GOVERNMENT OF TAMIL NADU

BOTANY

HIGHER SECONDARY FIRST YEAR

VOLUME - I

Untouchability is Inhuman and a Crime

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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
	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
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, Bioinformatics; Protein structure, Dynamic and Interactions Epigenetic	www.cdfd.org.in
Institute of Life Sciences, Bhubaneswar	Infectious disease;Immune 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 food Technological Research Institute, Mysore.	Food science and Technology	www.cftri.com
Central Institute of medicinal and Aromatic Plants, Lucknow.	Agronomy & soil sciences; 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
Bose Institute, Kolkatta	Molecular and cellular biology	www.boseinst.ernet.in
National Centre for Biological Sciecnes, Bengaluru	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
School of Medical Science and Technology, Indian Institute of Technology, Kharagpur, West Bengal.	Tissue Engineering; Biomaterials; Herbal medicine & Bio-Engineering.	www.smstweb.iitkgp.ernet.in
Institute of Wood Science and Technology, Bengaluru.	Tree improvement and Genetics; Chemistry of Forest Products.	iwst.icfre.gov.in
Centre for Ecological Sciences, Indian Institute of Science. Bengaluru.	Behaviour 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

Research Institutions in various areas of Botany		
Name of the Institution	**Research Areas**	**Website**
Indian Agricultural Research Institute (IARI) New Delhi	Genetics & Plant Breeding; Plant Pathology; Microbiology; Post Harvest Technology	www.iari.res.in
Indian Institute of Horticultural Research, Bengaluru	Horticultural Research; Biotechnology; Entomology; Pathology	www.iihr.res.in
Agharkar Research Institute, Pune	Biodiversity & Palaeobiology, Bioenergy, BioprospectingNanobioscicence	www.aripune.org
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 Soil Salinity Research Institute, Karnal, Haryana	Reclamation and Management of Salt affected soils. Bio-remediation of waste waters. Carbon Sequestration	www .cssri.nic.in
Central Institute of Post Harvest Engineering & Technology, Ludiana	Rapid Evaluation of Food Quality and Safety; Packaging and storage of agricultural produce and products.	www.ciphet.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
National Centre for Integrated Pest Management (ICAR) New Delhi	Pest Management	www.ncipm.org.in
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
Central Institute for Research on Cotton Technology, (CIRCOT) Mumbai	Improvement in Ginning of cotton; Improvement and quality evaluation of fibers and production of value added products.	www.circot.res.in
Directorate of Cashewnut & Cocoa, Agri, Kerala	Cocoa production and processing	www.dccd.gov.in

Research Institutions in various areas of Botany

Name of the Institution	Research Areas	Website
National Research Center on Plant Biotechnology, New Delhi	Genetic engineering for biotic resistance.	www.nrcpb.org
Indian Institute of Soil Sciences (IISS), Bhopal	Study of organic and inorganic nutrient sources affect soil biological activity.	www.iiss.nic.in
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
National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi	Agricultural technology policy.	www.ncap.res.in
National Institute of Abiotic Stress Management., Pune	Basic and strategic research on management of abiotic stresses of crop plants.	www.niam.res.in
Central Research Institute for Dryland Agriculture, Hyderabad	Dryland, Agrometerology and Crop sciences	crida.in
Central Research Institute for Jute & Allied Fibres, Kolkata, West Bengal	Crop improvement, Crop production, Crop protection, Agricultural research.	www.crijaf.org.in
Indian Institute of Pulses Research (IIPR), Kanpur	Genetics & Plant Breeding and Seed Science	www.iipr.res.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
Indian Institutes of Science Education and Research(IISER) - Berhampur, Bhopal, Kolkata, Mohali, Pune, Thiruvananthapuram, and Tirupati.	Microbial Ecology; Marine Molecular Ecology; Marine Biology.	www.iiserkol.ac.in www.issertvm.ac.in

Unit I: Diversity of Living World

Chapter 1

Living World

Learning Objectives

The learner will be able to,

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

Chapter Outline

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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

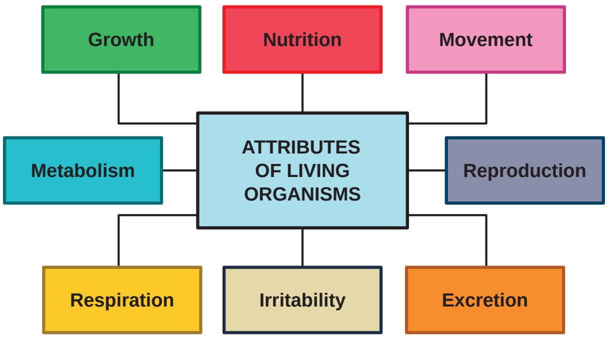


Figure 1.1: Attributes of living organisms

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 (Figure 1.2). Asexual reproduction refers to the production of the progeny possessing features more or less similar to those of parents. The sexual reproduction brings out variation through **recombination.** Asexual reproduction in living organisms occurs by the production of conidia (*Aspergillus, Penicillium*), budding (*Hydra* and Yeast), binary fission (Bacteria and *Amoeba*) fragmentation (*Spirogyra*), protonema (Mosses) and regeneration (*Planaria*). Exceptions are the sterile worker bees and mules.

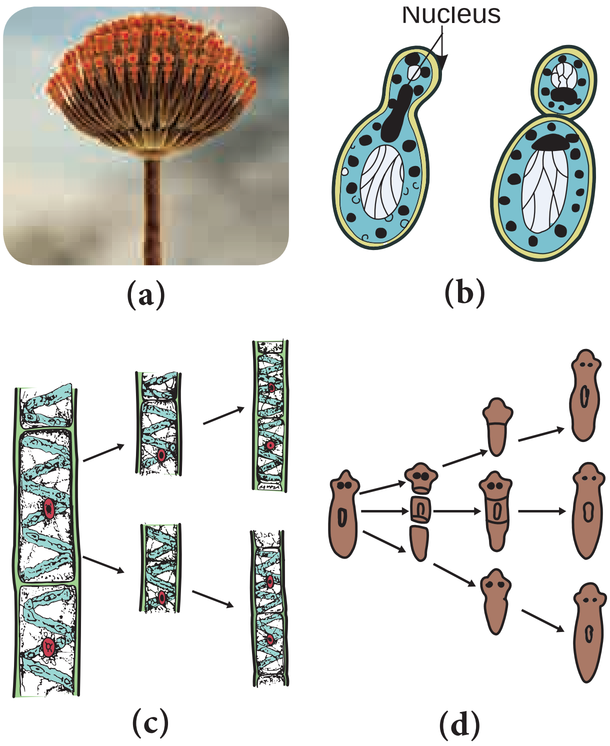


Figure 1.2: Types of Asexual Reproduction
(a) Conidia formation-*Penicillium*,
(b) Budding-Yeast, (c) Fragmentation-*Spirogyra*, (d) Regeneration-*Planaria*

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

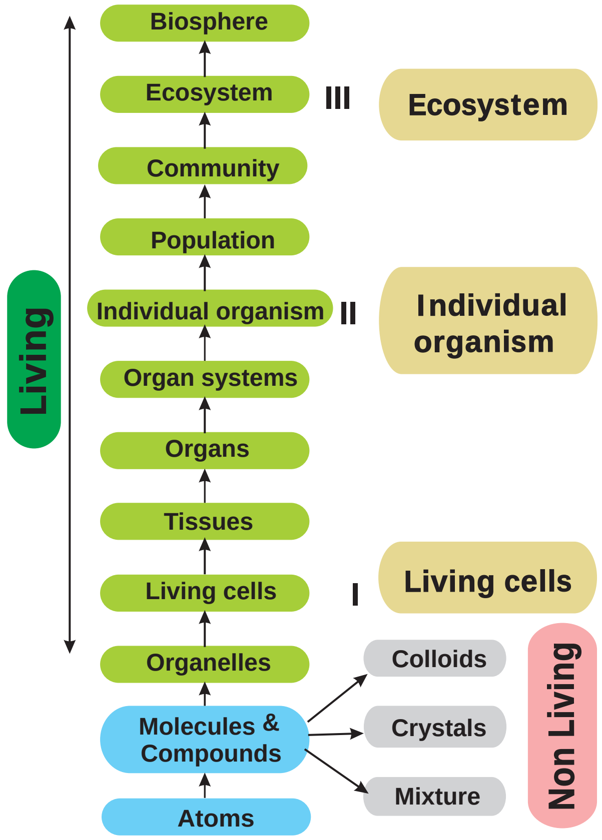


Figure 1.3: The levels of organization and integration in living organism

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

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

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" with Dr. J.H. Northrop for Chemistry in 1946.

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.

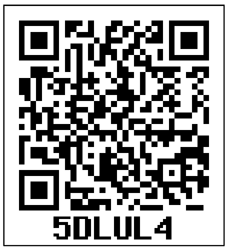
ii. Helical symmetry – Example: Influenza virus, TMV.

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



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

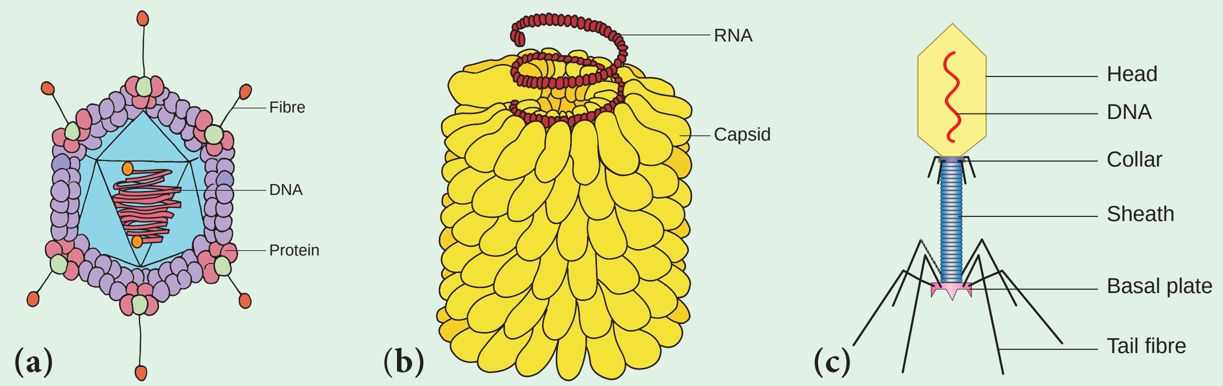


Figure 1.4: Shapes of Viruses

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

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 (−)sense 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

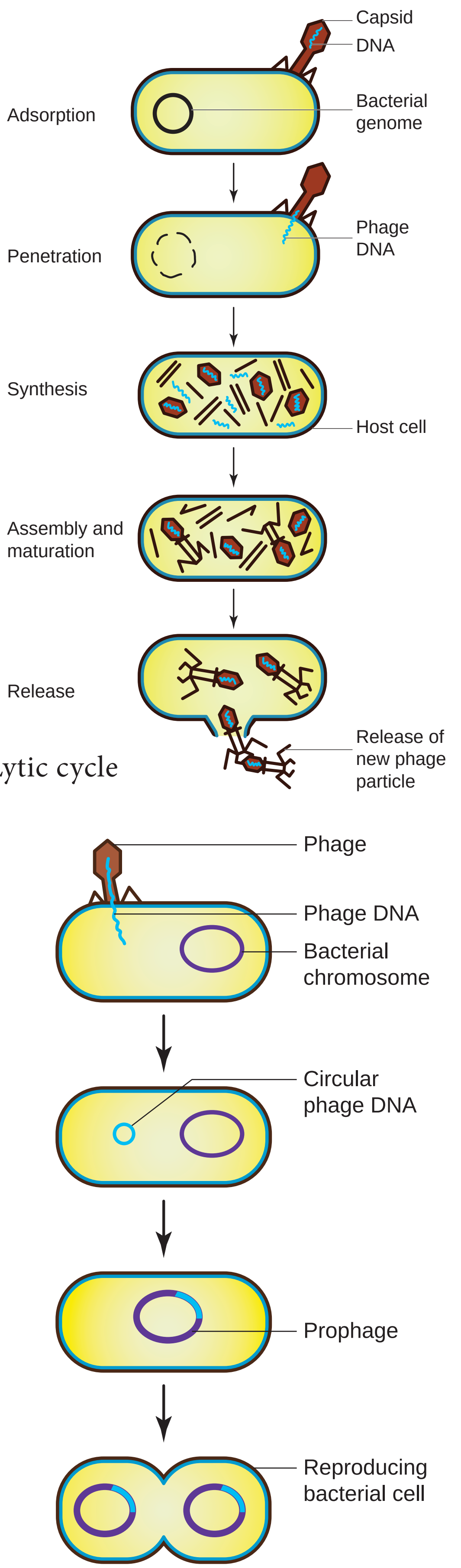
The penetration process involves mechanical and enzymatic digestion of the cell wall of the host. At the recognition site phage digests certain cell wall structure by viral enzyme (lysozyme). After pinning the tail sheath contracts (using ATP) and appears shorter and thicker. After contraction of the 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



(a) Lytic cycle

(b) Lysogenic cycle

Figure 1.5: Multiplication cycle of phage,

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

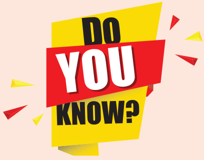
(a)

(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 viruses 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

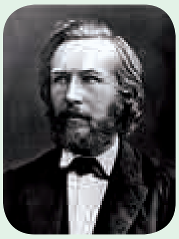
Classification is essential to achieve following needs

- 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

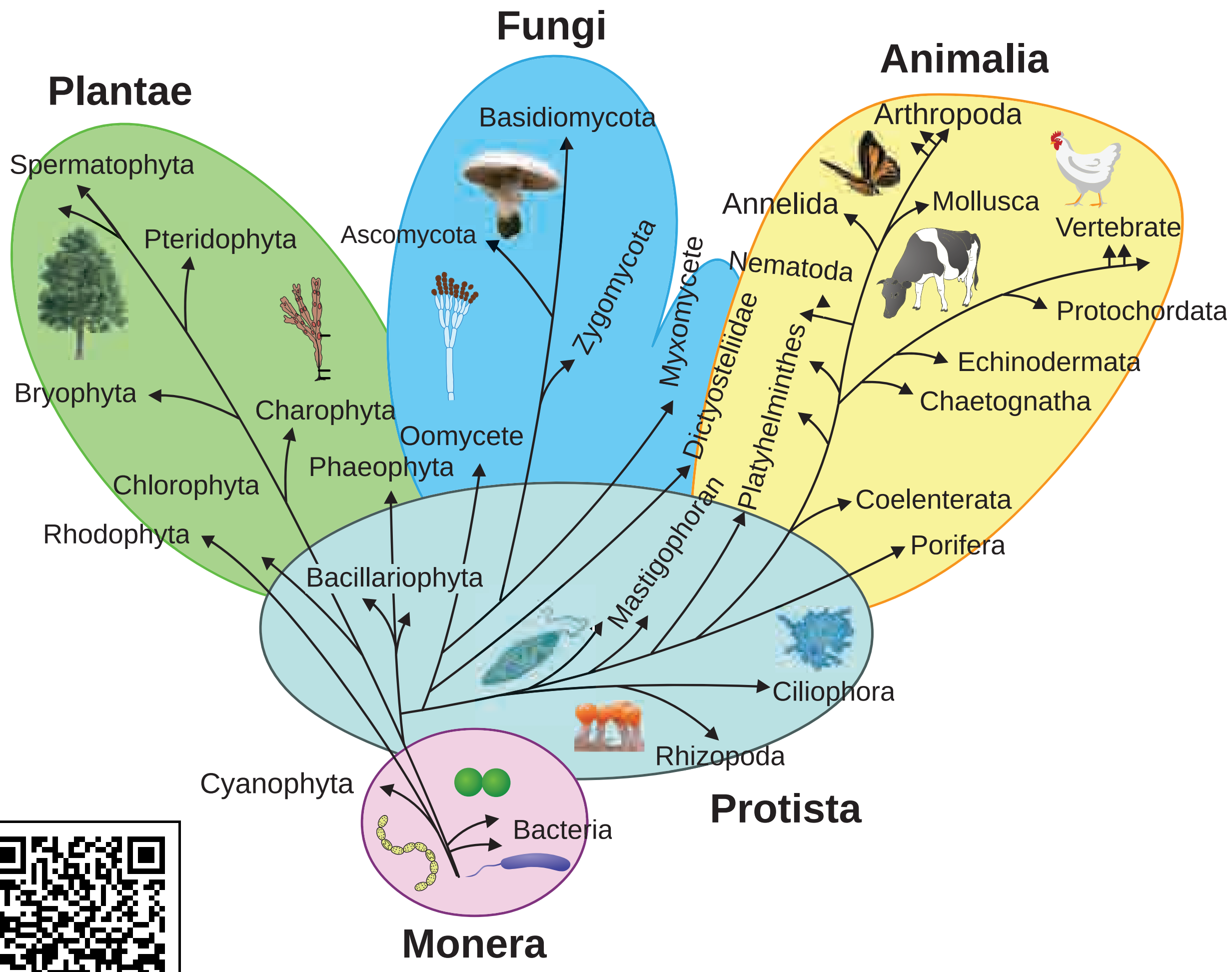
Merits

- 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.

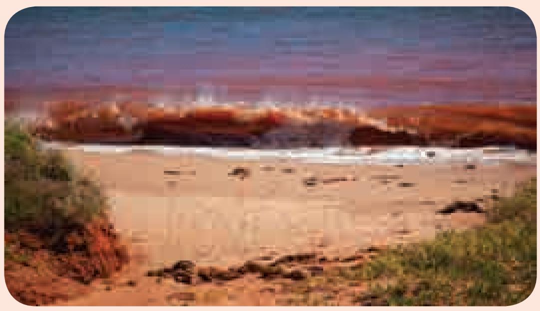


Table 1.5: Comparison of Five Kingdoms

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

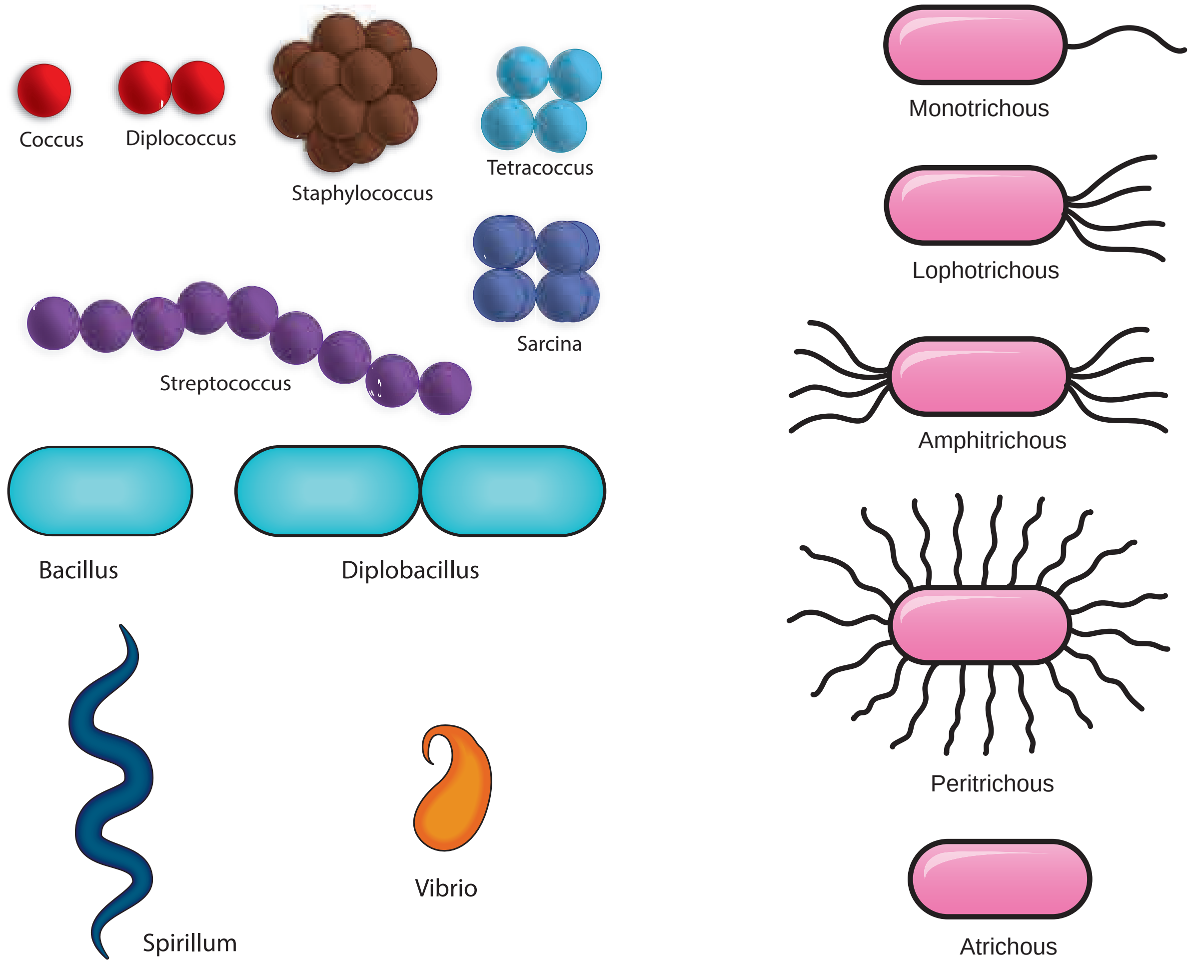


Figure 1.8: Shape and flagellation in bacteria

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)

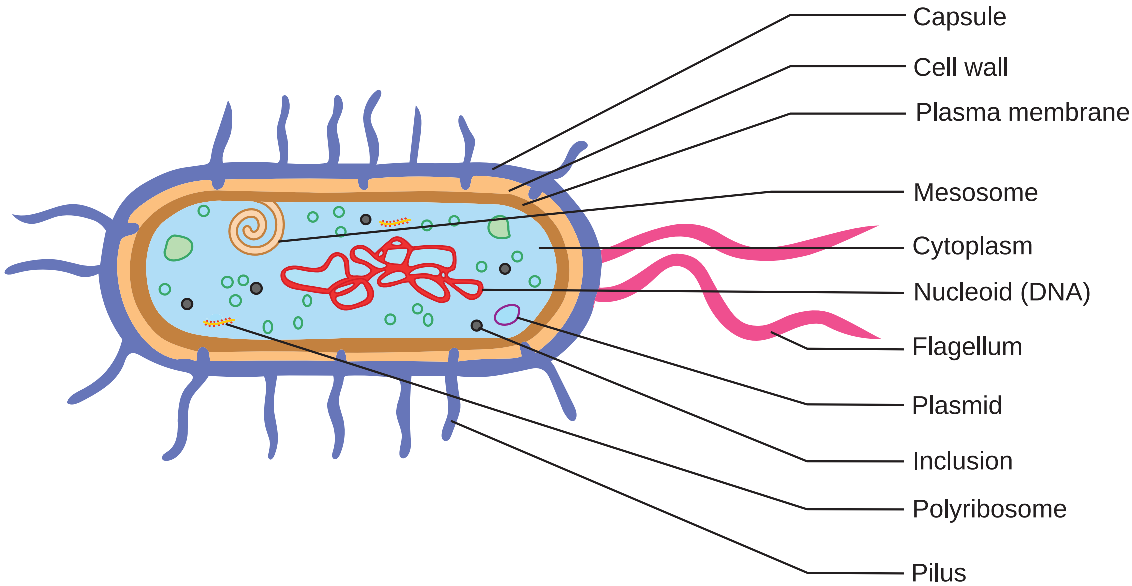


Figure 1.9: Ultrastructure of a bacterial cell

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 extra chromosomal 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.

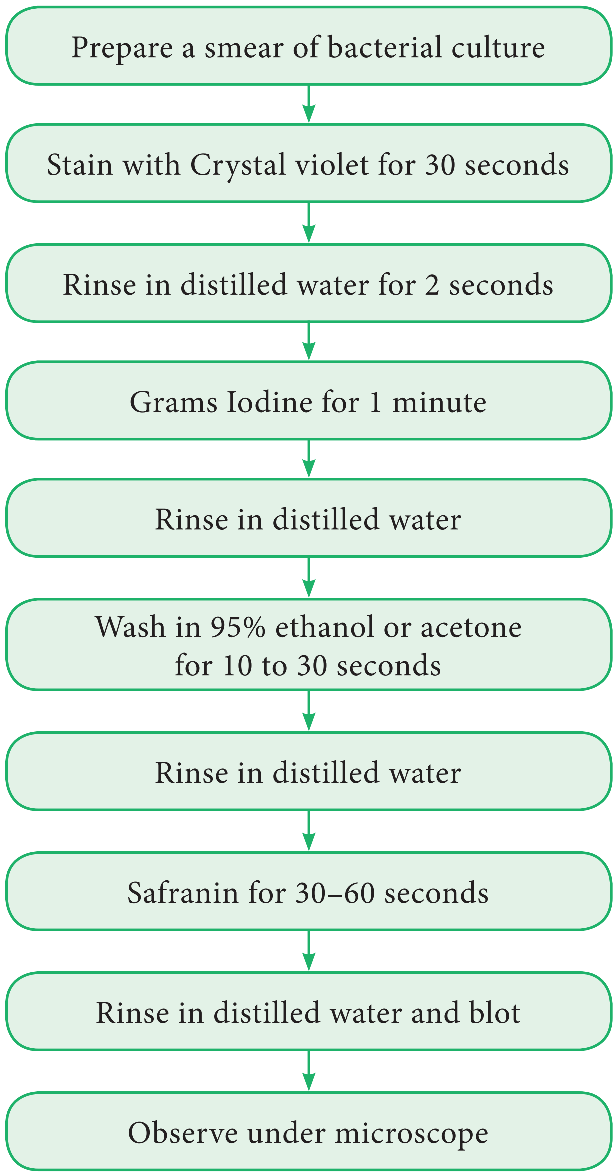


Figure 1.10: Steps involved in Gram Staining

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.

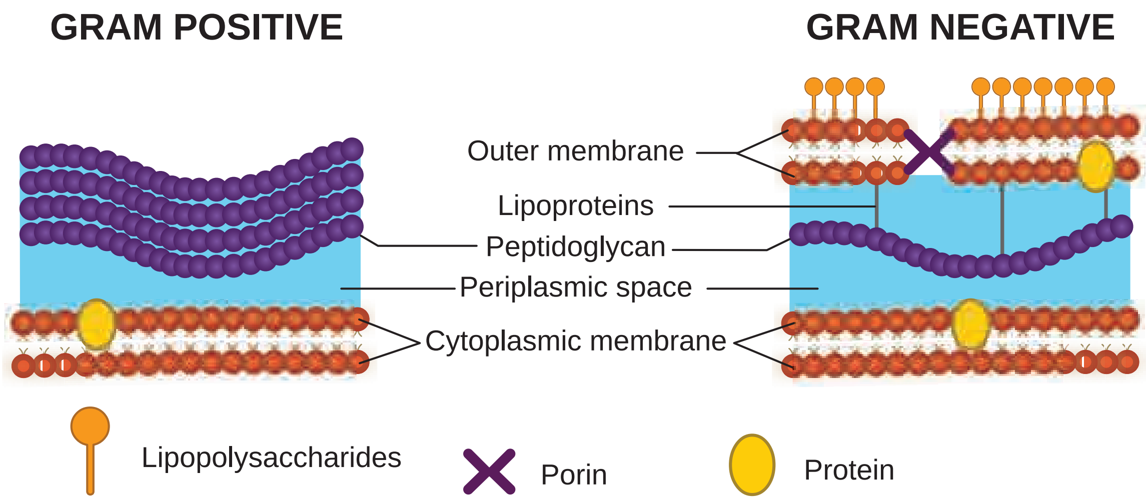


Figure 1.11: Difference between Gram positive and Gram negative bacteria

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 help 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. This type of bacteria obtain energy from organic or inorganic substance.

1.Chemolithotrophs

This type of bacteria oxidize inorganic compound to release energy.

Examples:

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

2. Chemoorganotrophs

This type of bacteria oxidize organic compounds to release energy.

Examples:

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

II. Heterotrophic Bacteria

They are Parasites (*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.

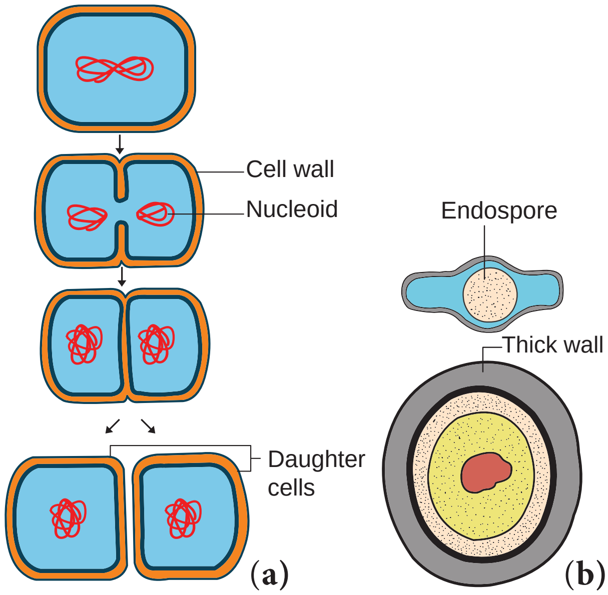


Figure 1.12: Asexual Reproduction in Bacteria (a) Binary fission, (b) Endospore

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).

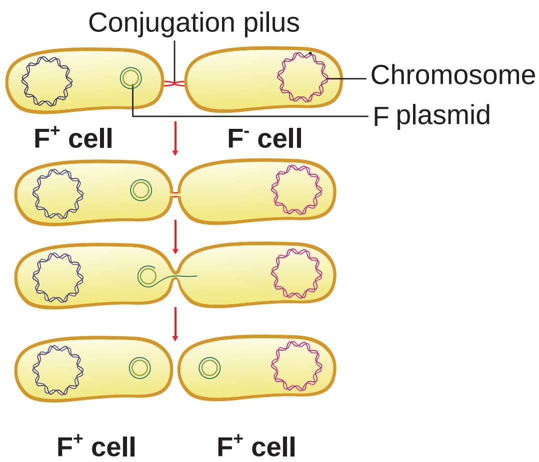


Figure 1.13: Conjugation

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 produce rough colonies and are avirulent (R-type). When S-type of cells were injected into the mouse, the mouse died. When R-type of cells were injected, the mouse survived. He injected heat killed S-type cells into the mouse the mouse did not die. When the mixture of heat killed S-type

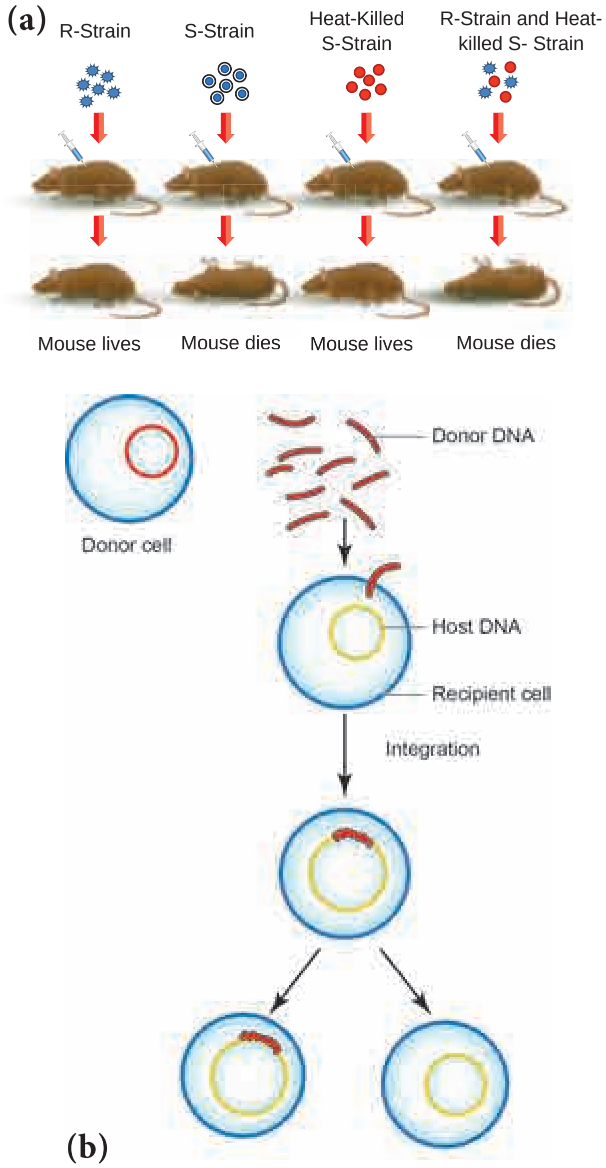


Figure 1.14: Transformation in Bacteria
(a) Griffith's experiment on Transformation
(b) Mechanism of Transformation

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.

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.

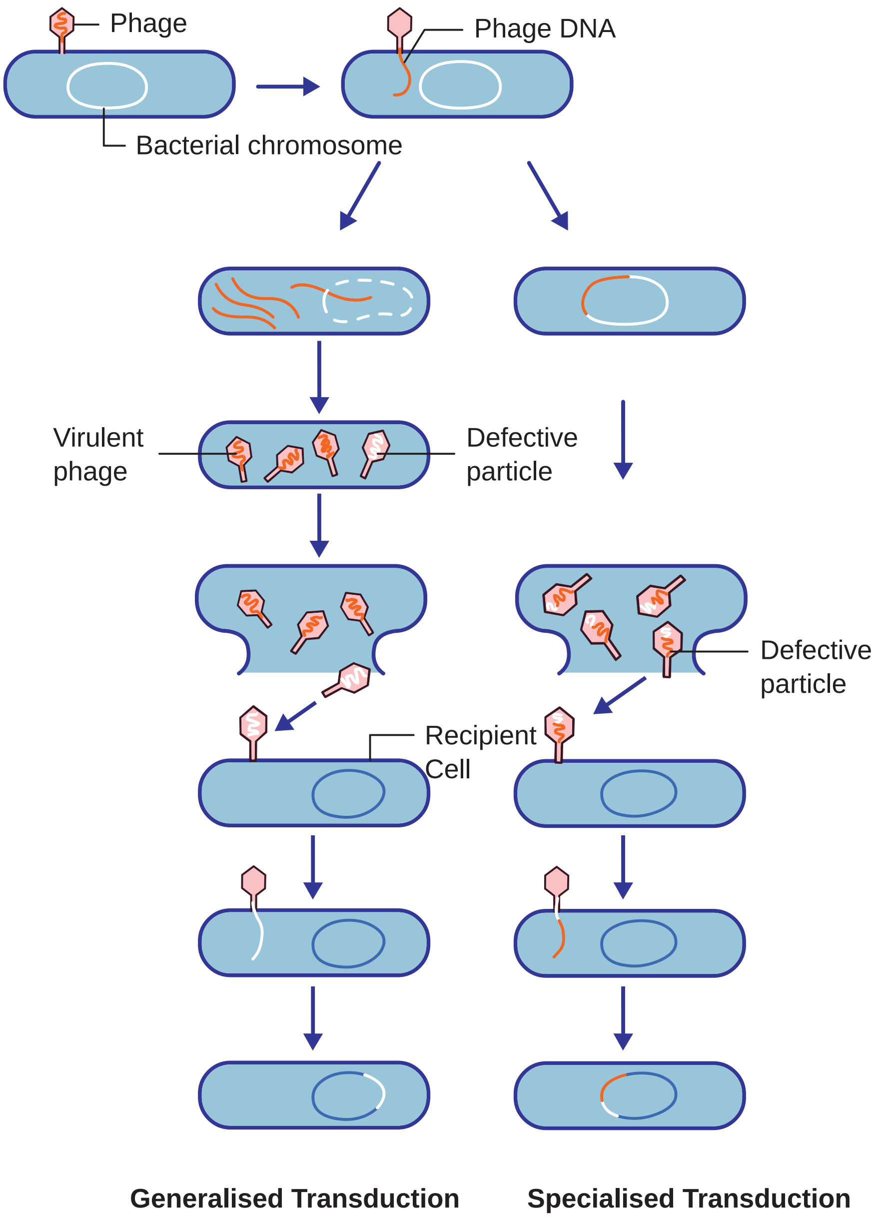


Figure 1.15: Transduction in Bacteria

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 cures urinary infections, tuberculosis, meningitis and pneumonia
2. Aureomycin	*Streptomyces aureofaciens*	It is used as a medicine to treat whooping cough and eye infections
3. Chloromycetin	*Streptomyces venezuelae*	It cure typhoid fever
4. Bacitracin	*Bacillus licheniformis*	It is used to treat syphilis
5. Polymyxin	*Bacillus polymyxa*	It cure some bacterial diseases
3. Industrial Uses		
1. Lactic acid	*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	Vitamins 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*

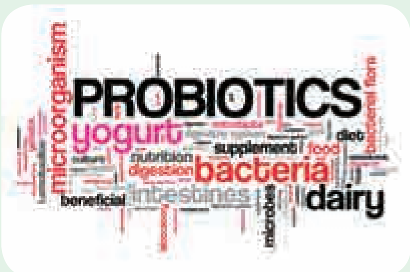
Table 1.10: Human diseases caused by Bacteria

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 pneumoniae*
6.	Plague	*Yersinia pestis*
7.	Diphtheria	*Corynebacterium diptheriae*
8.	Tetanus	*Clostridium tetani*
9.	Food poisoning	*Clostridium botulinum*
10.	Syphilis	*Treponema pallidum*

(a) **(b)**

Figure 1.16: 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-hydroxyl butyrate) a microbial plastic which is biodegradable.

1.4.8 Archaebacteria

Archaebacteria are primitive prokaryotes and are adapted to thrive in extreme environments like hot springs, high salinity, low pH and so on. They are mostly chemoautotrophs. The unique feature of this group is the presence of lipids like glycerol & isopropyl ethers in their cell membrane. Due to the unique chemical composition the cell membrane show resistance against cell wall antibiotics and lytic agents. Example: *Methanobacterium, Halobacterium, Thermoplasma*.

- *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.

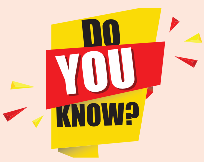
Stromatolites are deposits formed when colonies of cyanobacteria bind with calcium carbonate. They have a geological age of 2.7 billion years. Their abundance in the fossil record indicates that cyanobacteria helped in raising the level of free oxygen in the atmosphere.

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



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

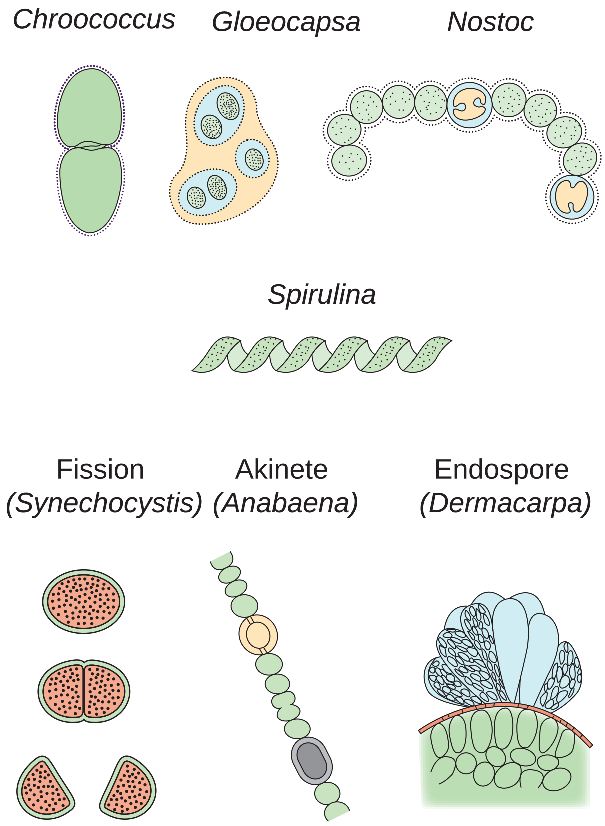


Figure 1.17: Structure and reproduction in cyanophyceae

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.

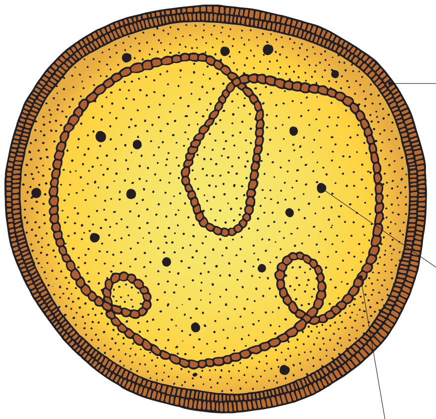


Figure 1.18: Structure of *Mycoplasma*

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. (Gr. mykes – mushroom:

logos – study). P.A. Micheli is considered as founder of Mycology. Few renowned mycologists include Arthur H.R. Buller, John Webster, D.L.Hawksworth, G.C.Ainsworth, B.B.Mundkur, K.C.Mehta, C.V. Subramanian and T.S. Sadasivan.

E.J. Butler (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*.

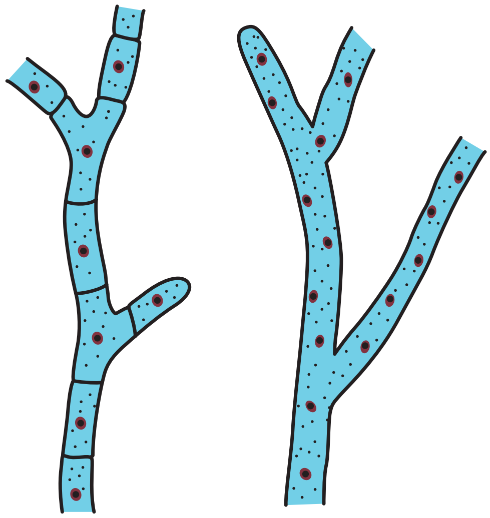


Figure 1.19: Types of mycelium

- 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*).

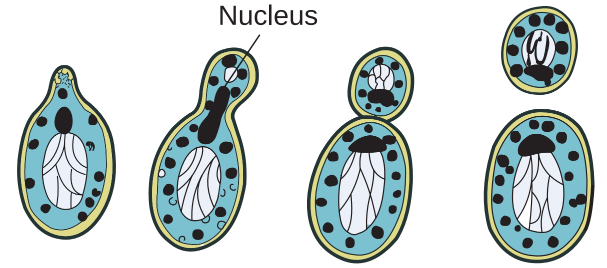
c. Oogamy – Fusion of both morphologically and physiologically dissimilar gametes. (Example: *Monoblepharis*)

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

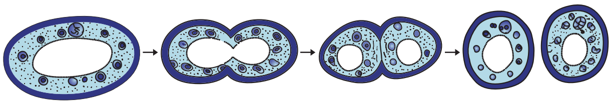
3. Gametangial copulation: Fusion of gametangia to form zygospore (Example: *Mucor, Rhizopus*).

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

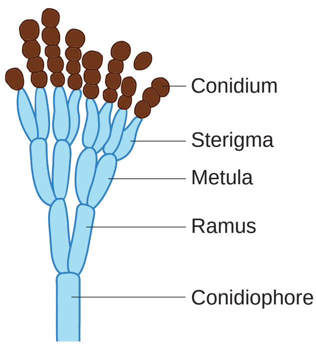
5. Somatogamy: Fusion of two somatic cells of the hyphae (Example: *Agaricus*)



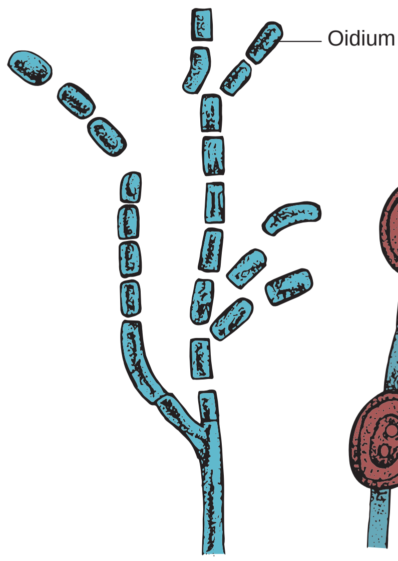
(a) Budding - Yeast



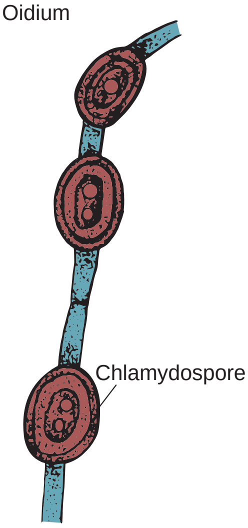
(b) Fission - Yeast



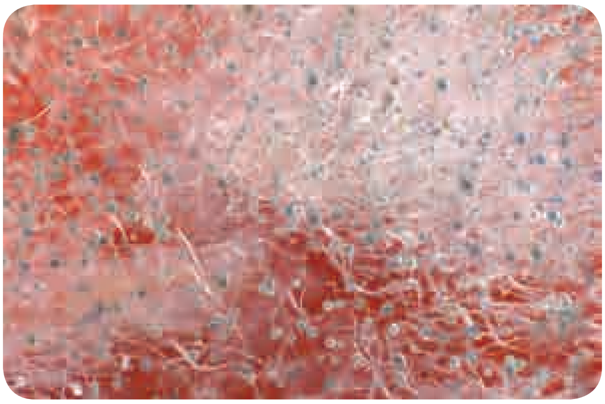
(c) Conidia formation - *Penicillium*



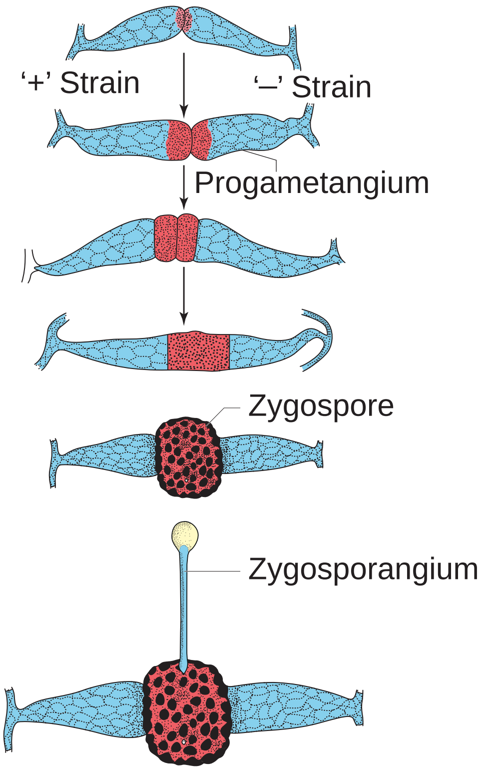
(d) Thallospore - *Erysiphe*



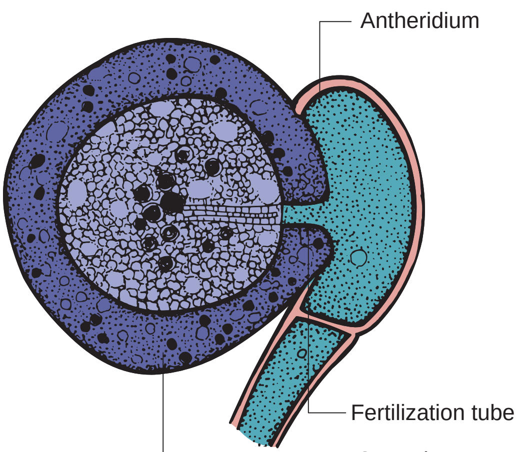
(e) Chlamydospore - *Fusarium*



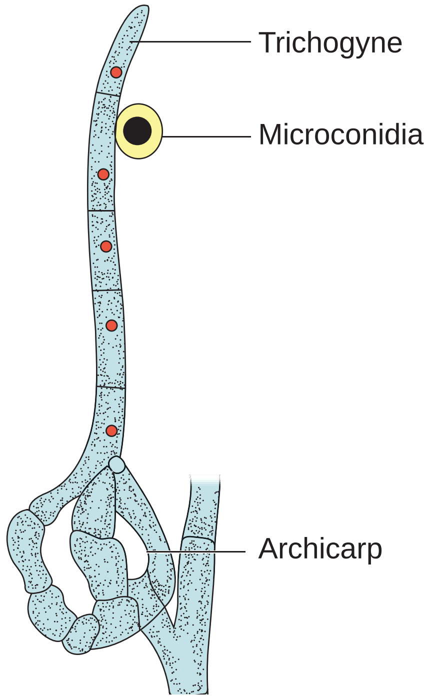
(f) Sporangia - *Mucor*



(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 outline of the classification is given below:

KINGDOM - MYCETEAE

DIVISION – GYMNOMYCOTA

- **SUBDIVISION – 1** ACRASIOGYMNOMYCOTINA
  - CLASS – Acrasiomycetes
- **SUBDIVISION – 2** PLASMODIOGYMNOMYCOTINA
  - CLASS – Protosteliomycetes
  - CLASS- Myxomycetes

DIVISION - MASTIGOMYCOTA

- **SUBDIVISION – 1** HAPLOMASTIGOMYCOTINA
  - CLASS – Chytridiomycetes
  - CLASS – Hyphochytridiomycetes
  - CLASS – Plasmodiophoromycetes
- **SUBDIVISION – 2** DIPLOMASTIGOMYCOTINA
  - CLASS - Oomycetes

DIVISION – AMASTIGOMYCOTA

- **SUBDIVISION -1** ZYGOMYCOTINA
  - Class – Zygomycetes
  - Class- Trichomycetes
- **SUBDIVISION -2** ASCOMYCOTINA
  - CLASS – Ascomycetes
- **SUBDIVISION -3** BASIDIOMYCOTINA
  - CLASS – Basidiomycetes
- **SUBDIVISION -4** DEUTEROMYCOTINA
  - CLASS - Deuteromycetes

1.5.5 Kingdom : Myceteae (Fungi)

Include achlorophyllous, saprophytic or parasitic organisms with Unicellular or multicellular (Mycelium) thallus surrounded by chitinous cell wall. Nutrition is absorptive except slime molds.Reproduction is through asexual and Sexual methods.

Division : I Gymnomycota

Nutrition Phagotrophic, members of this group lack cell wall. Example. *Dictyostelium*

Division :II Mastigomycota

Flagellate cells are present(Gamete/Zoospore). Nutrition absorptive, mycelium coenocytic. Example : *Albugo*

Division : III Amastigomycota

Unicellular to multicellular forms are included. The mycelium is septate. Asexual reproduction occurs by budding, fragmentation, sporangiospores, conidia etc., Meiosis is zygotic. Example : *Peziza*

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

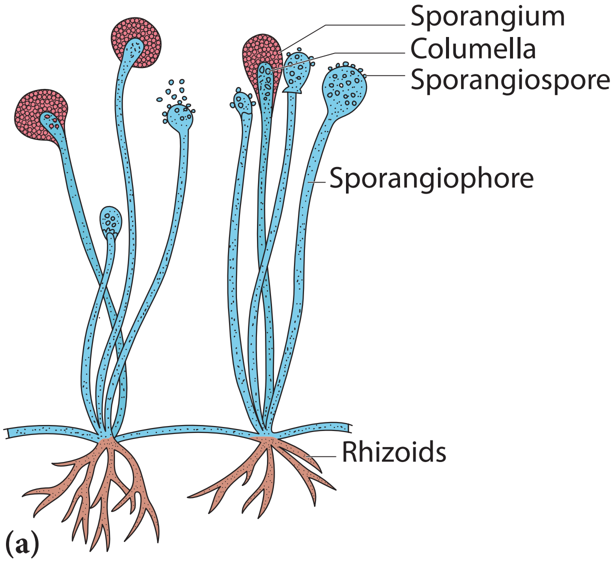
The salient features of some of the classes – Oomycetes, Zygomycetes, Ascomycetes, Basidiomycetes and Form class Deuteromycetes are discussed below.

Oomycetes

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

Zygomycetes

- Most of the species are saprophytic and live on decaying plant and animal matter in the soil. Some lead parasitic life (Example: *Entomophthora* on housefly)
- Bread mold fungi (Example: *Mucor, Rhizopus*) and Coprophilous fungi (Fungi growing on dung Example: *Pilobolus*) belong to this group (Figure 1.21).



(a)

(b)

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

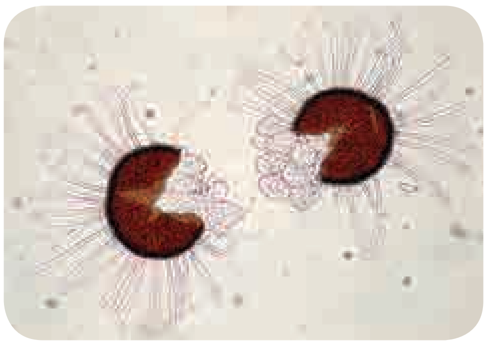
- The mycelium is branched and coenocytic.
- Asexual reproduction by means of spores produced in sporangia.
- Sexual reproduction is by the fusion of the gametangia which results in thick walled zygospore. It remains dormant for long periods. The zygospore undergoes meiosis and produce spores.

Ascomycetes

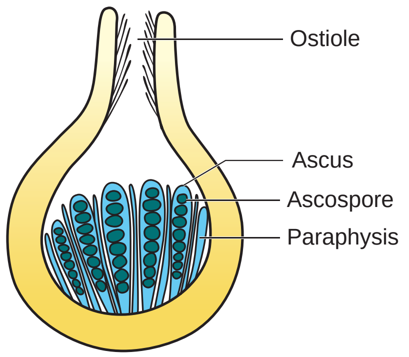
- Ascomycetes include a wide range of fungi such as yeasts, powdery mildews, cup fungi, morels and so on (Figure 1.22).

(a) *Morchella*

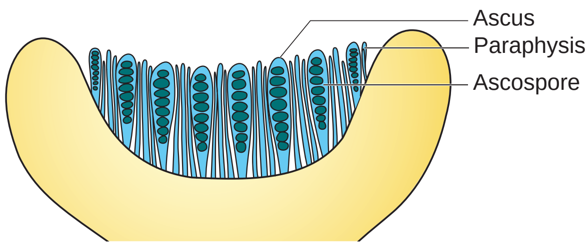
(b) *Peziza*



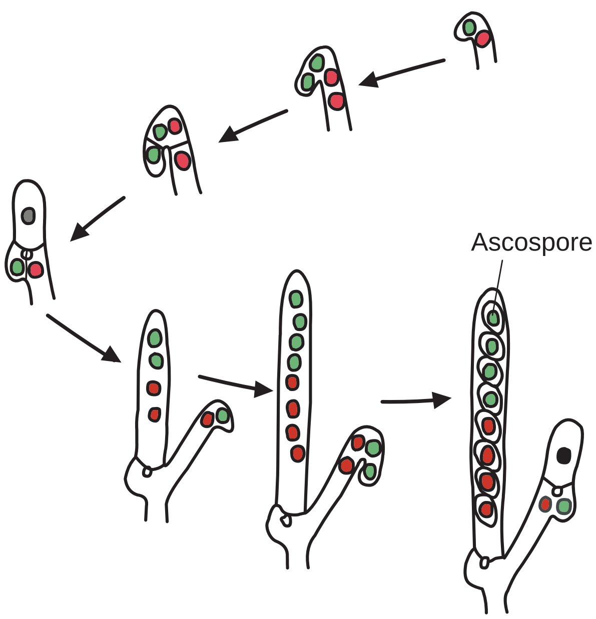
(c) Cleistothecium



(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

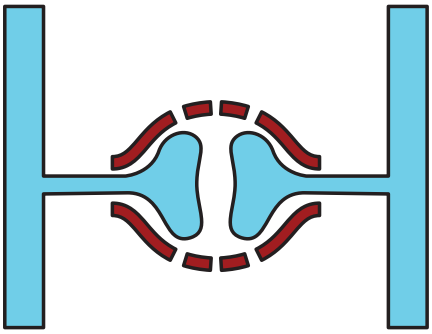
- Although majority of the species live in terrestrial environment, some live in aquatic environments both fresh water and marine.
- The mycelium is well developed, branched with simple septum.
- Majority of them are saprophytes but few parasites are also known (Powdery mildew – *Erysiphe*).
- Asexual 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

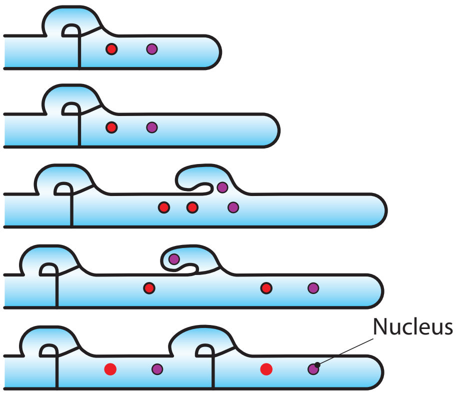
- Basidiomycetes include puff balls, toad stools, Bird's nest fungi, Bracket fungi, stink horns, rusts and smuts (Figure 1.23).

(a) *Agaricus*

(b) *Geaster*



(c) Dolipore septum



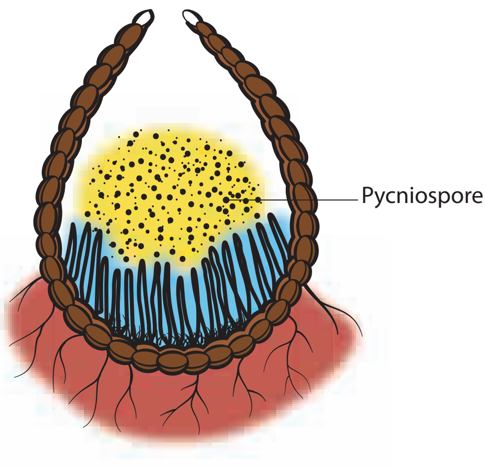
(d) Clamp connection

Figure 1.23: Structure and Reproduction in Basidiomycetes

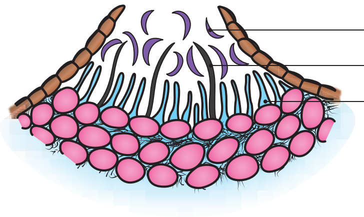
- The members are terrestrial and lead a saprophytic and parasitic mode of life.
- The mycelium is well developed, septate with dolipore septum(bracket like). Three types of mycelium namely Primary (Monokaryotic), Secondary (Dikaryotic) and tertiary are found.
- Clamp connections are formed to maintain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

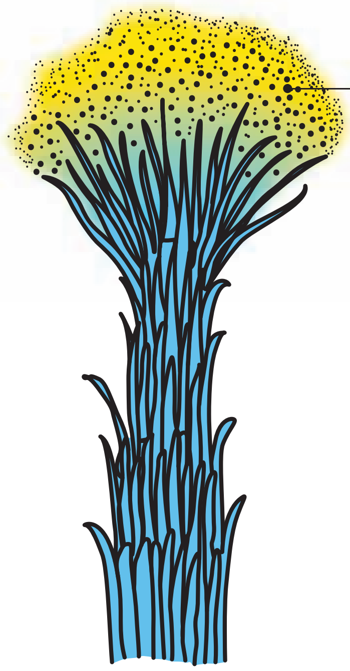
The fungi belonging to this group lack sexual reproduction and are called imperfect fungi. A large number of species live as saprophytes in soil and many are plant and animal parasites. Asexual reproduction takes place by the production of conidia, chlamydospores, budding, oidia etc., Conidia are also produced in special structures called pycnidium, Acervulus, sporodochium and Synnema



(a) Pycnidium - *Phoma*



(b) Acervulus - *Colletotrichum*



(c) Synnema - *Graphium*

Figure 1.24: Reproduction in Deuteromycetes

(Figure 1.24). Parasexual cycle operates in this group of fungi. This brings genetic variation among the species.

1.5.6. 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

(b) Anthracnose of beans

Figure 1.25: Fungal disease in plants.

Table 1.11: Diseases caused by fungi	
Name of the disease	***Causal organism***
Plant diseases Blast of Paddy	*Magnaporthe grisea*
Red rot of sugarcane	*Colletotrichum falcatum*
Anthracnose of Beans	*Colletotrichum lindemuthianum*
White rust of crucifers	*Albugo candida*
Peach leaf curl	*Taphrina deformans*
Rust of wheat	*Puccinia graminis tritici*
Human diseases	
Athlete's foot	*Epidermophyton floccosum*
Candidiasis	*Candida albicans*
Coccidioidomycosis	*Coccidioides immitis*
Aspergillosis	*Aspergillus fumigatus*

Activity 1.4

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.

1.5.7 *Rhizopus*

Class - Zygomycetes
Order - Mucorales
Family - Mucoraceae
Genus - *Rhizopus*

Rhizopus is a saprophytic fungus and grows on substrates like bread, jelly, leather, decaying vegetables and fruits. It is commonly called 'Bread mold'. *Rhizopus stolonifer* causes leak and soft rot of vegetables

Vegetative structure

The mycelium consists of aseptate, multinucleate (coenocyte) and profusely branched hyphae. There are horizontally growing aerial hyphae called **stolons**. The stolons produce rhizoids which are branched and penetrate the substratum and help in absorbing water and nutrients. Sporangiophores are borne exactly opposite to the rhizoids. The cell wall is made up of chitin and chitosan. The cell wall is followed by plasma membrane. The protoplast is granular containing many nuclei. Cell organelles like mitochondria, ribosomes and endoplasmic reticulum are present. The cell inclusions like glycogen and oil droplets are also found.

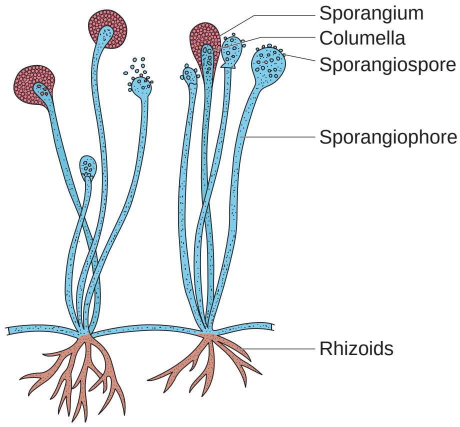


Figure 1.26: *Rhizopus*

Reproduction

Rhizopus reproduces by asexual and sexual methods.

Asexual reproduction

During favorable conditions, erect sporangiophores are produced exactly opposite to the region of formation of rhizoids of the mycelium. The sporangiophores are unicellular, unbranched and multinucleate structures which bear bag like structure called sporangia. Each sporangiophore bears a single sporangium.

Sporangium possesses a sterile region in the centre called **Columella**. Spores are produced around the columella. When the sporangial wall breaks, the columella collapses and the spores are dispersed. When the spores fall on a suitable substratum they germinate and produce new mycelia (Figure 1.26).

Sexual reproduction

Sexual reproduction is present and takes place through gametangial copulation. Most of the species are heterothallic but *Rhizopus sexualis* is homothallic. There is no morphological distinction between the two sexual hyphae although physiologically they are dissimilar. Since physiologically dissimilar thalli (hyphae) are involved in sexual reproduction, this phenomenon is called **heterothallism**. Mycelia which produce gametangia are of opposite strains (+) or (-). The first step is the formation of special hyphae called zygophores. The tips of the two zygophores swell to form progametangia. Further, a septum is formed near the tip of each progametangium and results in the formation of a terminal gametangium and a suspensor cell. The two gametangia fuse, and this is followed by plasmogamy and karyogamy. The fusion of nuclei results in the formation of a diploid zygospore. Many nuclei belonging to opposite strains (+ or –) pair and fuse to form many diploid nuclei. The zygospore enlarges and develops an outer thick dark and warty layer called exine and inner thin layer called intine. After the resting period the nuclei of zygospore undergo meiosis. The zygospore germinates to form sporangiophores and the zygosporangium contain mixture of (+) and (–) spores. When the spores fall on a suitable substratum, they germinate to produce mycelium (Figure 1.20). The life cycle of *Rhizopus* is given in figure 1.27.

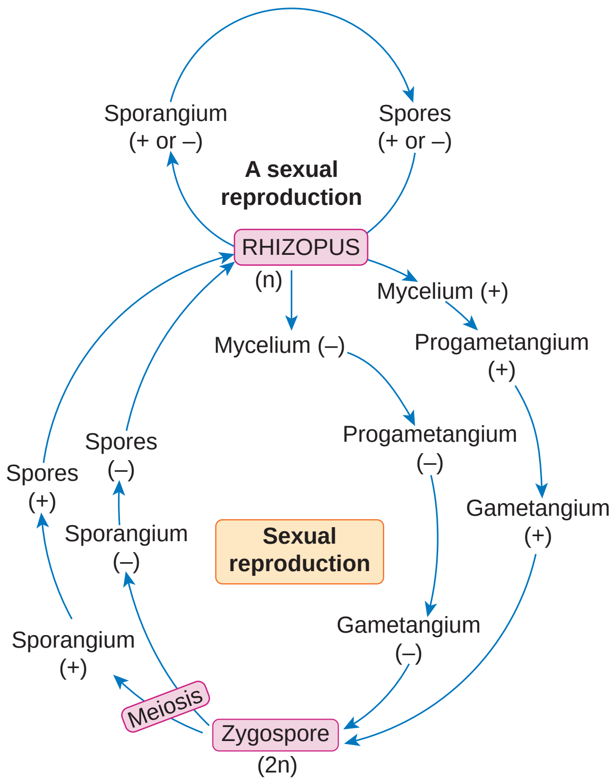


Figure 1.27: Life cycle of *Rhizopus*

1.5.8 Agaricus

Class - Basidiomycetes
Order - Agaricales
Family - Agaricaceae
Genus - *Agaricus*

It is a saprophytic fungus found on wood logs, manure piles, fresh litter, pastures etc., The fruit bodies are the visible part of the fungi. They are found in rings in some species like *Agaricus arvensis*, *Agaricus tabularis* and hence popularly called 'Fairy rings". *Agaricus campestris* is the most common 'field mushroom'.

Vegetative structure

The thallus is made up of branched structures called hyphae. A large number of hyphae constitute the mycelium.

Three types of mycelia are seen namely primary mycelium, secondary mycelium and tertiary mycelium, The primary mycelium develops from the germination of basidiospore. It is septate, uninucleate and haploid. It is also called **monokaryotic mycelium**. Fusion of two primary mycelium of opposite strains give rise to secondary mycelium or **dikaryotic mycelium**. The dikaryotic mycelium develops into hyphal cords called **Rhizomorphs**,. and perennates the soil for a long period. The tertiary mycelium is found in the fruit body called **basidiocarp**. Each cell of the hyphae posssess a cell wall made up of chitin and cell organelles like mitochondria, golgibodies, Endoplasmic reticulum etc., are also present.

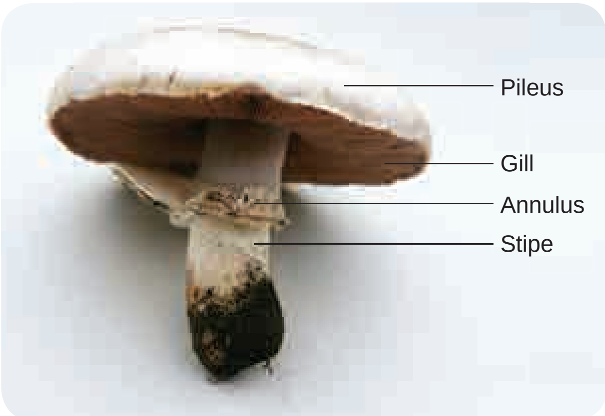


Figure 1.28: *Agaricus*-Basidiocarp

Asexual reproduction.

Agaricus produces chlamydospores during asexual reproduction. During favourable condition the chlamydospores germinate and produce mycelium.

Sexual reproduction

Agaricus reproduces by sexual method but sex organs are absent.Majority of the species are heterothallic. *Agaricus bisporus* is a homothallic species. The opposite strains of mycelium fuse(somatogamy) and results in the formation of dikaryotic or secondary mycelium. Karyogamy takes place in basidium and it is immediately followed by meiosis giving rise to four haploid basidiospores. The basidiospores are borne on sterigmata. The subterranean mycelial strands called rhizomorphs posssess dense knots of dikaryotic hyphae. These knots develop into Basidiocarps.

Basidiocarp

The mature basidiocarp is umbrella shaped and is divided into 3 parts namely stipe, pileus and gill. The stipe is thick, fleshy and cylindrical in structure. The upper part of the stipe possess a membranous structure called **annulus**. The upper convex surface is called **Pileus** which is white or cream in colour (Figure 1.28). The inner surface of pileus shows radially arranged **gills** or lamellae. The gills vary in length. On both the sides of the gills a fertile layer called **hymenium** is present. The stipe is hollow from the centre and the central part is made up of loosely arranged hyphae whereas the periphery is made up of compactly arranged hyphae forming **pseudoparenchymatous** tissue. The gill region is divided into 3 regions. The central part of gill between two hymenial layers is called **Trama** (Figure 1.29). The subhymenial layers have closely compact tissue . The **hymenium** is the fertile layer and possess club shaped basidia. The basidium is interspersed with sterile hyphae called paraphysis. Each basidium bears 4 basidiospores , of these two basidiospore belong to (+) strain and other two of them will be (–) strain. The basidiospores are borne on stalk like structures called **Sterigmata**. The basidiospore on germination produces

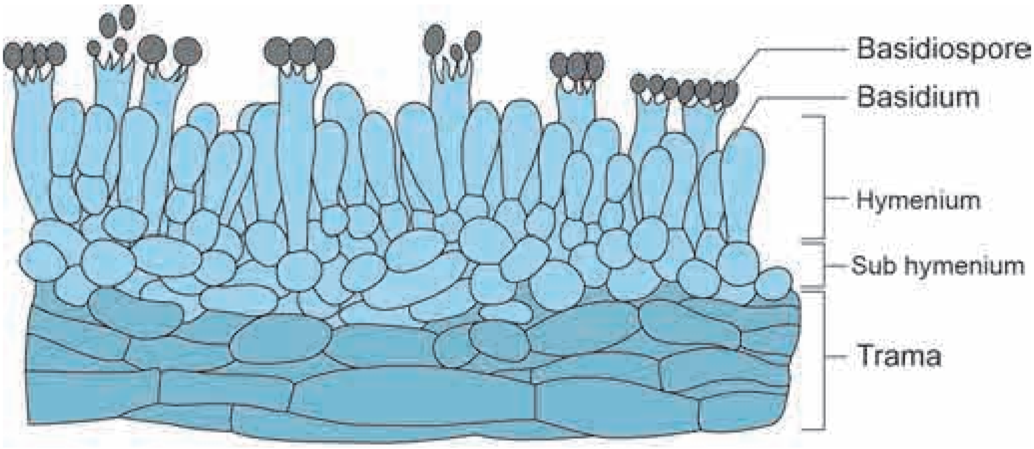


Figure 1.29: V.S. of *Agaricus* gill

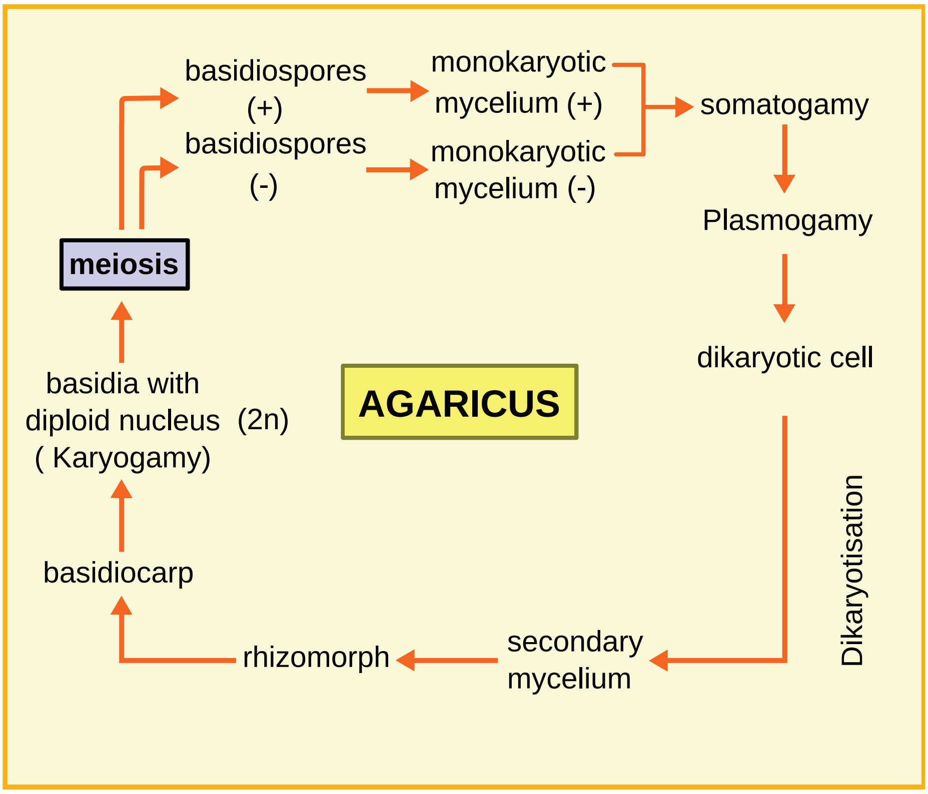


Figure 1.30: Life Cycle of *Agaricus*

the haploid primary mycelium.

Thus the life cycle of *Agaricus* shows a very short diploid phase, haploid phase and a prolonged dikaryotic phase (Figure 1.30).

1.5.9 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 1.31) Mycorrhizae are classified into three types

Importance of Mycorrhizae

- Helps to derive nutrition in *Monotropa*, a saprophytic angiosperm,
- Improves the availability of minerals

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.

and water to the plants.

- Provides drought resistance to the plants
- Protects roots of higher plants from the attack of plant pathogens

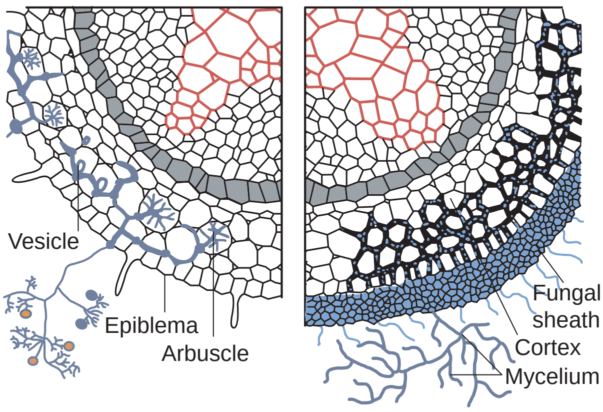


Figure 1.31: T.S. of root showing mycorrhizae

1.5.10 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 1.32).
- 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 1.32: 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.

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

Fungi are Eukaryotic, heterotrophic, unicellular or multicellular organisms. The cell wall is made up of chitin. They reproduce asexually by producing sporangiospores, conidia, Thallospores, chlamydospores etc., The sexual reproduction is isogamous, ansiogamous and oogamous. In addition, gametic copulation, gametic fusion, spermatisation are also found. They are beneficial to mankind. Some are known to cause disease in plants and human beings.

Rhizopus is commonly called' Bread mold fungi'. It belongs to the class Zygomycetes. Asexual reproduction occurs by the production of sporangiospores. During sexual reproduction gametangial copulation occurs and zygospore is formed. *Agaricus* belongs to the class Basidiomycetes.It is a saprophytic fungus. Three types of mycelium , primary, secondary and tertiary mycelium are produced. Sexual reproduction is present .Basidiocarps are produced after the sexual reproduction. It bears basidia on which four basidiospores are produced.

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

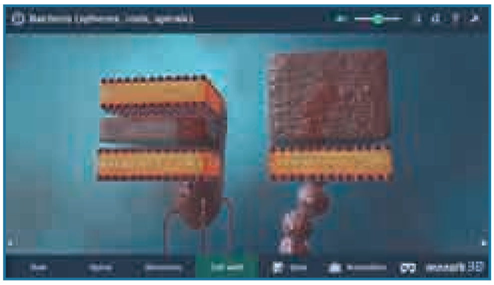
6. Differentiate Homoiomerous and Heteromerous lichens.
7. Write the distinguishing features of Monera.
8. Why do farmers plant leguminous crops in crop rotations/mixed cropping?
9. Briefly discuss on five Kingdom classification. Add a note on merits and demerits.
10. Give a general account on lichens.
11. Explain the asexual reproduction in *Rhizopus*.
12. Mention the steps involved in the sexual reproduction of *Rhizopus*.
13. Write outline the life cycle of *Agaricus*.
14. What is Sterigma?
15. Name the types of mycelium found in *Agaricus*.
16. Differentiate oidium and Chlamydospore.
17. Name the fungal group which possess dolipore septum.
18. Mention the diseases caused by fungi in plants.
19. Give two examples for mycorrhizae forming fungi.
20. Differentiate Gram positive and Gram negative bacteria.

ICT Corner

Bacteria

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

→

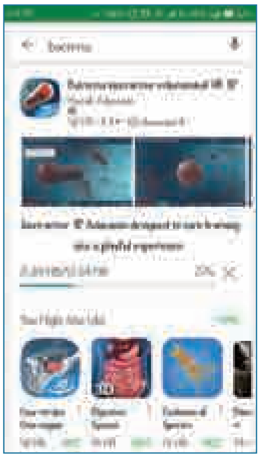


Steps

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

Activity

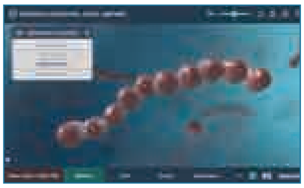
- Select structure tap and note the internal structure of bacteria
- Click cell wall and note the difference between different shapes



Step 1

Step 2

Step 3



Step 4

Step 5

URL:

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

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* Pictures are indicative only

Chapter 2

Plant Kingdom

Learning Objectives

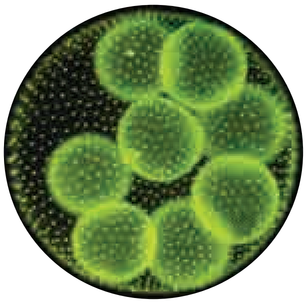
The learner will be able to,

- *Outline the classification of plants*
- *Illustrate the life cycles in plants*
- *Recognize the general characteristic features and reproduction of Algae*
- *Describe the structure, reproduction of Oedogonium and Chara*
- *Recognize the general characteristic features of Bryophytes*
- *Describe the structure, reproduction of Marchantia and Funaria*
- *Recognize the general characteristic features of Pteridophytes*
- *Describe the structure, reproduction of Selaginella and Adiantum*
- *Describe the general characteristic features of Gymnosperms*
- *Explain the structure, reproduction of Cycas and Pinus*
- *Recognize the salient features of Angiosperms*

Chapter Outline

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).

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

* 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 the world 2nd edition. Australian government, Department of environment, water Heritage and Arts.

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

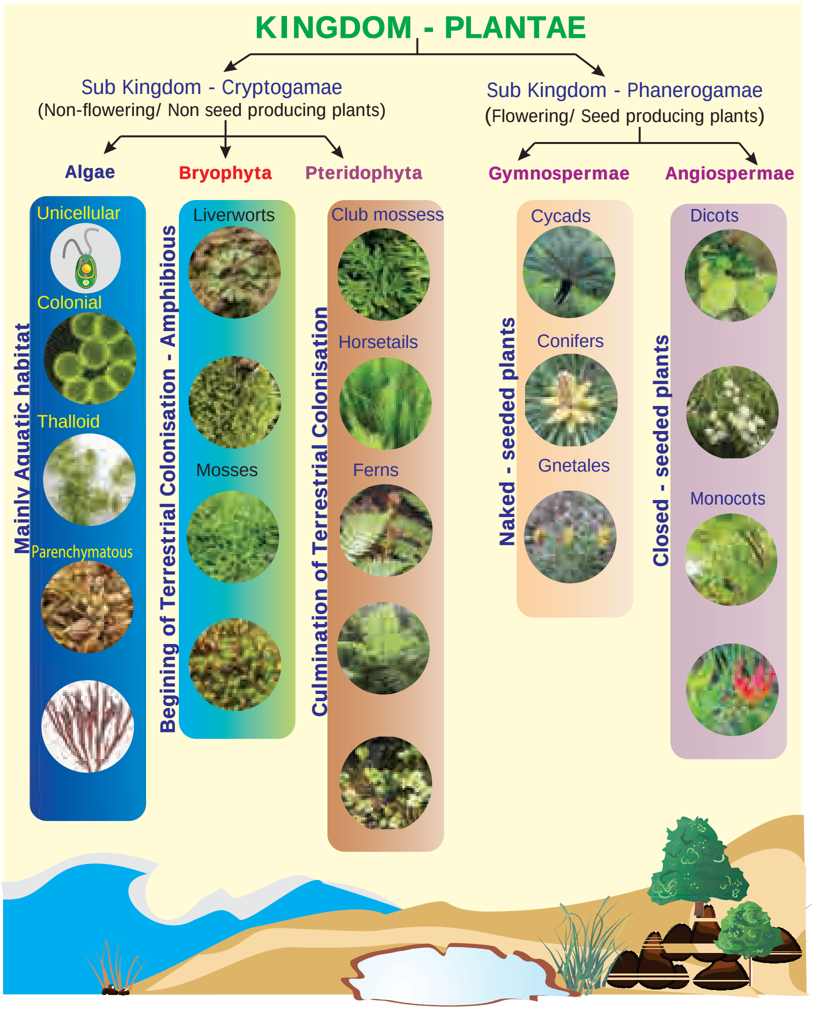


Figure 2.1: Classification of Plant Kingdom

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.

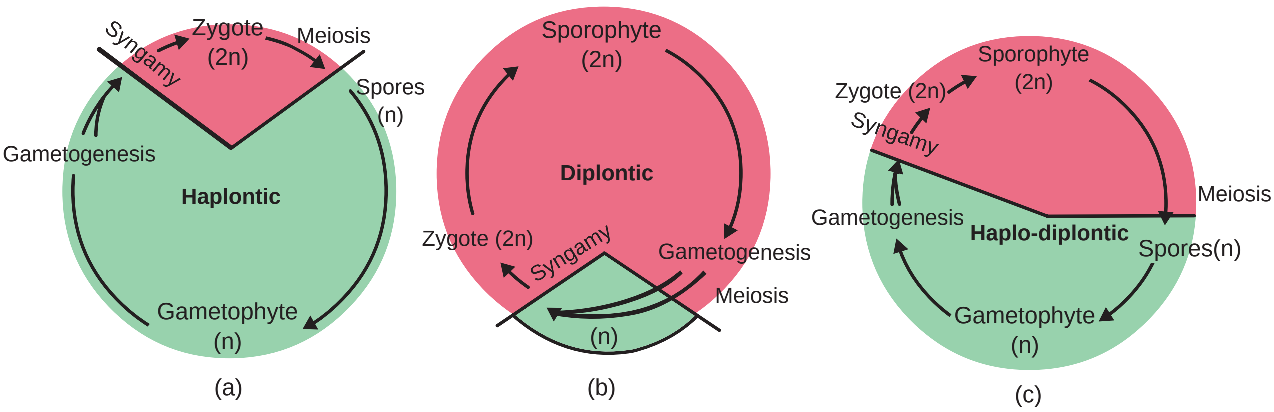


Figure 2.2: Life cycle patterns in plants a) Haplontic, b) Diplontic, c) Haplo-diplontic

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 Iyengar, 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

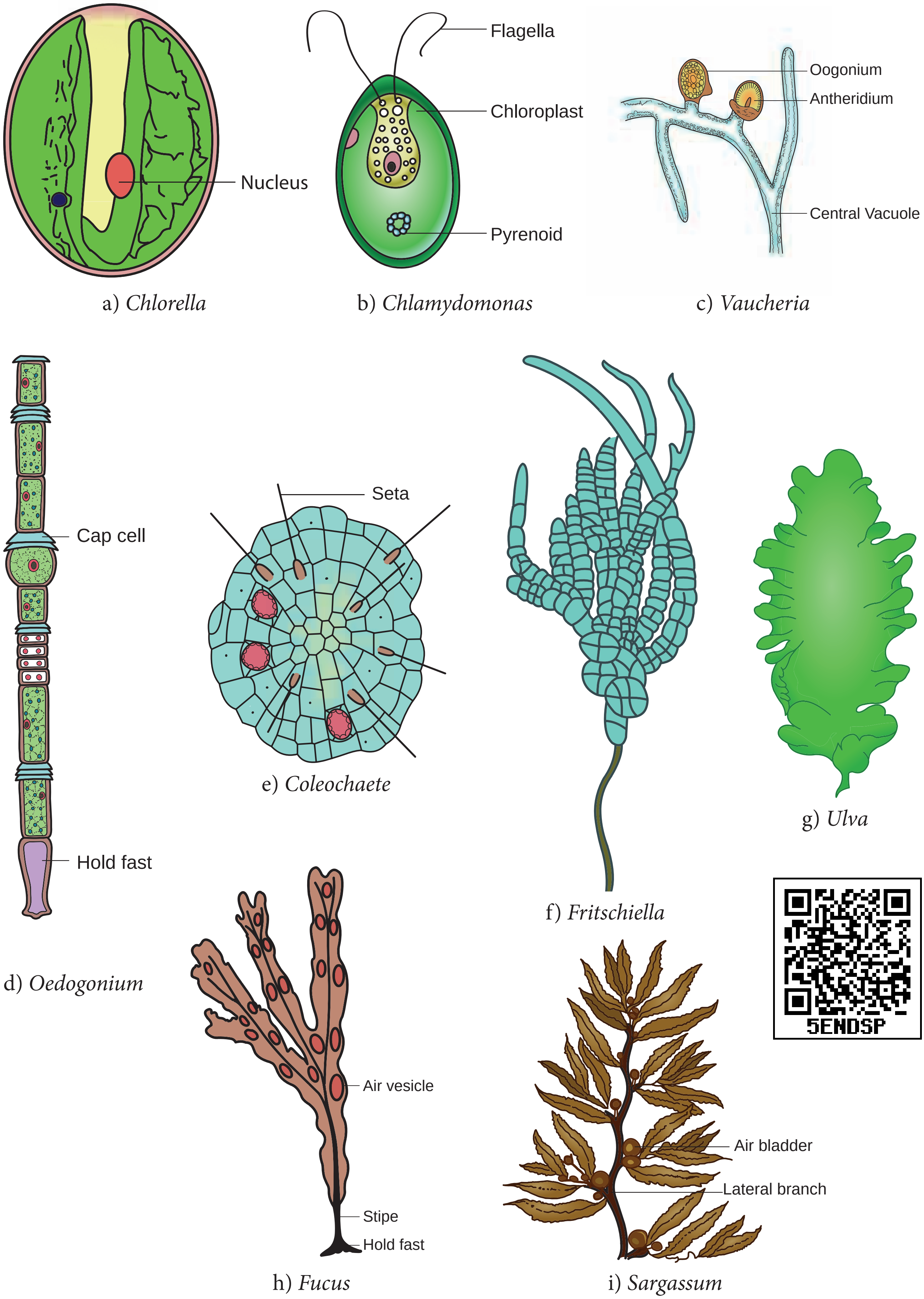
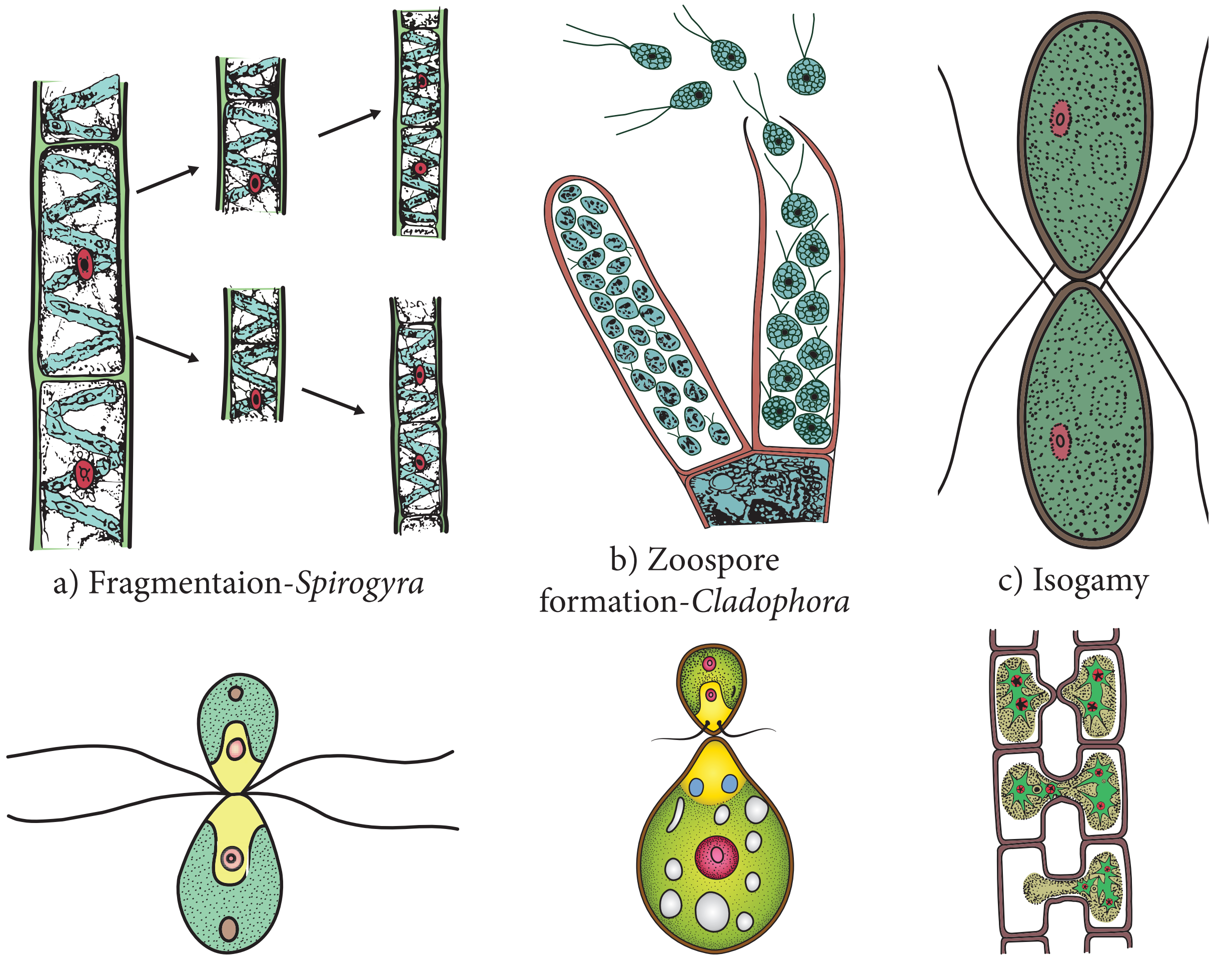


Figure 2.3: Thallus organization in Algae

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 types 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.

DO YOU KNOW?

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

Table 2.2 Classification of Algae

Class	Pigments	Flagella	Reserve food
Chlorophyceae	Chlorophyll a and b Carotenoids, Xathophyll	1,2,4 or more equal anterior whiplash flagella	Starch
Xanthophyceae	Chlorophyll a and b Carotenoids Xathophyll	2, unequal anterior 1 tinsel and 1 whiplash	Fats and leucosin
Chrysophyceae	Chlorophyll a and b Carotenoids,	1 or 2 unequal or equal anterior both whiplash or 1 whiplash and 1 tinsel	Oils and leucosin
Bacillariophyceae	Chlorophyll a and c Carotenoids,	1 anterior (only in male gametes) tinsel	Leucosin and Fats
Cryptophyceae	Chlorophyll a and c carotenoids and xanthophyll	unequal anterior both tinsel flagella	Starch
Dinophyceae	Chlorophyll a and c carotenoids and xanthophyll	Two unequal (whiplash) lateral flagella in different plane	Starch and oil
Chloromonadineae	Chlorophyll a and b Carotenoids, Xathophyll	2 equal flagella	oil
Euglenophyceae	Chlorophyll a and b	One or two anterior tinsel flagella	Fats and paramylon
Phaeophyceae	Chlorophyll a and c, Xanthophyll	Two unequal whiplash and tinsel lateral flagella	Laminarin starch and fats
Rhodophyceae	Chlorophyll a, r-Phycoerthythrin	absent	Floridean starch
Cyanophyceae	Chlorophyll a, carotenoids, c-Phycocyanin,Allophycocyanin	absent	Cyanophycean starch

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, Chloromonadineae, Euglenophyceae, Phaeophyceae, Rhodophyceae, Cyanophyceae (Table 2.2).

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.

2.3.3 Economic Importance

The Economic importance of Algae is given in Table 2.3

Table 2.3: 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

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.

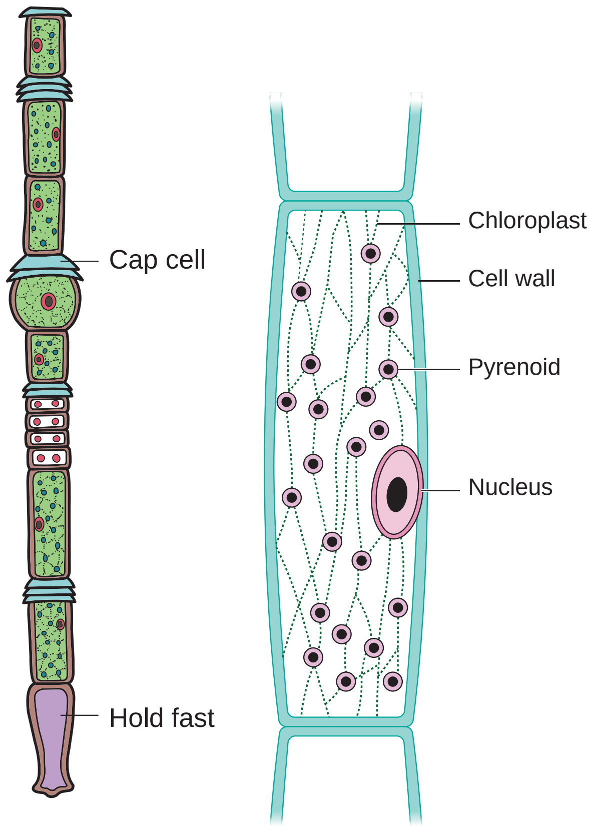
2.3.4 Oedogonium

Class – Chlorophyceae
Order - Oedogoniales
Family -Oedogoniaceae
Genus – *Oedogonium*

Oedogonium is a freshwater , filamentous alga and occurs in ponds, lakes and stagnant water. The filaments are attached to rocks. Some are epiphytic on aquatic plants. *Oedogonium terrestre* is a terrestrial form and grow in moist soils. The young filaments are attached but older ones are free floating.

Thallus structure

The thallus is filamentous ,multicellular and unbranched. All the cells of the filament are cylindrical except the basal and apical cell. The basal cell is colourless and forms hold fast. The proximal end of the hold fast extends to produce finger like projections which help the filament to attach on the substratum. The apical cell is rounded or elongated in shape. Each vegetative cell is cylindrical and possesses a thick cell wall. The inner layer is cellulosic and the outer layer is made up of pectin. A thin layer of chitin is present above the pectin layer. Next to the cell wall a plasma membrane is present. A large vacuole is present. The protoplasm contains reticulate chloroplast and it extends from one end of the cell to the other. A single nucleus and many pyrenoids are present. The distal end of some cells possess ring like markings called apical caps. Such cells are called cap cells. The presence of cap cell is characteristic feature of *Oedogonium* (Figure 2.5).

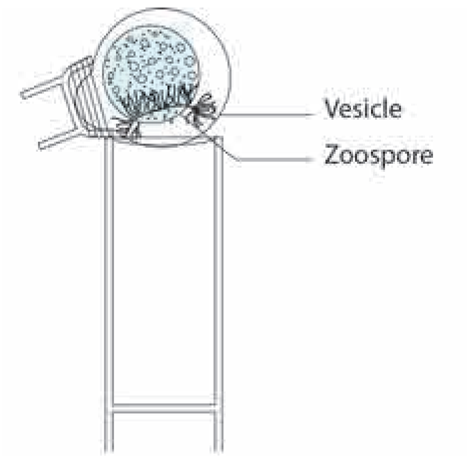


a) A single filament   b) A cell enlarged

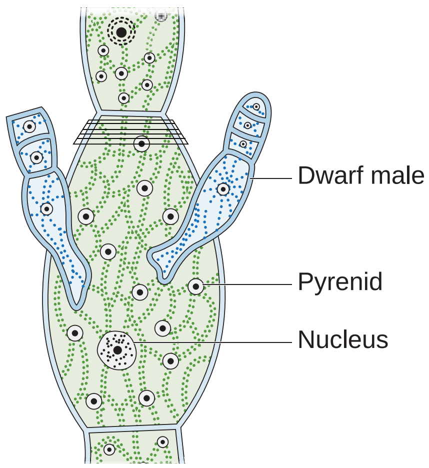
Figure 2.5: *Oedogonium*

Reproduction

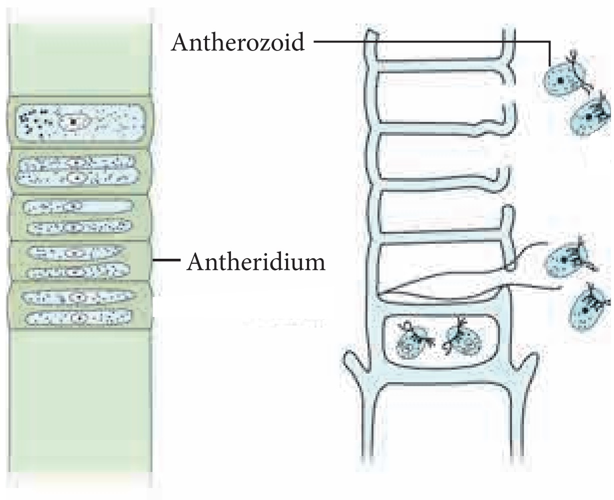
Oedogonium reproduces by vegetative, asexual and sexual methods. Vegetative reproduction takes place by fragmentation and akinete formation. During asexual reproduction zoospores are formed. During favourable conditions, some of the vegetative cells function as zoosporangia. Usually a single zoospore is produced per zoosporangium. A ring of short flagella is found at the base of colourless, beak like anterior end of the zoospore. This kind of flagellation is called stephanokont. The zoospore is released from the zoosporangium and swims in water (Figure 2.6). If it reaches a suitable substratum, it divides into two cells. The lower cell forms holdfast. The green upper cell divides and produces the filament.



a) Zoospore formation



b) Dwarf male



c) Filament showing antheridium

Figure 2.6: Reproduction in *Oedogonium*

Sexual reproduction is Oogamous. The male gametangium is antheridium and female gametangium is called Oogonium. Based on the distribution of sex organs there are two types of species namely Macrandrous and Nannandrous.

Macrandrous monoecious – Antheridia and Oogonia occur on same filament – *Oedogonium fragile*.

Macrandrous dioecious – Antheridia and Oogonia occur on separate filaments – *Oedogonium crassum*

In nannadrous species antheridia are produced on reduced male filaments called dwarf male plants(*O.cancatenatum*).

In nannandrous species antheridia develop on specialised 2–4 celled filaments called dwarf males. The dwarf male is developed from androspores released from the androsporangium.. If the androsporangia and oogonia develop on same filament, it is called **gynandrosporous** (*O. concatenatum*). If they are borne on different filaments it is called **idioandrosporous** (*O. conferatum*). The antheridium produces multiflagellate antherozoids. They are released by transverse splitting of the wall of antheridium. Antherozoids are attracted chemotactically towards the mature oogonium. A single antherozoid enters the oogonium through the opening present on the wall of the oogonium. The male nucleus fuses with the egg to form a diploid zygote. After fertilization the zygote separates from the oogonial wall and a thick wall is secreted around it. The diploid zygote undergoes meiosis to produce 4 haploid multiflagellate zoospores. The wall of the zygote ruptures to release the zoospores.The germination of the zoospore produces haploid filaments of *Oedogonium* (Figure 2.6).

In the life cycle of *Oedogonium* the diploid phase is short lived and is represented by zygote. The haploid phase is predominant and life cycle is of Haplontic type (Figure 2.7).

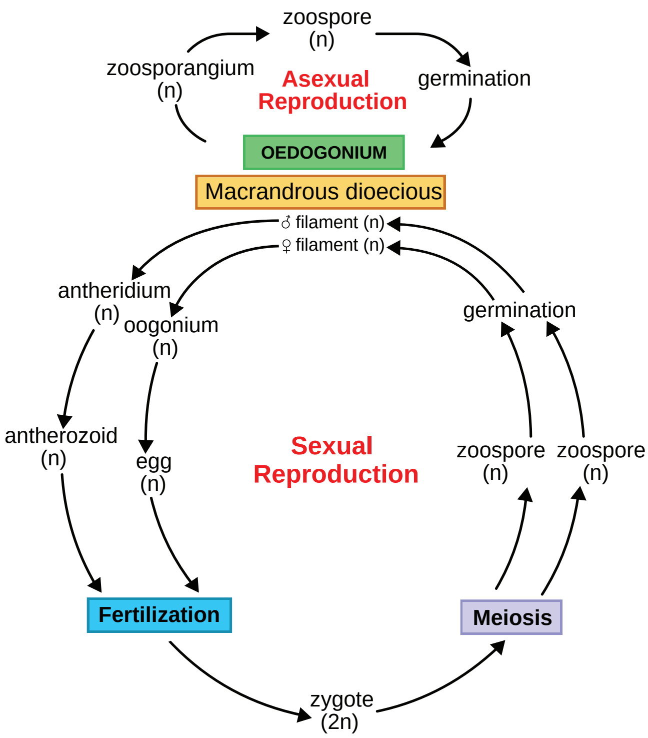


Figure 2.7: Life cycle of *Oedogonium*

2.3.5 Chara

Class – Chlorophyceae
Order – Charales
Family – Characeae
Genus – *Chara*

Chara is commonly called as ‘ stone wort’ It is a submerged aquatic freshwater alga growing attached to the mud of the lakes and slow running streams. *Chara baltica* grows in saline water. The thallus is often encrusted with calcium and magnesium carbonate.

Thallus structure

The plant body is multicellular, macroscopic and is differentiated into main axis and rhizoids. The rhizoids are thread-like, multicellular structures arise from the lower part of the thallus or peripheral cells of the lower node.They are characterised by the presence of oblique septa. The rhizoids fix the main axis on the substratum and helps in the absorption of salts and solutes (Figure 2.8).

The main axis is branched, long and is differentiated into nodes and internodes. The internode is made up of an elongated cell in the centre called axial cell or internodal cell. The axial cell is surrounded by vertically elongated small cells which originate from the node. They are called cortical cells. In *C. wallichii* and *C. corallina* the cortical cells are absent. Three types of appendages arise from the node. They are 1. Branches of limited growth 2. Branches of unlimited growth 3. Stipuloides. The growth of the main axis and its branching takes place by the apical cell.

The nodal cells are uninucleate with few ellipsoidal chloroplasts. The internodal cells are elongated and possesses a large central vacuole, many nuclei and numerous discoidal chloroplasts.

The cytoplasm is divided into outer ectoplasm and inner endoplasm. The endoplasm shows cytoplasmic streaming.

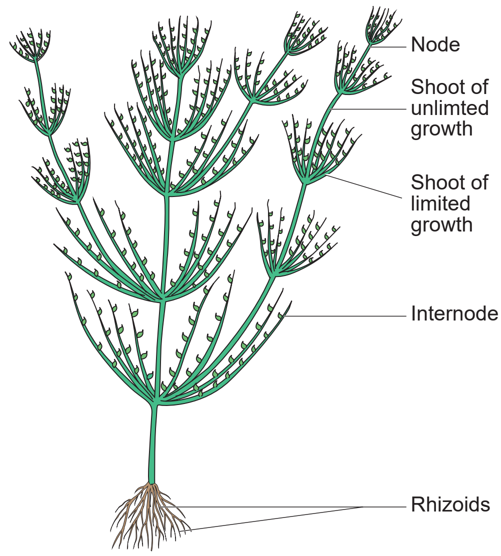


Figure 2.8: *Chara* Habit

Reproduction

Chara reproduces by vegetative and sexual methods. Vegetative reproduction takes place by Amylum stars, Root bulbils, Amorphous bulbils and secondary protonema.

Sexual reproduction - Sexual reproduction is Oogamous. Sex organs are macroscopic and are produced on the branches of limited growth. The male sex organ is called Antheridium or Globule and the female sex organ is called Oogonium or Nucule (Figure 2.9). The Nucule is located above the Globule. The antheridium is spherical, macroscopic and its wall is made up of eight cells called shield cells. The antheridium has spermatogenous filaments. These filaments produce antherozoids. The nucule is covered by five spirally twisted tube cells and five coronal cells are present at the top of the nucule (Figure 2.9). The centre of the nucule

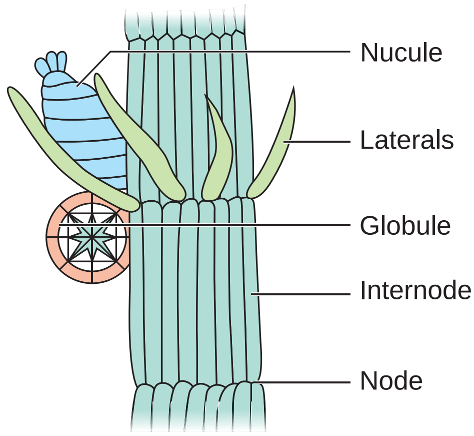


Figure 2.9: *Chara* sex organs

possesses a single egg. At maturity the tube cells separate and a narrow slit is formed. The antherozoids penetrate the oogonium and one of them fuses with the egg to form a diploid oospore. The oospore secretes a thick wall around and germinates after the resting period. The nucleus of the oospore divides to form 4 haploid daughter nuclei of which, three degenerate. The oospore or zygote germinates to produce haploid protonema. The plant body of *Chara* is

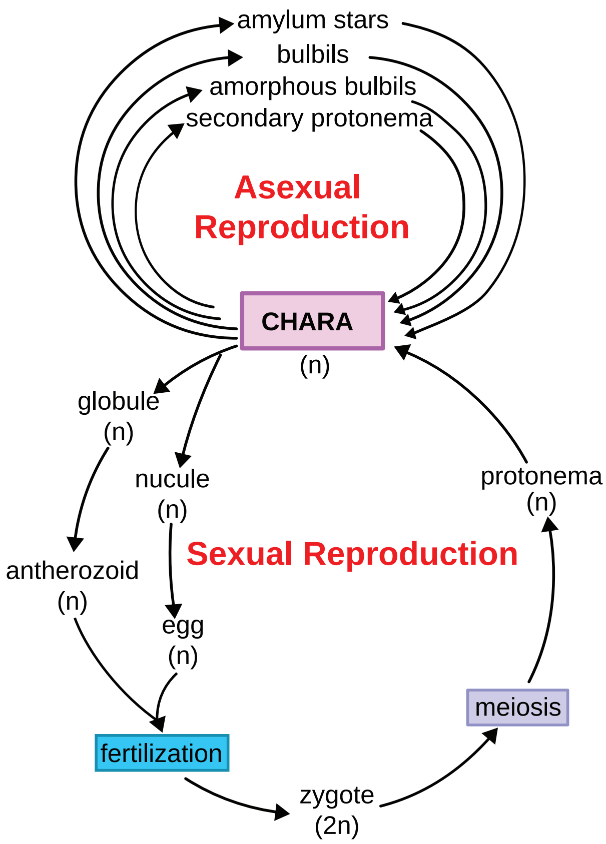


Figure 2.10: Life cycle of *Chara*

haploid and The oospore is the only diploid phase in the life cycle. Therefore, the life cycle is of haplontic type. Alternation of generations is present (Figure 2.10).

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.

Shiv Ram Kashyap
(1882-1934)

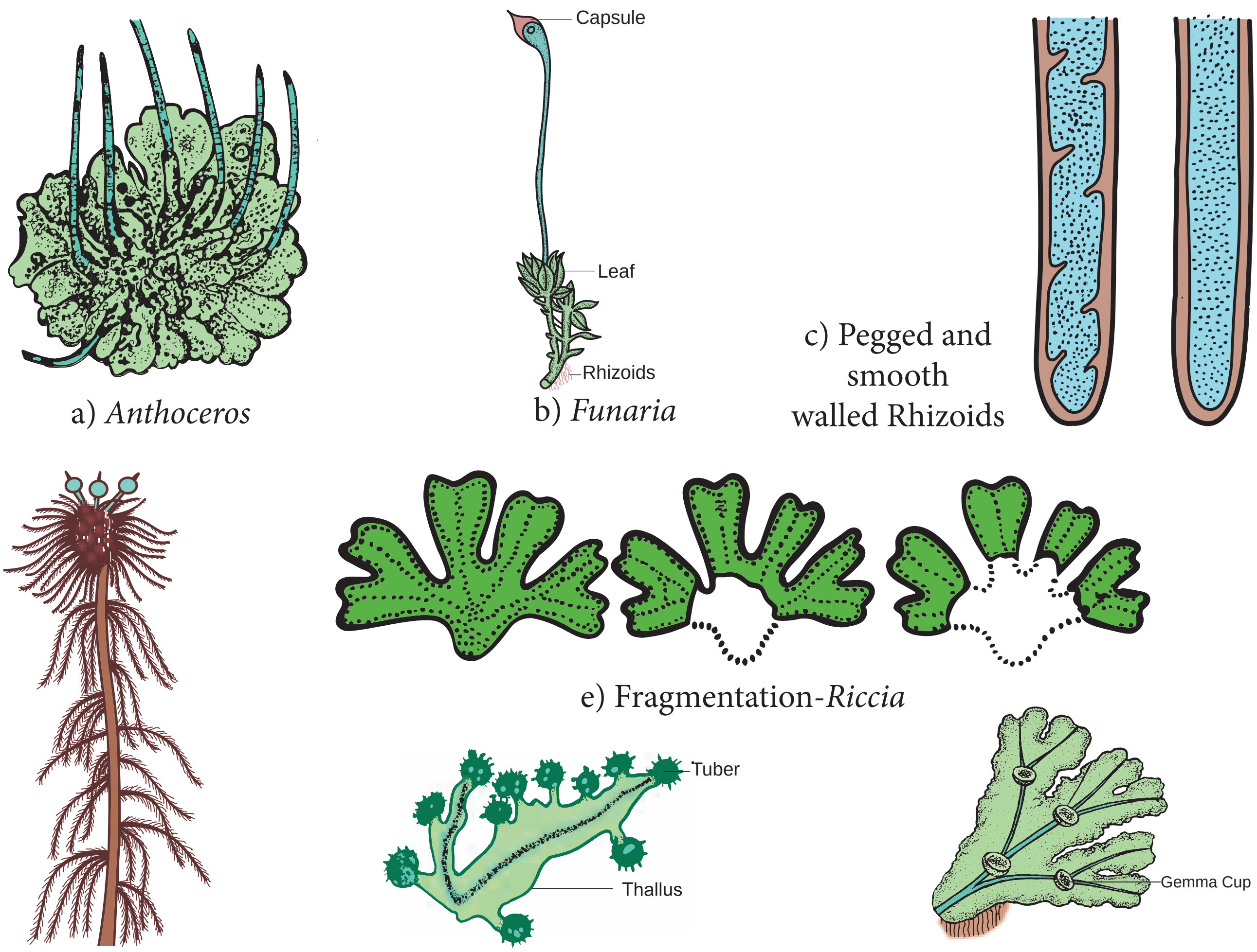
Father of Indian Bryology. He published a book-'Liverworts of Western Himalayas and Punjab Plains' He identified new genera like *Atchinsoniella, Sauchia, Sewardiella* and *Stephansoniella.*

Bryophytes are simplest land inhabiting cryptogams and are restricted to moist, 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 2.11
- 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:



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

Figure 2.11: Structure and reproduction in Bryophytes

Marchantia). The spores germinate to produce gametophyte.

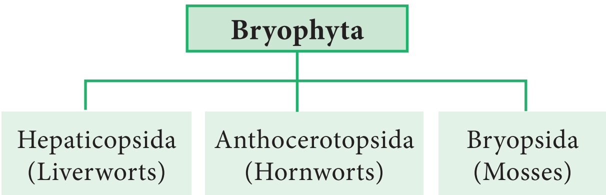
- The zygote, embryo and the sporogonium constitute sporophytic phase. The green long living haploid phase is called gametophytic phase The haploid gametophytic phase alternates with diploid sporophyte and shows heterologous alternation of generation.

2.4.2 Classification of Bryophytes

Proskauer in the year 1957 classified Bryophytes into 3 Classes namely

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

The outline of the classification is given below



Class: Hepaticopsida

They are lower forms of Bryophytes. They are more simple in structure than mosses and more confined to damp and shady places. They have an undifferentiated thallus. Protonernal stage is absent. Sporophyte is very simple and short lived. In some the foot and seta are absent. Example *Riccia*.

Class: Anthocerotopsida

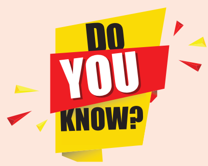
Gametophyte is undifferentiated thallus. Rhizoids are unicellular and unbranched. Protonemal stage is absent. Sporophyte is differentiated into foot and capsule and seta is absent Example: *Anthoceros*.

Class: Bryopsida

These are higher forms in which the gametophyte is differentiated into 'stem' like and'leaf' like parts and the former showing radial symmetry. Rhizoids are multi-cellular and branched. Protonemal stage is present. Sporophyte is differentiated into foot, seta and capsule. They have a more differentiated structure than liverworts. They often form dense cushions. Example: *Funaria*.

2.4.3 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* 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.



Buxbaumia aphylla and *Cryptothallus mirabilis* are saprophytic bryophytes

2.4.4 Marchantia

Class - Hepaticopsida
Order – Marchantiales
Family - Marchantiaceae
Genus - *Marchantia*

Marchantia grows in cool moist shady places. *Marchantia polymorpha* is the common species.

Gametophyte

The plant body of *Marchantia* is a gametophyte. It is prostrate,dorsiventral and dichotomously branched. The thallus on the dorsal surface possess conspicuous median midrib which is marked by a shallow groove on dorsal surface. The dorsal surface appears to have rhomboidal or polygonal diamond shaped areas which indicate the outline of the underlying air chambers of the thallus (Figure 2.12).

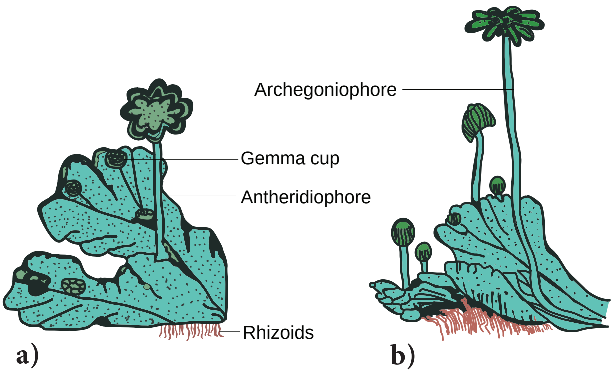


Figure 2.12: *Marchantia*

a) Thallus with antheridiophore

b) Thallus with archegoniophore

The dorsal surface also shows crescent shaped structures called gemma cups which contain vegetative reproductive structures called gemmae. The apical notch bears an apical cell which helps in the growth of the thallus.The ventral surface the thallus bears multicellular scales and rhizoids which help in fixation and absorption of water and minerals. The rhizoids are of two types namely smooth walled or pegged (tuberculate) type. On maturation the thallus bears erect antheriophores and archegoniophores.

Internal structure of Thallus

In transverse section the *Marchantia* thallus shows three parts namely: Epidermis, Photosynthetic region and storage region (Figure 2.13).

The epidermis has the upper and lower layers. The upper epidermis is single layered with thin walled parenchymatous cells. The cells possess chloroplasts. The upper epidermis is interrupted by many barrel shaped air pores which communicate with the air chambers. The pore is surrounded by 4 to 8 superimposed tiers of cells. Below the upper epidermis a number of air chambers are present in a single horizontal layer.The air chambers are separated from one another by partitions which extend from the epidermis to the floor of the air chambers. The floor of the chambers bears simple or branched green filaments. The cells of the filaments are involved in photosynthesis. The photosynthetic region is followed by storage region. It is made up of several parenchymatous cells arranged without intercellular spaces. The cells of this region contain starch grains and protein granules. The lower epidermis possesses rhizoids and multicellular scales.

Reproduction

Marchantia reproduces by vegetative and sexual methods.

1.Vegetative Reproduction takes place by progressive death and decay of thallus, formation of adventitious branches and by germination of gemmae. Death and decay of the thallus starts from posterior end .When it reach the point of dichotomy , two apical parts of the thallus get separated. Each one develops into an independent thallus. Adventitious branches are produced on the ventral surface of the gametophyte. The branches get separated from the parent thallus and grow into independent gametophytes. Gemmae are specialized multicellular asexual reproductive bodies. They are formed in small cupules known as gemma cups, present on the dorsal surface of the thallus. Usually

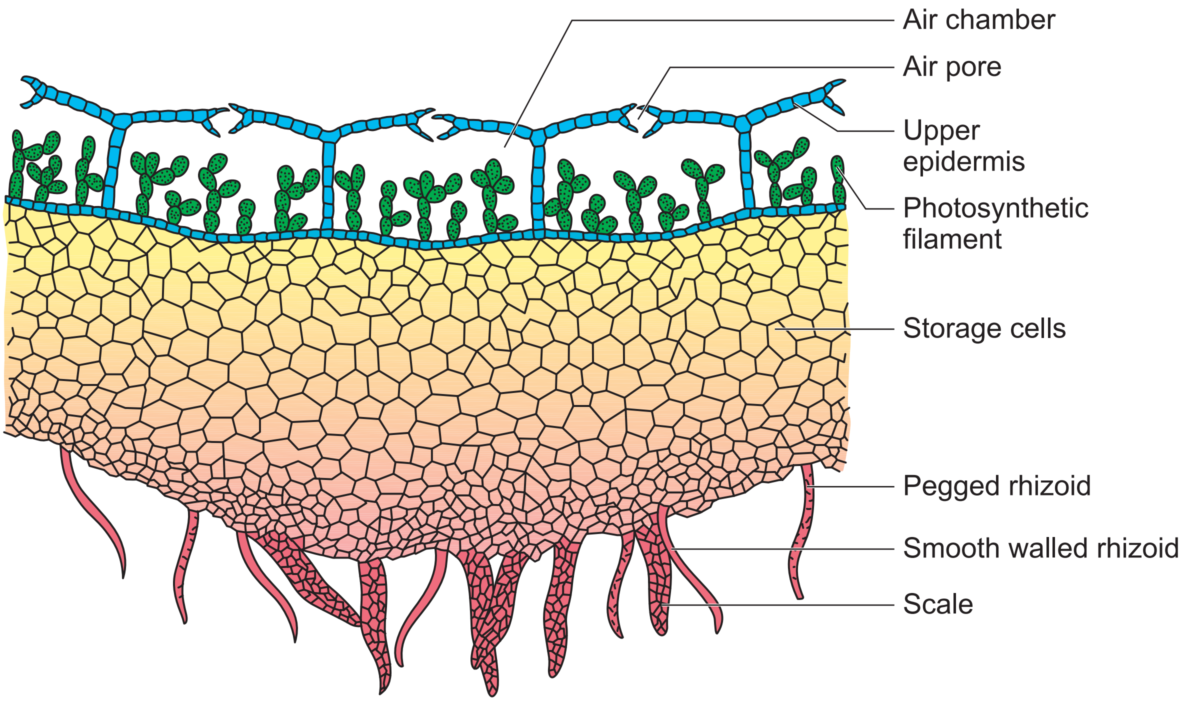
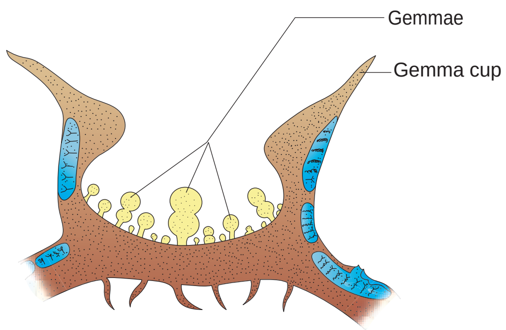
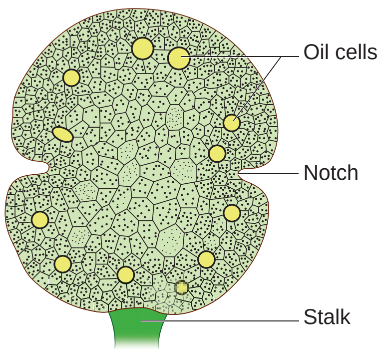


Figure 2.13: T.S. of Thallus

the gemmae present on the male thallus form male plants and those on the female thallus give rise to female plants (Figure 2.14).



a) V.S. of Gemma cup



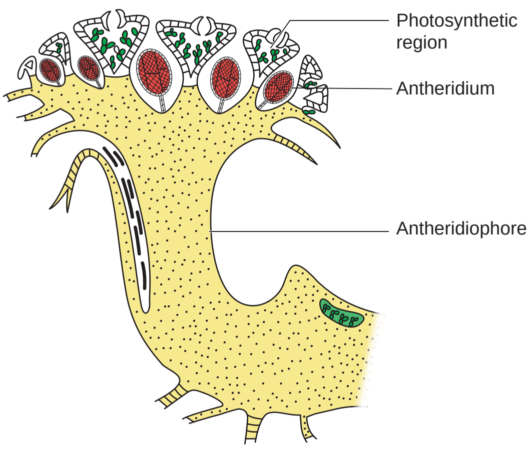
b) A gemma enlarged

Figure 2.14: Vegetative reproduction in *Marchantia*

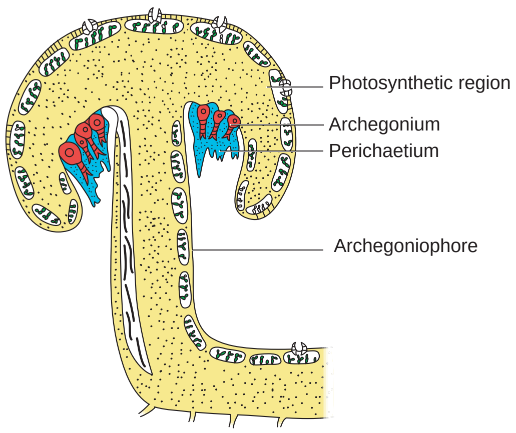
1. Sexual reproduction:

In *Marchantia*, sex organs are borne on special stalked receptacles called the gametophores. Those bearing antheridia are called antheridiophores and archegonia bearing structures are called archegoniophores (Figure 2.15). *Marchantia* is heterothallic or dioecious. i.e., male and female receptacles are present on different thalli. The sex organs in bryophytes are multicellular. The male sex organ is called antheridium. It produce biflagellate antherozoids. The female sex organ is flask shaped called archegonium and produces a single egg. Water is essential for fertilization. The antherozoids are released into water and are attracted towards archegonium through chemotaxis. Although many antherozoids enter the archegonium, only one fuses with the egg to form zygote. The zygote represent the first cell of the sporophytic generation. Zygote develops in to a multicellular structure called sporophyte. (Figure 2.16).

The sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nutrition from it. Sporophyte is differentiated into foot, seta and capsule. The foot is bulbous and is embedded in the gametophyte. It derives nutrition from the gametophyte and transfers to the sporophyte. Seta is short and connects foot and capsule. The capsule consists of single layered jacket layer and encloses numerous haploid spores and elaters. The capsule is covered by protective covering called calyptra. On maturation the capsule dehisces and spores are released. Elaters helps in the dispersal of spores. The spores under favourable conditions germinate and develop into new gametophyte. The haploid gametophytic phase alternates with diploid sporophytic phase, thus the life cycle of *Marchantia* shows alternation of generation (Figure 2.17).



a) L.S. of Antheridiophore



b) L.S. of Archegoniophore

Figure 2.15: *Marchantia* - Sex organs

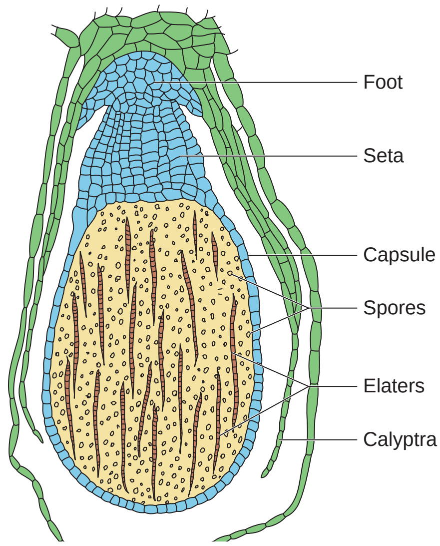


Figure 2.16: *Marchantia* - V.S. of Sporophyte

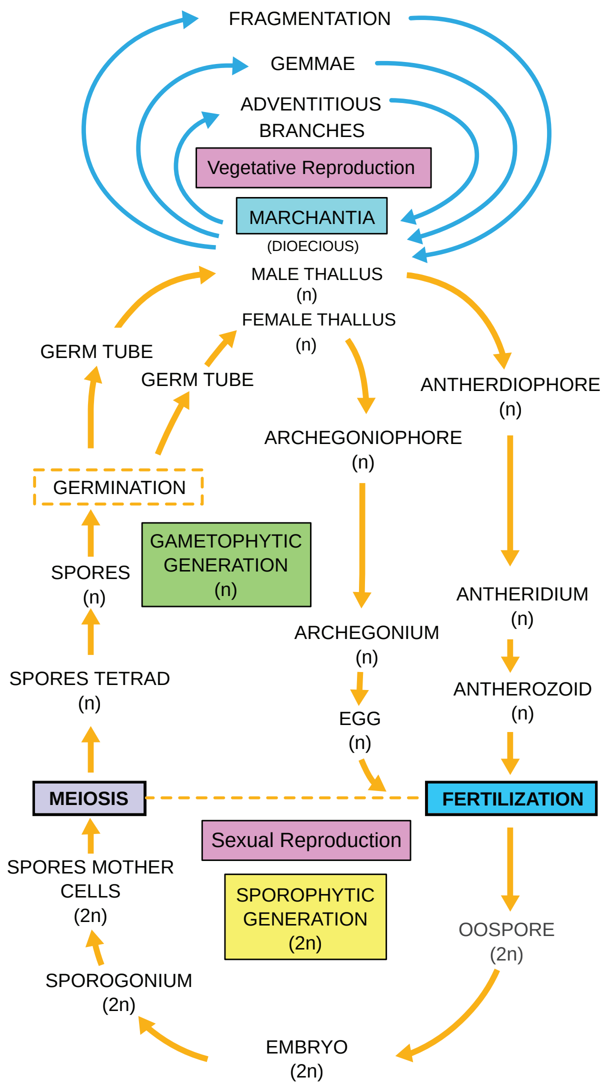


Figure 2.17: Life cycle of *Marchantia*

2.4.5 Funaria

Class – Bryopsida
Order- Funariales
Family – Funariaceae
Genus - *Funaria*

Funaria is commonly called 'cord moss'. It is distributed throughout the world. *Funaria hygrometrica* is the common species. It grows in close tufts on rocks, trunks of trees, damp walls and damp soils. They help in the process of soil formation (Pedogenesis).

External features

The plant body is a gametophyte . It is small, 1 to 3 cm high and consists of slender erect radial stem covered with small, simple leaf like structures arranged in a spiral manner. The gametophyte is attached to the substratum by means of multicellular rhizoids. They are characterized by the presence of oblique septa. The leaves are simple, sessile ovate and have broad membranous base and pointed apex.

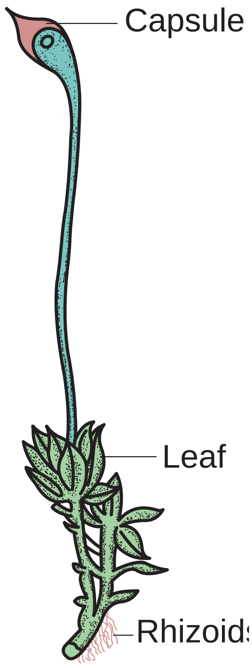


Figure 2.18: *Funaria* Habit

Internal structure

T.S. of axis

The T.S. of axis shows the presence of epidermis, cortex and central cylinder. The epidermis is the outermost layer and contain chloroplast bearing cells. The cortex is made up of parenchymatous tissue. The cells of the young axis bear chloroplasts. In mature stems the outermost cells become reddish brown colour and become thick walled. Small leaf traces are also noticed. The central cylinder is made up of long, narrow, thin walled, colourless cells which lack protoplasts. They help in the conduction of water and minerals.

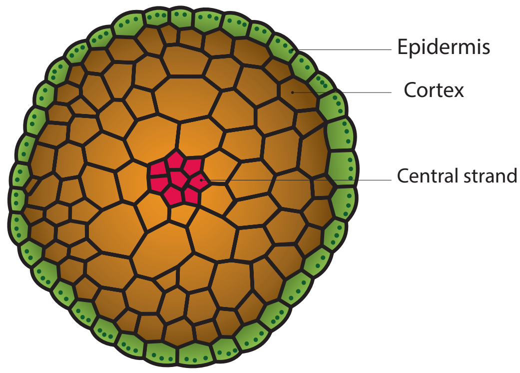


Figure 2.19: T.S. of axis

T.S. of leaf

A well defined midrib is present. It consists of several layers of cells but the lateral 'wing' or lamina is made up of single layer of thin walled cells which are rich in chloroplasts. Midrib contains small strands of slightly thickened narrow cells which help in conduction.

Reproduction

Funaria reproduces by vegetative and sexual methods.

Vegetative reproduction

Vegetative reproduction takes place by the following methods (Figure 2.20):

1. Fragmentation of primary protonema,
2. Formation of secondary protonema from any part of the gametophyte
3. Formation of gemmae on terminal cells of the protonema.

4. Development of Bulbils on the rhizoids.

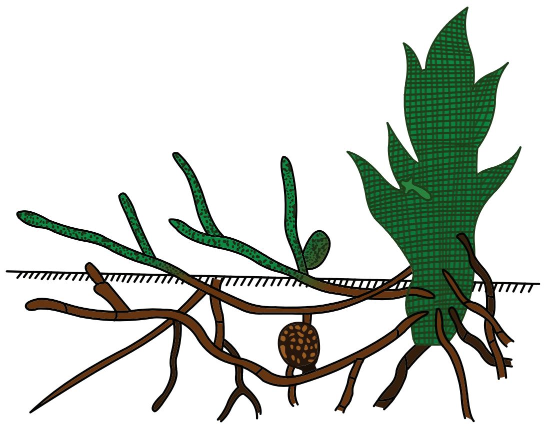
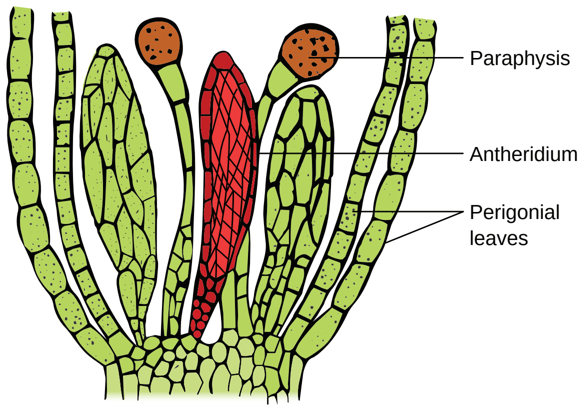


Figure 2.20: Vegetative reproduction (Protonema)

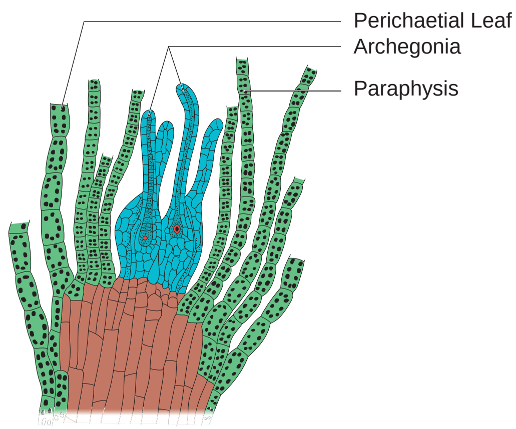
Sexual reproduction

Funaria is monoecious the male and female reproductive sex organs are borne on different branches of the same gametophyte. Male sex organ is antheridium and it is formed in groups on the antheridial branch.They are enclosed by special leaves called **perigonial leaves**. A large number of long multicellular hairs interspersed with antherdia called **paraphysis** are also present. They contain chloroplast and are involved in photosynthesis. They protect antheridial head from by minimizing transpiration, hold water between them through capillary action and secrete mucilage which helps in the liberation of antherozoids. Each antheridium is protected by single layer of jacket. It encloses a large mass of androcytes. The androcytes transform in to biflagellate antherozoids (Figure 2.21).

The female sex organ are the archegonia and are borne in clusters on the archegonial branch. Archegonial branches arise laterally at the base of the male branch. They are surrounded by **perichaetial leaves**. Paraphyses are also present. Each archegonium is flask shaped and is distinguished into a large venter and long neck region. The venter contains venter canal cell and egg. The neck contain neck canal cells (Figure 2.21). Water is essential for fertilization. Rain drops help in the transfer of antherozoids from antheridial head to archegonial head. The antherozoids are attracted to the archegonium through **chemotaxis**. A large number of antherozoids enter the neck of the archegonium but only one fuses with the egg to form a diploid zygote. The diploid zygote represents the first cell of sporophytic generation and divides to form a sporophyte.



a) Antheridial head



b) Archegonial head

Figure 2.21: *Funaria* - Sexual reproduction

Structure of Sporophyte or capsule

The structure of mature sporophyte of *Funaria* is complex. The sporophyte is differentiated into foot, seta and capsule (Figure 2.22). The foot is small, conical and is embedded in the gametophyte. The seta

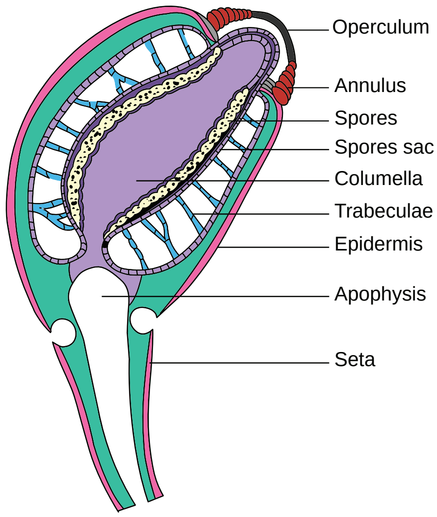


Figure 2.22: L.S. of capsule

is long, slender and conducts water and nutrients to the capsule . The capsule is differentiated into apophysis, theca proper and operculum. The cells constituting the wall of the capsule contain chloroplasts in them. The apophysis is the lowermost sterile region and connects the capsule with seta. The epidermis contains stomata which help in exchange of gases. The cells of the apophysis are photosynthetic, hence the sporophyte of *Funaria* partially depends on the gametophyte. The theca proper is the middle part and is fertile region of the capsule. It consists of a central columella surrounded by spore sac. The spore sac is surrounded by a single cylindrical air sac traversed by delicate filaments made up of parenchyma cells called **trabeculae**. The trabeculae extend from the outer wall of the spore sac to the innermost layer of the capsule wall. The spore sac contains spore mother cells which undergo meiotic division to produce haploid spores. The apical region consists of the operculum and peristome. The operculum is the lid of the capsule and comes out as a circular cup shaped lid after the dehiscence of the capsule. The peristome has one or two rows of thickened, tooth like projections found on the top of the capsule. They are hygroscopic and help in the dispersal of the spores. During favourble conditions the spores germinate to produce thread like green branched structure called protonema. It produces rhizoids and number of lateral buds which develop into new plants. In the life cycle of *Funaria* the haploid gametophytic phase (n)alternates with diploid sporophytic phase (2n) and shows alternation of generation (Figure 2.23).

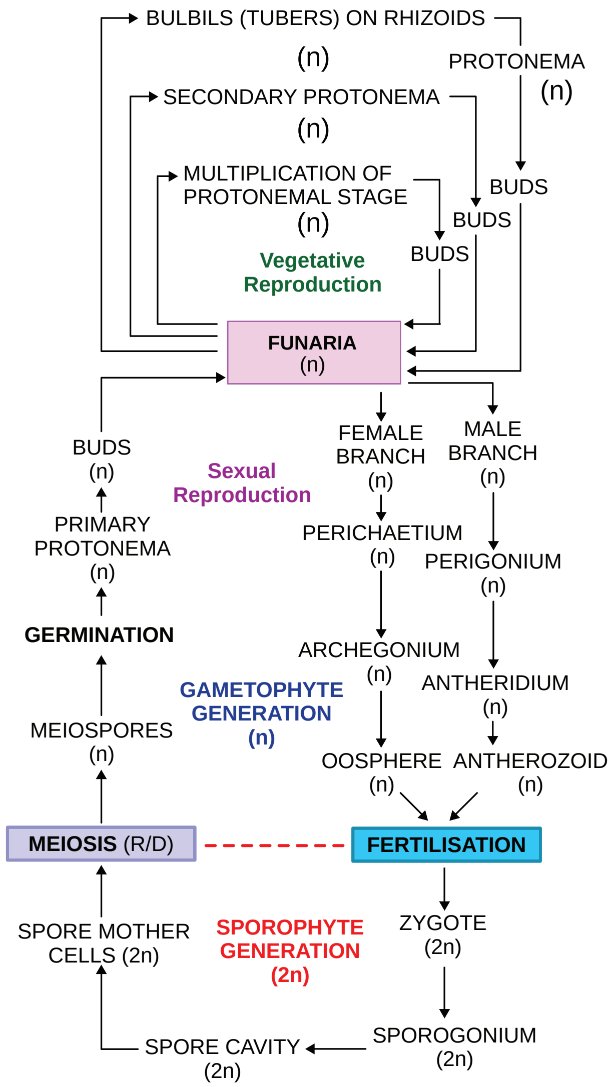


Figure 2.23: Life cycle of *Funaria*

2.5 Pteridophytes

Seedless Vascular Cryptogams

From the previous chapter 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. The photographs for some pteridophytes are given in Figure 2.24.

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.**

a) *Lycopodium* (club moss) b) *Equisetum* (Horse tail) c) *Azolla* (Water fern)

Figure 2.24: Pteridophytes

2.5.2 Classification of Pteridophytes

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.

2.5.3 Economic Importance

The Economic importance of Pteridophyte is given in Table 2.4

Table 2.4: 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.

Division- PTERIDOPHYTA

Sub division

Psilophytopsida	Psilotopsida	Lycopsida	Sphenopsida	Pteropsida
All are extinct plants. Plant body had only stem and rhizome. Roots and leaves were absent. Homosporous Spore tetrads were borne at the terminal sporangia. Example: *Rhynia*.	The plant body is rootless and have fungal association. Small, scaly appendages represent the leaves. Gametophyte is colourless and have fungal association. They are homosporous and spores are produced in sporangia or synangia. Example: *Psilotum*.	The plant body is differentiated into root, stem and leaves. Leaves are small, univeined, spirally arranged. Ligules are present. Sporophylls are arranged in the form of strobilus. Both homospory (*Lycopodium*) and heterospory (*Selaginella*) are found. Example: *Selaginella*.	The plant body is differentiated into root, stem and leaves. Stem shows jointed nodes and internodes. Small, scaly leaves are arranged at nodes in whorls. Peltate disc of sporangiophore possess compact strobilus. Homosporous but incipient heterospory is found in *Equisetum arvense*.	The plant body is differentiated into root, stem and leaves. Includes all the megaphyllous pteridophytes. leaf gap is present sporangia are organized into sorus. Both homosporus and heterosporus forms are present. Example: *Marsilea*

2.5.4 Selaginella

Division – Lycophyta
Class – Ligulopsida
Order – Selaginellales
Family – Selaginellaceae
Genus – *Selaginella*

Selaginella is commonly called 'spike moss'. They are distributed in humid temperate and tropical rain forests. *Selaginella rupestris* and *Selaginella lepidophylla* are Xerophytic. *Selaginella kraussiana*, *Selaginella chrysocaulos, Selaginella megaphylla* are some common species. In few *Selaginella* species during dry season the entire plant body gets curled and become fresh, green when moisture is available. Due to this they are called **Resurrection plants**. Example *S. lepidophylla*

External morphology

Habit

The plant body of *Selaginella* is sporophyte (2n) and it is differentiated into root, stem, and leaves (Figure 2.25). There exist variations in the habit of *Selaginella*. Some species possess prostrate creeping system (*S. kraussiana*); suberect (*S. rupestris*); erect (*Selaginella erythropus*); Climbing (*Selaginella alligans*). *S. oregana* is an epiphyte. Most of the species are perennials. on the basis of structure of stem and arrangement of leaves, *Selaginella* is divided into two sub genera namely Homoeophyllum and Heterophyllum.

Homeophyllum include species with erect stem and spirally arranged leaves. (Example: *S. upestris* and *S. oregana*). Heterophyllum include species with prosrate stem with short erect branches and dimorphic leaves (Example: *S. kraussiana* and *S. lepidophylla*).

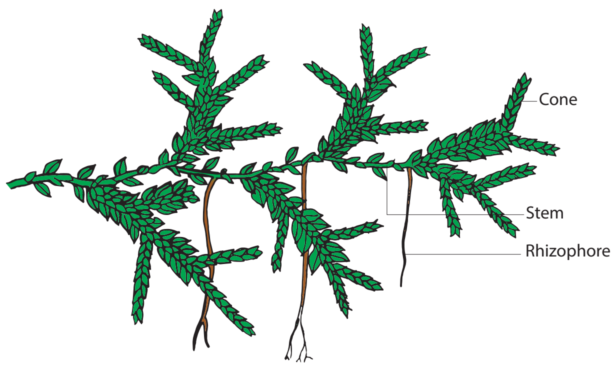


Figure 2.25: *Selaginella* Habit

Root

Primary roots are short lived and the adult plant has adventitious roots. The root may arise at the point of dichotomous branching or knot like swelling present at the basal portion of the stem. Roots are endogenous in origin.

Rhizophore

In many species long, cylindrical, unbranched and leafless structures arise from the lower side of the stem at the point of dichotomy called rhizophores. They grow vertically downwards and produce tufts of adventitious roots.

Stem

The stem may be erect, dichotomously branched or prostrate with lateral branching. The prostrate stem is dorsiventral.

Leaves

The leaves are microphyllous, sessile and simple. A single midvein is present in the leaves. The vegetative leaf as well as the sporophyll bears a small membranous tongue like structure on adaxial surface called **ligule**. The basal part of the ligule possess a hemispherical mass of thin walled cells called **glossopodium**. The function of ligule is not known, but it is viewed to be associated with water absorption, secretion and prevent dessication of shoot. The members belonging to Homeophyllum type possess same type of leaves spirally arranged on the stem whereas the Heterophyllum type have two types of leaves- two dorsal rows of small leaves(Microphylls) and two ventral rows of large leaves(Megaphylls).

Internal structure

Root

The transverse section of the root reveals an outermost layer called epidermis. It is made up of tangentially elongated cells. The cortex is homogeneous made up of thin walled parenchyma . The innermost layer of cortex is called endodermis. The stele is a protostele, monarch and xylem is exarch (Figure 2.26).

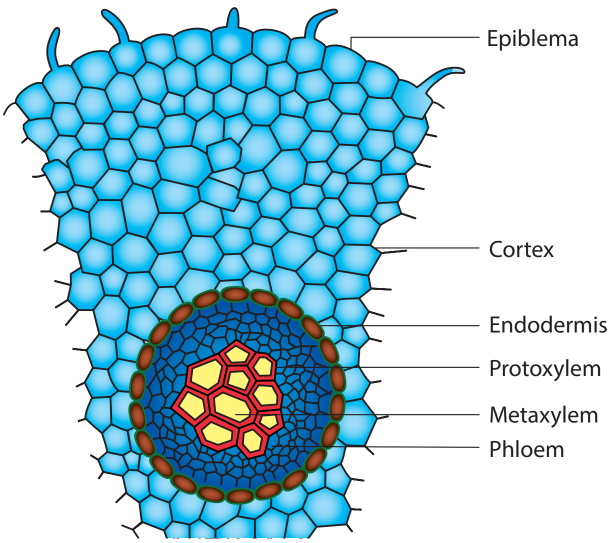


Figure 2.26: T.S. of root

Rhizophore

The outermost layer of Rhizophore is the epidermis. It is single layered and is covered with a thick cuticle. The cortex is differentiated into outer scelrenchymatous and inner parenchymatous layers. The innermost layer of cortex forms endodermis. The stele is a protostele Figure 2.37. It is monarch and exarch but it is centrifugal in *S. kraussiana* and crescent shaped in *S. atroviridis*.

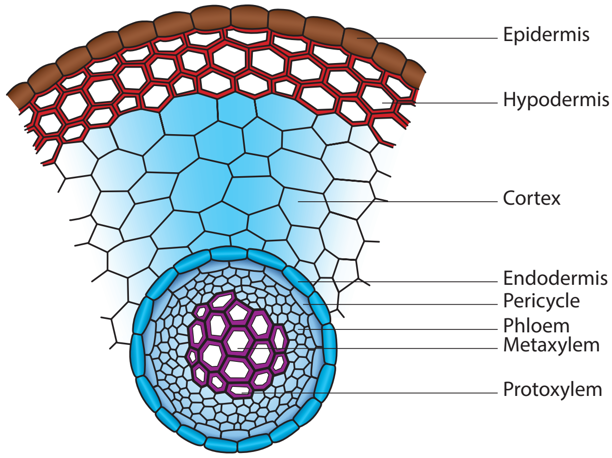


Figure 2.27: T.S. of Rhizophore

Stem

The anatomy of the stem reveals the presence of epidermis, cortex and stelar region (Figure 2.28).

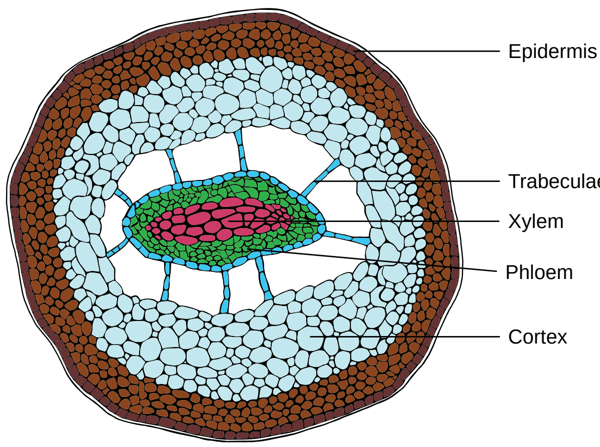


Figure 2.28: T.S. of Stem

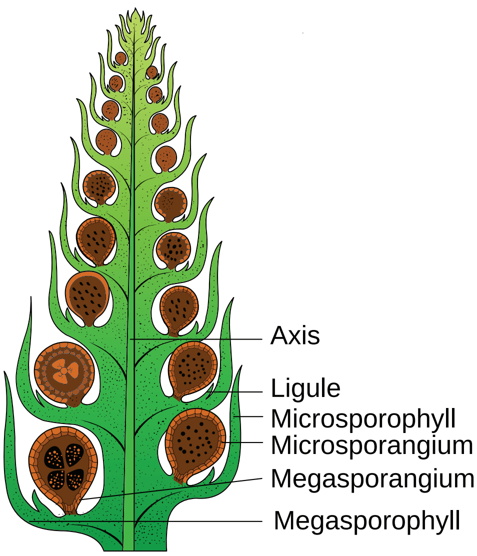
The epidermis is parenchymatous and is covered with a thick cuticle. The cortex is parenchymatous with cells arranged without intercellular spaces. A sclerenchymatous hypodermis is noticed in *Selaginella lepidophylla*. The presence of radially elongated endodermal cells called **trabeculae** is the characteristic feature of *Selaginella*. The casparian strips are found on the lateral walls. The rapid stretching of the innermost cortical cells in comparison with stele results in air spaces and stele appears to be suspended in air space with the help of trabeculae. The stele is a protostele and exarch. A variation in number of steles is found. It may be monostelic (*S. spinulosa*); distelic (*S. kraussiana*)or polystelic (*S. laevigata*). The xylem is monarch(*S. kraussiana*) or diarch (*S. oregana*). Tracheids are present but vessels are also noticed in *S. densa* and *S. rupestris*.

Leaf

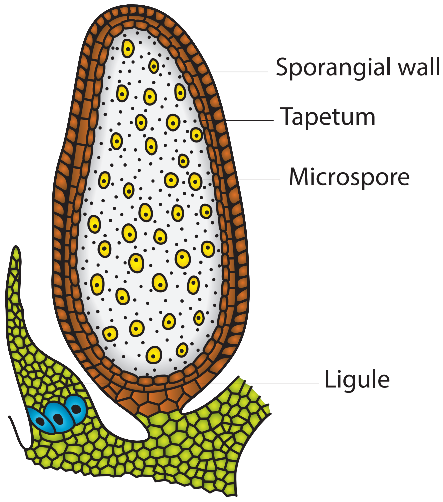
The leaf shows upper and lower epidermis. The epidermal cells have chloroplast. Stomata occur on both surfaces. The mesophyll is made up of loosely arranged thin walled cells with intercellular spaces. There is a median vascular bundle surrounded by a bundle sheath. In vascular bundle xylem is surrounded by phloem.

Reproduction

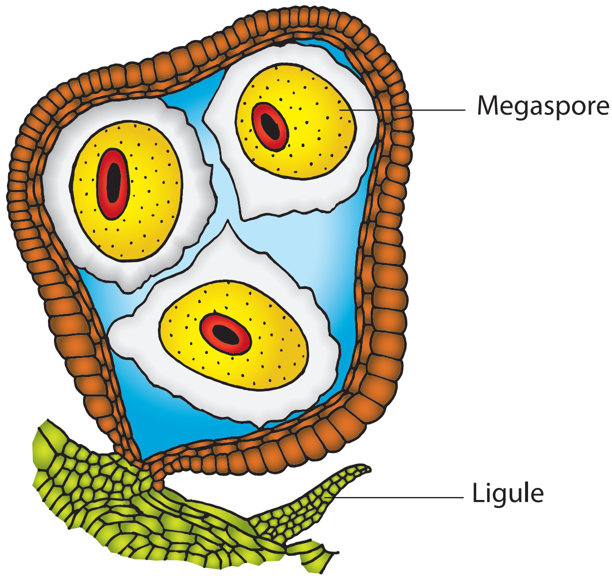
Selaginella shows both vegetative and asexual modes of reproduction.



a) L.S. of cone



b) A microsporangium enlarged



c) A megasporangium enlarged

Figure 2.29: Reproduction in *Selaginella*

Vegetative reproduction

Selaginella reproduces vegetatively by fragmentation, bulbil formation, tuber formation and resting buds.

Sexual reproduction

During sexual reproduction spores are produced (Figure 2.29). *Selaginella* is heterosporous and produces two types of spores namely microspores in microsporangium and megaspores in megasporangium. The sporangia are borne singly in the axils of microsporophyll and megasporophyll respectively. The sporophylls are arranged spirally around a central axis and aggregate to form strobili or cones. Variations in the distribution of microsporangia and megasporangia among the species are seen. In S. *selaginoides* and S. *rupestris* megasporangia are present in the basal part of the cone. *S. kraussiana* possesses a single megasporangium at the base of the strobilus. In *S. inaequifolia* one side of the strobilus bear only megasporangia and other microsporangia. Separate strobili for microsporangia and megasporangia are present in *S. gracilis*. and *S. atro-viridis*.

The development of sporangium is of eusporangiate type. The sporangial initial divides periclinally to form outer jacket initials and inner archesporial initials. The archesporial initials by repeated anticlinal and periclinal divisions form sporogenous cells. Microspore mother cells of microsporangium undergo reduction division to produce halpoid microspores. Similarly the megaspore mother cell undergoes reduction division to produce 4 haploid megaspores. The microspore and megaspore represent the male and female gametophyte and germinate inside the sporangium. The microspores produce biflagellate antherozoids. Archegonia develop in the megaspore. The antherozoids swim in water and reach the archegonium. Fertilization brings the fusion of male and female nucleus which result in the formation of a diploid zygote. The diploid zygote represents the first cell of sporophyte.

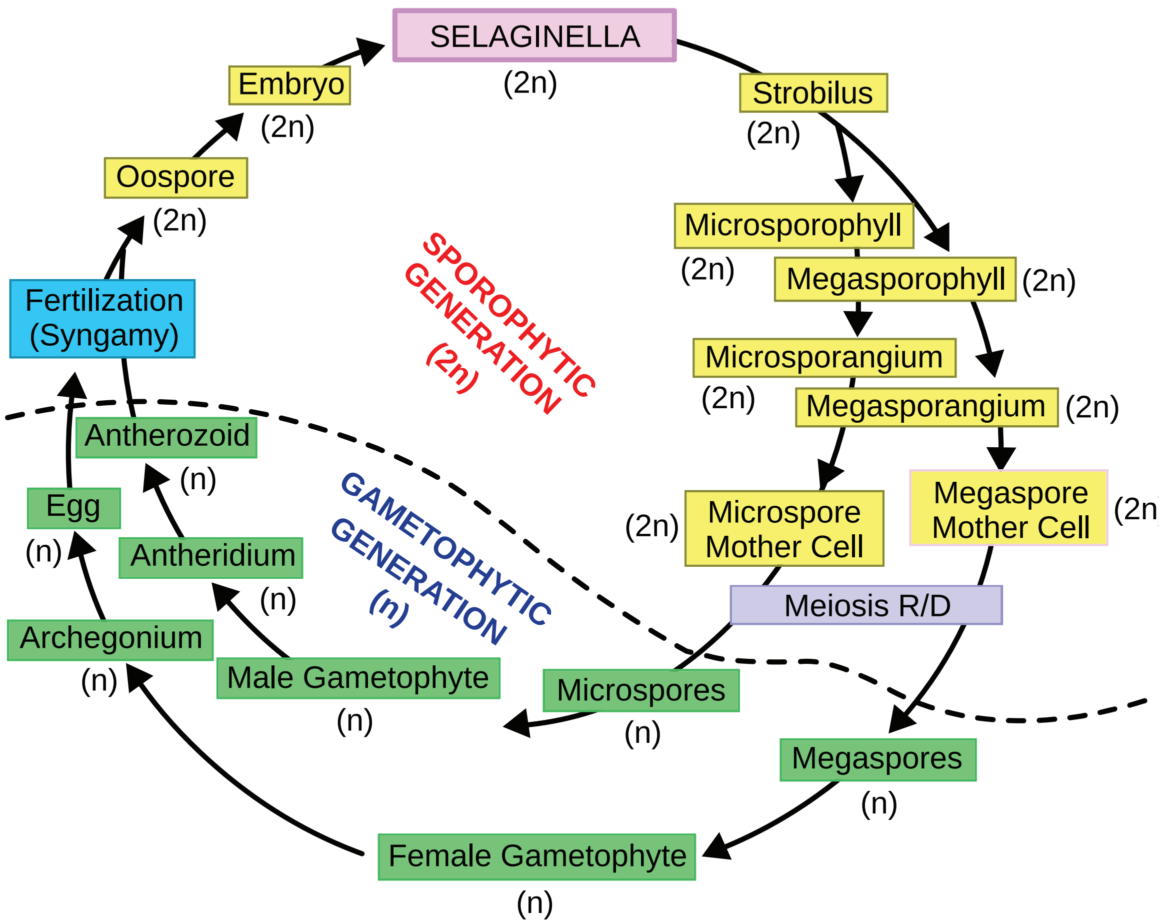


Figure 2.30: Life cycle of *Selaginella*

It undergoes several mitotic division to form embryo. The embryo develops into a mature sporophytic plant.

In the life cycle of *Selaginella* alternation of sporophytic and gametophytic generation is present (Figure 2.30).

2. 5.5 Adiantum

Division – Pteropsida
Class - Leptosporangiopsida
Order – Filicales
Family – Polypodiaceae
Genus – *Adiantum*

Adiantum is commonly known as 'Maiden hair fern' or 'Walking fern'. They are distributed in the tropical and temperate regions of the world. Some of the Indian species include *Adiantum capillus-veneris, Adiantum pedatum, Adiantum caudatum* and *Adiantum venustum*. The sporophyte is differentiated into rhizome, roots and leaves Figure 2.31.

External features

Rhizome

The rhizome is a perennial, subterranean dichotomously branched structure and is creeping in *A. capillus-veneris* or may be erect as in *A. caudatum*. It is covered with persistent leaf bases and hairy outgrowths called **ramenta**.

Root

The roots are adventitious and arise from the rhizome.

Leaf

The leaves are also called fronds and are pinnately compound (unipinnate- *A. caudatum*, bipinnate- *A. capillus-veneris*) the young leaves are circinately coiled. The petiole is long, black and shiny. The venation is free and dichotomous in all the species. The vein spread in a fan-like manner in the lamina. The leaves bear marginal sori which are covered by a **false indusium.**

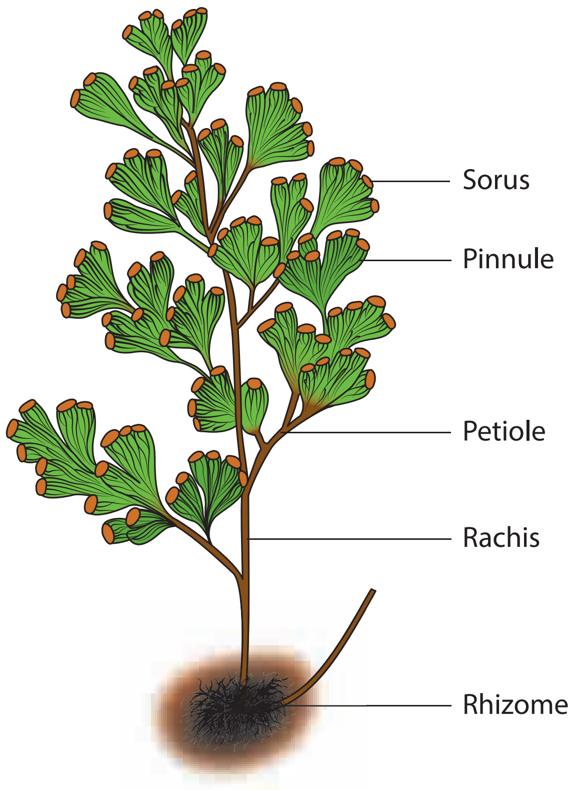


Figure 2.31: Adiantum Habit

Internal structure

Root

The root is differentiated into epidermis, cortex and central vascular cylinder.

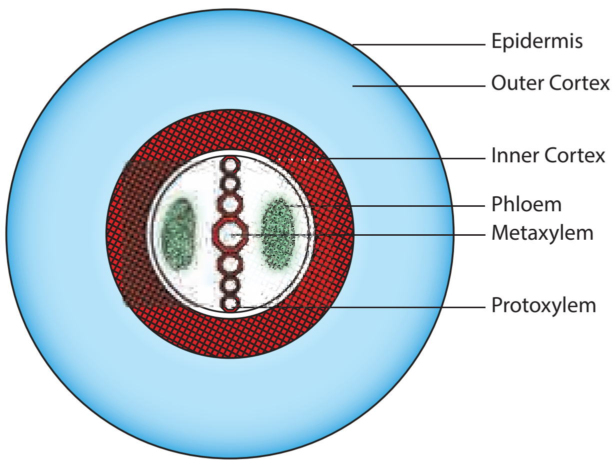


Figure 2.32: T.S. of root

The epidermis is the outermost layer and bears unicellular root hairs. The cortex is divided into outer wide parenchymatous and inner narrow sclerenchymatous layer. The stele is simple and possesses a central core of xylem in diarch condition with phloem on either side of it (Figure 2.32).

Rhizome

The rhizome in transverse section shows a single layered epidermis covered by cuticle. Some epidermal cells bear multicellular hairs. The Epidermis is followed by two to three layered hypodermis made up of sclerenchyma tissue. A parenchymatous ground tissue is present. The young rhizomes have amphiphloic siphonostele. The older rhizomes have solenostele or dictyostele (Figure 2.33).

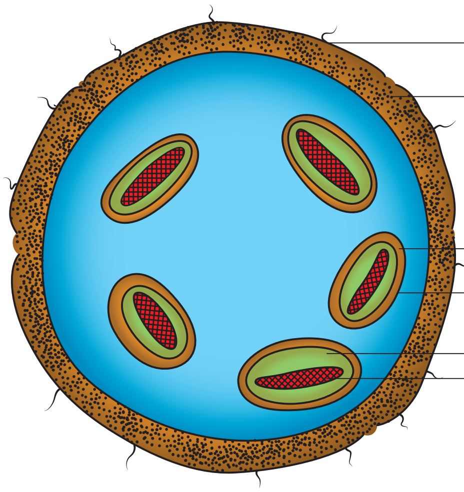


Figure 2.33: T.S. of Rhizome

Petiole

The petiole in T.S. shows a single layered epidermis with thick cuticle. Epidermis is followed by a sclerenchymatous hypodermis which provides mechanical support. There is an extensive parenchymatous ground tissue. The central region possesses a single large horse shoe shaped stele. Xylem forms central core surrounded by phloem (Figure 2.34).

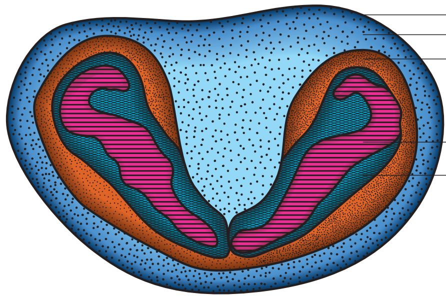


Figure 2.34: T.S. of Petiole

Pinnule

The Pinnule shows upper and lower epidermis. The cells contain chloroplasts. Stomata are confined to lower epidermis. The mesophyll is not differentiated into palisade and spongy parenchyma. The vascular bundle is surrounded by sclerenchymatous bundle sheath.

Reproduction

Adiantum is homosporous. The reproduction takes place by the production of spores. The spores are produced in sporangia. A group of sporangia forms sori. The sori are marginal but the reflex margins of the pinna form a protective membranous structure called *false indusium* (Figure 2.35). The development of sporangium is of leptosporangiate type.

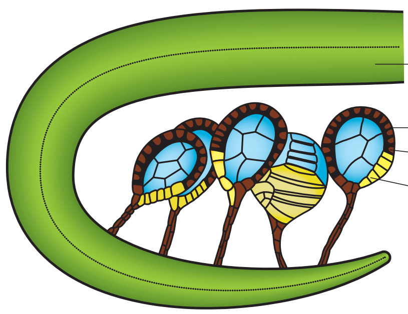


Figure 2.35: V.S. of Sporophyll

The sorus does not show any definite sequence hence fall under mixed type.

A mature sporangium bears a multicellular stalk and a spherical or elliptical single layered structure called **capsule**. The capsule contains haploid spores. The wall of the capsule is differentiated into thick walled annulus and thin walled **stomium**. On maturity the sporangium bursts and spores are released. The spores germinate and undergo repeated division to produce a **prothallus**. The prothallus is flat, green and heart shaped. It is monoecious and represents the gametophytic phase. Sex organs called **antheridia** and **archegonia** develop on the prothallus. Antheridia release multiflagellate antherozoids which swim in water and reach the egg of the archegonium to accomplish fertilization. The fertilization results in zygote(2n) and it represents the first cell of sporophytic generation. The zygote develops into embryo which further differentiates into sporophyte. Thus *Adiantum* shows alternation of generation (Figure 2.36).

2.5.6 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 (Figure 2.37).

There are two types of steles

1. Protostele
2. Siphonostele

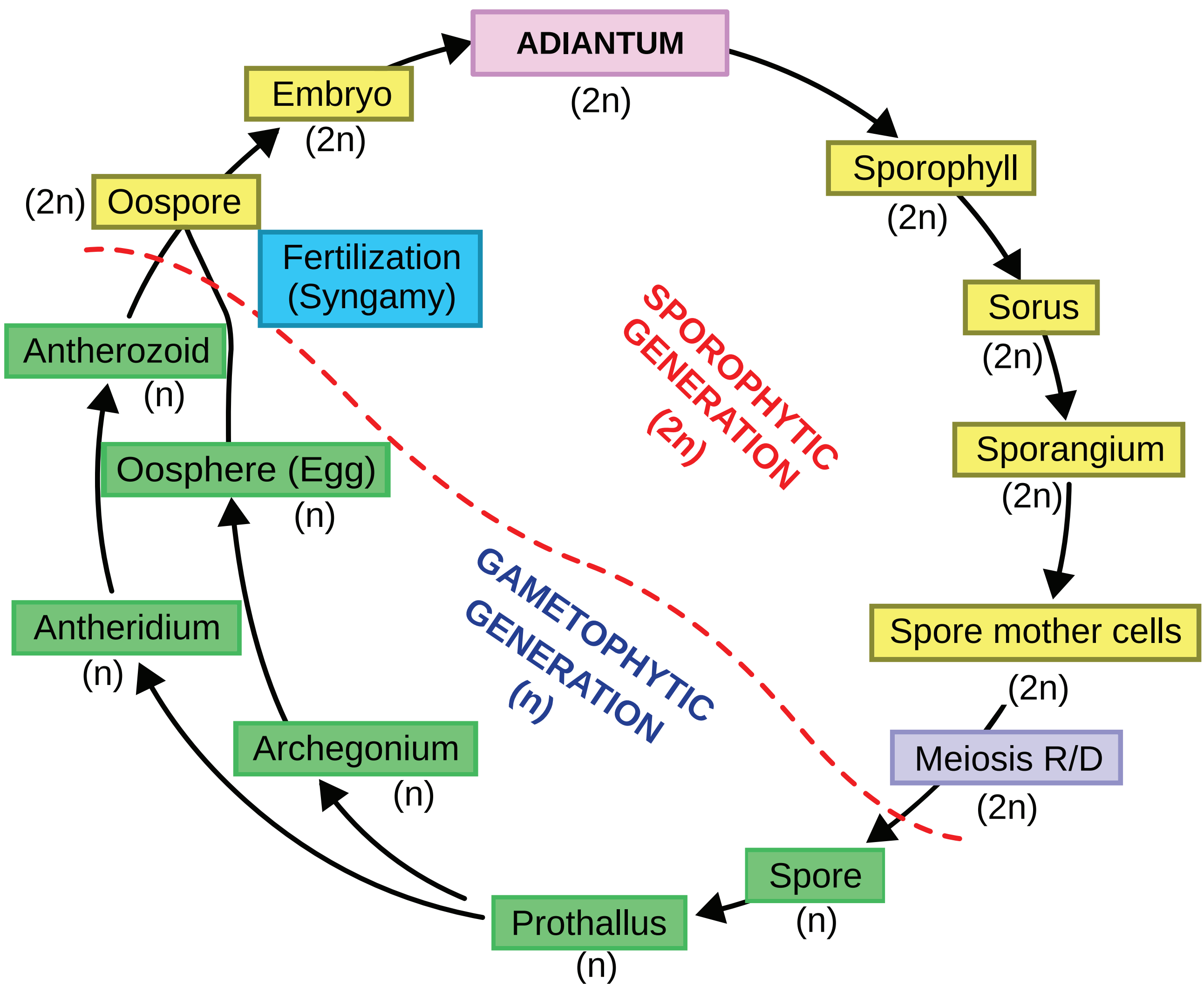


Figure 2.36: Life cycle of *Adiantum*

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.*

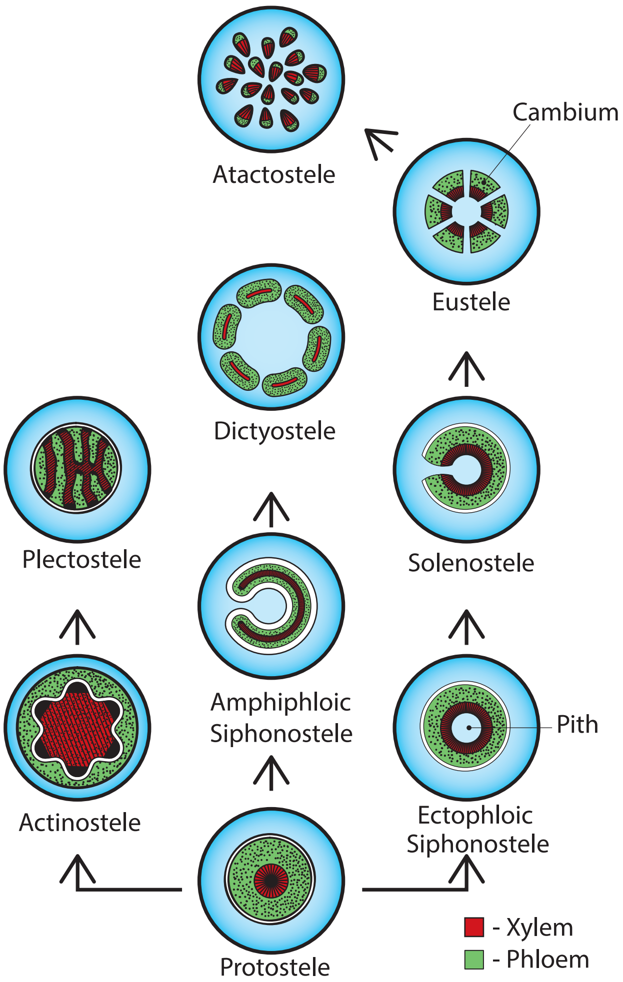


Figure 2.37: Types of Stele

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.

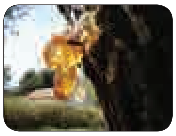
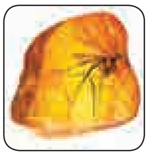
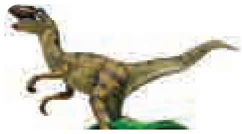
(v) **Atactostele**: The stele is split into distinct collateral vascular bundles and are scattered in the ground tissue Example: Monocot stem.

(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 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 2.38

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

Figure 2.38: Gymnosperms

2.6.2 Classification of Gymnosperms

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

GYMNOSPERMS		
Class-I	Class-II	Class-III
Cycadopsida	**Coniferopsida**	**Gnetopsida**
Orders: 1. Pteridospermales 2. Bennettitales 3. Pentoxylales 4. Cycadales	Orders: 1. Cordaitales 2. Coniferales 3. Taxales 4. Ginkgoales	Order: 1. Gnetales

General Characters of Main classes:

Class I – Cycadopsida

- Plants are palm-like or fern-like.
- Compound, frond-like pinnate leaves.
- Manoxylic wood.
- Sperms are motile.
- Flower like structures are absent. Strobili are simple.

  Example: *Cycas, Zamia*.

Class II – Coniferopsida

- Tall trees with simple leaves of varied shape.
- Wood is pycnoxylic.
- Cone like strobili are present.
- Motile sperms are absent (except *Ginkgo biloba*). Example: *Pinus*.

Class III – Gnetopsida

- Shrubs, trees and lianas.
- Leaves are elliptical or strap-shaped, simple, opposite or whorled.
- Motile sperms are absent.
- Wood contains vessels.
- Strobili is called as inflorescence.
- Flower like structure with perianth is present. Example: *Gnetum, Ephedra*.

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 2.5

Table 2.5: 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
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

Table 2.6: 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

2.6.4 Cycas

Class – Cycadopsida
Order – Cycadales
Family- Cycadaceae
Genus - *Cycas*

It is widely distributed in tropical and sub tropical region of eastern hemisphere of the world. *Cycas revoluta*, *Cycas beddomei*, *Cycas circinalis, Cycas rumphii* are some of the common species. The plant body is sporophyte and resemble a small palm. The growth is very slow. It is evergreen and xerophytic in nature.

Sporophyte:-

The sporophyte is differentiated into root, stem and leaves. The stem is columnar bearing a crown of spirally arranged pinnately compound leaves (Figure 2.39).

External features

Figure 2.39: *Cycas* Habit

Root

Two types of roots are found in *Cycas*. They are the tap root and coralloid root.

The primary root persists and forms the tap root. Some of the lateral roots give rise to branches which grow vertically upward below the ground level. They branch repeatedly to form dichotomously branched coral- like roots called coralloid roots. The cortical region of the coralloid root contains the Blue green alga – *Anabaena* sp. which helps in nitrogen fixation (Figure 2.40).

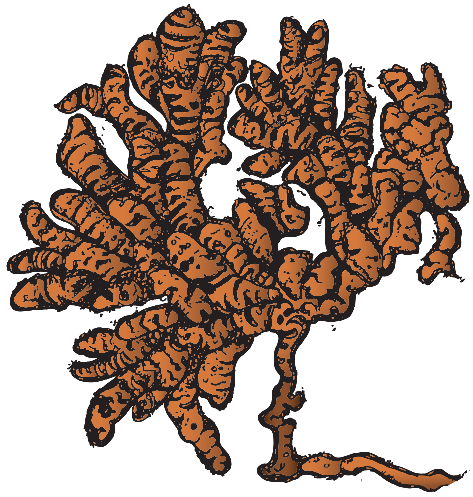


Figure 2.40: Coralloid root

Stem

The stem is columnar, unbranched and woody. It is covered with persistent woody leaf bases. The stem also bears adventitious buds at the base.

Leaves

Cycas has two types of leaves

(i) Foliage or assimilatory leaves
(ii) Scale leaves

(i) Foliage or assimilatory leaves

Foliage leaves are large, pinnately compound and form a crown at the top of the stem. Each leaf has 80-100 pairs of sessile leaflets. The apex is acute or spiny. The leaflet has a single midvein. Lateral veins are absent. Circinate vernation is present and young leaves are covered with **ramenta**.

(ii) Scale leaves

Scale leaves are brown, small, triangular and persistent which are protective in function. They are covered with ramenta.

Internal structure

T.S. of Root

The internal organization of the primary root reveals the following parts. 1. Epiblema, 2. Cortex 3. Vascular region (Figure 2.41). Epiblema is the outermost layer and is made up of single layered parenchyma. It is followed by thin walled parenchymatous cortex. The cortex is delimited by single layered endodermis. A multilayered parenchymatous pericycle is present and it surrounds the vascular tissue. The xylem is diarch in young root and tetrarch in older ones. Secondary growth is present. Coralloid root also shows similar structure but the middle cortex is characterized by the presence of Algal zone. Blue green alga called, *Anabaena* is found in this zone. The xylem is triarch and exarch.

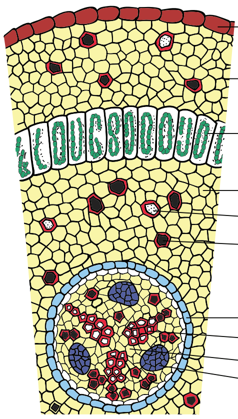


Figure 2.41: T.S. of Coralloid root

T.S. of Stem

The cross section of young stem is irregular in outline due to the presence of persistent leaf bases. It is differentiated into epidermis, cortex and vascular cylinder. It resembles the structure of a dicot stem (Figure 2.42).

The epidermis is the outermost layer and is covered with thick cuticle. It is discontinuous due to the presence of leaf bases. The cortex constitutes the major part and is made up of thin walled parenchymatous cells. The cells are filled with starch grains. Cortex also possesses several mucilage ducts and tannin cells. In young stem the vascular bundles are arranged in the form of a ring. A broad medullary ray is present. The vascular bundles are conjoint, collateral, endarch and open. Xylem is made up of tracheids and phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The cambium present in the vascular bundle is active for short period. The secondary cambium is formed from the pericycle or cortex and helps in secondary growth of the stem. The cortical region shows a large number of leaf traces. The presence of direct leaf traces and girdling leaf trace is the unique feature of *Cycas* stem. Secondary growth results in polyxylic condition. Phellogen and cork are formed and replace the epidermis.The wood formed belongs to manoxylic type.

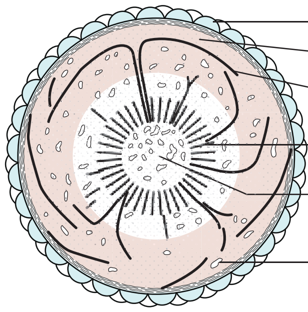


Figure 2.42: T.S. of stem

T.S. of Rachis

The outermost layer is epidermis and is covered by thick cuticle. The hypodermis is made up of two layers of sclerenchyma on the adaxial side and many layered on the abaxial side. The ground tissue is parenchymatous. The peculiar feature of the rachis is the arrangement of vascular bundle i.e., in an inverted Omega shape pattern (Figure 2.43). Each vascular bundle is covered by a single layered sclerenchymatous bundle sheath. Vascular bundles are collateral, endarch and open. A single layered endodermis and few layered pericycle surrounds the bundle. A diploxylic condition is present in the vascular bundles.(presence of both centripetal and centrifugal xylem).

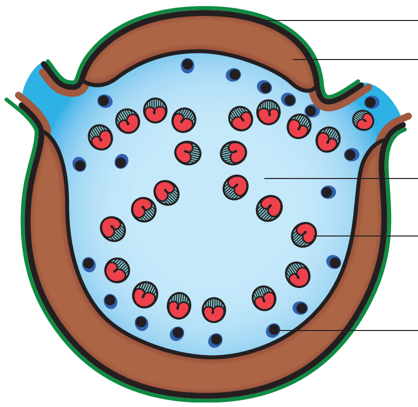


Figure 2.43: T.S. of Rachis

T.S. of Leaflet

The leaflet of *Cycas* in transverse section shows the presence of upper and lower epidermis. The epidermal cells are thick walled and are covered with thick cuticle. The lower epidermis is not continuous and is interrupted by sunken stomata. The hypodermis consists of sclerenchyma cells to prevent transpiration. The mesophyll is differentiated into palisade and spongy

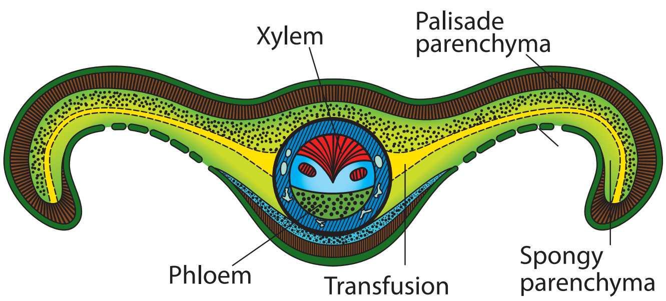


Figure 2.44: T.S. of leaflet

parenchyma. The cells of this layer are involved in photosynthesis. The spongy parenchyma present in close proximity to the lower epidermis bear large intercellular spaces which help in gaseous exchange.

Layers of colourless, elongated cells which run parallel to the leaf surface from the midrib to the margin of the leaflet are seen. These constitute the **Transfusion tissue** that helps in the lateral conduction of water. The vascular bundle has xylem facing upper epidermis and phloem facing lower epidermis. The protoxylem occupies the centre, hence the bundle is mesarch. The vascular bundle has a sclerenchymatous bundle sheath (Figure 2.44).

Reproduction

Cycas reproduces by both vegetative and sexual methods

Vegetative reproduction

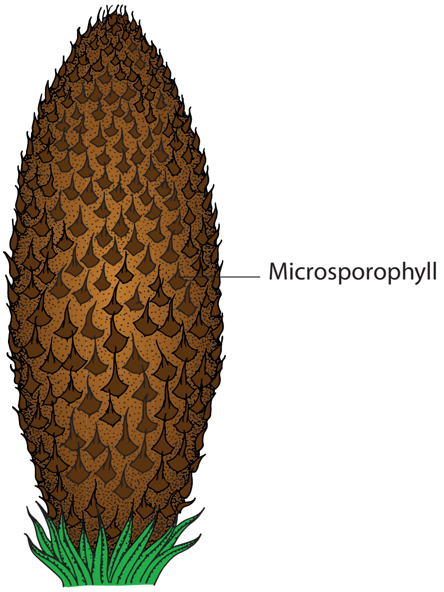
It takes place by adventitious buds or bulbils. They develop in the basal part of the stem. The bulbils on germination produce new plants.

Sexual reproduction

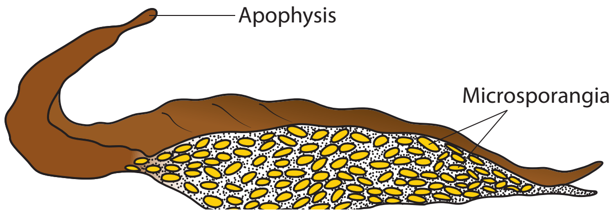
Cycas is dioecious i.e., male and female cones are produced in separate plants. It is heterosporous and produces two types of spores (Figure 2.45).

Male cone

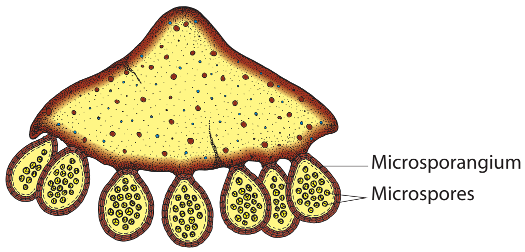
The male cone or staminate cone are borne singly on the terminal part of the stem. The growth of the stem is continued by the formation of axillary buds at the base of the cone. The male cone is displaced to one side showing sympodial growth in the stem. Male cones are stalked, compact, oval or conical and woody in structure. It consists of several microphylls which are arranged spirally around a central cone axis.



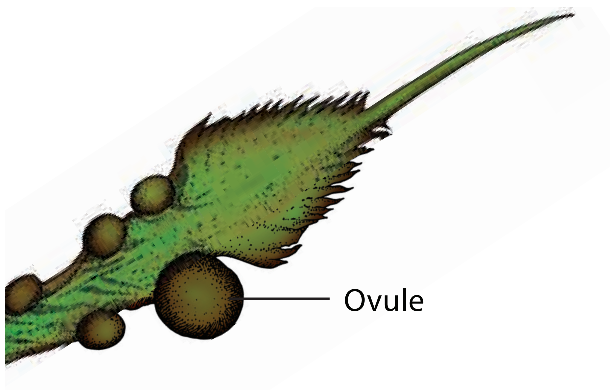
a) Male cone entire



b) A microsporophyll enlarged



c) T.S. of Microsporophyll



d) Megasporophyll

Figure 2.45: Reproduction in *Cycas*

Microsporophylls

Microsporophylls are flat, leaf-like and woody structures with narrow base and expanded upper portion. The upper expanded portion becomes pointed and is called apophysis. The narrow base is attached to the cone axis. Each microsporophyll contains thousands of microsporangia in groups called sori on abaxial (lower) surface. Development of sporangium is of Eusporangiate type. The spore mother cell undergoes meiosis to produce halpoid microspores. Each Microsporangium bears large number of microspores or pollen grains. Each sporangium is provided with a radial line of dehiscence, which helps in the dispersal of spores. Each microspore (Pollen grain) is a rounded, unicellular and uninucleate structure surrounded by outer thick exine and an inner thin intine. The microspore represents the male gametophyte.

Megasporophylls

The megasporophylls of *Cycas* are not organised into cones. They occur in close spirals around the tip of the stem of female plant. The megasporophylls are flat and measuring 15-30 cm in length. Each megasporophyll is differentiated into a basal stalk and an upper leaf like portion. The ovules are attached to the lateral side of the sporophyll. The ovules contain megaspore and it represent the female gametophyte.

Structure of Ovule

Cycas produces the largest ovule of the plant kingdom. The ovules are orthotropous, unitegmic and possess a short stalk. The single integument is very thick and covers the ovule leaving a small opening called *micropyle*. The integument consists of 3 layers, the outer and inner are fleshy (**sarcotesta**), the middle layer is stony called **sclerotesta**. The inner layer remains fused with the nucellus. The nucellus grows out into a beak-like structure and the upper part dissolves and forms a cavity-like structure called **pollen chamber**. A single megaspore mother cell undergoes meiosis to form four haploid megaspores. The lowermost becomes functional and others get degenerated. The nucellus gets reduced in the form of a thin papery layer in mature seeds and encloses the female gametophyte An enlarged megaspore or the embryo-sac is present within the nucellus. An archegonial chamber with 3-6 archegonia are present in the archegonial chamber below the pollen chamber (Figure 2.46).

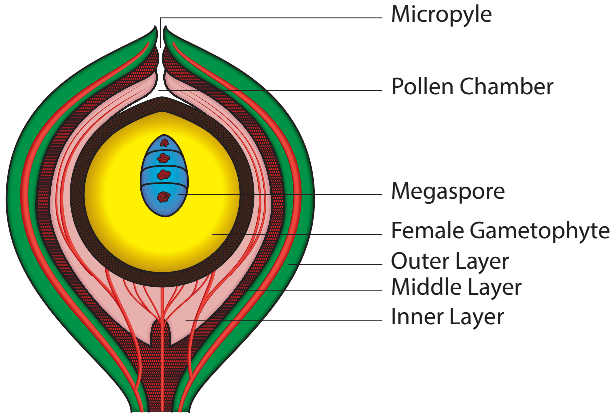


Figure 2.46: L.S. of Ovule

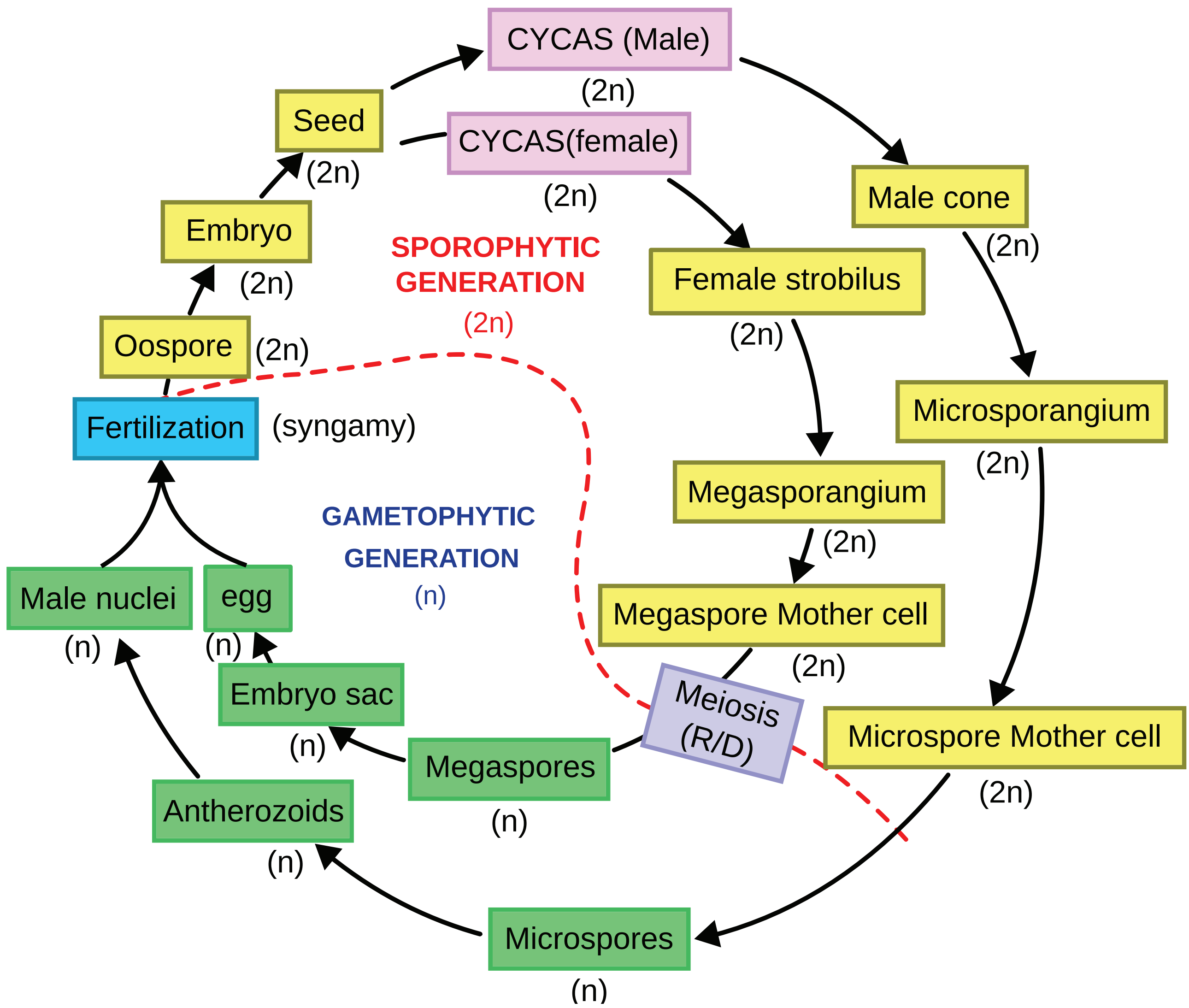


Figure 2.47: Life cycle of *Cycas*

Pollination and Fertilization.

Pollination is carried out by wind and occurs at 3 celled stage(a prothallial cell, a large tube cell and a small generative cell). Pollen grains gets lodged in the pollen chamber after pollination. The generative cell divides into a stalk and a body cell. The body cell divides to produce two large multiciliated antherozoids or sperms. During fertilization, one of the male gamete or multiciliated antherozoid fuses with the egg of the archegonium to form a diploid zygote (2n). The endosperm is haploid. The interval between pollination and fertilization is 4- 6 months. The zygote undergoes mitotic division and develops into embryo. The ovule is transformed into seed. The seed has two unequal cotyledons. Germination is hypogeal. The life cycle shows alternation of generations (Figure 2.47).

2.6.5 Pinus

Class – Coniferopsida
Order – Coniferales
Family –Pinaceae
Genus - *Pinus*

Pinus is a tall tree, looks conical in appearance and forms dense evergreen forest in the North temperate and sub-alpine regions of the world. They mostly grow in high altitudes (ranging from 1,200 to 3,000 metres). Some species of this genus include, *Pinus roxburghii, P. wallichiana, P. gerardiana* and *P. insularis.*

External features

The plant body is sporophyte and is differentiated into root, stem and leaves. The main stem is branched. The branches are dimorphic with long and short branches (Figure 2.48).

Figure 2.48: *Pinus* Habit

Root

Tap root system is found in *Pinus*. The root hairs are not well developed and the roots are covered with fungal hyphae called mycorrhizae.

Stem

The stem is cylindrical, erect, woody and branched. The branches are monopodial. The branches are of two types.

(i) Long shoots or branches of unlimited growth, (ii) Dwarf shoot or branches of limited growth

(i) Long shoots or branches of unlimited growth

The long shoot is present on the main trunk the apical buds grow indefinitely, They shorten gradually towards the tip, thus providing a pyramidal appearance to the tree. These branches bear scale leaves only.

(ii) Dwarf shoot or branches of limited growth

These branches do not have apical buds and hence show only limited growth. They develop in the axils of scale leaves and bear both scale and foliage leaves.

Leaves

There are two types of leaves 1. scale leaves, 2. foliage leaves

1. Scale leaves:

They are dark, brown, membranous, thin and small. They are present on both long and dwarf shoots. Their function is to protect young buds. The scale leaves on the dwarf shoots have a distinct midrib and are called "**Cataphylls**".

2. Foliage leaves:

The foliage leaves are green angular and needle like structures. They are borne on the dwarf shoot. A dwarf shoot with a group of needle like foliage leaves is known as **foliar spur**. The number of needles per dwarf shoot varies among the species. It may be one (*Pinus monophylla*), two (*P. sylvestris*), three (*P. geraradiana*), four (*P. quadrifolia*) and five (*P. excelsa*).

Internal Structure

T.S. of root

The internal structure of root reveals the presence of epiblema, cortex and stele.

The epiblema is made up of single layer of parenchymatous cells. Cortex is the wide zone and consists of parenchyma. Some of the cells have resin ducts. A single layered endodermis with suberised wall is present and is impregnated with tannins.A multilayered pericycle made up of parenchyma is present. Vascular tissue is radial, diarch with exarch xylem. The protoxylem bifurcates to form a 'Y' shaped structure and a resin duct lies in between the two arms of protoxylem. Secondary growth is present (Figure 2.49).

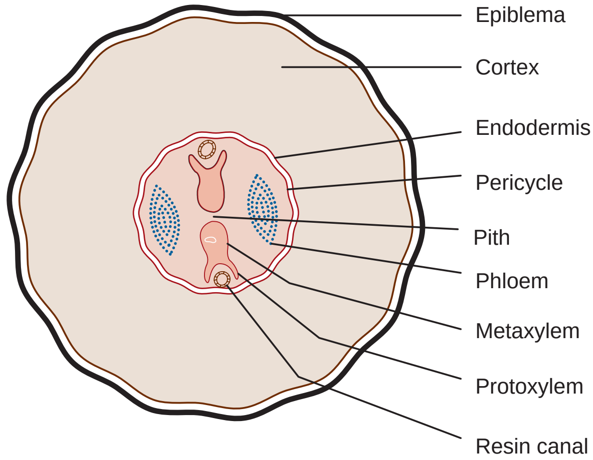


Figure 2.49: T.S. of *Pinus* root

T.S. of Stem

The internal organization of the stem shows three regions namely epidermis, Cortex and vascular tissue (Figure 2.50).

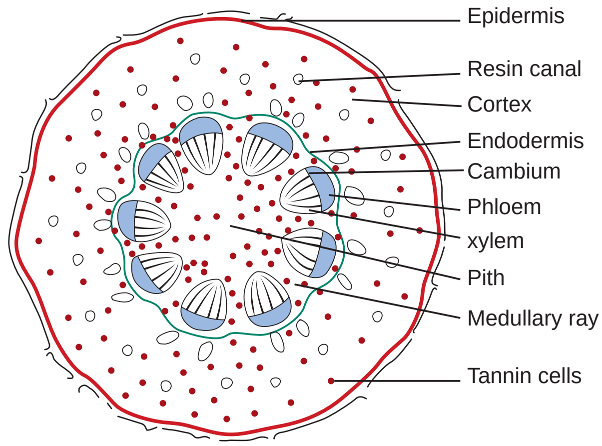


Figure 2.50: T.S. of *Pinus* stem

Epidermis is the outermost layer composed of compactly arranged and heavily cutinized cells. Epidermis is followed by few layers of sclerenchymatous hypodermis. The cortex consists of thin walled parenchyma cells. Resin canals and tannin filled cells are present in this region. Endodermis is indistinguishable from cortical cells. Vascular region is surrounded by pericycle. A ring consists of five or six vascular bundles are present. Vascular bundles are conjoint, collateral, open and endarch. Pith and medullary rays are present. Secondary growth is present and annual rings are formed.

T.S. of needle or foliage leaf

The internal structure of needle shows xerophytic adaptations. In cross section the outline appears more or less triangular and is divided into epidermis, mesophyll and vascular bundles. The epidermis is single layered and possesses thick cuticle and sunken stomata.Epidermis is followed by a few layers of sclerenchymatous hypodermis. It is interrupted by sub-stomatal cavities (Figure 2.51).

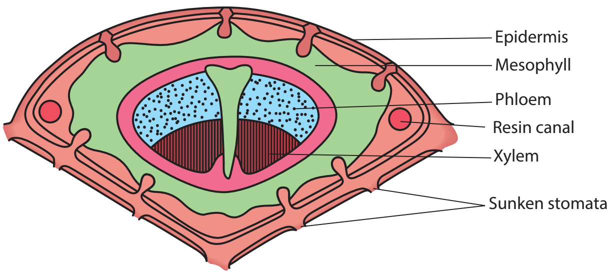


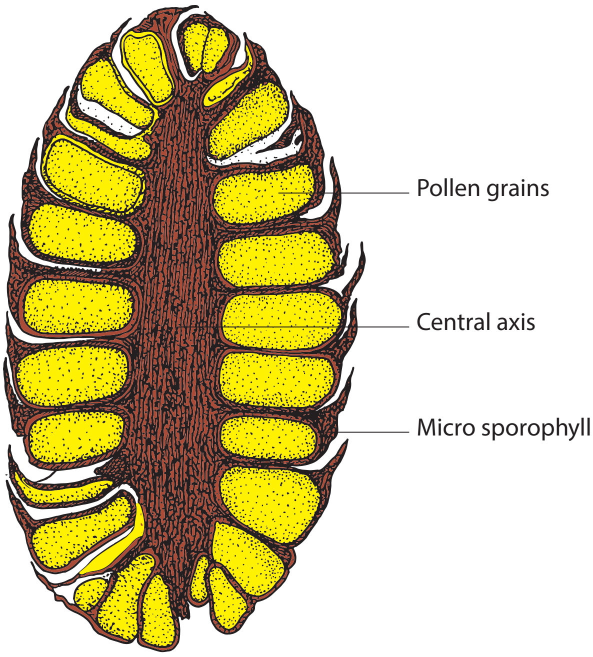
Figure 2.51: T.S. of *Pinus* needle leaf

Mesophyll is not differentiated into palisade and spongy parenchyma. Thin walled cells with chloroplasts are present. The cells are peculiar with numerous small infoldings which project into the cavities. The infoldings increase the photosynthetic area of the needle leaves Resin canal is present in the mesophyll. A single layered endodermis separates the vascular region from the cortex. A multilayered pericycle containing starch is present. Two types of specialised cells called **albuminous cells** and **tracheidal cells** are present. The former helps to pass substances from the mesophyll to the phloem while the latter helps in water conduction and constitutes transfusion tissue. Two vascular bundles are present. They are separated by sclerenchyma tissue. The Vascular bundles are conjoint, collateral and open.

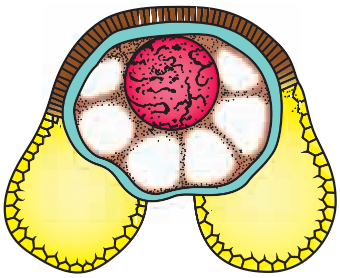
Reproduction

Pinus is heterosporous and produces two types of spores called. microspores and megaspores. The plants are monoecious. Both male and female cones or strobili develop on the different branches of the same plant (Figure 2.52).

a) *Pinus* - A twig with male cones

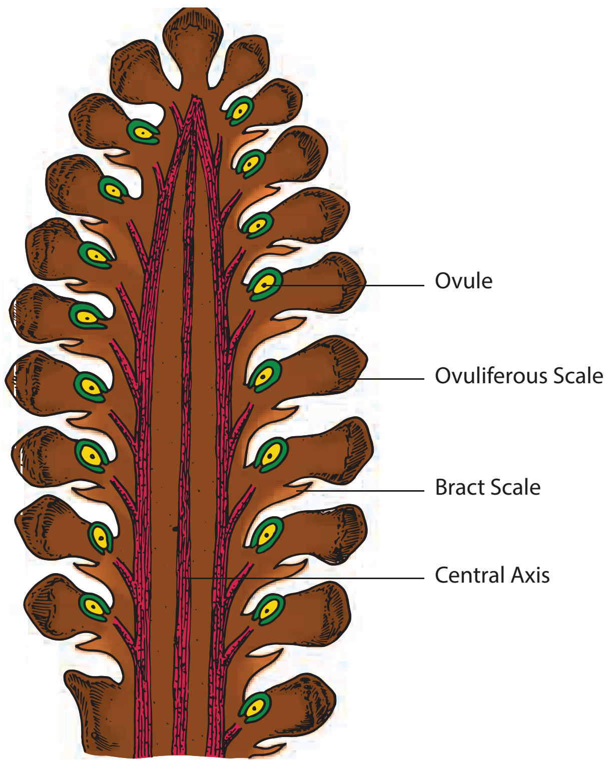


b) L.S. of male cone



c) A mature pollen grain

d) *Pinus* - A twig with female cone



e) L.S. of female cone

Figure 2.52: Reproduction in *Pinus*

Male cone

Male cones are produced in clusters on branches of unlimited growth. Each cone develops on the axil of scale leaf . The male cone consists of a centrally located cone axis surrounded by numerous spirally arranged microsporophyll. It bears two microsporangia at the base of the abaxial side of the microsporophyll. Each sporangium bears numerous winged microspores (n) or pollen grains. The microspores represent the male gametophyte

Female cone:-

Female cones are formed in the groups of 1 to 4 in the axils of the scale leaves. The female cone takes about three years to mature. It has the central axis around which megasporophylls are arranged spirally. The megasporophyll is the compound structure consisting of two types of scales. 1. Bract scale (sterile), and 2. Ovuliferous scales (fertile). The dorsal surface of each ovuliferous scale bears two ovules. Ovules bear megaspores which represent the female gametophyte.

Pollination and fertilization

In *Pinus* wind pollination takes place (Anemophilous). The microspore or pollen grain is released in the 4 celled stage(two prothallial cell, 1 generative and 1 tube cell). At the time of pollination a secretion oozes out from the micropyle of the ovule which entangles pollen grains which helps to lodge them in the pollen chamber. The tube cell protrudes to form pollen tube. The generative cell divides to produce stalk cell and body cell. The body cell divides into unequal male cells. Fertilization takes place after about a year of pollination. The pollen tube containing two male nuclei penetrates through the micropyle and reaches the egg. One of the male nuclei fuses with the egg forming diploid zygote and the remaning one gets degenerated. The fertilized egg

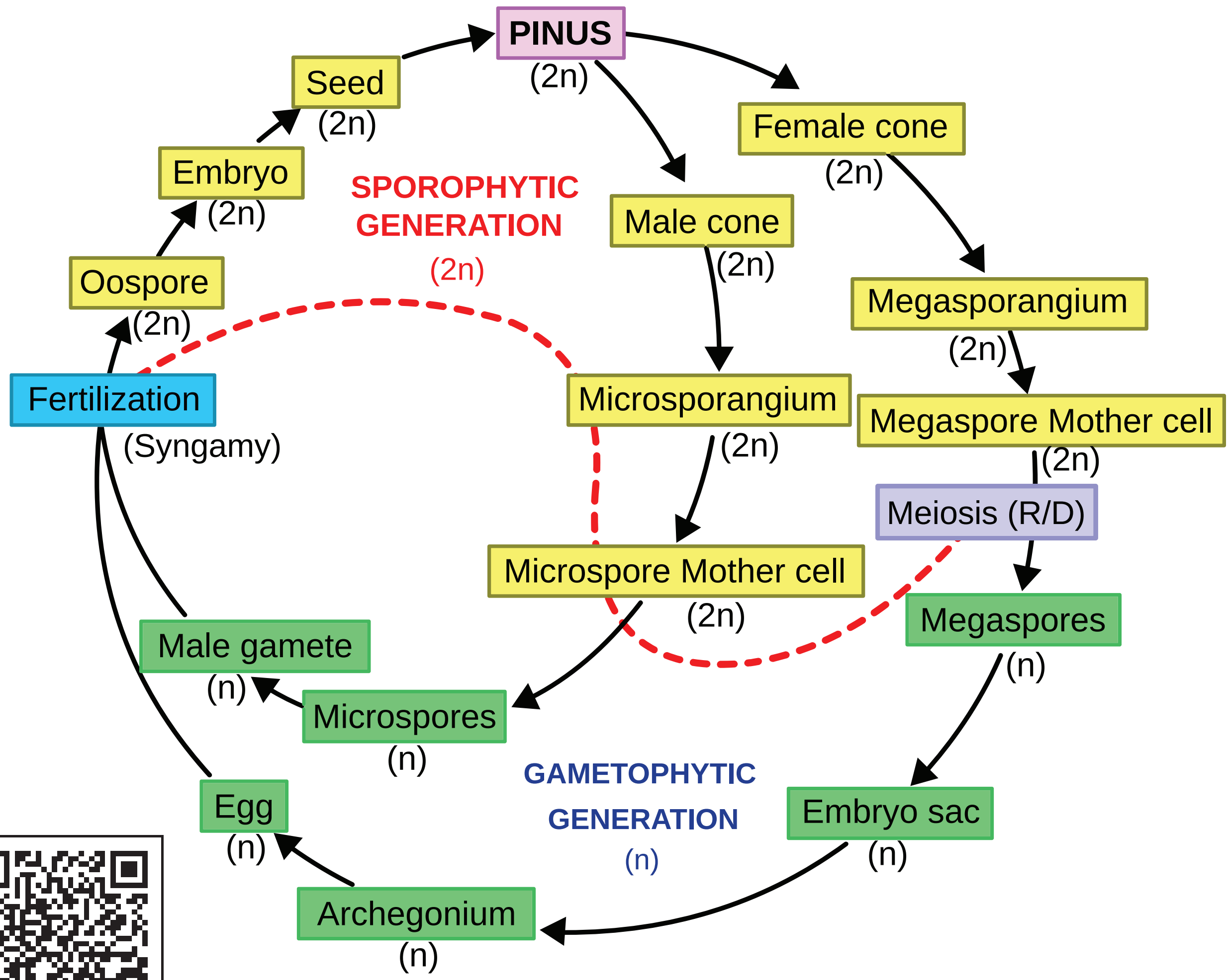


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Figure 2.53: Life cycle of *Pinus*

(zygote) undergoes mitotic division and develops into an embryo. Polyembryony is present. The embryo undergoes several changes and finally becomes a winged seed. The seed germination is epigeal. Life cycle of *Pinus* shows alternation of generation (Figure 2.53).

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

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 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.

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

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.

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.

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.

Oedogonium is a fresh water, filamentous, multicellular alga. The presence of cap cell is the prominent characteristic feature in addition reticulate chloroplast is present. Asexual reproduction takes place through Zoospores. The sexual reproduction is Oogamous.

Chara is a fresh water alga and is popularly called "Stone worts". The plant body is multicellular, macroscopic and is differentiated into main axis and rhizoids. Sexual reproduction is Oogamous.

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.

Marchantia belongs to the class Hepaticopsida. The thallus is dorsiventral and is attached to the substratum by means of rhizoids. The internal structure of the thallus reveals the presence of photosynthetic region and a storage region. Vegetative reproduction takes place through fragmentation and formation of Gemmae. The sexual reproduction is Oogamous. Sporophyte bears spores. Alternation of generation is present.

Funaria belongs to the class Bryopsida. The gametophyte is differentiated into leaf-like, stem-like structures with rhizoids. Gemmae, Protonema and bulbils help in asexual reproduction. Sexual reproduction is Oogamous. Alternation of generation is present.

Pteridophytes are also called vascular cryptogams. The plant body is sporophyte and is long lived ,which 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.

The term stele includes central cylinder of vascular tissues comprising xylem, phloem, pericycle, endodermis and pith . There are two major types of stele namely Protostele and Siphonostele.

Selaginella belongs to the class Lycopsida. The plant body is sporophyte. It is differentiated into stem, leaf, rhizophore and roots. Heterospory is found and two types of spores namely microspores and megaspores are produced in sporangia. The microsporangia and megasporania are borne on sporophylls. The sporophylls are organized to form cone. Sexual reproduction is oogamous. Alternation of generation is present.

Adiantum belongs to Pteropsida. The sporophyte is differentiated into root, rhizome and leaves. The spores are produced in sporangia and is covered by false indusium. The sexual reproduction is oogamous and sex organs (antheridum and archegonium) are produced on prothallus. Alternation of generation is present.

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

Cycas belongs to Cycadopsida. The plant body is sporophyte and looks like a small palm tree. Apart from Taproot Coralloid roots are present. It is dioecious, Microsporophylls are organized into male cone. Ovules are borne on megasporophylls which are not organized into cone. Fertilization results in zygote and it develops into embryo. Alternation of generation is present.

Pinus belongs to Coniferopsida.. The plant body is sporophyte and is differentiated into root, stem and leaves. The main stem is branched. The branches are dimorphic with long and short branches. It is monoecious, heterosporous and produces two types of spores called microspores and megaspores. 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.

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.
11. List the classes of algae.
12. Mention the pigments and storage food of Dinophyceae.
13. What are cap cells?
14. Name the flagellation found in the zoospore of *Oedogonium*
15. What is Nucule?
16. Differentiate nodal and internodal cells of *Chara*.
17. What are elaters?
18. What is protonema?
19. Where do we find false indusium?
20. Explain the internal structure of *Cycas* rachis.
21. Differentiate long and dwarf shoot.

ICT Corner

Different forms of plants

Is all the **plants** are same? →

Steps

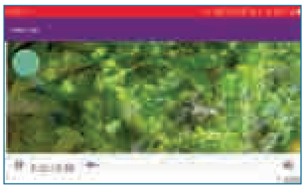
- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Characteristics of plants
- Click theory to know the basic about Characteristics of plants
- Register yourself with mail-id and create password to access online lab simulations

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/plantlifecycle.swf

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* 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.

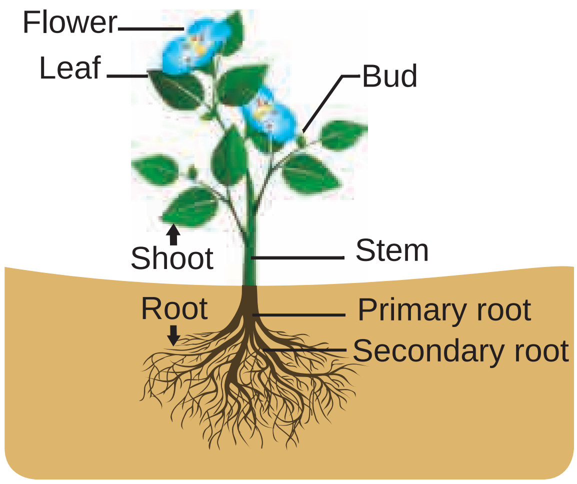


Figure: 3.1: Parts of a flowering plant

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

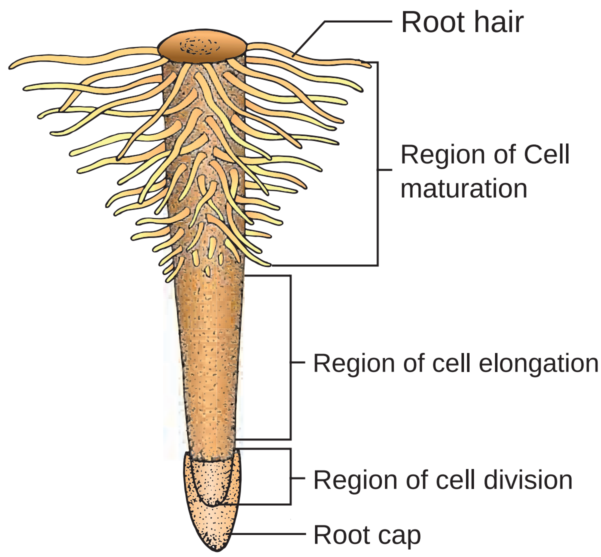


Figure 3.2: Regions of root

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

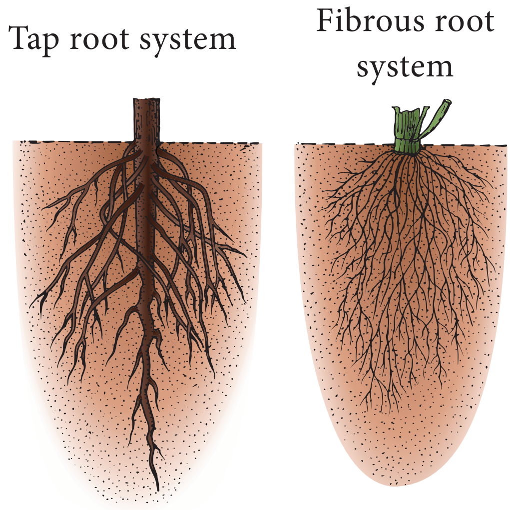


Figure 3.3: Types of root system

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

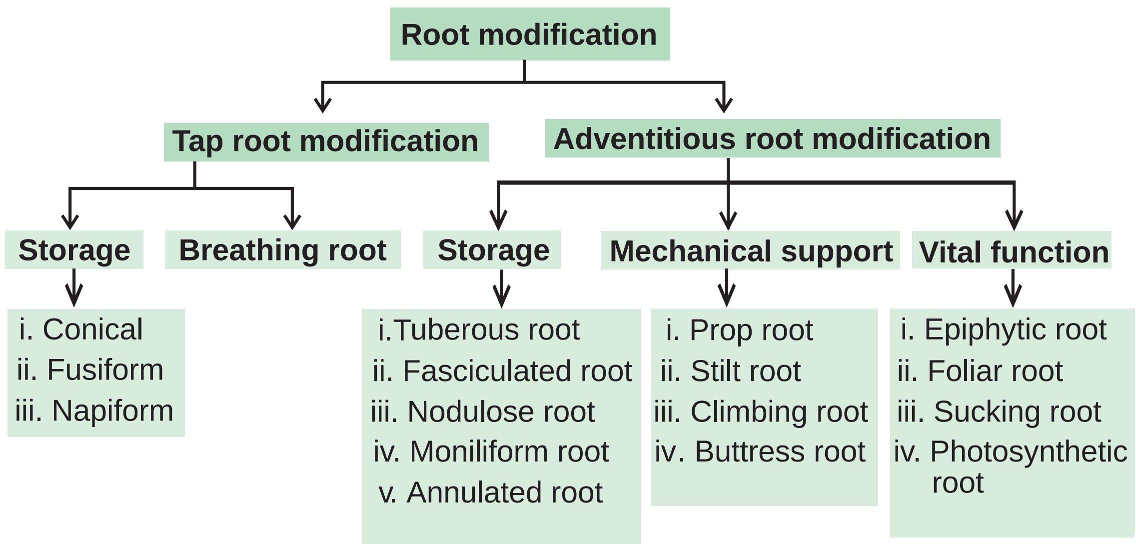
Root performs two kinds of functions namely primary and secondary functions.

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.



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*

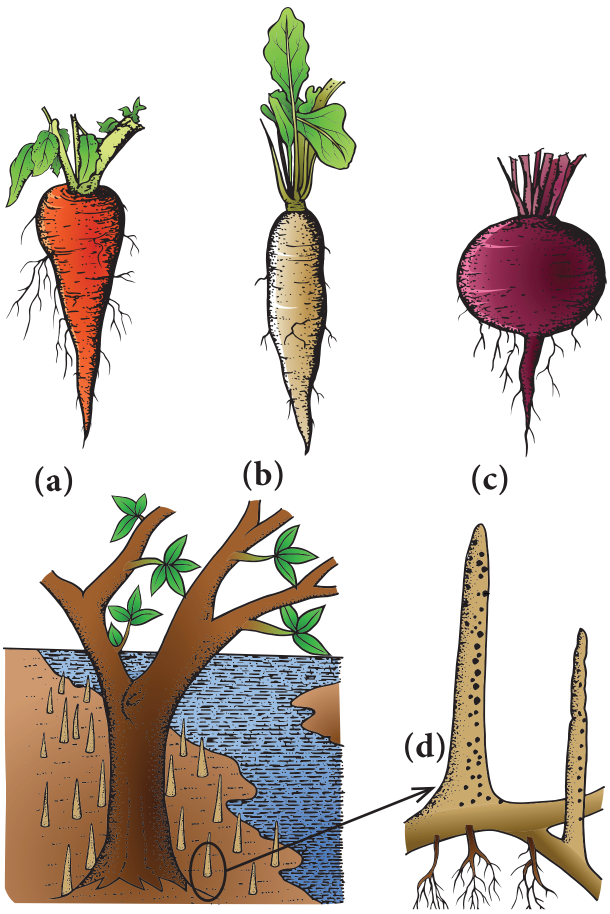


Figure 3.4: Tap root modification
(a) *Daucus carota* **(b)** *Raphanus sativus*
(c) *Beta vulgaris* **(d)** *Avicennia - pneumatophores*

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, Basella* (Indian spinach).

5. Annulated root

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

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, 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: *Bombax ceiba* (Red silk cotton tree), *Ceiba pentandra* (white silk cotton tree), *Terminalia arjuna, Delonix regia, Pterygota alata*.

c. Vital functions

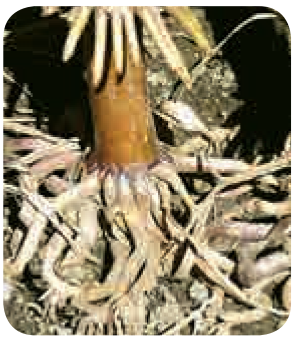
1. Epiphytic or velamen root

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.

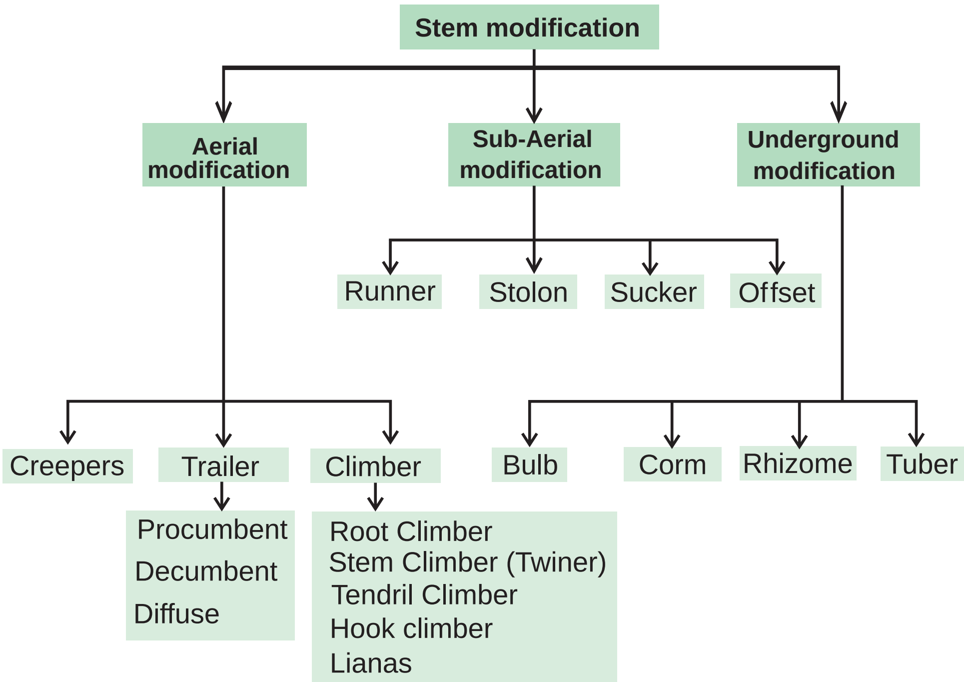
i. Root climbers

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 (figure: 3.17). 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)

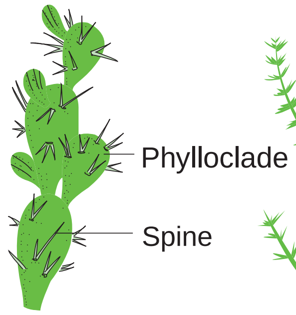
Woody perennial climbers found in tropical forests are lianas. They twine themselves around tall trees to get light. Example: *Hiptage benghalensis, Bauhinia vahlii, Entada pursaetha.*

vi. Tendril climbers

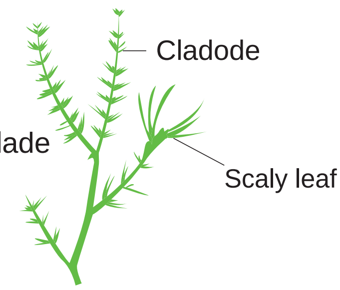
Tendrils are thread-like coiling structures which help the plants in climbing. Tendrils may be modifications of Stem – as in *Passiflora*, *Vitis* and *Cissus quadrangularis;* Inflorescence axis – *Antigonon;* Leaf – *Lathyrus;* Leaflets - *Pisum sativum;* Petiole – *Clematis;* Leaftip – *Gloriosa;* 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, Muehlenbeckia* (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

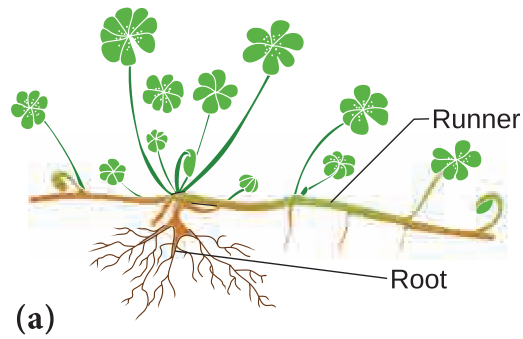
Thorn is a woody and sharp pointed modified stem. Either the axillary bud or the terminal bud gets modified into thorns. In *Carissa* apical bud modified into thorns. In *Citrus* and *Atalantia* axillary bud is modified into thorns.

II. Sub aerial stem modifications

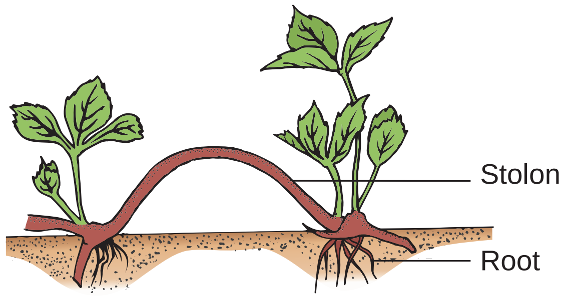
Sub aerial stem found in plants with weak stem in which branches lie horizontally on the ground. These are meant for vegetative propagation. They may be sub aerial or partially sub terranean.

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*).



(a)



(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).

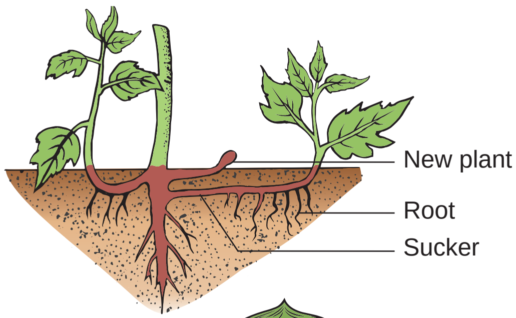
3. Sucker

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)

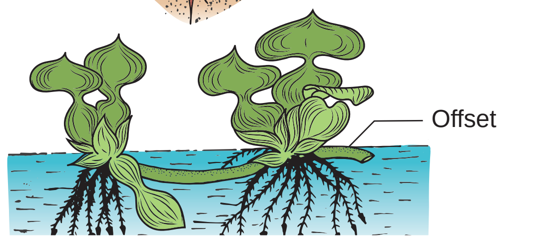


Figure 3.9: **(c)** Sucker-*Chrysanthemum*
(d) Offset-*Eichhornia*

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 an underground stem growing 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. 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 and swollen which is known as **pulvinus.** Example: *Clitoria, Lablab, Cassia, Erythrina, Butea, Peltophorum.*

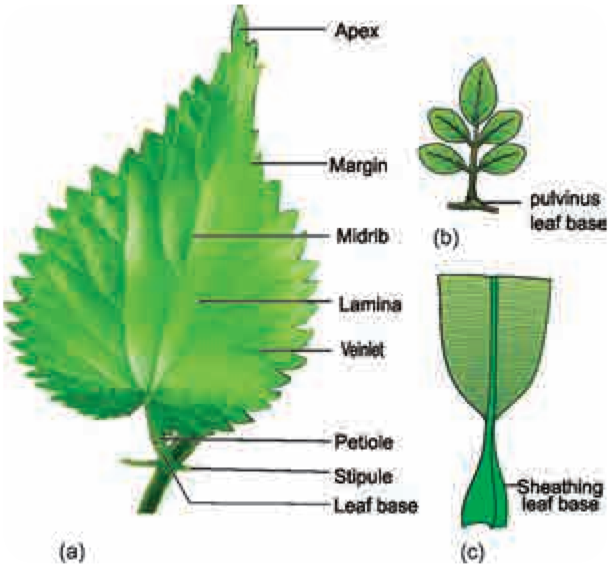


Figure 3.11: (a) Parts of the leaf **(b)** Pulvinus leaf base **(c)** Sheathing leaf base

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.

II. Petiole (stipe or mesopodium)

It is the bridge between lamina 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

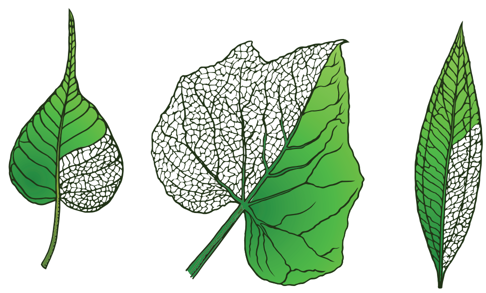
In this type of venation leaf contain a prominent midrib from which several secondary veins arise that branch and anastomose like a network. This type of venation is common in all dicot leaves. It is of two types.

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)

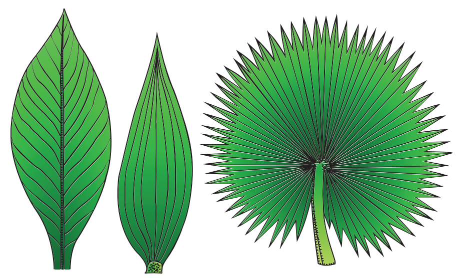
When there is a prominent midrib in the center, from which arise many veins perpendicularly and run parallel to each other. Example: *Musa*, Zinger, *Curcuma, Canna*.

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.

5FPWZA

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*

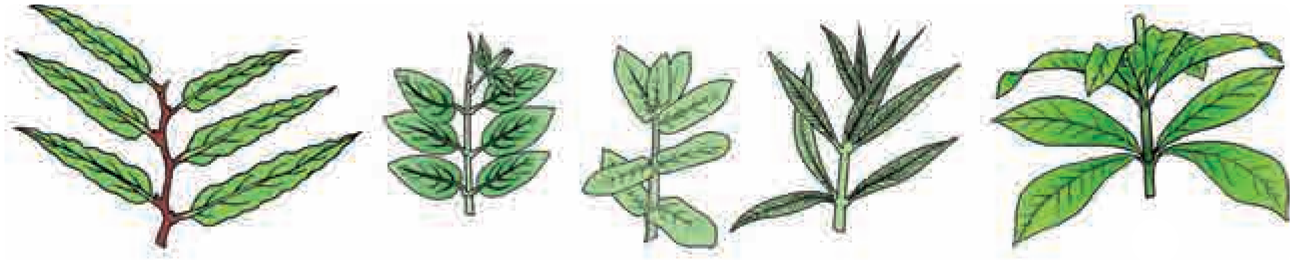


Figure 3.14: Phyllotaxy

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: *Tamarindus*, *Abrus, Sesbania, Saraca, Cassia.*

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

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

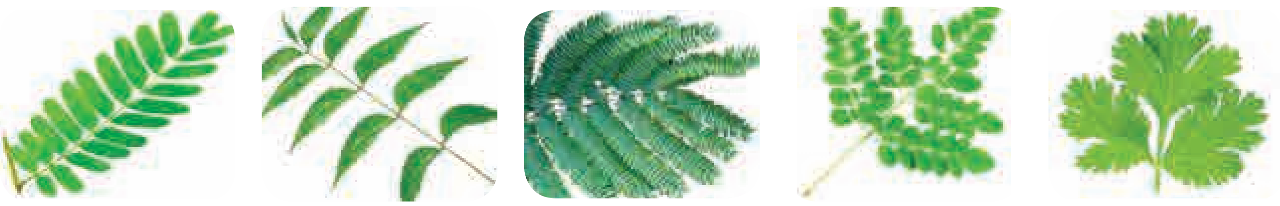
A palmately compound leaf is defined as one in which the petiole bears terminally, one or more leaflets which seem to be radiating from a common point like fingers from the palm.

i. **Unifoliolate:** When a single leaflet is articulated to the petiole is said to be unifoliolate. Example: *Citrus, Des modium 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 *Ceiba pentandra, 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.

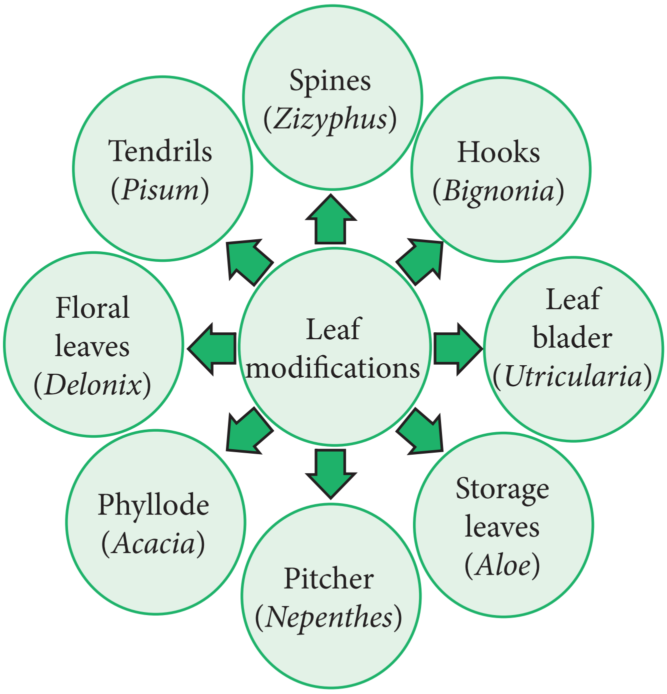
I. Leaf tendrils

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.*

Summary

Flowering plants consist of two major organ systems: Underground root system and aerial root system. Roots perform the functions of anchoring and absorbing nutrients from the soil. However some roots perform additional functions for which they undergo various modifications in shape, form and structure. Tap root continue the growth from the radical which further branches into secondary roots. Adventitious roots arise from different parts of the plant other than radical. Stem helps to display the leaves to get maximum sunlight and positioning flowers and fruits to attract pollination and dispersal agents. Apart from the normal functions the stems are modified to perform various functions such as food storage, perennation and protection. Leaves are exogenous in origin and function as food synthesizing and gaseous exchange sites. Some leaves also perform additional functions for which they are modified in their morphology. Leaves possess vascular tissues in the form of veins which render support to the lamina and help in transport of water, nutrients and food in and out of leaves. Phyllotaxy is the arrangement or distribution of leaves on the stem or its branches in such a way that they receive maximum sunlight to perform photosynthesis.

Activity

1. Collection of medicines prepared from root, stem, leaf of organic plants.
2. Prepare a report of traditional medicines.
3. Classroom level exhibition on Siddha and Ayurvedic medicine prepared from root, leaf, stem.
4. Growing micro greens in class room – project work. (Green seed sprouts)

Evaluation

5FYT1X

1. Which of the following is polycarpic plant?
   a. *Mangifera*
   b. *Bambusa*
   c. *Musa*
   d. *Agave*
2. Roots are
   a. Descending, negatively geotropic, positively phototropic
   b. Descending, positively geotropic, negatively phototropic
   c. Ascending, positively geotropic, negatively phototropic
   d. Ascending, negatively geotropic, positively phototropic
3. *Bryophyllum* and *Dioscorea* are example for
   a. Foliar bud, apical bud
   b. Foliar bud, cauline bud
   c. Cauline bud, apical bud
   d. Cauline bud, foliar bud
4. Which of the following is correct statement?
   a. In *Pisum sativum* leaflets modified into tendrils
   b. In *Atalantia* terminal bud is modified into thorns
   c. In *Nepenthes* midrib is modified into lid
   d. In *Smilax* inflorescence axis is modified into tendrils
5. Select the mismatch pair
   a. *Sagittaria* - Heterophylly
   b. *Lablab* - Trifoliolate
   c. *Begonia* - Leaf mosaic
   d. *Allamanda* - Ternate phyllotaxy

6. Draw and label the parts of regions of root.
7. Write the similarities and differences between
   1. *Avicennia* and *Trapa*
   2. Radical buds and foliar buds
   3. Phylloclade and cladode
8. How root climbers differ from stem climbers?
9. Compare sympodial branching with monopodial branching.
10. Differentiate pinnate unicostate with palmate multicostate venation

Climbers


Root climber - *Piper betel*


Stem climber - *Clitoria*


Thorn climber - *Bougainvillea*


Lianas - *Entada*


Tendril climber - *Cissus quadrangularis*

ICT Corner

Monocot and Dicot plants

Is plants differ **morphologically**?

→

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

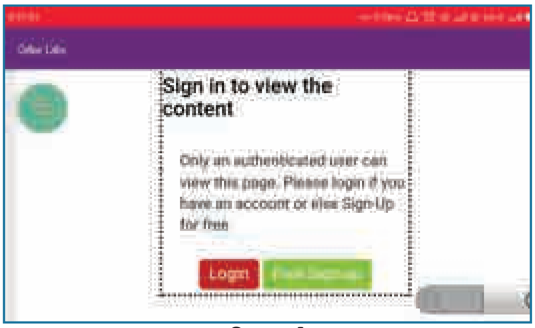
Activity

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

Step 1

Step 2

Step 3



Step 4

URL:

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* Pictures are indicative only