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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.

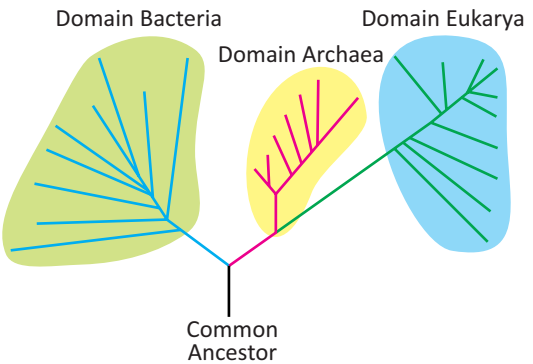


Figure 1.1: Evolutionary tree of the three domains

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.

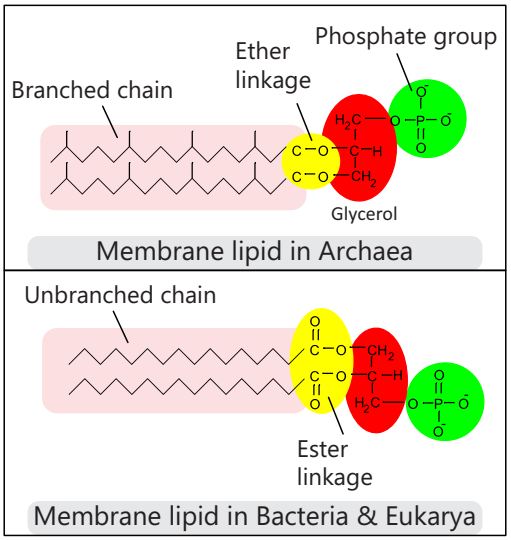


Figure 1.2: Difference in membrane lipids of Archaea and other organisms

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:

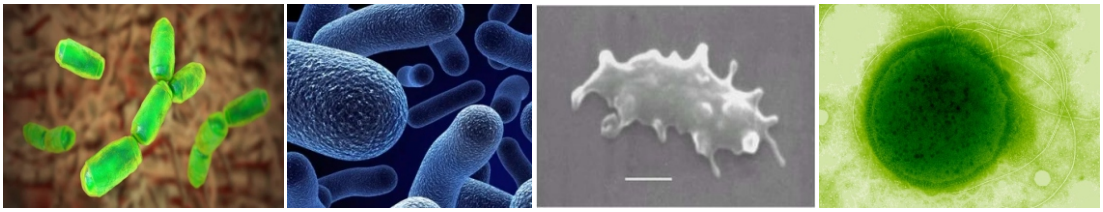
Archaea have unique metabolic processes like methanogenesis (production of methane), which is not found in bacteria or Eukarya.

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.

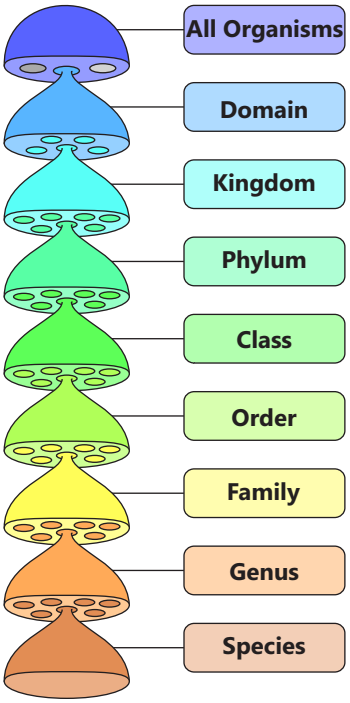


Figure 1.5: Taxonomic hierarchy

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