GOVERNMENT OF TAMIL NADU

BIO-BOTANY

HIGHER SECONDARY FIRST YEAR

VOLUME - I

Untouchability is Inhuman and a Crime

A publication under Free Textbook Programme of Government of Tamil Nadu

Department of School Education

Government of Tamil Nadu

First Edition - 2018

NOT FOR SALE

Content Creation

State Council of Educational
Research and Training

Printing & Publishing

Tamil NaduTextbook and Educational
Services Corporation

www.textbooksonline.tn.nic.in

CONTENTS

BIO-BOTANY

5CU7G6

E-book

5D43HT

Assessment

B181_11_BOT

DIGI links

Lets use the QR code in the text books ! How ?

- Download the QR code scanner from the Google PlayStore/ Apple App Store into your smartphone
- Open the QR code scanner application
- Once the scanner button in the application is clicked, camera opens and then bring it closer to the QR code in the text book.
- Once the camera detects the QR code, a url appears in the screen.Click the url and goto the content page.

HOW TO USE THE BOOK

Learning Objectives:	Learning objectives are brief statements that describe what students will be expected to learn by the end of school year, course, unit, lesson or class period.
Chapter Outline	Illustrate the complete overview of chapter
DO YOU KNOW?	Amazing facts, Rhetorical questions to lead students to biological inquiry
List of Botanical terms	Tamil terminology for Botanical terms given for easy understanding
Activity	Directions are provided to students to conduct activities in order to explore, enrich the concept.
Infographics	Visual representation of the lesson to enrich learning .
Evaluation	Assess students to pause, think and check their understanding
5CU7G6	To motivate the students to further explore the content digitally and take them in to virtual world
ICT	To enhance digital Science skills among students
Concept Map	Conceptual diagram that depicts relationships between concepts to enable students to learn the content schematically
Career corner	List of professions related to the subject
References	List of related books for further details of the topic
Web links	List of digital resources
Glossary	Explanation of scientific terms
Competitive Exam questions	Model questions to face various competitive exams

Scope of Botany
Higher Studies and Career Opportunities

TNAU

- B.Sc. Agriculture,
- B.Sc. Horticulture
- B.Sc. Forestry,
- B.Sc Sericulture
- B.Tech Biotechnology
- B.Tech Agricultural Engineering
- B.Tech Horticulture
- B.Tech Food process Engineering
- B.Tech Energy and
- Environmental Engineering
- B.Tech Bioinformatics
- B.Sc Agribusiness Management
- B.Tech Agricultural IT
- M. Tech. Environmental Engineering
- M. Sc in Agriculture
- M. Sc in Agricultural Extension
- M. Sc in Agronomy
- M. Sc in Soil Science
- M. Sc in Agricultural Biotechnology
- M. Sc in Agricultural Marketing
- M. Sc in Agricultural Microbiology
- M. Tech in Agricultural Engineering
- M. E in Agricultural Engineering
- Master of Agriculture in Entomology
- Master of Agriculture in Horticulture
- Master of Agriculture in Animal Sciences
- Master of Agriculture in Entomology
- Master of Agriculture in Plant Pathology
- Master of Agriculture in Agricultural Economics and Rural Sociology
- Master In Agriculture And Rural Development

TNMGRMU

MEDICAL

- MBBS
- M.D/M.S/M.D.S
- M.Ch. (5 year course)
- B.D.S
- M.D.S

Indian Medicine and Homoeopathy Courses

- B.A.M.S. - Ayurvedic Medicine
- B.H.M.S. - Homoeopathic Medicine
- B.N.Y.S. - Naturopathy and Yogic
- B.S.M.S. - Siddha Medicine
- B.U.M.S. - Unani Medicine

Allied Health Sciences

- B.Sc.(N)- Bachelor of Science in Nursing
- B.P.T.- Bachelor of Physiotherapy
- M.P.T. - Master of Physiotherapy
- B.O.T. - Bachelor of Occupational Therapy
- M.O.T. - Master of Occupational Therapy
- B.Sc. - Accident & Emergency Care Technology
- B.Sc. - Audiology & speech Language Pathology
- B.Sc. - Cardiac Technology
- B.Sc. - Cardio Pulmonary Perfusion Care Technology
- B.Sc. - Critical Care Technology
- B.Sc. - Dialysis Technology
- B.Sc. - Neuro Electrophysiology
- B.Sc. - Medical Sociology
- B.Sc. - Nuclear Medicine Technology
- B.Sc. - Operation Theatre & Anaesthesia Technology
- B.Sc. - Physician Assistant
- B.Sc. - Radiology Imaging Technology
- B.Sc. - Radiotherapy Technology
- B.Sc. - Fitness and Lifestyle Modifications
- B.Sc. - Clinical Nutrition

Diploma Course

- Accident & Emergency Care Technology
- Critical Care Technology
- Health Care Aide (as per 245th GC)
- Operation Theatre & Anaesthesia Technology
- Ophthalmic Nursing Assistant
- Scope Support Technology
- Medical Record Science
- Optometry Technology
- Radiology & Imaging Technology
- Medical Lab Technology
- Cardiac Non Invasive Technology
- Dialysis Technology

AIIMS

Undergraduate Courses (UG)

- MBBS
- B.Sc Nursing (post Certificate)
- B.Sc. (Hons.) Nursing
- Paramedical Courses (PM)
- B.Sc. (Hons.) Opthalmic Techniques
- B.Sc. (Hons.) Medical Technology

Postgraduate Courses (PG)

- M.D/M.S/M.D.S
- M.Ch. (5 year course)
- M.Sc. / M. Biotechnology

Integrated courses

Mode of selection: Entrance conducted by concern institution or NEET

M.Sc in Life sciences- 5 year Integrated course

- Indian institute of Science, Bengaluru
  Website: http://www.iisc.ac.in/
- National Institute of Science Education and Research (NISER) , Bhubaneswar, Kolkata , Pune , Mohali, Bhopal ,Thiruvananthapuram , Tirupati and Berhampur
  Website: http://www.niser.ac.in

B.Sc.,B.Ed -5 year Integrated course

- Regional Institute of Education Ajmer, Bhopal, Bhubaneswar, Mysuru and Shilillong

Website: www.riemysore.ac.in

SCIENCE

Courses in Arts & Science Coleges and Universities

- B.Sc. Botany
- B.Sc. Plant Biology & Plant Biotechnology
- B.Sc Biochemisty
- B.Sc Bio-computing
- B.Sc. Plant Pathology
- M.Sc. Botany
- M.Sc Biotechnology
- M.Sc. Bio-chemistry
- M.Sc. Bioinformatics
- M.Sc Immunology and Microbiology
- M.Sc. Applied Medical Biotechnology & clinical Research
- M.Sc. Genetic Engineering & Plant Breeding
- M.Sc. Applied Plant Science
- M.Sc. Plant Biology & Plant Biotechnology
- M.Sc. Plant molecular Biology
- M.Sc. Mycology & Plant pathology
- M.Sc. Plant science

ANNA UNIVERSITY

- B.E. Bio Medical Engineering
- B.Tech. Industrial Bio technology
- B.Tech. Food technology
- B.Tech. Bio technology

Research Institutions in various areas of Botany

Name of the Institution	Research Areas	Website
Indian Agricultural Research Institute (IARI) New Delhi	Genetics & Plant Breeding; Microbiology; Post Harvest Technology	www.iari.res.in
National Bureau of Plant Genetic Resources (NBPGR) New Delhi	Plant genetic resources management and use.	www.nbpgr.ernet.in
Institute of Forest Genetics and Tree Breeding, Coimbatore.	Tree improvement; Bio-prospecting of Forest Natural Resources	www .ifgtb.icfre.gov.in
Central Plantation crops Research Institute, Kerala	Crop improvement; Production; Protection; Plant physiology and Biochemistry.	www.cpcri.gov.in
Indian Institute of Crop Processing Technology, Thanjavur.	Agricultural Process Engineering Renewable energy for food processing .	www.iicpt.edu.in
Central Tuber Crops Research Institute, Thiruvananthapuram.	Development of Agro techniques for tuber crops	www.ctcri.org
Indian Institute of Spices Research, Kozhikode.	Collection, conservation, evaluation and cataloging of germplasm.	www.spices.res.in
Central Institute for Cotton Research, Nagpur, (Regional station: Coimbatore & Sirsa)	Crop improvement, Crop Production and Crop Protection.	www.cicr.org.in
Directorate of Cashewnut & Cocoa, Agri, Kerala	Cocoa production and processing	www.dccd.gov.in
National Research Center on Plant Biotechnology, New Delhi	Genetic engineering for biotic resistance.	www.nrcpb.org
National Institute of Plant Genome Research (NIPGR), New Delhi	Structural and Functional Genomics in Plants; Computational biology; Genome analysis and molecular mapping..	www.nipgr.res.in
Sugarcane Breeding Institute, ICAR, Coimbatore.	Breeding of superior sugarcane varieties/ genotypes;	www.sugarcane.res.in
Central Research Institute for Dryland Agriculture, Hyderabad	Dryland, Agrometerology and Crop sciences	crida.in
National Research Centre for Groundnut(NRCG) Junagarh, Gujarat	Productivity and quality of groundnut; repository of groundnut germplasm and information on groundnut researches	www.nrcg.res.in
International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi	Mammalian Biology; Plant Biology; Synthetic Biology and Biofuels.	www.icgen.org
National Institute of Virology, Pune	Epidemology, Basic virology; Diagnostics.	www.niv.co.in
Center for DNA Fingerprinting and Diagnostics, Hyderabad	Computational Biology. Protein structure, Dynamic and Interactions Epigenetic	www.cdfd.org.in
Institute of Life Sciences, Bhubaneswar	Infectious disease;Iimmune biology; Cancer biology; Nanotechnology	www.ils.res.in
Centre for Cellular and Molecular Biology, Hyderabad.	Genetics & evolution, Genomics; Cell Biology & Development.	www.ccmb.res.in
Central Institute of medicinal and Aromatic Plants, Lucknow.	Biotechnology, Crop protection; Genetics and plant breeding	www.cimap.res.in
National Botanical Research Institute, Lucknow.	Genetics and molecular biology; Plant microbe interaction & Pharmacogonosy.	www.nbri.res.in
Institute of Genomics and Integrative Biology	Genomics and Molecular medicine, Chemical and systems biology.	www.igib.res.in
National Centre for Biological Sciecnes, Bangalore	Biochemistry, Biophysics, Bioinformatics, Genetics and development;Cellular organization & signelling neurobiology etc.	www.ncbs.res.in
Birbal Sahni Institute od Palaeobotany (BSIP) Lucknow.	Palynology in fossil fuel exploration; Dendrochronology; Ethnobotany; Micropaleontology; Carbon 14Dating	www.bsip.res.in
North East Institute of Science & Technology Jorhat, Assam.	Chemical science; Biological sciences;Material sciences; Agro-science and technology; Geosciences.	www.rrljorhat.res.in
Institute of Wood Science and Technology, Bangalore.	Tree improvement and Genetics; Chemistry of Forest Products.	iwst.icfre.gov.in
Centre for Ecological Sciences, Indian Institute of Science. Bangalore.	Behavior Ecology; Evolution; climate change & conservation.	www.ces.iisc.ernet.in
Botanical Survey of India(BSI), Kolkatta	To Survey, research and conservation of plant resources, flora and endangered species.	www.bsi.gov.in

Chapter 1

Unit I: Diversity of Living World

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 on the structure and uses of Mycorrhizae and Lichens.*

Chapter Outline

5DCYJG

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 harbors 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.

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

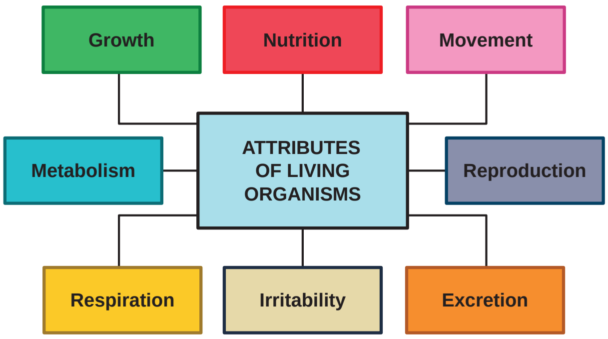


Figure 1.1: Attributes of living organisms

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. However, cell division occurs in living organisms to repair and heal the worn out tissues. 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. Asexual reproduction (Figure 1.2) 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

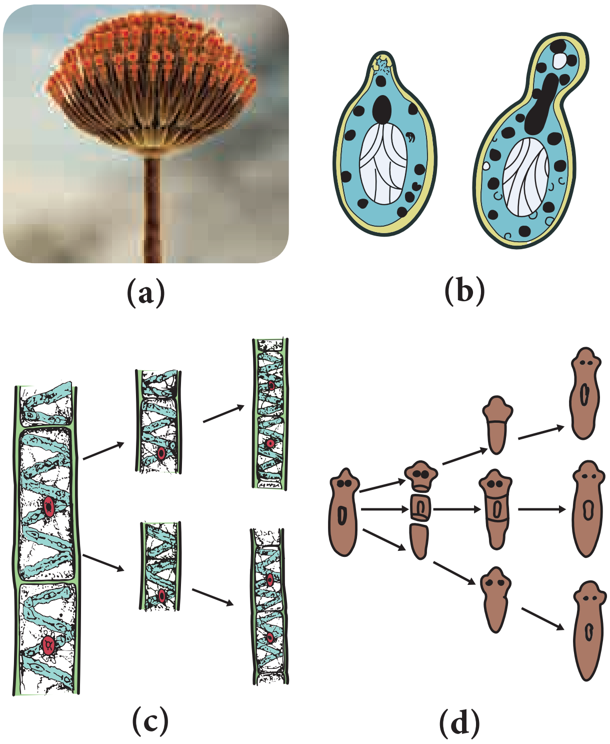


Figure 1.2: Types of Asexual Reproduction (a) Conidia formation-*Penicillium*, (b) Budding-Yeast, (c) Fragmentation-*Spirogyra*, **(d)** Regeneration-*Planaria*

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.

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.

Metabolism

The sum total 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

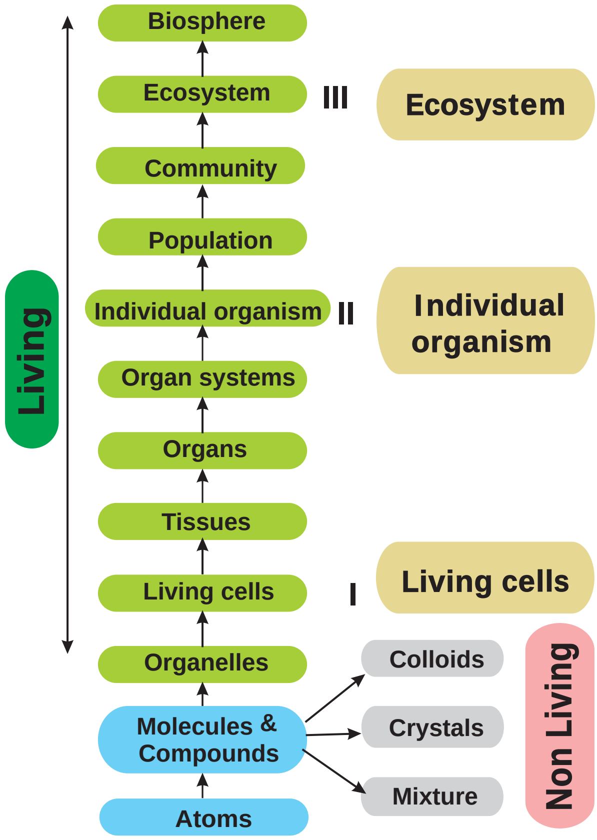


Figure 1.3: The levels of organization and integration in living organism

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 news papers 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**.

W.M. Stanley (1904-1971)

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

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.

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

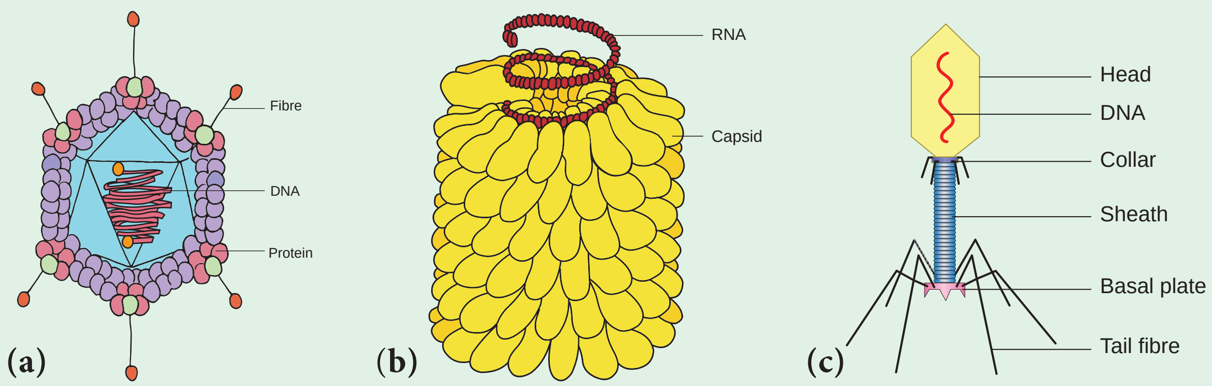
5DLUL4

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



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

Figure 1.4: Shapes of Viruses

Table 1.2: Different Classes of viruses

Class	Example
Class 1 - Viruses with dsDNA	Adenoviruses
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 (–) antisense ssRNA	Rhabdo viruses
Class 6 – Viruses with (+) sense ss RNA –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

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 (Parvoviruses), dsDNA (Bacteriophages), ssRNA (TMV) and dsRNA(wound tumour virus).

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 280x150µm with a molecular weight of 39×10^6 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

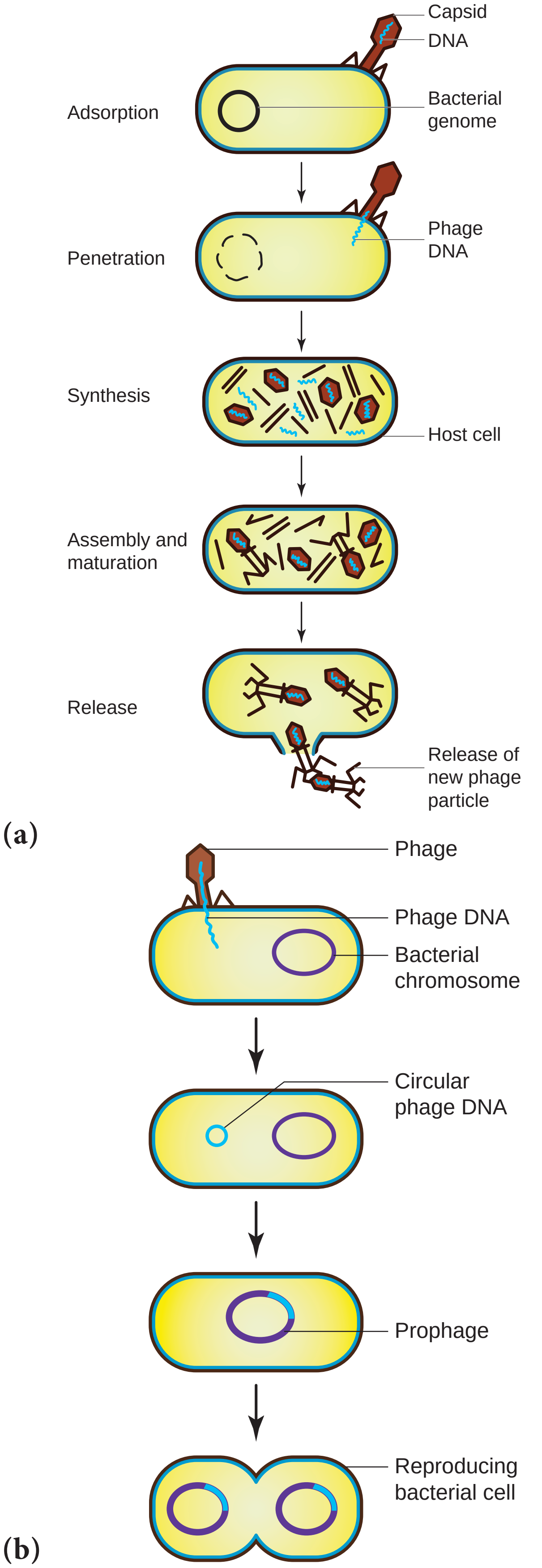


Figure 1.5: Multiplication cycle of phage (a) Lytic cycle, (b) Lysogenic cycle

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.

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 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.

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.**

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

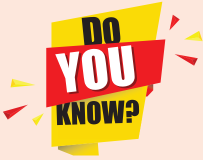
(a)

(b)

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

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



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 virus were employed as potential insecticides.

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 came 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 animal 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

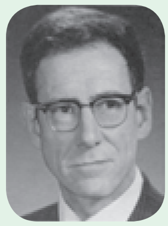
Classification is essential to achieve following needs

- 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

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

1.3.3 Five Kingdom Classification

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

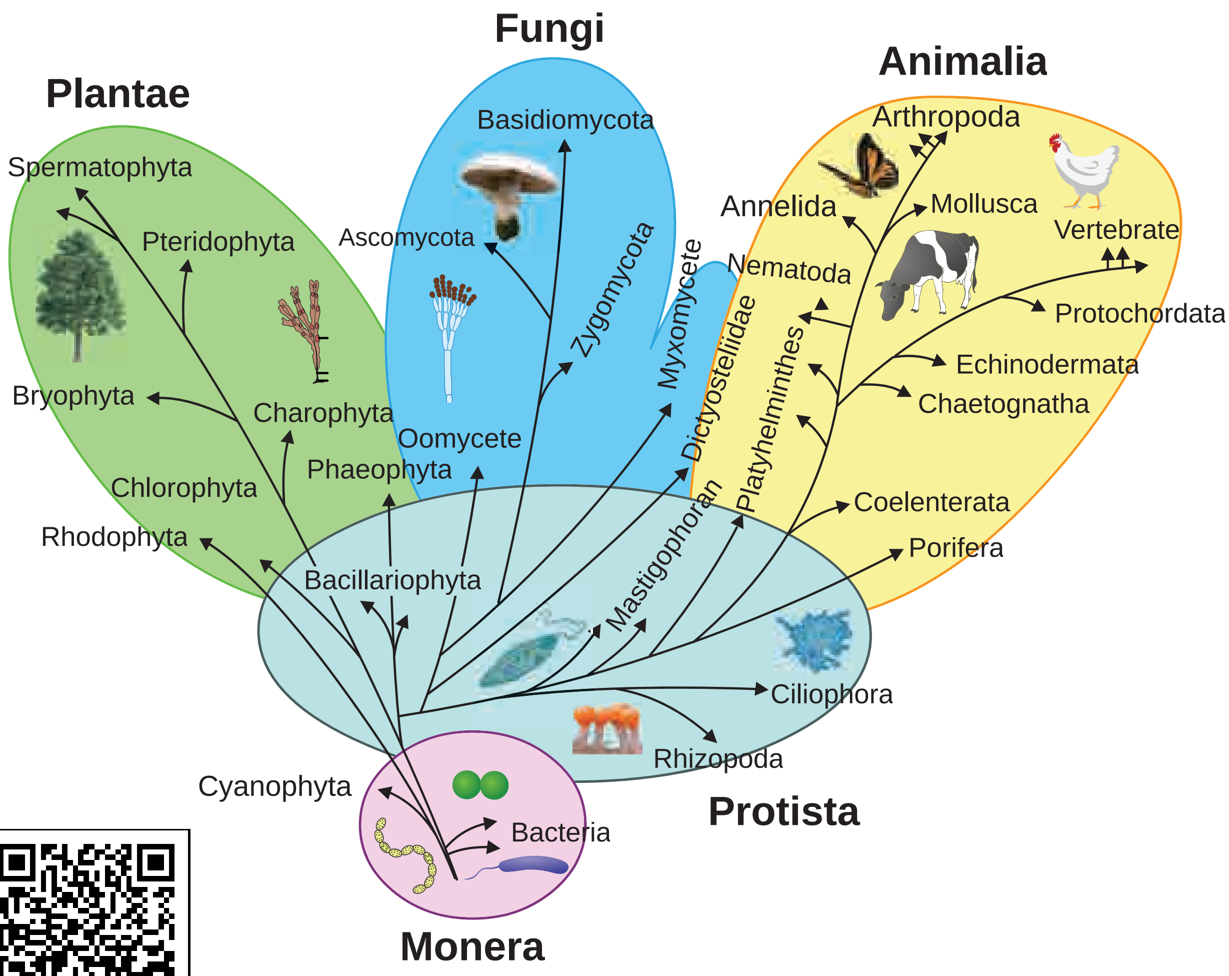
Merits

- 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 Ruggerio *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 superkingdoms (**Prokaryota** and **Eukaryota**) **Prokaryota** include



5DVQHR

Figure 1.7: Five kingdom classification

two kingdoms namely **Archaebacteria** and **Eubacteria.** Eukaryota include 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 colorless 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

DO YOU KNOW?

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.

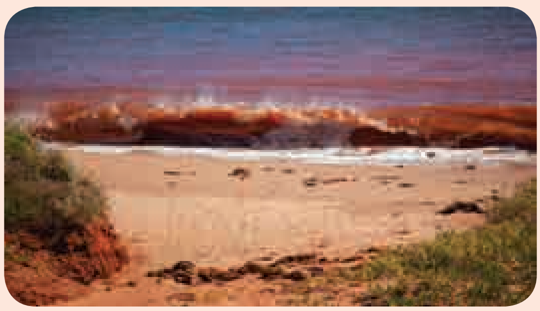


Table 1.5: Comparison of Five Kingdoms

Criteria	Kingdom				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Level of organization	Unicellular	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

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

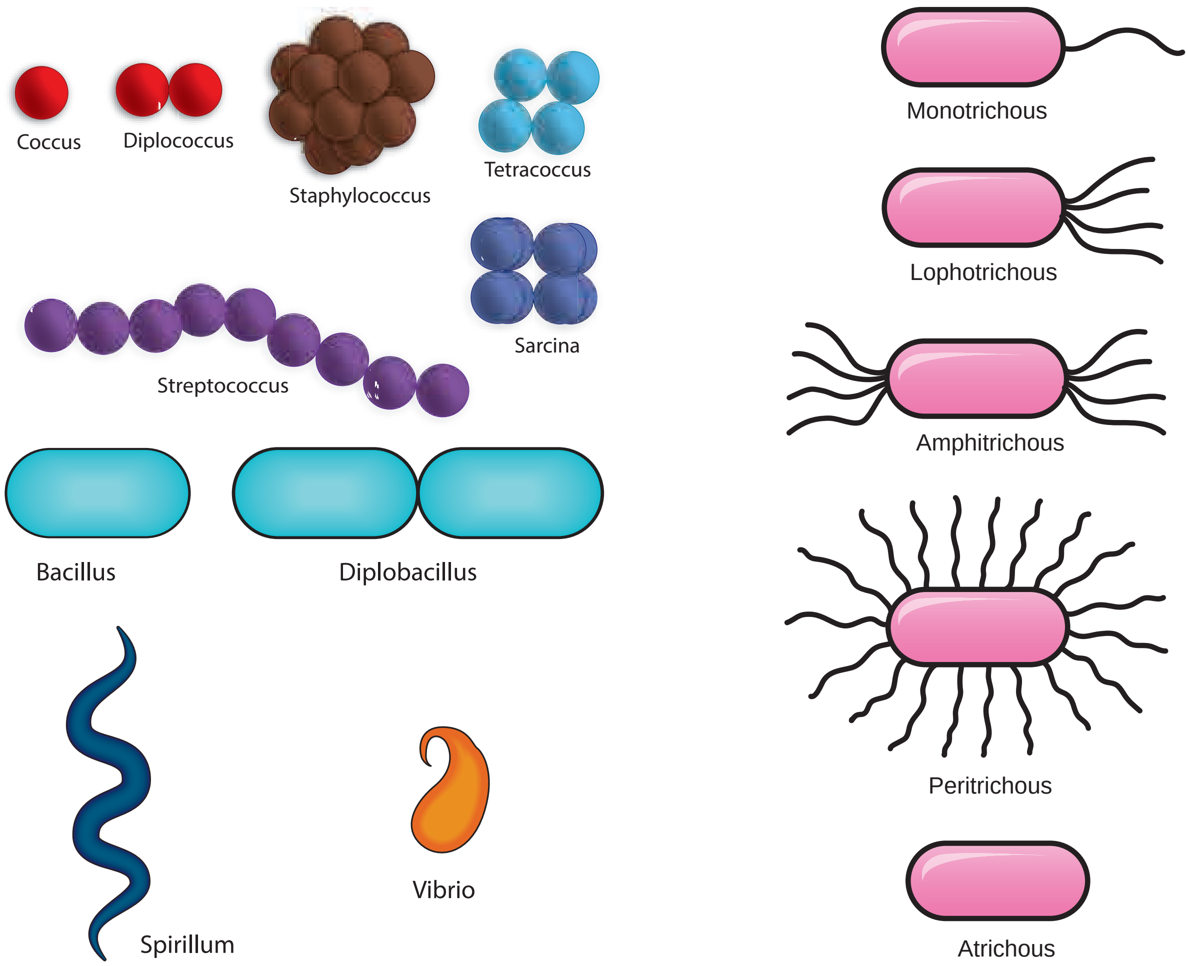


Figure 1.8: Shape and flagellation in bacteria

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)

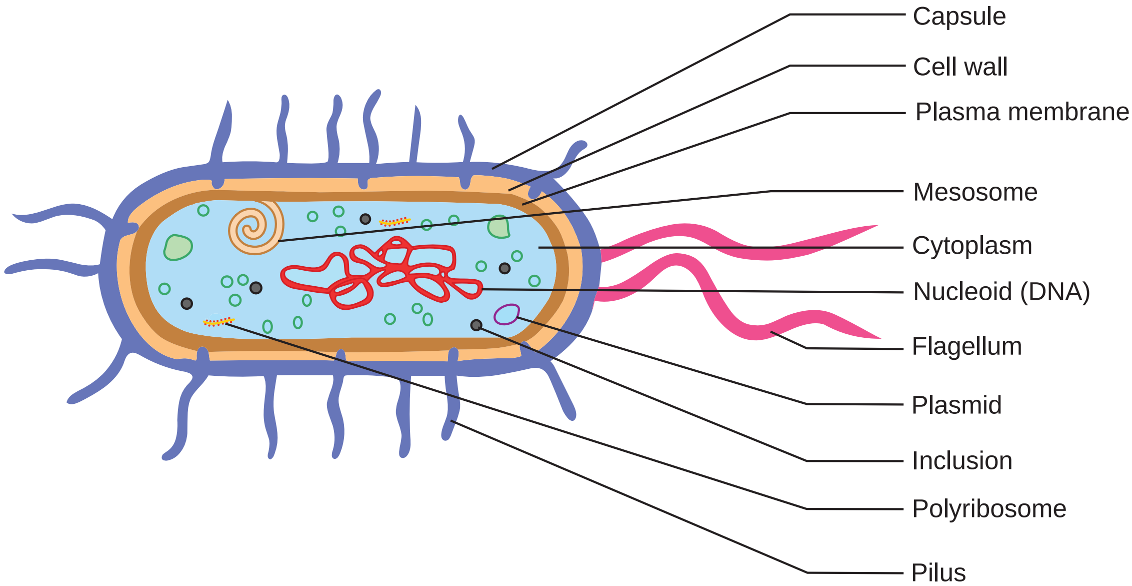


Figure 1.9: Ultrastructure of a bacterial cell

DO YOU KNOW?

- 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).

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 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.

Cell wall

The bacterial cell wall is granular and is rigid. It provide 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 extrachromosomal double stranded, circular, self-replicating, autonomous elements. 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 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. 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 processes 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.

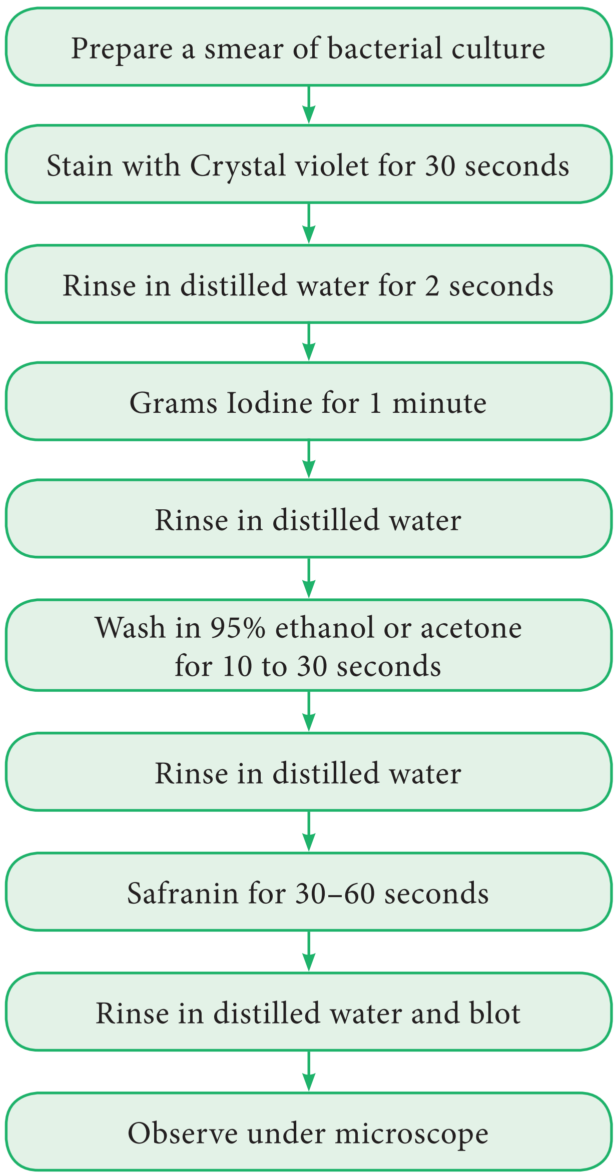


Figure 1.10: Steps involved in Gram Staining

Most of the gram positive cell wall contain considerable amount of teichoic acid and teichuronic acid. In addition, they may contain 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 are due to differences in the structure and composition of the cell wall (Figure 1.11). The difference between Gram Positive and Gram negative bacteria is given in Table 1.6.

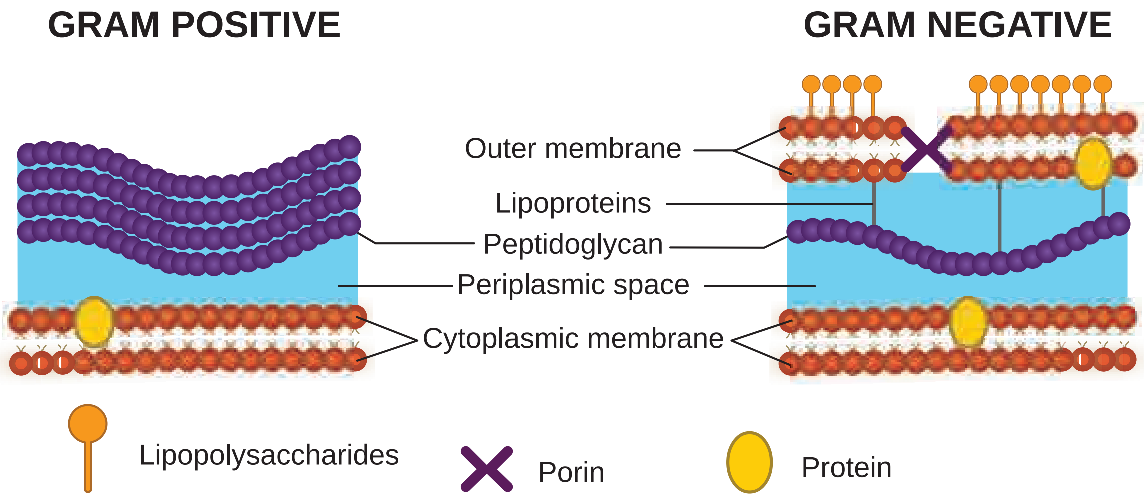


Figure 1.11: Difference between Gram positive and Gram negative bacteria

Table 1.6: Difference between Gram Positive and Gram Negative Bacteria

S.No	Characteristics	Gram positive Bacteria	Gram negative Bacteria
1.	Cell wall	Single layered with 0.015μm-0.02μm	Triple layered with 0.0075μm–0.012μm thick
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

What are Magnetosomes ?

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

1.4.5 Life processes in Bacteria

Respiration

Two types of respiration is 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 synthesis 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. These 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 (*Clostridium, 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 1.12). 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.

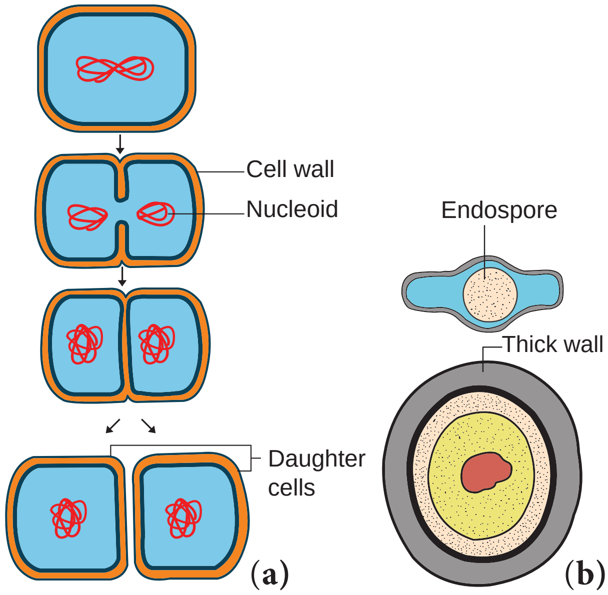


Figure 1.12: Asexual Reproduction in Bacteria (a) Binary fission, (b) Endospore

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 1.13).

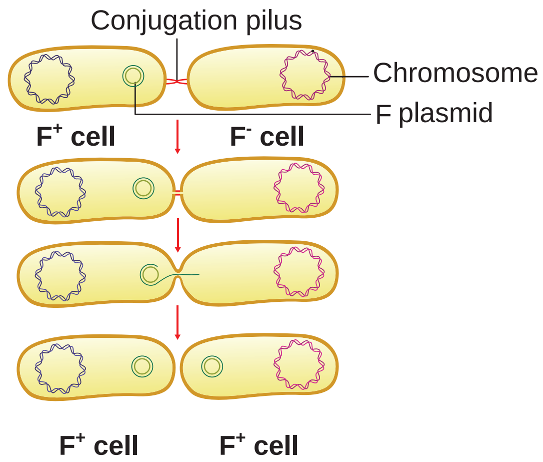


Figure 1.13: Conjugation

2. Transformation

Transfer of DNA from one bacterium to another is called **transformation** (Figure 1.14). 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 produced 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.

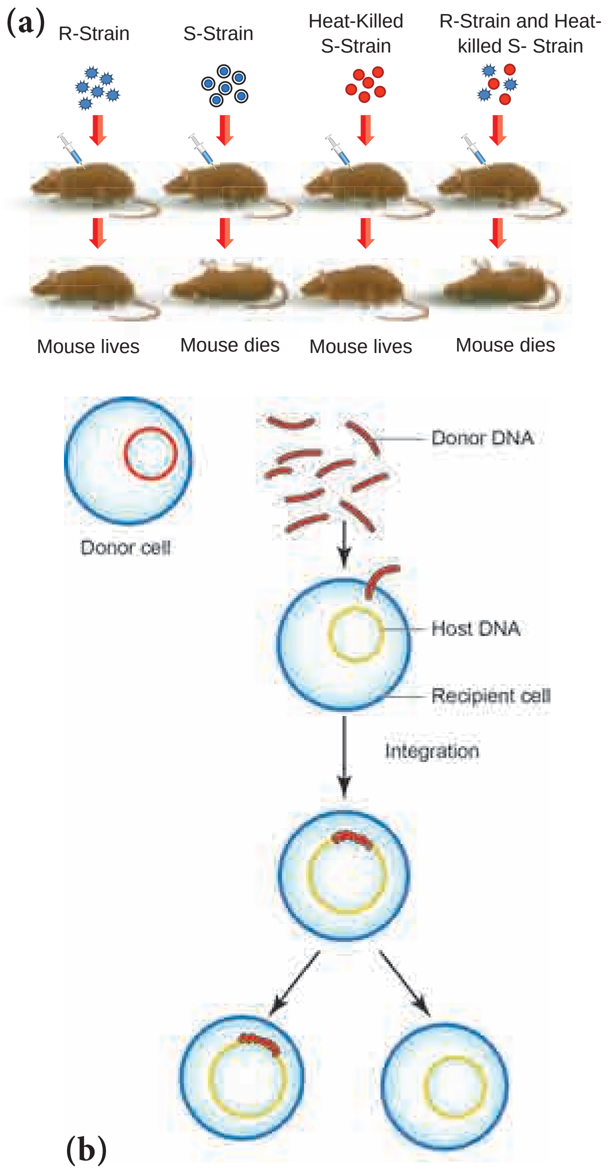


Figure 1.14: Transformation in Bacteria
(a) Griffith's experiment on Transformation
(b) Mechanism of Transformation

3. Transduction

Zinder and Lederberg (1952) discovered Transduction in *Salmonella typhimurum*. Phage mediated DNA transfer is called **Transduction** (Figure 1.15).

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.**

1.4.7 Economic importance of Bacteria

Bacteria are both beneficial and Harmful. The beneficial activities of bacteria are given in Table 1.7

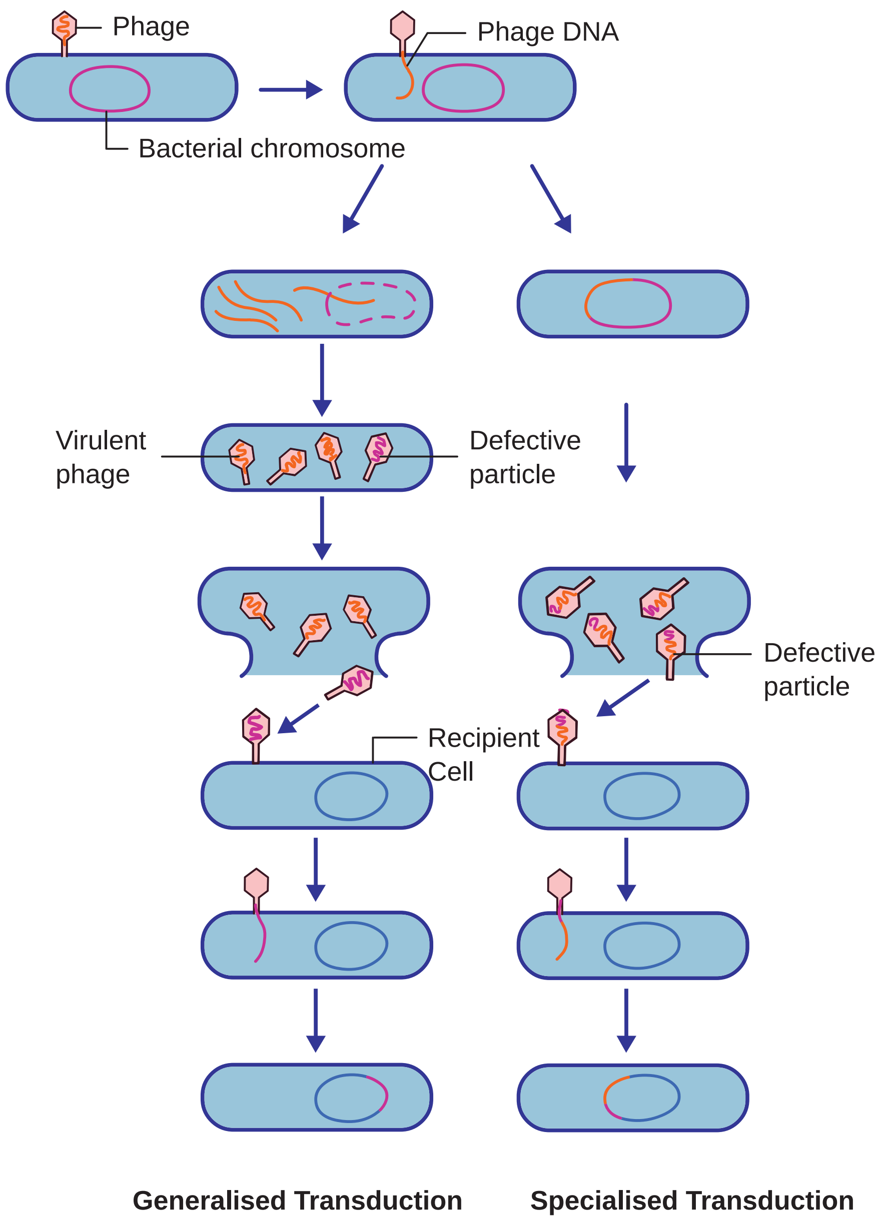


Figure 1.15: Transduction in Bacteria

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's cures urinary infections, tuberculosis, meningitis and pneumonia
2. Aureomycin	*Streptomyces aureofaciens*	It's 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	*Streptococcus lactis* and *Lactobacillus bulgaricus*	Convert milk sugar lactose into lactic acid
2. Butter	*Streptococcus lactis, Leuconostoc citrovorum*	Convert milk into butter, cheese, curd and yoghurt
3. cheese	*Lactobacillus acidophobus, 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)

(Continued)

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	Vitamin B_2 is prepared by the fermentation of sugar
10. Curing of Tea and Tobacco	*Mycococcus candisans, 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 1.16

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 chanvei*

Table 1.10: Human diseases caused by Bacteria

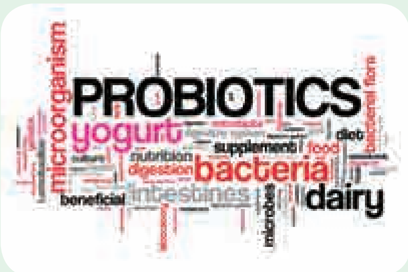
S.No	Name of the disease	Name of the pathogen
1.	Cholera	*Vibrio cholerae*
2.	Typhoid	*Salmonella typhi*
3.	Tuberculosis	*Mycobacterium tuberculosis*
4.	Leprosy	*Mycobacterium leprae*
5.	Pneumonia	*Diplococcus pneumonie*
6.	Plague	*Yersinia pestis*
7.	Diphtheria	*Corynebacterium diptheriae*
8.	Tetanus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


(a)


(b)

Figure 1.16: Plant diseases caused by bacteria (a) Citrus canker (b) Potato scab

Have you heard about the word "Probiotics"



Probiotic milk products, tooth paste are available in the Market. *Lactobacillus, 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.

DO YOU KNOW?

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

Ralstonia synthesize PHB (Poly-β-hydroxybutyrate) 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*.

DO YOU KNOW?

- *Pseudomonas putida* is a superbug (genetically engineered) which breakdown hydrocarbons.
- "Pruteen" is a single cell protein derived from *Methylophilus* and *Methylotropus*.
- *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.

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.

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 sea (Red sea). Species of *Nostoc*, *Anabaena* lead an endophytic life in the coralloid root of *Cycas*, leaves of aquatic fern *Azolla* and thallus of hornworts like *Anthoceros* 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, 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 1.17

DO YOU KNOW?

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

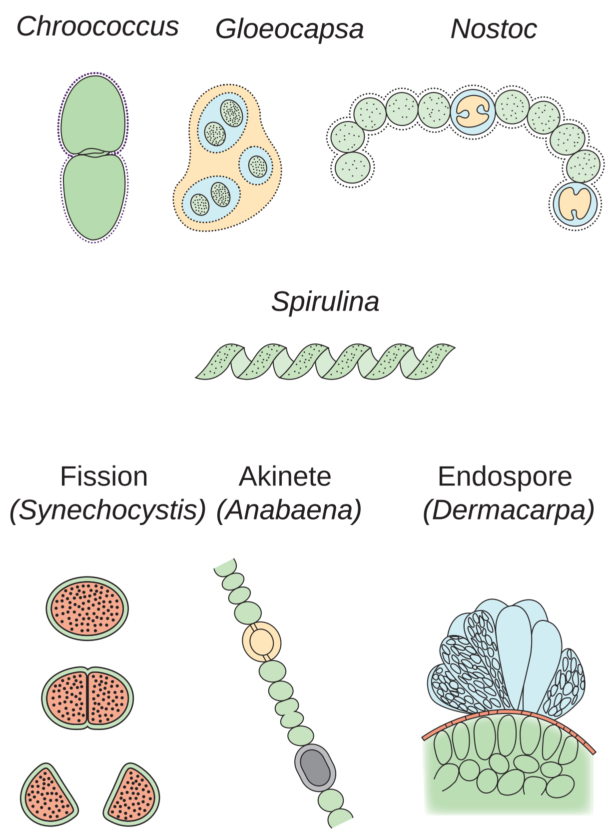


Figure 1.17: Structure and reproduction in cyanophyceae

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 appears 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 1.18.

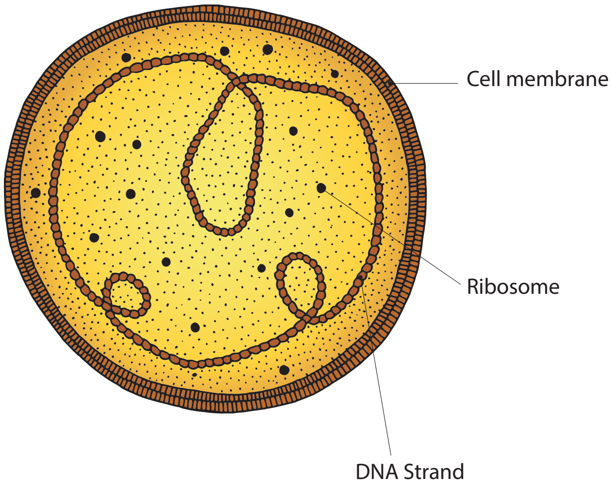


Figure 1.18: Structure of *Mycoplasma*

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 contain 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 odor" 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

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 was awarded Nobel Prize in Medicine in the year 1945.

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
1906	A.F.Blakeslee reported heterothallism in fungi
1952	Pontecarvo and Raper 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**

(Greek: *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 (1874-1943)

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) 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).
- The fungal mycelium is categorised into two types based on the presence or absence of septa (Figure 1.19). 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*

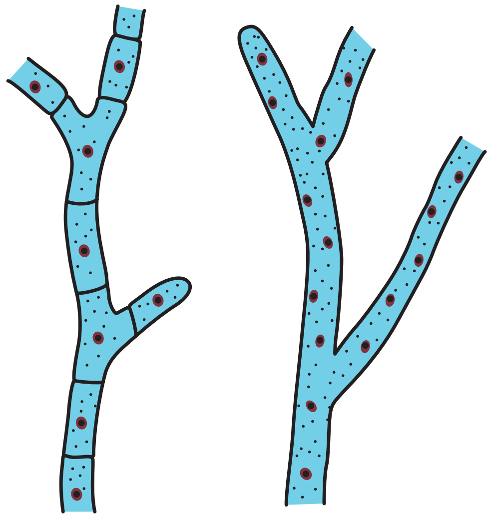


Figure 1.19: Types of mycelium

- 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**.

In 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 1.20

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*)

3. Oidia/Thallospores/Arthrospores: The hypha divide and develop in to spores called **oidia** (Example: *Erysiphe*).

4. Fission: The vegetative cell divide into 2 daughter cells. (Example: *Schizosaccharomyces*-yeast).

5. Budding: A small outgrowth is developed on parent cell, which gets detached and become 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*).

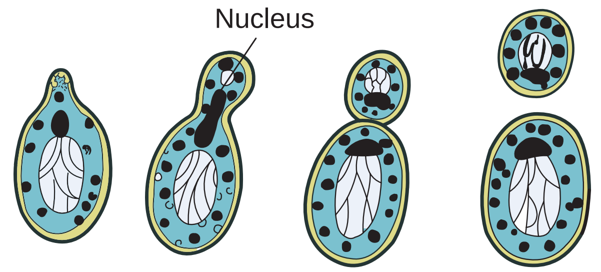
c. Oogamy – Fusion of both morphologically and physiologically dissimilar gametes. (Example: *Monoblepharis*)

2. Gametangial contact: During sexual reproduction a contact is established between antheridium and Oogonium (Example: *Albugo*)

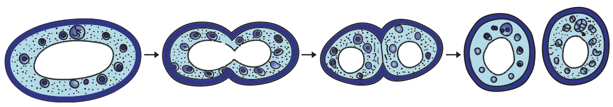
3. Gametangial copulation: Fusion of gametangia to form zygospore (Example: *Mucor, Rhizopus*).

4. Spermatization: In this method a uninucleate pycniospore/microconidium is transferred to receptive hyphal cell (Example: *Puccinia/Neurospora*)

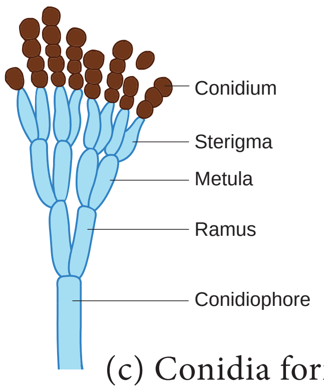
5. Somatogamy: Fusion of two somatic cells of the hyphae (Example: *Agaricus*)



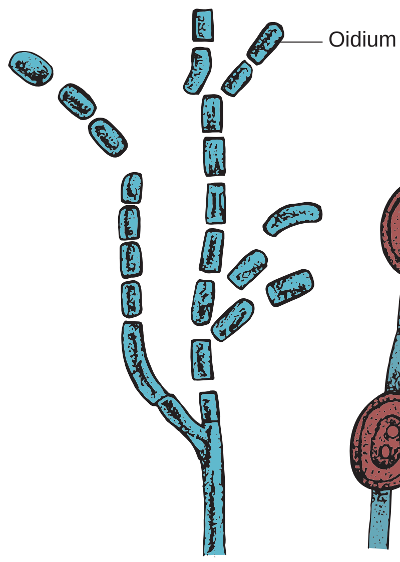
(a) Budding - Yeast

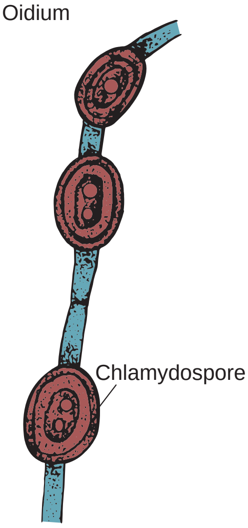


(b) Fission - Yeast



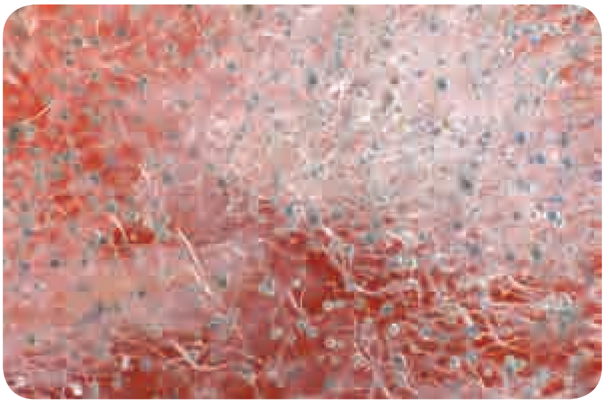
(c) Conidia formation - *Penicillium*



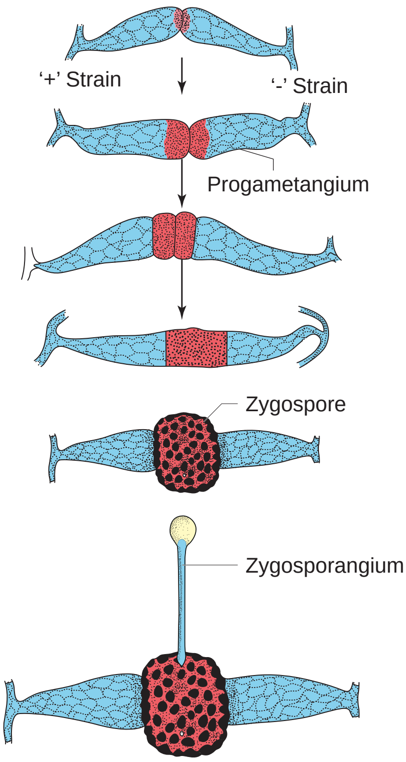


(d) Thallospore - *Erysiphe*

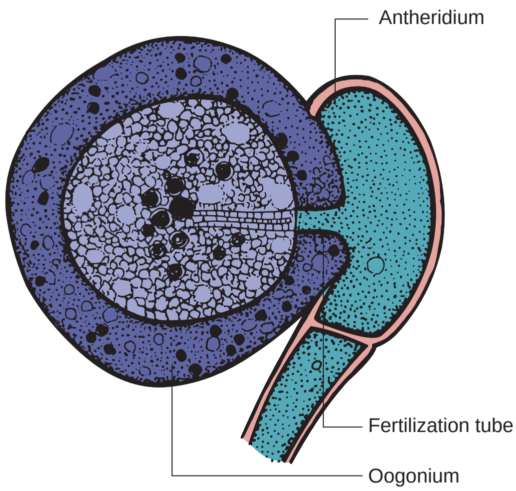
(e) Chlamydospore - *Fusarium*



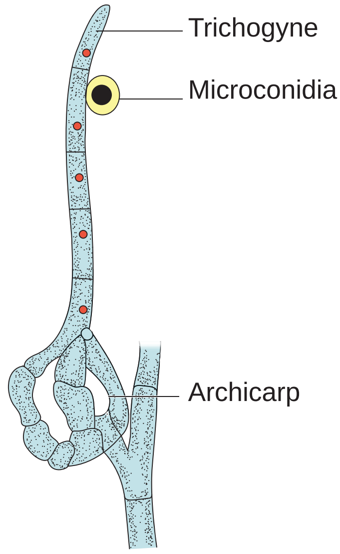
(f) Sporangia - *Mucor*



(g) Gametangial copulation - *Rhizopus*



(h) Gametangial contact - *Albugo*



(i) Spermatisation - *Neurospora*

Figure 1.20: 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.

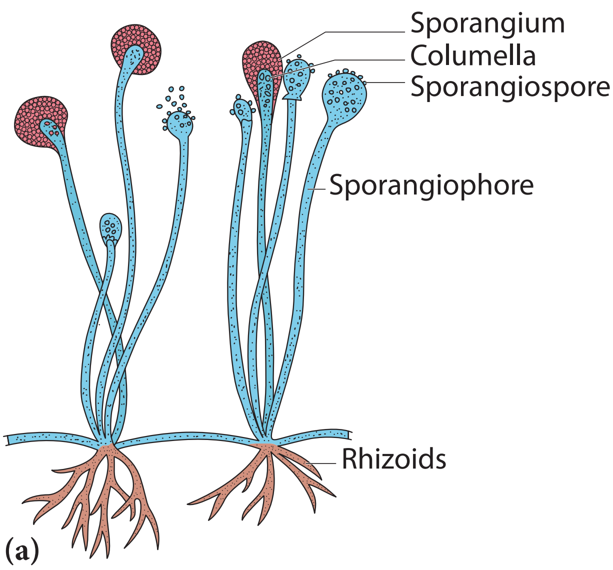
Recently, with the advent of molecular methods myxomycetes and oomycetes were reclassified and treated under chromista.

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 1.21).



(a)

(b)

Figure 1.21: Zygomycetes (a) *Rhizopus* (b) *Pilobolus*

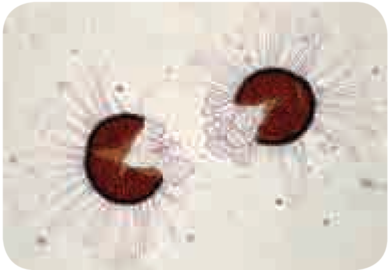
- The mycelium is branched and coenocytic.
- Asexual reproduction by means of spores produced in sporangia.
- Sexual reproduction is by the fusion of the gametangia which results in thick walled Zygospore. It remains dormant for long periods. The zygospore undergoes meiosis and produce spores.

Ascomycetes

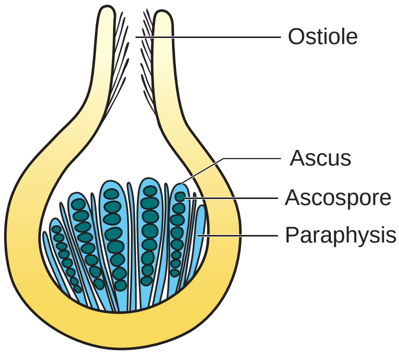
- Ascomycetes include a wide range of fungi such as yeasts, powdery mildews, cup fungi, morels and so on (Figure 1.22).

(a) *Morchella*

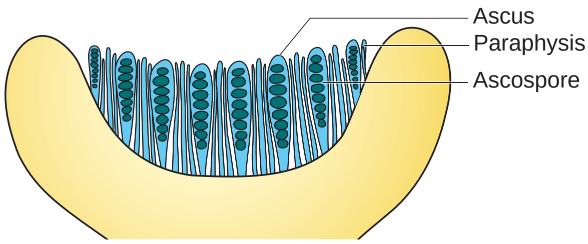
(b) *Peziza*



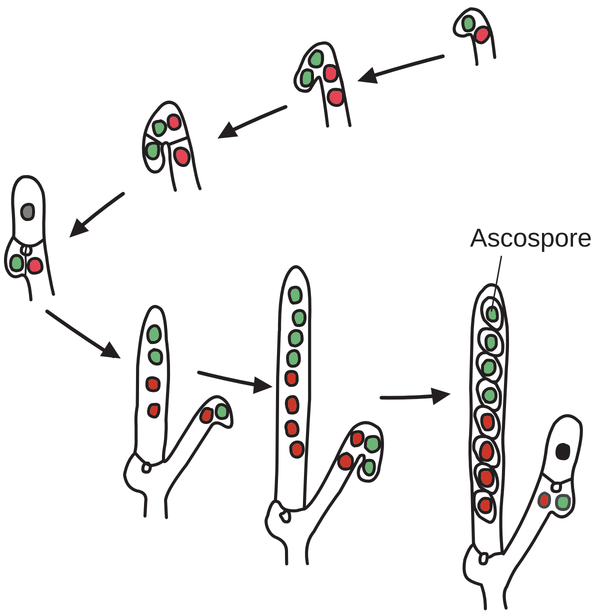
(c) Cleistothecium



(d) V.S. of Perithecium



(e) V.S. of Apothecium



(f) Steps involved in the development of Ascus

Figure 1.22: Structure and reproduction in Ascomycetes

- 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*).
- Asexual reproduction takes place by fission, budding, oidia, conidia, 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 form 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),

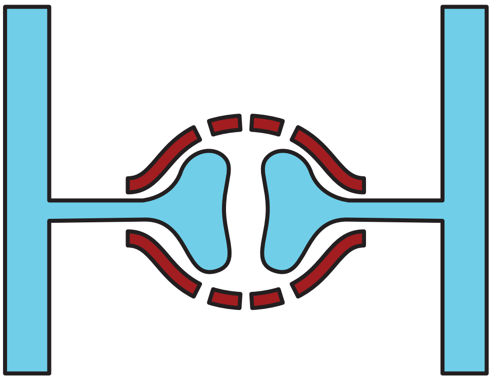
Perithecium (Flask shaped with ostiole), **Apothecium** (Cup shaped, open type) and **Pseudothecium**.

Basidiomycetes

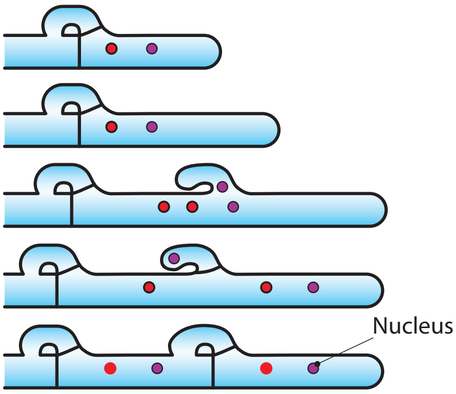
- Basidiomycetes include puff balls, toad stools, Bird's nest fungi, Bracket fungi, stink horns, rusts and smuts (Figure 1.23).

(a) *Agaricus*

(b) *Geaster*



(c) Dolipore septum



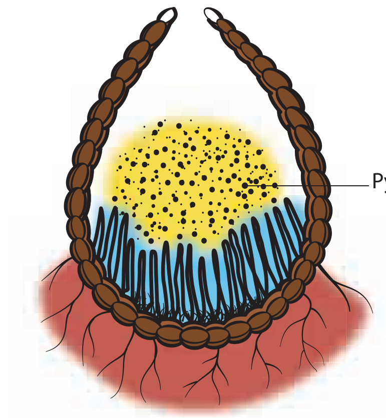
(d) Clamp connection

Figure 1.23: Structure and Reproduction in Basidiomycetes

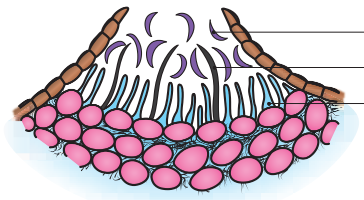
- The members are terrestrial and lead a saprophytic and parasitic mode of life.
- The mycelium is well developed, septate with dolipore septum(bracket like). Three types of mycelium namely Primary (Monokaryotic), Secondary (Dikaryotic) and tertiary are found.
- Clamp connections are formed to maintain 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

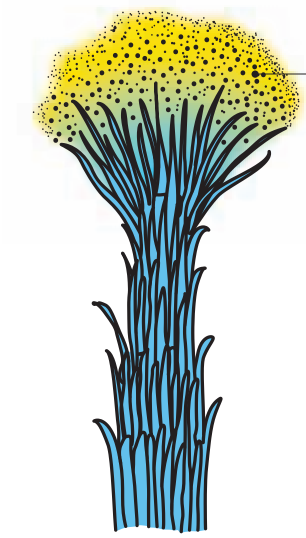
The fungi belonging to this group lack sexual reproduction and are called **imperfect fungi.** A large number of species live as saprophytes in soil and many are plant and animal parasites. Asexual reproduction takes place by the production of conidia, chlamydospores, budding, oidia etc., Conidia are also produced in special structures called **Pycnidium, Acervulus, Sporodochium** and **Synnema** (Figure 1.24). Parasexual cycle operates in this group of fungi. This brings genetic variation among the species.



(a) Pycnidium - *Phoma*



(b) Acervulus - *Colletotrichum*



(c) Synnemata - *Graphium*

Figure 1.24: Reproduction in Deuteromycetes

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 and Figure 1.25)

(a) Rust of wheat
Puccinia graminis var *tritici*

(b) Anthracnose of beans
Colletotrichum lindemuthianum.

Figure 1.25: Fungal disease in plants.

Table 1.11: Diseases caused by fungi

S. No	Name of the disease	*Causal organism*
	Plant diseases	
1.	Blast of Paddy	*Magnaporthe grisea*
2.	Red rot of sugarcane	*Colletotrichum falcatum*
3.	Anthracnose of Beans	*Colletotrichum lindemuthianum*
4.	White rust of crucifers	*Albugo candida*
5.	Peach leaf curl	*Taphrina deformans*
6.	Rust of wheat	*Puccinia graminis tritici*
	Human diseases	
1.	Athlete's foot	*Epidermophyton floccosum*
2.	Candidiasis	*Candida albicans*
3.	Coccidioidomycosis	*Coccidioides immitis*
4.	Aspergillosis	*Aspergillus fumigatus*

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.

DO YOU KNOW?

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

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

The Symbiotic association between fungal mycelium and roots of plants is called as **mycorrhizae.** In this relationship fungi absorbs 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 1.26) Mycorrhizae are classified into three types

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

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 Hartignet. 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(VAM) Example: *Gigaspora* 2. Ericoid mycorrhizae-Example: *Oidiodendron* 3. Orchid mycorrhizae -Example: *Rhizoctonia*	The fungi form both mantle and also penetrates the cortical cells.

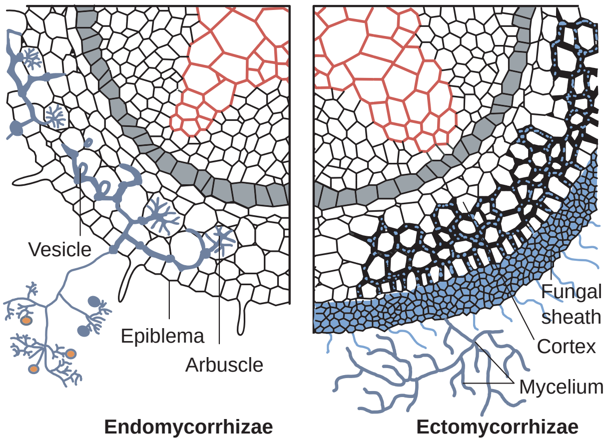


Figure 1.26: T.S. of root showing mycorrhizae

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**(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 1.27).
- 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**.

(a) Crustose lichen

(b) Foliose Lichen

(c) Fruticose Lichen

Figure 1.27: Types of Lichens

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 moss) 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. Cyanobacteeria 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

5E5LPE

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?

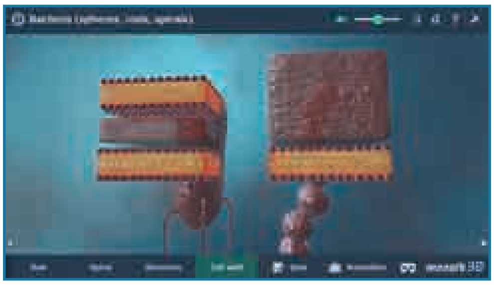
9. Briefly discuss on five kingdom classification. Add a note on merits and demerits.

10. Give a general account on lichens.

ICT Corner

Bacteria

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

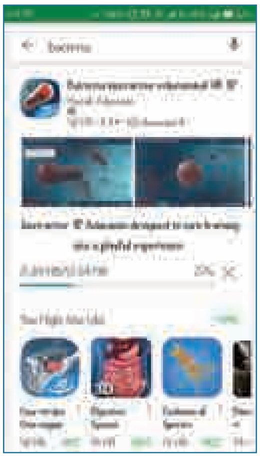


Steps

- 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

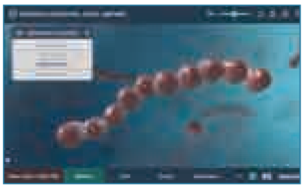
- Select structure tap and note the internal structure of bacteria
- Click cell wall and note the difference between different shapes



Step 1

Step 2

Step 3



Step 4

Step 5

URL:

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

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

B181_11_BOT

* Pictures are indicative only

Chapter 2

Plant Kingdom

Learning Objectives

The learner will be able to,

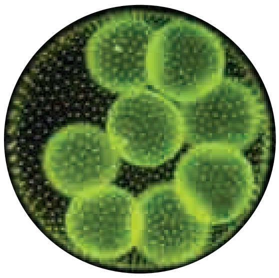
- *Outline the classification of plants*
- *Illustrate the life cycles in plants*
- *Recognize the general characteristic features and reproduction of Algae*
- *Recognize the general characteristic features of Bryophytes*
- *Recognize the general characteristic features of Pteridophytes*
- *Describe the general characteristic features of Gymnosperms*
- *Compare the characteristic features of Gymnosperms and Angiosperms*
- *Recognize the salient features of Angiosperms*

Chapter Outline

2.1 Classification of Plants
2.2 Life Cycle patterns in Plants
2.3 Algae
2.4 Bryophytes
2.5 Pteridophytes
2.6 Gymnosperms
2.7 Angiosperms

5EEHR2

Traditionally organisms existing on the earth were classified into plants and animals based on nutrition, locomotion and presence or absence of cell wall. Bacteria, Fungi, Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms were included under plant group. Recently, with the aid of molecular characteristics the Bacteria and Fungi were segregated and placed under separate kingdoms.



Botany is one of the oldest science in the world because its origin was from time immemorial as early men explored and identified plants for the needs of food, clothing, medicine, shelter etc., Plants are unique living entities as they are endowed with the power to harvest the light energy from the sun and to convert it to chemical energy in the form of food through the astounding reaction, **photosynthesis**. They not only supply nutrients to all living things on earth but sequester carbon-di-oxide during photosynthesis thus minimizing the effect of one of the major green house gases that increase the global temperature. Plants are diverse in nature, ranging from microscopic algae to macroscopic highly developed angiosperms. There are mysteries and wonders in the plant world in terms of size, shape, habit, habitat, reproduction etc., Although plants are all made up of cells there exists high diversity in form and structure.

Table 2.1: Total Number of Plant groups in the World and India		
Plant group	**Number of known species**	
	World#	**India***
Algae	40,000	7,357
Bryophytes	16,236	2,748
Pteridophytes	12,000	1,289
Gymnosperms	1,012	79
Angiosperms	2,68,600	18,386

** Source: Singh, P. and Dash, S.S. 2017-Plants discoveries 2016-New Genera, species and new records, BSI, India.*
 # Chapman, A.D. 2009, Number of living species in Australia and world 2nd Edition.

2.1 Classification of Plants

Classification widely accepted for plants now include Embryophyta which is divided into Bryophyta and Tracheophyta. The latter is further divided into Pteridophyta and Spermatophyta (Gymnospermae and Angiospermae). An outline Classification of Plant Kingdom is given in Figure 2.1.

Figure 2.1: Classification of Plant Kingdom

2.2 Life Cycle Patterns in Plants

Alternation of Generation

Alternation of generation is common in all plants. Alternation of the haploid gametophytic phase (n) with diploid sporophytic phase (2n) during the life cycle is called **alternation of generation.** Following type of life cycles are found in plants (Figure 2.2).

Haplontic Life Cycle

Gametophytic phase is dominant, photosynthetic and independent, whereas sporophytic phase is represented by the zygote. Zygote undergoes meiosis to restore haploid condition. Example: *Volvox*, *Spirogyra*.

Diplontic Life Cycle

Sporophytic phase (2n) is dominant, photosynthetic and independent. The gametophytic phase is represented by the single to few celled gametophyte. The gametes fuse to form Zygote which develops into Sporophyte. Example: *Fucus*, Gymnosperms and Angiosperms

Haplodiplontic Life Cycle

This type of life cycle is found in Bryophytes and pteridophytes which is intermediate between haplontic and diplontic type. Both the phases are multicellular. but they differ in their dominant phase.

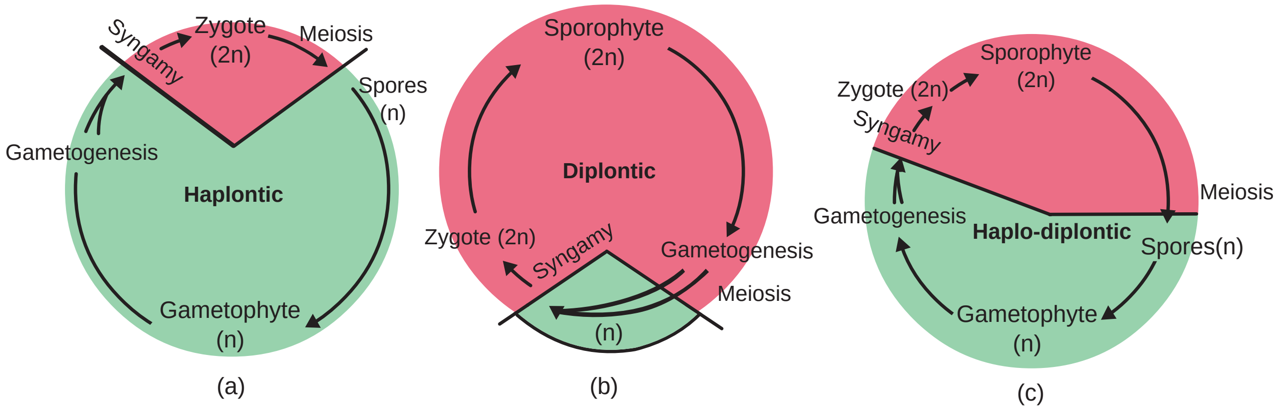


Figure 2.2: Life cycle patterns in plants a) Haplontic, b) Diplontic, c) Haplo-diplontic

In Bryophytes dominant independent phase is gametophyte and it alternates with short-lived multicellular sporophyte totally or partially dependent on the gametophyte.

In Pteridophytes sporophyte is the independent phase. It alternates with multicellular saprophytic or autotrophic, independent, short lived gametophyte(n).

2.3 Algae

Rain brings joy and life to various organisms on earth. Have you noticed some changes in and around you after the rain? Could you identify the reason for the slippery nature of the terrace and green patches on the wall of our home, green colour of puddles and ponds? Why should we clean our water tanks very often? The reason is algae. Algae are simple plants that lack true roots, true stems and true leaves. Two-third of our earth's surface is covered by oceans and seas. The photosynthetic plants called algae are present here. More than half of the total primary productivity of the world depends on this plant group. Further, other aquatic organisms also depend upon them for their existence.

M.O. Parthasarathy (1886-1963)
'Father of Indian Phycology'.

He conducted research on structure, cytology, reproduction and taxonomy of Algae. He published a Monograph on Volvocales. New algal forms like *Fritschiella, Ecballocystopsis, Charasiphon* and *Cylindrocapsopsis.* were reported by him.

Algae are autotrophs, and grow in a wide range of habitats. Majority of them are aquatic, marine (*Gracilaria,* and *Sargassum*) and freshwater (*Oedogonium,* and *Ulothrix*) and also found in soils (*Fritschiella,* and *Vaucheria*). *Chlorella* lead an endozoic life in *Hydra* and sponges whereas *Cladophora crispata* grow on the shells of molluscs. Algae are adapted to thrive in harsh environment too. *Dunaliella salina* grows in salt pans (**Halophytic alga**). Algae growing in snow are called **Cryophytic algae**. *Chlamydomonas nivalis* grow in snow covered mountains and impart red colour to the snow (**Red snow**). A few algae grow on the surface of aquatic plants and are called **epiphytic algae** (*Coleochaete,* and *Rhodymenia*). The study of algae is called **algology** or **phycology**. Some of the eminent algologists include F.E.Fritsch, F.E. Round, R.E. Lee, M.O. Parthasarathy, M.S. Randhawa, Y. Bharadwaja, V.S. Sundaralingam and T.V.Desikachary.

2.3.1 General Characteristic features

The algae show a great diversity in size, shape and structure. A wide range of thallus organisation is found in algae. Unicellular motile (*Chlamydomonas*), unicellular non-motile (*Chlorella*), Colonial motile (*Volvox*), Colonial non motile (*Hydrodictyon*), siphonous (*Vaucheria*), unbranched filamentous (*Spirogyra*), branched filamentous (*Cladophora*), discoid (*Coleochaete*) heterotrichous (*Fritschiella*), Foliaceous (*Ulva*) to Giant Kelps (*Laminaria* and *Macrocystis*). The thallus organization in algae is given in Figure 2.3

Algae are Eukaryotes except blue green algae. The plant body does not show differentiation into tissue systems. The cell wall of algae is made up of cellulose and hemicellulose. Siliceous walls are present in diatoms. In *Chara* the thallus is encrusted with calcium carbonate. Some algae possess algin, polysulphate esters of polysaccharides which are the

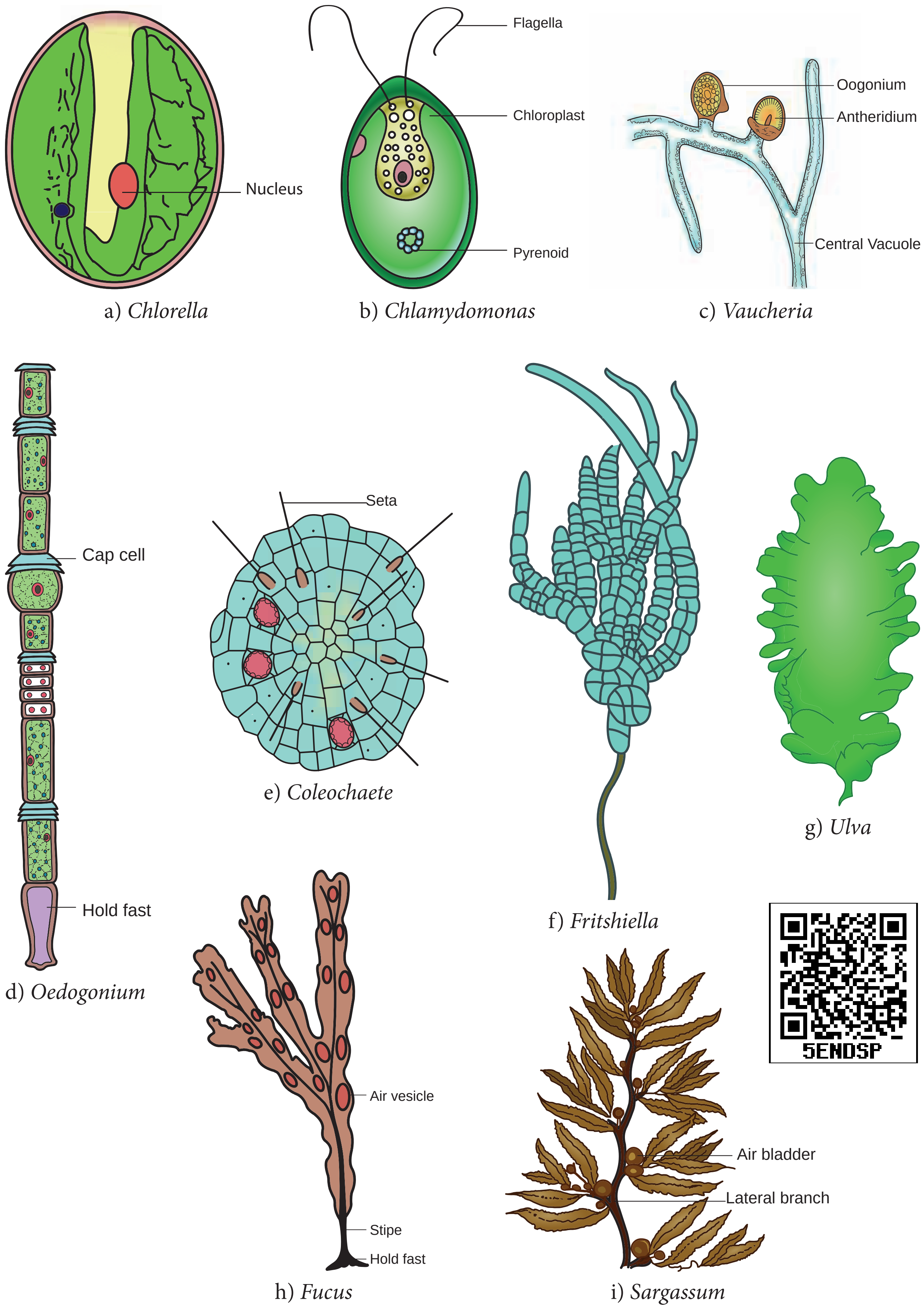
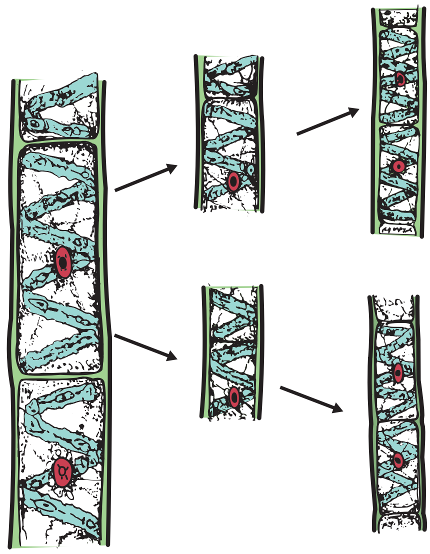


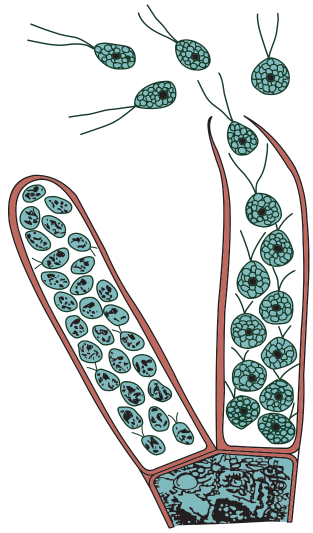
Figure 2.3: Thallus organization in Algae

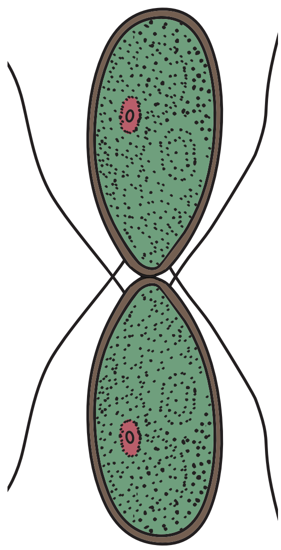
sources for the alginate, agar agar and Carrageenan. The cell has a membrane bound nucleus and cell organelles like chloroplast, mitochondria, endoplasmic reticulum, golgi bodies etc., Pyrenoids are present. They are proteinaceous bodies found in chromatophores and assist in the synthesis and storage of starch. The pigmentation, reserve food material and flagellation differ among the algal groups.

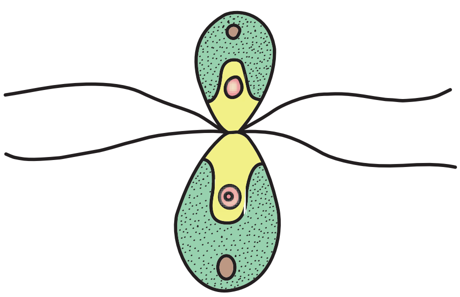
Algae reproduces by vegetative, asexual and sexual methods (Figure 2.4). Vegetative reproduction includes fission (In unicellular forms the cell divides mitotically to produce two daughter cells Example: *Chlamydomonas*); Fragmentation (fragments of parent thallus grow into new individual Example: *Ulothrix*) Budding (A lateral bud is formed in some members like *Protosiphon* and helps in reproduction) Bulbils, (a wedge shaped modified branch develop in *Sphacelaria*) Akinetes (Thick walled spores meant for perennation and germinates with the advent of favourable condition Example: *Pithophora*). Tubers (Structures found on the rhizoids and the lower nodes of *Chara* which store food materials).

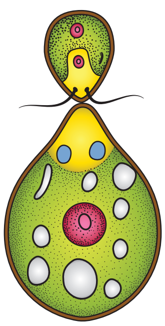
Asexual reproduction takesplace by the production of zoospores(*Ulothrix*, *Oedogonium*) aplanospore(thin walled non motile spores Example: *Vaucheria*);


a) Fragmentaion-*Spirogyra*


b) Zoospore formation-*Cladophora*


c) Isogamy


d) Anisogamy


e) Oogamy

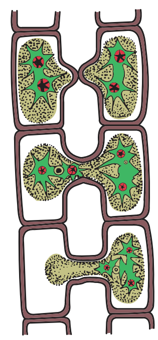
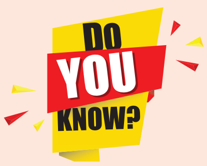

f) Scalariform conjugation-*Zygnema*

Figure 2.4: Reproduction in Algae

Autospores (spores which look similar to parent cell Example: *Chlorella*); Hypnospore (thick walled aplanospore – Example: *Chlamydomonas nivalis*); Tetraspores (Diploid thallus of *Polysiphonia* produce haploid spores after meiosis).

Sexual reproduction in algae are of three type 1. Isogamy (Fusion of morphologically and Physiologically similar gametes Example: *Ulothrix*) 2. Anisogamy (Fusion of either morphologically or physiologically dissimilar gametes Example: *Pandorina*) 3. Oogamy (Fusion of both morphologically and physiologically dissimilar gametes. Example: *Sargassum*). The life cycle shows distinct alternation of generation.



The Oldest recorded alga is *Grypania,* which was discovered in the banded iron formations of northern Michigan and dated to approximately 2100Ma

2.3.2. Classification

F.E. Fritsch proposed a classification for algae based on pigmentation, types of flagella, reserve food materials, thallus structure and reproduction. He published his classification in the book "**The structure and reproduction of the Algae**"(1935). He classified algae into 11 classes namely Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonodineae, Euglenophyceae, Phaeophyceae, Rhodophyceae, Cyanophyceae.

The salient features of Chlorophyceae, Phaeophyceae and Rhodophyceae are given below.

Chlorophyceae

The members are commonly called **'Green algae'**. Most of the species are aquatic(Fresh water-*Spirogyra*, Marine -*Ulva*). A few are terrestrial(*Trentipohlia*). Variation among the shape of the chloroplast is found in members of algae. It is Cup shaped (*Chlamydomonas*), Discoid (*Chara*), Girdle shaped, (*Ulothrix*), reticulate (*Oedogonium*), spiral (*Spirogyra*), stellate (*Zygnema*), plate like (*Mougeoutia*). Chlorophyll 'a' and Chlorophyll 'b' are the major photosynthetic pigments. Storage bodies called **pyrenoids** are present in the chloroplast and store starch. They also contain proteins. The cell wall is made up of inner layer of cellulose and outer layer of Pectin. Vegetative reproduction takes place by means of fragmentation and asexual reproduction is by the production of zoospores, aplanospores and akinetes. Sexual reproduction is present and may be isogamous, anisogamous or Oogamous. Examples for this group of algae includes *Chlorella, Chlamydomonas, Volvox, Spirogyra, Ulothrix, Chara* and *Ulva.*

Phaeophyceae

The members of this class are called **'Brown algae'**. Majority of the forms are found in marine habitats. *Pleurocladia* is a fresh water form. The thallus is filamentous (*Ectocarpus*) frond like (*Dictyota*)or may be giant kelps (*Laminaria* and *Macrocystis*). The thallus is differentiated into leaf like photosynthetic part called **fronds,** a stalk like structure called **stipe** and a **holdfast** which attach thallus to the substratum. The Pigments include Chlorophyll a, c, carotenoids and Xanthophylls. A golden brown pigment called **fucoxanthin** is present and it gives shades of colour from olive green to brown to the algal members of this group. Mannitol and Laminarin are the reserve food materials. Motile reproductive structures are present. Two laterally inserted unequal flagella are present. Among these one is whiplash and another is tinsel. Although sexual reproduction ranges from isogamy to Oogamy, Most of the forms show Oogamous type. Alternation of generation is present (isomorphic, heteromorphic or diplontic). Examples for this group include *Sargassum, Laminaria, Fucus* and *Dictyota.*

Rhodophyceae

Members of this group include **'Red algae'** and are mostly marine. The thallus is multicellular, macroscopic and diverse in form. *Porphyridium* is the unicellular form. Filamentous (*Goniotrichum*) ribbon like (*Porphyra*) are also present. *Corallina* and *Lithothamnion* are heavily impregnated with lime and form coral reefs. Apart from chlorophyll a, r-phycoerythrin and r-phycocyanin are the photosynthetic pigments. Asexual reproduction takes place by means of monospores, neutral spores and Tetraspores.

The storage product is floridean starch. Sexual reproduction is Oogamous. Male sex organ is spermatangium which produces spermatium. Female sex organ is called **carpogonium.** The spermatium is carried by the water currents and fuse with egg nucleus to form zygote. The zygote develops into carpospores. Meiosis occurs during carpospore formation. Alternation of generation is present. Examples for this group of algae include *Ceramium, Polysiphonia, Gelidium, Cryptonemia* and *Gigartina*

DO YOU KNOW?

A green alga *Botryococcus braunii* is employed in Biofuel production.

Algae in Health care

Kelps are the rich source of Iodine

Chlorella is used as Single cell protein (SCP).

Dunaliella salina an alga, growing in Salt pan is complement to our health and provide β carotene.

DO YOU KNOW?

A Productive Cultivation in Sea

Algae like *Kappaphycus alvarezii, Gracilaria edulis* and *Gelidiella acerosa* are commercially grown in the sea for harvesting the phycocolloids.

Sea Palm? It is *Postelia palmaeformis* a brown alga.

2.3.3 Economic Importance

The Economic importance of Algae is given in Table 2.2

Table 2.2: Economic importance of Algae	
Name of the Algae	**Economic importance**
Beneficial activities	
Chlorella, Laminaria, Sargassum, Ulva, Enteromorpha	Food
Gracilaria, Gelidiella, Gigartina	Agar Agar – Cell wall material used for media preparation in the microbiology lab. Packing canned food, cosmetic, textile paper industry
Chondrus crispus	Carrageenan – Preparation of tooth paste, paint, blood coagulant
Laminaria, Ascophyllum	Alginate – ice cream, paints, flame proof fabrics
Laminaria, Sargassum, Ascophyllum, Fucus	Fodder
Diatom (Siliceous frustules)	Diatomaceous earth– water filters, insulation material, reinforcing agent in concrete and rubber.
Lithophyllum, Chara, Fucus	Fertilizer
Chlorella	Chlorellin -Antibiotic
Chlorella, Scenedesmus, Chlamydomonas	Sewage treatment, Pollution indicators
Harmful activity	
Cephaleuros virescens	Red rust of coffee

2.4 Bryophytes

Amphibians of Plant Kingdom

In the previous chapter we noticed a wide range of thallus organization in Algae. Majority of them are aquatic. The development of heterotrichous habit, development of parenchyma tissue, dichotomous branching in some algae supports the view that colonization of plants in land occurred in the past. Bryophytes are simplest and most primitive plant groups descended from alga – like ancestors. They are simple embryophytes. Let us learn about the structure and reproduction of these primitive land plants called **Bryophytes** in detail.

Bryophytes are simplest land inhabiting cryptogams and are restricted to moist,

Shiv Ram Kashyap
(1882-1934)

Father of Indian Bryology. He published a book-'Liverworts of Western Himalayas and Punjab Plains' He identified new genera like *Atchinsoniella, Sauchia, Sewardiella* and *Stephansoniella.*

shady habitats. They lack vascular tissue and hence called **'Non- vascular cryptogams'**. They are also called as '**amphibians of plant kingdom'** because they need water for completing their life cycle.

2.4.1 General characteristic features

- The plant body of bryophyte is gametophyte and is not differentiated into root, stem and leaf like structure.
- Most of them are primitive land dwellers. Some of them are aquatic (*Riella, Ricciocarpus*).
- The gametophyte is conspicuous, long lived phase of the life cycle. Thalloid forms are present in liverworts and Hornworts. In Mosses leaf like, stem like structures are present. In Liverworts thallus grows prostrate on the ground and is attached to the substratum by means of rhizoids. Two types of rhizoids are present namely smooth walled and pegged. Multicellular scales are also present. In Moss the plant body is erect with central axis bearing leaf like expansions. Multicellular rhizoids are present. The structure and reproduction in Bryophytes is given in Figure 2.5.
- Vascular tissue like xylem and phloem are completely absent, hence called **'Non vascular cryptogams'.**
- Vegetative reproduction takes place by the formation of adventitious buds (*Riccia fluitans*) tubers develop in *Anthoceros*. In some forms small detachable branches or brood bodies are formed, they help in vegetative reproduction as in *Bryopteris fruticulosa*. In *Marchantia* propagative organs called **gemmae** are formed and help in reproduction.
- Sexual reproduction is Oogamous. Antheridia and Archegonia are produced in a protective covering and are multicellular.
- The antheridia produces biflagellate antherozoids which swims in thin film of water and reach the archegonium and fuse with the egg to form diploid zygote.
- Water is essential for fertilization.
- The zygote is the first cell of the sporophyte generation. It undergoes mitotic division to form multicellular undifferentiated embryo. The embryogeny is exoscopic (the first division of the zygote is transverse and the apex of the embryo develops from the outer cell). The embryo divides and give rise to sporophyte.
- The sporophyte is dependent on gametophyte.
- It is differentiated into three recognizable parts namely foot, seta and capsule. Foot is the basal portion and is embedded in the gametophyte

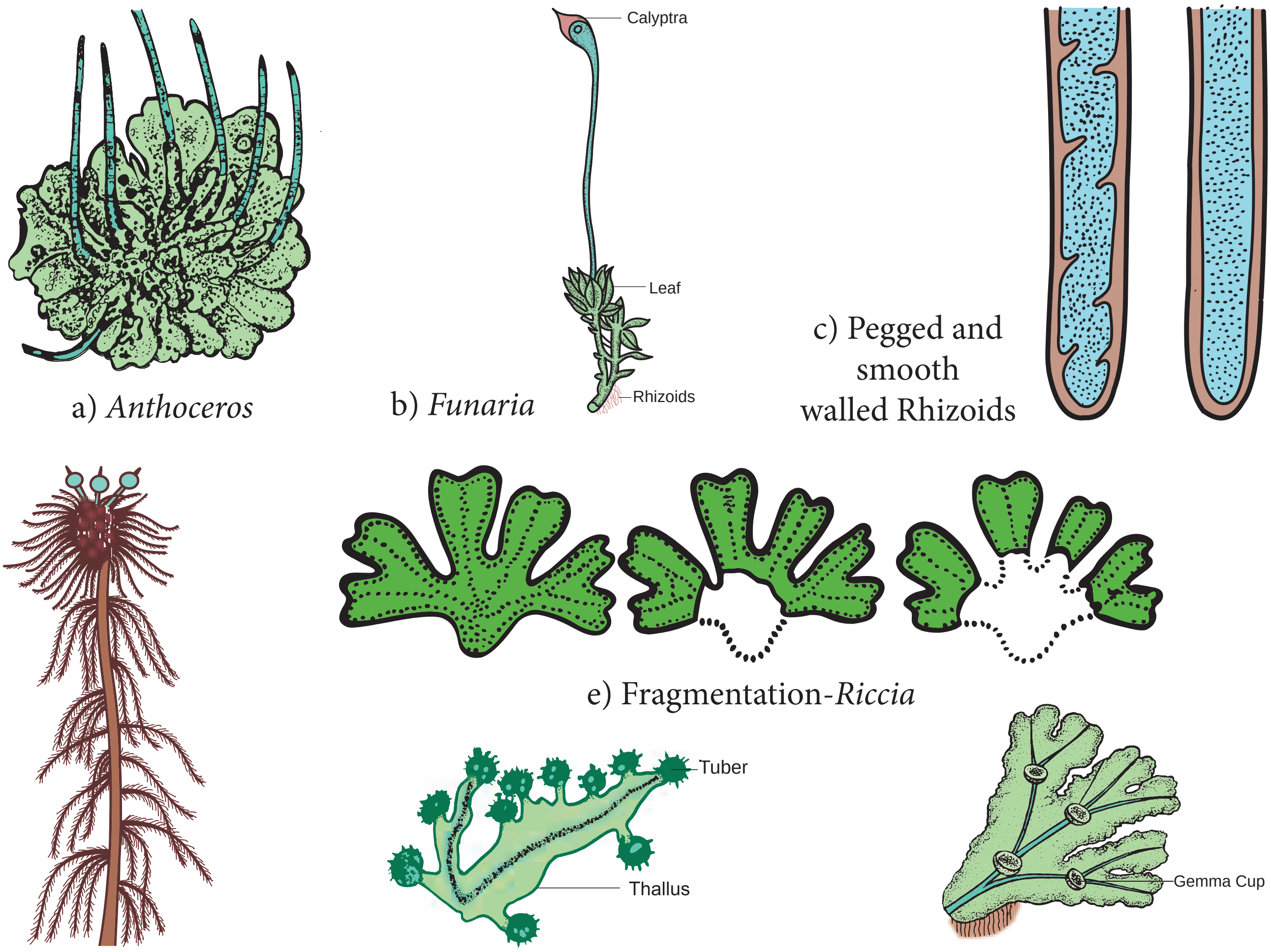
through which water and nutrients are supplied for the sporophyte. The diploid spore mother cells found in the capsule region undergoes meiotic division and give rise to haploid spores. Bryophytes are homosporous. In some sporophytes elaters are present and help in dispersal of spores (Example: *Marchantia*). The spores germinate to produce gametophyte.

- The zygote, embryo and the sporogonium constitute sporophytic phase. The green long living haploid phase is called **gametophytic** phase The haploid gametophytic phase alternates with diploid sporophyte and shows heterologous alternation of generation. Proskauer in the year 1957 classified Bryophytes into 3 Classes namely

i) **Hepaticopsida** (*Riccia, Marchantia, Porella, Riella*) ii) **Anthocerotopsida** (*Anthoceros* and *Dendroceros*) iii) **Bryopsida** (*Funaria, Polytrichum* and *Sphagnum*).

2.4.2 Economic importance

A large amount of dead thallus of *Sphagnum* gets accumulated and compressed, hardened to form peat. In northern Europe peat is used as fuel in commercial scale (Netherlands). Apart from this Nitrates, brown dye and tanning materials are derived from peat. *Sphagnum*



a) *Anthoceros* b) *Funaria* c) Pegged and smooth walled Rhizoids d) *Sphagnum* e) Fragmentation-*Riccia* f) Tubers-*Anthoceros* g) Gemmae-*Marchantia*

Figure 2.5: Structure and reproduction in Bryophytes

and peat are also used in horticulture as packing material because of their water holding capacity. *Marchantia polymorpha* is used to cure pulmonary tuberculosis. *Sphagnum*, *Bryum* and *Polytrichum* are used as food. Bryophytes play a major role in soil formation through succession and help in Soil conservation.

> **DO YOU KNOW?**
> *Buxbaumia aphylla* and *Cryptothallus mirabilis* are saprophytic bryophytes

2.5 Pteridophytes

Seedless Vascular Cryptogams

From the previous session we are aware of the salient features of amphibious plants called **Bryophytes.** But there is a plant group called **Pteridophytes** which are considered as first true land plants. Further, they were the first plants to acquire vascular tissue namely xylem and phloem, hence called **vascular cryptogams.** Club moss, Horsetails, quill worts, water ferns and Tree ferns belong to this group. This chapter deals with the characteristic features of Pteridophytes.

Pteridophytes are the vascular cryptogams and were abundant in the Devonian period of Palaeozoic era (400 million years ago). These plants are mostly small herbaceous and grow well in moist, cool and shady places where water is available. Photographs for some pteridophytes are given in Figure 2.6.

2.5.1 General characteristic features of Pteridophytes:

- Plant body is sporophyte (2n) and it is the dominant phase. It is differentiated into root, stem and leaves.
- Roots are adventitious.
- Stem shows monopodial or dichotomous branching.
- Leaves may be microphyllous or megaphyllous.
- Stele is protostele but in some forms siphonostele is present (*Marsilea*)
- Tracheids are the major water conducting elements but in *Selaginella* vessels are found.
- Sporangia, spore bearing bag like structures are borne on special leaves called **sporophyll.** The sporophylls gets organized to form cone or strobilus. Example: *Selaginella*, *Equisetum* .
- They may be **homosporous** (produce one type of spores-*Lycopodium*) or **Heterosporous** (produce two types of spores-*Selaginella*). Heterospory is the origin for seed habit.
- Development of sporangia may be **eusporangiate** (development of sporangium from group of initials) or **leptosporangiate** (development of sporangium from single initial).
- Spore mother cells undergo meiosis and produce spores (n).

- Spore germinates to produce haploid, multicellular green, cordate shaped independent gametophytes called **prothallus.**
- Fragmentation, Resting buds, root tubers and adventitious buds help in Vegetative reproduction.
- Sexual reproduction is Oogamous. Sex organs, namely antheridium and archegonium are produced on the prothallus.
- Antheridium produces spirally coiled and multiflagellate antherozoids.
- Archegonium is flask shaped with broad venter and elongated narrow neck. The venter possesses egg or ovum and neck contain neck canal cells.
- Water is essential for fertilization. After fertilization a diploid zygote is formed and undergoes mitotic division to form embryo.
- Pteridophytes show **apogamy** and **apospory.**

Reimer (1954) proposed a classification for Pteridophytes In this classification, the Pteridophytes are divided into five subdivisions. 1. Psilophytopsida 2. Psilotopsida 3. Lycopsida 4. Sphenopsida 5. Pteropsida. There are 19 orders and 48 families in the classification.

a) *Lycopodium* (club moss)

b) *Equisetum* (Horse tail)

c) *Azolla* (Water fern)

Figure 2.6: Pteridophytes

2.5.2 Economic Importance

The Economic importance of Pteridophyte is given in Table 2.3

Table 2.3: Economic importance of Pteridophyte

Pteridophyte	Uses
Rumohra adiantiformis (leather leaf fern)	Cut flower arrangements
Marsilea	Food
Azolla	Biofertilizer
Dryopteris filix–mas	Treatment for tapeworm.
Pteris vittata	Removal of heavy metals from soils - Bioremediation
Pteridium sp.	Leaves yield green dye
Equisetum sp.	Stems for scouring
Psilotum, Lycopodium, Selaginella, Angiopteris, Marattia	Ornamental plants

DO YOU KNOW?

- The success and dominance of vascular plants is due to the development of,
- Extensive root system.
- Efficient conducting tissues.
- Cuticle to prevent desiccation.
- Stomata for effective gaseous exchange.

2.5.3 Types of Stele

The term stele refers to the central cylinder of vascular tissues consisting of xylem, phloem, pericycle and sometimes medullary rays with pith.

There are two types of steles

1. Protostele
2. Siphonostele

1. Protostele:

In protostele phloem surrounds xylem. The type includes Haplostele, Actinostele, Plectostele, and mixed protostele.

(i) Haplostele: Xylem surrounded by phloem is known as **haplostele.** Example: *Selaginella.*

(ii) Actinostele: Star shaped xylem core is surrounded by phloem is known as **actinostele.** Example: *Lycopodium serratum.*

(iii) Plectostele: Xylem plates alternates with phloem plates. Example: *Lycopodium clavatum.*

(iv) Mixed prototostele: Xylem groups uniformly scattered in the phloem. Example: *Lycopodium cernuum.*

2. Siphonostele:

In siphonostele xylem is surrounded by phloem with pith at the centre. It includes Ectophloic siphonostele, Amphiphloic siphonostele, Solenostele, Eustele, Atactostele and Polycylic stele.

(i) Ectophloic siphonostele: The phloem is restricted only on the external side of the xylem. Pith is in centre. Example: *Osmunda.*

(ii) Amphiphloic siphonostele: The phloem is present on both the sides of xylem. The pith is in the centre. Example: *Marsilea.*

(iii) Solenostele: The stele is perforated at a place or places corresponding the origin of the leaf trace.

(a) Ectophloic solenostele – Pith is in the centre and the xylem is surrounded by phloem. Example: *Osmunda.*

(b) Amphiphloic solenostele – Pith is in the centre and the phloem is present on both sides of the xylem. Example: *Adiantum pedatum.*

(c) Dictyostele – The stele is separated into several vascular strands and each one is called **meristele.** Example: *Adiantum capillus-veneris.*

(iv) Eustele: The stele is split into distinct collateral vascular bundles around the pith. Example: Dicot stem.

(v) Atactostele: The stele is split into distinct collateral vascular bundles and are scattered in the ground tissue Example: Monocot stem.

(vi) Polycyclicstele: The vascular tissues are present in the form of two or more concentric cylinders. Example: *Pteridium.*

2.6 Gymnosperms

Naked Seed producing Plants

Michael Crichton's Science fiction in a book transformed into a Film of Steven

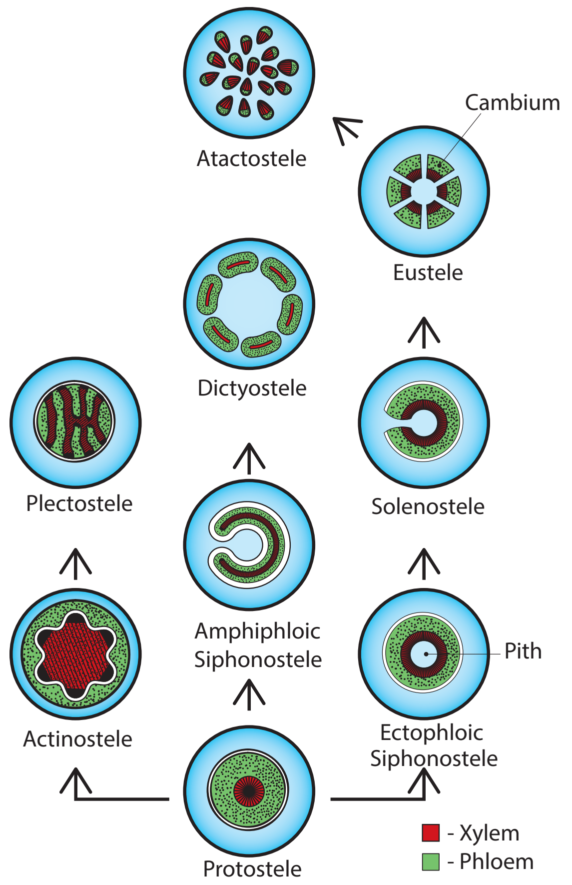
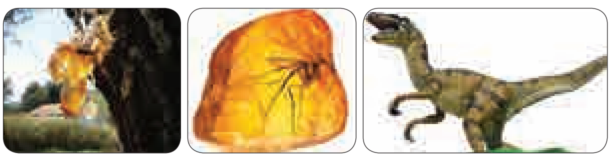


Figure 2.7: Types of Stele

Spielberg (1993) called **Jurassic Park**. In this film you might have noticed insects embedded in a transparent substance called **amber** which preserves the extinct forms. What is amber? Which group of plants produces Amber?



Amber is a plant secretion that is a efficient preservative that doesn't get degraded and hence can preserve remains of extinct life forms. The amber is produced by ***Pinites succinifera***, a Gymnosperm.

In this chapter we shall discuss in detail about one group of seed producing plants called **Gymnosperms.**

Gymnosperms (Gr. Gymnos= naked; sperma= seed) are naked seed producing plants. They were dominant in the Jurassic and cretaceous periods of Mesozoic era. The members are distributed throughout the temperate and tropical region of the world.

2.6.1 General characteristic features

- Most of the gymnosperms are evergreen woody trees or shrubs. Some are lianas (*Gnetum*)
- The plant body is sporophyte and is differentiated into root, stem and leaves.
- A well developed Tap root system is present. Coralloid Roots of *Cycas* have symbiotic association with blue green algae. In *Pinus* the roots have mycorrhizae.
- The stem is aerial, erect and branched or unbranched (*Cycas*) with leaf scars.
- In conifers two types of branches namely branches of limited growth (Dwarf shoot) and Branches of unlimited growth (Long shoot) is present.
- Leaves are dimorphic, foliage and scale leaves are present. Foliage leaves are green, photosynthetic and borne on branches of limited growth. They show xerophytic features.
- The xylem consists of tracheids but in *Gnetum* and *Ephedra* Vessels are present.
- Secondary growth is present. The wood may be **Manoxylic** (Porous, soft, more parenchyma with wide medullary ray -*Cycas*) or **Pycnoxylic** (compact with narrow medullary ray-*Pinus*).
- They are Heterosporous. The plant may be monoecious (*Pinus*) or dioecious (*Cycas*).

- Microsporangia and Megasporangia are produced on Microsporophyll and Megasporophyll respectively.
- Male and female cones are produced.
- Anemophilous pollination is present.
- Fertilization is siphonogamous and pollen tube helps in the transfer of male nuclei.
- Polyembryony (presence of many embryo) is Present. The naked ovule develops into seed. The **endosperm** is haploid and develop before fertilization.
- The life cycle shows alternation of generation. The sporophytic phase is dominant and gametophytic phase is highly reduced. The photograph of some of the Gymnosperms is given in Figure 2.8

a) *Cycas* b) *Thuja* c) *Taxus* d) *Ginkgo*

Figure 2.8: Gymnosperms

- Sporne (1965) classified gymnosperms into 3 classes, 9 orders and 31 families. The classes include i) Cycadospsida ii) Coniferopsida iii) Gnetopsida.

2.6.2 Comparison of Gymnosperm with Angiosperms

Gymnosperms resemble with angiosperms in the following features

- Presence of well organised plant body which is differentiated into roots, stem and leaves
- Presence of cambium in gymnosperms as in dicotyledons.
- Flowers in *Gnetum* resemble to the angiosperm male flower. The Zygote represent the first cell of sporophyte.
- Presence of integument around the ovule
- Both plant groups produce seeds
- Pollen tube helps in the transfer of male nucleus in both.
- Presence of Eustele.

The difference between Gymnosperms and Angiosperms were given in Table 2.4

Table 2.4: Difference between Gymnosperms and Angiosperms

S.No	Gymnosperms	Angiosperms
1.	Vessels are absent [except Gnetales]	Vessels are present
2.	Phloem lacks companion cells	Companion cells are present
3.	Ovules are naked	Ovules are enclosed within the ovary

Continued

4.	Wind pollination only	Insects, wind, water, animals etc., act as pollinating agents
5.	Double fertilization is absent	Double fertilization is present
6.	Endosperm is haploid	Endosperm is triploid
7.	Fruit formation is absent	Fruit formation is present
8.	Flowers absent	Flowers present

2.6.3 Economic importance of Gymnosperms

The Economic importance of Gymnosperms is given in Table 2.5

Table 2.5: Economic importance of Gymnosperms

S.No	Plants	Products	uses
1.	*Cycas circinalis, Cycas revoluta*	Sago	Starch used as food
2.	*Pinus gerardiana*	Roasted seed	Used as a food
3.	*Abies balsamea*	Resin (Canada balsam)	Used as mounting medium in permanent slide preparation
4.	*Pinus insularis, Pinus roxburghii*	Rosin and Turpentine	Paper sizing and varnishes
5.	*Araucaria* (monkey's puzzle), *Picea* and *Phyllocladus*	Tannins	Bark yield tannins and is used in Leather industries
6.	*Taxus brevifolia*	Taxol	Drug used for cancer treatment
7.	*Ephedra gerardiana*	Ephedrine	For the treatment of asthma, bronchititis
8.	*Pinus roxburghii*	Oleoresin	Used to make soap, varnishes and printing ink
9.	*Pinus roxburghii, Picea smithiana*	Wood pulp	Used to make papers
10.	*Cedrus deodara*	wood	Used to make doors, boats and railway sleepers
11.	*Cedrus atlantica*	oil	Used in perfumery
12	*Thuja, Cupressus, Araucaria, and Cryptomeria*	whole plant	Ornamental plants/Floral Decoration

Know about Fossil plants

The national wood fossil park is situated in Tiruvakkarai, a Village of Villupuram district of Tamil Nadu. The park contains petrified wood fossils approximately 20 million years old. The term 'form genera' is used to name the fossil plants because the whole plant is not recovered as fossils instead organs or parts of the extinct plants are obtained in fragments. Shiwalik fossil park-Himachal Pradesh, Mandla Fossil park-Madhya Pradesh, Rajmahal Hills–

Jharkhand, Ariyalur – Tamilnadu are some of the fossil rich sites of India.

Prof. Birbal Sahni (1891-1949)

Father of Indian Palaeobotany. He described Fossil plants from Rajmahal Hills of Eastern Bihar. *Pentoxylon sahnii*, *Nipanioxylon* are some of the form genera described by him. Birbal Sahni Institute of Palaebotany is located in Lucknow.

Some of the fossil representatives of different plant groups are given below

Fossil algae - *Palaeoporella*, *Dimorphosiphon*

Fossil Bryophytes – *Naiadita, Hepaticites, Muscites*

Fossil Pteridophytes – *Cooksonia, Rhynia,, Baragwanthia, Calamites*

Fossil Gymnosperms – *Medullosa, Lepidocarpon, Williamsonia, Lepidodendron*

Fossil Angiosperms – *Archaeanthus, Furcula*

2.7 Angiosperms

In the previous lesson the characteristic features of one of the spermatophyte called **Gymnosperms** were discussed. Spermatophytes also include plants bearing ovules enclosed in a protective cover called Ovary, such plants are called Angiosperms. They constitute major plant group of our earth and are adapted to the terrestrial mode of life. This group of plants appeared during the early cretaceous period (140 million years ago) and dominates the vegetation on a world scale. The sporophyte is the dominant phase and gametophyte is highly reduced.

2.7.1 Salient features of Angiosperms

- Vascular tissue (Xylem and Phloem) is well developed.
- Flowers are produced instead of cone
- The embryosac (Ovule) remains enclosed in the ovary.
- Pollen tube helps in fertilization, so water is not essential for fertilization.
- Double fertilization is present. The endosperm is triploid.
- Angiosperms are broadly classified into two classes namely Dicotyledons and Monocotyledons.

2.7.2 Characteristic features of Dicotyledons and Monocotyledons

Current Angiosperm Phylogeny Group (APG) System of classification doesn't recognize dicots as a monophyletic group. Plants that are traditionally classified under dicots are dispersed in several clades such as early Magnolids and Eudicots.

Angiosperms

Dicotyledons

Morphological features

Reticulate venation is present in the leaves. Presence of two cotyledons in the seed. Primary root radicle persists as Tap root.

Flowers tetramerous or Pentamerous.

Tricolpate (3 furrow) pollen is present.

Anatomical features

- Vascular bundles are arranged in the form of a ring in stem.
- Vascular bundles are open (Cambium present).
- Secondary growth is present.

Monocotyledons

Morphological features

Parallel venation is present in the leaves. Presence of single cotyledon in the seed. Radicle doesn't persist and fibrous root is present.

Flowers trimerous.

Monocolpate (1 furrow) Pollen is present.

Anatomical features

- Vascular bundles are scattered in the stem
- Vascular bundles are closed (Cambium absent).
- Secondary growth is absent.

Summary

Plant Kingdom includes Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms

The life cycle in plants fall under three types 1. Haplontic, 2. Diplontic and 3. Haplodiplontic

Algae are autotrophic, chlorophyll bearing organisms. The Plant body is not differentiated into root like, stem like or leaf like structures. A wide range of thallus organization is found in algae. They reproduce vegetatively through fragmentation, tuber and akinete formation. Zoospores, autospores and hypnospores are produced during asexual reproduction and Sexual reproduction occurs through isogamy, anisogamy and oogamy.

Bryophytes are simplest land plants. They are called **amphibians** of plant kingdom or nonvascular cryptogams. The plant body is gametophyte. The sporophyte depends upon gametophyte. Conducting tissues like xylem and phloem is absent. Vegetative reproduction takes place through fragmentation, formation of adventitious bud and Gemmae. Sexual reproduction is Oogamous. Water is essential for fertilization.

Pteridophytes are also called **vascular cryptogams.** The plant body is sporophyte and is long lived and is differentiated into root, stem and leaves. They may be homosporous or heterosporous. The sporangia with spores are found in sporophylls. The sporophylls organise to form cones or strobilus. The spores germinates to produce haploid, multicellular heart shaped independent gametophyte called **prothallus.** Sexual reproduction is oogamous. The life cycle shows Alternation of generation.

Gymnosperms are naked seed producing plants. The plant body is sporophyte and it is the dominant phase. Coralloid roots are found in *Cycas*. The roots of *Pinus* possess mycorrhizal association. Two types of branches called **Long shoot** and **dwarf shoot** are present. Stem shows secondary growth. Spores are produced in cones. Pollen tube helps in fertilization. The endosperm is haploid. Alternation of generation is present.

Angiosperms are highly evolved plant group and their ovules remain enclosed in an ovary. A wide range of habit is present. These include trees, shrubs, herbs, climbers, lianas. Double fertilization is present. The endosperm is triploid. They are classified into Dicotyledons and Monocotyledons. The life cycle shows alternation of generation.

Evaluation

1. Which of the plant group has gametophyte as a dominant phase
   a. Pteridophytes b. Bryophytes
   c. Gymnosperm d. Angiosperm
2. Which of following represent gametophytic generation in pteridophytes
   a. Prothallus
   b. Thallus
   c. Cone
   d. Rhizophore
3. The haploid number of chromosome for an Angiosperm is 14 , the number of chromosome in its endosperm would be
   a. 7 b. 14 c. 42 d. 28
4. Endosperm in Gymnosperm is formed
   a. At the time of fertilization
   b. Before fertilization
   c. After fertilization
   d. Along with the development of embryo
5. Differentiate halpontic and diplontic life cycle.
6. What is plectostele? give example.
7. What do you infer from the term pycnoxylic?
8. Mention two characters shared by gymnosperms and angiosperms.
9. Do you think shape of chloroplast is unique for algae. Justify your answer?
10. Do you agree with the statement 'Bryophytes need water for fertilization'? Justify your answer.

ICT Corner

Different forms of plants

Is all the **plants** are same?

Steps

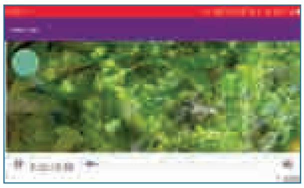
- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Characteristics of plants
- Click theory to know the basic about Characteristics of plants
- Register yourself with mail-id and create password to access online lab simulations

Activity

- Select video and record your observations of different forms of plant group.

Step 1

Step 2



Step 3

Step 4

URL:

https://play.google.com/store/apps/details?id=in.edu.olabs.olabs&hl=en

Alternate web:

http://www.phschool.com/atschool/phbio/active_art/plant_life_cycle/plantlife-cycle.swf

B181_11_BOT

* Pictures are indicative only

Unit II: Plant Morphology and Taxonomy of Angiosperm

Chapter 3

Vegetative Morphology

Learning Objectives

The learner will be able to,

- *Explore the parts of the flowering plants*
- *Differentiate vegetative morphology and reproductive morphology*
- *Compare various root systems and their modifications*
- *Understand the stem modifications and functions*
- *Interpret the structure of leaf and functions of leaf*

Chapter Outline

5FG1XM

The study of various external features of the organism is known as **morphology. Plant morphology** also known as **external morphology** deals with the study of shape, size and structure of plants and their parts (roots, stems, leaves, flowers, fruits and seeds). Study of morphology is important in taxonomy. Morphological features are important in determining productivity of crops. Morphological characters indicate the specific habitats of living as well as the fossil plants and help to correlate the distribution in space and time of fossil plants. Morphological features are also significant for phylogeny.

Plant Morphology can be studied under two broad categories:

A. **Vegetative morphology** – It includes shoot system and root system
B. **Reproductive morphology** – It includes Flower/inflorescence, Fruit and Seed

A. Vegetative morphology

Vegetative morphology deals with the study of shape, size and structure of plants and their parts roots, stems and leaves. To understand the vegetative morphology the following important components are to be studied. They are, 1) Habit, 2) Habitat and 3) Lifespan.

3.1 Habit

The general form of a plant is referred to as habit. Based on habit plants are classified into herbs, shrubs, climbers (vines) and trees.

I. Herbs

Herbs are soft stemmed plants with less wood or no wood. According to the duration of their life they may be classified as **annuals**, **biennials** and **perennials**. Perennial herbs having a bulb, corm, rhizome or tuber as the underground stem are termed as **geophytes.** Example: *Phyllanthus amarus, Cleome viscosa.*

II. Shrubs

A shrub is a perennial, woody plant with several main stems arising from the ground level. Example: *Hibiscus*

III. Climbers (Vine)

An elongated weak stem generally supported by means of climbing devices are called **Climbers** (vines) which may be annual or perennial, herbaceous or woody.

Liana is a vine that is perennial and woody. Liana's are major components in the tree canopy layer of some tropical forests. Example: *Ventilago, Entada*, *Bougainvillea.*

IV. Trees

A tree is a stout, tall, perennial, woody plant having one main stem called **trunk** with many lateral branches. Example: mango, sapota, jack, fig, teak. If the trunk remains unbranched it is said to be **caudex.** Example: Palmyra, coconut.

3.2 Plant habitat

Depending upon where plants grow habitats may be classified into major categories: I. Terrestrial and II.Aquatic.

I. Terrestrial

Plants growing on land are called **terrestrial plants.** The following table illustrate the types of terrestrial plants classified based on their environmental adaptation.

II. Aquatic

Plants that are living in water environment are called **aquatic plants** or hydrophytes.

3.3 Life Span

Based on life span plants are classified into 3 types. They are annual, biennial and perennial

Terrestrial habitat		
Types	**Nature of environmental adaptation**	**Example**
Mesophytes	Growing in soils with sufficient water	*Azadirachta indica*
Xerophytes	Growing on dry habitats	*Opuntia*, *Euphorbia*
Psammophytes	Growing on sand	*Ipomoea pes-caprae, Spinifex littoralis*
Lithophytes	Growing on rock	Many algae and lichens, *Ficus spp*

Aquatic habitat		
Types	**Nature of environmental adaptation**	**Example**
Free Floating	Growing on water surface	*Eichhornia, Trapa, Pistia, Lemna*
Submerged	Plants growing completely under water	*Hydrilla, Vallisneria*
Emergent	Plants with roots or stems anchored to the substrate under water and aerial shoots growing above water	*Limnophyton, Typha*
Floating leaved	Anchored at bottom but with floating leaves	*Nelumbo, Nymphaea*
Mangroves	Plants growing emergent in marshy saline habitat	*Avicennia, Rhizophora*

I. Annual (Therophyte or Ephemerals)

A plant that completes its life cycle in one growing season. Example: Peas, maize, water melon, groundnut, sunflower, rice and so on.

II. Biennial

A plant that lives for two seasons, growing vegetatively during the first season and flowering and fruiting during the second season. Example: Onion, Lettuce, Fennel, Carrot, Radish, Cabbage and Spinach.

III. Perennial (Geophyte)

A plant that grows for many years that flowers and set fruits for several seasons during the life span. When they bear fruits every year, they are called **polycarpic.** Example: mango, sapota. Some plants produce flowers and fruits only once and die after a vegetative growth of several years. These plants are called **monocarpic**. Example: *Bamboo, Agave, Musa, Talipot palm.*

3.4 Parts of a flowering plant

Flowering plants are called **"Angiosperms"** or **Magnoliophytes**. They are sporophytes consisting of an axis with an underground **"Root system"** and an aerial **"Shoot System".** The shoot system has a stem, branches and leaves. The root system consists of root and its lateral branches.

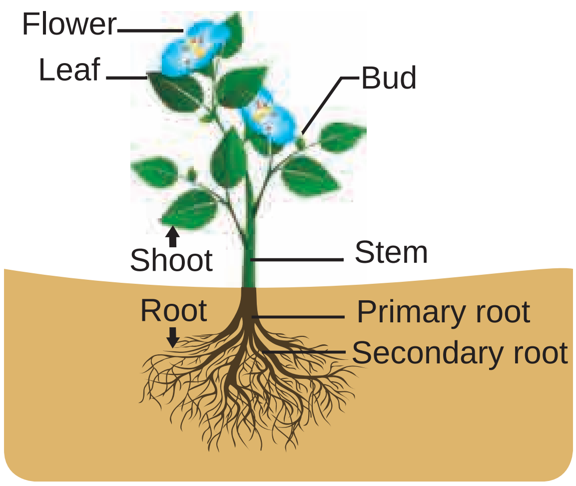


Figure: 3.1: Parts of a flowering plant

3.5 Root System

The root is non-green, cylindrical descending axis of the plant that usually grows into the soil (positively geotropic). It develops from the radicle which is the first structure that comes out when a seed is placed in the soil. Root is responsible for absorption of water and nutrients and anchoring the plant.

I. Characteristic features

- Root is the descending portion of the plant axis.
- Generally non-green in colour as it lacks chlorophyll.
- Does not possess nodes, internodes and buds (Exception in sweet potato and members of Rutaceae, roots bear buds which help in vegetative propagation)
- It bears root hairs (To absorb water and minerals from the soil)
- It is positively geotropic and negatively phototropic in nature.

II. Regions of root

Root tip is covered by a dome shaped parenchymatous cells called **root cap.** It protects the meristematic cells in the apex. In *Pandanus* multiple root cap is present. In *Pistia* instead of root cap root pocket is present. A few millimeters above the root cap the following three distinct zones have been classified based on their meristematic activity.

1. Meristematic Zone
2. Zone of Elongation
3. Zone of Maturation

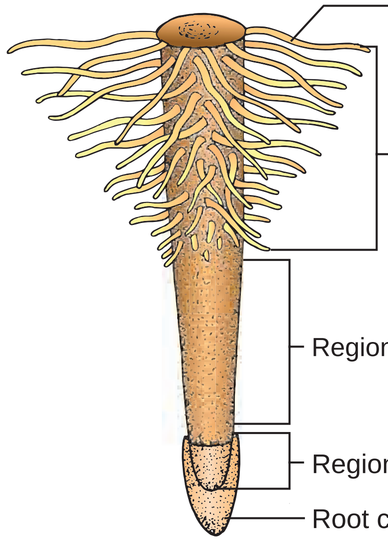


Figure 3.2: Regions of root

Table: Root zones			
Feature	**1. Meristematic Zone Region of cell division**	**2. Zone of Elongation**	**3. Zone of Maturation**
Position	It lies just above the root cap	It lies just above the meristematic zone	It lies above the zone of elongation.
Types of cells	Meristematic cells, actively divide and continuously increase in number	Elongated cells	Mature differentiated cells
Functions	This is the main growing tip of the root	The cells increase the length and cause enlargement of the root.	The cells differentiate into various tissues like epidermis, cortex and vascular bundles. It also produces root hairs which absorb water and minerals from the soil

3.5.1 Types of root

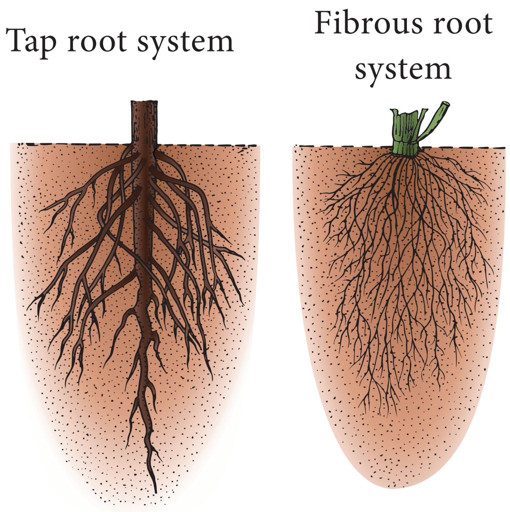


Figure 3.3: Types of root system

I. Tap root system

Primary root is the direct prolongation of the radicle. When the primary root persists and continues to grow as in dicotyledons, it forms the main root of the plant and is called the **tap root.** Tap root produces lateral roots that further branches into finer roots. Lateral roots along with its branches together called as **secondary roots.**

II. Adventitious root system

Root developing from any part of the plant other than radicle is called **adventitious** root. It may develop from the base of the stem or nodes or internodes. Example: *Monstera deliciosa, Ficus benghalensis, Piper nigrum*. In most of the monocots the primary root of the seedling is short lived and lateral roots arise from various regions of the plant body. These are bunch of thread-like roots equal in size which are collectively called **fibrous** root system generally found in grasses. Example: *Oryza sativa, Eleusine coracana, Pennisetum americanum*.

III. Functions of root

Root performs two kinds of functions namely primary and secondary functions.

Primary function

1. Absorb water and minerals from soil.
2. Help to anchor the plant firmly in the soil.

Secondary function

In some plants roots perform additional functions. These are called **secondary functions.** To perform additional functions, these roots are modified in their structure.

Root modification

- **Tap root modification**
  - **Storage**
    - i. Conical
    - ii. Fusiform
    - iii. Napiform
  - **Breathing root**
- **Adventitious root modification**
  - **Storage**
    - i. Tuberous root
    - ii. Fasciculated root
    - iii. Nodulose root
    - iv. Moniliform root
    - v. Annulated root
  - **Mechanical support**
    - i. Prop root
    - ii. Stilt root
    - iii. Climbing root
    - iv. Buttress root
  - **Vital function**
    - i. Epiphytic root
    - ii. Foliar root
    - iii. Sucking root
    - iv. Photosynthetic root

3.5.2 Modifications of root

I. Tap root modification

a. Storage roots

1. Conical Root

These are cone like, broad at the base and gradually tapering towards the apex. Example: *Daucus carota*.

2. Fusiform root

These roots are swollen in the middle and tapering towards both ends. Example: *Raphanus sativus*

3. Napiform root

It is very broad and suddenly tapers like a tail at the apex. Example: *Beta vulgaris*

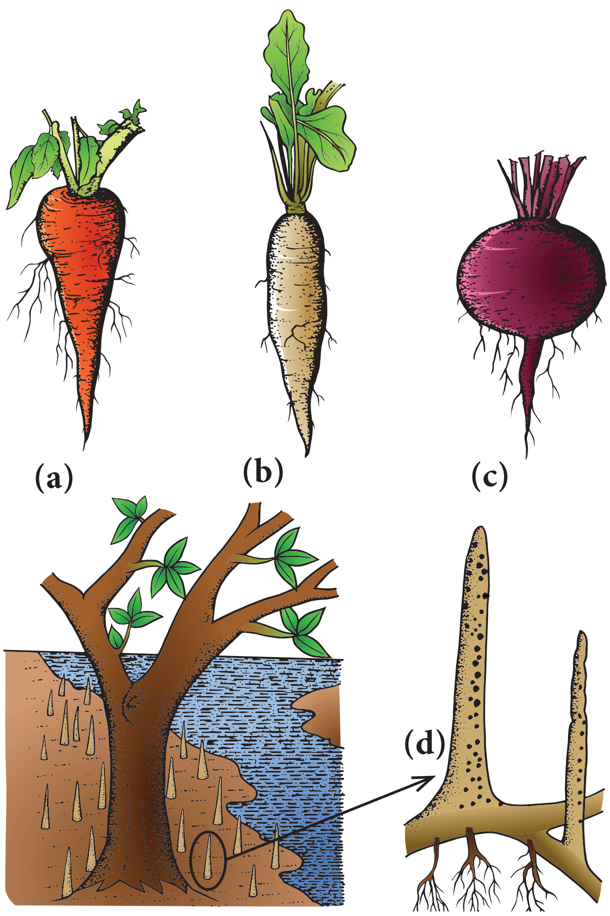


Figure 3.4: Tap root modification
(a) *Daucus carota* **(b)** *Raphanus sativus*
(c) *Beta vulgaris* **(d)** *Avicennia Pneumatophores*

b. Breathing root

Some mangrove plants like ***Avicennia, Rhizophora, Bruguiera*** develop special kinds of roots (Negatively geotropic) for respiration because the soil becomes saturated with water and aeration is very poor. They have a large number of breathing pores or pneumatophores for exchange of gases.

II. Adventitious root modification

a. Storage roots

1. Tuberous root

These roots are swollen without any definite shape. Tuberous roots are produced singly and not in clusters. Example: *Ipomoea batatas.*

2. Fasciculated root

These roots are in cluster from the base of the stem Example: *Dahlia, Asparagus, Ruellia.*

3. Nodulose root

In this type of roots swelling occurs only near the tips. Example: *Maranta* (arrow root) *Curcuma amada* (mango ginger), *Curcuma longa* (turmeric)

4. Moniliform or Beaded root

These roots swell at frequent intervals giving them a beaded appearance. Example: *Vitis, Portulaca, Momordica* Indian spinach.

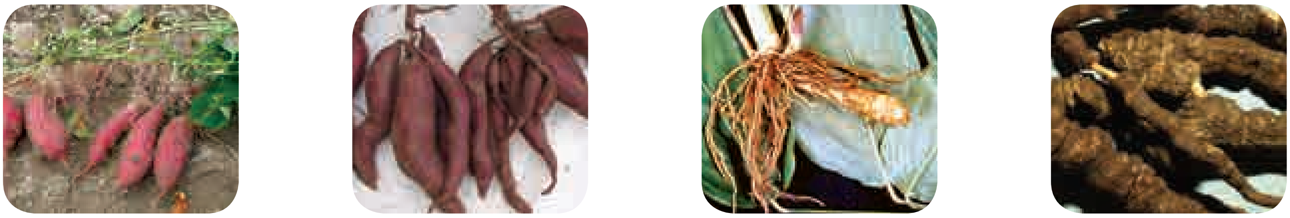
5. Annulated root

These roots have a series of ring- like swelling on their surface at regular intervals. Example: *Ipecac* (*Psychotria*)

b. Mechanical support

1. Prop (Pillar) root

These roots grow vertically downward from the lateral branches into the soil.



Ipomoea batatas *Dahlia* *Maranta* *Psychotria*

Figure 3.5: Adventitious Root Modification for Storage

Example: *Ficus benghalensis* (banyan tree), Indian rubber.

2. Stilt (Brace) root

These are thick roots growing obliquely from the basal nodes of the main stem. These provide mechanical support. Example: *Saccharum officinarum, Zeamays and Pandanus, Rhizophora.*

3. Climbing (clasping or clinging) roots

These roots are produced from the nodes of the stem which attach themselves to the support and help in climbing. To ensure a foothold on the support they secrete a sticky juice which dries up in air, attaching the roots to the support. Example: *Epipremnum pinnatum, Piper betel, Ficus pumila.*

4. Buttress root

In certain trees broad plank like outgrowths develop towards the base all around the trunk. They grow obliquely downwards and give support to huge trunks of trees. This is an adaptation for tall rain forest trees. Example: silk cotton tree (*Bombax*), white cotton tree (*kapok*), *Terminalia arjuna, Delonix regia, Pterygota alata.*

c. Vital functions

1. Epiphytic or velamen root

Some epiphytic orchids develop a special kind of aerial roots which hang freely in the air. These roots develop a spongy tissue called **velamen** which helps in absorption of moisture from the surrounding air. Example: *Vanda, Dendrobium, Aerides.*

2. Foliar root

Roots are produced from the veins or lamina of the leaf for the formation of new plant. Example: *Bryophyllum, Begonia, Zamioculcas.*

Ficus benghalensis *Saccharum officinarum* *Epipremnum pinnatum* *Bombax*

Figure 3.6: Adventitious root modification for mechanical support

3. Sucking or Haustorial roots

These roots are found in parasitic plants. Parasites develop adventitious roots from stem which penetrate into the tissue of the host plant and suck nutrients.

Example: *Cuscuta* (dodder), *Cassytha*, *Orobanche* (broomrape), *Viscum* (mistletoe), *Dendrophthoe*.

4. Photosynthetic or assimilatory roots

Roots of some climbing or epiphytic plants develop chlorophyll and turn green which help in photosynthesis. Example: *Tinospora*, *Trapa natans* (water chestnut), *Taeniophyllum*.

3.6 Shoot system

The plumule of the embryo of a germinating seed grows into stem. The epicotyl elongates after embryo growth into the axis (the stem) that bears leaves from its tip, which contain the actively dividing cells of the shoot called **apical meristem.** Further cell divisions and growth result in the formation of mass of tissue called **a leaf primordium.** The point from which the leaf arises is called **node**. The region between two adjacent nodes is called **internode.**

I. Characteristic features of the stem

1. The stem is usually the aerial portion of the plant
2. It is positively phototropic and negatively geotropic
3. It has nodes and internodes.
4. Stem bears vegetative bud for vegetative growth of the plant, and floral buds for reproduction, and ends in a terminal bud.
5. The young stem is green and thus carries out photosynthesis.
6. During reproductive growth stem bears flowers and fruits.
7. Branches arise exogenously
8. Some stems bears multicellular hairs of different kinds.

II. Functions of the stem

Primary functions

1. Provides support and bears leaves, flowers and fruits.
2. It transports water and mineral nutrients to the other parts from the root.
3. It transports food prepared by leaves to other parts of the plant body.

Vanda *Bryophyllum* *Cuscuta* *Tinospora*

Figure 3.7: Adventitious Root Modification for Vital Functions

Secondary functions

1. **Food storage**- Example: *Solanum tuberosum, Colocasia* and *Zingiber officinale*
2. **Perennation / reproduction** – Example: *Zingiber officinale, Curcuma longa*
3. **Water storage** – Example: *Opuntia*
4. **Bouyancy** – Example: *Neptunia*
5. **Photosynthesis** – Example: *Opuntia, Ruscus, Casuarina, Euphorbia, Caralluma.*
6. **Protection** – Example: *Citrus, Duranta, Bougainvillea, Acacia, Fluggea, Carissa.*
7. **Support** - Example: *Passiflora, Bougainvill*ea, *Vitis, Cissus quadrangularis.*

3.6.1 Buds

Buds are the growing points surrounded by protective scale leaves. The bud primordium matures into bud. They have compressed axis in which the internodes are not elongated and the young leaves are closed and crowded. When these buds develop, the internodes elongate and the leaves spread out. Buds have architecture identical to the original shoot and develop into lateral branches or may terminate by developing into a flower or inflorescence. Based on Origin Buds are classified into (a) Terminal or Apical bud (b) Lateral or Axillary or Axil bud. Based on Function Buds classified into (a) Vegetative bud (b) Floral or Reproductive bud

1. **Terminal bud or apical bud:** These buds are present at the apex of the main stem and at the tips of the branches.
2. **Lateral bud or Axillary bud:** These buds occur in the axil of the leaves and develop into a branch or flower.
3. **Extra axillary bud :** These buds are formed at nodes but outside the axil of the leaf as in *Solanum americanum.*
4. **Accessory bud :** An extra bud on either side (collateral bud) or above (superposed bud or serial bud) the axillary bud. Example: *Citrus* and *Duranta*
5. **Adventitious buds:** Buds arising at any part other than stem are known as **adventitious bud. Radical buds** are those that arises from the lateral roots which grow into plantlets. Example: *Millingtonia, Bergera koenigii (Murraya koenigii), Coffea arabica* and *Aegle marmelos*. **Foliar buds** are those that grow on leaves from veins or from margins of the leaves. Example: *Begonia* (Elephant ear plant) and *Bryophyllum* (Sprout leaf plant). **Cauline buds** arise directly from the stem either from cut, pruned ends or from branches. Adventitious buds function as propagules which are produced on the stem as tuberous structures. Example: *Dioscorea, Agave*.
6. **Bulbils (or specialized buds) :** Bulbils are modified and enlarged bud, meant for propagation. When bulbils detach from parent plant and fall on the ground, they germinate into new plants and serve as a means of vegetative propagation. In *Agave* and *Allium proliferum* floral buds get modified into bulbils. In *Lilium bulbiferum* and *Dioscorea bulbifera,* the bulbils develop in axil of leaves. In *Oxalis*, they develop just above the swollen root.

3.6.2 Types of Stem

Majority of angiosperm possess upright, vertically growing erect stem. They are (i) Excurrent, (ii) Decurrent, (iii) Caudex, (iv) Culm.

i. Excurrent

The main axis shows continuous growth and the lateral branches gradually becoming shorter towards the apex which gives a conical appearance to the trees. Example: *Polyalthia longifolia, Casuarina.*

ii. Decurrent

The growth of lateral branch is more vigorous than that of main axis. The tree has a rounded or spreading appearance. Example: *Mangifera indica, Azadirachta indica, Tamarindus indicus, Aegle marmelos*

iii. Caudex

It's an unbranched, stout, cylindrical stem, marked with scars of fallen leaves. Example: *Cocus nucifera, Borassus flabelliformis, Areca catechu*

iv. Culm

Erect stems with distinct nodes and usually hollow internodes clasped by leaf sheaths. Example: Majority of grasses including Bamboo.

3.6.3 Modification of Stem

I. Aerial modification of stem

1. Creepers

These are plants growing closer (horizontally) to the ground and produces roots at each node. Example: *Cynodon dactylon, Oxalis, Centella*

2. Trailers (Stragglers)

It is a weak stem that spreads over the surface of the ground without rooting at nodes. They are divided into 3 types,

i. **Prostrate (Procumbent):** A stem that grows flat on the ground. Example: *Evolvulus alsinoides, Indigofera prostrata.*

ii. **Decumbent:** A stem that grows flat but becomes erect during reproductive stage. Example: *Portulaca, Tridax, Lindenbergia*

iii. **Diffuse:** A trailing stem with spreading branches. Example: *Boerhaavia diffusa, Merremia tridentata*

3. Climbers

These plants have long weak stem and produce special organs for attachment for climbing over a support. Climbing helps to display the leaves towards sunlight and to position the flower for effective pollination.

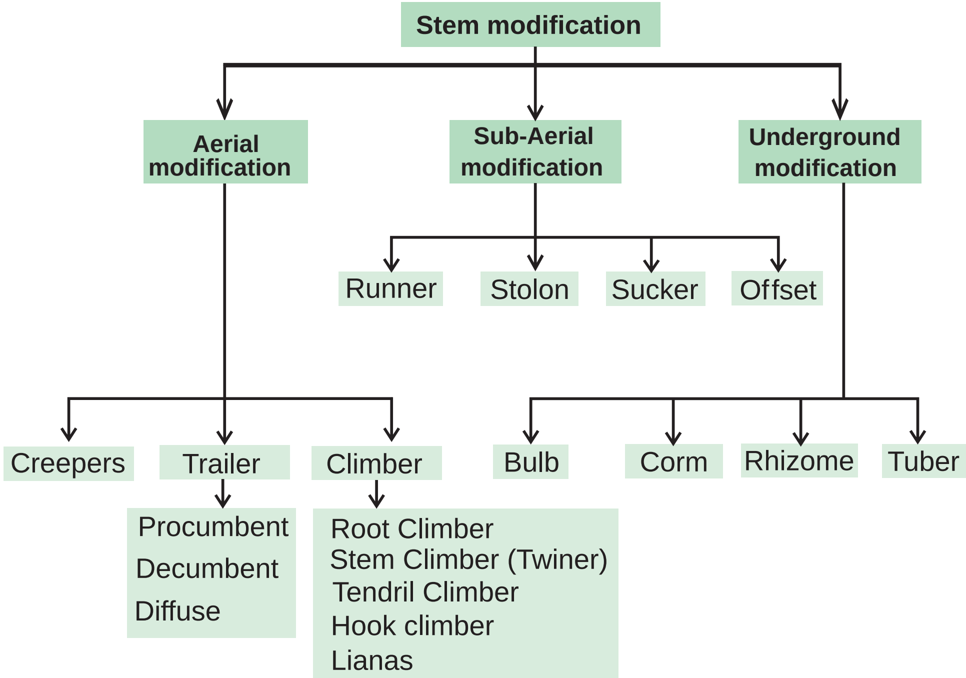
i. Root climbers

Plants climbing with the help of adventitious roots (arise from nodes) as in species of *Piper betel, Piper nigrum, Hedera helix, Pothos, Hoya.*

ii. Stem climbers (twiners)

These climbers lack specialised structure for climbing and the stem itself coils around the support. Example: *Ipomoea, Convolvulus, Dolichos, Clitoria, Quisqualis.*

Stem climbers may coil around the support clockwise or anti-clockwise. Clockwise coiling climbers are called **dextrose.** Example: *Dioscorea alata*. Anti-clockwise coiling climbers are called **sinistrose.** Example: *Dioscorea bulbifera*.



iii. Hook climbers

These plants produce specialized hook like structures which are the modification of various organs of the plant. In *Artabotrys* inflorescence axis is modified into hook. In *calamus* (curved hook) leaf tip is modified into hook. In *Bignonia unguis-cati* the leaflets are modified into curved hook. In *Hugonia* the axillary buds modified into hook.

iv. Thorn climbers

Climbing or reclining on the support with the help of thorns as in *Bougainvillea* and *Carissa*.

v. Lianas (woody stem climber)

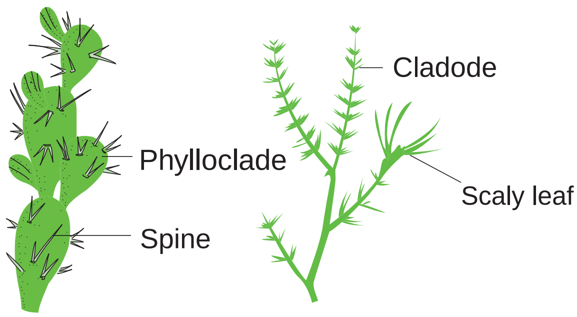
Woody perennial climbers found in tropical forests are lianas. They twine themselves around tall trees to get light. Example: *Hiptage benghalensis, Bauhinia vahlii, Entada pursaetha.*

vi. Tendril climbers

Tendrils are thread-like coiling structures which help the plants in climbing. Tendrils may be modifications of Stem – as in *Passiflora*, *Vitis* and *Cissus quadrangularis;* Inflorescence axis – *Antigonon;* Leaf – *Lathyrus;* Leaflets - *Pisum sativum;* Petiole – *Clematis;* Leaftip – *Gloriosa;* Stipules – *Smilax*. In pitcher plant (*Nepenthes*) the midrib of the leaf often coils around a support like a tendril and holds the pitcher in a vertical position.

Phylloclade

This is a green, flattened cylindrical or angled stem or branch of unlimited growth, consisting of a series of nodes and internodes at long or short intervals. Phylloclade is characteristic adaptation of xerophytes where the leaves often fall off early and modified into spines or scales to reduce transpiration. The phylloclade takes over all the functions of leaves, particularly photosynthesis. The phylloclade is also called as **cladophyll.** Example: *Opuntia, Phyllocactus, Muehlenbergia* (flattened phylloclade) *Casuarina, Euphorbia tirucalli, Euphorbia antiquorum* (cylindrical phylloclade).



(a) (b)

Figure 3.8: (a) Phylloclade-*Opuntia*
(b) Cladode-*Asparagus*

Cladode

Cladode is a flattened or cylindrical stem similar to Phylloclade but with one or two internodes only. Their stem nature is evident by the fact that they bear buds, scales and flowers. Example: *Asparagus* (cylindrical cladode), *Ruscus* (flattened Cladode).

Thorns

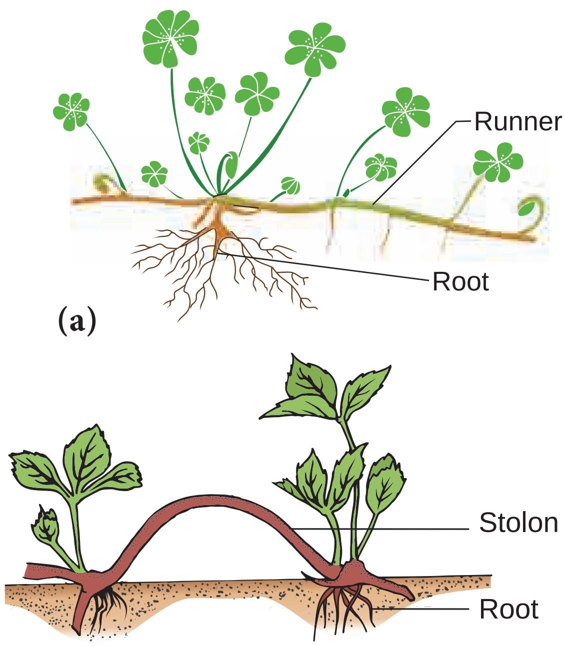
Thorn is a woody and sharp pointed modified stem. Either the axillary bud or the terminal bud gets modified into thorns. In *Carissa* apical bud modified into thorns. In *Citrus* and *Atalantia* axillary bud is modified into thorns.

II. Sub aerial stem modifications

Sub aerial stem found in plants with weak stem in which branches lie horizontally on the ground. These are meant for vegetative propagation. They may be sub aerial or partially sub terranean.

1. Runner

This is a slender, prostrate branch creeping on the ground and rooting at the nodes. Example: *Centella* (Indian pennywort), *Oxalis* (wood sorrel), lawn grass (*Cynodon dactylon*).



(b)

Figure 3.9: **(a)** Runner-*Oxalis*
(b) Stolon-*Fragaria*

2. Stolon

This is also a slender, lateral branch originating from the base of the stem. But it first grows obliquely above the ground, produces a loop and bends down towards the ground. When touches the ground it produces roots and becomes an independent plantlet. Example: *Mentha piperita* (peppermint), *Fragaria indica* (wild strawberry).

3. Sucker

Sucker develops from a underground stem and grows obliquely upwards and gives rise to a separate plantlet or new plant. Example: *Chrysanthemum, Musa, Bambusa*.

4. Offset

Offset is similar to runner but found in aquatic plants especially in rosette leaved forms. A short thick lateral branch arises from the lower axil and grows horizontally leafless for a short distance, then it produces a bunch of rosette leaves and root at nodes. Example: *Eichhornia* (water hyacinth), *Pistia* (water lettuce).

(c)

(d)

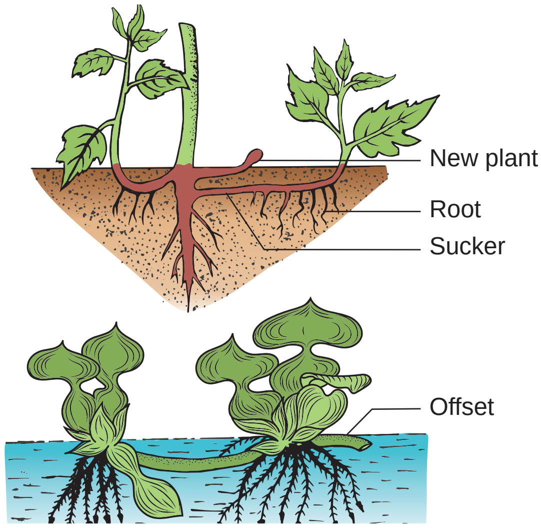


Figure 3.9: **(c)** Sucker-*Chrysanthemum*
(d) Offset-*Eichhornia*

III. Underground stem modifications

Perennial and some biennial herbs have underground stems, which are generally known as **root stocks**. Rootstock functions as a storage and protective organ. It remains alive below the ground during unfavourable conditions and resumes growth during the favourable conditions.

Underground stems are not roots because they possess nodes, internodes, scale-leaves and buds. Rootstock also lack root cap and root hairs but they possess terminal bud which is a characteristics of stem.

1. Bulb

It is a condensed conical or convex stem surrounded by fleshy scale leaves. They are of two types 1. Tunicated (coated) bulb: In which the stem is much condensed and surrounded by several concentric layers of scale leaves. The inner scales commonly fleshy, the outer ones dry. These are two types (a) Simple Tunicated bulb Example: *Allium cepa* (b) Compound Tunicated bulb. Example: *Allium sativum*. 2. Scaly bulb: They are narrow, partially overlap each other by their margins only. Example: *Tulipa spp*.

Pseudobulb is a short erect aerial storage or propagating stem of certain epiphytic and terrestrial sympodial orchids. Example: *Bulbophyllum*.

2. Corm

This is a succulent underground stem with an erect growing tip. The corm is surrounded by scale leaves and exhibit nodes and internodes. Example: *Amorphophallus, Gladiolus, Colocasia, Crocus, Colchicum*

Bulb-
Allium cepa

Rhizome
Zingiber officinale

Corm-*Colocasia*

Tuber
Solanum tuberosum

Figure 3.10: Underground Stem Modification

3. Rhizome

This is a underground stem grows horizontally with several lateral growing tips. Rhizome posses conspiquous nodes and internodes covered by scale leaves. Example: *Zingiber officinale, Canna, Curcuma longa, Maranta arundinacea, Nymphaea, Nelumbo*.

4. Tuber

This is a succulent underground spherical or globose stem with many embedded axillary buds called **"eyes".** Example: *Solanum tuberosum, Helianthus tuberosus*

IV. Stem Branching

Branching pattern is determined by the relative activity of apical meristems. The mode of arrangement of branches on a stem is known as **branching.** There are two main types of branching, 1. Lateral branching and 2. Dichotomous branching. Based on growth pattern stems may show indeterminate or determinate growth.

1. **Indeterminate:** The terminal bud grows uninterrupted and produce several lateral branches. This type of growth is also known as **monopodial branching.** Example: *Polyalthia, Swietenia, Antiaris.*
2. **Determinate:** The terminal bud caese to grow after a period of growth and the further growth is taken care by successive or several lateral meristem or buds. This type of growth is also known as **sympodial branching.** Example: *Cycas.*

3.7 Leaf

Leaves are green, thin flattened lateral outgrowths of the stem and exogenenous in origin. They arise from the nodes of the stem and have limited growth and life span. Leaves are the primary photosynthetic organs and the main site of transpiration. All the leaves of a plant together are referred to as **phyllome**.

I. Characteristics of leaf

1. Leaf is a lateral appendage of the stem.
2. It is borne at the node of the stem.
3. It is exogenous in origin.
4. It has limited growth.
5. It does not posses apical bud.
6. It has three main parts namely, leaf base, petiole and lamina.
7. Lamina of the leaf is traversed by vascular strands, called **veins.**

II. Functions of the leaf

Primary functions

1. Photosynthesis
2. Transpiration
3. Gaseous exchange
4. Protection of buds
5. Conduction of water and dissolved solutes.

Secondary functions

1. Storage – Example: *Aloe, Agave, Kalanchoe, Sedum, Brassica oleracea.*
2. Protection – Example: *Berberis, Opuntia, Argemone mexicana.*
3. Support – Example: *Gloriosa, Nepenthes*
4. Reproduction - Example: *Bryophyllum, Begonia, Zamioculcas.*

3.7.1 Parts of the leaf

Three main parts of a typical leaf are:

i. Leaf base (Hypopodium)
ii. Petiole (Mesopodium)
iii. Lamina (Epipodium)

I. Leaf base (hypopodium)

The part of the leaf attached to the node of the stem is called **leaf base.** Usually it protects growing buds at its axil.

Pulvinus: In legumes leafbase become broad, thick and swollen which is known as **pulvinus.** Example: *Clitoria, Lablab, Cassia, Erythrina, Butea, Peltophorum.*

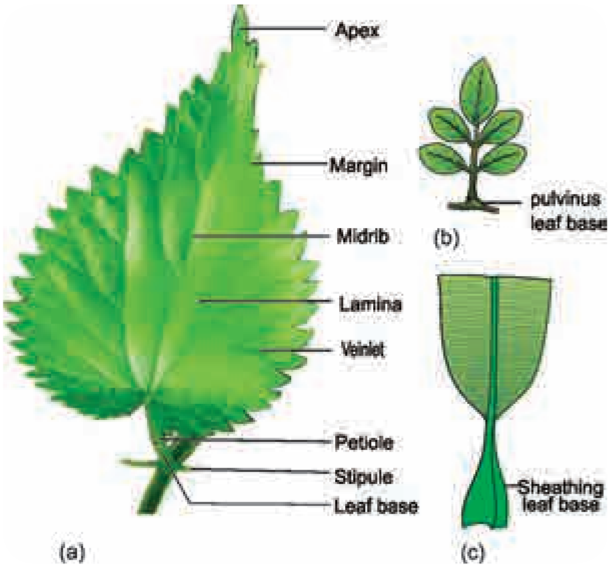


Figure 3.11: (a) Parts of the leaf **(b)** Pulvinus leaf base **(c)** Sheathing leaf base

Sheathing leafbase: In many monocot families such as Arecaceae, Musaceae, Zingiberaceae and Poaceae the leafbase extends into a sheath and clasps part or whole of the internode. Such leafbase also leave permanent scars on the stem when they fall. Example: *Arecaceae*

II. Petiole (stipe or mesopodium)

It is the bridge between leaf and stem. Petiole or leaf stalk is a cylindrical or sub cylindrical or flattened structure of a leaf which joins the lamina with the stem. A leaf with petiole is said to be **petiolate.** Example: *Ficus, Hibiscus, Mangifera, Psidium*. Leaves that do not possess petiole is said to be **sessile**. Example: *Calotropis, Gloriosa.*

III. Lamina (Leaf blade)

The expanded flat green portion of the leaf is the blade or lamina. It is the seat of photosynthesis, gaseous exchange, transpiration and most of the metabolic reactions of the plant. The lamina is traversed by the midrib from which arise numerous lateral veins and thin veinlets. The lamina shows great variations in its shape, margin, surface, texture, colour, venation and incision.

Stipules

In most of the dicotyledonous plants, the leaf base bears one or two lateral appendages called the **stipules.** Leaves with stipules are called **stipulate**. The leaves without stipules are called **exstipulate or estipulate**. The stipules are commonly found in dicotyledons. In some grasses (Monocots) an additional out growth is present between leaf base and lamina. It is called **Ligule.** Sometimes, small stipule like outgrowths are found at the base of leaflets of a compound leaf. They are called **stipels.** The main function of the stipule is to protect the leaf in the bud condition.

3.7.2 Venation

The arrangement of veins and veinlets on the leaf blade or lamina is called **venation.** Internally, the vein contains vascular tissues. Conventionally venation is classified into two types namely, Reticulate venation and Parallel venation.

I. Reticulate venation

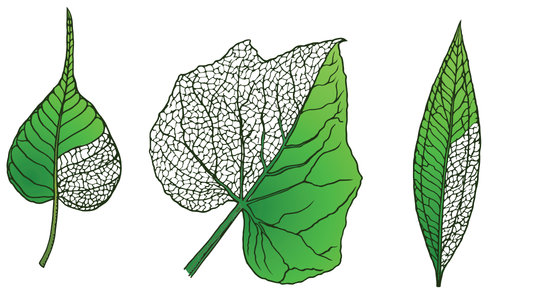
In this type of venation leaf contain a prominent midrib from which several secondary veins arise that branch and anastomose like a network. This type of venation is common in all dicot leaves. It is of two types.

1. **Pinnately reticulate venation (unicostate):** In this type of venation there is only one midrib in the centre which forms many lateral branches to form a network. Example: *Mangifera indica, Ficus religiosa, Nerium.*

2. **Palmately reticulate venation (multicostate):** In this type of venation there are two or more principal veins arising from a single point and they proceed outwards or upwards. The two types of palmate reticulate venation are

   i. **Divergent type:** When all principal veins originate from the base and diverge from one another towards the margin of the leaf as in *Cucurbita, Luffa, Carica papaya*, etc.,

   ii. **Convergent:** When the veins converge to the apex of the leaf, as in Indian plum (*Zizyphus*), bay leaf (*Cinnamomum*)



(a) *Ficus* **(b)** *Cucurbita* **(c)** *Cinnamomum*

Figure 3.12: Types of reticulate venation

(a) Pinnately reticulate
(b) Palmately reticulate (Divergent)
(c) Palmately reticulate (Convergent)

II. Parallel venation

Veins run parallel to each other and do not form a prominent reticulum. It is a characteristic feature of monocot leaves. It is classified into two sub types.

1. Pinnately Parallel Venation (Unicostate)

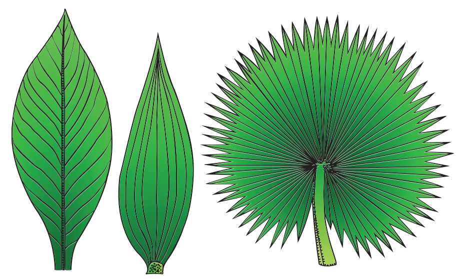
When there is a prominent midrib in the center, from which arise many veins perpendicularly and run parallel to each other. Example: *Musa*, Zinger, *Curcuma*, *Canna*.

2. Palmate Parallel Venation (Multicostate)

In this type several veins arise from the tip of the petiole and they all run parallel to each other and unite at the apex. It is of two sub types.

i. **Divergent type:** All principal veins originate from the base and diverge towards the margin, the margin of the leaf as in fan palm (*Borassus flabelliformis*)

ii. **Convergent type:** All principal veins run parallel to each other from the base of the lamina and join at the apex as in Bamboos, rice, water hyacinth.



(a) Canna **(b)** Bamboo **(c)** Borassus

Figure 3.13: Types of Parallel venation

(a) Pinnately parallel venation
(b) Palmately parallel(Convergent)
(c) Palmately parallel (Divergent)

3.7.3 Phyllotaxy

The mode of arrangement of leaves on the stem is known as **phyllotaxy (Gk. Phyllon = leaf ; taxis = arrangement).** Phyllotaxy is to avoid over crowding of leaves and expose the leaves maximum to the sunlight for photosynthesis. The four main types of phyllotaxy are (1) Alternate (2) Opposite (3) Ternate (4) Whorled.

1. Alternate phyllotaxy

In this type there is only

DO YOU KNOW?

Modern morphologist Hickey (1973) and Hickey and Wolf (1975) classified the venation into following major types based on the pattern of primary, secondary and tertiary venation.

- Craspedodromous – In which secondary veins terminate at the leaf margin. (sub types are simplecraspedodromous, semicraspedodromous, mixed craspedodromous).
- Camptodromous – In which secondary veins do not terminate at the margin. (sub types are brochidodromous, eucamptodromous, cladodromous, reticulodromous).
- Hyphodromous – With only the primary midrib vein present or evident and secondary veins either absent, very reduced or hidden with the leaf mesophyll.
- Parallellodromous – Venation is equivalent to parallel in which two or more primary or secondary veins run parallel to one another, converging at the apex.
- Actinodromous – If three or more primary veins diverge from one point.
- Palinoactinodromous – Similar to actinodromous, but the primary veins have additional branch in above the main point of divergence of the primaries.
- Flabellate – Venation is that in which several equal, fine veins branch toward the apex of the leaf.
- Campylodromous – Venation is that in which several primary veins run in prominent, recurved arches at the base, curving upward to converge at the leaf apex.
- Acrodromous – If two or more primary veins run in convergent arches toward the leaf apex.

one leaf per node and the leaves on the successive nodes are arranged alternate to each other. Spiral arrangement of leaves show vertical rows are called **orthostichies**. They are two types.

a) **Alternate spiral:** In which the leaves are arranged alternatively in a spiral manner. Example: *Hibiscus, Ficus*.

b) **Alternate distichous** or **Bifarious**: In which the leaves are organized alternatively in two rows on either side of the stem. Example: *Monoon longifolium* (*polyalthia longifolia*).

2. Opposite phyllotaxy

In this type each node possess two leaves opposite to each other. They are organized in two different types.

i. **Opposite superposed:** The pair of leaves arranged in succession are in the same direction, that is two opposite leaves at a node lie exactly above those at the lower node. Example: *Psidium* (Guava), *Eugenia jambolana* (Jamun), *Quisqualis* (Rangoon creeper).

ii. **Opposite decussate:** In this type of phyllotaxy one pair of leaves is placed at right angles to the next upper or lower pair of leaves. Example: *Calotropis, Zinnia, Ocimum*

3. Ternate phyllotaxy

In this type there are three leaves attached at each node. Example: *Nerium*

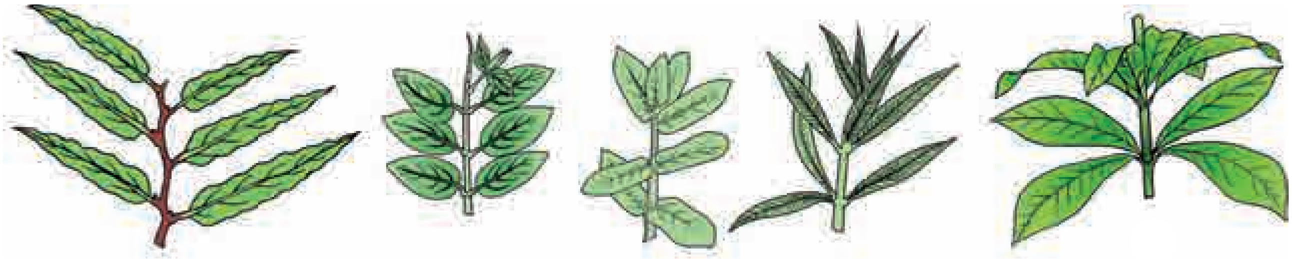


Figure 3.14: Phyllotaxy

4. Whorled (verticillate) type of phyllotaxy

In this type more than three leaves are present in a whorl at each node forming a circle or whorl. Example: *Allamanda*, *Alstonia scholaris*.

3.7.4 Leaf mosaic

In leaf mosaic leaves tend to fit in with one another and adjust themselves in such a way that they may secure the maximum amount of sunlight with minimum amount of overlapping. The lower leaves have longer petioles and successive upper leaves possess decreasing length petioles. Example: *Acalypha, Begonia*.

3.7.5 Leaf type

The pattern of division of a leaf into discrete components or segments is termed leaf type.

Based on the number of segments

I. Simple leaf

A leaf is said to be simple when the petiole bears a single lamina; lamina may be entire (undivided) Example: Mango or incised to any depth but not upto the midrib or petiole. Example: *Cucurbita*.

II. Compound leaf

Compound leaf is one in which the main rachis bears more than one lamina surface, called **leaflets.** Compound leaves have evolved to increase total lamina surface. There is one axillary bud in the axil of the whole compound leaf. The leaflets however, do not possess axillary buds.

1. Pinnately compound leaf

A pinnately compound leaf is defined as one in which the rachis, bears laterally a number of leaflets, arranged alternately or in an opposite manner, as in tamarind, *Cassia.*

i. **Unipinnate:** The rachis is simple and unbranched which bears leaflets directly on its sides in alternate or opposite manner. Example: *Rose*, *Neem*. Unipinnate leaves are of two types.

   a. when the leaflets are even in number, the leaf is said to be **paripinnate**. Example: Tamarind, *Abrus, Sesbania, Saraca, Cassia*.

   b. when the leaflets are odd in number, the leaf is said to be **imparipinnate.** Example: Rose, Neem (*Azadirachta*), Chinese box (*Murraya*).

ii. **Bipinnate:** The primary rachis produces secondary rachii which bear the leaflets. The secondary rachii are known as **pinnae.** Number of pinnae varies depending on the species. Example: *Delonix*, *Mimosa*, *Acacia nilotica, Caesalpinia*.

- **Foliage leaves** — are ordinary green, flat, lateral appendages of the stem or the branch borne at the node.
- **Cotyledons or seed leaves** — are attached to the axis of the embryo of the seed. As the seed germinates, they usually turn green and become leaf-like.
- **Cataphylls or scale leaves** — are reduced forms of leaves, stalkless and often brownish. They are the bud-scales, scales on the rhizome (underground stems), and also on other parts of the plant body (Bamboo).
- **Prophylls** — the first formed leaves are called prophylls.
- **Floral leaves** — are members of a flower, forming into two accessory whorls (calyx and corolla), two essential whorls(androecium and gynoecium).
- **Hypsophylls or bract leaves** — these leaves cover the flower or an inflorescence in their axil. The main function of these leaves is to protect the flower buds.

iii. **Tripinnate:** When the rachis branches thrice the leaf is called **tripinnate.** (i.e) the secondary rachii produce the tertiary rachii which bear the leaflets. Example: *Moringa, Oroxylum*.

iv. **Decompound:** When the rachis of leaf is branched several times it is called **decompound.** Example: *Daucus carota, Coriandrum sativum, Foeniculum vulgare.*

2. Palmately compound leaf

A palmately compound leaf is defined as one in which the petiole bears terminally, one or more leaflets which seem to be radiating from a common point like fingers from the palm.

i. **Unifoliolate:** When a single leaflet is articulated to the petiole is said to be unifoliolate. Example: *Citrus, Desmodium gangeticum.*

ii. **Bifoliolate:** When there are two leaflets articulated to the petiole it is said to be bifoliolate. Example: *Balanites roxburghii, Hardwickia binata, Zornia diphylla*

iii. **Trifoliolate:** There are three leaflets articulated to the petiole it is said to be trifoliolate. Example: wood apple (*Aegle marmelos*), Clover (*Trifolium*), *Lablab, Oxalis*

iv. **Quadrifoliolate:** There are four leaflets articulated to the petiole it is

(a) (b) (c) (d) (e)

Figure 3.15: Types of pinnately compound leaves

(a) Unipinnate (Paripinnate)-*Tamarindus* **(b)** Unipinnate (Imparipinnate)-*Azadirachta* **(c)** Bipinnate-*Caesalpinia* **(d)** Tripinnate-*Moringa* **(e)** Decompound-*Coriandrum*

(a) (b) (c) (d) (e)

Figure 3.16: Types of palmately compound leaves

(a) Unifoliolate - *Citrus* (b) Bifoliolate – *Zornia* **(c)** Trifoliolate – *Aegle marmelos*
(d) Quadrifoliolate – *Paris quadrifolia* (e) Multifoliolate – *Bombax*

said to be quadrifoliolate. Example: *Paris quadrifolia, Marsilia*

v. **Multifoliolate or digitate:** Five or more leaflets are joined and spread like fingers from the palm, as in silk cotton tree, *Cleome pentaphylla, Bombax ceiba*

3.7.6 Modification of Leaf

The main function of the leaf is food preparation by photosynthesis. Leaves also modified to perform some specialized functions. They are described below.

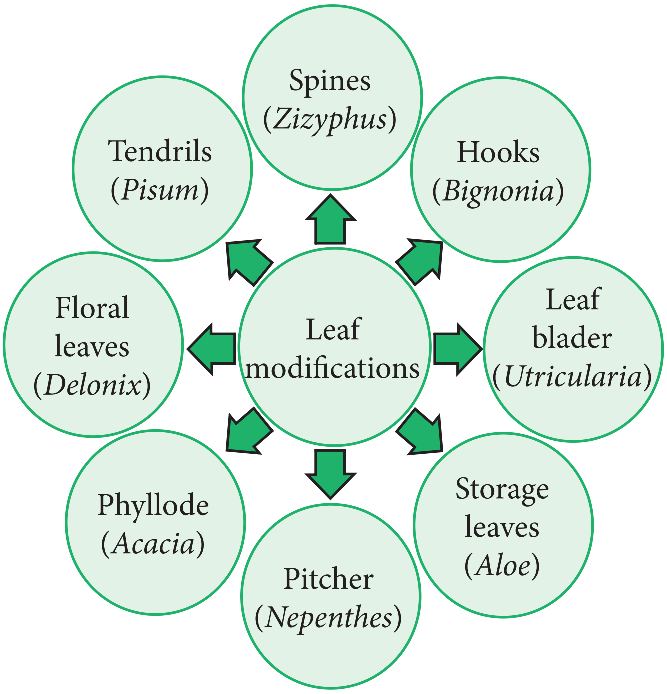
I. Leaf tendrils

In some plants Stem is very weak and hence they have some special organs for attachment to the support. So some leaves are partially or wholly modified into tendril. Tendril is a slender wiry coiled structure which helps in climbing the support. Some of the modification of leaf tendrils are given below:

Entire leaf—*Lathyrus,* stipules—*Smilax,* terminal leaflet—*Naravelia,* Leaf tip—*Gloriosa*, Apical leaflet—*Pisum,* petiole—*Clematis.*

II. Leaf hooks

In some plants, leaves are modified into hook-like structures and help the plant to climb. In cat's nail (*Bignonia unguis-cati)* an elegant climber, the terminal leaflets become modified into three, very sharp, stiff and curved hooks, very much like the nails of a cat. These hooks cling to the bark of a tree and act as organs of support for climbing. The leaf spines of *Asparagus* also act as hooks.



III. Leaf Spines and Prickles

Leaves of certain plants develop spinesent structures. Either on the surface or on the margins as an adaptation to herbivory and xeric conditions. Example: *Argemone mexicana* (Prickly poppy), *Solanum trilobatum, Solanum virginianum*. In xerophytes such as *Opuntia* (Prickly pear) and *Euphorbia* leaves and stipules are modified into spines.

Prickles are small, sharp structure which are the outgrowths from epidermal cells of stem or leaf. It helps the plant in scrambling over other plants. It is also protective against herbivory. Example: *Rosa spp, Rubus spp.*

IV. Storage Leaves

Some plants of saline and xerophytic habitats and members of the family Crassulaceae commonly have fleshy or swollen leaves. These succulent leaves store water, mucilage or food material. Such storage leaves resist desiccation. Example: *Aloe, Agave, Bryophyllum, Kalanchoe*, *Sedum, Sueada*, *Brassica oleracea* (cabbage-variety *capitata*).

V. Phyllode

Phyllodes are flat, green-coloured leaf-like modifications of petioles or rachis. The leaflets or lamina of the leaf are highly reduced or caducous. The phyllodes perform photosynthesis and other functions of leaf. Example: *Acacia auriculiformis* (Australian *Acacia*), *Parkinsonia.*

VI. Pitcher

The leaf becomes modified into a pitcher in *Nepenthes* and *Sarracenia*. In *Nepenthes* the basal part of the leaf is laminar and the midrib continues as a coiled tendrillar structure. The apical part of the leaf as modified into a pitcher the mouth of the pitcher is closed by a lid which is the modification of leaf apex.

VII. Bladder

In bladderwort (*Utricularia*), a rootless free-floating or slightly submerged plant common in many water bodies, the leaf is very much segmented. Some of these segments are modified to form bladder-like structures, with a trap-door entrance that traps aquatic animalcules.

VIII Floral leaves

Floral parts such as sepals, petals, stamens and carpels are modified leaves. Sepals and petals are leafy. They are protective in function and considered non-essential reproductive parts. Petals are usually coloured which attract the insects for pollination. Stamens are considered pollen bearing microsporophylls and carpels are ovule bearing megasporophylls.

3.7.7 Ptyxis

Rolling or folding of individual leaves may be as follows:

1. **Reclinate** - when the upper half of the leaf blade is bent upon the lower half as in loquat (*Eriobotrya japonica*).
2. **Conduplicate** - when the leaf is folded lengthwise along the mid-rib, as in guava, sweet potato and camel's foot tree (*Bauhinia*).

Leaf hooks-*Bignonia* Leaf spines- *Zizyphus* Phyllode-*Acacia* Pitcher-*Nepenthes*

Figure 3.17: Leaf Modification

3. **Plicate or plaited** – when the leaf is repeatedly folded longitudinally along ribs in a zig-zag manner, as in *Borassus flabellifer*.
4. **Circinate** - when the leaf is rolled from the apex towards the base like the tail of a dog, as in ferns.
5. **Convolute** - when the leaf is rolled from one margin to the other, as in banana, aroids and Indian pennywort. *Musa* and members of Araceae.
6. **Involute** - when the two margins are rolled on the upper surface of the leaf towards the midrib or the centre of the leaf, as in water lily, lotus, Sandwich Island Climber (*Antigonon*) and *Plumbago*.
7. **Crumpled** - when the leaf is irregularly folded as in cabbage.

3.7.8 Leaf duration

Leaves may stay and function for few days to many years, largely determined by the adaptations to climatic conditions.

Cauducuous (Fagacious)

Falling off soon after formation. Example: *Opuntia, Cissus quadrangularis.*

Deciduous

Falling at the end of growing season so that the plant (tree or shrub) is leafless in winter/summer season. Example: *Maple, Plumeria, Launea, Erythrina.*

Evergreen

Leaves persist throughout the year, falling regularly so that tree is never leafless. Example: *Mimusops, Calophyllum*.

Marcescent

Leaves not falling but withering on the plant as in several members of Fagaceae.

3.7.9 Leaf symmetry

1. Dorsiventral leaf

When the leaf is flat, with the blade placed horizontally, showing a distinct upper surface and a lower surface, as in most dicotyledons, it is said to be dorsiventral. Example: *Tridax*.

2. Isobilateral leaf

When the leaf is directed vertically upwards, as in many monocotyledons, it is said to be isobilateral leaf. Example: *Grass*.

3. Centric leaf

When the leaf is more or less cylindrical and directed upwards or downwards, as in pine, onion, etc., the leaf is said to be centric.

4. Heterophylly

Occurrence of two different kinds of leaves in the same plant is called **heterophylly.** Heterophylly is found in many aquatic plants. Here, the floating or aerial leaves and the submerged leaves are of different kinds. The former are generally broad, often fully expanded, and undivided or merely lobed, while the latter are narrow, ribbon-shaped, linear or much dissected. Heterophylly in water plants is, thus, an adaptation to two different conditions of the environment. Example: water crowfoot (*Ranunculus aquatilis*), water plantain (*Alisma plantago*), arrowhead (*Sagittaria*), *Limnophila heterophylla*.

Terrestrial (land) plants also exhibit this phenomenon. Among them *Sterculia villosa*, jack (in early stages), *Ficus heterophylla* show leaves varying from entire to variously lobed structures during different developmental stages. Young leaves are usually lobed or dissected and the mature leaves are entire. Such type is known as **developmental heterophylly.** Example: *Eucalyptus, Artocarpus heterophyllus.*