. They possess a network of neurons in body. There is a nerve ring around the pharynx, which is attached to four longitudinal nerve cords. They have raised hair-like sense organ called sensory papillae, present on lips. They do not have defined respiratory and circulating systems. They are unisexual i.e.; male nematodes have testes and female nematodes have ovaries.

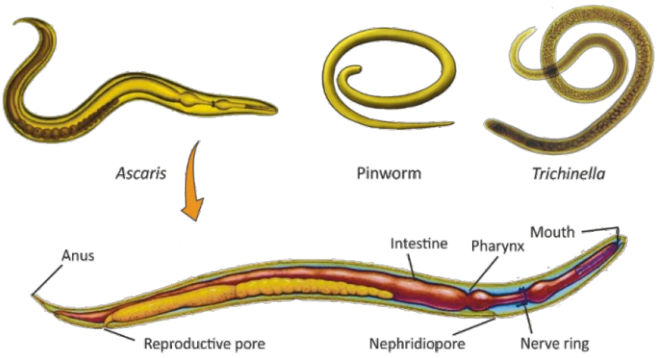


Figure 1.12: Representative roundworms and general structure

5- Phylum Mollusca

Molluscs have soft un-segmented bodies. They are widely distributed in natural habitats. Some of them are exclusively aquatic e.g., mussels, octopus and oyster. The others live in moist places e.g., land snail.

In open-type system, the blood does not retain the vessel. Rather, it directly bathes cells in tissue spaces (sinuses).

Molluscs are triploblastic and have bilateral symmetry. They possess true coelom. Among coelomates, they are included in the group called protostomes. Their body can be divided into three parts i.e., head, visceral mass (contains organs of digestion, excretion and reproduction), and foot (attached with visceral mass). They have an epithelial envelope around the visceral mass, called as mantle. The space between mantle and visceral mass is called as mantle cavity. In most molluscs, the outer surface of mantle secretes a calcareous shell. All molluscs (except bivalvia) have is a rasping tongue-like organ, called radula. All of them (except cephalopods) have open type blood circulatory system. Their heart consists of a single ventricle and two auricles. They possess tube-like digestive system in which the gut has two openings, i.e., mouth and anus. Their excretory system consists of paired tubular structures called nephridia. Wastes are gathered from sinuses and discharged into coelom around the heart. The nephridia open in this coelom. They have tiny cilia around their openings, which move the fluid from coelom into the nephridia. Nephridia discharge waste materials in mantle cavity, from where they are expelled out. In molluscs, gills work for the exchange of gases. They have three pairs of interconnected ganglia present in the head, visceral mass and foot. The ganglia are interconnected by means of nerve cord. They move with the help of muscular foot. Some molluscs are sessile. Most molluscs are unisexual.

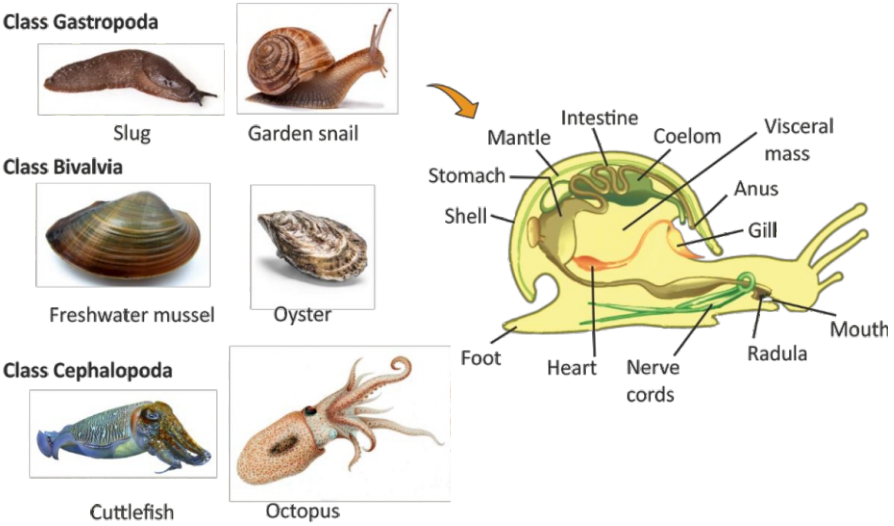


Figure 1.13: Representative molluscs and general structure

6- Phylum Annelida

Annelids are commonly called segmented worms. They are found in marine water (e.g., nereis), freshwater (e.g., leech), and in damp soil (e.g., earthworm). Some annelids are ectoparasites e.g., leeches.

Their body is divided transversely into a number of similar parts called segments. Internally, the segments are separated from each other by cross walls called septa. Each segment is provided with its own circulatory, excretory and neural elements. This type of segmentation in body is called metameric segmentation. Annelids are bilaterally symmetrical and triploblastic. They are protostome coelomates. Annelids have special parts called setae. Setae are chitinous bristles in the ventral wall of each segment. Setae are absent in leeches. Their body wall is surrounded by a moist, acellular cuticle secreted by epidermis. They possess tube-like digestive system. The digestive tube is divided into distinct parts, each performing a specific function. The parasitic annelids have simplified digestive system.

The segments are indicated externally by constrictions of the body surface in the form of little rings ("Annelid" means "little ring").

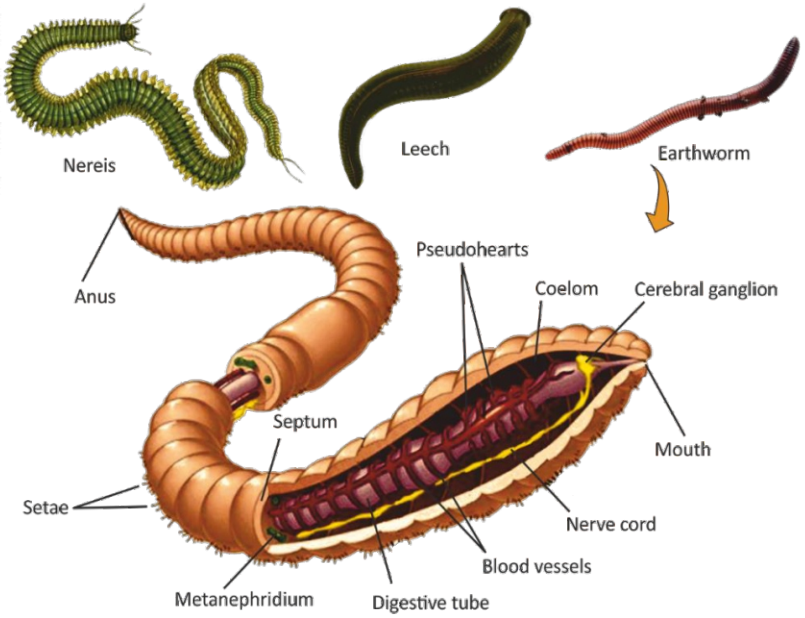


Figure 1.14: Representative annelids and general structure

Their excretory system consists of ciliated, funnel-shaped metanephridia. Each segment has one pair of metanephridia. They possess a closed-type circulatory system. Blood always flows in blood vessels. They have specialized pulsating blood vessels (pseudohearts). Blood of most annelids has respiratory pigment, haemoglobin, dissolved in blood plasma. Gaseous exchange occurs through the skin. There is a

cerebral ganglion or brain in the anterior segment. A double, longitudinal ventral nerve cord arises from brain and gives nerves in each segment. Ganglia are also present in each segment. They have tactile receptors, chemoreceptors, balance receptors, and photoreceptors. Some annelids also well-developed eyes with lenses. Most annelids are hermaphrodite (e.g., earthworm, leech) and some are unisexual (e.g., nereis).

7- Phylum Arthropoda

Diverse groups such as insects, crustaceans, spiders, scorpions, and centipedes are included in this phylum. They are found in every type of habitat. Many of terrestrial members can also fly.

Arthropods are the most successful of all invertebrates. About 900,000 species – two thirds of all the named species on Earth arthropods.

They are triploblastic, bilateral symmetrical, protostome coelomates. The coelom is reduced and is present only around reproductive and excretory systems. They have jointed appendages which are modified for specialized functions e.g., running, crawling swimming, capturing prey, respiration, reproduction etc. In different arthropods, the jointed appendages around the mouth, are modified in different ways and form mouth parts. The body is segmented. Some segments are fused to form specialized body regions called tagmata. These include head, thorax and abdomen. They have exoskeleton or cuticle, which is secreted by the epidermis of body wall. It is made chiefly of chitin. In young arthropods, exoskeleton is shed from time to time. After shedding the exoskeleton, the animal grows at a fast rate and then re-secretes new exoskeleton. This process is called ecdysis or molting.

They possess open-type circulatory system. Most of the time, blood flows in hemocoel, which is derived from an embryonic cavity called blastocoel. Their blood is colourless as it is without haemoglobin and is known as haemolymph. Most arthropods possess a respiratory system that consists of air tubes called trachea. Main tracheal tubes open out through openings called spiracles. Aquatic arthropods respire through gills. Arthropods have tube-like digestive system. The alimentary canal is divided into different parts. Their excretory system comprises of Malpighian tubules. These are narrow tubules projected from the alimentary canal, attached at the junction of midgut and hindgut. The nitrogenous wastes are excreted in the form of solid uric acid crystals. They have well-developed central nervous system with three fused pairs of cerebral ganglia (brain) in head. There is a double ventral nerve cord which has ventral ganglia in each segment. Smaller nerves arise from ventral ganglia in each segment. They have well developed compound eyes and antennae. They can swim, crawl or fly depending on their habitat.

They are unisexual.

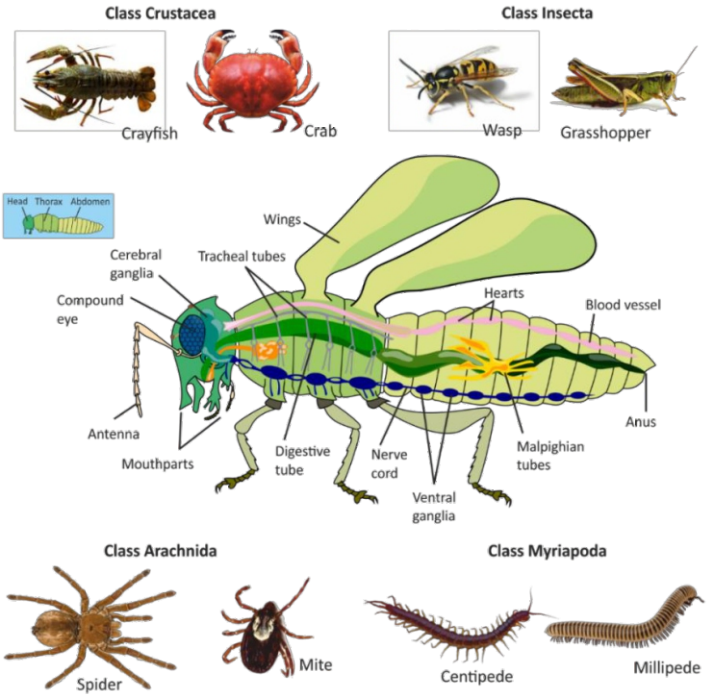


Figure 1.15: Representative arthropods and general structure

Important arthropods include insects (e.g., mosquito, butterfly, moth, wasp, beetles, grasshopper), crabs, lobsters, prawn, shrimps, crayfishes, spider, tick, mite, scorpion, centipedes and millipedes.

8- Phylum Echinodermata

They are exclusively marine animals. Some are flattened like biscuit (e.g., cake urchin), some are star-shaped with short arms (e.g., sea star or starfish), some are globular (e.g., sea urchin), some are star-shaped with long arms (e.g., brittle star), and some are elongated (e.g., sea cucumber).

They are triploblastic and deuterostomes coelomates. Their larvae are bilateral symmetrical but the adults show radial symmetry. In their radial symmetry, the body parts are arranged in five, or multiple of five, around an oral-aboral axis. They possess a calcareous endoskeleton in the form of plates called ossicles. These plates are derived from mesoderm but come out of skin also and make spines on the skin. They have water-vascular system consisting of tubes and spaces present in the coelom. A ring canal surrounds the mouth. It opens outside through a sieve-like plate, called madreporite. Five (or a multiple of five) radial canals branch from the ring canal. Many lateral canals emerge from each radial canal and each lateral canal ends at a tube foot. Tube feet are the extensions of water vascular system. The tube feet extend and attach with some substrate. When water is drawn back from the sucked tube feet, they

contracts and body is pulled. Echinoderms possess tube-like digestive system. The mouth leads to oesophagus, stomach, intestine and rectum. The rectum opens out through anus.

There are no specialized organs for respiration and excretion. They possess a poorly developed nervous system made of a nerve net, a nerve ring, and five (or multiple of five) radial nerves. Most sensory receptors are distributed over the surface of the body and tube feet. Asexual reproduction involves division of the body, followed by the regeneration of each half. Echinoderms are unisexual.

Many echinoderms are able to regenerate the lost parts, and some, especially sea stars and brittle stars, drop various parts when they are under attack and then regenerate the lost parts.

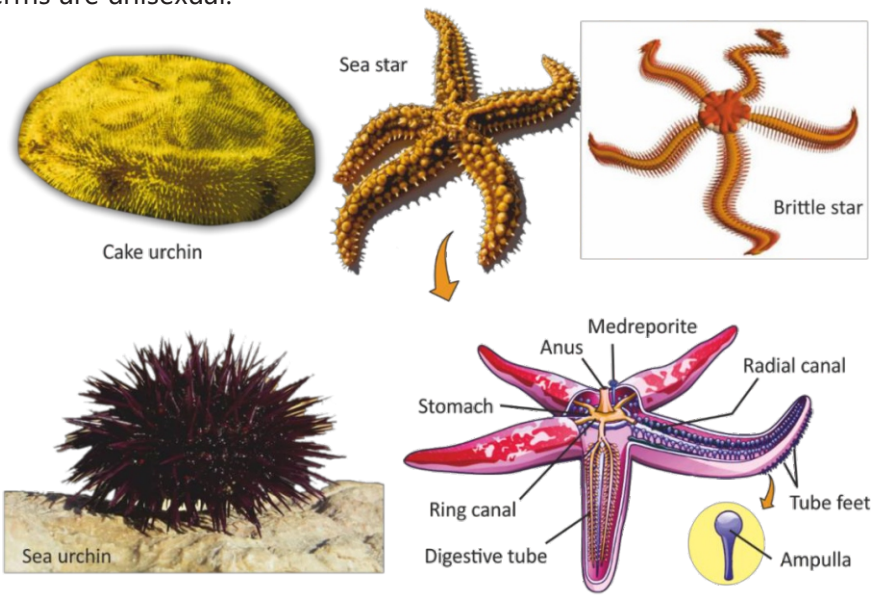


Figure 1.16: Representative echinoderms and general structure

10- Phylum Chordata

Chordates are bilateral symmetrical, triploblastic, deuterostome coelomates. The following four characteristics are unique to chordates, present at some stage in development.

1. Notochord: All chordates develop notochord during embryonic life. It is a rod-like semi rigid body of vacuolated cells. It extends throughout the length of body between gut and dorsal nerve cord. The lower chordates retain this notochord throughout life. While, in vertebrates it is partly or entirely replaced by vertebral column, during development.

2. Pharyngeal slits: These are a series of openings in the lateral walls of pharynx. All chordates develop paired gill slits in embryonic stage. In some chordates (e.g.,

Amphioxus and fishes), these develop into gills. In some (e.g., most amphibians), these are functional for some period in their life history. In others (e.g., reptiles, birds and mammals), these are modified for various purposes.

3. Tubular nerve cord: In all chordates, a tubular nerve cord runs through the longitudinal axis of the body, just dorsal to the notochord. It expands anteriorly as a brain.

4. Post anal tail: All chordates develop a tail, posteriorly beyond the anal opening. Some chordates retain it throughout life while others degenerate it during embryonic life.

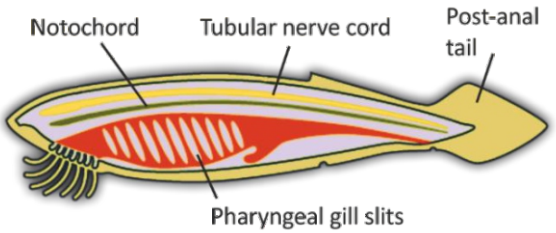


Figure 1.17: Diagnostic characters of chordates

Phylum chordata includes two major groups i.e., invertebrate chordates and vertebrates.

- **Subphylum Urochordata** includes the invertebrates chordates in which notochord and nerve cord are present only in their free-swimming larvae. Sea squirts are the examples of urochordates.
- **Subphylum Cephalochordata** includes the invertebrate chordates in which notochord persists throughout life. Amphioxus is a common cephalochordate.

Figure 1.18: Sea squirts

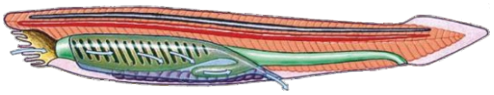


Figure 1.19: Amphioxus

- **Vertebrates:** They have a vertebral column and cranium. Vertebrates are divided into seven classes which are placed into two groups.

1.5- CLASSIFICATION OF VERTEBRATES

Vertebrates are divided into two groups.

1. **Group Pisces:** It includes 3 classes i.e., Cyclostomata, Chondrichthyes, and Osteichthyes. They do not have limbs.

2. **Group Tetrapoda:** It includes 4 classes i.e., Amphibia, Reptilia, Aves, and Mammalia. They have four limbs.

1. Class Cyclostomata

These are jawless fishes. Lampreys and hagfish are common examples. Their bodies are eel-like and not covered with scales. They possess cartilaginous skeleton. Like other fishes, they have a single-circuit heart with one atrium and one ventricle. Fertilization is external.

Figure 1.20: Jawless fishes

2. Class Chondrichthyes

The group includes sharks, skates, rays, and ratfishes. They have skeleton of cartilage. Their body is covered by placoid (tooth-like) scales, called denticles. They have jaws and biting mouthparts. The pectoral and pelvic fins are paired. There are two dorsal fins. They possess single-circuit heart with one atrium and one ventricle. There is a pair of small openings, called spiracle, behind eyes. These are used for breathing. They do not have swim bladder. Fertilization is internal.

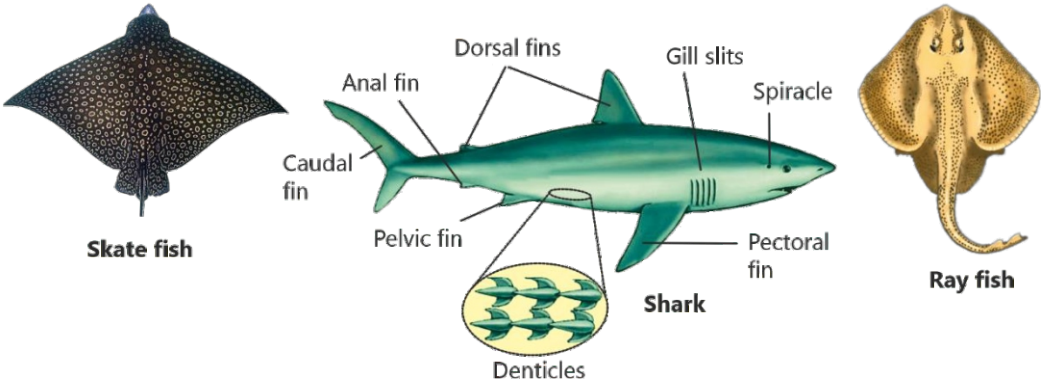


Figure 1.21: Cartilaginous fishes

3. Class Osteichthyes

The have bony endoskeleton, streamlined body, dermal bony scales, and terminal mouth with jaws (with or without teeth). Notochord is replaced by vertebral column, but some bony fishes may retain it in reduced form. They also have a swim bladder that helps in buoyancy. They possess both median (dorsal, caudal and ventral) and paired (pelvic and pectoral) fins. They contain four pairs of gills. A protective bony flap, operculum, protects the gills. They have well developed nervous system in which there are ten pairs of cranial nerves. Fertilization is mostly external. The freshwater bony

fishes include rohu, trout, Katla, catfish etc. The marine bony fishes include seahorse, flying fish and angler fish etc.

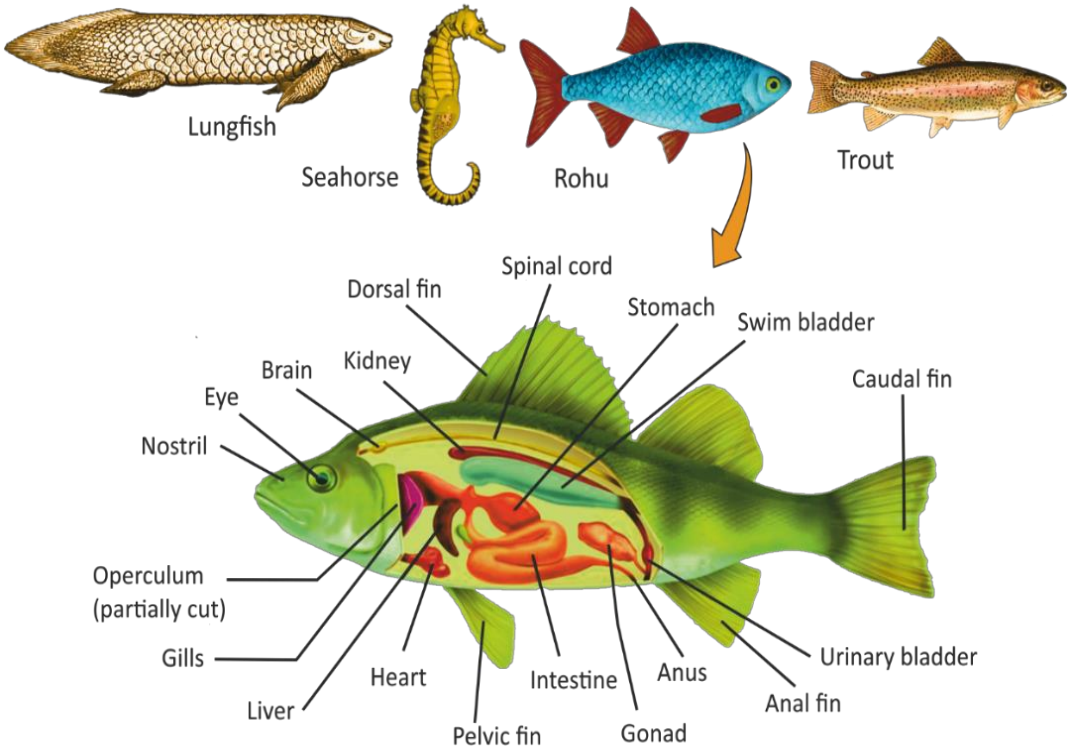


Figure 1.22: Representative bony fishes and general structure

4. Class Amphibia

It is the first class of tetrapods. They have bony endoskeleton. Unlike fishes, amphibians have a neck. The first vertebra (cervical vertebra) moves against the back of skull and allows the skull to nod vertically. Their skin is smooth (without scales) and moist. It helps in gas exchange, temperature regulation, and absorption and storage of water. Their heart is **double-circuit**. It is three-chambered, with two atria and one ventricle. They respire by gills in the larval stage and by lungs and skin in the adult stage. They depend on external heat source and so are **ectotherms**. They cannot regulate their body temperature and cannot maintain it constant. So, they are **poikilothermic** animals and hibernate in winter. Salamander, newts, and mud puppies are tailed amphibians. Frogs and toads are tail-less amphibians, and caecilians are leg-less amphibians. Amphibians are unisexual. Fertilization is usually external.

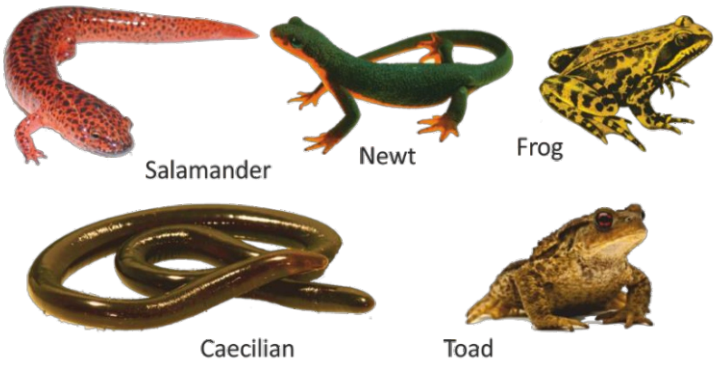


Figure 1.23: Representative amphibians

5. Class Reptilia

Reptiles are the first animal group that possess amniotic eggs. **Amniotic** eggs make protective extra-embryonic membranes i.e., amnion, allantois, and chorion. These membranes protect the embryo from drying out, nourish it and enable it to develop on land. The amniotic eggs also contain a large amount of yolk, the primary food supply for the embryo. Such eggs have abundant albumin, which provides additional nutrients and water. The amniotic eggs are also covered with leathery calcareous shell which is

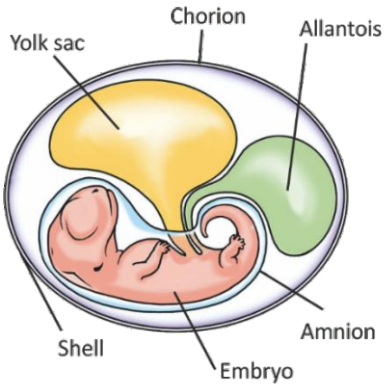


Figure 1.24: Amniotic egg

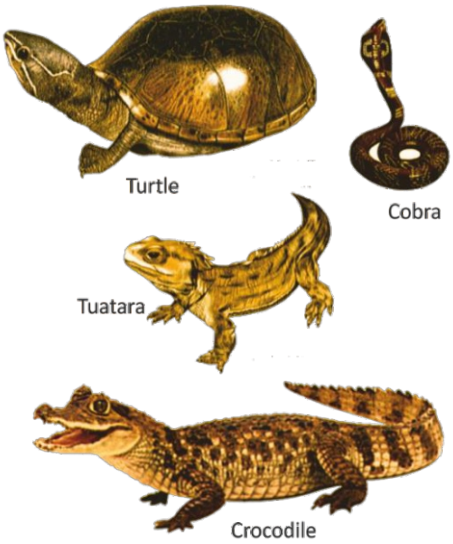


Figure 1.25: Representative reptiles

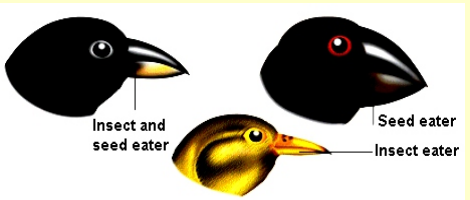
partly permeable to gases but not to water.

Reptiles have dry scaly skin. The bony endoskeleton of reptiles is harder than amphibians. The skull is longer than amphibians. In reptiles, first two cervical vertebrae (atlas and axis) allow more movements of head. In their heart, ventricle is incompletely partitioned, into left and right ventricles.

Reptiles, like amphibians, are **ectothermic** and use external heat source for thermoregulation. They cannot keep their body temperature at constant, and are **poikilotherms**. Fertilization in internal. They are oviparous (egg-laying). The present-day reptiles are lizards, snakes, tuatara and crocodiles.

6. Class Aves

Birds have a covering of feathers on the body. Feathers form the flight surfaces that provide lift and aid in steering. Feathers also prevent heat and water loss. Birds are **endotherms**. It means that they can obtain heat from cellular processes. A source of internal heat allows them to maintain a nearly constant core temperature. The animals who can maintain their core temperature are known as **homeotherms**.



Bills and tongues are modified for a variety of feeding habits and food sources.

The body of birds is streamlined and spindle shaped. The forelimbs are modified into wings. Their bones are light due to large air spaces. A lighter sheath called bill replaces the teeth. The sternum (chest bone) bears a large, bone called keel for the attachment of flight muscles.

In many birds a diverticulum of the oesophagus, called **crop**, is a storage structure that allows birds to quickly ingest large quantities of food. A region of stomach, called **gizzard**, has muscular walls to crush food. Their heart is four-chambered, with complete separation of atria and ventricles. Birds have much developed nervous system. Vision and hearing are important senses for most birds.

Their external nares open in pharynx through nasal passage ways. The pharynx leads to trachea and then bronchi. The organ of voice, called **syrinx**, is situated at the lower end of trachea. The bronchi lead to a complex system of **air sacs** that occupy much of the body and even extend to some of the bones. The air sacs connect to lungs, which are made of small air tubes called **parabronchi**.

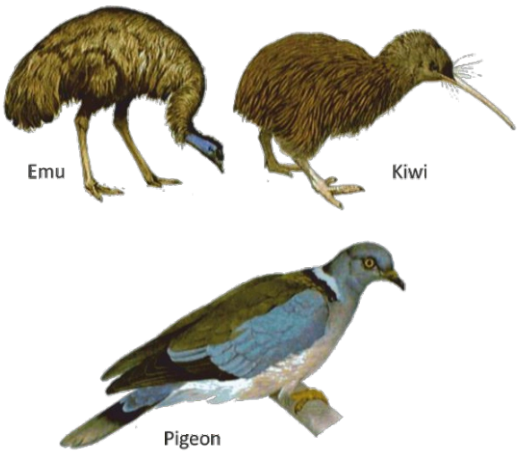


Figure 1.26: Representative birds

Like reptiles and mammals, birds have **amniotic** eggs with large amounts of yolk and albumin. Such eggs are also covered with leathery shell. In birds, fertilization is internal and development is external i.e., they are **oviparous**. Some birds have

secondarily lost the power of flight and are called **running birds** e.g., ostrich, kiwi, rhea, cassowary, and emu. The flying birds include pigeon, parrot, crow, eagle, robin etc.

7. Class Mammalia

Mammalia includes the group of vertebrates which are nourished by milk from the mammary glands of mother, and have hair on their body. Mammals have skin glands, developed from epidermis. Sebaceous (oil) glands secrete oily secretion. Sudoriferous (sweat) glands release watery secretions used in evaporative cooling. Mammary glands are functional in female mammals. Most mammals have two sets of teeth during their lives i.e., milk teeth and permanent teeth. External ear or pinna is present. The middle ear has a chain of three bones i.e., incus, malleus and stapes. Mammals are endothermic and homoeothermic animals. They possess four-chambered heart. They have a muscular diaphragm that separates the coelom into thoracic and abdominal cavities. They have well developed voice apparatus in the form of larynx (with vocal cords) and epiglottis. In mammals, fertilization is internal. There are three groups of mammals:

Most mammals (placental mammals) give birth to young ones i.e., they are **viviparous**. Some mammals lay eggs and so are **oviparous**. While some (marsupials).

1. In egg-laying mammals lay eggs in which whole development of their embryo proceeds. These mammals are found in Australia e.g., Duckbill platypus and echidna (spiny anteater).
2. Some mammals (marsupials) have a pouch (marsupium) on the abdomen of female. These mammals give birth to immature young ones which complete their development in mothers' pouch. They are called **ovoviviparous**. Opossum, kangaroo and Tasmanian wolf are the examples of such mammals.

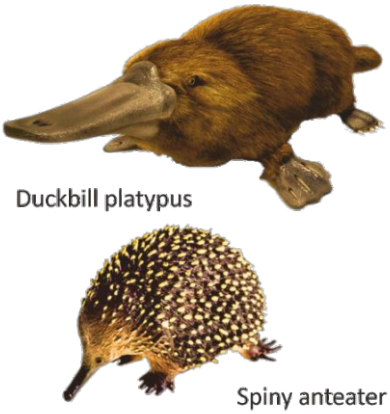


Figure 1.27: Representative egg-laying mammals

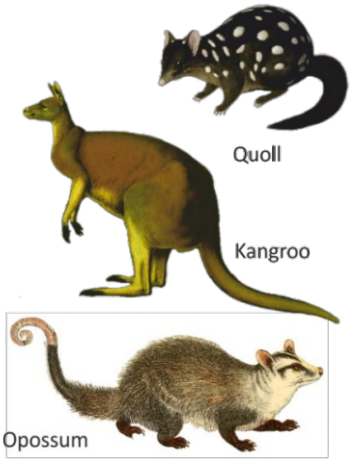


Figure 1.28: Representative pouched mammals

3. Placental mammals are the most advanced mammals. During development, a structure called placenta, is formed between mother's uterus wall and foetus body. The foetus is nourished and wastes from foetus are removed through this placenta. Dolphin, rat, monkey, bat, elephant and human are some examples of placental mammals.

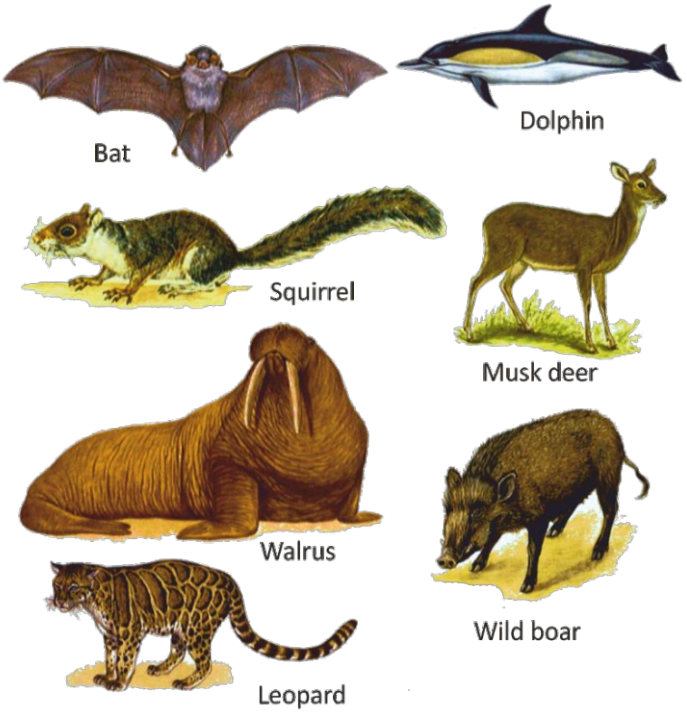


Figure 1.29: Representative eutherians

1.6- CLASSIFICATION OF VIRUSES

Viruses are not considered organisms because they are acellular i.e.; not made of cells. They lack any of the characteristics of the three domains of life and are not classified in any domain and kingdom.

Prions and viroids are also acellular. They are also not considered living organisms. Prions are composed of protein only and Viroids are composed of circular RNA only. Both these particles cause infectious diseases in certain plants.

A virus consists of nucleic acid (DNA or RNA) surrounded by a protein coat. They cannot run any metabolism and depend upon the host cell (including plants, animals, and bacteria) to replicate and synthesize their proteins.

Viruses are classified based on several characteristics, including their genetic material, replication strategy, morphology, and the hosts they infect. The classification of viruses follows guidelines established by the International Committee on Taxonomy of Viruses (ICTV).

Classification on the basis of Host Range

1. Animal Viruses: Infect animals, including humans. Examples: Influenza virus, Rabies virus.
2. Plant Viruses: Infect plants. Examples: Tobacco mosaic virus, Potato virus X.
3. Bacteriophages: Infect bacteria. Examples: T4 phage, Lambda phage.
4. Archaea Viruses: Infect archaea. Examples: Sulfolobus spindle-shaped virus.

Classification on the basis of Morphology

1. Helical Viruses: These have a capsid with a helical structure surrounding the nucleic acid. Examples: Tobacco mosaic virus, Rabies virus.
2. Icosahedral Viruses: These have a capsid with a symmetrical icosahedral shape. Examples: Adenoviruses, Herpesviruses.
3. Complex Viruses: These have a complex structure, often with a combination of icosahedral and helical features, and sometimes additional structures like tails. Examples: Bacteriophages (viruses that infect bacteria).
4. Enveloped Viruses: These have an outer lipid envelope derived from the host cell membrane, surrounding their capsid. Examples: Influenza virus, HIV.
5. Non-enveloped (Naked) Viruses: These lack an outer lipid envelope and consist only of a capsid enclosing the nucleic acid. Examples: Poliovirus, Adenovirus.

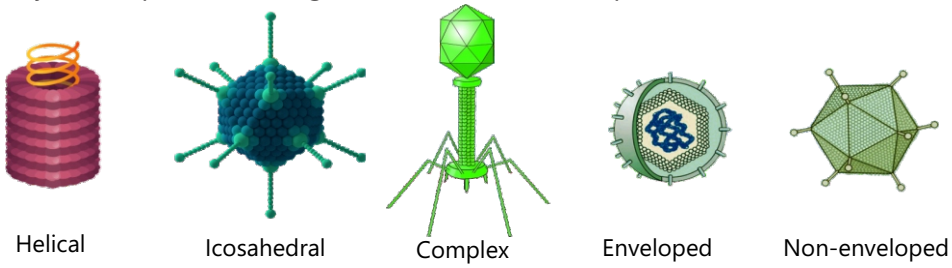


Figure 1.30: Basic shapes of viruses

Classification on the basis of Genetic Material

1. DNA Viruses: Viruses with DNA as their genetic material. This DNA can be single-stranded (ssDNA) or double-stranded (dsDNA). Examples include:
   - dsDNA viruses: Adenoviruses (cause respiratory infections), Herpesviruses (cause herpes, chickenpox).
   - ssDNA viruses: Parvoviruses (cause gastroenteritis).
2. RNA Viruses: Viruses with RNA as their genetic material. This RNA can be single-stranded (ssRNA) or double-stranded (dsRNA). Examples include:
   - ssRNA viruses: Coronaviruses (cause COVID-19), Influenza viruses (cause flu).
   - dsRNA viruses: Rotaviruses (cause gastroenteritis).

Classification on the basis of Replication Strategy

1. Positive-Sense RNA Viruses: The RNA genome is directly translated into proteins by the host cell's ribosomes. Examples include Poliovirus, Hepatitis C virus.

2. Negative-Sense RNA Viruses: The RNA genome is transcribed into mRNA by a viral RNA polymerase before translation. Examples include Rabies virus, Ebola virus.
3. Reverse Transcribing Viruses: These viruses replicate through a DNA intermediate using the enzyme reverse transcriptase. They can have RNA or DNA genomes. Examples include:
   - RNA genome: Retroviruses like HIV (cause AIDS).
   - DNA genome: Hepadnaviruses like Hepatitis B virus.

1.7- BIODIVERSITY

Biodiversity, a term derived from "biological diversity," refers to the variety of life forms present in different ecosystems, encompassing the diversity of species, genes, and ecosystems. It represents the richness and variability of living organisms and their interactions with each other and their environments.

Ecosystem:
An ecosystem is a dynamic and interactive system composed of living organisms and their physical environment. It includes all the biotic factors as well as the abiotic factors.

Niche:
A niche refers to the role or function of an organism or species within an ecosystem. It includes its habitat, its interactions with other organisms (predation, competition, and symbiosis), and its role in energy flow within the ecosystem.

Biodiversity Assessment Levels

The assessment of biodiversity involves multiple levels, each providing unique insights into the complexity of life.

Species Level: At the species level, biodiversity is assessed by identifying and counting the different species present within a given area. Species diversity includes not only the number of species but also their relative abundance and distribution.

Genetic Level: At the genetic level, biodiversity refers to the variety of genetic information contained within all individual organisms of a species. This genetic diversity is crucial for the adaptability and survival of species, enabling them to cope with environmental changes and challenges.

Ecosystem Level: At this level, biodiversity assessment includes the range of habitats, from forests and wetlands to grasslands and deserts. It involves understanding how different ecosystems function and how they contribute to overall ecological health.

Importance of Random Sampling in Determining Biodiversity

Random sampling is a fundamental technique in ecological studies for assessing biodiversity within a specific area. This method is crucial for several reasons:

1. **Minimizes Bias:** It ensures that every part of the study area has an equal chance of being sampled, which provides a more accurate representation of the overall biodiversity.