Unit I: Diversity of Living World

Chapter 1

Living World

Learning Objectives

The learner will be able to,

- *Differentiate living and non-living things.*
- *Appreciate the attributes of living organisms.*
- *Compare the different classifications proposed by biologists.*
- *Recognize the general characters, structure and reproduction of Bacteria.*
- *Identify the characteristic features of Archaebacteria, Cyanobacteria, Mycoplasma and Actinomycetes.*
- *Describe the characteristic features of fungi.*
- *Discuss the structure and uses of Mycorrhizae and Lichens.*

Chapter Outline

Earth was formed some 4.6 billion years ago. It is the life supporting planet with land forms like mountains, plateaus, glaciers, etc. Life on earth exists within a complex structure called **biosphere**. There exist many mysteries and wonders in the living world some are not

visible but the activity of some capture the attention of all. For example the response of sunflower to the sunlight, the twinkling firefly in the dark forest, the rolling water droplets on the surface of lotus leaf, the closure of the leaf of venus fly trap on insect touch and a squid squeezing ink to escape from its predator. From this it is clear that the wonder planet earth harbours both landforms and life forms. Have you thought of DNA molecule? It is essential for the regulation of life and is made up of carbon, hydrogen, oxygen, nitrogen and phosphorus. thus nonliving and living things exist together to make our planet unique.

5DCYJG

According to a survey made by Mora *et al.,* 2011 the number of estimated species on earth is 8.7 million. The living world includes microbes, plants, animals and human beings which possess unique and distinct characteristic feature.

1.1 Attributes of living organisms

The attributes of living organisms are given below and is represented in Figure 1.1.

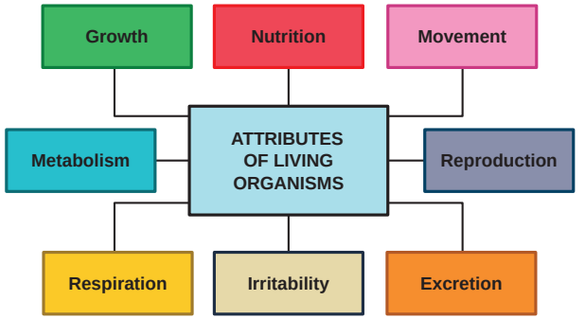


Figure 1.1: Attributes of living organisms

Growth

Growth is an intrinsic property of all living organisms through which they can increase cells both in number and mass. Unicellular and multicellular organisms grow by cell division. In plants, growth is indefinite and occurs throughout their life. In animals, growth is definite and occurs for some period. Growth in non-living objects is **extrinsic**. Mountains, boulders and sand mounds grow by simple aggregation of material on the surface. Living cells grow by the addition of new protoplasm within the cells. Therefore, growth in living thing is **intrinsic**. In unicellular organisms like Bacteria and Amoeba growth occurs by cell division and such cell division also leads to the growth of their population. Hence, growth and reproduction are mutually inclusive events.

Cellular structure

All living organisms are made up of cells which may be prokaryotic or eukaryotic. **Prokaryotes** are unicellular, lack membrane bound nuclei and organelles like mitochondria, endoplasmic reticulum, golgi bodies and so on (Example: Bacteria and Blue green algae). In **Eukaryotes** a definite nucleus and membrane bound organelles are present. Eukaryotes may be unicellular (*Amoeba*) or multicellular (*Oedogonium*).

Reproduction

Reproduction is one of the fundamental characteristic features of living organisms. It is the tendency of a living organism to perpetuate its own species. There are two types of reproduction namely asexual and sexual (Figure 1.2).

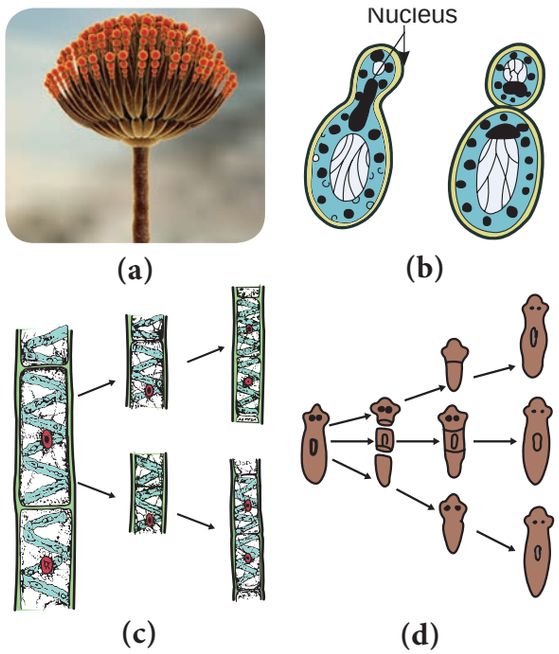


Figure 1.2: Types of Asexual Reproduction (a) Conidia formation-*Penicillium*, (b) Budding-Yeast, (c) Fragmentation-*Spirogyra,* (d) Regeneration-*Planaria*

Asexual reproduction refers to the production of the progeny possessing features more or less similar to those of parents. The sexual reproduction brings out variation through **recombination.** Asexual reproduction in living organisms occurs by the production of conidia (*Aspergillus, Penicillium*), budding (*Hydra* and Yeast), binary fission (Bacteria and *Amoeba*) fragmentation (*Spirogyra*), protonema (Mosses) and regeneration (*Planaria*). Exceptions are the sterile worker bees and mules.

Response to stimuli

All organisms are capable of sensing their environment and respond to various physical, chemical and biological stimuli. Animals sense

their surroundings by sense organs. This is called **Consciousness**. Plants also respond to the stimuli. Bending of plants towards sunlight, the closure of leaves in touch-me-not plant to touch are some examples for response to stimuli in plants. This type of response is called **Irritability.**

Homeostasis

Property of self-regulation and tendency to maintain a steady state within an external environment which is liable to change is called **Homeostasis**. It is essential for the living organism to maintain internal condition to survive in the environment.

Metabolism

The sum of all the chemical reactions taking place in a cell of living organism is called **metabolism**. It is broadly divided into **anabolism** and **catabolism.** The difference between anabolism and catabolism is given in Table 1.1.

Table 1.1: Difference between anabolism and catabolism

Anabolism	Catabolism
Building up process	Breaking down process
Smaller molecules combine together to form larger molecule	Larger molecule break into smaller units
Chemical energy is formed and stored	The stored chemical energy is released and used
Example: Synthesis of proteins from amino acids	Example: Breaking down of glucose to CO_2 and water

Movement, Nutrition, Respiration and Excretion are also considered as the property of living things. The levels of organization in living organism begin with atoms and end in **Biosphere**. Each level cannot exist in isolation instead they form levels of integration as given in Figure 1.3.

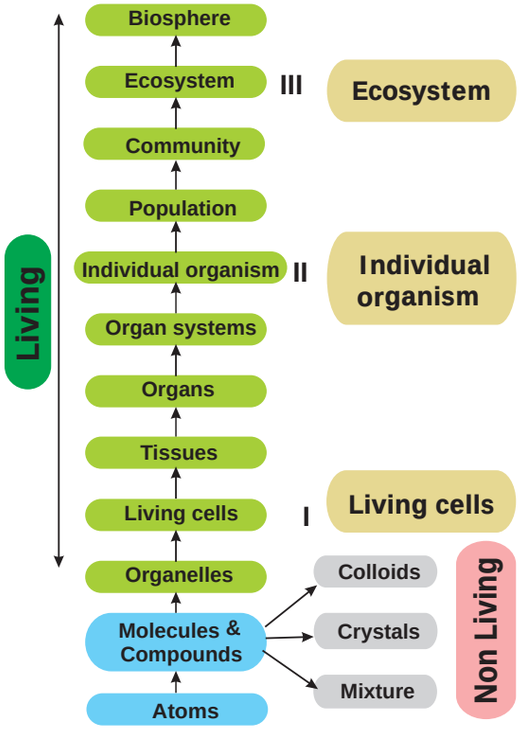


Figure 1.3: The levels of organization and integration in living organism

Activity 1.1

Collect *Vallisneria* leaves or *Chara* from nearby aquarium and observe a leaf or *Chara* thallus (internodal region)under the microscope. You could see cells clearly under the microscope. Could you notice the movement of cytoplasm? The movement of cytoplasm is called cytoplasmic streaming or **cyclosis**.

1.2 Viruses

Did you go through the headlines of newspapers in recent times? Have you heard of the terms EBOLA, ZIKA, AIDS, SARS, H1N1 etc.? There are serious entities which are considered as **"Biological Puzzle"** and cause disease in man. They are called viruses. We have learnt about the attributes of living world in the previous chapter. Now we shall discuss about viruses which connect the living and nonliving world.

The word virus is derived from Latin meaning 'Poison'. Viruses are sub-microscopic, obligate intracellular parasites. They have nucleic acid core surrounded by protein coat. Viruses in their native state contain only a single type of nucleic acid which may be either DNA or RNA. The study of viruses is called **Virology**.

An American Scientist obtained virus in crystallised form from infected tobacco juice in the year 1935. He was jointly awarded "Nobel Prize" with Dr. J.H. Northrop for Chemistry in 1946.

W.M. Stanley (1904-1971)

1.2.1 Milestones in Virology

1796 Edward Jenner used vaccination for small pox

1886 Adolf Mayer demonstrated the infectious nature of Tobacco mosaic virus using sap of mosaic leaves

1892 Dimitry Ivanowsky proved that viruses are smaller than bacteria

1898 M.W. Beijierink defined the infectious agent in tobacco leaves as '*Contagium vivum fluidum*'

1915 F.W.Twort identified Viral infection in Bacteria

1917 d'Herelle coined the term 'Bacteriophage'

1984 Luc Montagnier and Robert Gallo discovered HIV (Human Immuno Deficiency Virus).

1.2.2 Size and Shape

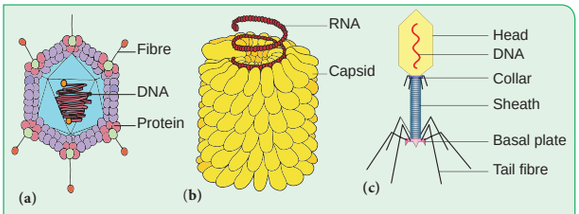
Viruses are ultramicroscopic particles. They are smaller than bacteria and their diameter range from 20 to 300 nm. (1nm = 10^{-9}metres). Bacteriophage measures about 10-100 nm in size. The size of TMV is 300×20 nm.

Generally viruses are of three types based on shape and symmetry (Figure 1.4).

i. Cuboid symmetry – Example: Adenovirus, Herpes virus.

ii. Helical symmetry – Example: Influenza virus, TMV.

iii. Complex or Atypical – Example: Bacteriophage, Vaccinia virus.



(a) Adenovirus, (b) Tobacco Mosaic virus, (c) T_4 Bacteriophage

Figure 1.4: Shapes of Viruses

1.2.3 Characteristic Features of Viruses

Living Characters

- Presence of nucleic acid and protein.
- Capable of mutation
- Ability to multiply within living cells.
- Able to infect and cause diseases in living beings.
- Show irritability.
- Host –specific

Non-living Characters

- Can be crystallized.
- Absence of metabolism.
- Inactive outside the host.
- Do not show functional autonomy.
- Energy producing enzyme system is absent.

1.2.4 Classification of Viruses

Among various classifications proposed for viruses the classification given by David Baltimore in the year 1971 is given below. The classification is based on mechanism of RNA production, the nature of the genome (single stranded –ss or double stranded - ds), RNA or DNA, the use of reverse transcriptase (RT), ss RNA may be (+) sense or (–) antisense. Viruses are classified into seven classes (Table 1.2).

Viral genome

Each virus possesses only one type of nucleic acid either DNA or RNA. The nucleic acid may be in a linear or circular form. Generally

nucleic acid is present as a single unit but in wound tumour virus and in influenza virus it is found in segments. The viruses possessing DNA are called **'Deoxyviruses'** whereas those possessing RNA are called **'Riboviruses'**. Majority of animal and bacterial viruses are DNA viruses (HIV is the animal virus which possess RNA). Plant viruses generally contain RNA (Cauliflower Mosaic virus possess DNA). The nucleic acids may be single stranded or double stranded. On the basis of nature of nucleic acid viruses are classified into four Categories. They are Viruses with ssDNA (Parvo viruses), dsDNA (Bacteriophages), ssRNA (TMV)and dsRNA(Wound Tumour Virus).

Table 1.2: Different Classes of viruses

Class	Example
Class 1 – Viruses with dsDNA	Adeno viruses
Class 2 –Viruses with (+) sense ssDNA	Parvo viruses
Class 3 – Viruses with dsRNA	Reo viruses
Class 4 – Viruses with (+)sense ssRNA	Toga viruses
Class 5 – Viruses with (−)sense ssRNA	Rhabdo viruses
Class 6 – Viruses with (+) sense ssRNA –RT: that replicate with DNA intermediate in life cycle	Retro viruses
Class 7 – Viruses with ds DNA –RT: that replicate with RNA intermediate in life cycle	Hepadna viruses

1.2.5 Tobacco Mosaic Virus (TMV)

Tobacco mosaic virus was discovered in 1892 by Dimitry Ivanowsky from the Tobacco plant. Viruses infect healthy plants through vectors like aphids, locusts etc. The first visible symptom of TMV is discoloration of leaf colour along the veins and show typical yellow and green mottling which is the mosaic symptom. The downward curling and distortion of young apical leaves occurs, plant becomes stunted and yield is affected.

Structure

Electron microscopic studies have revealed that TMV is a rod shaped (Figure 1.4b) helical virus measuring about 300x20nm with a molecular weight of $39x10^6$ Daltons. The virion is made up of two constituents, a protein coat called **capsid** and a core called **nucleic acid**. The protein coat is made up of approximately 2130 identical protein subunits called **capsomeres** which are present around a central single stranded RNA molecule. The genetic information necessary for the formation of a complete TMV particle is contained in its RNA. The RNA consists of 6,500 nucleotides.

1.2.6 Bacteriophage

Viruses infecting bacteria are called **Bacteriophages**. It literally means 'eaters of bacteria' (Gr: Phagein = to eat). Phages are abundant in soil, sewage water, fruits, vegetables, and milk.

Structure of T_4 bacteriophage

The T_4 phage is tadpole shaped and consists of head, collar, tail, base plate and fibres (Figure 1.4). The head is hexagonal which consists of about 2000 identical protein subunits. The long helical tail consists of an inner tubular core which is connected to the head by a collar. There is a base plate attached to the end of tail. The base plate contains six spikes and tail fibres. These fibres are used to attach the phage on the cell wall of bacterial host during replication. A dsDNA molecule of about 50 µm is tightly packed inside the head. The DNA is about 1000 times longer than the phage itself.

1.2.7 Multiplication or Life Cycle of Phages

Phages multiply through two different types of life cycle. a. Lytic or Virulent cycle b. Lysogenic or Avirulent life cycle.

a. Lytic Cycle

During lytic cycle of phage, disintegration of host bacterial cell occurs and the progeny virions are released (Figure 1.5a). The steps involved in the lytic cycle are as follows:

(i) Adsorption

Phage (T_4) particles interact with cell wall of host (*E. coli*). The phage tail makes contact between the two, and tail fibres recognize the specific receptor sites present on bacterial cell surface. The lipopolysaccharides of tail fibres act as receptor in phages. The process involving the recognition of phage to bacterium is called **landing**. Once the contact is established between tail fibres and bacterial cell, tail fibres bend to anchor the pins and base plate to the cell surface. This step is called **pinning.**

(ii) Penetration

The penetration process involves mechanical and enzymatic digestion of the cell wall of the host. At the recognition site phage digests certain cell wall structure by viral enzyme (lysozyme). After pinning the tail sheath contracts (using ATP) and appears shorter and thicker. After contraction of the base plate enlarges through which DNA is injected into the cell wall without using metabolic energy. The step involving injection of DNA particle alone into the bacterial cell is called **Transfection**. The empty protein coat leaving outside the cell is known as **'ghost'**.

(iii) Synthesis

This step involves the degradation of bacterial chromosome, protein synthesis and DNA replication. The phage nucleic acid takes over the host biosynthetic machinery. Host DNA gets inactivated and breaks down. Phage DNA suppresses the synthesis of bacterial protein and directs the metabolism of the cell to synthesis the proteins of the phage particles and simultaneously replication of Phage DNA also takes place.

(iv) Assembly and Maturation

The DNA of the phage and protein coat are synthesized separately and are assembled to form phage particles. The process of assembling the phage particles is known as **maturation**. After 20 minutes of infection, about 300 new phages are assembled.

(v) Release

The phage particle gets accumulated inside the host cell and are released by the lysis of host cell wall.

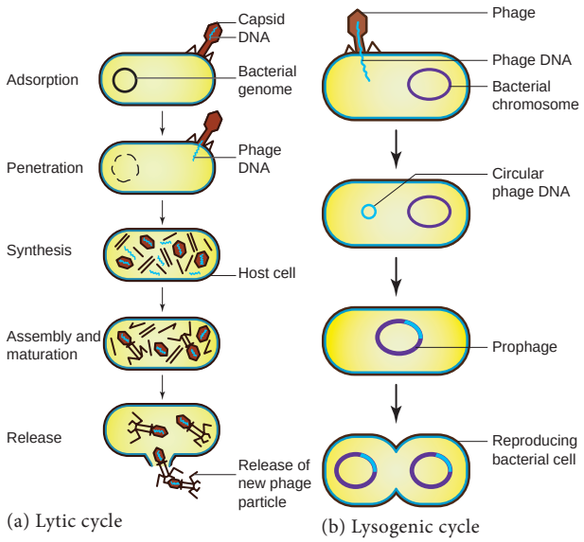


Figure 1.5: Multiplication cycle of phage

b. Lysogenic Cycle

In the lysogenic cycle the phage DNA gets integrated into host DNA and gets multiplied along with nucleic acid of the host. No independent viral particle is formed (Figure 1.5b).

As soon as the phage injects its linear DNA into the host cell, it becomes circular and integrates into the bacterial chromosome by recombination. The integrated phage DNA is now called **prophage.** The activity of the prophage gene is repressed by two repressor proteins which are synthesized by phage genes. This checks the synthesis of new phages within the host cell. However, each time the bacterial

Viruses infecting blue green algae are called **Cyanophages** and are first reported by Safferman and Morris in the year 1963(Example LPP1 - *Lyngbya, Plectonema* and *Phormidium*). Similarly, Hollings(1962) reported viruses infecting cultivated Mushrooms and causing die back disease. The viruses attacking fungi are called **Mycoviruses** or **Mycophages.**

cell divides, the prophage multiplies along with the bacterial chromosome. On exposure to UV radiation and chemicals the excision of phage DNA may occur and results in lytic cycle.

Virion is an intact infective virus particle which is non-replicating outside a host cell.

Viroid is a circular molecule of ssRNA without a capsid and was discovered by T.O.Diener in the year 1971. The RNA of viroid has low molecular weight. Viroids cause citrus exocortis and potato spindle tuber disease in plants.

Virusoids were discovered by J.W.Randles and Co-workers in 1981.They are the small circular RNAs which are similar to viroids but they are always linked with larger molecules of the viral RNA.

Prions were discovered by Stanley B. Prusiner in the year 1982 and are proteinaceous infectious particles. They are the causative agents for about a dozen fatal degenerative disorders of the central nervous system of humans and other animals. For example Creutzfeldt – Jakob Disease (CJD), Bovine Spongiform Encephalopathy (BSE) – commonly known as mad cow disease and scrapie disease of sheep.

1.2.8 Viral diseases

Viruses are known to cause disease in plants, animals and Human beings (Figure 1.6). A list of viral disease is given in Table 1.3.

Figure 1.6: Viral diseases (a) Mosaic disease of tomato, (b) Symptom of Chicken pox

Streaks on Tulip flowers are due to Tulip Breaking Virus which belong to Potyviridae group.

Viruses of Baculoviridae group are commercially exploited as insecticides. Cytoplasmic Polyhedrosis Granulo viruses and Entomopox viruses were employed as potential insecticides.

Table 1.3: Viral diseases

Plant diseases	Animal diseases	Human diseases
1.Tobacco mosaic 2. Cauliflower mosaic 3. Sugarcane mosaic 4. Potato leaf roll 5. Bunchy top of banana 6. Leaf curl of papaya 7. Vein clearing of Lady's finger 8. Rice Tungro disease 9. Cucumber mosaic 10. Tomato mosaic disease	1. Foot and mouth disease of cattle 2. Rabies of dog 3. Encephalomyelitis of horse	1. Common cold 2. Hepatitis B 3. Cancer 4. SARS(Severe Acute Respiratory Syndrome) 5. AIDS(Acquired Immuno Deficiency Syndrome) 6. Rabies 7. Mumps 8. Polio 9. Chikungunya 10. Small Pox 11. Chicken pox 12. Measles

1.3 Classification of Living World

From the previous chapter we know that the planet earth is endowed with living and non -living things. In our daily life we see several things in and around us. Imagine, you are on a trip to Hill station. You are enjoying the beauty of mountains, dazzling colour of the flowers, and melodious sound of the birds. You may be capturing most of the things you come across in the form of photography. Now, from this experience can you mention the objects you have come across? Can you record your observations and tabulate them?. How will you organize the things? Will you place mountain and flowers together or tall trees and trailing herbs in one category or place it in different category? If you place it in different category, what made you to place them in different category? So classification is essential and could be done only by understanding and comparing the things based on some characters. In this chapter we shall learn about classification of living world.

Many attempts have made in the past to classify the organisms on earth. **Theophrastus**, "Father of Botany" used the morphological characters to classify plants into trees, shrubs and herbs. Aristotle classified animals into two groups. i.e., *Enaima* (with red blood) and *Anaima* (without red blood).

Carl Linnaeus classified living world into two groups namely Plants and Animals based on morphological characters. His classification faced major setback because Prokaryotes and Eukaryotes were grouped together. Similarly fungi, heterotrophic organisms were placed along with the photosynthetic plants. In course of time, the development of tools compelled taxonomists to look for different areas like cytology, anatomy, embryology, molecular biology, phylogeny etc., for classifying organisms on earth. Thus, new dimensions to classifications were put forth from time to time.

1.3.1 Need of Classification

Classification is essential to achieve following needs.

- To relate things based on common characteristic features.
- To define organisms based on the salient features.
- Helps in knowing the relationship amongst different groups of organisms.
- It helps in understanding the evolutionary relationship between organisms.

1.3.2 Classification of Living World

A comparison of classification proposed for classification of living world is given in Table 1.4.

1.3.3 Five Kingdom Classification

R.H.Whittaker, an American taxonomist proposed five Kingdom classification in the year 1969. The Kingdoms include **Monera,**

Table 1.4: Systems of Classification

Two Kingdom	Three Kingdom	Four Kingdom	Five Kingdom
 **Carl Linnaeus (1735)**	 **Ernst Haeckel (1866)**	 **Copeland (1956)**	 **R.H. Whittaker (1969)**
1. Plantae 2. Animalia	1. Protista 2. Plantae 3. Animalia	1. Monera 2. Protista 3. Plantae 4. Animalia	1. Monera 2. Protista 3. Fungi 4. Plantae 5. Animalia

Table 1.5: Comparison of Five Kingdoms

Criteria	Kingdom				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Level of organization	Mostly Unicellular, rarely multicellur	Unicellular	Multicellular and unicellular	Tissue/organ	Tissue/organ/organ system
Cell wall	Present (made up of Peptidoglycan and Mucopeptides)	Present in some (made up of cellulose), absent in others	Present (made up of chitin or cellulose)	Present (made up of cellulose)	absent
Nutrition	Autotrophic (Phototrophic, Chemoautotrophic) Heterotrophic (parasitic and saprophytic)	Autotrophic-Photosynthetic. Heterotrophic	Heterotrophic-parasitic or Saprophytic	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic)
Motility	Motile or non-motile	Motile or non-motile	Non-motile	Mostly Non-motile	Mostly motile
Organisms	Archaebacteria, Eubacteria, Cyanobacteria, Actinomycetes and Mycoplasma	Chrysophytes, Dinoflagellates, Euglenoids, Slime molds, *Amoeba, Plasmodium, Trypanosoma, Paramecium*	Yeast, Mushrooms and Molds	Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms	Sponges, Invertebrates and Vertebrates

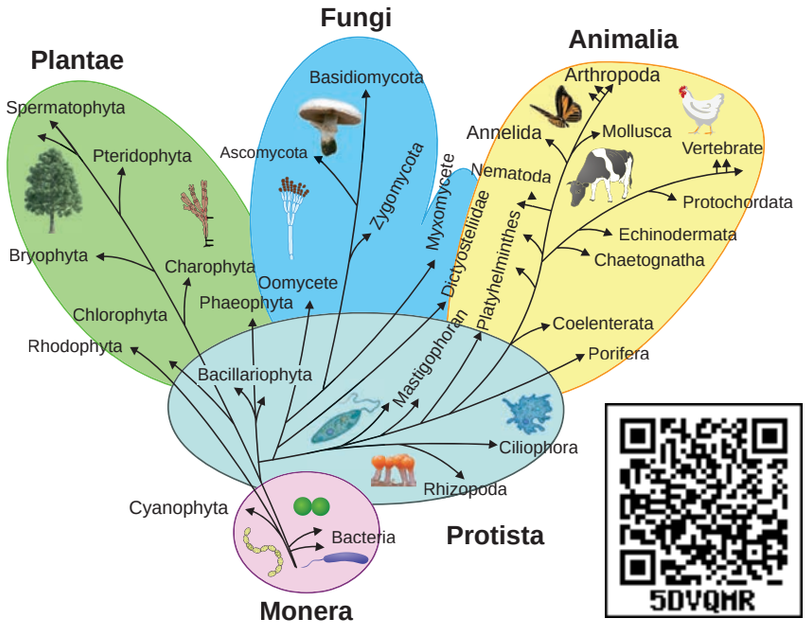


Figure 1.7: Five Kingdom Classification

Protista, Fungi, Plantae and Animalia (Figure 1.7). The criteria adopted for the classification include cell structure, thallus organization, mode of nutrition, reproduction and phylogenetic relationship**.** A comparative account of the salient features of each Kingdom is given in Table 1.5

Merits

- The classification is based on the complexity of cell structure and organization of thallus.
- It is based on the mode of nutrition
- Separation of fungi from plants
- It shows the phylogeny of the organisms

Demerits

- The Kingdom Monera and protista accommodate both autotrophic and heterotrophic organisms, cell wall lacking and cell wall bearing organisms thus making these two groups more heterogeneous.
- Viruses were not included in the system.

Carl Woese and co-workers in the year 1990 introduced three domains of life *viz.,* **Bacteria**, **Archaea** and **Eukarya** based on the difference in rRNA nucleotide sequence, lipid structure of the cell membrane. A revised six Kingdom classification for living world was proposed by Thomas Cavalier-Smith in the year 1998 and the Kingdom **Monera** is divided in to **Archaebacteria** and **Eubacteria.** Recently Ruggierio *et al.*, 2015 published a seven Kingdom classification which is a practical extension of Thomas Cavalier's six Kingdom scheme. According to this classification there are two Super Kingdoms. (**Prokaryota** and **Eukaryota**) **Prokaryota** includes two Kingdoms namely **Archaebacteria** and **Eubacteria.** Eukaryota includes the **Protozoa, Chromista, Fungi, Plantae** and **Animalia.** A new Kingdom, the **Chromista** was erected and it included all algae whose chloroplasts contain chlorophyll a and c, as well as various colourless forms that are closely related to them. Diatoms, Brown algae, Cryptomonads and Oomycetes were placed under this Kingdom.

Activity 1.2

Visit to a pond and record the names of the biotic components of it with the help of your teacher. Tabulate the data and segregate them according to Five Kingdom Classification.

Red tide is caused by toxic bloom of Dinoflagellates like *Gymnodinium breve* and *Gonyaulax tamarensis*.

A major red tide incident in west coast of Florida in the year 1982 killed Hundreds and thousands of fishes.

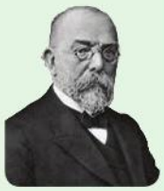
1.4 Bacteria

Bacteria Friends or Foes?

Have you noticed the preparation of curd in our home? A little drop of curd turns the milk into curd after some time. What is responsible for this change? Why it Sours? The change is brought by *Lactobacillus lactis*, a bacterium present in the curd. The sourness is due to the formation of Lactic

acid. Have you been a victim of Typhoid? It is a bacterial disease caused by *Salmonella typhi,* a bacterium. So we can consider this prokaryotic organism as friend and foe, due to their beneficial and harmful activities.

Robert Koch (1843–1910)



Robert Heinrich Hermann Koch was a German physician and microbiologist. He is considered as the founder of modern bacteriology.

He identified the causal organism for Anthrax, Cholera and Tuberculosis. The experimental evidence for the concept of infection was proved by him (Koch's postulates). He was awarded Nobel prize in Medicine/Physiology in the year 1905.

1.4.1 Milestones in Bacteriology

1829 C.G. Ehrenberg coined the term Bacterium

1884 Christian Gram introduced Gram staining method

1923 David H. Bergy published First edition of Bergey's Manual

1928 Fredrick Griffith discovered Bacterial transformation

1952 Joshua Lederberg discovered of Plasmid

Bacteria are prokaryotic, unicellular, ubiquitous, microscopic organisms. The study of Bacteria is called Bacteriology. Bacteria were first discovered by a Dutch scientist, Anton van Leeuwenhoek in 1676 and were called "animalcules".

1.4.2 General characteristic features of Bacteria

- They are Prokaryotic organisms and lack nuclear membrane and membrane bound organelles.
- The Genetic material is called **nucleoid** or **genophore** or **incipient nucleus**
- The cell wall is made up of Polysaccharides and proteins
- Most of them lack chlorophyll, hence they are heterotrophic (*Vibrio cholerae*) but some are autotrophic and possess Bacteriochlorophyll (*Chromatium*)
- They reproduce vegetatively by Binary fission and endospore formation.
- They exhibit variations which are due to genetic recombination and is achieved through conjugation, transformation and transduction.

The shape and flagellation of the bacteria varies and is given in Figure 1.8.

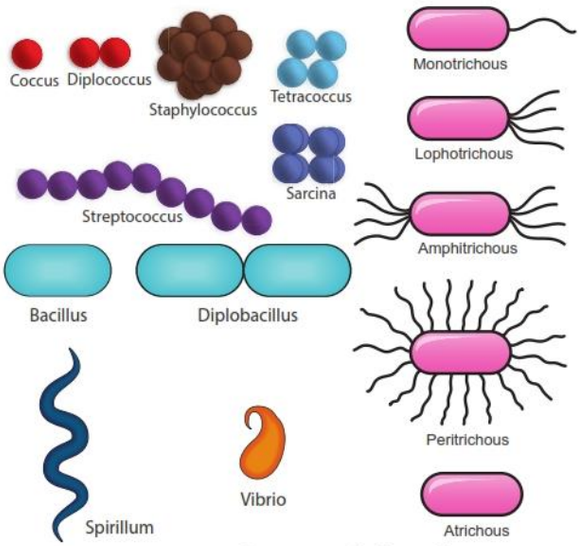


Figure 1.8: Shape and flagellation in bacteria

1.4.3 Ultrastructure of a Bacterial cell

The bacterial cell reveals three layers (i) Capsule/Glycocalyx (ii) Cell wall and (iii) Cytoplasm (Figure 1.9).

Capsule/Glycocalyx

Some bacteria are surrounded by a gelatinous substance which is composed of polysaccharides or polypeptide or both. A thick layer of **glycocalyx** bound tightly to the

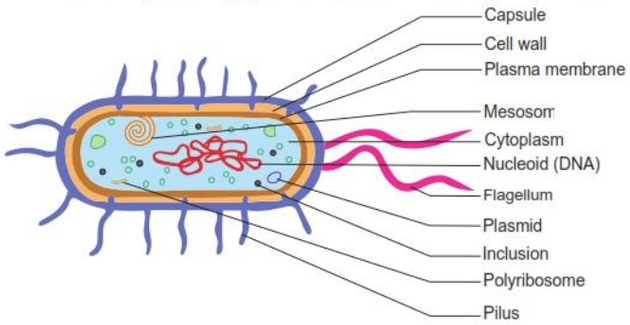


Figure 1.9: Ultrastructure of a bacterial cell

cell wall is called **capsule**. It protects cell from desiccation and antibiotics. The sticky nature helps them to attach to substrates like plant root surfaces, Human teeth and tissues. It helps to retain the nutrients in bacterial cell.

Duodenal and Gastric ulcers are caused by *Helicobacter pylori*, a Gram negative bacterium

- Bt toxin from *Bacillus thuringiensis* finds application in raising insect resistant crops (Bt Crops).

Cell wall

The bacterial cell wall is granular and is rigid. It provides protection and gives shape to the cell. The chemical composition of cell wall is rather complex and is made up of peptidoglycan or mucopeptide (N-acetyl glucosamine, N-acetyl muramic acid and peptide chain of 4 or 5 aminoacids). One of the most abundant polypeptide called porin is present and it helps in the diffusion of solutes.

Plasma membrane

The plasma membrane is made up of lipoprotein. It controls the entry and exit of small molecules and ions. The enzymes involved in the oxidation of metabolites (i.e., the respiratory chain) as well as the photosystems used in photosynthesis are present in the plasma membrane.

Cytoplasm

Cytoplasm is thick and semitransparent. It contains ribosomes and other cell inclusions. Cytoplasmic inclusions like glycogen, poly-β-hydroxybutyrate granules, sulphur granules and gas vesicles are present.

Bacterial chromosome

The bacterial chromosome is a single circular DNA molecule, tightly coiled and is not enclosed in a membrane as in Eukaryotes. This genetic material is called **Nucleoid or Genophore.** It is amazing to note that the DNA of *E.coli* which measures about 1mm long when uncoiled, contains all the genetic information of the organism. The DNA is not bound to **histone** proteins. The single chromosome or the DNA molecule is circular and at one point it is attached to the plasma membrane and it is believed that this attachment may help in the separation of two chromosomes after DNA replication.

Plasmid

Plasmids are extra chromosomal double stranded, circular, self-replicating, autonomous elements. The size of a plasmid varies from 1 to 500 kb usually plasmids contribute to about 0.5 to 5.0% of the total DNA of bacteria. They contain genes for fertility, antibiotic resistant and heavy metals. It also help in the production of bacteriocins and toxins which are not found in bacterial chromosome. The number of plasmids per cell varies. Plasmids are classified into different types based on the function. Some of them are F (Fertility) factor, R (Resistance) plasmids, Col (Colicin) plasmids, Ri (Root inducing) plasmids and Ti (Tumour inducing) plasmids.

Mesosomes

These are localized infoldings of plasma membrane produced into the cell in the form of vesicles, tubules and lamellae. They are clumped and folded together to maximize their surface area and helps in respiration and in binary fission.

Polysomes / Polyribosomes

The ribosomes are the site of protein synthesis. The number of ribosome per cell varies from 10,000 to 15,000. The ribosomes are 70S type and consists of two subunits (50S and 30S). The ribosomes are held together by mRNA and form polyribosomes or polysomes.

Flagella

Certain motile bacteria have numerous thin hair like projections of variable length emerge from the cell wall called flagella. It is 20–30 μm in diameter and 15 μm in length. The flagella of Eukaryotic cells contain 9+2 microtubles

but each flagellum in bacteria is made up of a single fibril. Flagella are used for locomotion. Based on the number and position of flagella there are different types of bacteria (Figure 1.8)

Fimbriae or Pili

Pili or fimbriae are hair like appendages found on surface of cell wall of gram-negative bacteria (Example: *Enterobacterium*). The pili are 0.2 to 20 µm long with a diameter of about 0.025µm. In addition to normal pili there are special type of pili which help in conjugation called sex pili are also found.

1.4.4 Gram staining procedure

The Gram staining method to differentiate bacteria was developed by Danish Physician Christian Gram in the year1884. It is a differential staining procedure and it classifies bacteria into two classes - Gram positive and Gram negative. The steps involved in Gram staining procedure is given in Figure 1.10. The Gram positive bacteria retain crystal violet and appear dark violet whereas Gram negative type loose the crystal violet and when counterstained by safranin appear red under a microscope.

Most of the gram positive cell wall contain considerable amount of teichoic acid and teichuronic acid. In addition, they may contain

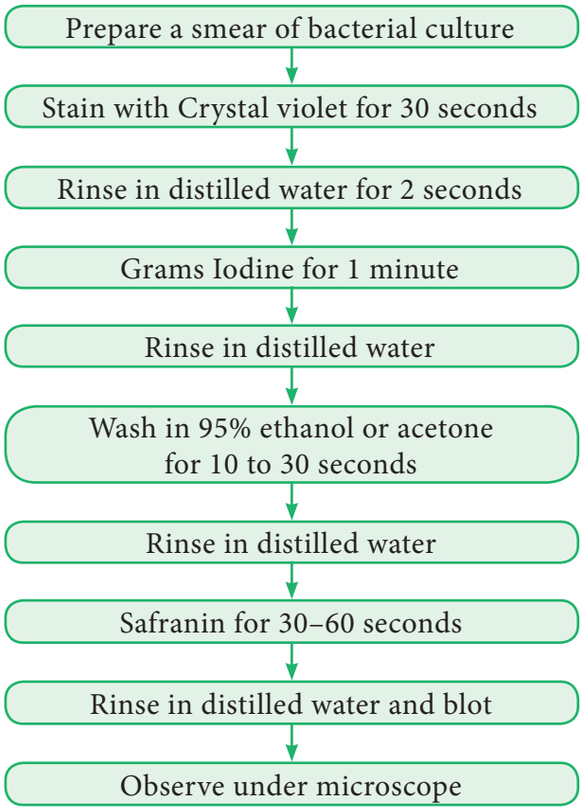


Figure 1.10: Steps involved in Gram Staining

polysaccharide molecules. The gram negative cell wall contains three components that lie outside the peptidoglycan layer. 1. Lipoprotein 2. Outer membrane 3.Lipopolysaccharide. Thus the different results in the gram stain

Table 1.6: Difference between Gram Positive and Gram Negative Bacteria

S. No.	Characteristics	Gram positive Bacteria	Gram negative Bacteria
1.	Cell wall	Thick layered with (0.015 µm-0.02µm)	Thin layered with (0.0075µm–0.012µm)
2.	Rigidity of cell wall	Rigid due to presence of Peptidoglycans	Elastic due to presence of lipoprotein-polysaccharide mixture
3.	Chemical composition	Peptidoglycans-80% Polysaccharide-20% Teichoic acid present	Peptidoglycans-3 to 12% rest is polysaccharides and lipoproteins. Teichoic acid absent
4.	Outer membrane	Absent	Present
5.	Periplasmic space	Absent	Present
6.	Susceptibility to penicillin	Highly susceptible	Low susceptible
7.	Nutritional requirements	Relatively complex	Relatively simple
8.	Flagella	Contain 2 basal body rings	Contain 4 basal body rings
9.	Lipid and lipoproteins	Low	High
10.	Lipopolysaccharides	Absent	Present

are due to differences in the structure and composition of the cell wall. The difference between Gram Positive and Gram negative bacteria is given in Table 1.6.

What are Magnetosomes ?

Intracellular chains of 40-50 magnetite (Fe_3O_4) particles are found in bacterium *Aquaspirillum magnetotacticum*. and it help the bacterium to locate nutrient rich sediments.

1.4.5 Life processes in Bacteria

Respiration

Two types of respiration are found in Bacteria. They are 1. Aerobic respiration 2. Anaerobic respiration.

1. Aerobic respiration

These bacteria require oxygen as terminal acceptor and will not grow under anaerobic conditions. (i.e. in the absence of O_2) **Example:** *Streptococcus.*

Obligate aerobes

Some *Micrococcus* **species** are obligate aerobes (i.e. they must have oxygen to survive).

2. Anaerobic respiration

These bacteria do not use oxygen for growth and metabolism but obtain their energy from fermentation reactions.**Example:** *Clostridium.*

Facultative anaerobes

There are bacteria that can grow either using oxygen as a terminal electron acceptor or anaerobically using fermentation reaction to obtain energy. When a facultative anaerobe such as *E. coli* is present at a site of infection like an abdominal abscess, it can rapidly consume all available O_2 and change to anaerobic metabolism producing an anaerobic environment and thus allow the anaerobic bacteria that are present to grow and cause disease. **Example:** *Escherichia coli* and *Salmonella.*

Capnophilic Bacteria

Bacteria which require CO_2 for their growth are called as capnophilic bacteria. **Example:** *Campylobacter.*

Nutrition

On the basis of their mode of nutrition bacteria are classified into two types namely autotrophs and heterotrophs.

I Autotrophic Bacteria

Bacteria which can synthesise their own food are called autotrophic bacteria. They may be further subdivided as

A. Photoautotrophic bacteria

Bacteria use sunlight as their source of energy to synthesize food. They may be

1. Photolithotrophs

In photolithotrophs the hydrogen donor is an inorganic substance.

a. Green sulphur bacteria: In this type of bacteria the hydrogen donor is H_2S and possess pigment called **Bacterioviridin.** Example: *Chlorobium.*

b. Purple sulphur bacteria: For bacteria belong to this group the hydrogen donor is thiosulphate, **Bacteriochlorophyll** is present**.** Chlorophyll containing chlorosomes are present Example: *Chromatium*.

2. Photoorganotrophs

They utilize organic acid or alcohol as hydrogen donor. Example: Purple non sulphur bacteria – *Rhodospirillum.*

B. Chemoautotrophic bacteria

They do not have photosynthetic pigment hence they cannot use sunlight energy. This type of bacteria obtain energy from organic or inorganic substance.

1. Chemolithotrophs

This type of bacteria oxidize inorganic compound to release energy.

Examples:

1. Sulphur bacteria - *Thiobacillus thiooxidans*
2. Iron bacteria - *Ferrobacillus ferrooxidans*
3. Hydrogen bacteria - *Hydrogenomonas*
4. Nitrifying bacteria - *Nitrosomonas* and *Nitrobacter*

2. Chemoorganotrophs

This type of bacteria oxidize organic compounds to release energy.

Examples:

1. Methane bacteria – *Methanococcus*
2. Acetic acid bacteria – *Acetobacter*
3. Lactic acid bacteria – *Lactobacillus*

II. Heterotrophic Bacteria

They are Parasites (*Mycobacterium*) Saprophytes (*Bacillus mycoides*) or Symbiotic *(Rhizobium* in root nodules of leguminous crops).

1.4.6 Reproduction in Bacteria

Bacteria reproduces asexually by binary fission, conidia and endospore formation (Figure 1.11). Among these, binary fission is the most common one.

Binary fission

Under favourable conditions the cell divides into two daughter cells. The nuclear material divides first and it is followed by the formation of a simple median constriction which finally results in the separation of two cells.

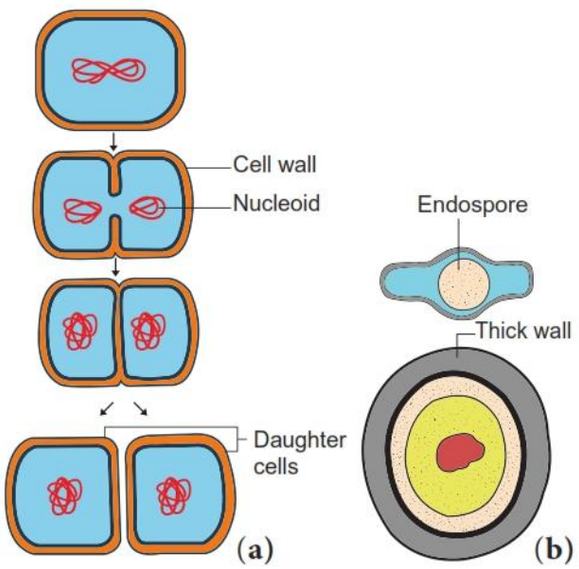


Figure 1.11: Asexual Reproduction in Bacteria (a) Binary fission, (b) Endospore

Endospores

During unfavourable condition bacteria produce endospores. Endospores are produced in *Bacillus megaterium*, *Bacillus sphaericus* and *Clostridium tetani.* Endospores are thick walled resting spores. During favourable condition, they germinate and form bacteria.

Sexual Reproduction

Typical sexual reproduction involving the formation and fusion of gametes is absent in bacteria. However gene recombination can occur in bacteria by three different methods they are

1. Conjugation
2. Transformation
3. Transduction

1. Conjugation

J. Lederberg and Edward L. Tatum demonstrated conjugation in *E. coli.* in the year 1946. In this method of gene transfer the donor cell gets attached to the recipient cell with the help of pili. The pilus grows in size and forms the conjugation tube. The plasmid of donor cell which has the F^+ (fertility factor) undergoes replication. Only one strand of DNA is transferred to the recipient cell through conjugation tube. The recipient completes the structure of double stranded DNA by synthesizing the strand that complements the strand acquired from the donor (Figure 1.12).

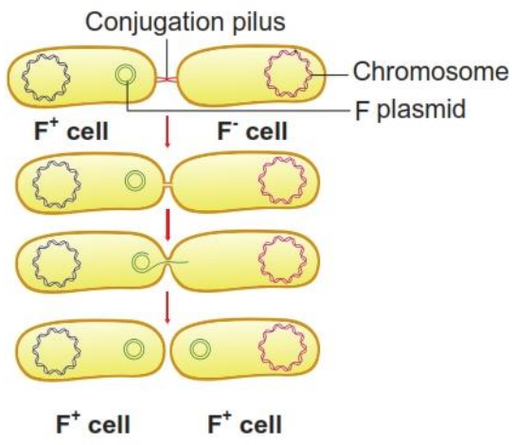


Figure 1.12: Conjugation

2. Transformation

Transfer of DNA from one bacterium to another is called transformation (Figure 1.13). In 1928 the bacteriologist Frederick Griffith

demonstrated transformation in Mice using *Diplococcus pneumoniae*. Two strains of this bacterium are present. One strain produces smooth colonies and are virulent in nature (S-type). In addition another strain produce rough colonies and are avirulent (R-type). When S-type of cells were injected into the mouse, the mouse died. When R-type of cells were injected, the mouse survived. He injected heat killed S-type cells into the mouse. The mouse did not die. When the mixture of heat killed S-type cells and R-type cells were injected into the mouse, the mouse died. The avirulent rough strain of *Diplococcus* had been transformed into S-type cells. The hereditary material of heat killed S-type cells had transformed R-type cell into virulent smooth strains. Thus the phenomenon of changing the character of one strain by transferring the DNA of another strain into the former is called Transformation.

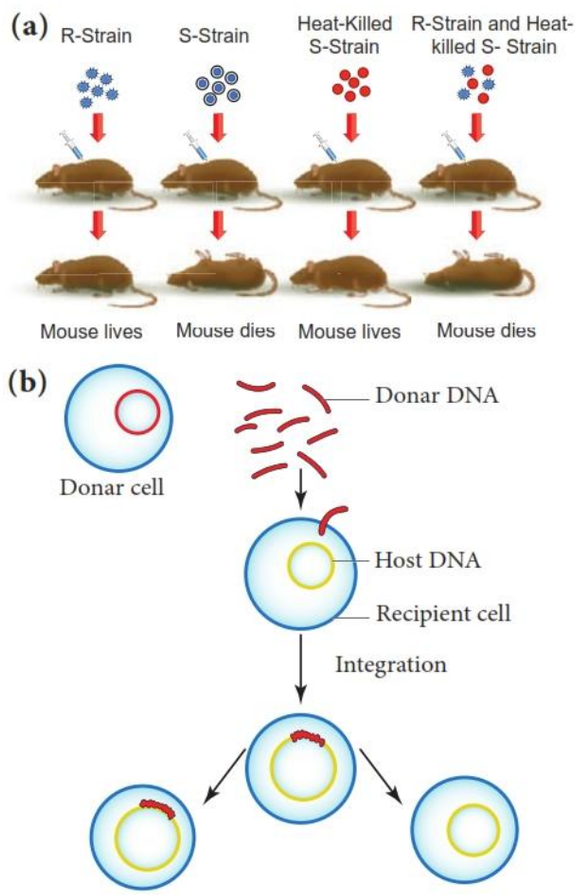


Figure 1.13: Transformation in Bacteria
(a) Griffith's experiment on Transformation
(b) Mechanism of Transformation

3. Transduction

Zinder and Lederberg (1952) discovered Transduction in *Salmonella typhimurum*. Phage mediated DNA transfer is called Transduction (Figure 1.14).

Transduction is of two types

(i) Generalized transduction (ii) Specialized or Restricted transduction

(i) Generalized Transduction

The ability of a bacteriophage to carry genetic material of any region of bacterial DNA is called generalised transduction.

(ii) **Specialized or Restricted Transduction**

The ability of the bacteriophage to carry only a specific region of the bacterial DNA is called specialized or restricted transduction.

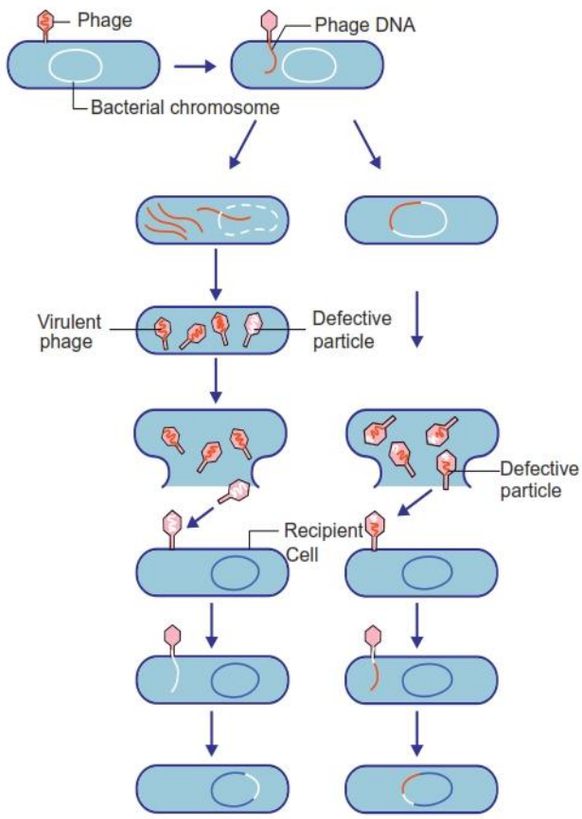


Figure 1.14: Transduction in Bacteria

1.4.7 Economic importance of Bacteria

Bacteria are both beneficial and harmful. The beneficial activities of bacteria are given in table 1.7.

Table 1.7: Economic importance of Bacteria

Beneficial aspects	Bacteria	Role
1. Soil fertility		
Ammonification	1. *Bacillus ramosus* 2. *Bacillus mycoides*	Convert complex proteins in the dead bodies of plants and animals into ammonia which is later converted into ammonium salt
Nitrification	1. *Nitrobacter* 2. *Nitrosomonas*	Convert ammonium salts into nitrites and nitrates
Nitrogen fixation	1. *Azotobacter* 2. *Clostridium* 3. *Rhizobium*	(i) Converting atmospheric nitrogen into organic nitrogen (ii) The nitrogenous compounds are also oxidized to nitrogen (iii) All these activities of bacteria increase soil fertility
2. Antibiotics		
1. Streptomycin	*Streptomyces griseus*	It cures urinary infections, tuberculosis, meningitis and pneumonia
2. Aureomycin	*Streptomyces aureofaciens*	It is used as a medicine to treat whooping cough and eye infections
3. Chloromycetin	*Streptomyces venezuelae*	It cure typhoid fever
4. Bacitracin	*Bacillus licheniformis*	It is used to treat syphilis
5. Polymyxin	*Bacillus polymyxa*	It cure some bacterial diseases
3. Industrial Uses		
1. Lactic acid	*Lactobacillus lactis* and *Lactobacillus bulgaricus*	Convert milk sugar lactose into lactic acid
2. Butter	*Lactococcus lactis, Leuconostoc citrovorum*	Convert milk into butter, cheese, curd and yoghurt
3. cheese	*Lactobacillus acidophilus, Lactobacillus lactis*	
4. Curd	*Lactobacillus lactis*	
5. Yoghurt	*Lactobacillus bulgaricus*	
6. Vinegar (Acetic acid)	*Acetobacter aceti*	This bacteria oxidizes ethyl alcohol obtained from molasses by fermentation to vinegar(acetic acid)
7. Alcohol and Acetone (i) Butyl alcohol (ii) Methyl alcohol	*Clostridium acetobutylicum*	Alcohols and acetones are prepared from molasses by fermentation activity of the anaerobic bacterium.
8. Retting of fibres	*Clostridium tertium*	The fibres from the fibre yielding plants are separated by the action of *Clostridium* is called retting of fibres.
9. Vitamins	*Escherichia coli*	Living in the intestine of human beings produce large quantities of vitamin K and vitamin B complex.
	Clostridium acetobutylicum	Vitamins B_2 is prepared by the fermentation of sugar.
10. Curing of Tea and Tobacco	*Micrococcus candicans, Bacillus megatherium*	The special flavor and aroma of the tea and tobacco are due to fermentation.

Bacteria are known to cause disease in plants, animals and Human beings. The List is given in Table 1.8, 1.9, 1.10 and Figure 1.15.

Table 1.8: Plant diseases caused by Bacteria

S.No.	Name of the Host	Name of the disease	Name of the pathogen
1	Rice	Bacterial blight	*Xanthomonas oryzae*
2	Apple	Fire blight	*Erwinia amylovora*
3	Carrot	Soft rot	*Erwinia caratovora*
4	Citrus	Citrus canker	*Xanthomonas citri*
5	Cotton	Angular leaf spot	*Xanthomonas malvacearum*
6	Potato	Ring rot	*Clavibacter michiganensis* subsp. *sepedonicus*
7	Potato	Scab	*Streptomyces scabies*

Table 1.9: Animal diseases caused by Bacteria

S. No	Name of the Animal	Name of the disease	Name of the pathogen
1.	Sheep	Anthrax	*Bacillus anthracis*
2.	Cattle	Brucellosis	*Brucella abortus*
3.	Cattle	Bovine tuberculosis	*Mycobacterium bovis*
4.	Cattle	Black leg	*Clostridium chauvoei*

Table 1.10: Human diseases caused by Bacteria

Serial No.	Name of the disease	Name of the pathogen
1.	Cholera	*Vibrio cholerae*
2.	Typhoid	*Salmonella typhi*
3.	Tuberculosis	*Mycobacterium tuberculosis*
4.	Leprosy	*Mycobacterium leprae*
5.	Pneumonia	*Diplococcus pneumoniae*
6.	Plague	*Yersinia pestis*
7.	Diphtheria	*Corynebacterium diptheriae*
8.	Tetanus	*Clostridium tetani*
9.	Food poisoning	*Clostridium botulinum*
10.	Syphilis	*Treponema pallidum*

(a) (b)

Figure 1.15: Plant diseases caused by bacteria (a) Citrus canker (b) Potato scab

Have you heard about the word "Probiotics"

Probiotic milk products and tooth paste are available in the market. *Lactobacillus and Bifidobacterium* are used to prepare probiotic yoghurt and tooth paste

Activity 1.3

Collect some root nodules of leguminous crops. Draw diagram. Wash it in tap water and prepare a smear by squeezing the content into a clean slide. Follow Gram staining method and identify the bacteria.

Bacteria forms Biofilms and leads to dental caries and Urinary tract infection (UTI)

Ralstonia synthesize PHB (Poly-β-hydroxyl butyrate) a microbial plastic which is biodegradable.

1.4.8 Archaebacteria

Archaebacteria are primitive prokaryotes and are adapted to thrive in extreme environments like hot springs, high salinity, low pH and so

on. They are mostly chemoautotrophs. The unique feature of this group is the presence of lipids like glycerol & isopropyl ethers in their cell membrane. Due to the unique chemical composition the cell membrane show resistance against cell wall antibiotics and lytic agents. Example: *Methanobacterium, Halobacterium, Thermoplasma*.

1.4.9 Cyanobacteria (Blue Green Algae)

How old are Cyanobacteria ?
Stromatolites reveals the truth.

Stromatolites are deposits formed when colonies of cyanobacteria bind with calcium carbonate. They have a geological age of 2.7 billion years. Their abundance in the fossil record indicates that cyanobacteria helped in raising the level of free oxygen in the atmosphere.

- *Pseudomonas putida* is a superbug genetically engineered which breakdown hydrocarbons.
- "Pruteen" is a single cell protein derived from *Methylophilus methylotrophus*.
- *Agrobacterium tumefaciens* cause crown gall disease in plants but its inherent tumour inducing principle helps to carry the desired gene into the plant through Genetic engineering.
- *Thermus aquaticus* is a thermophilic gram negative bacteria which produces Taq Polymerase a key enzyme for Polymerase Chain Reaction (PCR).
- *Methanobacterium* is employed in biogas production. *Halobacterium*, an extremophilic bacterium grows in high salinity. It is exploited for the production β carotene.

Cyanobacteria are popularly called as 'Blue green algae' or 'Cyanophyceae'. They are photosynthetic, prokaryotic organisms. According to evolutionary record Cyanobacteria are primitive forms and are found in different habitats. Most of them are fresh water and few are marine (*Trichodesmium* and *Dermacarpa*) *Trichodesmium erythraeum* a cyanobacterium imparts red colour to Red sea. Species of *Nostoc*, *Anabaena* lead an endophytic life in the coralloid root of *Cycas*, leaves of aquatic fern *Azolla* by establishing a symbiotic association and fix atmospheric nitrogen. Members like *Gloeocapsa, Nostoc*, *Scytonema* are found as phycobionts in lichen thalli.

Salient features

- The members of this group are prokaryotes and lack motile reproductive structures.
- The thallus is unicellular in *Chroococcus*, Colonial in *Gloeocapsa* and filamentous trichome in *Nostoc*.
- Gliding movement is noticed in some species (*Oscillatoria*).
- The protoplasm is differentiated into central region called centroplasm and peripheral region bearing chromatophore called chromoplasm.
- The photosynthetic pigments include c-phyocyanin and c-phycoerythrin along with myxoxanthin and myxoxanthophyll.
- The reserve food material is Cyanophycean starch.
- In some forms a large colourless cell is found in the terminal or intercalary position called Heterocysts. They are involved in nitrogen fixation.
- They reproduce only through vegetative methods and produce Akinetes (thick wall dormant cell formed from vegetative cell), Hormogonia (a portion of filament get detached and reproduce by cell division), fission and endospores.
- The presence of mucilage around the thallus is characteristic feature of this group. Therefore, this group is also called Myxophyceae.
- Sexual reproduction is absent.
- *Microcystis aeruginosa*, *Anabaena flos-aquae* cause water blooms and release toxins and affect the aquatic organism.

Most of them fix atmospheric nitrogen and are used as biofertilizers (Example: *Nostoc, Anabaena*). *Spirulina* is rich in protein hence it is used as single cell protein. The thallus organisation and methods of reproduction is given in Figure 1.16.

DO YOU KNOW?

A prokaryote takes a joy ride on polar bear (*Aphanocapsa montana* - a cynobacterium grow on the fur of polar bear).

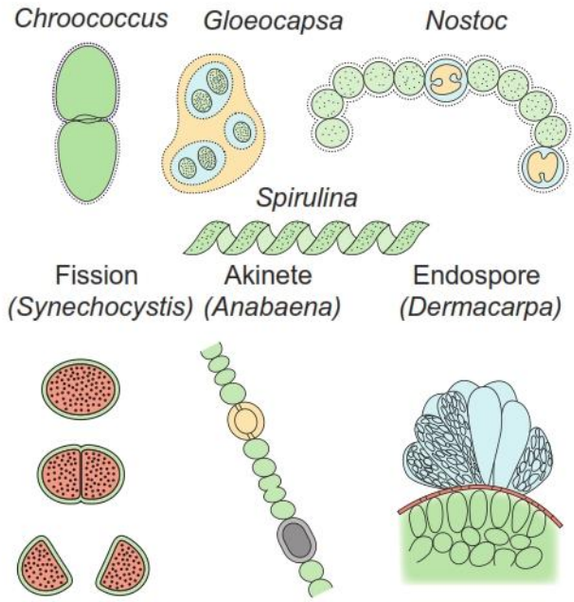


Figure 1.16: Structure and reproduction in cyanophyceae

1.4.10 Mycoplasma or Mollicutes

The Mycoplasma are very small (0.1–0.5µm), pleomorphic gram negative microorganisms. They are first isolated by Nocard and co-workers in the year 1898 from pleural fluid of cattle affected with bovine pleuropneumonia. They lack cell wall and appear like "Fried Egg" in culture. The DNA contains low Guanine and Cytosine content than true bacteria. They cause disease in animals and plants. Little leaf of brinjal, witches broom of legumes phyllody of cloves, sandal spike are some plant diseases caused by mycoplasma. Pleuropneumonia is caused by *Mycoplasma mycoides*. The structure of Mycoplasma is given in Figure 1.17.

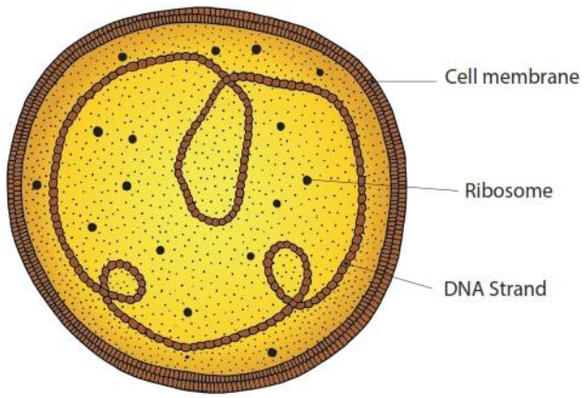


Figure 1.17: Structure of *Mycoplasma*

1.4.11 Actinomycetes (Actinobacteria)

Actinomycetes are also called 'Ray fungi' due to their mycelia like growth. They are anaerobic or facultative anaerobic microorganisms and are Gram positive. They do not produce an aerial mycelium. Their DNA contains high guanine and cytosine content (Example: *Streptomyces*).

Frankia is a symbiotic actinobacterium which produces root nodules and fixes nitrogen in non – leguminous plants such as *Alnus* and *Casuarina*. They produce multicellular sporangium. *Actinomyces bovis* grows in oral cavities and cause lumpy jaw.

Streptomyces is a mycelial forming Actinobacteria which lives in soil, they impart "earthy odour" to soil after rain which is due to the presence of Geosmin (volatile organic compound). Some important antibiotics namely, Streptomycin, Chloramphenicol, and Tetracycline are produced from this genus.

1.5 Fungi

World War II and Penicillin

History speaks on fungi

Sir Alexander Fleming

Discovery of Penicillin in the year 1928 is a serendipity in the world of medicine. The History of World War II recorded the use of Penicillin in the form of yellow powder to save lives of soldiers. For this discovery - The wonderful antibiotic he

shared Nobel Prize in Medicine in the year 1945 along with Ernest Boris chain and Sir Howard Walter Florey.

1.5.1 Milestones in Mycology

1729 P.A.Micheli conducted spore culture experiments

1767 Fontana proved that Fungi could cause disease in plants

1873 C.H. Blackley proved fungi could cause allergy in Human beings

1904 A.F.Blakeslee reported heterothallism in fungi

1952 Pontecorvo and Roper reported Parasexual cycle

The word 'fungus' is derived from Latin meaning 'mushroom'. Fungi are ubiquitous, eukaryotic, achlorophyllous heterotrophic organisms. They exist in unicellular or multicellular forms. The study of fungi is called mycology. (Gr. mykes – mushroom: logos – study). P.A. Micheli is considered as founder of Mycology. Few renowned mycologists include Arthur H.R. Buller, John Webster, D.L.Hawksworth, G.C.Ainsworth, B.B.Mundkur, K.C.Mehta, C.V. Subramanian and T.S. Sadasivan.

E.J. Butler is the Father of Indian Mycology. He established Imperial Agricultural Research Institute at Pusa, Bihar. It was later shifted to New Delhi and at present known as Indian Agricultural Research Insitute (IARI).

E.J. Butler (1874-1943)

He published a book, 'Fungi and Disease in Plants' on Indian plant diseases in the year 1918.

1.5.2 General characteristic features

- Majority of fungi are made up of thin, filamentous branched structures called hyphae. A number of hyphae get interwoven to form mycelium.The cell wall of fungi is made up of a polysaccharide called **chitin** (polymer of N-acetyl glucosamine) and fungal cellulose.
- The fungal mycelium is categorised into two types based on the presence or absence of septa (Figure 1.18). In lower fungi the hypha is aseptate, multinucleate and is known as coenocytic mycelium (Example: *Albugo*). In higher fungi a septum is present between the cells of the hyphae. Example: *Fusarium*.

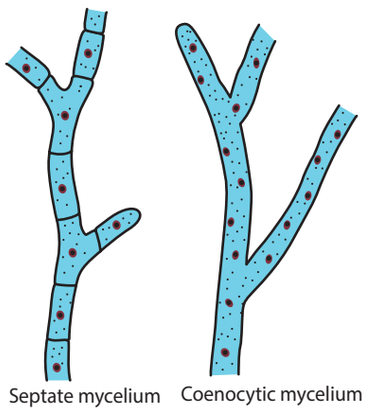


Figure 1.18: Types of mycelium

- The mycelium is organised into loosely or compactly interwoven fungal tissues called **plectenchyma**. It is further divided into two types **prosenchyma** and **pseudoparenchyma**. In the former type the hyphae are arranged loosely but parallel to one another. In the latter hyphae are compactly arranged and loose their identity.
- In holocarpic forms the entire thallus is converted into reproductive structure whereas in Eucarpic some regions of the thallus are involved in the reproduction other regions remain vegetative. Fungi reproduce both by asexual and sexual methods. The asexual phase is called **Anamorph** and the sexual phase is called **Teleomorph**. Fungi having both phases are called **Holomorph**.

General sexual reproduction in fungi includes three steps 1. Fusion of two protoplasts (plasmogamy) 2. Fusion of nuclei (karyogamy) and 3. Production of haploid spores through meiosis. Methods of reproduction in fungi is given in Figure 1.19.

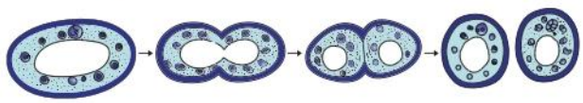
1.5.3 Methods of Reproduction in Fungi

Asexual Reproduction

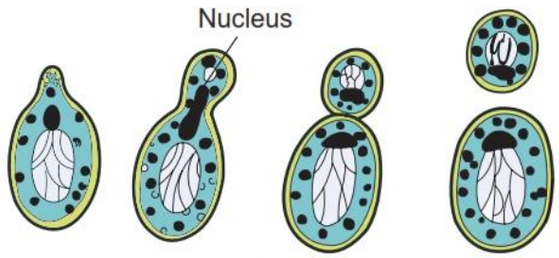
1. Zoospores: They are flagellate structures produced in zoosporangia (Example: Chytrids).
2. Conidia: The spores produced on condiophores (Example: *Aspergillus, Penicillium*).
3. Oidia/Thallospores/Arthrospores: The hypha divided and developed in to spores called oidia (Example: *Erysiphe*).
4. Fission: The vegetative cell divides into 2 daughter cells. (Example: *Schizosaccharomyces*-yeast).
5. Budding: A small outgrowth is developed on parent cell, which gets detached and becomes independent. (Example: *Saccharomyces*-yeast)
6. Chlamydospore: Thick walled resting spores are called chlamydospores (Example: *Fusarium*).

Sexual Reproduction

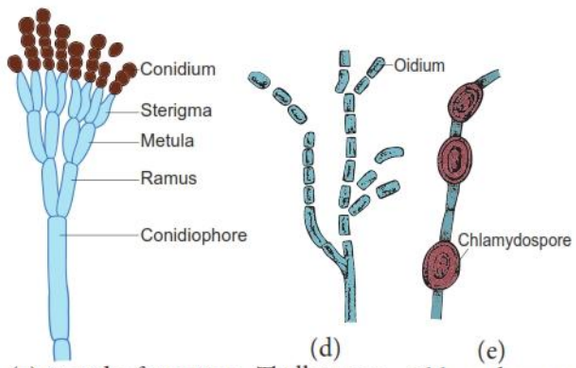
1. Planogametic copulation: Fusion of motile gamete is called planogametic copulation. a. Isogamy – Fusion of morphologically and physiologicall similar gametes. (Example: *Synchytrium)*. b. Anisogamy – Fusion of morphologically or physiologically dissimilar gametes (Example: *Allomyces*). c. Oogamy – Fusion of both morphologically and physiologically dissimilar gametes. (Example: *Monoblepharis*).
2. Gametangial contact: During sexual reproduction a contact is established between antheridium and Oogonium (Example: *Albugo*).
3. Gametangial copulation: Fusion of gametangia to form zygospore (Example: *Mucor, Rhizopus*).
4. Spermatization: In this method a uninucleate pycniospore/microconidium is transferred to receptive hyphal cell (Example: *Puccinia, Neurospora*)
5. Somatogamy: Fusion of two somatic cells of the hyphae (Example: *Agaricus*)



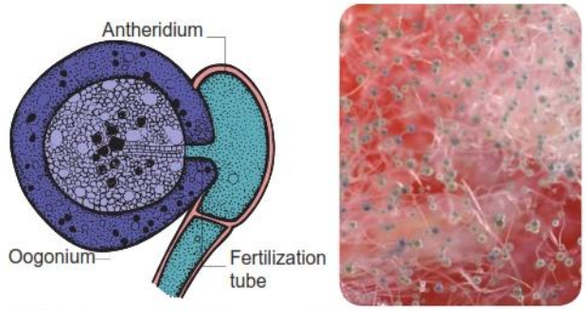
(a) Fission - Yeast



(b) Budding - Yeast

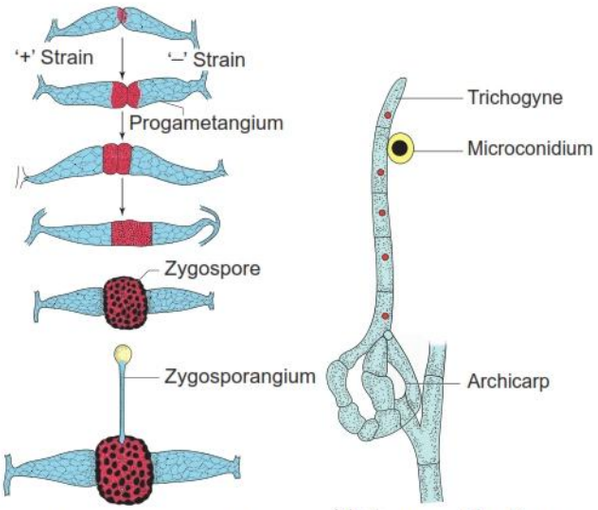


(c) Conidia formation - *Penicillium* (d) Thallospore - Erysiphe (e) Chlamydospore - Fusarium



(f) Gametangial contact - *Albugo* (g) Sporangia - *Mucor*

Figure 1.19: Reproduction in Fungi



(h) Gametangial copulation - *Rhizopus*

(i) Spermatisation - *Neurospora*

Figure 1.19: Reproduction in Fungi

1.5.4 Classification of Fungi

Many mycologists have attempted to classify fungi based on vegetative and reproductive characters. Traditional classifications categorise fungi into 4 classes – Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. Among these 'Phycomycetes' include fungal species of Oomycetes, Chytridiomycetes and Zygomycetes which are considered as lower fungi indicating algal origin of fungi. Constantine J. Alexopoulos and Charles W. Mims in the year 1979 proposed the classification of fungi in the book entitled 'Introductory Mycology'. They classified fungi into three divisions namely Gymnomycota, Mastigomycota and Amastigomycota. There are 8 subdivisions, 11 classes, 1 form class and 3 form subclasses in the classification proposed by them.

The salient features of some of the classes – Oomycetes, Zygomycetes, Ascomycetes, Basidiomycetes and Form class Deuteromycetes are discussed below.

Oomycetes

Coenocytic mycelium is present. The cell wall is made up of Glucan and Cellulose. Zoospore with one whiplash and one tinsel flagellum is present. Sexual reproduction is oogamous. Example: *Albugo.*

Zygomycetes

- Most of the species are saprophytic and live on decaying plant and animal matter in the soil. Some lead parasitic life (Example: *Entomophthora* on housefly).
- Bread mold fungi (Example: *Mucor, Rhizopus*) and coprophilous fungi (Fungi growing on dung Example: *Pilobolus*) belong to this group (Figure 1.20).

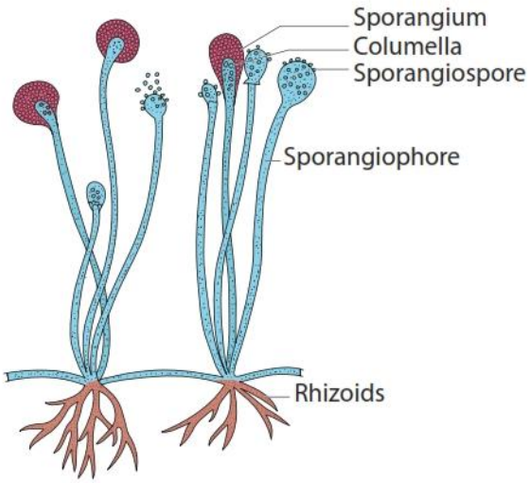


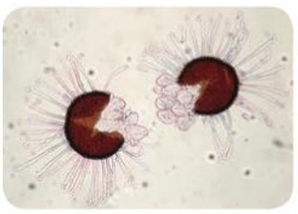
Figure 1.20: Zygomycetes – *Rhizopus*

- The mycelium is branched and coenocytic.
- Asexual reproduction by means of spores produced in sporangia.
- Sexual reproduction is by the fusion of the gametangia which results in thick walled zygospore. It remains dormant for long periods. The zygospore undergoes meiosis and produce spores.

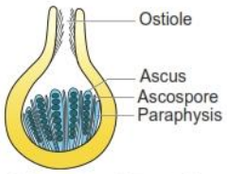
Ascomycetes

- Ascomycetes include a wide range of fungi such as yeasts, powdery mildews, cup fungi, morels and so on (Figure 1.21).
- Although majority of the species live in terrestrial environment, some live in aquatic environments both fresh water and marine.
- The mycelium is well developed, branched with simple septum.
- Majority of them are saprophytes but few parasites are also known (Powdery mildew – *Erysiphe*).

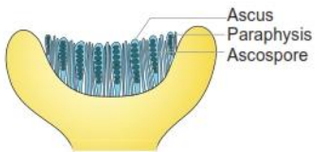
(a) *Peziza*



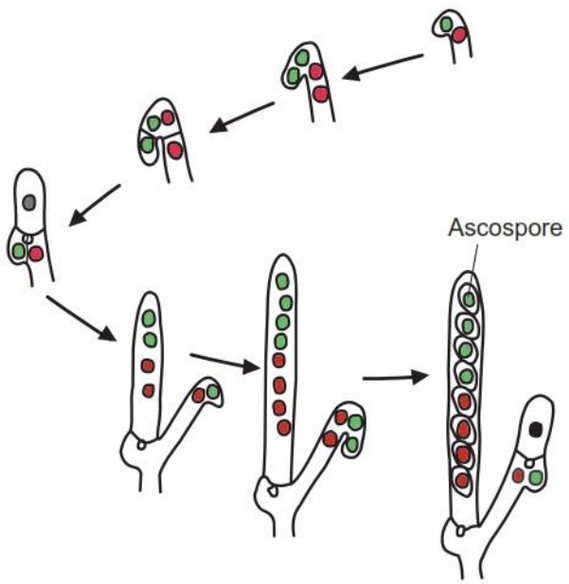
(b) Cleistothecium



(c) V.S. of Perithecium



(d) V.S. of Apothecium



(e) Steps involved in the development of Ascus

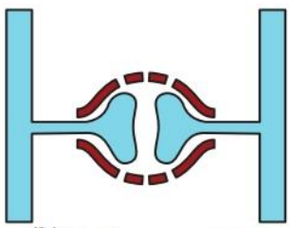
Figure 1.21: Structure and reproduction in Ascomycetes

- Asexual reproduction takes place by fission, budding, oidia, conidia, and chlamydospore.
- Sexual reproduction takes place by the fusion of two compatible nuclei.
- Plasmogamy is not immediately followed by karyogamy, instead a dikaryotic condition is prolonged for several generations.
- A special hyphae called ascogenous hyphae is formed.
- A crozier is formed when the tip of the ascogenous hyphae recurves forming a hooked cell. The two nuclei in the penultimate cell of the hypha fuse to form a diploid nucleus. This cell forms young ascus.
- The diploid nucleus undergo meiotic division to produce four haploid nuclei, which further divide mitotically to form eight nuclei. The nucleus gets organised into 8 ascospores.
- The ascospores are found inside a bag like structure called ascus. Due to the presence of ascus, this group is popularly called "Sac fungi".
- Asci gets surrounded by sterile hyphae forming fruit body called ascocarp.
- There are 4 types of ascocarps namely **Cleistothecium** (Completely closed), **Perithecium** (Flask shaped with ostiole), **Apothecium** (Cup shaped, open type) and **Pseudothecium**.

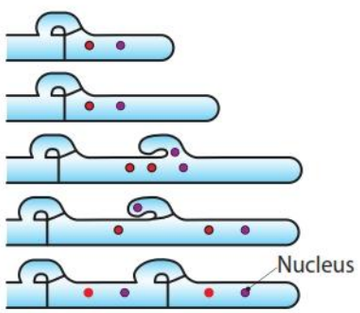
Basidiomycetes

- Basidiomycetes include puff balls, toad stools, Bird's nest fungi, Bracket fungi, stink horns, rusts and smuts (Figure 1.22).

(a) *Geaster*



(b) Dolipore septum



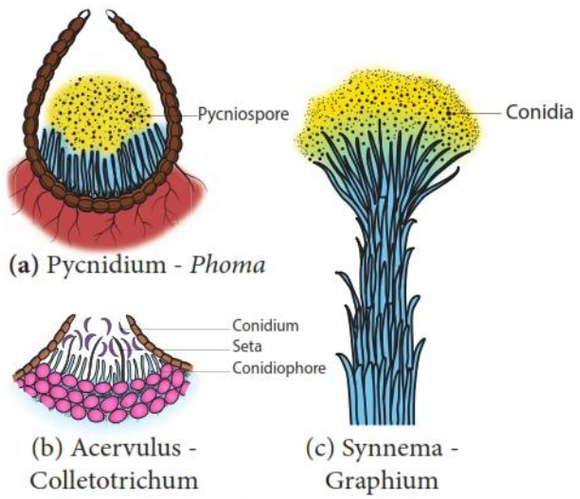
(c) Clamp connection

Figure 1.22: Structure and Reproduction in Basidiomycetes

- The members are terrestrial and lead a saprophytic and parasitic mode of life.

- The mycelium is well developed, septate with dolipore septum(bracket like). Three types of mycelium namely primary (Monokaryotic), secondary (Dikaryotic) and tertiary are found.
- Clamp connections are formed to maintain dikaryotic condition.
- Asexual reproduction is by means of conidia, oidia or budding.
- Sexual reproduction is present but sex organs are absent. Somatogamy or spermatisation results in plasmogamy. Karyogamy is delayed and dikaryotic phase is prolonged. Karyogamy takes place in basidium and it is immediately followed by meiotic division.
- The four nuclei thus formed are transformed into basidiospores which are borne on sterigmata outside the basidium (Exogenous). The basidium is club shaped with four basidiospores, thus this group of fungi is popularly called "Club fungi". The fruit body formed is called Basidiocarp.

Deuteromycetes or Fungi Imperfecti



(a) Pycnidium - *Phoma*

(b) Acervulus - Colletotrichum

(c) Synnema - Graphium

Figure 1.23: Reproduction in Deuteromycetes

The fungi belonging to this group lack sexual reproduction and are called imperfect fungi. A large number of species live as saprophytes in soil and many are plant and animal parasites. Asexual reproduction takes place by the production of conidia, chlamydospores, budding, oidia etc., Conidia are also produced in special structures called **pycnidium**, **acervulus**, **sporodochium** and **synnemata** (Figure 1.23). Parasexual cycle operates in this group of fungi. This brings genetic variation among the species.

1.5.5 Economic importance

Fungi provide delicious and nutritious food called mushrooms. They recycle the minerals by decomposing the litter thus adding fertility to the soil. Dairy industry is based on a single celled fungus called yeast. They deteriorate the timber. Fungi cause food poisoning due the production of toxins. The Beneficial and harmful activities of fungi are discussed below:

Beneficial activities

Food

Mushrooms like *Lentinus edodes, Agaricus bisporus, Volvariella volvaceae* are consumed for their high nutritive value. Yeasts provide vitamin B and *Eremothecium ashbyii* is a rich source of Vitamin B_{12}.

Medicine

Fungi produce antibiotics which arrest the growth or destroy the bacteria. Some of the antibiotics produced by fungi include Penicillin (*Penicillium notatum*) Cephalosporins (*Acremonium chrysogenum*) Griseofulvin (*Penicillium griseofulvum*). Ergot alkaloids (Ergotamine) produced by *Claviceps purpurea* is used as vasoconstrictors.

Industries

Production of Organic acid: For the commercial production of organic acids fungi are employed in the Industries. Some of the organic acids and fungi which help in the production of organic acids are: citric acid and gluconic acid – *Aspergillus niger*, Itaconic acid – *Aspergillus terreus*, Kojic acid – *Aspergillus oryzae.*

Bakery and Brewery

Yeast(*Saccharomyces cerevisiae*) is used for

fermentation of sugars to yield alcohol.Bakeries utilize yeast for the production of Bakery products like Bread, buns, rolls etc., *Penicillium roquefortii* and *Penicillium camemberti* were employed in cheese production.

Production of enzymes

Aspergillus oryzae, *Aspergillus niger* were employed in the production of enzymes like amylase, protease, lactase etc. **Rennet** which helps in the coagulation of milk in cheese manufacturing is derived from *Mucor* spp.

Agriculture

Mycorrhiza forming fungi like *Rhizoctonia, Phallus*, *Scleroderma* helps in absorption of water and minerals.

Fungi like *Beauveria bassiana, Metarhizium anisopliae* are used as Biopesticides to eradicate the pests of crops. Gibberellin, produced by a fungus *Gibberella fujikuroi* induce the plant growth and is used as growth promoter.

Harmful activities

Fungi like *Amanita phalloides*, *Amanita verna*, *Boletus satanus* are highly poisonous due to the production of Toxins. These fungi are commonly referred as **"Toad stools"**.

Aspergillus, *Rhizopus, Mucor* and *Penicilium* are involved in spoilage of food materials. *Aspergillus flavus* infest dried foods and produce carcinogenic toxin called aflatoxin.

Patulin, ochratoxin A are some of the toxins produced by fungi.Fungi cause diseases in Human beings and plants (Table 1.11).

Activity 1.4

Get a button mushroom. Draw diagram of the fruit body. Take a thin longitudinal section passing through the gill and observe the section under a microscope. Record your observations.

Dermatophytes are fungi which cause infection in skin. Example: *Trichophyton*, *Tinea*, *Microsporum* and *Epidermophyton*

The late blight disease of Potato by *Phytophthora infestans* caused a million deaths, and drove more to emigrate from Ireland (1843-1845). In India *Helminthosporium oryzae,* Blight of Paddy is also a factor for Bengal famine in 1942-1943.

Table 1.11: Diseases caused by fungi

Name of the disease	***Causal organism***
Plant diseases	
Blast of Paddy	*Magnaporthe grisea*
Red rot of sugarcane	*Colletotrichum falcatum*
Anthracnose of Beans	*Colletotrichum lindemuthianum*
White rust of crucifers	*Albugo candida*
Peach leaf curl	*Taphrina deformans*
Rust of wheat	*Puccinia graminis tritici*
Human diseases	
Athlete's foot	*Epidermophyton floccosum*
Candidiasis	*Candida albicans*
Coccidioidomycosis	*Coccidioides immitis*
Aspergillosis	*Aspergillus fumigatus*

Activity 1.5

Keep a slice of bread in a clean plastic tray or plate. Wet the surface with little water. Leave the setup for 3 or 4 days. Observe the mouldy growth on the surface of the bread. Using a needle remove some mycelium and place it on a slide and stain the mycelium using lactophenol cotton blue. Observe the mycelium and sporangium under the microscope and record your observation and identify the fungi and its group based on characteristic features.

1.5.6 Mycorrhizae

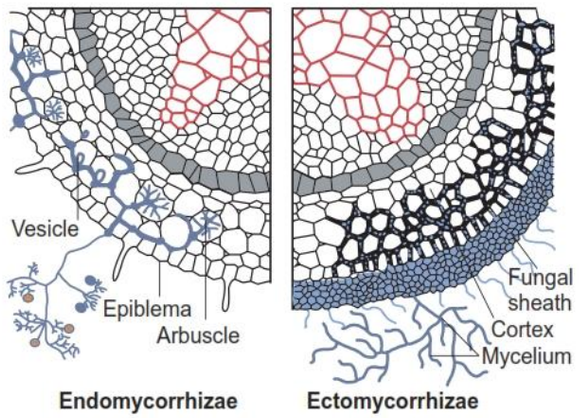


Figure 1.24: T.S. of root showing mycorrhizae

The symbiotic association between fungal mycelium and roots of plants is called as mycorrhizae. In this relationship fungi absorb nutrition from the root and in turn the hyphal network of mycorrhizae forming fungi helps the plant to absorb water and mineral nutrients from the soil (Figure 1.24). Mycorrhizae is classified into three types (Table 1.12)

Importance of Mycorrhizae

- Helps to derive nutrition in *Monotropa*, a saprophytic angiosperm,
- Improves the availability of minerals and water to the plants.
- Provides drought resistance to the plants
- Protects roots of higher plants from the attack of plant pathogens

1.5.7 Lichens

The symbiotic association between algae and fungi is called lichens. The algal partner is called Phycobiont or Photobiont., and the fungal partner is called Mycobiont. Algae provide nutrition for fungal partner in turn fungi provide protection and also help to fix the thallus to the substratum through rhizinae. Asexual reproduction takes place through fragmentation, Soredia and Isidia. Phycobionts reproduce by akinetes, hormogonia, aplanospore etc., Mycobionts undergo sexual reproduction and produce ascocarps.

Classification

- Based on the habitat lichens are classified into following types: **Corticolous(**

Table 1.12: Types of Mycorrhizae

Ectomycorrhizae	Endomycorrhizae	Ectendomycorrhizae
The fungal mycelium forms a dense sheath around the root called mantle. The hyphal network penetrate the intercellular spaces of the epidermis and cortex to form Hartig net. Example: *Pisolithus tinctorius*	The hyphae grows mainly inside the roots, penetrate the outer cortical cells of the plant root. A small portion of the mycelium is found outside the root. This form is also called Vesicular Arbuscular Mycorrhizal fungi (VAM Fungi) due to the presence of Vesicle or arbuscle like haustoria 1. Arbuscular mycorrhizae(AM) Example: *Gigaspora* 2. Ericoid mycorrhizae -Example: *Oidiodendron* 3. Orchid mycorrhizae -Example: *Rhizoctonia*	The fungi form both mantle and also penetrates the cortical cells.

on Bark) **Lignicolous**(on Wood) **Saxicolous**(on rocks) **Terricolous**(on ground) Marine(on siliceous rocks of sea) Fresh water(on siliceous rock of fresh water).

- On the basis of morphology of the thallus they are divided into **Leprose** (a distinct fungal layer is absent) **Crustose**-crust like; Foliose-leaf like; **Fruticose**- branched pendulous shrub like (Figure 1.25).

(a) Crustose lichen

(b) Foliose Lichen

(c) Fruticose Lichen

Figure 1.25: Types of Lichens

- The distribution of algal cells distinguishes lichens into two forms namely **Homoiomerous** (Algal cells evenly distributed in the thallus) and **Heteromerous** (a distinct layer of algae and fungi present).
- If the fungal partner of lichen belongs to ascomycetes, it is called **Ascolichen** and if it is basidiomycetes it is called **Basidiolichen**.

Lichens secrete organic acids like Oxalic acids which corrodes the rock surface and helps in weathering of rocks, thus acting as pioneers in Xerosere. Usnic acid produced from lichens show antibiotic properties. Lichens are sensitive to air pollutants especially to sulphur-di-oxide. Therefore, they are considered as pollution indicators. The dye present in litmus paper used as acid base indicator in the laboratories is obtained from *Roccella montagnei. Cladonia rangiferina* (Reindeer mose) is used as food for animals living in Tundra regions.

Summary

Earth is endowed with living and nonliving things. The attributes of living things include growth, metabolism, reproduction, irritability and so on. Viruses are considered as Biological puzzle and exhibit both living and non living characteristic features. They are ultramicroscopic, obligate parasites and cause disease in plants and animals. They multiply by lytic and lysogenic cycle.

Five Kingdom classification was proposed by Whittaker, which include Monera, Protista, Fungi, Plantae and Animalia. Carl woese divided the living world into 3 domains- Bacteria, Archaeae and Eukarya. The domain Eukarya include Plantae, Animalia and Fungi. A new Kingdom called Chromista was erected to include Diatoms, Cryptomonads and Oomycetes. Bacteria are microscopic, prokaryotic organisms and possess peptidoglycan in their cell wall. Based on Gram Staining method they are classified into Gram positive and Gram negative type. They reproduce asexually by binary fission. Sexual reproduction occurs through conjugation, transformation and transduction. Archaebacteria are prokaryotic and are adapted to thrive in extreme environments.

Cyanobacteria are prokaryotic organisms and are also called Blue Green Algae. The members of this group are ensheathed by mucilage cover. They reproduce by vegetative and asexual methods.

Fungi are eukaryotic, heterotrophic, unicellular or multicellular organisms. The cell wall is made up of chitin. They reproduce asexually by producing sporangiospores, conidia, thallospores, chlamydospores etc., The sexual reproduction is isogamous, ansiogamous and oogamous. In addition, gametic copulation, gametic fusion, spermatisation are also found. They are

beneficial to mankind. Some are known to cause disease in plants and human beings.

The symbiotic association between the roots of higher plants and fungal mycelium is called mycorrhizae. Lichen thallus includes both phycobiont and mycobiont. It is an example for symbiotic association.

Evaluation

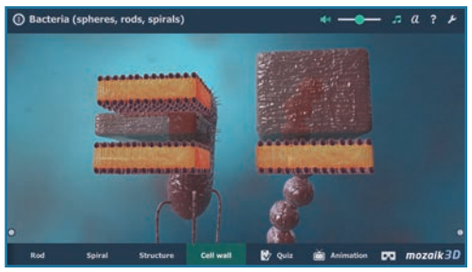
1. Which one of the following statement about virus is correct?
   a. Possess their own metabolic system
   b. They are facultative parasites
   c. They contain DNA or RNA
   d. Enzymes are present

2. Identify the incorrect statement about the Gram positive bacteria
   a. Teichoic acid absent
   b. High percentage of peptidoglycan is found in cell wall
   c. Cell wall is single layered
   d. Lipopolysaccharide is present in cell wall
3. Identify the Archaebacterium
   a. *Acetobacter* b. *Erwinia*
   c. *Treponema* d. *Methanobacterium*
4. The correct statement regarding Blue green algae is _____
   a. lack of motile structures
   b. presence of cellulose in cell wall
   c. absence of mucilage around the thallus
   d. presence of floridean starch
5. Identify the correctly matched pair
   a. Actinomycete – a) Late blight
   b. Mycoplasma – b) lumpy jaw
   c. Bacteria – c) Crown gall
   d. Fungi – d) sandal spike
6. Differentiate homoiomerous and heteromerous lichens.
7. Write the distinguishing features of monera.
8. Why do farmers plant leguminous crops in crop rotations/mixed cropping?
9. Briefly discuss on five Kingdom classification. Add a note on merits and demerits.
10. Give a general account on lichens.

ICT Corner

Bacteria

Let's explore the structure and shapes of **Bacteria.**

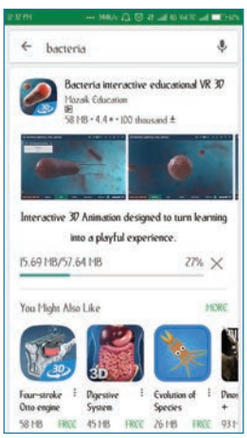


Steps

- Scan the QR code or go to google play store and type bacteria interactive educational VR 3D
- Download the app and install it
- Follow the above steps and explore the interactives of each part and its functions.

Activity

- Select structure tap and note the internal structure of bacteria
- Click cell wall and note the difference between different shapes



Step 1

Step 2

Step 3

Step 4

Step 5

URL:

https://play.google.com/store/apps/details?id=com.rendernet.bacteria&hl=en

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* Pictures are indicative only