BOTANY

HIGHER SECONDARY - FIRST YEAR

VOLUME - I

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PREFACE

We are passing through an "Era of Biology". Words like "Biotechnology', 'Bioremediation", "Biochips", "Biomineralization", "Bioinformatics" etc. have become familiar even with "common man". Certainly there is a new unusual never-before-tried approach to address and solve many problems associated with modern life and to enhance the quality and standard of living by application of modern tools of Biology; particularly the Genetically Modified Foods (GM Foods) and other GM Products have revolutionized our Life.

Application and exploitation of biological principles has become possible because of extensive knowledge and study of descriptive and functional aspects of living organisms over the years commonly studied under "Biology" which broadly comprises Botany and Zoology. Infact, Botany/Zoology is the 'mother science' of Molecular Genetics, Biochemistry, Microbiology, Molecular Cell Biology, Biochemical Engineering and ultimately Biotechnology, These recent applied fields are natrual outcome of a sound knowledge and study of basic Science, Botany (and of course Zoology). Without the study of structural and functional aspects of Green plants, Fungi, Bacteria, Viruses and their interrelationships, the"modern biology" is not possible. In fact, applied sciences, however 'modern', cannot replace basic sciences.

The notion of 'Boring Botany' with its tasks of memorising 'technical terms', drawing diagrams can be dispensed with if only it is realized that application of the discipline BOTANY has unlimited potentialities in our complicated modern life through what is called Modern Biology.

In this Book, BOTANY, a sincere attempt is made by my colleagues, on the basis of syllabus placed, to provide a simple and lucid account of Botany at the XI Standard.

Each chapter is discussed with simplicity and clarity with Self-Evaluation at the end of each lesson. While preparing for the examination, students should not restrict themselves to the question/problems given in the Self-Evaluvation, they must be prepared to answer the questions and problems from the entire text. Infact, they are advised to refer to 'Reference Books' listed at the end to further their knowledge.

DR. A. JAFFAR HUSSAIN
Chairperson
Text-Book Writing Committee (XI-Bio-Botany)

SYLLABUS : HIGHER SECONDARY - FIRST YEAR - BOTANY

Unit 1 : Biodiversity (20 hours)

Systematics : Two Kingdom and Five Kingdom Systems - Salient features of various Plant Groups (Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms) - Viruses - Bacteria - Algae : Spirogyra - Fungi : Mucor - Bryophyta : Riccia - Pteridophyta : Nephrolepsis - Gymnosperms : Cycas.

Unit 2 : Cell Biology (20 hours)

Cells as the basic Unit of Life - Cell Theory - Prokaryotic and Eukaryotic cells (Plant Cell) - Light Microscope and Electron Microscope (TEM & SEM) - Ultra Structure of Prokaryotic and Eukaryotic Cells - Cell Wall - Cell Membrane (Fluid Mosaic Model) Membrane Transport Model - Cell Organelles : Nucleus, Mitochondria, Plastid, Ribosomes - Cell Divisions : Amitosis, Mitosis and Meiosis and their significance.

Unit 3 : Plant Morphology (10 hours)

Structure and modifications of Root, Stem and Leaf - Structure and types of Inflorescences - Structure and types of flowers, fruits and seeds

Unit 4 : Genetics (10 hours)

Concept of Heredity and Variations - Mendel's Laws of Inheritance - Chromosomal basis of Inheritance - Intermediate Inheritance (incomplete Dominance) - Epistasis

Unit 5 : Plant Physiology (30 hours)

Cell as physiological unit - Properties of Protoplasm - Water relations - Absorption and movement - Diffusion, Osmosis, Plasmolysis - Theories of Water Transport - Root pressure - Transpiration pull - Factors affecting rate of Transpiration - Mechanism of Stomatal opening and closing - Potassium ion theory - Factors affecting Stomatal movement - Functions of Minerals - Essential major elements and trace elements - Deficiency symptoms of elements - Theories of Translocation - Translocation of Solutes - Nitrogen Metabolism and Biological Nitrogen Fixation Movements - Geotropism - Phototropism - Turgor Growth Movements - Tropic - Nastic & Nutation.

Unit 6 : Reproduction Biology (30 hours)

Modes of Reproduction in Angiosperms - Vegetative propagation (natural and artificial) - Micropropagation - Sexual Reproduction - Pollination : types - Double fertilization - Development of male and female gametophytes - Development of Dicot Embryo - Parthenogenesis and Parthenocarpy - Germination of Seeds - Parts of Seed - Types of Germination - Abscission & Senescence.

Unit 7 : Environmental Biology (20 hours)

Organisms and environment as factors : Air, Water, Soil, Temperature, Light and Biota - Hydrophytes, Mesophytes, Xerophytes and their adaptations - Natural Resources Types, use and misuse - Conservation of water (RWH) - Ecosystems: (a) Structure & Function, (b) Energy flow, (c) Decomposition, (d) Nutrient Cycling, (e) Major Biomes, Forests - Grasslands, Deserts - Ecological Succession : Mechanism & Types (Hydrosere & Xerosere).

Unit 8 : Practical Work (30 periods)

1. **Study of the following plants through specimens and slides and labelled sketches in the Botany Record Book**
   - 1.1 Spirogyra
   - 1.2 Mucor
   - 1.3 Riccia
   - 1.4 Neprolepsis
   - 1.5 Cycas

2. **Study of the plant cells**
   - 2.1 Onion peel : Observe in the microscope and draw labelled sketches
   - 2.2 Hydrilla leaves whole mount in pond water : observe and draw labelled sketches
   - 2.3 Squash preparation of onion root tip : Observe stages of Mitosis and draw labelled sketches

3. **Study of modifications of stem and root and draw labelled sketches**
   - 3.1 Undderground root modifications : Radish, Carrot, Beet-root
   - 3.2 Aerial roots : Banyan Prop Roots - Climbiung Root of piper betel
   - 3.3 Underground stem modifications : Potato, Ginger, Onion, Yams

4. **Flower : Structure, Vertical Section, Floral Diagram and Floral Form of the following**
   - 4.1 Hibiscus
   - 4.2 Datura

5. Physiology Experiments

5..1 Transpiration

(a) Transpiration pull

(b) Ganong's Potometer

5.2 Osmosis

(a) Osmometer - using semipermeable plant memabrane

(b) Potato Osmometer

5.3 Root Pressure : Experiment to demonstrate root pressure in Dicots

6. Germination of Seeds

6.1 Hypogeal type

6.2 Epigeal type (students to do project work)

7. Hydrophytes & Xerophytes

7.1 To study the specimens and write to note

(a) Hydrophytes : Hydrilla / Vallisneria, Eichhornia, Pistia

(b) Xerophytes : Opuntia, Euphorbia tirucalli, E. antiquorum, Aloe, Nerium.

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I. BIODIVERSITY

1. Systematics

Diversity in living organisms

There is a great diversity among living organisms found on the planet earth. They differ in their structure, habit, habitat, mode of nutrition, and physiology. The Biodiversity of the earth is enormous. Current estimates suggest that the earth may have anywhere from 10 to over 40 million species of organisms, but only about 1.7 million have actually been described including over 7,50,000 insects, about 2,50,000 flowering plants and 47,000 vertebrate animals. We call such a diversity among living organisms as **Biodiversity**. Even though there is such a variety and diversity among them, the living organisms show a lot of similarities and common features so that they can be arranged into many groups. In order to understand them and study them systematically, these living organisms, mainly the plants and animals are grouped under different categories.

The branch of biology dealing with identification, naming and classifying the living organisms is known as **Taxonomy**. Taxonomy in Greek means rendering of order. The word **Systematics** means to put together. It was **Carolus Linnaeus** who used this word first in his book '**Systema Naturae'**. Systematics may be defined as the systematic placing of organisms into groups or **taxa** on the basis of certain relationships between organisms.

Need for Classification

It is not possible for any one to study all the organisms. But if they are grouped in some convenient way the study would become easier as the characters of a particular group or a family would apply to all the individuals of that group. Classification allows us to understand diversity better.

History of Classification

In the 3rd and 4th century BC **Aristotle** and others categorized organisms into plants and animals. They even identified a few thousands or more of living organisms.

Hippocrates (460-377 BC), the Father of Medicine listed organisms with medicinal value. **Aristotle** and his student **Theophrastus** (370-282 BC) made the first attempt to classify organisms without stressing their medicinal value. They tried to classify the plants and animals on the basis of their form and habitat. It was followed by **Pliny the Elder** (23-79 AD) who introduced the first artificial system of classification in his book '**Historia Naturalis'**. **John Ray** an English naturalist introduced the term species for the first time for any kind of living things. It was then **Carolus Linnaeus** the Swedish naturalist of 18th century now known as Father of Taxonomy developed the **Binomial System of nomenclature** which is the current scientific system of naming the species. In his famous book '**Species Plantarum'**(1753) he described 5,900 species of plants and in "**systema Naturae'**(1758) he described 4200 species of animals.

Taxonomy and Phylogeny

Taxonomy is the branch of biology that deals with identification and nomenclature (naming) of living organisms and their classification on the basis of their similarities and differences. It was the Swiss-French botanist **Augustin-Pyramus de Candolle**(1778-1841) who coined the word Taxonomy, the science of naming and classifying of organisms.

Species

Species is the basic unit of Classification. It is defined as the group of individuals which resemble in their morphological and reproductive characters and interbreed among themselves and produce fertile offsprings.

Species are then grouped into more inclusive taxa, which are grouped into larger taxa so that the classification is a hierarchy of a system of units that increase in inclusiveness from each level to the next higher level. The seven main categories used in any plan of classification are given below.

1. Kingdom
2.Phylum or Division
3.Class
4.Order
5.Family
6.Genus
7.Species

Phylogeny

The evolutionary history of a particular taxon like species is called phylogeny. The classification based on the basis of evolution is called phylogenetic classification. Phylogenetic classification is not always possible since there are several gaps in the fossil records which form the basis of phylogenetic studies and also evolution is never unidirectional. Classification not explicitly based on evolutionary relationships is called artificial, for example, organisms are grouped according to usefulness (economic plants) size (herbs, shrubs) colour (flowers) ecological role (ground cover) and so-forth. Nevertheless many biologists make use of this non-systematic classification.

Two Kingdom System of Classification

Carolus Linnaeus(1758) divided all the living organisms into two kingdoms.

1. **Kingdom Plantae**
2. **Kingdom Animalia**

1. Kingdom Plantae:

This kingdom includes bacteria(Prokaryotes), photosynthetic plants and non - photosynthetic fungi. The characteristic features of this kingdom are:

1. Plants have branches, asymmetrical body with green leaves.
2. Plants are non motile and fixed in a place.
3. During the day time plants more actively involve in photosynthesis than in respiration and hence take more of CO_2 and liberate O_2 & during night O_2 is taken in and CO_2 is liberated.
4. They are autotrophic in their mode of nutrition since they synthesize their own food.
5. Plants have growing points which have unlimited growth.
6. Excretory system and nervous system are absent.
7. Reserve food material is starch.
8. Cells have a cell wall. Cells have a lager vacuole. Plant cells lack centrosome and they may have inorganic crystals.
9. Reproduction takes place with help of agents such as air, water and insects. Asexual and vegetative method of reproduction is also not uncommon.

2. Kingdom Animalia

This kingdom includes unicellular protozoans and multi-cellular animals or metazoans. They are characterized by

1. Definite shape of the body and absence of branches.
2. Ability to move from place to place.

3. During day and night take in O_2 and release CO_2 i.e only respiration takes place and there is no photosynthesis.
4. Holozoic mode of nutrition since no chlorophylls present and hence they are heterotrophs.
5. Growth is limited in animals. Growth stops after attaining a particular size and age.
6. Excretory system and nervous system are well developed.
7. Reserve food material is glycogen.
8. Lacks cell wall. They have small vacuoles. Centrosomes are present. Cells do not have inorganic crystals.
9. Animals do not depend on any external agents for sexual reproduction. Regeneration of body parts and asexual reproduction is found only in lower organisms.

Limitations of Two Kingdom System of Classification

The two kingdom system of Classification proposed by Linnaeus has been in use for a long time. But later it proved to be inadequate and unsatisfactory in view of new information and discoveries about the lower forms of organisms. The following are the shortcomings of the two kingdom system of classification.

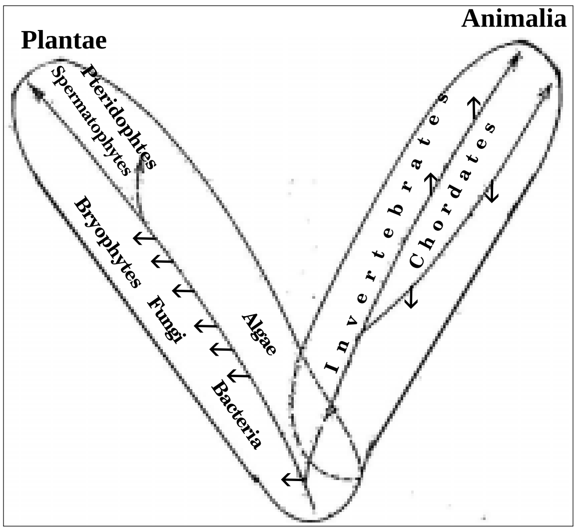


Fig: 1.1. Diagrammatic representation of Two Kingdom System

1. Certain organisms share the characteristics of both plants and animals. eg. Euglena and Sponges. In Euglena, some species have chlorophyll and are autotrophic like plants. However like animals they are dependent on an external supply of vitamins B, and B_{12} which they cannot synthesize themselves. A few species of Euglena lack chloroplasts and are therefore colourless and non-photosynthetic (heterotrophic). They have a saprotropic mode of nutrition, carrying out extra-cellular digestion.

Other colorless forms ingest small food particles and carryout intracellular digestion (holozoic nutrition). If green species of Euglena are kept in darkness they lose their chloroplasts and become colourless and survive saprotrophically. Chloroplasts return when the organisms are returned to light. Euglena is also characterized by the presence of an animal pigment **astaxanthin** in the eye spot.

2. Fungi are a group of organisms which have features of their own. They lack chlorophyll. They are heterotrophic like animals. They are placed along with green plants.
3. Many primitive organisms such as bacteria did not fit into either category and organisms like slime moulds are amoeboid but form fruiting bodies similar to fungi.
4. The status of virus whether they are living or non living is a point of debate even to -day.

For all these reasons the two hundred and fifty years old Linnaeus system of classifying organisms into two rigid groups animals and plants is considered highly arbitrary and artificial.

The Five Kingdom System of Classification

In order to suggest a better system of classification of living organisms, **R.H. Whittaker** (1969) an American Taxonomist divided all the organisms into 5 kingdoms based on their phylogenetic relationships. This classification takes into account the following important criteria.

1. Complexity of Cell structure – prokaryote to Eukaryote
2. Mode of nutrition – autotrophs and heterotrophs
3. Body organization -unicellular or multi-cellular
4. Phylogenetic or evolutionary relationship

The Five kingdoms are **Monera, Protista, Fungi, Plantae** and **Animalia.**

1. Monera

The Kingdom of Prokaryotes

This kingdom includes all prokaryotic organisms i.e. mycoplasma, bacteria, actinomycetes(filamentous bacteria) and cyanobacteria (blue green Algae). They show the following characters.

1. They are microscopic. They do not possess a true nucleus. They lack membrane bound organelles.

2. Their mode of nutrition is autotrophic or heterotrophic. Some bacteria are autotrophic and are photosynthetic. i.e. they can synthesize their organic food in the presence of sunlight eg. ***Spirillum***. Some bacteria are chemosynthetic i.e. they can synthesize their organic food by deriving energy from some chemical reactions. eg. ***Nitrosomonas*** and ***Nitrobacter*.**
3. Many other bacteria like ***Rhizobium***, ***Azotobacter*** and ***Clostridium*** can fix atmospheric nitrogen into ammonia. This phenomenon is called **Biological Nitrogen Fixation** .
4. Some bacteria are parasites and others live as symbionts.
5. Some monerans like Archaebacteria can live in extreme environmental conditions like absence of oxygen (anaerobic), high salt condition, high temperature like 80^0c or above and highly acidic soils.

2. Kingdom Protista

This kingdom includes eukaryotic unicellular mostly aquatic cells. They show the following characters.

1. They have a typical Eukaryotic cell organization.
2. They often bear cilia or flagella for locomotion. Most of them are photosynthetic autotrophs. They form the chief producers of food in oceans and in fresh water. All unicellular plants are collectively called as phytoplanktons and unicellular animals as zooplanktons. Phytoplanktons are photosynthetically active and have cell wall.
3. Zooplanktons are mostly predatory. They lack cell wall and show holozoic mode of nutrition as in Amoeba.
4. Some protists are parasitic. Some are symbionts while others are decomposers.

Euglena, a protozoan has two modes of nutrition. In the presence of sunlight it is autotrophic and in the absence of sunlight it is heterotrophic. This mode of nutrition is known as **myxotrophic** and hence they form a border line between plants and animals and can be classified in both.

3. Kingdom Fungi

This kingdom includes moulds, mushrooms, toad stools, puffballs and bracket fungi. They have eukaryotic cell organization. They show the following characteristics.

1. They are either unicellular or multi-cellular organisms.

2. Their mode of nutrition is heterotrophic since they lack the green pigment chlorophyll. Some fungi like ***Puccinia*** are parasites while others like ***Rhizopus*** are saprotrophic and feed on dead organic matter.
3. Their body is made up of numerous filamentous structures called hyphae.
4. Their cell wall is made up of chitin.

4. Kingdom Plantae

It includes all multi-cellular plants of land and water. Major groups of **Algae, Bryophytes, Pteridophytes, Gymnosperms** and **Angiosperms** belong to this kingdom. It shows the following characteristics.

1. The cells have a rigid cell wall made up of cellulose.
2. They show various modes of nutrition. Most of them are autotrophs since they have chlorophyll. Some plants are heterotrophs. For eg. ***Cuscuta*** is a parasite. ***Nepenthes*** and ***Drosera*** are insectivorous plants.

5. Kingdom Animalia

This kingdom includes all multi-cellular eukaryotic organisms. They are also referred to as metazoans. They show the following characteristic features.

1. All animals show heterotrophic mode of nutrition. They form the consumers of an ecosystem.
2. They have contractibility of the muscle cells.
3. They can transmit impulses due to the presence of nerve cells.
4. Some groups of animals are parasites eg. tapeworms and roundworms.

Merits of the Five Kindom Classification

1. It shows the phylogenetic relationships among the organisms.
2. It is based on the complexity of the cell structure from prokaryotic to eukaryotic cell organization.
3. It is based on the complexity of body organization from unicellular to multi-cellular.
4. It is based on the modes of nutrition: autotrophic or heterotrophic mode of nutrition.

Demerits of Five Kingdom Classification

1. ***Chlamydomonas*** and ***Chlorella*** are included under the kingdom Plantae. They should have been included under kingdom Protista since they are unicellular.

2. Animal protozoans are not included along with animals.
3. Animal protozoans are included under the kingdom Protista which include unicellular plants. They show different modes of nutrition.
4. Yeasts, though unicellular eukaryotes, are not placed in the kingdom Protista.

Table : 1.1

Major differences among five kingdoms in the Five Kingdom System of Classification:

Property	**Monera**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell organization	Mostly unicellular	Mostly unicellular	Multicellular and unicellular	Mostly Multicellular	Mostly Multicellular
Cell wall	Present in most	Present in some: absent in others	Present	Present	absent
Nutritional class	Phototrophic,heterotrophic or chemoautotrophic	Heterotrophic and phototrophic	Heterotrophic	phototrophic	Heterotrophic
Mode of nutrition	Absorptive	Absorptive or ingestive	Absorptive	Mostly Absorptive	Mostly ingestive
Motility	Motile or non motile	Motile or nonmotile	Nonmotile	Mostly nonmotile	Mostly Motile

Difficulties in classification

Since living organisms exhibit great variety and diversity and also they have evolved through millions of years and there are many missing links between groups, it is very difficult to have a clear cut and well defined classification. Biological classification reflects the state of our knowledge. It changes as we acquire new information. By the 1970s molecular biologists realized that prokaryotes consist of two different and unrelated groups. To accommodate this new information three microbiologists, **C.Woese**, **O.Kandler**, and **M.L Wheelis** introduced a new classification scheme in 1990. They proposed that all organisms be divided into three major groups called **domains:** the **Eucarya** (containing all eukaryotes), the **Bacteria** (containing most familiar prokaryotes), and the **Archaea** (originally called archaebacteria and containing prokaryotes that live mostly in extreme environments.) This scheme is currently accepted by most biologists.

Classification will undoubtedly continue to change.

SELF EVALUATION

One Mark

Choose the correct answer

1. The basic unit of classification is

   a. genus b.species c.family d.taxon

2. Unicellular plants found floating in oceans and freshwater are called

   a. algae b.zooplanktons c.phytoplanktons d.epiphytes

3. Carolus Linnaeus proposed the following system of classification

   a. Phylogenetic b. Two kingdoms c. Five Kingdoms d. Natural

Fill in the blanks

1. "Systema Naturae" is written by______________
2. Father of Ayurveda is________________
3. __________ introduced the term species for the first time.
4. The author of "Species Plantarum" is ____________
5. __________ coined the word Taxonomy.

Match the following

Fossil records	- Five kingdom System
Whittaker	- Species
Carolus Linnaeus	- Taxonomy
John Ray	- Phylogenetic studies
Augustin de Candolle	- Species Plantarum

Two Marks

1. Define biodiversity.
2. What are the aims of classification?
3. Define Taxonomy.
4. Define species.
5. Write the hierarchy of the units of classification.
6. Define phylogeny.
7. Give any two reasons why phylogenetic classification is not always possible?
8. What is meant by phylogenetic classification?
9. What is meant by artificial system of classification? Give example.
10. What are Archaebacteria?
11. Name the three domains according to the modern classification proposed by C.Woese, O.Kandler and M.C.Wheelis.
12. Define systematics.

Five Marks

1. List the differences between plants and animals.
2. How do you justify a separate kingdom status for fungi.
3. What are the difficulties encountered in classifying Euglena?

Ten Marks

1. Discuss the Five kingdom system of classification. List it's merits and demerits.
2. Discuss the Two kingdom system of classification. List it's merits and demerits.

2. Salient Features of Various Groups

2.1 Viruses

Introduction

Viruses are still biologists' puzzle because they **show both living and non-living characters**. Hence viruses are regarded as a separate entity. It is not taken into account in Whittaker's five kingdom classification. Viruses are now defined as ultramicroscopic, disease causing intra cellular **obligate parasites**.

Brief history of discovery

Viruses were not known to biologists for a long time due to their ultramicroscopic structure though their presence was apparent by infectious diseases which were proved not due to bacteria. It attracted the attention of investigators only in the 19th century when a virus called **tobacco mosaic virus (TMV**) caused severe damage to commercially important tobacco crop.

Table : 1.2. Enigma of Viruses

Living characteristics of virus	Non-living characteristics of virus
1. Ability to multiply inside a host plant or animal cell	Inability to multiply extra cellularly
2. Ability to cause diseases	Absence of any metabolic activity
3. Possession of nucleic acid, protein, enzyme, etc.	Absence of protoplasm
4. Ability to undergo mutation	Can be crystallized.

Mayer demonstrated that the disease could be transmitted just by applying the sap of infected leaf to the leaf of healthy plant. He thought that the disease was due to a bacterium. It was then the Russian biologist **Iwanowsky** (1892) who demonstrated that the sap of infected leaves even after passing through bacterial filter remained infective, ruling out the bacterium as the causative agent. Dutch microbiologist **Beijerinc**k (1898) confirmed the findings of **Iwanowsky** and called the fluid **"contagium vivum fluidum**" which means contagious living fluid. This was later on called virion (poison) and the disease causing agent as virus. **W.M. Stanley** (1935), the American biochemist, isolated virus in crystalline form and demonstrated that even in that state it maintained the infectivity. This marked the beginning of a new branch of science called **virology.**

General characteristics

Viruses are ultramicroscopic and can cause diseases in plants and animals. They are very simple in their structure. They are composed of **nucleic acid** surrounded by a **protein coat**. Nucleic acid can be **either RNA or DNA**, but never both. They have no cellular organization and have no machinery for any metabolic activity. They are obligate intracellular parasites and they multiply within their host cells. Once outside the host cell they are completely inactive.

Size and Shape

Viruses are very minute particles that they can be seen only under electron microscope. They are measured in millimicrons (1 millimicron = 1/1000micron). (1micron – 1/1000 millimeter). Generally they vary from 2.0 mm to 300 mm in size.

Very small size and ability to pass through bacterial filters are classic attributes of viruses. The following methods are used to determine the size of the viruses.

1. Direct observation by using electron microscope:
2. Filtration through membranes of graded porosity: In this method viruses are made to pass through a series of membranes of known pore size, the approximate size of any virus can be measured by determining which membrane allows the virus to pass through and which membrane holds it back.
3. Sedimentation by ultra centrifugation : The relationship between the size and shape of a particle and its rate of sedimentation permits determination of particle size.
4. Comparative measurements: The following data is used for reference.

a*. *Staphylococcus has a diameter of 1000 mm.

b. Bacteriophage varies in size from 10-100 nm.

Broadly speaking viruses occur in three main shapes:

1. **Cubic symmetry**: polyhedral or spherical – eg. **Adeno virus, HIV**
2. **Helical symmetry**: e g . ***Tobacco Mosaic virus* (TMV)*, Influenza virus***.
3. **Complex or atypical** eg. **Bacteriophage, Pox virus**.

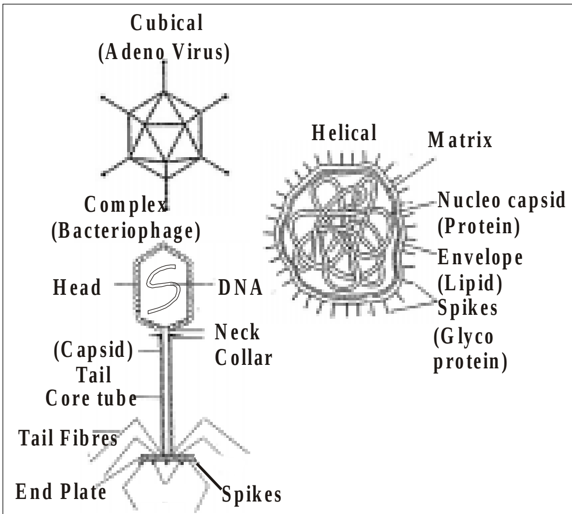


Fig. 1.2 Different shapes of Viruses

Structure of a virus

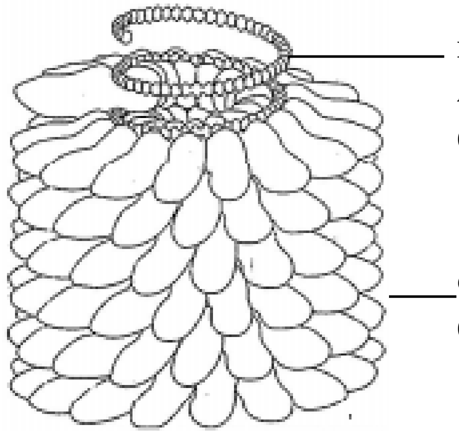


Fig.1. 3 Basic components of a virus (TMV)

A virus is composed of two major parts 1.**Capsid** (the protein coat) 2.**Nucleic acid**. The capsid is the outer protein coat. It is protective in function. It is often composed of many identical subunits called **capsomeres**. Some of the viruses have an outer covering called **envelope** eg. HIV. They are called enveloped viruses. Others are called naked viruses or non- enveloped viruses. The capsid is in close contact with the nucleic acid and hence known as **nucleocapsid.** The nucleic acid forms the central core. Unlike any living cell a virus contains either DNA or RNA, but never both. The infective nature of the virus is attributed to the nucleic acid while host specificity is attributed to the protein coat.

Virion

An intact, infective virus particle which is non-replicating outside a host cell is called virion.

Viroids

A viroid is a circular molecule of ss RNA without a capsid. Viroids cause several economically important plant diseases, including Citrus exocortis.

Prions(pronounced "preeons")

They are proteinaceous infectious particles. They are the causative agents for about a dozen fatal degenerative disorders of the central nervous systems of humans and other animals. *eg. Creutzfeldt-Jacob Disease(CJD), Bovine Spongiform Encephalopathy (BSE)-Commonly known as mad cow disease, etc* .They are very unique among infectious agents because they contain no genetic material i.e DNA/RNA. Stanley Prusiner did most of the work on prions and was awarded Nobel Prize in 1998.

Classification of virus

Although viruses are not classified as members of the five kingdoms, they are diverse enough to require their own classification scheme to aid in their study and identification.

According to the type of the host they infect, viruses are classified mainly into the following four types.

1. Plant viruses including algal viruses-RNA/DNA

2.Animal viruses including human viruses-DNA/RNA

3.Fungal viruses(Mycoviruses)-ds RNA

4.Bacterial viruses (Bacteriophages) including cyanophages-DNA

1.Plant viruses

They infect plants and cause diseases. Some common plant viral diseases are:

a. Mosaic diseases of tobacco (TMV), cucumber (CMV), cauliflower.

b. Bunchy top of banana

c. Leaf-roll of potato

d. Spotted wilt of tomato

Generally, plant viruses have RNA with the exception of some viruses such as cauliflower mosaic virus which has DNA.

2. Animal viruses

They infect animals and cause diseases. The nucleic acid is either DNA or RNA. some of the diseases caused by viruses in human beings are: common cold, measles, small pox (now extinct) chicken pox, Jaundice, herpes, hapatitis A B,C,D,E,G, influenza, polio, mumps, rabies, AIDS and SARS. Viruses also cause diseases in cattle. eg. Foot and mouth disease. (FMD) in cattle, encephalomyelitis of horse, distemper of dog, rabbies etc.

3. Viruses that cause diseases in fungi are called **mycophages** and viruses that attack blue green algae/cyanobacteria and cause diseases are called **cyanophages.**

4. Bacteriophages

Virus that infects bacteria is called **bacteriophage** or simply **phage**. It is tadpole like and the nucleic acid is DNA eg. T_2, T_4, T_6 bacteriophages.

Life cycle of a phage

Phages exhibit two different types of life cycle.

1. Virulent or lytic cycle

2. Temperate or lysogenic cycle.

1. Virulent or lytic cycle

Intra cellular multiplication of the phage ends in the lysis of the host bacterium and the release of progeny **virions**. Replication of a virulent phage takes place in the following stages.

1. Adsorption 2.Penetration 3.Synthesis of phage components 4.Assembly 5.Maturation 6.Release of progeny phage particles

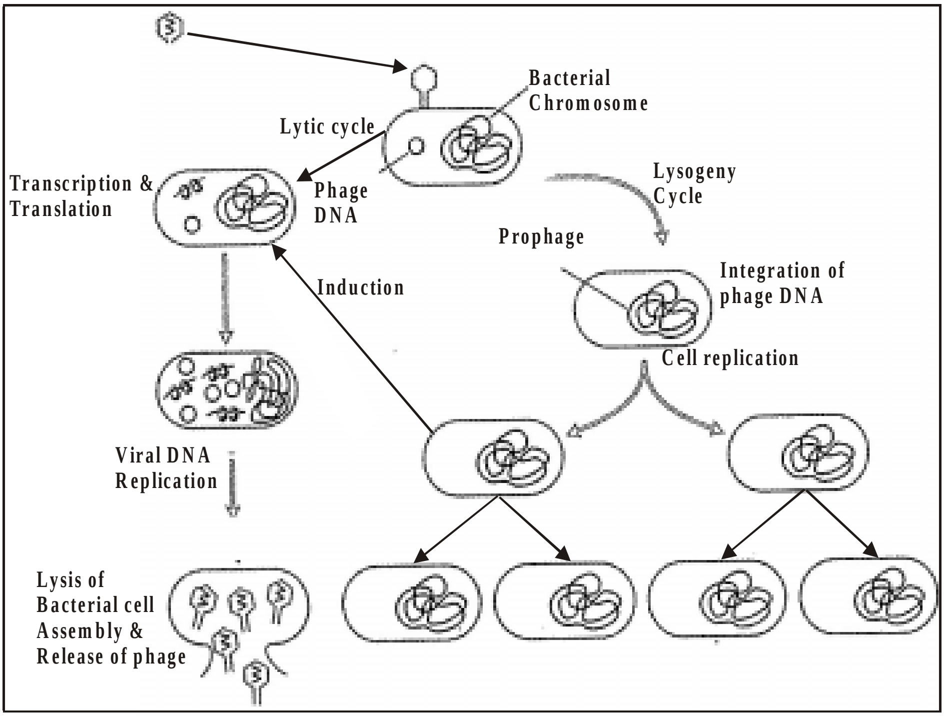


Fig.1.4 Lytic and Lysogenic cycle of a phage

1. Adsorption

The attachment of the phage to the surface of a susceptible bacterium by means of its tail is called adsorption. Host specificity of the phage is determined in the adsorption stage of the cycle itself. Artificial injection by direct injection of phage DNA can be achieved even in strains of bacteria that are not susceptible to the phage. The infection of a bacterium by the naked phage nucleic acid is known as **transfection**.

2. Penetration

The process of penetration resembles injection through a syringe. The phage DNA is injected into the bacterial cell through the hollow core. After penetration the empty head and the tail of the phage remain outside the bacterium as the shell.

3.Synthesis of phage components

During this stage synthesis of bacterial protein, DNA, and RNA ceases. On the other hand, phage DNA, head protein and tail protein are synthesized separately in the bacterial cell. The DNA is compactly '**packaged**' inside the polyhedron head and finally the tail structures are added.

4. The **assembly** of phage components into mature infectious phage particle is known as **(5) Maturation.**

6. Release of phages

Release of phages typically takes place by the **lysis** of the bacterial cell. During the replication of phages, the bacterial cell wall is weakened and it assumes a spherical shape and finally burst or lyse. Mature daughter phages are released.

Lysogenic cycle

The temperate phages enter into a symbiotic relationship with the host cells. There is no death or lysis of the host cells. Once inside the host cell the temperate phage nucleic acid becomes integrated with the bacterial genome. Now the integrated phage nucleic acid is called a **prophage**.

The prophage behaves like a segment of the host chromosome and replicates along with it. This phenomenon is called **lysogeny**. The bacterium that caries a prophage within its genome is called **lysogenic bacterium**.

The prophage confers certain new properties on the bacterium. This is called **lysogenic conversion** or **phage conversion**. An example is toxin production by the **Diptheria bacillus** which is determined by the presence of prophage beta. The elimination of prophage abolishes the toxigenicity of the bacillus.

Plant viral disease

Bunchy top of banana

Banana bunchy top virus causes this disease. The infected plant shows extremely stunted growth. Leaves become short and narrow. Affected leaves are crowded in a **rosette** like fashion (bunch of leaves) at the top of the plant. **Chlorosis** and curling of the leaves also occur. Diseased plants should immediately be uprooted and burnt to avoid further infection.

Emerging viral infections**(in human beings)**

Recent examples of emerging viral infections in different regions of the world include ebola virus, HIV, dengue, hemorrhagic fever, lassa fever, Rift valley fever, SARS.

AIDS: (Acquired Immuno Deficiency Syndrome) is a recently discovered sexually transmitted virus disease. It is caused by **Human Immuno Deficiency Virus (HIV).**

HIV belongs to a group of viruses called **retroviruses**. It infects the T_4 lymphocytes known as **helper cells** which form the main line of body immune system. HIV kills the **T_4 lymphocytes** and the resulting depletion of T_4 cell population creates an immune deficiency. This paves way for many opportunistic pathogens to attack. AIDS by itself is not a killer disease. It is only the other opportunistic pathogens which kill the infected persons.

Symptoms

HIV infection causes fever, loss of body weight, persistent generalized lymph node enlargement and opportunistic infections like T.B . etc. The AIDS patients may also have headache, fatigue, persistent diarrhoea, dry cough, lymphomas and damage of the central nervous system. Often there is appearance of thrush in the mouth and throat and night sweats. Changes in behaviour and mental illness may also occur.

Mode of infection

Primarily HIV is sexually transmitted. It is predominant among homosexuals. Persons with veneral diseases, persons who have many sexual partners and prostitutes will have more chances of HIV infection. The commonest method of transmission is through sexual intercourse with many persons.

The other methods of transmission are during blood transfusion, tissue or organ donation of HIV infected persons to healthy persons, injections with unsterilized syringes and needles and shared needles by drug addicts. AIDS can spread from infected mother to the child during pregnancy or through breast feeding.

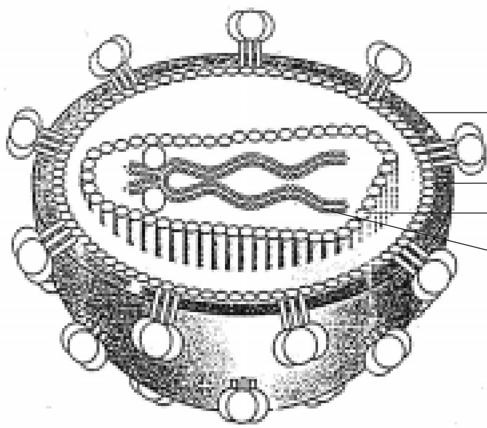


Fig : 1.5 Human Immuno Deficiency Virus

Prevention

Since there is no cure for AIDS the best approach to control AIDS is prevention. Reduction of sexual promiscuity and adoptions of prophylactic measures (such as the use of condoms) can reduce transmission through sexual intercourse. Transmission through the shared needles by drug addicts may be reduced by proper education. The transmission through blood transfusion may be eliminated by proper serological screening of donated blood for the presence of HIV antibodies. Transmission from infected mother to child can be reduced by preventing or terminating pregnancy. Drugs like **AZT** (azidothymidine) only help to increase the life span of the victim by few a months and do not offer complete cure for the disease.

Viruses and cancer

Cancer is an uncontrollable and unorganized growth of cells causing malignant tumour. The cells of this tumours have the capacity to spread indiscriminately anywhere in the body. In recent years, there has been increasing evidence to prove that the cancer is caused by the DNA virus called **Simian virus (SV-40)** and a group of RNA viruses called retroviruses. The cancer causing viruses are also called **oncogenic** viruses. It is now believed that some viruses are involved in leukemia, sarcoma and some kind of breast cancer also.

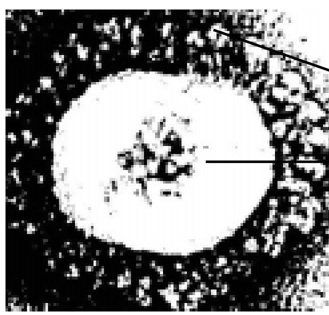


Fig: 1.6 Human CoronaVirus

A new disease called SARS

Severe Acute respiratory Syndrome (SARS) is a respiratory illness that has recently been reported in South East Asia, North America and Europe.

It has created panic among the people all over the world and has resulted in great economic loss for many countries like China, Singapore etc.

Symptoms

It begins with high fever. Other symptoms include headache, discomfort and body aches. Patient may develop dry cough and have trouble in breathing.

How SARS spread

It appears to spread by person to person contact especially with infectious material (for example respiratory secretions.)

The viruses that cause SARS are constantly changing their form which will make developing a vaccine difficult. SARS is caused by a group of viruses called **corona viruses** which are **enveloped** viruses. Their genome is single stranded RNA. The nucleocapsid is helical. These viruses have petal shaped surface projections arranged in a fringe like a **solar corona**.

Viral vaccines

The purpose of viral vaccine is to utilize the immune response of the host to prevent viral diseases. Vaccination is the most cost effective method of prevention of serious viral infection.

Interferons (IFN$_s$)

They are the host coded proteins of cytokine family that inhibit viral replication. They are produced by intact animal or cultured cells in response to viral infection or other inducers. They are believed to be the part of body's first line of defense against viral infection.

Significance of Viruses

1. Viruses are a kind of biological puzzle to biologists since they are at the threshhold of living and non-living things showing the characteristics of both.
2. Viruses are very much used as biological research tools due to their simplicity of structure and rapid multiplication. They are widely used in research especially in the field of **molecular biology, genetic engineering, medicine** etc.
3. Viruses are used in eradicating harmful pests like insects. Thus they are used in **Biological Control Programmes**.

4. Plant Viruses cause great concern to agriculturists by their pathogenic nature. Bacteriophages attack the N_2 fixing bacteria of soil and are responsible for reducing the fertility of soil.
5. In industry, viruses are used in preparation of **sera** and **vaccines.**

SELF EVALUATION

One Mark

Choose the correct answer

1. T.M.V has the following symmetry.

   a. Cubical b. helical c.atypical d.square

2. The infective nature of virus is due to

   a. protein coat b. nucleic acid c. envelope d.tail fibres.

3. Developing a vaccine for SARS is difficult because

   a. it spreads by infectious materials b. it is an enveloped virus

   c. it is constantly changing it's form d. it has ssRNA

Fill in the banks

1. ________ isolated first virus in crystalline form.
2. The two important components of viruses are ___________ and ___________.
3. All ________viruses have ds.RNA.
4. _________ is a plant virus which has DNA
5. _________ virus causes AIDS.

Match

Cyanophage	- Corona virus
Mycophage	- HIV
SARS	- Blue green algae
AIDS	- Bacteria
Phage	- Fungi

Two Marks

1. Justify: Viruses are biologists' puzzle.
2. Define: virus
3. List any two living characteristics of virus.
4. List any two non-living characteristics of virus.
5. Viruses can undergo mutation. What does this signify?
6. Viruses can be crystallized. What does this signify?
7. What are the three main symmetry of viruses?
8. What is the principle used in sedimentation by ultra centrifugation method of measuring the size of a virus?
9. What are enveloped viruses?
10. Define nucleocapsid.
11. Name any two plant diseases / animal diseases/human diseases caused by viruses?
12. Define virion/ viroid/ prion
13. What are oncogenic viruses?
14. What are interferons?

Five Marks

1. Discuss the methods that are used to measure the size of a virus?
2. What is meant by biological control? Illustrate your answer with suitable examples.
3. Write a note on: Significance of viruses.

Ten Marks

1. Distinquish lytic cycle of a phage from lysogenic cycle .
2. Write an essay on the cause, symptoms and prevention of **AIDS /SARS**

2.2 Bacteria

Introduction

In 1676 **Anton Van Leeuwenhoek** discovered the microbial world by his simple microscope. It was only after the invention of compound microscope by **Hooke** in 1820, that bacteria came to lime light. These very minute creatures were designated as “small microscopic species” or “ **Infusorial animalcules**”. **Louis pasteur**(1822-95) made a detailed study of bacteria and proposed **germ theory of disease. Robert Koch,** a german microbiologist, was the first scientist to prove the cause and effect relationship between microbes and animal diseases. **Ehrenberg**(1829) was the first to use the term **bacterium**. The branch of study that deals with bacteria is called **Bacteriology**. Bacteria are unicellular organisms and they are prokaryotic. i.e they do not have a membrane bound nucleus and membrane bound organelles .

Occurrence

Bacteria are omnipresent. They are found in all environments, where organic matter is present. They are found in air, water, soil and also in or on the bodies of plants and animals. Some of the bacteria live as **commensals** (eg**. Escherichia coli** in the human intestine) and some live as **symbionts** (eg**. Rhizobium**) in the root nodules of leguminous plants. Several of them cause diseases in plants, animals and human beings.

Size

Bacteria are very small, most being approximately 0.5 to 1 micron in diameter and about 3 to 5 microns in length.

Classification of bacteria based on the shape and arrangement

The rigid bacterial cell wall determines the shape of a cell. Typical bacterial cells are spherical (**Cocci**), straight rods (**Bacilli**) or rods that are helically curved (**spirilla),** some bacterial cells are **pleomorphic** ie they can exhibit a variety of shapes eg. ***Arthrobacter***

Cocci bacteria appear in several characteristic arrangements depending on their plane of division.

A. **Diplococci:** Cells divide in one plane and remain attached in pairs.

B. **Streptococci:** cells divide in one plane and remain attached to form chains.

C. **Tetracocci**: Cells divide in two planes and form group of four cells.

D. **Staphylococci:** cells divide in three planes, in an irregular pattern, producing bunches of cocci.

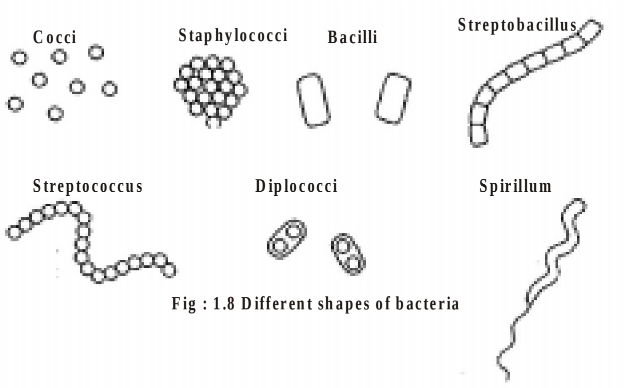


Fig : 1.8 Different shapes of bacteria

E**. Sarcinae:** cells divide in three planes, in a regular pattern, producing a **cuboidal** arrangement of cells.

Bacilli forms occur singly or in pairs (**diplobacilli**) or form chains (**streptobacilli**). In ***Corynebacterium diphtheriae*** which is a bacillus species, the cells are arranged side by side like match sticks (**palisade** arrangement)

Flagellation in Bacteria

All spirilla, about half of the bacilli and a small number of cocci are flagellated. Flagella vary both in number and arrangement according to two general patterns. 1. In a **polar arrangement**, the flagella are attached at one or both the ends of the cell. Three sub types of this pattern are:

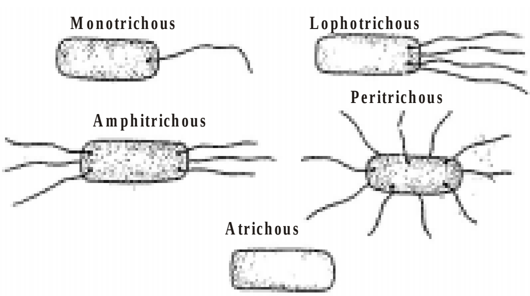


Fig : 1.9 Flagellar arrangement in Bacteria

a. **monotrichous** – with a single flagellum

b. **lophotrichous** – with small bunches or tufts of flagella emerging from one end

c. **amphitrichous** – with flagella at both poles of the cell

2. In a **peritrichous** arrangement flagella are dispersed randomly over the surface of the cell.

3. **Atrichous** bacteria lack flagellum.

Flagellar Functions

They can detect and move in response to chemical signals – a type of behaviour called **chemotaxis.** Positive chemotaxis is movement of cell in the direction of a favourable chemical stimulus (usually a nutrient). Negative chemotaxis is movement away from a repellant (potentially harmful) compound.

Nutrition in Bacteria

Autotrophic Bacteria

Some bacteria can synthesize their food and hence they are autotrophic in their mode of nutrition. They may be **photo autotrophs** (eg. **Spirillum)** or **chemoautotrophs** eg**. *Nitrosomonas*** or ***Nitrobacter*.**

Photoautotrophic bacteria

They use sunlight as their source of energy to synthesize food. But unlike photosynthetic eukaryotic cells they do not split water to obtain reducing power. So Oxygen is not evolved during bacterial photosynthesis. Depending upon the nature of the hydrogen donor these bacteria may be

1. Photolithotrops

In this the hydrogen donor is an inorganic substance. In green sulphur bacteria(eg. ***Chlorobium*)** hydrogen sulphide (H_2s) is the hydrogen donor. The chlorophyll is **bacterioviridin**

In purple sulphur bacteria (eg**. *Chromatium***) thiosulphate acts as hydrogen donor. The chlorophyll is **bacteriochlorophyll.**

2. Photo-organolithotrophs

In this the hydrogen donor is an organic acid or alcohol eg. Purple non sulphur bacteria (eg. ***Rhodospirillum***)

Chemoautotrphic bacteria

They do no have photosynthetic pigments and hence they cannot use sunlight energy. Instead they obtain energy in the form of ATP by oxidising inorganic or organic compounds. The energy thus obtained is used to reduce CO_2 to organic matter. Based on the type of substance oxidized they may be

1. **Chemolithotrophs:** Inorganic compound is oxidized to release energy. eg. Sulphur bacteria (eg. ***Thiobacillus*)**

   Iron bacteria (eg**. *Ferrobacillus***), Hydrogen bacteria eg**. *Hyderogenomonas*** and Nitrifying bacteria (eg ***Nitrosomonas*** and ***Nitrobacter*)**

2. **Chemo – organotrophs**: In this type it is an organic compound that is oxidized to release energy. eg. Methane bacteria (***Methanococcus***).

Acetobacteria and ***Lactobacillus*** are also examples for chemo-organotrophs.

Heterotrophic Bacteria

They depend upon other organisms (living/dead) for their food since they cannot synthesize their own food. They may be saprotrophic e.g (***Bacillus subtilis***), parasitic e.g. Plant parasite-(***Xanthomonas citrii***) animal parasite e.g.(***Bacillus anthracis***) , Human parasite e.g (***Vibrio cholerae***) or symbiotic in association with roots of the family **Leguminosae**. e.g. **(Rhizobium)**

Respiration in Bacteria

Aerobic Bacteria: These bacteria require oxygen as terminal acceptor of electrons and will not grow under anaerobic conditions(i.e in the absence of O_2) Some micrococcus species are **obligate aerobes** (i.e they must have oxygen to survive)

Anaerobic bacteria : These bacteria do not use oxygen for growth and metabolism but obtain their energy from fermentation reaction. eg. ***Clostridium*** **species**.

Capnophilic bacteria are those that require CO_2 for growth.

Facultative anaerobes: Bacteria can grow either oxidatively using oxygen as a terminal electron acceptor or anaerobically using fermentation reaction to obtain energy. Bacteria that are facultative anaerobes are often termed "**aerobes**". When a facultative anaerobe such as E. Coli is present at a site of an 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.

Endospores are structures formed in bacillus bacteria during unfavourable conditions. Fortunately most pathogenic bacteria (except tetanus and anthrax bacteria) do not form endospores.

Reproduction: Reproduction by binary fission is very common. It is the method by which many bacteria multiply very rapidly explaining the cause of spoilage of food stuffs, turning of milk into curd etc.

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. **Transduction** 3. **Transformation**

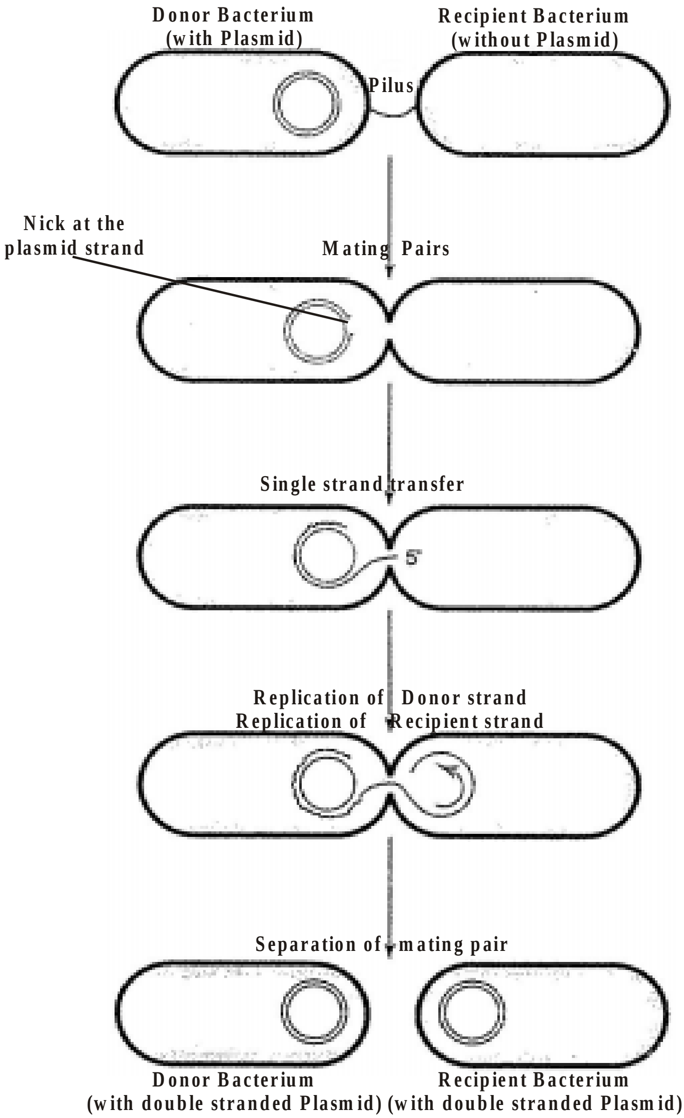


Fig : 1.10 Conjugation in Bacteria

1. **Conjugation**: 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 compliments the strand acquired from the donor.

2. **Transduction** : Donor DNA is carried in a phage coat and is transferred into the recipient by the mechanism used for phage infection.

3. **Transformation** : The direct uptake of donor DNA by the recipient cell may be natural or forced. Relatively few bacterial species are naturally competent for transformation. These species assimilate donor DNA in linear form. Forced transformation is induced in the laboratory, where after treatment with high salt and temperature shock many bacteria are rendered competent for the assimilation of extra-cellular plasmids. **The capacity to force bacteria to incorporate extra-cellular plasmids by transformation is fundamental to genetic Engineering.**

Economic Importance of Bacteria

Bacteria play an important role in day to day activities of human beings. Some of them have harmful effects and others are useful to man kind.

Harmful activities

1. Diseases caused by bacteria in plants:

Name of the host	Name of the disease	Name of the pathogen
Citrus	Citrus Canker	*Xanthomonas citri*
Rice	Bacterial blight	*Xanthomonas oryzae*
Cotton	Angular leaf spot	*Xanthomonas malvacearum*
Pears	Fire blight	*Pseudomonas solanacearum*
Carrot	Soft rot	*Erwiinia caratovora*

2. Diseases caused by bacteria in animals :

Name of the host	Name of the disease	Name of the pathogen
Sheep	Anthrax	*Bacillus anthracis*
Cattle	Brucellosis	*Brucella abortus*
Sheep,goat	Brucellosis	*Brucella melitensis*

3. Diseases caused by bacteria in human beings:

Name of the disease	Name of the pathogen
Cholera	*Vibrio cholerae*
Typhoid	*Salmonella Ttyphi*
Tuberculosis	*Mycobacterium tuberculosis*

Beneficial Activities of Bacteria

1. **Sewage disposal** : Organic matter of the sewage is decomposed by saprotrophic bacteria.
2. **Decomposition of plant and animal remains**: Saprotrophic bacteria cause decay and decomposition of dead bodies of plants and animals. They release gases and salts to atmosphere and soil. Hence these bacteria are known as nature's scavengers.

3. Soil fertility :

1. The **ammonifying** bacteria like ***Bacillus ramosus*** and ***B. mycoides*** convert complex proteins in the dead bodies of plants and animals into ammonia which is later converted into ammonium salts.
2. The **nitrifying bacteria** such as ***Nitrobacter, Nitrosomonas*** convert ammonium salts into nitrites and nitrates.
3. **Nitrogen fixing bacteria** such as ***Azotobacter*** and ***Clostridium*** and ***Rhizobium*** (a symbiotic bacterium) are capable of converting atmospheric nitrogen into organic nitrogen. All these activities of bacteria increase soil fertility.

Recycling of matter

Bacteria play a major role in cycling of elements like carbon, oxygen, Nitrogen and sulphur. Thus they help in maintaining environmental balance. As biological scavengers they oxidize the organic compounds and set free the locked up carbon as CO_2. The nitrogenous organic compounds are decomposed to form ammonia which is oxidized to nitrite and nitrate ions by the action of nitrifying bacteria. These ions are used by higher plants to synthesize nitrogenous organic compounds. The nitrogenous compounds are also oxidized to nitrogen by denitrifying bacteria.

Role of Bacteria in Industry

1. Dairy Industry

Lactic acid bacteria e.g.(***Streptococcus lactis)*** are employed to convert milk sugar lactose into lactic acid.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 4C_3H_6O_3 + \text{Energy}$$

Lactose   Lactic Acid

Different strains of lactic acid bacteria are used to convert milk into curd, yoghurt(***Lactobacillus bulgaricus***) and cheese(***Lactobacillus acidophobus***).

2. Vinegar

Vinegar (Acetic acid) is obtained by the activity of acetic acid bacteria (***Acetobactor aceti***). This bacterium oxidizes ethyl alcohol obtained from molasses by fermentation to acetic acid or vinegar.

3. Alcohols and Acetone

Butyl alcohol, methyl alcohol and acetone are prepared from molasses by the fermentation activity of the anaerobic bacterium ***Clostridium acetobutylicum*.**

Curing of tobacco,tea and coffee

The leaves of tea, tobacco and beans of coffee are fermented by the activity of certain bacteria to impart the characteristic flavour. This is called **curing of tea, tobacco and coffee**.

Retting of fibres

The fibres from the fibre yielding plants are separated by the action of bacteria like ***Clostridium*** species. This is called retting of fibres.

Role of bacteria in medicine

1. **Antibiotics:** Antibiotics such as bacitracin (***Bacillus subtilis***), polymyxin(***Bacillus polymyxa***), Streptomycin(***Streptomyces griseus***) are obtained from bacterial sources.
2. **Vitamins**: ***Escherichia coli*** living in the intestine of human beings produce large quantities of vitamin K and vitamin B complex. Vitamin B_2 is prepared by the fermentation of sugar by the action of ***clostridium*** species.

Role of bacteria in genetic engineering

Most of our knowledge in genetics and molecular biology during 20^{th} century has been due to research work on micro-organisms, especially bacteria such as ***E.coli.*** One success has been the transfer of human insulin genes into bacteria and commercial production of insulin has already commenced.

Role of bacteria in biological control

Certain Bacillus species such as ***B.thuringiensis*** infect and kill the caterpillars of some butterflies and related insects. Since the bacteria do not affect other animals or plants they provide an ideal means of controlling many serious crop pests.

SELF EVALUATION

One Mark

Choose the correct answer

1. The chlorophyll pigment found in green sulphur bacteria is

   a.bacteriochlorophyll b.bacterioviridin c.phycocyanin d.phycoerythrin

2. Cell which keeps changing it's shape is called

   a. Spirilla b.Pleomorphic c. Symbiont d. Gram – negative

Fill in the blanks

1. __________ proposed germ theory of disease .
2. __________ bacteria require CO_2 for growth .
3. __________ is a type of movement of cells in response to chemical signals.
4. __________ is not evolved during bacterial photosynthesis.

Two Marks

1. What are commensals?
2. What are Gram-Positive bacteria?
3. What are Gram-Negative bacteria?
4. What are Chemoautotrophs?
5. What is transduction/ transformation.
6. Name any four plant diseases / human diseases caused by bacteria?
7. Give reason: Bacteria are also known as nature's scavengers.
8. Name some antibiotics obtained from bacteria

Five Marks

1. Describe the various steps in Gram's staining procedure?
2. What are the different shapes found in bacteria? Give examples.
3. Describe the various types of flagellation found in bacteria.
4. Discuss the role of bacteria in industry?
5. Discuss the role of bacteria in soil fertility.

Ten Marks

1. Write an essay on sexual reproduction in bacteria.
2. Discuss the economic importance of bacteria.
3. Write an essay on nutrition in bactera.

2.3 Fungi

Conventionally Fungi have been included in plant kingdom. But in pursuance of **Whittaker**'s five kingdom classification **Fungi** and **Plants** (Algae, Bryophytes, Pteridophytes Gymmosperms and Angiosperms) are described here as two separate kingdoms. Angiosperms are not described in detail here.

Salient Features

Fungi are non chlorophyllous, eukaryotic, organisms. They are a large and successful group. They are universal in their distribution. They resemble plants in that they have cell walls. But they lack chlorophyll which is the most important attribute of plants. They are ubiquitous in habitat which ranges from aquatic to terrestrial. They grow in dark and moist habitat and on the substratum containing dead organic matter. Mushrooms, moulds and yeasts are the common fungi. They are of major importance for the essential role they play in the biosphere and for the way in which they have been exploited by man for economic and medical purposes. The study of fungi is known as **Mycology.** It constitutes a branch of microbiology because many of the handling techniques used, such as sterilizing and culturing procedures are the same as those used with bacteria.

Distinguishing Features of Fungi

1. They have definite cell wall made up of **chitin** – a biopolymer made up of n- acetyl glucosamine units.
2. They are without chlorophyll, hence they exhibit heterotrophic mode of nutrition. They may be saprotrophic in their mode of nutrition or parasitic or symbiotic.
3. They are usually non – motile except the subdivision Mastigomycotina.
4. Their storage product is not starch but glycogen and oil.
5. They reproduce mostly by spore formation. However sexual reproduction also takes place.

Structure

The body structure of fungi is unique. The somatic body of the fungus is unicelllular or multi-cellular or coenocytic. When multi-cellular it is composed of profusely branched interwoven, delicate, thread like structures called **hyphae,** the whole mass collectively called **mycelium.** The hyphae are not divided into true cells. Instead the protoplasm is either continuous or is interrupted at intervals by cross walls called **septa** which divide the hyphae into compartments similar to cells. Thus hyphae may be **aseptate(**hyphae without cross walls) or **septate** (hyphae with cross walls).When aseptate they are **coenocytic** containing many nuclei. Each hypha has a thin rigid wall, whose chief component is chitin, a nitrogen containing polysaccharide also found in the exoskeleton of arthropods. Within the cytoplasm the usual eukaryotic organelles are found such as mitochondria, golgi-apparatus, endoplasmic reticulum, ribosomes and vacuoles. In the older parts, vacuoles are large and cytoplasm is confined to a thin peripheral layer.

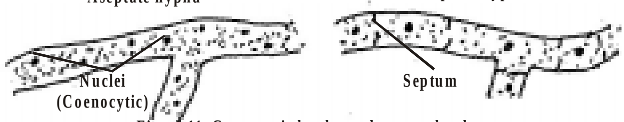


Fig : 1.11. Coenocytic hypha and septate hypha

Nutrition

Fungi are heterotrophic in their mode of nutrition that is they require an organic source of carbon. In addition they require a source of nitrogen, usually organic substances such as amino acids. The nutrition of fungi can be described as **absorptive** because they absorb nutrients directly from outside their bodies. This is in contrast to animals which normally ingest food and then digest it within their bodies before absorption takes place. With fungi, digestion is external using extra-cellular enzymes. Fungi obtain their nutrients as saprotrophs,parasites or symbionts.

Saprotrophs

A saprotroph is an organism that obtains its food from dead and decaying matter. It secretes enzymes on to the organic matter so that digestion is outside the organism. Soluble products of digestion are absorbed and assimilated within the body of the saprotroph.

Saprotrophic fungi and bacteria constitute the **decomposers** and are essential in bringing about decay and recycling of nutrients. They produce **humus** from animal and plant remains. Humus, a part of soil, is a layer of decayed organic matter containing many nutrients. Some important fungi are the few species that secrete the enzyme cellulase which breaks down cellulose. Cellulose being an important structural component of plant cell walls, rotting of wood and other plant remains is achieved by these decomposers secreting cellulases.

Parasites

A parasite is an organism that lives in or on another organism, the host from which it obtains its food and shelter. The host usually belongs to a different species and suffers harm from the parasite. Parasites which cause diseases are called **pathogens**. Some parasites can survive and grow only in living cells and are called **biotrophs** or **Obligate Parasites**. Others can infect their host and bring about it's death and then live saprotrophically on the remains, they are called **necrotrophs** or **facultative parasites**. Fungal parasites may be facultative or obligate and more commonly attack plants than animals. The hyphae penetrate through stomata, or enter directly through the cuticle or epidermis or through wounds of plants. Inside the plant hosts, the hyphae branch profusely between cells, sometimes producing pectinases(enzymes) which digest the middle lamellae of the cell walls. Subsequently the cells may be killed with the aid of toxins and cellulases which digest the cell walls. Cell constituents may be absorbed directly or digested by the secretion of further fungal enzymes.

Obligate parasites often possess specialized penetration and absorption devices called **haustoria.** Each haustorium is a modified hyphal outgrowth with a large surface area which pushes into living cells without breaking their plasma membrane and without killing them. Haustoria are rarely produced by facultative parasites.

Symbiosis :

Two important types of symbiotic union are made by fungi.

1. Lichens and 2. **Mycorrhizae**.

Lichens

They are symbiotic association found between **algae** and **fungi.** The alga is usually a green alga or blue green alga. The fungus is an ascomycete or basidiomycete. It is believed that the alga contributes organic food from photosynthesis and the fungus is able to absorb water and mineral salts. The fungus can also conserve water and this enables some lichens to grow in extreme dry conditions where no other plants can exist.

Mycorrhizae

These are symbiotic associations between a fungus partner and roots of higher plants. Most land plants enter into this kind of relationship with soil fungi. The fungus may form a sheath around the center of the root (an **ectotrophic mycorrhiza**) or may penetrate the host tissue (an **endotrophic mycorrhiza**). The former type is found in many forest trees such as conifers,beech and oak and involve the fungi of the division **basidiomycetes**. The fungus receives carbohydrates and vitamins from the tree and in return breaks down proteins of the soil humus to amino acids which can be absorbed and utilized by the plant. In addition the fungus provides a greater surface area for absorption of ions such as phosphates.

Classification of Fungi

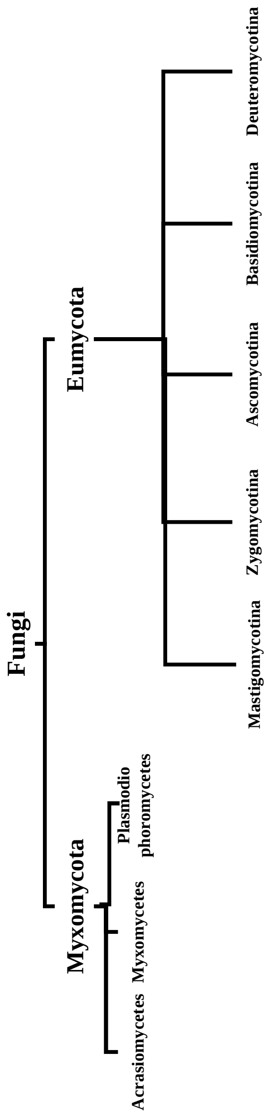


Fig. 1.12. Classification of Fungi by Ainsworth

Traditionally fungi have been regarded as plants. At one time fungi were given the status of a class and together with the class algae formed the division **Thallophyta** of the Plant Kingdom. The thallophyta were those plants whose bodies could be described as **thalli**. A thallus is a body, often flat, which is not differentiated into true roots, stem and leaves and lack a true vascular system. A modification of the scheme of classification of fungi proposed by **Ainsworth(**1973) and adopted by **Webster**(1980) is outlined below.

Division **Myxomycota:** They lack cell wall and are quite unusual organisms. Possess either a plasmodium, a mass of naked, multinucleate protoplasm, which feeds by ingesting particulate matter and shows amoeboid movement, or pseudoplasmodium, an aggregation of separate amoeboid cells. Both are of a slimy consistency, hence they are also called "Slime moulds". It includes three classes.

Division **Eumycota:** True fungi, all with cell wall. It is customary to recognize five subdivisions under this division.

A. Mastigomycotina: These are zoosporic fungi, many are solely aquatic. Three classes are included in this, each characterized by their distinctive type of zoospores.

B. Zygomycotina: Vegetative body haplophase. Asexual spores are non-motile spores. Sexual reproduction takes place by the complete fusion of two multi-nucleate gametangia producing a zygospore. Because of this the fungi of the class zygomycetes are also known as conjugation fungi. Cell wall is made up of chitin and chitosan. It includes two classes. The common **black, bread moulds *Rhizopus*** and ***Mucor*** belong to this group. Rhizopus is a very common saprotroph similar in appearance to Mucor, but more widespread.

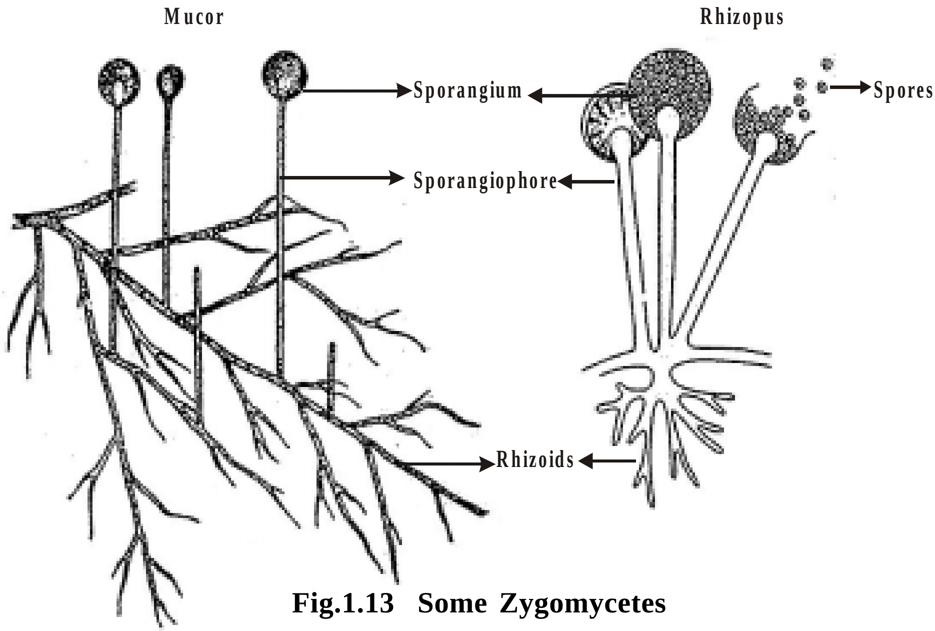


Fig.1.13 Some Zygomycetes

C. **Ascomycotina:** Hyphae are septate, vegetative body is haplophase. It has five classes.This subdivision includes forms such as yeasts, brown moulds, green moulds, pink moulds, cup fungi, and edible morels. In this group of fungi asexual reproduction takes place by various types of non-motile spores such as oidia, chlamydospores and conidia. Sexual reproduction takes place by means of gametangial copulation (yeasts). gametangial contact (***Penicillium***) and by somatogamy (***Morchella***). The ascomycetes or sac fungi are characterized by the development of spores called **ascospores.** These ascospores are enclosed in a sac like structure, the **ascus**. In primitive ascomycetes the asci occur singly. In advanced ascomycetes, groups of asci get aggregated to form campact fruiting bodies called the **ascocarps**. The ascocarps are of three types.

1.Cleistothecium:

These are closed and spherical ascocarps. eg. ***Eurotium***

2. Perithecium:

These are flask shaped ascocarps. eg. **Neurospora.**

3. Apothecium :

These are cup shaped ascocarps. eg.**Peziza.**

D.Basidiomycotina: It includes three classes. hyphae are septate, vegetative body is dikaryophase. It includes the highly evolved fungi. This group got its name from the **basidium**, the club shaped structure formed at the tip of the reproductive hypha. Each basidium bears four **basidiospores** at its tip. Large reproductive structures or fruiting bodies called **basidiocarps** are produced in this group of fungi. Common examples for basidiomycetes include mushrooms, toadstools, puffballs and bracket fungi . The mycelia of this group are of two types. Primary and secondary. Primary mycelium multiplies by oidia, conidia like spores and pycnidiospores. Distinct sex organs are absent. Fusion occurs between two basidiospores or between two hyphal cells of primary mycelia. Advanced forms of basidiomycetes produce fruiting bodies called **basidiocarps.** Fruiting bodies vary in size from small microscopic to large ones.

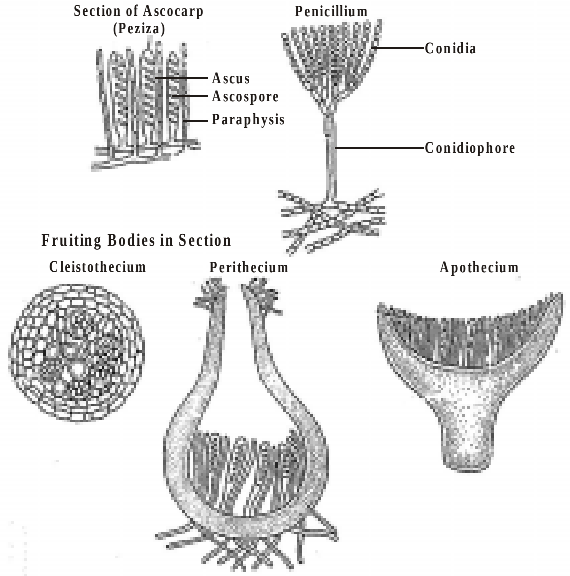


Fig : 1.14. Some Ascomycetes and their Ascocarps

E.Deuteromycotina: Three classes are included under this. They are the so-called "**Fungi Imperfecti**". It is a group of fungi known only from their asexual (imperfect or anamorphic) or mycelial state. Their sexual (perfect or teleomorphic) states are either unknown or may possibly be lacking altogether.

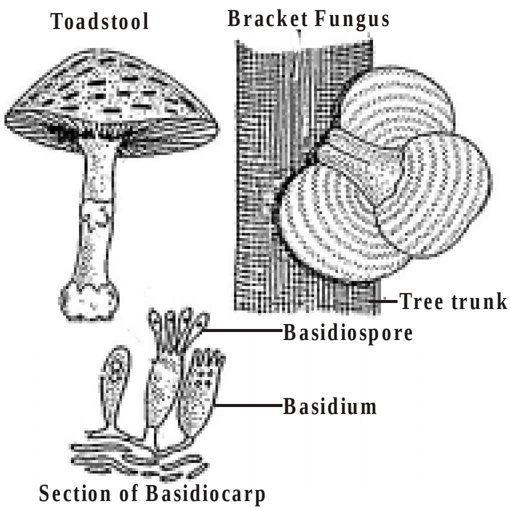


Fig : 1.15. Some Basidiomycetes and their Basidiocarps

Economic importance of Fungi

Fungi are useful to mankind in many ways. These organisms play an important role in medicine, agriculture and industry. They have harmful effects also.

Useful aspects of fungi

The antibiotic **Penicillin** was discovered in 1928 by **Alexander Fleming** of Britain from the fungus **Penicillium notatum**, which in 1940s emerged as a '**wonder drug**' for the treatment of bacterial diseases. It gave another important '**niche**' to fungi in the realm of biological sciences as producers of antibiotics. Many other important antibiotics are produced by moulds

Many fungi such as yeast, mushrooms, truffles, morels etc., are edible. Edible mushrooms contain proteins and vitamins. Certain species of **Agaricus** such **as A. Bisporus, A. arvensis** are edible. **Volvariella volvacea** and **V. dispora** are also edible mushrooms cultivated commercially.

Brewing and baking industries rely heavily on the uses of **yeast *(saccharomyces)***.Yeasts ferment sugar solution into alcohol and carbon-di oxide. Alcohol is used in brewing industry and CO_2 in baking industry.

The '**biochemical genetics'** which later developed into the fasinating '**molecular biology'** was founded by studies with **Neurospora crassa,** a fungus which even dethroned **Drosophila from** the Kingdom of genetics as this fungus was especially suited for genetical analysis. Fungi like ***Neurospora*** and **Aspergillus** continue to be important organisms studied in genetics.

"Without fungi even death will be incomplete" said Pasteur. The dead cellulosic vegetation is decomposed into carbon and minerals by the saprotrophic fungi and these elements are returned to the same environment from where they were obtained. Thus fungi maintain the carbon and mineral cycles in nature.

Harmful aspects of Fungi

Fungi are great nuisance. They grow on every thing from jam to leather and spoil them. **LSD** (d- lysergic acid diethylamide) produced from the fungus ergot

Table : 1.3. Some fungal diseases

Common fungal diseases of plants	**Causal organisms**
1. Wilt of cotton	***Fusarium oxysporum* f.*sp.vasinfectum***
2. Tikka disease (Leaf spot) of ground nut	***Cercospora personata***
3. Red rot of sugarcane	***Colletotrichum falcatum***

Fungal diseases of human beings	**Causal organisms**
1. Ring worm (tinea)	***Epidermophyton spp.***
2. Ring worm(tinea)	***Trichophyton spp.***
3. Candidiasis	***Candida albicans***

(**Claviceps purpurea**) produces hallucinations. Hence this fungus is called " **hallucinogenic fungus**" and has caused greatest damage to the frustrated youth by giving an unreal, extraordinary lightness and hovering sensation.

The association of fungi with several plant diseases has now come to light. The devastating disease called '**late blight of potato'** caused by the fungus **Phytophthora infestans** in Ireland in the year 1845 has resulted in such a disaster that about one million people died of starvation and over 1.5 million people fled to other countries since potato was the staple food of Ireland. Since then '**Plant pathology'** a new science started which deals with diseases of plants caused not only by fungi but also by bacteria, viruses etc.

SELF EVALUATION

One Mark

Choose the correct answer

1. The study of Fungi is called
   a. phycology b. plant pathology c. systematics d.mycology
2. The fungal cell wall is made up of
   a. chitin b. cellulose c. pectin d. peptidoglycan

Fill in the blanks

1. The storage products of fungi are __________ and __________
2. Haustoria are rarely produced by_________ parasites.

Two Marks

1. What is a coenocytic mycelium?
2. What is meant by septate hypha?
3. Distinguish obligate parasite from facultative parasites.
4. What are haustoria?
5. What are mycorrhizae?
6. Name some fungal diseases of plants.
7. Name some edible fungi.
8. Justify the statement by Pasteur: "Without fungi even death will be incomplete"
9. Which fungus is called hallucinogenic fungus and why?

Five Marks

1. Write about the symbiotic mode of nutrition as seen in fungi.
2. Give the salient features of the subdivision Ascomycotina / Basidiomycotina / Zygomycotina

Ten Marks

1. Write an essay on the mode of nutrition in fungi.
2. Give a concise account on the economic importance of fungi.

2.3.1 Mucor

Division	:	Eumycota
Sub Division	:	Zygomycotina
Class	:	Zygomycetes
Order	:	Mucorales
Family	:	Mucoraceae
Genus	:	Mucor

Occurrence : ***Mucor*** is a saprotrophic fungus. The appearance of the sporangiophores and sporangia resembles a collection of pins and hence it is commonly known as **"pin mould"**. As the matured sporangia are black in colour, it is also called **"black bread mold"**. There are more than 50 species that have been reported in this genus. It grows on dung (eg : **Mucor mucedo**), wet shoes, stale moist bread, rotton fruit, decaying vegetables and other stale organic media. It can be grown easily in the laboratory on a piece of moist bread or on horse dung kept under a bell jar in a warm place for three or four days.

Somatic structure : The body of ***Mucor*** is composed of a mass of white, delicate, cottony threads collectively known as **mycelium**. It is always much branched and **coenocytic** i.e. aseptate and multinucleate. Each thread of the mycelium is known as **hypha** which is aseptate. The mycelium spreads in all directions over the substratum. Some of the hyphal branches penetrate down into the substratum to absorb water and nutrients.

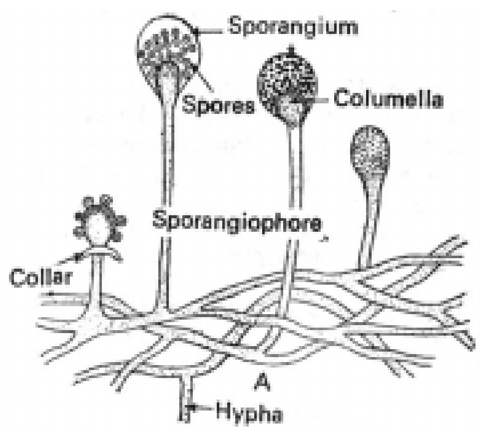


Fig.1.16 Mucor - Mycelium with sporongia and spores

Reproduction : This takes place vegetatively, asexually and sexually. The asexual reproduction by formation of spores is very common in ***Mucor***.

Vegetative reproduction : Fragmentation of the mycelium results in the multiplication of the fungus by developing fresh stock of mycelia.

Asexual reproduction : Asexual reproduction is by spores or chlamydospores or sometimes by **oidia**.

Sporangiospores or spores : ***Mucor*** readily reproduces asexually by forming sporangiospores or spores (Fig.). Here the spores are produced in sporangia. Under favourable conditions of moisture and temperature, numerous slender, erect hyphae called **sporangiophores** arise from the mycelium. These sporangiophores are hyaline and do not produce rhizoids at their base. The apex of the sporangiophore enlarges to form a vesicle which may be globose or spherical, multispored and columellate structure - the **sporangium**. As the hypha begins to swell, the protoplasmic contents migrate to its tip and accumulate there. The protoplasm differentiates into a central vacuolated region and an outer fertile dense peripheral region containing large number of nuclei. The central vacuolated region is separated from the peripheral region by a cleft or furrow and this furrow later develops into a wall. This central sterile region is called **columella**. The peripheral fertile region forms spores as follows : The peripheral protoplasm now gives rise to a number of small, multi-nucleate, angular masses by cleavage. Each multinucleate mass becomes rounded off and is covered by a wall forming a spore. The spore wall thickens and darkens. The wall of the sporangium is thin and brittle. The columella swells due to the accumulation of a quantity of fluid and exerts a considerable pressure on the wall of the sporangium.

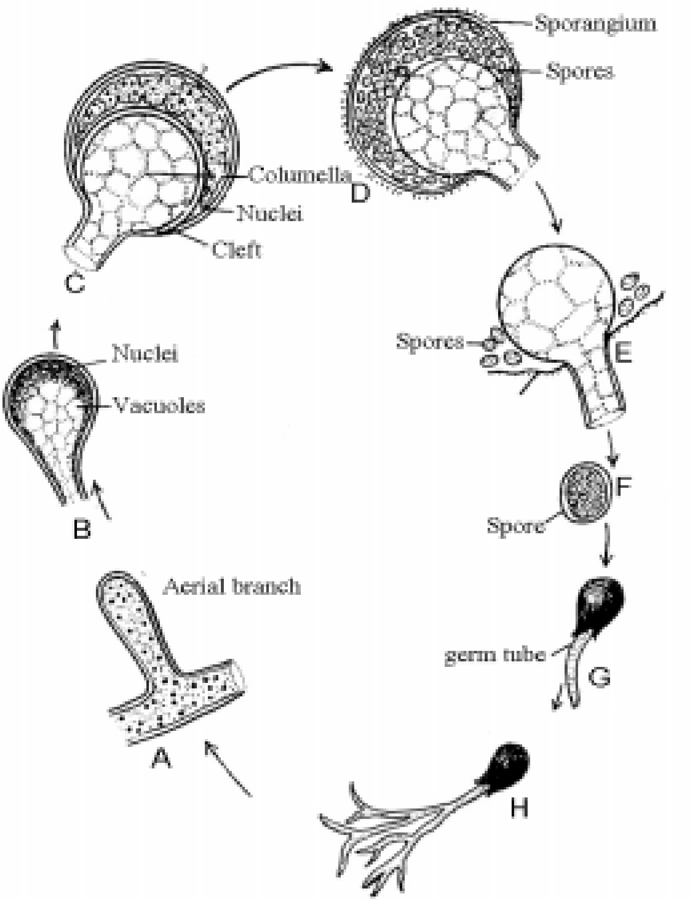


Fig.1.17. Asexual reproduction in *Mucor*.

A, somatic hypha.

B, swelling of tiop of an aerial branch.

C, formation of columella and its separation from the denser region by a cleft. D, formation of a sportes.

E, liberation of spores. F, multinucleate spore.

G,H, germination of spores developing into a branched mycelium

As a consequence, the sporangium bursts, setting free the spores. The spores are blown by wind. The columella persists for some time after the bursting of the sporangium. Being very minute, light and dry the spores float about in the air, and under favourable conditions, they germinate in a suitable medium to produce a new thallus of ***Mucor***.

Chlamydospores. It is sometimes seen that under unfavourable conditions, the mycelium of ***Mucor*** becomes segmented into a short chain of cells. These cells swell up and become thick-walled and large. These are called **chlamydospores**. These spores are resting spores. They germinate under favourable conditions to give rise to somatic structure of the fungus.

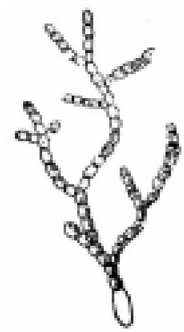


Fig.1.18 Yeast like oidia

Sometimes the hyphae produce yeast-like budding cells called **'oidia'**.

Sexual reproduction : The mycelium of most of the species of ***Mucor*** is unisexual and hence unable to produce both the male and female gametangia. Sexual reproduction takes place when hyphae derived from different spores come in contact with one another. 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**. The two sexual hyphae are called (+) and minus (-) strains. Here (+) strain and (-) strain hyphae readily mate and hence are called mating types. Whereas (+) and (+) or (-) and (-) strains do not mate. The growth of the (+) strain (female) is more vigorous than that of (-) strain (male). In heterothallic species (eg. *M. mucedo*), sexual reproduction begins when (+) and (-) strain hyphae intermix. In some species (eg. *M. hiemalis*) any two hyphae from the same mycelium derived from a single spore may initiate sexual reproduction. This phenomenon is called **homothallism**.

When a (+) strain and (-) strain hyphae of heterothallic species (eg. *M. mucedo*) come in contact with one another, the tips of both hyphae swell to form **progametangia**. The two progame-tangia meet and adhere together at their tips. Each progametangium gets transformed into a terminal **gametangium** and a basal **suspensor** (Fig.). Each multinucleate gametangium is regarded as a **coenogamete**. The wall between the two gametangia dissolves and the protoplasm of both gametangia fuse to form a black thick-walled **zygospore**. As the thick-walled zygospore has reserve food material, it is able to tide over unfavourable

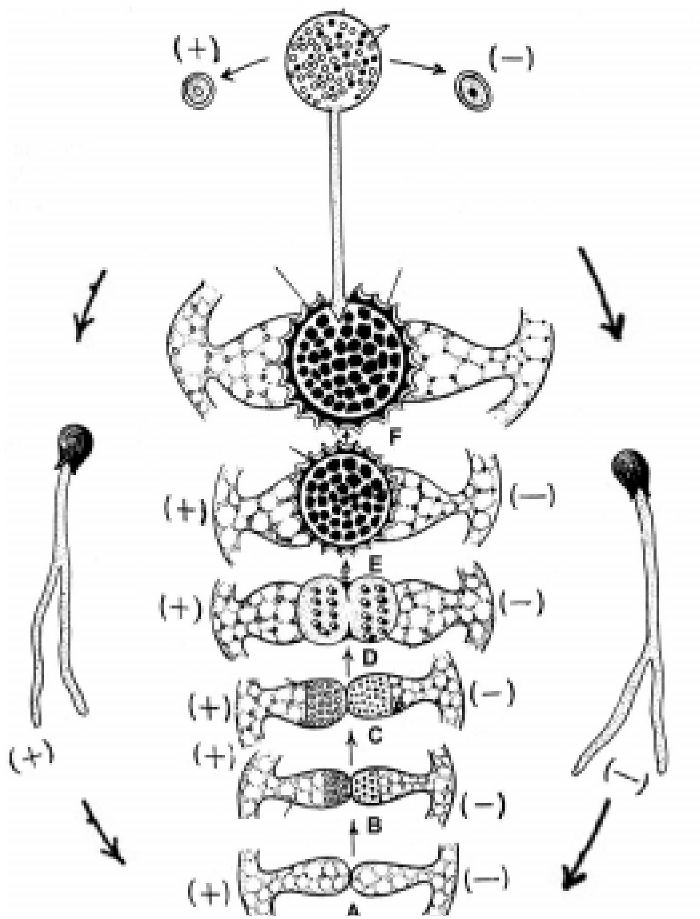


Fig.1.19 Sexual reproduction in *Mucor*

A,B & C, Opposing tips of hyphae forming progametangia and coenogametes. D. Karyogamy. E, Zygospore. F, Germination of zygospore following meioss

conditions. During favourable conditions, the zygospore germinates and undergoes meiosis to produce a sporangiophore and a sporangium at its tip (Fig.). Such a sporangium lacks columella and produces numerous haploid spores. The spores are released due to dehiscence of sporangium. Upon germination, the spores produce (+) or (-) strain hyphae.

In unusual cases, the gametangia fail to fuse and develop into thick-walled structures called **azygospores**.

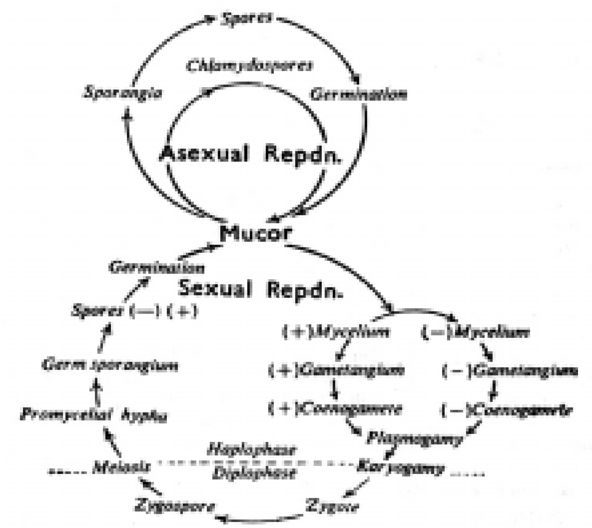


Fig.1.20 Life-Cycle of *Mucor*

SELF EVALUATION

One mark

1. ***Mucor*** is commonly called
   a) Black bread mould   b) Red bread mould
   c) White bread mold   d) Brown bread mold

2. The mycelium of ***Mucor*** has this condition
   (a) Uninucleate   (b) Binucleate (c) Multi nucleate (d) None of the above

3. The erect hypha that bears sporangium is known as
   (a) Zoospore (b) Sporangiophore (c) Zygospore (d) Azygospore

Fill in the blanks

1. The multinucleate gametes of ***Mucor*** are called_____________.

2. ______is formed by the fusion of two gametes of different strains in ***Mucor***.

3. The basal part of the terminal gametangium is known as__________ in ***Mucor***.

4. The dome shaped sterile portion of the sporangium is known as________ .
5. Each thread of the mycelium of ***Mucor*** is known as____________.

Two Marks

1. Describe the mycelium of ***Mucor***.
2. What is coenocytic condition?
3. What is columella? Where it can be seen?
4. How azygospores are produced?

Five Marks

1. Briefly describe the process of production of zygospore.
2. Give an account of asexual reproduction in ***Mucor***.
3. Briefly write about Chlamydospores.
4. Describe the somatic structure of ***Mucor***.

Ten Marks

1. Write briefly about the sexual reproduction in ***Mucor***.
2. Trace the life cycle of ***Mucor*** with properly labelled diagrams.
3. Describe the process of homothallism and heterothallism.

2.4 Algae

Salient Features

Algae are autotrophic organisms and they have chlorophyll. They are O_2 producing photosynthetic organisms that have evolved in and have exploited an aquatic environment. The study of Algae is known as **Algology** or **phycology.**

In Algae the plant body shows no differentiation into root, stem or leaf or true tissues. Such a plant body is called **thallus.** They do not have vascular tissues. The sex organs of this group of **kingdom plantae** are not surrounded by a layer of sterile cells.

Occurrence and Distribution

Most of the algae are aquatic either fresh water or marine. Very few are terrestrial. A few genera grow even in extreme condition like thermal springs, glaciers and snow.

The free floating and free swimming minute algae are known as **phytoplanktons**. Species that are found attached to the bottom of shallow water along the edges of seas and lakes are called **Benthic.** Some of the algae exhibit symbiotic association with the higher plants. Some species of algae and fungi are found in association with each other and they are called **Lichens.** A few species of algae are **epiphytes** (i.e they live on another plant or another alga) and some of them are **lithophytes** (i.e they grow attached to rocks)

Thallus organization

The thalli of algae exhibit a great range of variation in structure and organization. It ranges from microscopic unicellular forms to giant seaweeds like ***Macrocystis*** which measures up to 100 meters long. Some of them form **colonies**, or **filaments**. The unicellular form may be motile as in ***Chlamydomonas*** or non-motile as in ***Chlorella.*** Most algae have filamentous thallus. eg. ***Spirogyra*****.** The filaments may be branched. These filamentous form may be free floating or attached to a substratum. Attachment of the filament is usually effected through a simple modification of the basal cell into a **holdfast.** Some of the Algae are macroscopic. eg. ***Caulerpa, Sargassum, Laminaria, Fucus*** etc.where the plant body is large. In ***Macrocystis*** it is differentiated into root, stem and leaf like structures.

The chlroplasts of algae present a varied structure. For eg. they are cup shapedin *Chlamydomonas*, ribbon-like in *Spirogyra* and star shaped in *Zygnema*.

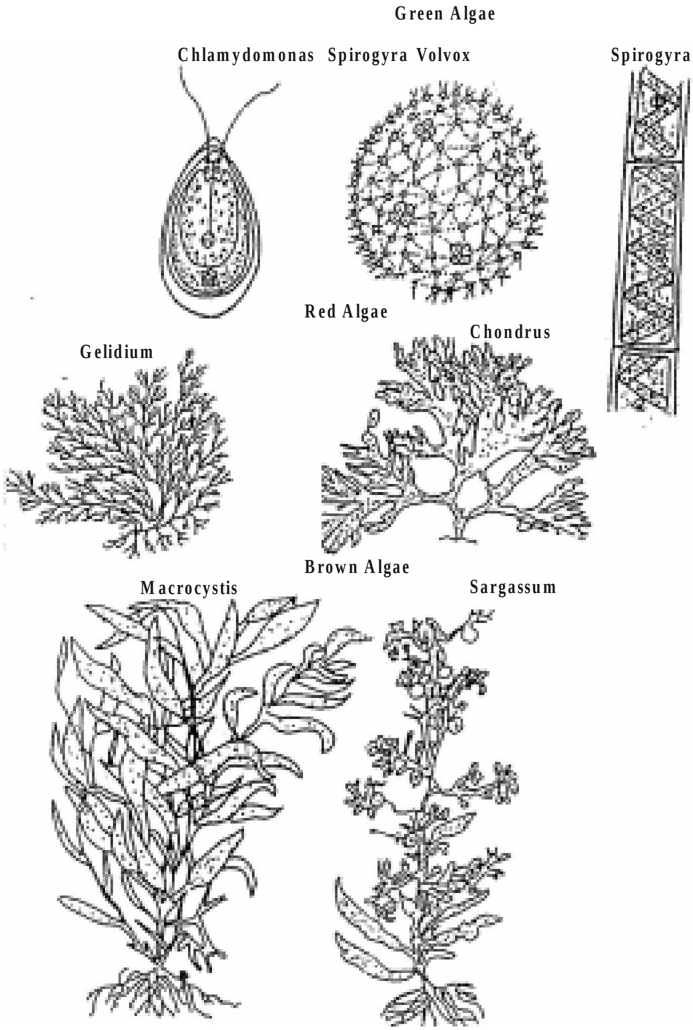


Fig : 1.21. Thallus Organization in Algae

Cell Structure & Pigmentation

With the exception of blue green algae which are treated as *Cyanobacteria*, all algae have eukaryotic cell organization. The cell wall is made up of cellulose and pectin. There is a well defined nucleus and membrane bound organelles are found.

Three types of Photosynthetic pigments are seen in algae. They are 1. **Chlorphylls 2. Carotenoids 3. Biliproteins.** While **chlorophyll a** is universal in all algal classes, **chlorophyll b,c,d,e** are restricted to some classes of algae.

The yellow, orange or red coloured pigments are called **carotenoids**. It includes the caroteins and the Xanthophylls. The water soluble biliproteins called **phycoerythrin** (red) and **phycocyanin** (blue) occur generally in the Rhodophyceae and ***Cyanophyceae*** and the latter is now called ***cyanobacteria***. These pigments absorb sunlight at different wavelengths mainly in blue and red range and help in photosynthesis. Pigmentation in algae is an important criterion for classification.

The colour of the algae is mainly due to the dominance of some of the pigments. For example in red algae(class Rhodophyceae) the red pigment phycoerythrin is dominant over the others. The pigments are located in the membranes of chloroplasts. In each chloroplast one or few spherical bodies called **pyrenoids** are present. They are the centres of starch formation.

Nutrition and reserve food materials in Algae

Algae are autotrophic in their mode of nutrition. The carbohydrate reserves of algae are various forms of starch in different classes of Algae. For example, in Chlorophyceae, the reserve food is **starch** and in Rhodophyceae it is **Floridean starch,** in Phaeophyceae it is **laminarian starch** while in Euglenophyceae it is **paramylon.** Members of Phaeophyceae store **mannitol** in addition to carbohydrate. Members of Xanthophyceae and Bacillariophyceae store **fats, oils** and **lipids**. The nature of reserve food material is also another important criterion used in classification.

Arranagement of Flagella

Flagella or cilia(sing.flagellum / cilium) are organs of locomotion that occur in a majority of algal classes. There are two types of flagella namely **whiplash** (Acronematic) and **tinsel** (pantonematic).

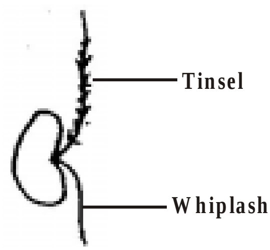


Fig : 1.22. Types of Flagella

The whiplash flagellum has a smooth surface while the tinsel flagellum has fine minute hairs along the axis. The number, insertion, pattern and kind of flagella appear to be consistent in each class of algae and it is an important criterion for classification of algae. Motile cells of the Algae are typically biflagellate. When both flagella are of equal length and appearance, they are described as **isokont. Heterokont** forms have dissimilar flagella with reference to their length and types. **Red algae(Rhodophyta) and Blue green algae(Cyanophyta) lack flagella**. Each flagellum consists of two central microtubles surrounded by a peripheral layer of nine doublet microtubles. This is called 9+2 pattern of arrangement which is a characteristic feature of eukaryotic flagellum. The entire group of microtubles is surrounded by a membrane.

Reproduction

Three common methods of reproduction found in Algae are 1. Vegetative 2. Asexual and 3. Sexual

Vegetative reproduction

It lakes place by fragmentation or by the formation of adventitious branches.

Asexual reproduction:

It takes place by means of different kinds of spores like Zoospores, Aplanospores and Akinetes. Zoospores are naked, flagellated and motile. eg.(*Chlamydomonas*) Aplanospores are thin walled and non motile (eg *Chlorella*) Akineties are thick walled and non motile spores (eg *Pithophora*)

Sexual Reproduction

Sexual reproduction involves fusion of two gametes. If fusing gametes belong to the same thallus it is called homothallic and if they belong to different thalli it is heterothallic. Fusing gametes may be isogametes or heterogametes.

Isogamy

It is the fusion of two morphologically and physiologically similar gametes.eg. *Spirogyra* and some species of *Chlamydomonas* .

Heterogamy

This refers to the fusion of dissimilar gametes. It is of two types 1. Anisogamy 2. Oogamy

1. **Anisogamy** is the fusion of two gametes which are morphologically dissimilar but physiologically similar (both motile or both non-motile)
2. **Oogamy** refers to the fusion of gametes which are both morphologically and physiologically dissimilar. In this type of fusion the male gamete is usually referred to as **antherozoid** which is usually motile and smaller in size and the female gamete which is usually non- motile and bigger in size is referred to as **egg.** The sex organ which produces the antherozoids is called **antheridium** and the egg is produced in **oogonium.** The fusion product of antherozoid and egg is called **Zygote.** The zygote may germinate directly after meiosis or may produce **meiospores** which in turn will germinate.

Classification

F.E. Fritsch (1944-45) classified algae into 11 classes in his book **"Structure and Reproduction of Algae"** based on the following characteristics.

1. Pigmentation 2. Reserve food 3. Flagellar arrangement 4. Thallus organization 5. Reproduction.

The 11 classes of algae are:

1. **Chlorophyceae 2. Xanthophyceae 3. Chrysophyceae 4. Bacillariophyceae 5. Cryptophyceae 6. Dinophyceae 7. Chlromonodineae 8.Euglenophyceae 9. Phaeophyceae 10. Rhodophyceae and 11. Myxophyceae**

Some major groups of Algae and their characteristics are summarized in Table 1.4.

Economic Importance of Algae

Recent estimates show that nearly half the world's productivity that is carbon fixation, comes from the oceans. This is contributed by the algae, the only vegetation in the sea. Algae are vital as primary producers being at the start of most of aquatic food chains.

Algae as Food: Algae are important as a source of food for human beings, domestic animals and fishes. Species of ***Porphyra*** are eaten in Japan, England and USA. ***Ulva, Laminaria, Sargassum*** and ***Chlorella*** are also used as food in several countries. Sea weeds (***Laminaria, Fucus***, ***Ascophyllum***) are used as fodder for domestic animals.

Algae in Agriculture: Various blue green algae such as ***Oscillatoria, Anabaena, Nostoc, Aulosira*** increase the soil fertility by fixing the atmospheric nitrogen. In view of the increasing energy demands and rising costs of chemically making nitrogenous fertilizers, much attention is now being given to nitrogen fixing bacteria and blue green algae. Many species of sea weeds are used as fertilizers in China and Japan.

Algae in Industry

a. **Agar – agar** : This substance is used as a culture medium while growing bacteria and fungi in the laboratory. It is also used in the preparations of some medicines and cosmetics. It is obtained from the red algae ***Gelidium*** and ***Gracilaria*.**

b. A phycocolloid **Alginic acid** is obtained from brown algae. Algin is used as emulisifier in ice creams, tooth pastes and cosmetics.

c. **Idodine:** It is obtained from kelps (brown algae) especially from speicies of ***Laminaria***.

d. **Diatomite** : It is a rock-like deposit formed on the siliceous walls of diatoms(algae of **Chrysophyceae**). When they die they sediment, so that on the seabed and lake bottom extensive deposits can be built up over long periods of time. The resulting '**diatomaceous earth'** has a high proportion of silica. Diatomite is used as a fire proof material and also as an absorbent.

Table : 1.4. Characteristics of Major Groups of Algae

Class	Pigments	Flagella	Reserve food
Chlorophyceae (green algae)	Chlorophyll-a,b Carotene XanthophyII	Two identical flagella per cell	Starch
Xanthophyceae	Chlorophyll-a, b Carotene XanthophyII	Heterokont type, one whiplash type and other tinsel	Fats and Leucosin
Chrysophyceae (diatoms, golden algae)	ChlorophyII-a, b Carotenoids	One,two or more unequal flagella	Oils and Leucosin
Bacillariophyceae	Chlorophyll-a, c Carotenes	Very rare	Leucosin and fats
Cryptophyceae	Chlorophyll-a, c Carotenes and xanthophylls	Heterokont type-one tinsel and other whiplash	Starch
Dinophyceae (Dinoflagellates)	ChlorophyII-a, c Carotenoids Xanthophyll	Two unequal lateral flagella in different plane.	Starch and oil
Chloromonodineae	ChlorophyII-a, b Carotenes Xanthophyll	Isokont type	Oil
Euglenophyceae (Euglenoids)	Chlorophyll-a, b	One,two or three anterior flagella.	Fats and paramylon
Phaeophyceae (brown algae	ChlorophyII-a Xanthophyll	Two dissimilar lateral flagella	Laminarin, fats
Rhodophyceae (Red algae)	Chlorophyll-a Phycocyanin Phycoerythrin	Non-motile	Starch
Myxophyceae	Chlorophyll-a, carotene, phycocyanin, phycoerythrin	Non-motile	Cyanophyce an starch

It is used in sound and fire proof rooms. It is also used in packing of corrosive materials and also in the manufacture of dynamite.

Algae in space travel: ***Chlorella pyrenoidosa*** is used in space travel to get rid of Co_2 and other body wastes. The algae multiplies rapidly and utilizes the Co_2 and liberate 0_2 during photosynthesis. It decomposes human urine and faeces to get N_2 for protein synthesis.

Single cell protein (SCP): ***Chlorella*** and ***Spirullina*** which are unicellular algae are rich in protein and they are used as protein source. Besides, ***Chlorella*** is a source of vitamin also. The rich protein and aminoacid content of ***chlorella*** and ***Spirulina*** make them ideal for single cell protein production. An antibiotic **Chlorellin** is extracted from ***Chlorella***.

Sewage Disposal: Algae like ***Chlorella*** are grown in large shallow tanks, containing sewage. These algae produce abundant oxygen by rapid photosynthesis. Microorganisms like aerobic bacteria use these oxygen and decompose the organic matter and thus the sewage gets purified.

Harmful effects of Algae

Under certain conditions algae produce **'blooms',** that is dense masses of material. This is especially true in relatively warm conditions when there is high nutrient availability, which sometimes is induced by man as and when sewage is added to water or inorganic fertilizers run off from agricultural land into rivers and lakes. As a result of this a sudden and explosive growth of these primary producers (algae) occurs. They are produced in such a huge quantity that they die before being eaten. The process of decomposition is carried out by aerobic bacteria which in turn multiply rapidly and deplete the water of oxygen. The lack of oxygen leads to the death of fish and other animals and plants in the lakes. The increase of nutrients which starts off the entire process is called **eutrophication** and if rapid it constitutes a major problem of pollution. The toxins produced by algal bloom can also lead to mortality. This can be a serious problem in lakes and oceans. Sometimes the toxins may be stored by shellfish feeding on the algae and be passed on to man causing the disease called paralytic shellfish poisoning. Algae also cause problems in water storage reservoirs where they may taint the water and block the beds of sand used as filters.

Self Evaluation

One Mark

Choose the correct answer

1. Phycology is the study of

   a. plants b.virus c.Algae d.bacteria

Fill in the blanks

1. __________ is the red colour pigment found in algae.
2. ___________ is the blue colour pigment found in algae.
3. ___________ algae lack motile cells.

Match

Macroscopic	- Attached to the bottom of shallow water
Epiphyte	- Laminaria
Benthic	- Spirogyra
Lithophyte	- Growing on another plant
Filamentous	- Grow attached to the rocks.

Two Marks

1. Define: thallus
2. What is a Lichen?
3. Name the three types of photosynthetic pigments found in algae?
4. Differentiate a whiplash flagellum from a tinsel flagellum.
5. What are pyrenoids?
6. Differentiate isokont from heterokont type of flagella?
7. Define isogamy / heterogamy/ anisogamy/ oogamy.
8. What is agar-agar?
9. What is diatomite?
10. Write any two uses of diatomite.
11. How are the algae used in space travel?
12. What is SCP?
13. How are algae used in sewage disposal?
14. What is algal bloom. How does it affect the lakes?
15. Algae are not associated with diseases unlike many fungi and bacteria. What is the reason for this?

Five Marks

1. What is eutrophication? What is it's significance?
2. Write notes on: Nutrition and reserved food materials in algae.
3. Write about the pigmentation in algae.

Ten Marks

1. Write an essay on the economic importance of algae.
2. Write an essay on reproduction in algae.

2.4.1 Spirogyra

Class : Chlorophyceae

Order : Conjugales

Family : Zygnemaceae

Genus : Spirogyra (Spiro-coiled; gyra-curved)

Occurrence

Spirogyra is a very common free floating fresh water alga found in fresh water pools, ponds, lakes etc., in great abundance. It is also known as **"water silk"** or **"pond silk"**. The filaments are slimy in nature because of the presence of a mucilaginous substance around them. **Spirogyra adnata** is an attached form and found in flowing waters. In later stage this species also becomes free floating. Some of the species develop rhizoid like **haptera**, occasionally at the basal ends of the filaments. **Spirogyra** is a chlorophyllous alga. **S. columbiana** is reported from South India and **S. jogensis** has been reported from Jog falls, Mysore.

Structure

The filaments of **Spirogyra** are unbranched with many cells placed end to end. All the cells are similar in structure. The cells are cylindrical in shape and some time several times longer than their breadth. The cell wall of the filament is usually two-

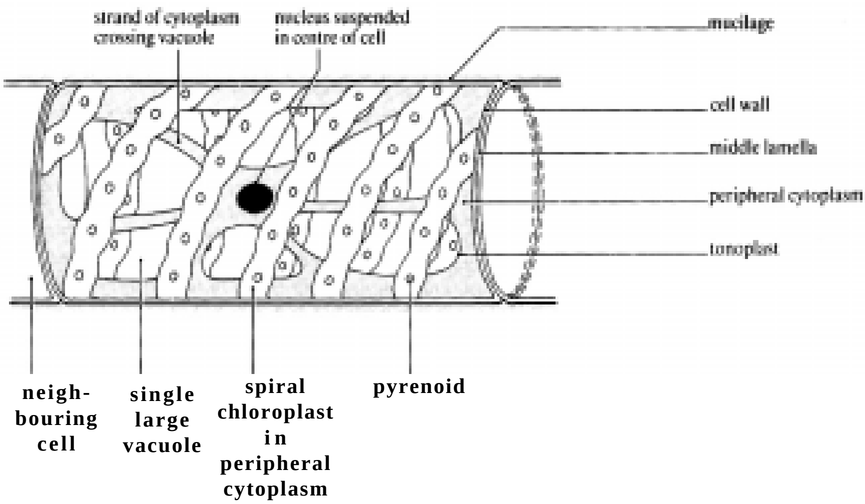


Fig.1.23 Structure of Spirogyra cell - Diagram of Side View

layered. The outer most layer consists of pectic substances and the layer just outside the protoplast consists of cellulose, the outer most portion of pectic substances dissolve in water to form **slimy sheath**. This is some times referred to as the **third layer** of the cell wall. The cells are uninucleate, the nucleus is usually situated in the centre of the cell and connected by cytoplasmic strands to the dense cytoplasm of the peripheral region. There is a big central vacuole the **cytoplasmic strands** are also called as primordial utricle. In **Spirogyra** the chlorololats are spiral and ribbon like, they may be serrated or smooth at the margins. The number of chloroplasts ranges 1-14 in different species. Many pyrynoids are found in each ribbon like chloroplast. Some times the filaments of some species of Spirogyra exhibit gliding movements.

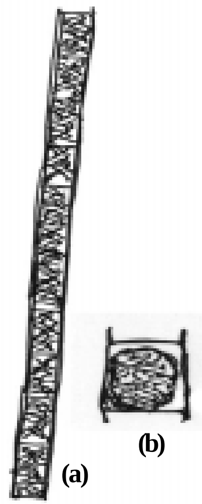


Fig.1.24 (a) Spirogyra habit (b) Aknite

Reproduction

It takes place by the following methods.

(1) Vegetative Reproduction

By (a) parthenospores, (b) akinetes and (c) aplanospores

(2) Sexual reproduction by conjugation

(1) Vegetative reproduction

The vegetative filaments break accidentally into many small fragments. Each such fragment developes into a new filament.

(a) By parthenospore

Some times the contents of a cell recede from the cell wall and lie in the middle. A thick wall surrounds the whole content which is called a **parthenospore**. It directly forms a new plant.

Parthenogenesis

The formation of **parthenospores** or **azygospores**, has been observed in many species. Here the conjugation does not take place and the contents of the cells become rounded. The walls are serrated around these protoplasts and they are called parthenospores (or) azygospores. Azygospore formation occurs in **S. greenlandica**. The process of formation of parthenospores is known as **parthenogenesis**.

(b) By akinetes

In **S. farlowi** thick walled akinetes are formed. The entire cell content of the akinete gives rise to a new plant.

(c) By aplanospores

During unfavourable conditions, aplanospores are formed in **Spirogyra**. The contents recede from the cell wall and the whole structure comes to rest. It is non-motile. On the return of favurable conditions the old cell wall of the parent is cast off and new wall develops. They directly give rise to a new plant.

Sexual Reproduction

In Spirogyra the sexual reproduction takes place by special gametes called **aplanogametes** and the process is **aplanogamy**. The motile gametes are always lacking. Aplanogammy takes place by conjugation, which may be **scalariform** or **lateral**. In each cell a single aplanogamete is produced which moves into the other cell through a conjugation tube in amoeboidal fashion. The species may be homothallic or heterothallic Scalariform conjugation is the process of reproduction of heterothallic species. Lateral conjugation, takes place in homothallic species. In scalariform conjugation the aplano gametes of two filaments opposite to one another, unite where as in lateral conjugation the aplanogametes of the two adjacent cells of the same filament unite.

Scalariform conjugation

This type of reproduction is found in majority of the species of **Spirogyra**. The filaments taking part in conjugation lie side by side. Very soon the out growths are given out from the lateral walls of the opposite cells of the filaments. The out growths of opposite cells touch each other very soon the wall of contact dissolves and a tubular passage is formed between the two opposite cells of the two filaments lying side by side. This tubular passage is called **conjugation tube**. Simultaneously the contents of the cells retract and aplanogametes are developed. A single aplanogamete is developed in each cell. The aplanogametes formed in the cells of one filament pass into the opposite cells of the other filament through conjugation tubes in amoeboid

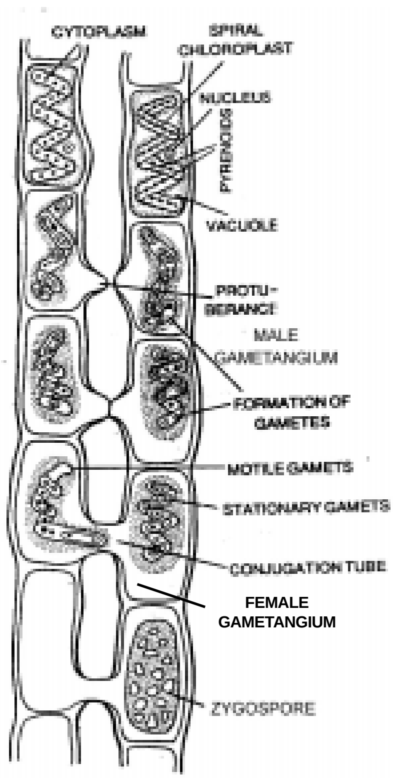


Fig. 1.25 Scalariform conjugation in Spirogyra

fashion. The plasmogamy is followed by karyogamy. The transferring aplanogametes are considered to be **male gametes** while the receiving aplanogametes are **female gametes**. Just after the fusion the walls are formed around the zygote and they are called **zygospores**. A single zygospore develops in each cell of the female filament. The wall of the female decays and the zygospores are set free in the water. Each zygospore germinate into a new plant after a resting period.

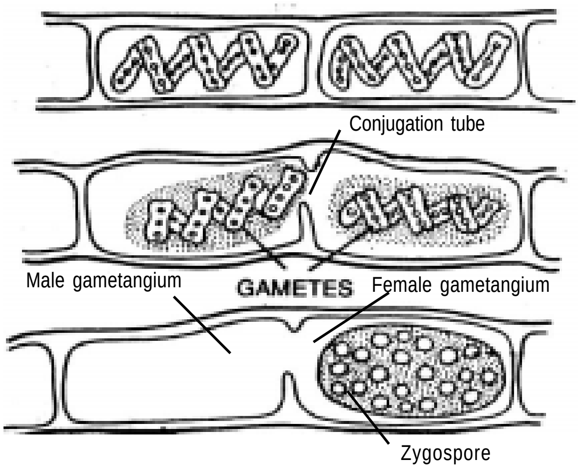


Fig. 1.26 Lateral conjugation in Spirogyra

Lateral conjugation

This type of reproduction occurs in homothallic species. Here the aplanogametes of the adjacent cells of the same filament unite. At the septum a tube like structure develops and through this opening the content of one cell passes into the other. Then both a manosomefes fuse to form a zygote. The empty cells are considered as male gametangia and the cells with zygotes are female gametangia. Very soon a thick wall is secreted around each zygote and dark coloured zygospores develop. They undergo a period of rest and germinate under favourable conditions.

Germination of zygospore

Prior to germination, the diploid nucleus divides meiotically and, four haploid nuclei are formed. Three of the four haploid nuclei disintegrate and only one remains functional. The zygospore wall breaks and the germling comes out which soon develops into a new filament.

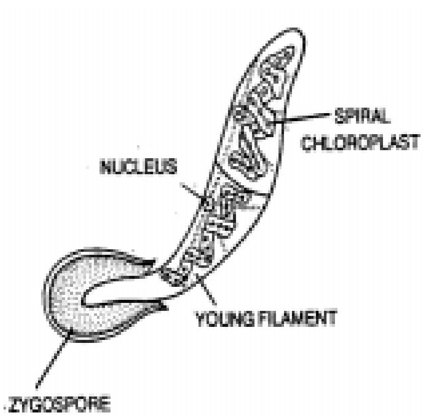


Fig. 1.27 Germination of Zygospore

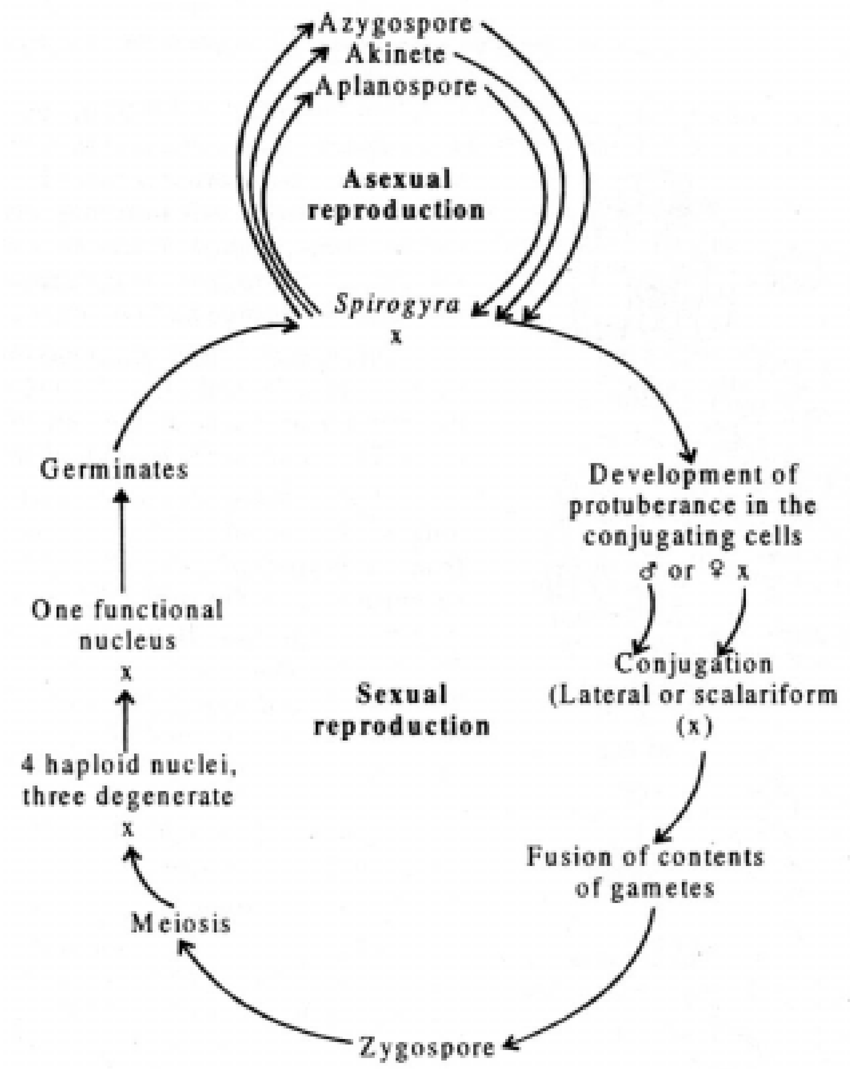


Fig.1.28 Schematic representation of Life Cycle of a Spirogyra

Self Evaluation
One Mark

Choose the correct answer

1. Spirogyra occurs in
   a) Running salt water b) Running fresh water c) Marine water d) Stagnant water

2. On germination each zygospore of Spirogyra gives rise to
   a) Four plants b) Two plants c) Three plants d) One plant
3. In Spirogyra pyrenoid is found in
   a) Nucleus b) Cell wall c) Chloroplast d) Cytoplasm
4. The slimy sheath that is seen in Spirogyra is considered sometime as
   a) Third layer b) Second layer c) First layer d) Fourth layer
5. In Spirogyra cells the chloroplasts are
   (a) Spherical in shape (b) Conical in shape
   (c) Spiral in shape (d) Rectangular in shape
6. Scalariform conjugation is the process of reproduction in
   (a) Homothallic species (b) Parthenocarpic species
   (c) Symbiotic species (d) Heterothallic species

Fill in the blanks

1. .... is the common name of Spirogyra.
2. .... are produced as a result of Parthenogenesis.
3. Vegetative reproduction takes place by....................

Two Marks

1. Define conjugation.
2. What are common names of Spirogyra.
3. Briefly explain the nature of cell wall in Spirogyra.
4. Define aplanogametes.

Five Marks

1. Differentiate zygospore from azygospore.
2. What is parthnegenesis?
3. Give a brief out line of scalariform conjugation with proper example.
4. Describe the external structure of Spirogyra.

Ten Marks

1. Describe the two types of sexual reproduction seen in Spirogyra.
2. Give an account of the habitat and structure of Spirogyra.
3. Describe the Life Cycle of Spirogyra.

2.5 Bryophytes

There are fossil records of blue green algae (Cyanobacteria) living 3000 million years ago and many eukaryotic organisms have existed for more than 1000 million years. However the first organisms to colonize the land, primitive plants did so only 420 millions years ago. The greatest simple problem to overcome in making the transition from water to land is that of desiccation. Any plant not protected in some way, for example, by a waxy cuticle, will tend to dry out and die very soon.

Salient features of Bryophyta

Bryophyta are the simplest group of land plants. They are relatively poorly adapted to life on land, so they are mainly confined to damp,shady places. These are **terrestrial non-vascular plants**(no vascular tissue namely xylem and phloem) which still require moist environment to complete their life-cycle. Hence these are called **amphibians** of plant kingdom. They are more advanced than algae in that they develop special organs. The male sex organ is called antheridium and the female sex organ is called archegonium. Bryophytes show distinct alternation of generation in their life cycles. Bryophytes include mosses, liverworts and hornworts.

Distinguishing features of Bryophytes

1. They are small terrestrial plants.
2. They are without a distinct root system but are attached to the substratum by means of thin, filamentous outgrowth of the thallus called rhizoids.
3. Water and mineral salts can be absorbed by the whole surface of the plant body, including the rhizoids. So the main function of rhizoids is anchorage, unlike true roots (true roots also possess vascular tissues, as do true stems and leaves). Thus the “stems” and “leaves” found in some Bryophytes are not homologous with stems and leaves of vascular plants. The plant body is called thallus.
4. They do not possess true vascular tissues.
5. Male sex organ is called antheridium and female sex organ is called archegonium.
6. Sex organs are multi-cellular and they have a protective jacket layer of sterile cells.
7. Sexual reproduction is of oogamous type.

8. Bryophytes show distinct alternation of gametophytic generation with sporophytic generation.
9. Gametophyte generation is dominant and independent.
10. Sporophyte generation is very small, microscopic and dependent on the gametophyte phase.

Alternation of Generations

In common with all land plants and some advanced algae such as ***Laminaria,*** bryophytes exhibit alternation of generations. Two types of organism, a **haploid gametophyte** generation and a **diploid sporophyte** generation, alternate in the life cycle. The cycle is summarized in the fig below.

The haploid generation is called the gametophyte because it undergoes sexual reproduction to produce gametes. Production of gametes involves **mitosis**, so the gametes are also haploid. The gametes fuse to form a **diploid zygote** which grows into the next generation, the diploid sporophyte generation. It is called sporophyte because it undergoes asexual reproduction to produce spores. Production of spores involves **meiosis**, so that there is a return to the haploid condition. The haploid spores give rise to the gametophyte generation.

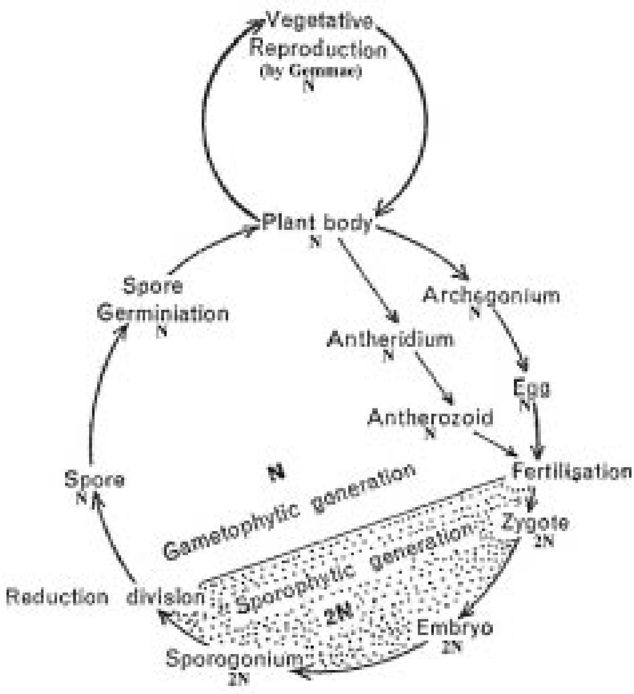


Fig : 1.18. Generalised life cycle of a Bryophyte plant showing alternation of generation

One of the two generations is always more conspicuous and occupies a greater proportion of the life cycle. This generation is called as the dominant generation**.** **In all Bryophytes the gametophyte generation is dominant**. **In all other land plants the sporophyte generation is dominant**. It is customary to place the dominant generation in the top half of the life cycle diagram. The figure given above summarises the life cycle of a typical Bryophyte. One point that must be remembered here is that gamete production involves mitosis and not meiosis as in animals. Meiosis occurs before the production of spores.

BRYOPHYTA

1. **Hepaticae**	2. **Anthocerotae**	3. **Musci**
Liverworts	**hornworts**	**Mosses**
Eg. *Riccia*	**eg. *Anthoceros***	**eg.*Funaria***

Classification

Bryophyta is divided into three major classes.

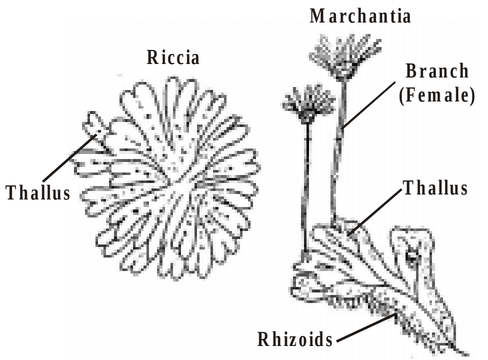


Fig : 1.30. Some liverworts

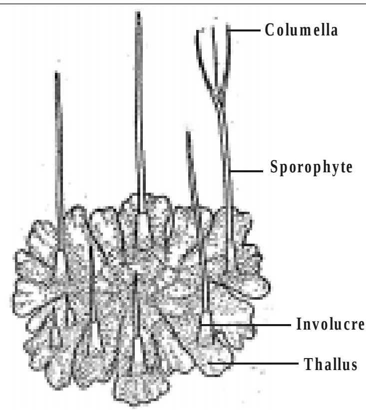


Fig: 1.31. Hornwort-Anthoceros

1. Class Hepaticae

These are lower forms of Bryophytes. They are more simple in structure than mosses and more confined to damp and shady habitats. They have an undifferentiated thallus. Protonemal stage is absent. Sporophyte is very simple and short lived . In some forms sporophyte is differentiated into foot, seta and capsule. Eg. ***Marchantia***. In some the foot and seta are absent. Eg. ***Riccia.***

2. Class Anthocerotae

Gametophyte is undifferentiated thallus. Rhizoids are unicellular and unbranched. Protonemal stage is absent. Sporophyte is differentiated into foot and capsule and no seta. Eg. ***Anthoceros***.

3. Class Musci

They have a more differentiated structure than liverworts. They often form dense cushions. 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 Eg. ***Funaria*.**

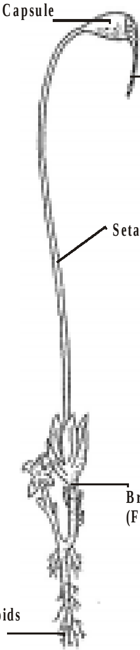


Fig : 1.32. Moss - Funaria

Economic Importance

1. Bryophytes form dense mat over the soil and prevent soil erosion.
2. **Sphagnum** can absorb large amount of water. It is extensively used by gardeners in nursery to keep seedlings and cut plant parts moist during propagation.
3. Peat is a valuable fuel like coal. Mosses like Sphagnum which got compacted and fossilized over the past thousands of years have become peat.
4. Mosses are good sources of animal food in rocky areas.

SELF EVALUATION

One Mark

Choose the correct answer

1. Production of gametes in Bryophytes involve

   a. Meiosis b. Mitosis c. fertilization d. reduction division

Fill in the blanks

1. In all bryophytes __________ generation is dominant.
2. In all land plants other than bryophytes __________ generation is dominant.

Two Marks

1. Give reasons: Bryophytes are called the amphibians of plant kingdom.
2. Name the three main classes of Bryophyta.
3. What is peat?
4. How is ***Sphagnum*** used in nursery?

Ten Marks

1. Discuss the problems associated with the transition from an aquatic environment to terrestrial habitat.
2. Discuss the classification of Bryophyta.

2.5.1 Riccia

Class : Hepaticae
Order : Marchantiales
Family : Ricciaceae
Genus : Riccia

Riccia, which belongs to the family Ricciaceae is the single genus with 130 species. **Riccia** is more confined to damp and shady habitats. It can grow in water, plains and in hilly regions. It has an undifferentiated thallus and simple in structure.

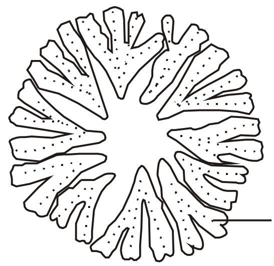


Fig.1.33 Riccia thallus - habit

The following are some of the important species of **Riccia**, **R. fluitans, R. gangetica, R. cruciata, R. kashyapii, R. discolor** (this is also called as **R. himalayensis**). Of these, **R. gangetica** and **R. fluitans** are native of India. Excepting **R. fluitans**, the rest are land plants. **R. fluitans** is aquatic in nature and is found floating in stagnant waker reservoir.

Riccia thallus grow in large number in close association, covering the surface like a mat. They are relatively poorly adapted to life on land. So they are mainly confined to damp and shady places. The species of **Riccia** are terrestrial, nonvascular plants commonly called **amphibians** of plant kingdom.

The structure of mature gametophyte

Riccia has two generations namely, gametophytic and sporophytic. Gametophytic generation is dominant and independent. Sporophyte is dependent upon the gametotophyte.

The adult terrestrial gametophyte is prostrate, rosette-like dichotomously branched dorsiventral and deep green coloured plant found on suitable substratum of dampsoil. The dichotomous branching of the thallus is found quiet close to each other and thus a **rosette-like** appearance is attained. Each and every branch of the thallus is more of less spoon shaped or rectangular in outline. A distinct longitudinal groove is found on the dorsal side of each branch of the thallus. The growing point is situated in the notch found between dichotomous branched thallus. Numerous scales and rhizoids are seen on the ventral surface of the thallus. The ventral surface bears a row of one celled thick, multicellular scales. They are arranged close to each other towards the apex of the branch. The older parts of the thallus bear two rows of scales.

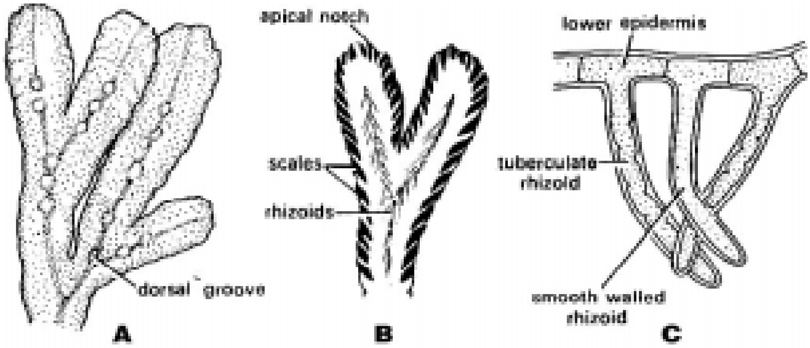


Fig.1.34. Riccia thallus (a) dorsal surface (b) ventral surface (c) smooth walled and tuberculate rhizoids

The rhizoids absorb the nutrients and water from substratum, and in this way they perform the function of the roots. The rhizoids are of two types, i.e. smooth-walled and tuberculate. In each case the rhizoids are unicellular. They are absent in **R. fluitans** (aquatic species).

Internal structure of the thallus

The cross section of the thallus shows simple tissue arrangement. Two regions are distinctly seen. The dorsal region is capable of food preparation. It is provided with chlorophyllous tissues and the ventral region is storage in function as it contains parenchyma tissue which is colourless. However, the inter cellular spaces are absent and the cells are filled up with starch grains. From the single layered epidermis formed by the compactly arranged storage tissues several unicellular rhizoids (smooth walled or tuberculate) and muticellular scales are given out.

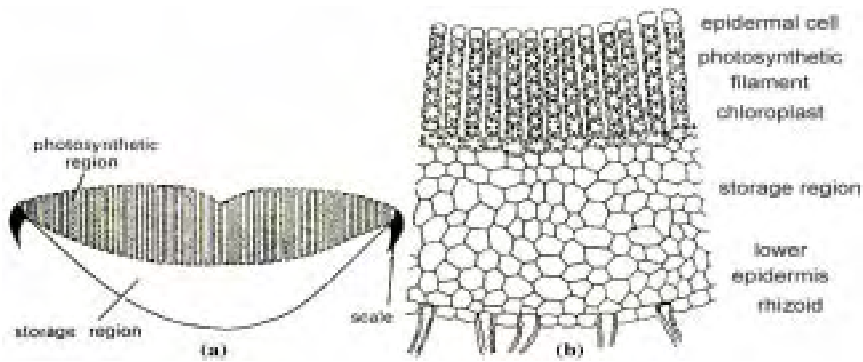


Fig.1.35 Riccia thallus internal structure (a) transverse section of thallus (diagrammatic), (b) a part of T.S. of thallus showing cellular details

Chlorophyllous tissue

The dorsal region of the thallus consists of chlorophyllous cells. These cells with distinct chloroplasts in them are are arranged in vertical rows. There are regular air canals in between the two vertical rows of the chlorophyllous cells and this region is photosynthetic and synthesise carbohydrates. The epidermis of the dorsal surface of the thallus is discontinuous and open outside at several places by the opening of air canals. The epidermis is single layered. The exchange of gases takes place through the air canals.

Reproduction

The reproduction in **Riccia** takes place by means of (1) vegetative and (2) sexual methods.

(1) Vegetative Reproduction

(a) By the death and decay of the older parts of the thallus

(b) By adventitious branches

(c) By cell division or gemma formation

(d) By tubers

(e) By thick apices

By adventitious Branches

In several species of Riccia, the adventitious branches are produced on the ventral surface of the thallus. These branches get detached from the thalli and develop into new gametophytes.

By Tubers

In species such as **R. discolor**, the vegetative tubers develop at the apices of the branches of the thallus which face adverse conditions and develop into new plants on the approach of favourable conditions.

By cell division or gemma formation

Riccia may also reproduce vegetatively by cell division of the young rhizoids which develop into gemma-like structure. These structures give rise to new plants.

Sexual reproduction

Gemetophyte Generation

Majority of the species of **Riccia** are homothallic (monoecious) i.e., and antheridia and archegonia are borne upon the same thallus. The species of this type are **R. glauca** and **R. gangetica**. The heterothallic (dioecious) species are also common. In such species the antherdia and archegonia develop separately on different thalli and the important species of this type are **R. himalayensis** and **R. frostii**.

Sporophyte generation

At the time of formation of spores, there is genotypic type of sex determination i.e., two spores of a tetrad develop into female and two into male gametophytes, after meiosis.

Sexorgans

The sex organs, antheridia and archegonia, are produced in the groove situated on the dorsal surface of the mature gametophyte in acropetal succession.

In homothallic species, the alternate groups of antheridia and archegonia are found at a sufficient distance from the growing point, even though the sex organs start growing initially on the floor of the dorsal groove as they grow, the surrounding tissue also grows quickly. As a result of which a distinct chamber is seen surrounding the male and the female sex organs. They are the antheridial and archegonial chambers.

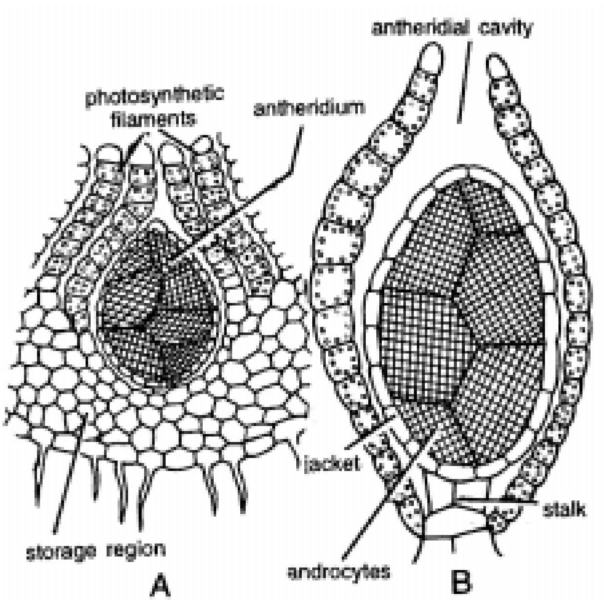


Fig. 1.36. Riccia - Male sex organs.
A, Vertical section of the thallus showing position of antheridium B, An antheridium

Structure of mature antheridium

A mature antheridium remains embedded in an antheridial chamber, which opens by an ostiole on the dorsal side of the thallus. The mature antheridium consists of a few celled stalk and the antheridium proper. The antheridium proper may be rounded or somewhat pointed at its apical end. A sterile single layered jacket-layer encircles the antheridium and protects it. The mature antheridium contains androcytes within the jacket layer. Each androcyte metamorphoses into an **antherozoid**. Each antherozoid is a curved structure with two flagella.

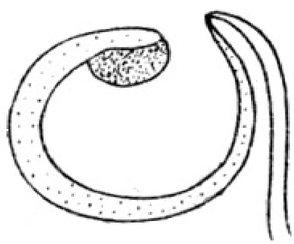


Fig. 1.37. Riccia - Antherozoid

Structure of mature archegonium

Mature archegonium is a flask-shaped structure attached to the thallus by a short stalk. It consists of an elongated neck made up of 6 rows of cells and a **bulbous venter**. The six vertical rows of the cells enclose a neck canal. There are four **cover cells** at the top of neck canal. Prior to maturity, the four neck canal cells, found within the neck canal, disintegrate into mucilaginous mass. The venter has a single layered wall around it which is of 12-20 cells in perimeter. The venter encloses a **venter canal cell** and the **large egg**. The venter canal cell disintegrates on maturity and only the large egg remains in the venter. The muilagenous mass absorbs water by imbibition and because of the pressure, the cover cells become separated from each other and an opening is formed. The mucilaginous mass extrudes through the opening and attracts the antherozoids, which enmass around the opening.

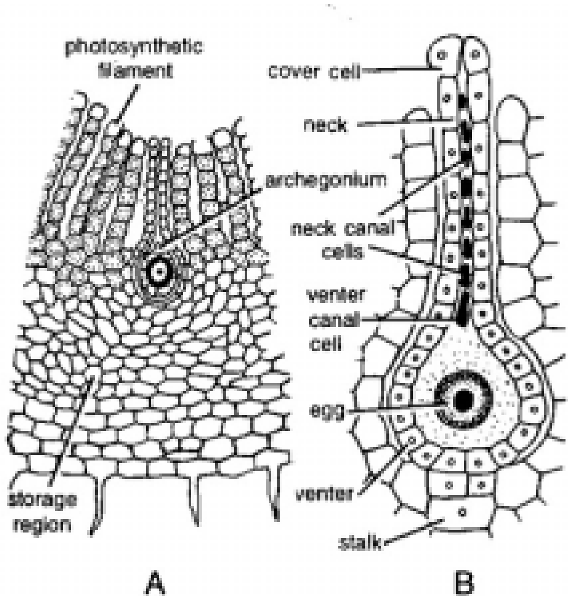


Fig. 1.38. Riccia - Female sex organs.
A, Vertical section of the thallus showing position of archegonium B, An archegonium

The venter cells are stimutated by the process of fertilization, they divide periclinally and the wall of the venter benomes two celled in thickness, ultimately a two layered **calyptra** is formed inside which, the developing embryo is situated.

Fertilization

Water is indispensable for the process of fertilization. The antherozoids reach the mouth of the archegonuim through the medium of water. The mucilaginous mass of the neck region absorbs water and swells and as a result the cover cells get separated. This results in the formation of a passage which facilitates the entry of sperms or antherozoid. The antherozoids enter the mouth of the archegonuim, travel through the neck and reach the vicinity of the egg. One of the antherozoids penetrates egg cell and the fertilization is effected. Ultimately by the union of the nuclei of male and female gametes, a zygote is formed. The zygote contains 2n number of chromosomes i.e., the zygote is diploid.

Sporophyte Generation

The diploid zygote is the first cell of the sporophyte generation. This cell secretes a wall around it soon after the fertilization and enlarges in size and nearly fills the cavity of the venter. Afterwards it undergoes division and attains two celled stage. The upper cell is known as **epibasal cell** and lower cell is known as **hypobasal cell.**

Sporophyte

The two cells of the embryo (epibasal and hypobasal) divide further and give rise to a **four celled stage** of the embryo which is followed by eight-celled stage.

At a later stage the embryo is differentiated into two regions. The outer layer is **amphithecium** and the inner mass of cells is **endothecium.** The amphithecium is protective in nature whereas endothecium gives rise to a mass of sporogenous cells. **Sporemother** cells are produced from sporogenous cells. Spore mother cells undergo meiotic division and tetrads are produced. Thus a tetrad of four spores is formed. The spores becomes separated from each other only on maturation. The spores are haploid in nature. On the death and decay of the thallus, the spores get free from the sporogonium.

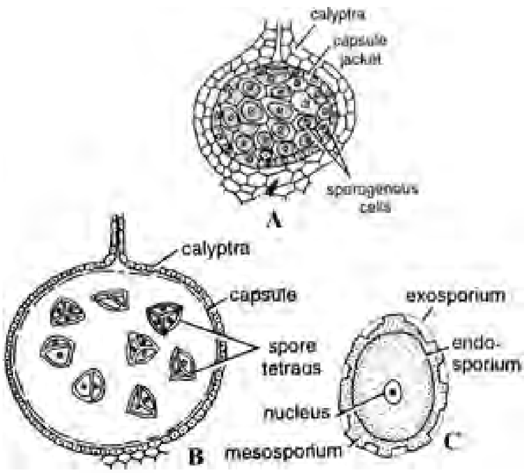


Fig. 1.39. Riccia - Sporophyte
A, Developing sporophyte. B, Mature sporophyte. C, Single spore

Structure of the spore

The mature spore is three layered. The outer most, cutinized layer is **exosporium,** the middle layer is **mesosporium** which is thick walled and consists of three concentric zones. The inner most layer is **endosporium.** The spore is the beginning of the gametophytic generation.

Life cycle

Riccia shows alternation of generations a haploid gametophyte generation and a diploid sporophyte generation alternate each other.

The haploid generation is called the gametophyte because it undergoes sexual reproduction to produce male and female gametes. Production of gametes involves mitosis, so the gametes are also haploid. The male and female gametes of Riccia fuse to form a diploid zygote which grows into the next generation the diploid sporophyte generation. Sporophyte produces spore tetrads. Production of spore involves meiosis. Hence, there is a return to the haploid condition. The haploid spores give rise to the gametophyte generation. In **Riccia,** the gametophyte generation is dominant.

The life cycle of Riccia shows regular alternation of gametophytic and sporophyte generations. The two generations are morphologically different hence this type of alternation of generation is known as **heteromorphic.**

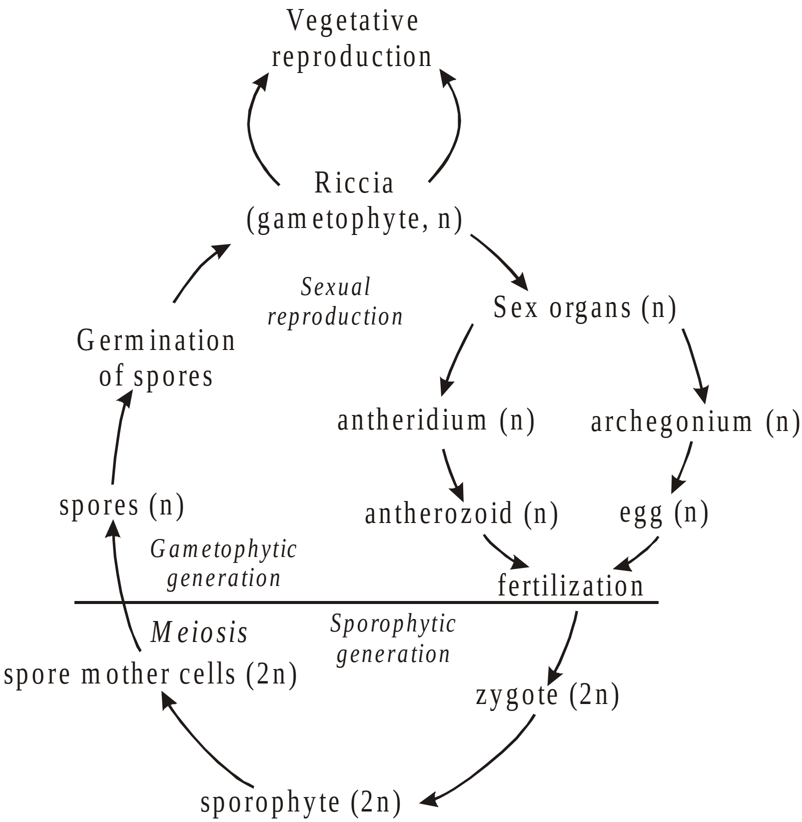


Fig.1.40 Riccia - Life Cycle Showing Alternation of generations

SELF EVALUATION

One Mark

1. Choose the correct answer :

1. Riccia discolor is also known as
   (a) **R. cruciata** (b) R. himalayensis
   (c) R. kashyapii (d) R. gangetica
2. **Ricca** is mainly confined to the following places
   (a) Dry shady place (b) Aquatic area
   (c) Damp shady place (d) Hot and dry place
3. The scales that are seen in **Riccia** are
   (a) Multicellular (b) Two celled
   (c) Unicellur (d) Three celled

2. Fill in the blanks

1. R. discolor is also called as
2. .... is an aquatic form.
3. **Riccia** is commonly called as .... of plant kingdom.

Two Marks

1. Where can we come across Riccia?
2. Which plant is known as the amphibian of plant kingdom? Why it is called so?
3. Give a brief account of the kinds of Rhizoids of Riccia thallus.
4. Where the air canals are seen? Mention the role played by them.
5. How vegetative reproduction is taking place in Riccia (give an out-line).

Five Marks

1. Describe the external structure of **Riccia** thallus.
2. Describe vegetative reproduction in **Riccia**.
3. Give an account of the internal structure of the thallus.
4. Give a brief account of the structure of a mature archegonium and the process of fertilization.
5. Write about the sporophyte of Riccia in detail.

Ten Marks

1. Write an essay on the internal and external features of **Riccia.**
2. Describe the structure of sex organs of **Riccia** with suitable diagrams.
3. Give an account of the types of reproduction that you can come across in **Riccia.**
4. Trace the life cycle of **Riccia** with suitable diagrams and illustrations.
5. What do you mean by heteromorphic alternation of generations? Explain this phenomenon with any one of the forms studied by you.

2.6. Pteridophytes

This division includes club mosses, horsetails and ferns. The oldest known pteridophytes are fossils from the end of the silurian period, 380 million years ago. Pteridophyta constitutes the earliest known vascular plants. Vascular plants are those plants that contain the vascular tissue that is the conducting tissues of xylem and phloem. Sometimes all vascular plants are included in one division the **Tracheophyta** . This is to emphasise the advance nature of vascular tissue over the simple conducting cells of some Bryophytes and Algae. Tracheophyta includes **pteridophytes** and the more advanced **spermatophytes** (seed bearing plants) as two subdivisions.

Presence of vascular tissue is a feature of the sporophyte generation, which in the bryophytes is small and dependent on the gametophyte. The occurrence of vascular tissue in the the sporophyte is one reason why sporophyte generation has become the dominant one in all vascular plants. The vascular tissue of pteridophytes shows certain primitive features compared with flowering plants. The xylem of pteridophytes contains only tracheids rather than vessels and the phloem contains sieve cells rather than sieve tubes.

Vascular tissue has two important roles to perform. Firstly it forms a transport system, conducting water and food around the multi- cellular body, thus leading to the development of large, complex bodies. Secondly, xylem, one of the vascular tissues, supports these large bodies since xylem contains lignified cells of great strength and rigidity.

Salient features of Pteridophytes

Pteridophytes are the **vascular Cryptogams**. They are **seedless** and they are the simplest plants among the Tracheophytes (Plants having vascular tissues). Pteridophytes were world wide in distribution and abundant in the geological past. Today, they are best represented by the **ferns**. The non-fern pteridophytes are comparatively less in number. These plants are mostly small and herbaceous. They grow well in moist, cool and shady places where water is available.

Distinguishing characters of Pteridophytes

1. The life cycle shows distinct heteromorphic alternation of generation.
2. Plant body of Sporophyte is dominant phase.
3. Sporophyte is differentiated into true root, stem and leaves.
4. Vascular tissue i.e xylem and phloem are present. Xylem lacks vessels but tracheids are present. In phloem sieve tubes and companion cells are absent.
5. Asexual reproduction takes place by spores.

6. Most pteridophytes are **homosporous** i.e they produce one type of spores. A few show **heterospory** i.e they produce two types of spores **microspores** and **megaspores.**
7. Spores are produced from spore mother cells after meiosis in multi-cellular sporangia.
8. Sporangia bearing leaves are called **sporophylls**.
9. Spores on germination develop into gametophyte which is haploid, multi-cellular, green and an independent structure.
10. The gametophyte develops multi-cellular sex organs. The male sex organ is called **antheridium** and the female sex organ is called **archegonium.**
11. Sex organs have a sterile jacket.
12. Antherozoids are spirally coiled and multiflagellate.
13. Fertilization takes place inside archegonium.
14. Opening of sex organs and transfer of male gametes to archegonium for fertilization are dependent on water.
15. Fertilized egg i.e zygote develops into embryo.

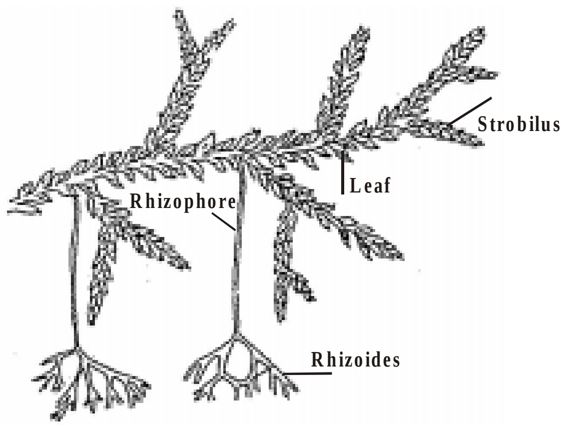


Fig: 1.41. Microphyllous Pteridophyte - Selaginella

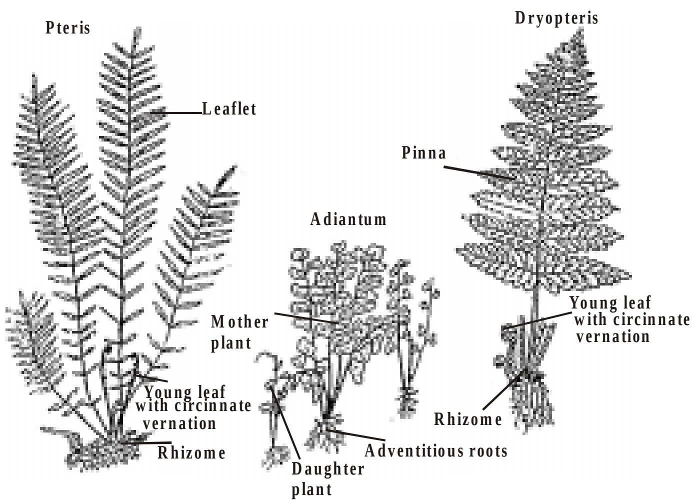


Fig: 1.42. Ferns

Some common examples of microphyllous pteridophytes are ***Psilotum***, ***Lycopodium, Selaginella, Isoetes, Equisetum*** etc.

Ferns represent a more specialized group of higher pteridophytes with larger leaves (**megaphyllous**). They are world wide in distribution and grow luxuriantly in forests, mountains, valleys etc. Some common examples of ferns are ***Nephrolepis, Ophioglossum, Osmunda, Pteris, Adiantum, Marsilea, Azolla, Salvinia*** etc.

Characteristics of Pteridophytes

Heterospory

In some pteridophytes the gametophyte is protected by remaining in the spores of the previous sporophyte generation. In such cases there are two types of spore and the plants are therefore described as **heterosporous.** Plants producing only one type of spore, like the Bryophytes, are described as **homosporous.**

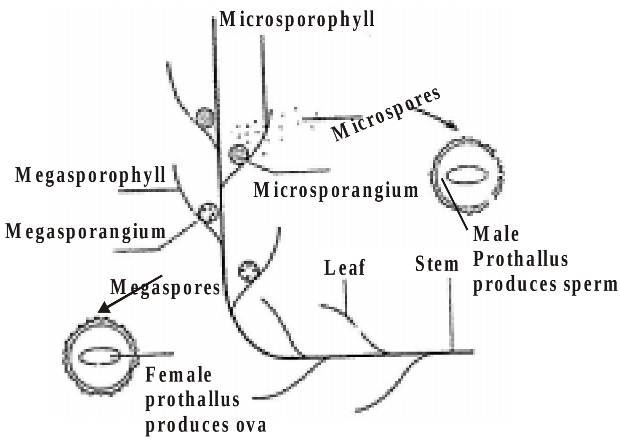


Fig : 1.43. Diagramatic representation of heterospory

In heterosporous plants two types of spores are produced. 1. large spores called **megaspores** and 2. small spores called **mircrospores**. Megaspores give rise to **female gametophytes** (prothalli). Female gametophyte bears the female sex organs namely archegonia. The microspores give rise to **male gametophytes** (Prothalli). This bears the male sex organs namely antheridia. Sperms (antherozoids) produced by the antheridia travel to the female sex organ namely archegonium found in female gametophyte. Both male and female gametophytes remain protected inside their respective spores. The microspore is small and they are produced in large numbers and they are dispersed by wind from the parent sporophyte, the male gametophyte that the microspore contains within is therefore dispersed with it. The evolution of heterospory is an important step towards the evolution of seed bearing plants.

Economic importance of pteridophytes

1. Ferns are grown as ornamental plants for their beautiful fronds.
2. The rhizomes and petioles of the fern ***Dryopteris*** yield a vermifuge drug.
3. The sporocarps of ***Marsilea*** (a water fern) are used as food by certain tribal people.

SELF EVALUATION

One Mark

Fill in the blanks

1. The process of evolution of the seed habit is associated with the origin of __________
2. The dominant phase changed from_________ to ___________ as in all Pteridophytes,Gymnosperms and Angiosperms.

Two Marks

1. What is meant by Tracheophyta?
2. Justify: the vascular tissue of pteridophyte is primitive when compared with flowering plants.
3. What are the functions of vascular tissue?
4. What are the advantages of seed development in Phaenerogams?
5. Name any two economically important products of Pteridophytes.

Five Marks

1. What are the salient features of Pteridophytes?
2. What is heterospory? What is it's significance?

Ten Marks

1. List the strategies that the plants had to develop in order to survive on land.

2.6.1 Nephrolepsis

Division	:	Tracheophyta
Sub division	:	Pteropsida
Class	:	Leptosporangiatae
Order	:	Filicales
Family	:	Dennstaedtiaceae
Genus	:	Nephrolepsis

The genus **Nephrolepsis** is a tropical fern with about 30 species. Most of the species are found in terrestrial habitats. Some species are epiphytes e.g., **N. volubilis** and **N. ramosa**. Several species are grown as ornamental plants. In India, there are 5 species. Of these, **N. acuta** and **N. tuberosa** are common species.

Morphology of sporophyte

The sporophyte consists of rhizome, roots and leaves.

Rhizome : The rhizome is short and erect or sub-erect, producing elongated slender stolons. Some species have creeping rhizome with adpressed scales. The rhizome of **N. tuberosa** bears tubers which act as reservoirs for carbohydrates and water. The rhizome is covered with scales.

Root : The roots arise from the thizome and stolon. The roots are adventitious and branched.

Leaves : The leaves are long, narrow and herbaceous. They are pinnately compound and their length varies from 40 cm to 70 cm or more. The pinnae are sessile, subsessile or shortly petioled. They have usually rounded or cordate base. The veins are prominent and the veinlets are branched with open ends. The tips of veinlets are gland dotted and they extend upto the margins.

Fig.1.44. A-D Nephrolepsis tuberosa
A, a leaf. B, a pinna, C. Soras, D. Sporangium (after beddome)

The petiloe, rachis and pinnae are covered with multicellular brown haris or scales called **ramenta.**

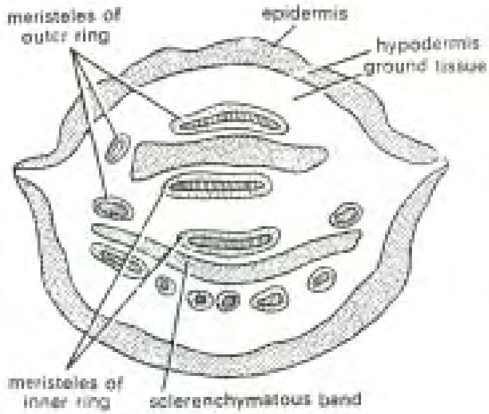


Fig.1.45. TS of Rhizome

Anatomy

Rhizome: The Rhizome is differentiated into epidermis, hypodermis, ground tissue and stele. The stele is a meristele (Fig) A meristele is a part of dictyostele found between two neighbouring leaf gaps and appear as separate strand in a transverse section. A dictyostele is a solenostele with leaf gaps and distinct vascular strands. A solenostele is a condition when a mass of parenchyma cells found in the centre of the xylem. The epidermis is the protective layer with a thick layer of cuticle. The hypodermis is more or less continuous and heavily sclerotic. This region is followed by parenchymatous ground tissue with starch grains.

The stele structure varies within the same rhizome. A mature rhizome with many leaves has dictyostele which gets separated into a number of strands called meristeles. Each meristele is surrounded by its own endodermis which is followed by pericycle. The pericycle is followed by phloem. The central region of stele is occupied by xylem.

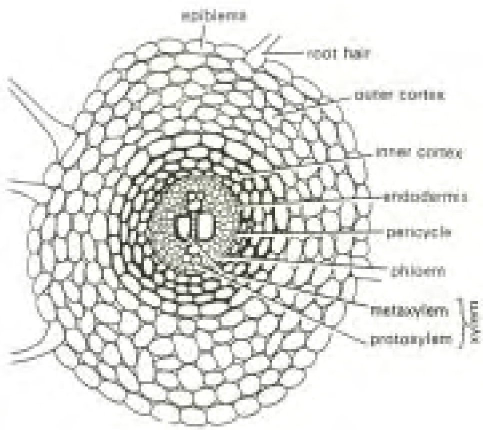


Fig.1.46. TS of Roots

Root: The transverse section of root has three distinct parts - epiblema, cortex and vascular cylinder (fig). The epiblema is the outermost layer of thin walled cells. Some cells of this region produce unicellular root hairs. The cortex is divided into outer parenchymatous and inner sclerenchymatous regions. The latter provides machanical support to roots. The innermost region of cortex has endodermis. Next to this layer is pericycle.

The vascular cylinder is diarch and exarch. A diarch condition consists of two protoxylem points. An exarch condition refers to presence of protoxylem away from the centre of the axis.

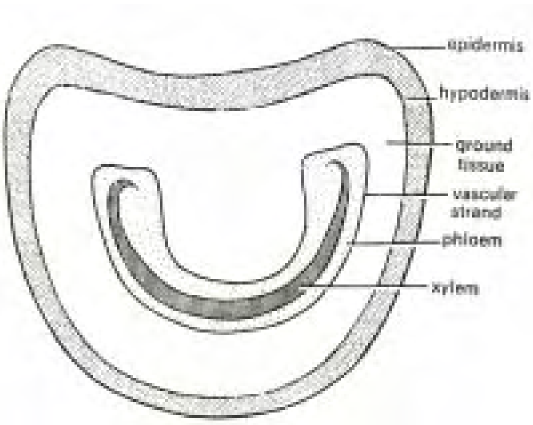


Fig.1.47. TS of Rachis

Rachis or Petiole: The transverse section of rachis has epidermis, hypodermis, ground tissue and stele (fig). The epidermis consists of a single layer of cells with cuticle. This layer is followed by 2-3 layered sclerenchymatous hypodermis. Next to this is a broad zone of parenchymatous ground tissue. At the centre, a 'U' shaped meristele is located. This stele is similar to that of rhizome.

Pinna: The internal structure resembles a dicot leaf. The upper and lower epidermis are single layered. The outer walls of both epidermis have thick cuticle. The mesophyll region is differentiated into a columnar palisade parenchyma and loosely arranged spongy parenchyma cells. A concentric vascular bundle is found in the centre with a distinct bundle sheath.

Reproduction

Vegetative reproduction is by death and decay of the underground rhizome. The rhizome is dichotomously branched and grows indefinitely. When the death and decay of rhizome reaches up to the point of dichotomy, both the branches separate and each grows into a new plant.

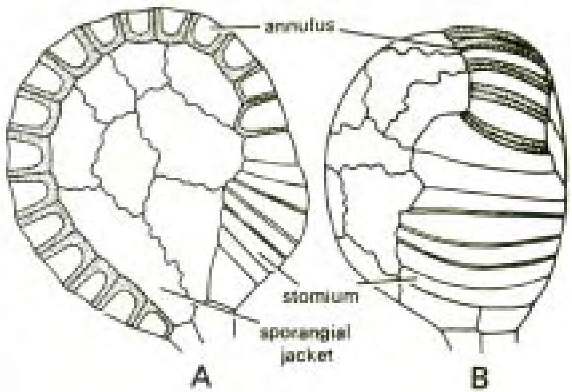


Fig.1.48. Structure of mature sporangium

Reproduction by spores: Sori, formed on the lower side of the mature pinnae, are arranged in two rows; one on either side of the midvein. The sori are groups of sporengia. They are superficial in origin and arise at the tips of veinlets. They are distinct and maintain their individuality. Some species of Nephrolepis show fusion of adjacent sori. Each sorus has an indusium which covers the sorus. The indusium is reniform i.e., kidney-shaped, roundish or sub-orbicular.

Each sporangium is mounted on a long stender stalk. The annulus consists of thick-walled cells extending from the base to almost three-fourth of the capsule. The distal end of annulus has a strip of thin-walled cells. This region is called stomium. Each sporangium produces 32-64 haploid spores after meiotic division of spore mother cells.

At maturity, the annulus tears the sporangial wall from the stomium and turns backward. This kind of dehiscence leads to the release of spores.

Gametophyte (Prothallus)

Upon germination, each haploid spore develops into a multicellular chlorophyllous filament. The filament further develops into a flat, green coloured and more or less heart-shaped prothallus or gametophyte. A mature prothallus is 3-8mm in diameter with rhizoids which anchor the prothallus in the soil.

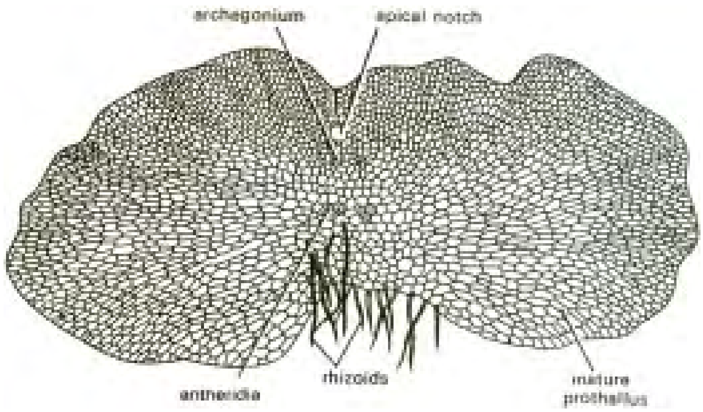
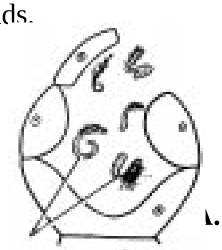


Fig.1.49. Structure of mature prothallus

The male sexorgan (Antheridium) and female sexorgan (Archegonium) are produced in the prothallus. Antheridia are found in the basal central region and archegonia are found near the apical notch of the prothallus.

Each mature antheridium produces 30-40 multiflagellate male gametes or antherozoids.



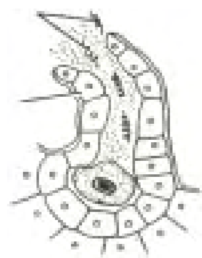


Fig.1.50 Sex organs A. Mature Antheridium B.Mature Archegonium

Each mature archegonium is differentiated into neck which is composed of four vertical rows of cells and a basal venter. The venter contains a single large ovum or egg.

Fertilization: Water is essential for fertilization. After the release of antherozoids from antheridium, they swim in a thin film of water present on the surface of the prothallus. They are attracted towards the neck of archegonia by chemicals oozing out of the neck. Thus the antherozoids are directed towards the egg. Even though many antherozoids enter the neck only one fuses with the egg and forms zygote.

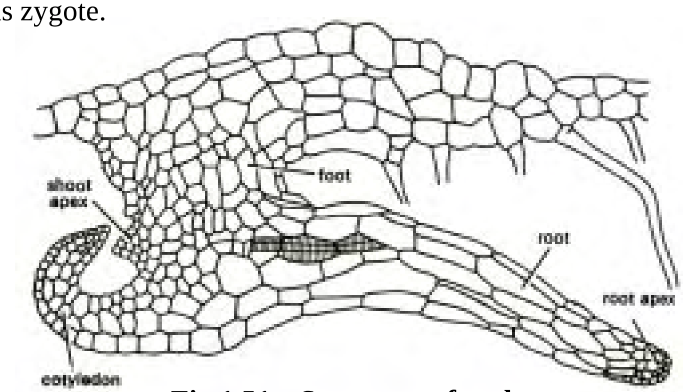


Fig.1.51. Structure of embryo

The zygote, formed by the fusion of antherozoid and egg, is the starting point for the next sporophyte generation. It increases in size and almost completely occupies the venter. By repeated divisions, the zygote develops into an embryo consisting of shoot apex, cotyledon, foot and root. The foot absorbs nutrients for the developing

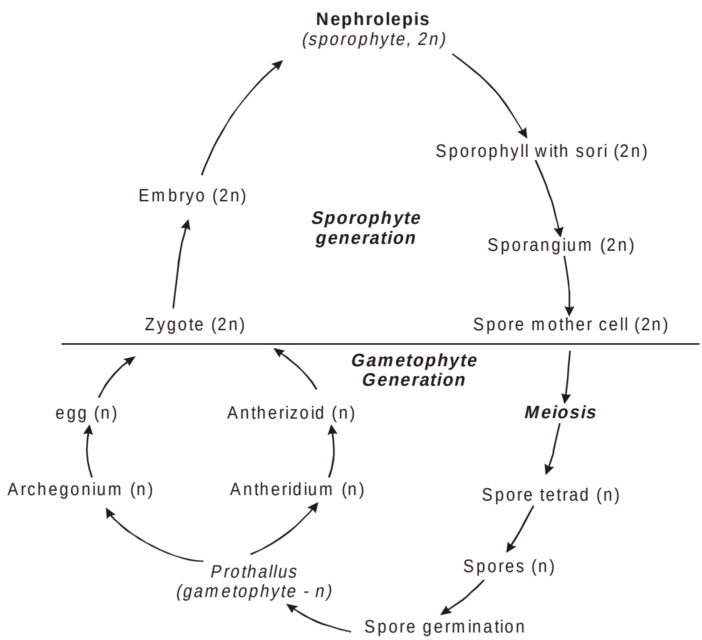


Fig.1.52. Life Cycle - Nephrolepsis

embryo from the prothallus. The venter forms a protective cover called **calyptra** for the developing embryo. The root and cotyledon grow more rapidly than the shoot and finally form a new sporophyte plant. The prothallus gradually decays once the young sporophyte is well established.

Self Evaluation

One Mark

Choose the correct answer

1. Gameophyte of Nephrolepis is otherwise known as
   a) Antheridium b) Male gamete c) Prothallus d) Antherozoid
2. When a mass of parenchyma found in the centre xylem, the stele is called
   a) Dictyostele b) Solenostele c) meristele d) actinostele
3. Multicellular prawn hairs or scales found on the rachis are called
   a) scale leaves b) ramenta c) vernation d) cirinat

Fill in the blanks

1. A cluster of sporangia is known as ....
2. The outermost cell layer that covers root is called ....
3. The egg of Nephrolepis gametophyte is found in the.................... of archegonium.
4. The gametophyte of Nephrolepis is attached to the soil with the help of

Two Marks

1. What is meant by diarch vascular cylinder?
2. What is meant by exarch vascular cylinder?
3. What is meant by meristele?

Five Marks

1. Draw the diagram of the sporangium of Nephrolepis.
2. Describe the structure of antheridium.
3. Describe the structure of archegonium.
4. Explain what is meant by alternation of generation.

Ten Marks

1. Describe the structure of prothallus.
2. Describe the lifecycle of Nephrolepis.
3. Describe the transverse section of rhizome.
4. Describe the transverse section of rhizome.
5. Describe how a new sporophyte emerges from zygote.

2.7 Spermatophytes (Gymnosperms)

The most successful and advanced group of land plants are the **spermatophytes (sperma – seed**). One of the main problems that had to be faced by plants living on land was the vulnarability of their gametophyte generation. For example in ferns the gametophyte is a delicate prothallus and it produces the male gametes (sperms) which are dependent on water for swimming to reach the female gamete in archegonia. In seed plants, however, the gametophyte generation is protected and very much reduced. Three important developments have been made by seed plants. 1. **The development of heterospory**. 2. **The development of seeds**. 3. **The development of non-swimming male gametes.**

Classification and Characteristic of Spermatophytes

Division : Spermatophyta (seed bearing plants)

General Characteristics

Heterosporous - microscope = pollen grain, megaspore = embryo sac. The embryo sac remains completely enclosed in the ovule ; a fertilized ovule is a seed. Sporophyte is the dominant generation, gametophyte is very much reduced. Water is not needed for sexual reproduction because male gametes do not swim, complex vascular tissues in roots, stem and leaves are present. It includes two classes namely Gymnospermae and angiospermae.

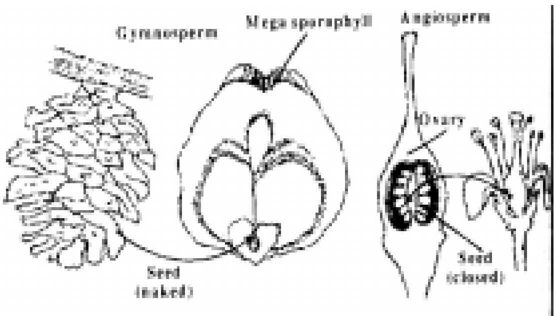


Fig.1.53. Seeds of Gymnosperm and Angiosperm compared

GYMNOSPERMS

Salient features of Gymnosperms

Gymnosperms represent a primitive group of seed bearing plant (Spermotophytes) in which the **seeds are naked** i.e. they are not covered by the fruit wall as in Angiosperms (the word **Gymnos** means naked and **spermos** means seed). This is because in Gymnosperms the ovules are exposed and they are not covered by ovary. Instead the ovules are borne directly on open carpellary leaves called megasporophylls and hence they are naked and they develop into naked seeds after fertilization.

Table : 1.5. Differences between class Gymnospermae and Angiospermae

Class Gymnospermae (Cycads Conifers, and Ginkgos)	Class Angiospermae(flowering plants)
1. No vessels in xylem, only tracheids(except Gnetales) no companion cells in phloem.	xylem has vessels, phloem contains companion cells
2. Usually have cones on which sporangia and spores develop.	Produce flowers in which sporangia and spores develop
3. Seeds are naked that is the seeds are exposed; they are not enclosed in ovary.	Seeds are enclosed in ovary.
4. No fruit because no ovary	After fertilization ovary develops into fruit.

Gymnosperms were most abundant during the Mesozoic era (225 million years) ago. However, they form only a small part of the present day vegetation. There are about 70 genera and 900 species of gymnosperms distributed in tropical and temperate regions. Most of them are Conifers mostly evergreen, with needle like leaves. They are found in the form of **coniferous forests** in the Himalayas in the Indian sub-continent. The common conifers are species of **pine, fir, spruce,*Cedar*,*Cupressus*, *Sequoia gigantia*,** (red wood tree which measures more than 100 meters in height).

Distinguishing features of Gymnosperms

1. Gymnosperms are woody perennial which are mainly trees and rarely shrubs.
2. The life cycle of gymnosperms shows **heteromorphic** alternation of generations.
3. They form an intermediate group between pteridophytes and Angiosperms i.e they are more advanced than pteridophytes but are primitive than angiosperms.
4. The plant body is the **sporophyte (diploid)** mostly a tree with well developed roots, stem and leaves.

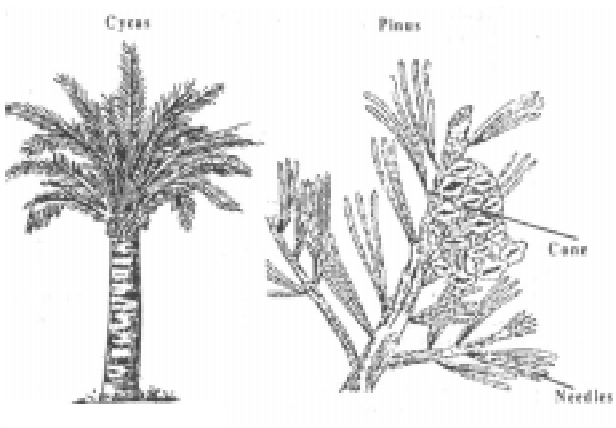


Fig.1.54. Gymnosperms

5. The sporophyte bears two types of fertile leaves, the microsporophyll that produces microspores and megasporophyll that produces megaspores.
6. Mostly the spores are grouped into compact **cones** or **strobili.**
7. Spores on germination develop into gametophytes which are very much reduced, microscopic and dependent on sporophyte.
8. Ovules are naked.
9. Pollination is mostly by wind (**anemophilous**).
10. Fertilization involves only one fusion. Female gametophyte provides nutrition to the developing embryo. The endosperm (female gametophyte) is a pre-fertilization tissue and is haploid.sac) and the embryo (of the next sporophyte generation). All the nutrients for life are supplied
11. Seeds are naked and not embedded in fruit.
12. Vessels are absent in xylem (except **Gnetales)**

Classification of Gymnosperms

Chamberlain has classified gymnosperms into two classes 1. class **Cycadophyta** 2. Class **Coniferophyta** .The class Cycadophyta consists of plants with simple stem, thick cortex but thin wood and simple sporophylls. The class Coniferophyta consists of plants with profusely branched stem, thin cortex, thick wood and complex sporophylls.

Economic importance of Gymnosperms

1. Woods of many conifers are used in the manufacture of paper. eg. ***Pinus.*** Conifers are the source of soft wood for construction, packing and ply wood industry eg. ***Cedrus, Agathis***
2. Turpentine is obtained from the resin of ***Pinus***. It is used as solvent in paint and polishes. It is also used medicinally for pain, bronchitis etc.
3. Seeds of ***Pinus gerardiana*** are edible.
4. **Ephedrine** is an alkaloid obtained from ***Ephedra***. It is used in curing asthma and respiratory problems.
5. Saw dust of conifers is used in making linoleum and plastics.
6. Pinus species yield a resin called rosin which is used in water proofing and sealing joints.
7. ***Araucaria*** is an ornamental plant.

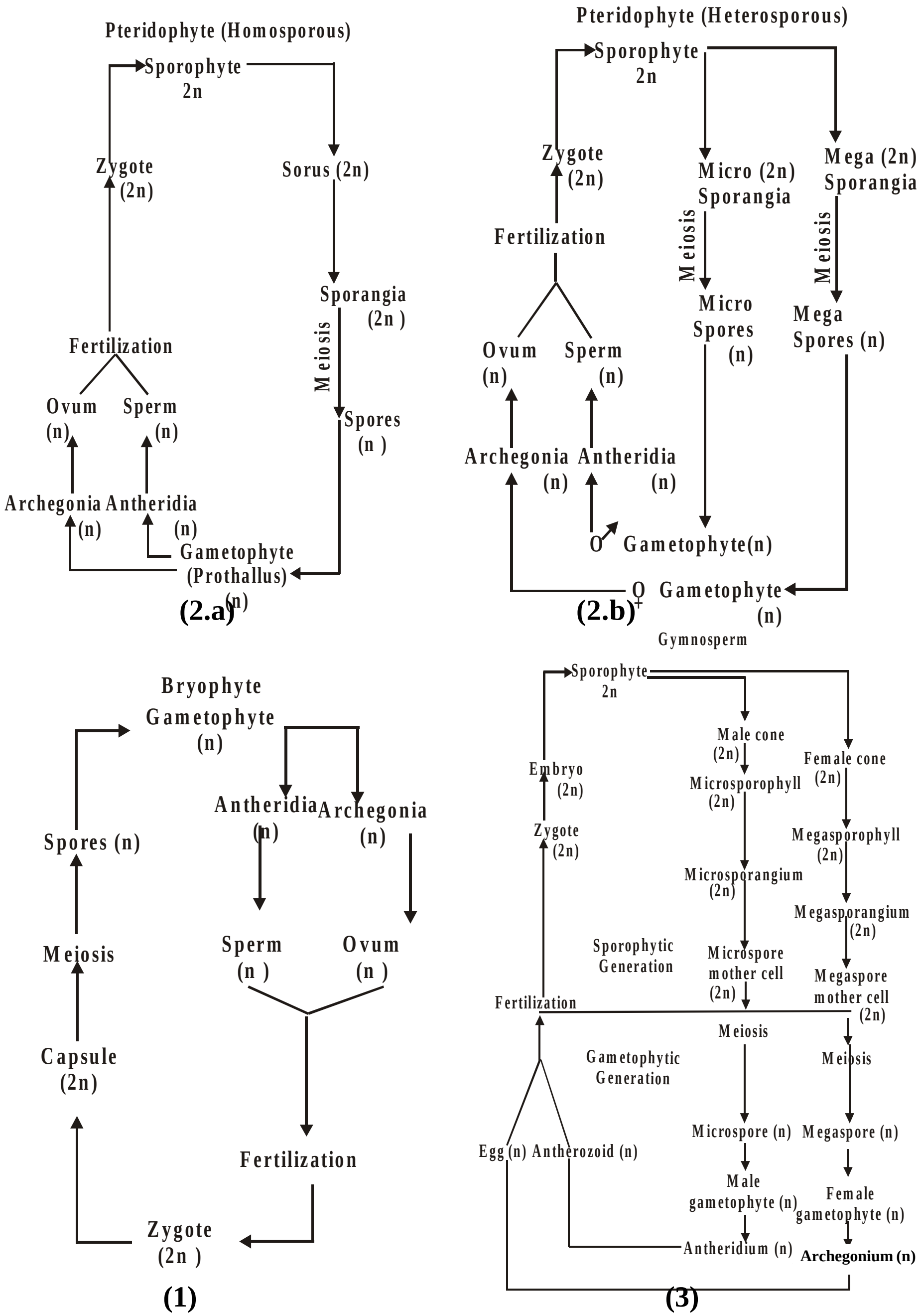


Fig.1.55. Graphical representation of life cycles of various plant groups

SELF EVALUATION

One Mark

Fill in the blanks

1. The most successful and advanced group of land plants are____________
2. All seed plants are ________
3. The most extreme reduction of gametophyte has taken place in__________.
4. The equivalent structure to a megasporangium, in a seed plant is called an ___________.
5. The equivalent structure to a microsporangium, in a seed plant is called __________

Two Marks

1. Name the three important developments that have been made by the seed plants.
2. Define heterospory.
3. Justify the statement: a seed is a complex structure containing cells from three generations.
4. Why do we call the seeds of gymnosperms as naked?
5. Name the two classes of Gymnospermae.

Five Marks

1. Discuss the advantages associated with seed habit.
2. List the differences between Gymnospermae and Angiospermae.
3. Write the salient features of Gymnosperms.
4. Write about the economic importance of gymnosperms.

2.7.1 Cycas

Division : Cycadophyta
Class : Cycadopsida
Order : Cycadales
Family : Cycadaceae
Genus : Cycas

Gymnosperms are plants which produce naked seeds i.e., plants which lack ovary and hence do not produce fruits. Cycas belongs to this group of plants.

The genus **cycas** is the most widely distributed genus of the order cycadales. There are about 20 species which grow in the wilderness in China, Japan, Australia, Africa, Nepal, Bangladesh, Burma and India. **C. circinalis, C. pectinata, C. rumphii** and **C. beddomei**, are found in the wilderness in India. **C. revoluta** is grown in gardens in India.

Species of Cycas are of considerable economic importance. Starch is extracted from several species of cycas. Young succulent leaves are used as vegetable in some parts of India. Several species of cycas are of medicinal value. The juice of young leaves of **C. circinalis** is used as a remedy for stomach disorders, flatulence, blood vomiting and skin diseases. The decoction of young seeds of this species is purgative and emetic. A tincture prepared from the seeds of **C. revoluta** is used to relieve headache, giddiness and sore throat.

Fig. 1.56. Cycas - Habit

Morphology of sporophyte: Cycas is an evergreen slow-growing palm-like small tree with an average height of 1.5 to 3 meters (fig). It is commonly found in dry habitats. It also grows well in gardens of tropical countries including India. The sporophyte is differentiated into roots, stem, and leaves.

Roots: There are two types of roots in **cycas** 1) Normal roots, 2) Negatively geotropic roots called coralloid roots.

Normal roots: The long-lived primary root is usually thick and short but the lateral roots are thin and long. These roots are positively geotropic. Their main functions are anchorage and absorption of water and mineral nutrients.

Fig. 1.57. Coralloid roots

Coralloid roots: These roots are negatively geotropic and grow on the surface of the soil. They are dichotomously branched and appear as coralline masses (fig). A specific algal zone with colonies of **Anabaena** or other blue green algae is present in the cortex of these roots. The algal cells may help in N_2 fixation. These roots respire through special openings called lenticels.

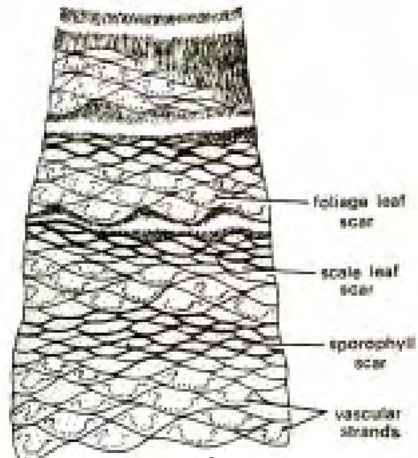


Fig. 1.58. A part of mature stem

Stem: The young stem is tuberous and subterranean and its apical part is covered with brown scale leaves. The old stem is thick, columnar and woody. It is covered with persistent and woody leaf bases. The stem is usually unbranched, but sometimes due to shoot tip injury, the stem branches dichotomously.

Leaves: Cycas has dimorphic leaves namely 1) Foliage or assimilatory leaves and 2) Scale leaves.

i) Foliage or assimilatory leaves

Large, pinnately compound (fig) foliage leaves form a crown at the top of the stem. Each leaf has 80-100 pairs of leaflets. They are arranged on both sides of the rachis in opposite or alternate manner. The leaflets are sessile, elongated and ovate or lanceolate with flat or revolute margins. The tip of each leaflet is acute or spiny. Each leaflet has a single midvein. Lateral veins are absent.

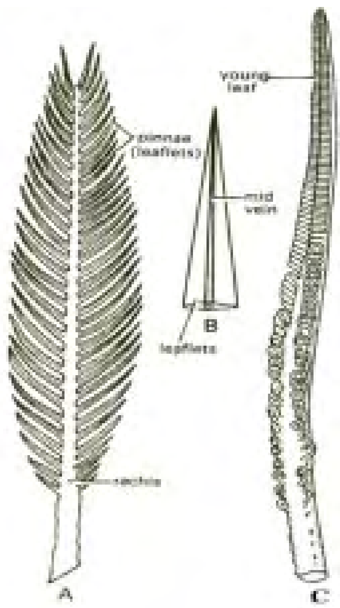


Fig. 1.59. Cycas Leaf-let

A, Compound leaf. B.Upper portion of a leaf-let

C. Young leaf showing circinate vernation of leaf-lets

The rachis of a very young leaf is circinate with circinately coiled leaflets like those of ferns.

ii) Scale leaves

These are small, rough, dry and triangular in shape. They protect the shoot apex and other aerial parts. They do not produce starch by photosynthesis. The foliage and scale leaves are arranged in close alternate whorls at the apex of the stem.

Anatomy

Normal root: A cross section of normal root (fig) consists of epiblema, cortex and central vascular tissue.

Epiblema: It is composed of a single layer of thin-walled cells.

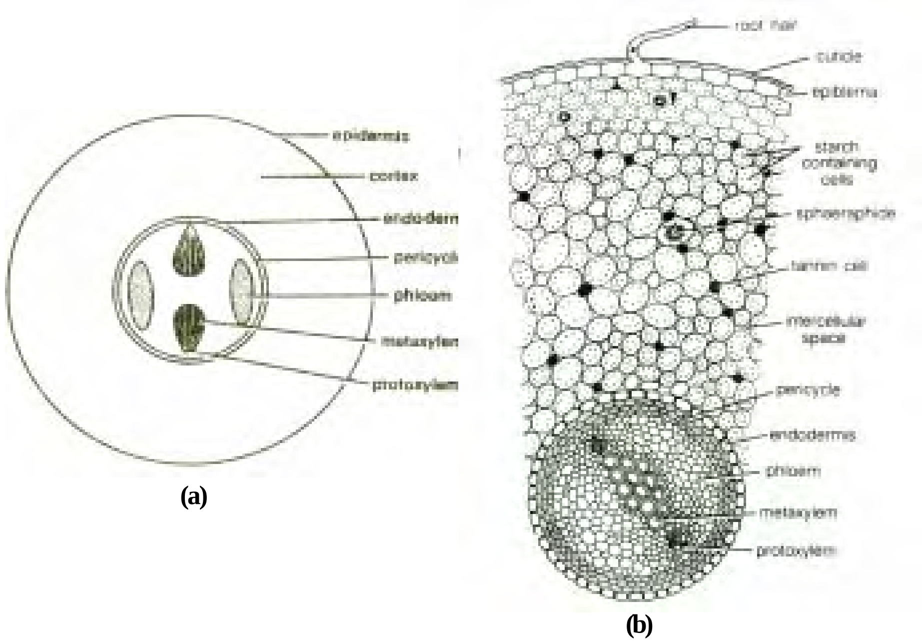


Fig. 1.60. Cycas - Normal young root
(A) Ground plan TS (B) A portion enlarged

Cortex: It is a multilayered zone of thin-walled parenchymatous cells. These cells are filled with starch. Tannin cells and mucilage cells are also present in the cortex. The innermost layer of the cortex is endodermis. Pericycle is a multi-layered zone found next to endodermis.

Vascular tissue: This tissue forms a central diarch stele. The diarch steel refers to the presence of two patches of protoxylem points. The xylem consists of xylem tracheids. A tracheid is one celled, non-living, elongated xylem element with thick lignified and pitted cell walls. The xylem is exarch i.e., the protoxylem is pointing towards the periphery while the metaxylem is located near the centre of roots. The pith is either reduced or completely absent.

The normal roots exhibit secondary growth, which starts by the formation of cambium strips that are formed inner to the primary phloem strands (fig). These cambium strips cut off secondary phloem towards the outer side and secondary xylem towards the inner side. Due to the development of secondary structures the primary phloem is crushed while the primary xylem is found in the centre. A distinct layer of cork cambium (phellogen) arisis in the outer region of cortex which gives rise to cork (phellem) on its outer side and secondary cortex (phelloderm) on its inner side. Cork, cork cambium and cork cortex or secondary cortex are collectively known as periderm.

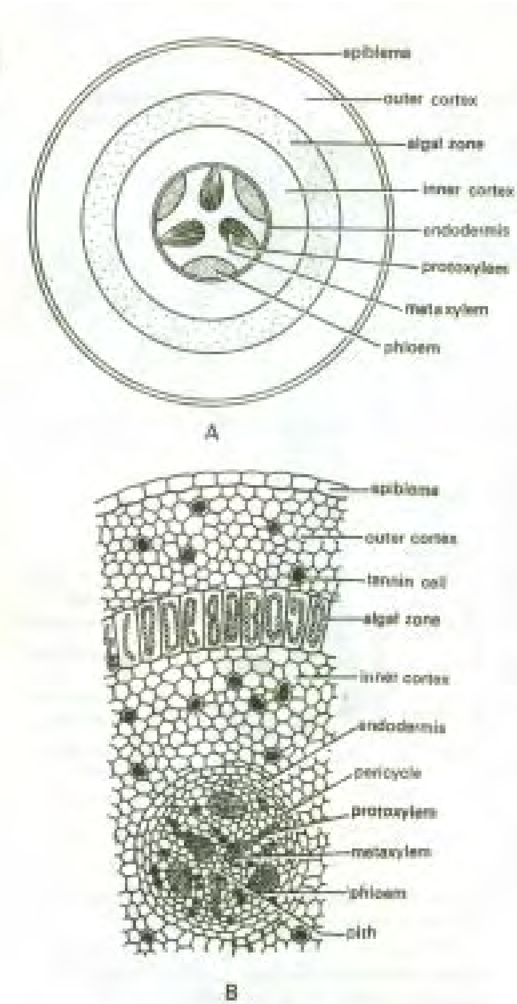


Fig.1.61 Coralloid root
A. Ground plan TS B. A portion enlarged

Coralloid roots: The internal structure of coralloid roots is similar to that of normal roots except in certain respects. The cortex of coralloid root is differentiated into i) outer cortex composed of polygonal cells, ii) inner cortex consisted of thin-walled parenchymatous cells and iii) middle cortex made up of a single layer of loosely connected thin-walled and radially elongated cells with blue green algal forms such as **Anabaena** or **Nostoc**. Coralloid roots show little or no secondary growth.

Stem : The stem is irregular in outline due to the presence of numerous persistent leaf bases. Its internal structure is similar to that of dicots of Angiosperms. Young stem of cycas is differentiated into epidermis, cortex and vascular cylinder (fig). The epidermis is the outermost layer of stem covered with a thick cuticle. Cortex forms the major part of the stem. It is composed of parenchymatous cells with rich starch grains. The cortex is traversed by several mucilagenous canals and many leaf traces. The inner most layer of cortex is endodermis which is followed by pericycle. However, these two regions are not distinctly seen.

In the young stem, vascular region is very small when compared to the cortical zone. There are several vascular bundles arranged in a ring. The vascular bundles are conjoint, collateral, endarch and open. The individual bundles are separated by parenchymatous medullary rays. The xylem consists of tracheids and paraenchyma. Xylem vessels are absent. The phloem consists of sieve tubes and phloem parenchyma. There are no companion cells.

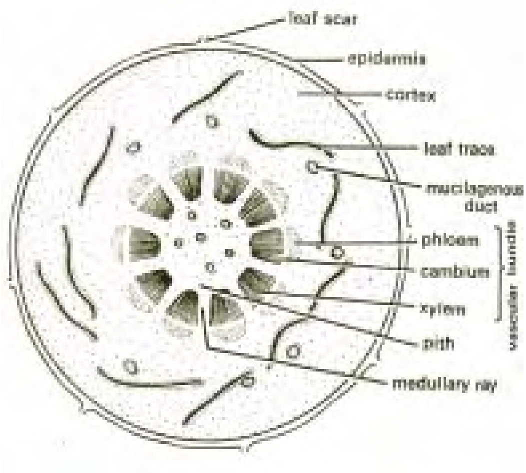


Fig.1.62 Young Stem TS

There is a parenchymatous pith present in the centre of the stem. The pith cells are rich in starch and some cells contain tannin and mucilagenous substances.

Secondary growth i.e., the formation of secondary xylem and secondary phloem from cambium as found in dicot stems, is observed in old stems of *cycas*. In addition to secondary xylem and secondary phloem, the cambium also forms parenchymatous medullary rays. A well developed stem of **cycas** is called manoxylic because the wood is not compact due to well developed pith, cortex and broad medullary rays with limited vasculature.

Rachis : Transverse section of rachis is more or less circular in outline. It has two rows of leaflets inserted on one side. The internal structure is differentiated into epidermis, hypodermis, ground tissue and vascular tissue (fig).

Epidermis is covered with a thick cuticle. The epidermis is interrupted by sunken stomata. The epidermis is followed by hypodermis. The hypodermis consists of outer thin-walled chlorenchymatous cells (2-3 layers) and the inner thick walled sclerenchymatous cells (4-5 layers). The ground tissue consists of parenchymatous cells with mucilage canals.

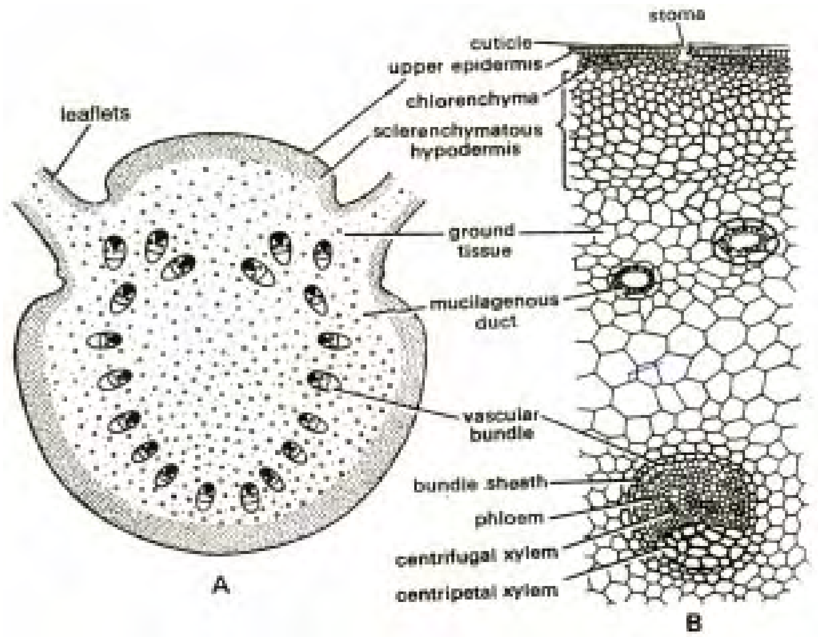


Fig.1.63. Rachis A. Ground plan B. A portion enlarged

The vascular bundles are arranged in an inverted omega-shaped manner. The bundles are conjoint, collateral, open and diploxylic. Diploxylic condition refers to the presence of centrifugal and centripetal xylem.

Leaflet : Transverse section of *cycas* leaflet shows the following tissues i) upper and lower epidermis, ii) hypodermis, iii) mesophyll, iv) transfusion tissue and v) vascular bundles.

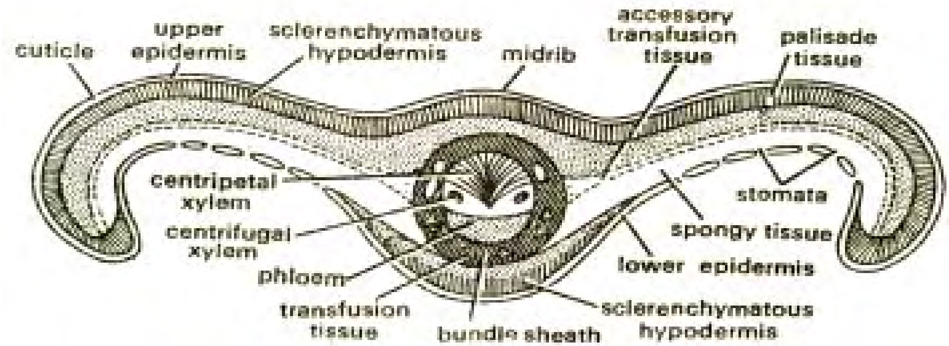
i) The upper and lower epidermis are the outermost cellular layers (one celled thick) of the upper and lower sides respectively of the leaflets. Both of them are covered by thick cuticle. The upper epidermis is continuous, whereas the lower epidermis is interrupted by sunken stomata.

ii) Hypodermis : This layer is made up of sclerenchymatous cells. The hypodermal layer protects the plant from over-heating and excessive transpiration.

iii) Mesophyll : This tissue consists of palisade and spongy parenchyma cells. The palisade layer is a single continuous layer of column-like cells. The spongy parenchyma consists of several layers of loosely arranged oval or irregular cells. Both pallisade and spongy parenchyma cells are rich in chloroplasts.

iv) Transfusion tissue : This tissue consists of two small groups of short and wide tracheid-like cells with thickenings / pits on their walls. A few layers of transversely elongated cells are present in both the wings between palisade and spongy parenchyma cells. These layers are called accessory transfusion tissue or secondary transfusion tissue.

v) Vascular bundle : There is only one vascular bundle present in the midrib region of the leaflet. It is conjoint, collateral, open and diploxylic. The triangular centrifugal xylem is well-developed with endarch protoxylem. Phloem is arc-shaped and remains separated by cambium. Phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent.



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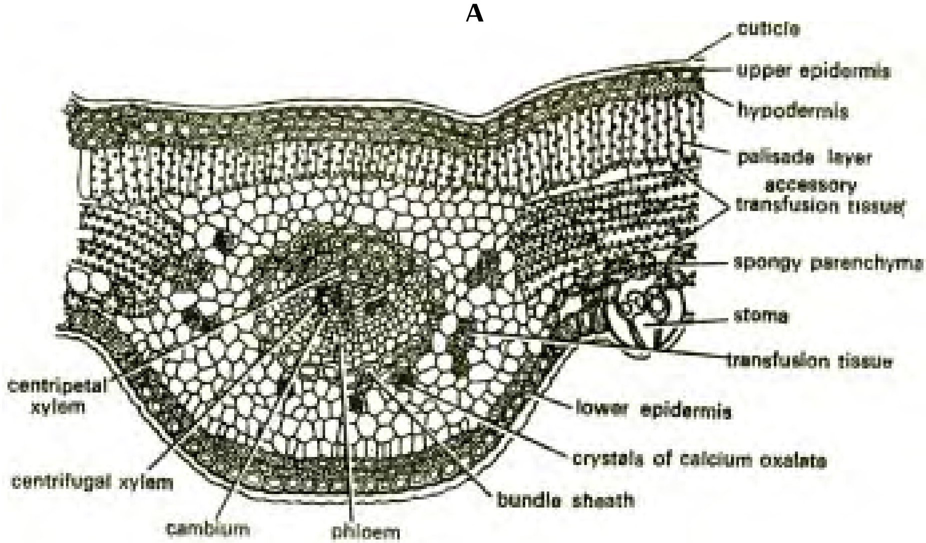


Fig. 1.64. Leaf-let A. TS Groun plan. B. TS of a portion through midrib

Reproduction : **Cycas** reproduces by vegetative and sexual means.

Vegetative reproduction

Vegetative reproduction is by the formation of adventitious buds or bulbils . The bulbils develop from the basal part of stem especially from cortical cells. They are found between the persistent leaf bases. They are more or less oval shaped. Several scale leaves are arranged spirally and compactly over a dormant stem in a bulbil. Upon detachment from the stem, a bulbil germinates to produce a new plant. A bulbil from male plant produces a new male plant while a bulbil from female plant produces a new female plant.

Sexual Reproduction : Cycas is strictly dioecious ie., male and female plants are distinctly different from each other. .

The male plant of **Cycas** produces male **strobilus** (cone) at the apex of the stem in between the crown of foliage leaves. Each male cone is a shortly stalked compact, oval or conical woody structure. It is 40-80 cm in length, perhaps the largest among plants. Each male cone consists of several microsporophylls which are arranged spirally around a central axis. Each microsporophyll is a woody, brown coloured and more or less horizontally flattened structure with a narrow base and an expanded upper portion. The upper part is expanded and becomes pointed at its tip. The narrow basal part is attached to the cone axis.

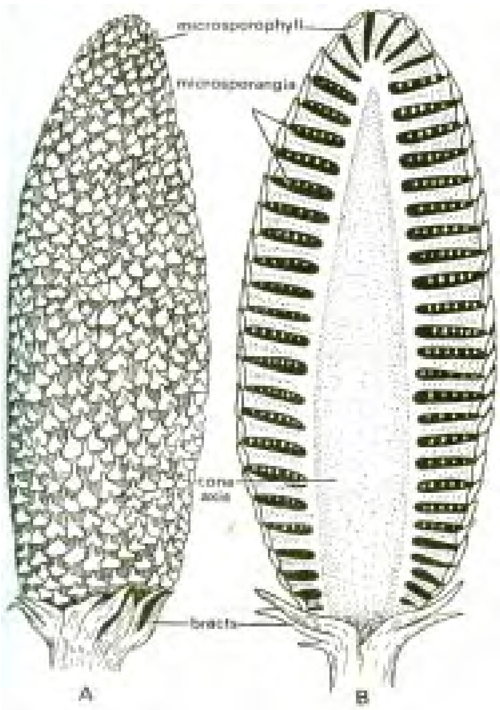


Fig.1.65. Microsporophyll A. Entire, cone B. longitudinal section

Each microsporophyll contains an upper (adaxial) and a lower (abaxial) surface. Thousands of microporangia are present in the middle region of the lower surface in the form of groups of microsporangia. Each such group is called sorus with 3-5 microsporangia.

In the transverse section of a microsporophyll there are several shortly-stalked oval or sac-like microsporangia. Each microsporangium is covered by 3 distinct layers of cells. Pollen grains or microspores are produced at the end of meiotic division of microspore mother cells found in the microsporangium.

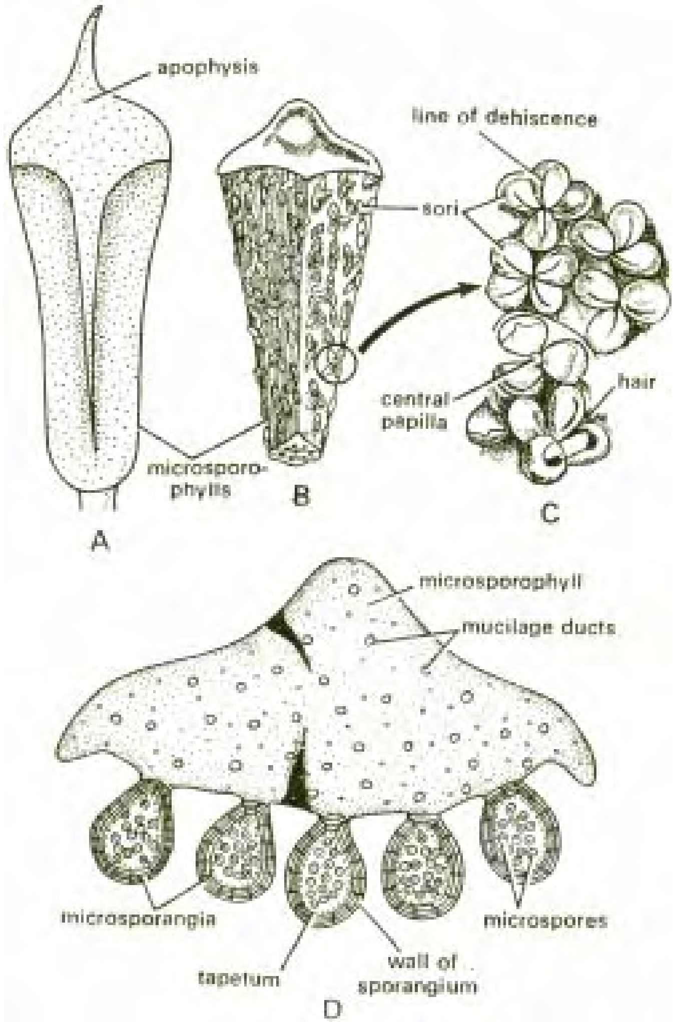


Fig.1.65. Microsporophyll A. Adaxial surface, B. Abaxial surface C. Sori, D. Microsprophyll TS

Male gametophyte

Each microspore on pollen develops into male gametophyte partly even before the release of pollens from microsporangium. The transfer of pollens from male plant to the female plant is called pollination. At this stage, the male gametophyte has a prothallial cell, a generative cell and a tube cell. Dispersal of pollens is effected by wind

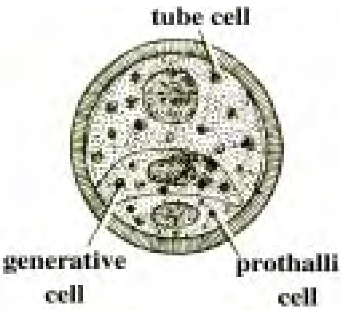


Fig.1.67 Pollen grain

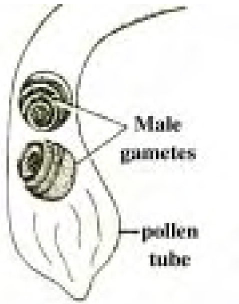
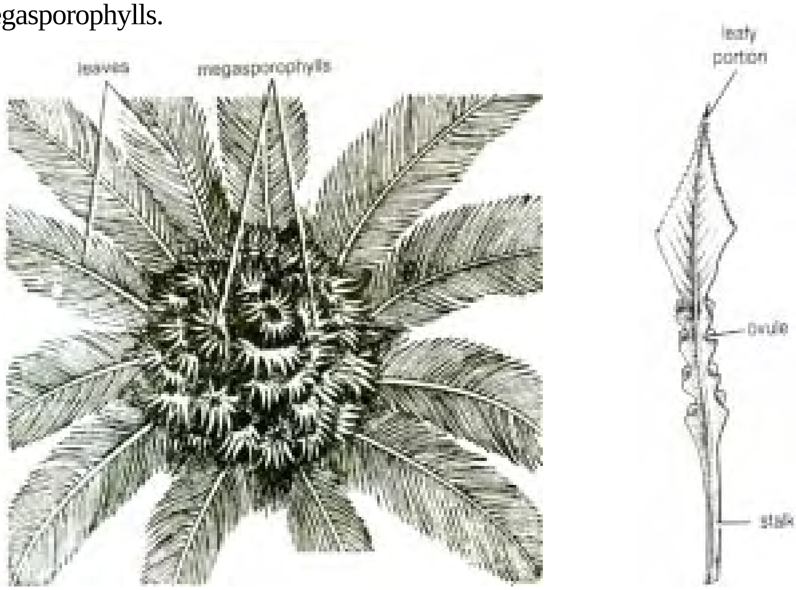


Fig.1.68 Pollen tube with male gametes

(anemophyllous). Further development of male gametophyte starts only after the pollen reaches nucellar surface of the ovule where the pollen germinates to produce pollen tube. The pollen tube carries two top-shaped sperms. Each sperm contains thousands of cilia . By means cilia, the sperms move freely in the pollen tube.

The pollen tube. The pollen tube penetrates the nucellar region of the ovule and subsequently delivers the male gametes into the archegonial chamber.

The female plant produces megasporophylls that are not organised into cones and instead they occur in close spirals in acropetal succession around the stem apex (fig). New megasporophylls are produced in large numbers every year. The megasporophylls of a year occupy the region between the successive whorls of leaves. The growth of the female plant is monopodial; the axis contines to grow as it produces foliage leaves and megasporophylls.



A **B**

Fig.1.69 Cycas

A. Cluster of megasporophylls at the apex of the stem B. Single megasporophyll

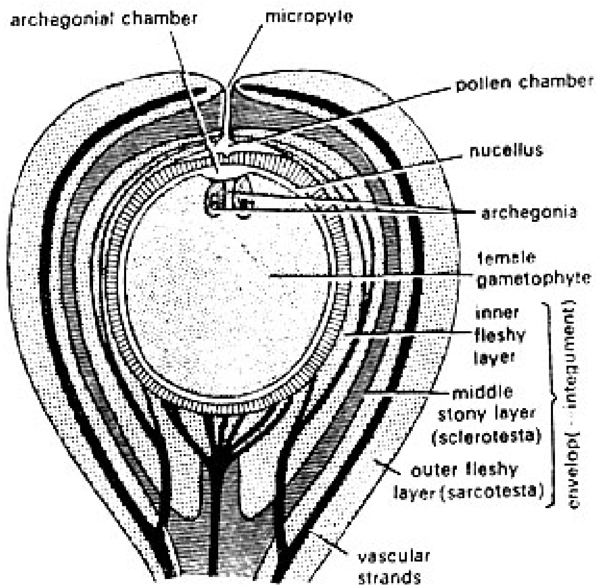


Fig.1.70. Structure of ovule LS

The megasporophylls are considered to be modified leaves. They are flat, dorsiventral and measuring 15-30 cm in length A megasporophyll is differentiated into a basal stalk and an upper pinnate lamina. Ovules are formed on the lateral sids of the stalk. The number of ovules per megasporophyll varies from 2-10 depending upon the species.

Ovule : The ovule of cycas is orthotropous and unitegmic. It is sessile or shortly stalked and perhaps the largest ovule (about 6 cm length and 4 cm width) in the plant kingdom.

Each ovule consists of a large nucellus surrounded by a single integument. The integument remains fused with the body of the ovule except at the apex of the nucellus where it forms a nucellar beak and an opening called micropyle. The opposite end of the microphyle is called chalaza. The integument is very thick and is differentiated into three layers - the outer and inner fleshy layers and a hard and stony middle layer. Some cells in the nucellar beak dissolve to form a pollen chamber. The young ovule is green and hairy whereas the mature one is red or orange without hairs.

One of the deeply situated cells in the nucellus differentiates into megaspore mother cell and divides meiotically to produce 4 linearly arranged haploid megaspores. Of the four megaspores, the upper three cells degenerate while the lowermost acts as functional megaspore.

Female gametophyte : The functional megaspore develops into a large, haploid multicellular tissue called female prothallus or endosperm. The nucellus is used up as the female gametophyte develops. At this stage, some superficial cells of the female gametophyte at the micropylar end enlarge and develop into 2-8 archegonia. Each archegonium has a large egg nucleus and venter canal nucleus. The arehegonial chamber is found above the archegonia.

Fertilization : The fusion of male and female gametes is called fertilization. The pollen tube of the pollen releases sperms or male gametes into the archegonial chamber. Normally, only one male gamete enters each archegonium and fuses with the egg thus resulting in the formation of zygote. Only one egg, in any one of the archegonia, is fertilized. The diploid zygote develops into embryo. The embryo takes about one year for its complete development. The ovule ultimately gets transformed into seed.

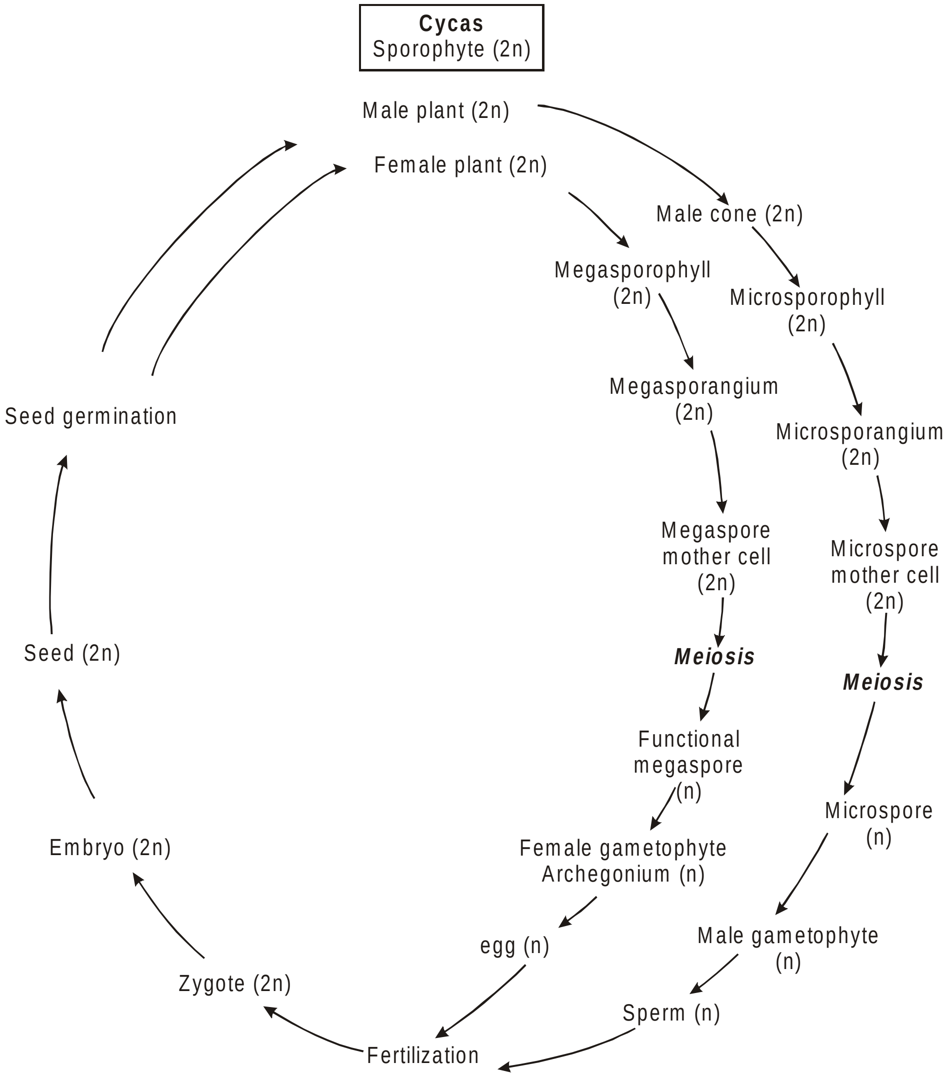


Fig.1.71. Life cycle of a Cycas

SELF-EVALUATION

One Mark

Choose the correct answer :

1. A special type of root of ***cycas*** that exhibits negative geotropism is called
   a) prop root b) normal root c) coralloid root d) aerial root
2. The following species is grown in gardens in India
   a) cycas circinalis b) c. revoluta c) c. pectinata d) c. romphii
3. The following alga is found in collalloid roots of cycas
   a) anabaena b) ulothrix c) volvox d) chlamydomonas

Fill in the blanks

1. The innermost layer of cortex is called
2. The outermost layer of root is called
3. The female sex organ of ***cycas*** is called
4. The pollen grains of ***cycas*** are dispersed by

Two marks

1. What is transfusion tissue?
2. What is meant by manoxylic wood?
3. What is meant by bulbil?
4. What is dioecious condition?

Five marks

1. Describe the external structure of a microsporophyll.
2. Describe the L.S. of male cone.
3. Describe the structure of a pollen grain.
4. Brief the economic importance of ***cycas.***
5. Describe the L.S. of seed.

Ten marks

1. Describe the T.S. of corralloid root.
2. Describe the T.S. of leaflet.
3. Describe the internal structure of stem.
4. Describe the internal structure of microsporophyll.
5. Describe the structure of ovule?

II. CELL BIOLOGY

1. The Cell - Basic Unit of Life

A cell is a structural and functional unit of all living organisms. It is microscopic and capable of independent existence. All living things are made up of cells. The outward differences among the various biological forms may bewilder us. But underlying these differences is a powerful uniformity. That is all biological systems are composed of same types of molecules and they all employ similar principles of organization at the cellular level. We shall see for example, that all living organisms employ the same genetic code and a similar machinery for protein synthesis.

Organisms contain organs, organs composed of tissues, tissues are made up of cells; and cells are formed of organelles and organelles are made up of molecules. However, in all living organisms, the cell is the functional unit.All of biology revolves around the activity of the cell. **Loewy** and **Siekevitz** defined cell as a unit of an organism delimited by a plasma membrane in animal cells and cell wall and plasma membrane in plant cells. Thus cell forms the basic unit of life.

A brief history about the discovery of cells

The study of cell is impossible without microscope. **Anton van Leewenhoek** (1632-1723) studied the structure of bacteria, protozoa spermatozoa, red blood cells under the simple microscope which he examined under a simple microscope that was designed by him. The word cell was first coined by **Robert Hooke** in 1665 to designate the empty honey-comb like structures viewed in a thin section of bottle cork which he examined.

In 1838, the German botanist **Schleiden** proposed that all plants are made up of plant cells. Then in 1839 his colleague, the anatomist **Theodore Schwann** studied and concluded that all animals are also composed of cells. Even at that time the real nature of a cell was a big question. Cell theory was again rewritten by **Rudolf Virchow** in 1858.

Robert Brown in 1831 discovered the presence of nucleus in the cells of orchid roots. This was an important discovery. **Purkinje** coined the term protoplasm for the slimy substance that is found inside the cells. In the 20th century, Various modern micro techniques have been employed in cytological investigation. With the invention of electron microscope in the year 1932 more and more information about the cell and various organellses of the cells become available to us. On the basis of the structure, the cells are classified into **prokaryotic** and **eukaryotic** cells.

Eukaryotic cells vary very much in shape and size. The smallest cells are found among bacteria (0.2 to 50 microns). The largest plant cell is the ovule of ***Cycas.*** The shape of the cells also varies considerably. It may be spherical, polygonal, oval, rectangular, cylindrical, ellipsoidal etc.,

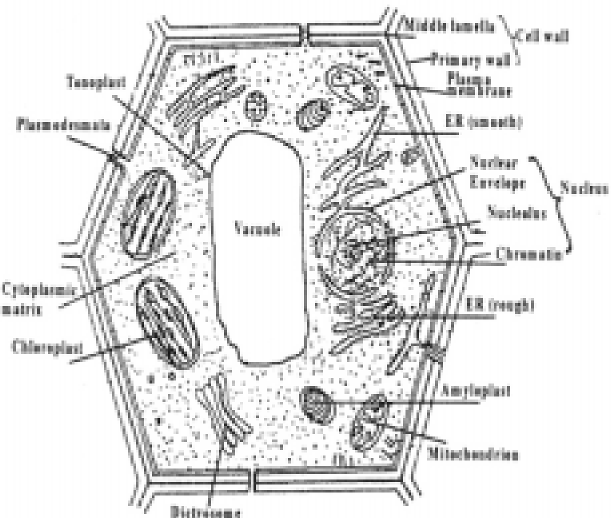


Fig : 2.1. Diagrammatic representation of eucaryotic Plant Cell

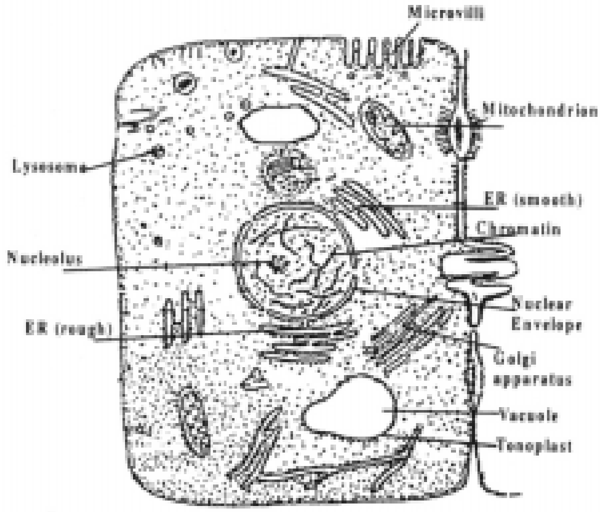


Fig : 2.2. Diagrammatic representation of eucaryotic Animal Cell

Dynamic nature of cell

A cell in an adult organism can be viewed as a steady - state system. The DNA is constantly read out into a particular set of **mRNA (transcription)** which specify a particular set of proteins **(translation)**. As these proteins function they are being degraded and replaced by new ones and the system is so balanced that the cell neither grows, shrinks, nor changes its function. Considering this static view of the cell, however, one should not miss the all-important dynamic aspect of cellular life.

The dynamics of a cell can be best understood by examining the course of a cell's life. A new cell is formed when one cell divides or when two cells, (a sperm and an egg) fuse. Both these events start a cell-replication programme. This usually involves a period of cell growth, during which proteins are made and **DNA** replicated, followed by cell division when a cell divides into two daughter cells. Whether a

Table 2.1 Differences between plant and animal cell

Plant cell	Animal cell
1. Plant cell has an outer rigid cell wall, made up of cellulose	Cell wall is absent. Plasma membrane is the outermost covering.
2. Plant cell has a distinct, definite shape because of the rigid cell wall. So, the shape of cell in permanent.	The shape of the animal cell is not so definite. It can change its shape.
3. Plant cell contains plastids. Most important of this is the green chloroplast.	Plastids are absent.
4. Vacuoles are fewer and larger.	Vacuoles are either absent or very small in number and size.
5. Centrosome is present only in the cells of some lower plants.	All the animal cells have centrosomes
6. Dictyosome (Golgi complex) is dispersed throughout the cytoplasm. It comprises stacks of single membranous lamellar discs.	Golgi complex is organized in the cytoplasm. It appears as shallow saucer shaped body or narrow neck bowl-like form. It consists of interconnecting tubules in distal region.
7. Lysosomes are found only in the eukaryotic plant cells.	Found in all cells.
8. Plant cell is larger than the animal cell.	Animal cell is small in size.
9. Mostly, starch is the storage material.	Glycogen is the storage material
10. During cytoplasmic division a cell plate is formed in the centre of the cell.	During cytoplasmic division a furrow appears from the periphery to the centre of the cell.

given cell will grow and divide is a highly regulated decision of the body, ensuring that adult organism replaces worn out cells or makes new cells in response to a new need. The best example for the latter is the growth of muscle in response to exercise or damage. However, in one major and devastating disease namely cancer, the cells multiply even though there is no need in the body. the understand how cells become cancerous, biologists have intensely studied the mechanism that controls the growth and division of cells.

Cell Cycle

The cell cycle follows a regular timing mechanism. Most eukaryotic cells live according to an internal clock, that is they proceed through a sequence of phases, called **cell cycle.** In the cell cycle **DNA** is **Duplicated** during **synthesis (S) Phase** and the copies are distributed to daughter cells during **mitotic (M) phase.**

Most growing plant and animal cells take 10-20 hours to double in number and some duplicate at a much slower rate.

The most complicated example of cellular dynamics occurs during **differentiation** i.e when a cell changes to carry out a specialized function. This process often involves changes in the morphology of a cell based on the function it is to perform. This highlights the biological principle that **"form follows function"**

Unchecked cell growth and multiplication produce a mass of cells, a tumor. Programmed Cell Death (**PCD**) plays a very important role by balancing cell growth and multiplication. In addition, cell death also eliminates unecessary cells.

Plant cells differ from animal cells in many ways. These differences are tabulated in page 53.

SELF EVALUATION

One Mark

Choose the correct answer

1. The process in which DNA is constantly read out into a particular set of mRNA is called

   a. translation b.protein synthesis c.DNA duplication d.transcription

2. The process of changing the form in order to carry out a specialized function is called

   a. differentiation b.growth c.cell division d.cell elongation

Two Marks

1. Define:Cell cycle
2. What is meant by cell differentiation.
3. Explain the statement: "form follows function"
4. What is PCD?

Ten Marks

1. Tabulate the differences between a plant cell and an animal cell.

2. Cell Theory

In the year (1839) **Schleiden** and **Schwann** have jointly proposed the **“Cell Theory”** It states that all living organisms are made up of cells and cells are the structural and functional units of all organisms.

Development of Cell Theory

If we study the step by step development of cell theory we will understand how scientific methodology operates. It includes the following steps 1.observation 2.Hypothesis 3.Formulation of theory 4.modification of theory (if it warrants). Observations were made by Schleiden (1804 - 1881) a German botanist. He examined a large variety of plants and found that all of them were composed of cells. In 1838 he concluded that cells are the ultimate structural units of all plant tissues.

Schwann, a German Zoologist studied many types of animals and found that animal cells lack a cell wall and they are covered by a membrane. He also stated that animal cells and plant cells were basically identical but for the cell wall. He observed that both contain nucleus and a clear substance around it. He defined the cell as a membrane bound nucleus containing structure. He proposed a hypothesis that the bodies of animals and plants are composed of cells and their products.

Schleiden and Schwann both together discussed Schwann’s hypothesis and they formulated **cell theory.** The important aspects of cell theory are:

1. All living organisms are made up of minute units, the cells which are the smallest entities that can be called living.
2. Each cell is made up of protoplasm with a nucleus and bounded by plasma membrane with or without a cell wall.
3. All cells are basically alike in their structure and metabolic activities.
4. Function of an organism is the sum total of activities and interaction of its constituent cells.

Exception to cell Theory

1. Viruses are biologists’ puzzle. They are an exception to cell theory. They lack protoplasm, the essential part of the cell.
2. Bacteria and **cyanobacteria** (Blue Green algae) lack well organized nucleus.
3. Some of the protozons are acellular.

4. The coenocytic hyphae of some fungi eg. ***Rhizopus*** have undivided mass of protoplasm, in which many nuclei remain scattered.
5. Red Blood Corpuscles (**RBC**) and mature sieve tubes are without nuclei.

A cell may grow, secrete, divide or die while its adjacent cells may lie in a different physiological state. Many of the subsequent findings about the cell like this had necessitated modification in cell theory. The modified form of cell theory has been given the higher status as cell principle or cell Doctrine.

Cell Principle or Cell Doctrine

The important features of cell doctrine are:

1. All organisms are made up of cells.
2. New cells are produced from the pre-existing cells.
3. Cell is a structural and functional unit of all living organisms.
4. A cell contains hereditary information which is passed on from cell to cell during cell division.
5. All the cells are basically the same in chemical composition and metabolic activities.
6. The structure and functionof the cell are controlled by DNA.
7. Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

Self evaluation
One Mark
Choose the correct answer

1. An exception to cell theory is

   a.viruses b. bryophyte c. seed plant d. pteridophyte

Fill in the blanks

1. .... and .... proposed cell theory.
2. Cells are the .... and .... units of life.
3. The modified cell theory is called ....

Two Marks

1. Name the steps involved in scientific methodology.
2. State the cell theory as proposed by Schleiden and Schwann
3. Name any two exceptions to cell theory.

Five Marks

1. State the important features of cell doctrine.

Ten Marks

1. Describe the development of cell theory.

3. Prokaryotic and Eukaryotic Cell (Plant Cells)

All living things found on the planet earth are divided into two major groups namely, prokaryotes and Eukaryotes based on the types of cells these organisms possess. Prokaryotic cells lack a well defined nucleus and have a simplified internal organization. Eukaryotic cells have a more complicated internal structure including a well defined, membrane - limited nucleus. Bacteria and Cyanobacteria are prokaryotes. Fungi, plants and animals are eukaryotes.

Prokaryotes

In general, Prokaryotes consist of a single closed compartment containing the **cytosol** and bounded by the plasma membrane. Although bacterial cells do not have a well defined nucleus, the genetic material, DNA, is condensed into the central region of the cell. In all prokaryotic cells, most of or all the genetic information resides in a single circlular DNA molecule, in the central region of the cell. This region is often referred ot as **incipient nucleus** or **nucleoid.** In addition, most ribosomes, the cell's protein synthesizing centres are found in the DNA-free region of the cell. Some bacteria also have an invagination of the cell membrane called a mesosome, which is associated with synthesis of DNA and secretion of proteins. Thus we can not say that bacterial cells are completely devoid of internal organization.

Bacterial cells possess a cell wall which lies adjacent to the external side of the plasma membrane. The cell wall is composed of layers of peptidoglycan, a complex of proteins and oligosaccharides. It protects the cell and maintains its shape.

Some bacteria (eg ***E.coli***) have a thin cell wall and an unusual outermembrane separated from the cell wall by the periplasmic space. Such bacteria are not stained by Gram staining technique and thus are classified as Gram-negative bacteria. Other bacteria (eg.***Bacillus polymyxa***) that have a thicker cell wall without an outer membrane take the Gram stain and thus are classified as Gram positive bacteria.

Ultra structure of a prokaryotic cell

The bacterium is surrounded by two definite membranes separated by the periplasmic space. The outer layer is rigid, serves for mechanical protection and is designated as the cell wall. The chemical composition of the cell wall is rather

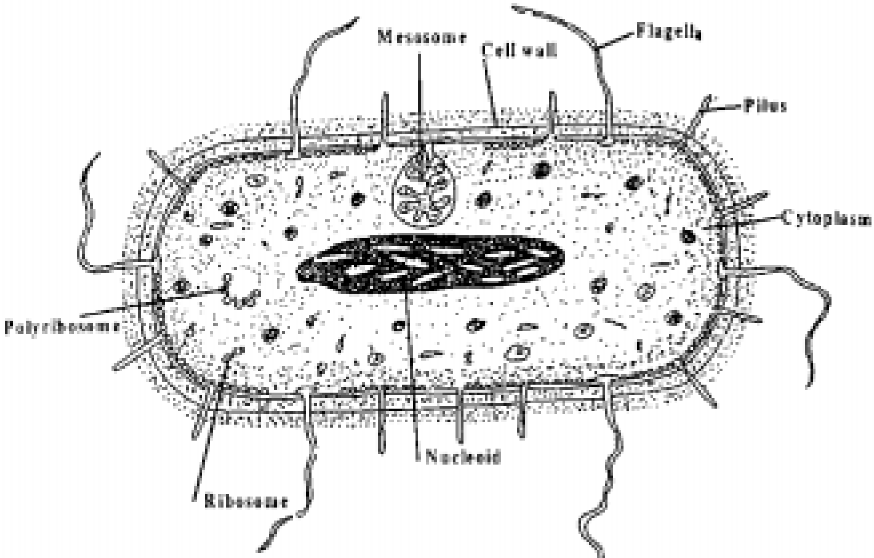


Fig : 2.3. Ultra structure of a prokaryotic Cell (Bacteria)

complex; it contains peptidoglycan, polysaccharides, lipid and protein molecules. One of the most abundant polypetides, porin, forms channels that allow for the diffusion of solutes. The plasma membrane is a lipoprotein structure serving as a molecular barrier with the surrounding medium. the plasma membrane controls the entry and exit of small molecules and ions. The enzymes involved in the oxidation of matabolites (i.e. the respiratory chain) as well as the photosystems used in photosynthesis, are present in the plasma membrane of prokaryotes.

The bacterial chromosome is a single circular molecule of naked DNA tightly coiled within the nucleoid which appears in the electron microscope as a lighter region of the protoplasm. It is amazing to note that the DNA of ***E.coli*** which measures about 1 mm long when uncoiled,contains all the genetic information of the organism. In this case, there is sufficient information to code for 2000 to 3000 different protiens.

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.

In addition to a chromosome, certain bacteria contain a small, extrachromosomal circular DNA called **plasmid.** The plasmid is responsible for the antibiotic resistance in some bacteria. These plasmids are very much used in genetic engineering where the plasmids are separated and reincorporated, genes (specific pieces of DNA) can be inserted into plasmids, which are then transplanted into bacteria using the techniques of genetic engineering.

Surrounding the DNA in the darker region of the protoplasm are 20,000 to 30,000 particles called ribosomes. These are composed of RNA and proteins and are the sites of protein synthesis. Ribosomes exist in groups called **polyribosomes** or **polysomes.** Each ribosome consists of a large and a small sub unit. the remainder of the cell is filled with H_2O, various RNAs, protein molecules (including enzymes) and various smaller molecules.

Certain motile bacteria have numerous, thin hair like processes of variable length called flagella. Flagella are used for locomotion. In contrast with the flagella of eukaryotic cells which contain 9+2 micortubles each flagellum in bacteria is made of a single fibril.

It was Fox *et al* who divided the living organisms into two kingdoms Prokaryota and Eukaryota. Prokaryotes are in turn classified into two major sub groups 1) the ***Archae bacteria*** and 2) ***Eubacteria.*** Cyanobacteria are included in the group Eubacteria. the Cyanobacterial prokaryotes, commonly called bluegreen algae, are photosynthetic. In cyanobacterial cells, the photosynthetic, respiratory and genetic apparatuses are present but not delimited from each other by any bounding membrane of their own. No sharp boundaries divide the cell into special regions. But, there are several cell components with characteristic fine structure. These are distributed throughout the cell in patterns varying from species to species and also in different developmental stages in the same species.

These cyanobacterial cells have an elaborate photosynthetic membrane system, composed of simple thylakoids and a central nucleoplasmic area which is usually fibrillar or granular or both. The cell also includes various kinds of granular inclusions, a rigid, several layered cell wall and a fibrous sheath over the cell wall.The characteristic collective properties of Cyanobacteria include oxygenic photosynthesis, chromatic adaptation, nitrogen fixation and a capacity for cellular differentiation by the formation of heterocysts, akinetes and hormogonia.

Eukaryotes

Eukaryotes comprise all members of Plant Kingdom, Fungi and Animal Kingdoms, including the unicellular fungus Yeast, and protozoans. Eukaryotic cells, like prorkaryotic cells are surrounded by a plasma membrane. However, unlike prokaryotic cells, most eukaryotic cells contain internal membrane bound organelles.

Each type of organelle plays a unique role in the growth and metabolism of the cell, and each contains a set of enzymes that catalyze requisite chemical reactions.

The largest organelle in a eukaryotic cell is generally the **nucleus,** which houses most of the cellular DNA. The DNA of eukaryotic cells is distributed among 1 to about 50 long linear structures called **chromosomes.** The number

Table 2.2 The differences between Prokaryotes and Eukaryotes

Property	Prokaryotes	Eukaryotes
Size	Most of them are very small. Some are larger than 50 µm.	Most are large cells (10-100µm). Some are larger than 1 mm.
General Characteristics	All are microbes. Unicellular or colonial. The nucleoid is not membrane bound.	Some are microbes; most are large organisms. All possess a membrane-bound nucleus.
Cell Division	No mitosis or meiosis. Mainly by binary fission or budding.	Mitosis and meiosis types of cell division occur.
Sexual system	Absent in most forms, when present unidirectional transfer of genetic material from donor to recipient.	Present in most forms, equal male and female participation in fertilization.
Development	No multi-cellular development from diploid zygotes. No extensive tissue differentiation.	Haploid forms are produced by meiosis and diploid from zygotes. Multi-cellular organisms show extensive tissue differentiation.
Flagella Type	Some have simple bacterial flagella composed of only one fibril.	Flagella are of 9 + 2 type
Cell Wall	Made up of peptidoglycan (mucopeptide). Cellulose is absent.	Cell wall is made up of cellulose in plants and chitin in fungi.
Organelles	Membrane bound organelles such as endoplasmic reticulum, golgi complex, mitochondria, chloroplasts and vacuoles are absent.	Membrane bound organelles such as endoplasmic reticulum, golgi complex, mitochondria, chloroplasts and vacuoles are present.
Ribosomes	Ribosomes are smaller made of 70s units (s refers to Svedberg unit, the sedimentation coefficient of a particle in the ultra centrifuge).	Ribosomes are larger and made of 80s units.
DNA	Genetic material (DNA) is not found in well-organized chromosomes.	Genetic material is found in well organized chromosomes.

and size of the chromosomes are the same in all cells of an organism but vary among different species of organisms. The total DNA (the genetic information) in the chromosomes of an organism is referred to as its **genome.** In addition to the nucleus, several other organelles are present in nearly all eukaryotic cells, the **mitochondria** in which the cell's energy metabolism is carried out, the rough and smooth **endoplasmic reticula,** a network of membranes in which proteins and lipids are synthesized and **peroxysomes,** in which fatty acids and amino acids are degraded. **Chloroplasts**, the site of photosynthesis are found only in plants and some single celled organisms. Both plant cells and some single celled eukaryotes contain one or more **vacuoles**, large, fluid – filled organelles in which nutrients and waste compounds are stored and some degradative reactions occur. The cytosol of eukaryotic cells contains an array of fibrous proteins collectively called the **cytoskeleton**. Cytosol is the soluble part of the cytoplasm. It is located between the cell organelles. The plant cell has a rigid **cell wall** composed of cellulose and other polymers. The cell wall contributes to the strength and rigidity of plant cell.

Some familiar prokaryotes are: Bacteria, filamentous bacteria (Actinomycetes) and Cyanobacteria.

Some familiar eukaryotes are: Fungi, plants and animals.

SELF EVALUATION

One Mark

Choose the correct answer

1. The extra-chromosomal DNA found in the bacterium ***E.coli*** is called
   a. measosome   b. nucleoid   c. incipient nucleus   d. plasmid

Fill in the blanks

1. Bacteria having a thin wall and an outer membrane separated from the cell wall are usually Gram——————.
2. The plasmid is responsible for ———— of the bacterium.
3. Plasmids are very much used in ——————
4. Ribosomes that exist in groups are called——————

Two Marks

1. What is meant by incipient nucleus.
2. What are the uses of plasmid?
3. Distinguish a prokaryotic cell form a eukaryotic cell.

Five Marks

1. Describe the ultra structure of a prokaryotic cell.

Ten Marks

1. Tabulate the differences between prokaryotes and eukaryotes.

4. Light Microscope and Electron Microscope (TEM & SEM)

The modern, complete understanding of cell architecture is based on several types of microscopy. Schleiden and Schwann using a primitive light microscope, first described individual cells as the fundamental unit of life and light microscopy continued to play a major role in biological research. The development of electron microscopes has greatly extended the ability to resolve sub-cellular particles and it has provided new information on the organization of plant and animal tissues. The nature of the image depends on the type of light or electron microscope used and on the way in which the cell or tissue has been prepared for observation.

Light microscopy

The compound microscope which is most commonly used today contains **several lenses** that magnify the image of a specimen under study. The total magnification of the object is a product of the magnification of the individual lenses; if the objective lens magnifies 100-fold (a **100 ×** lens, usually employed) and the eye piece magnifies 10-fold, the final magnification recorded by the human eye or on film will be 1000-fold (**100 × 10**).

The limit of resolution of a light microscope using visible light is about **0.2µm (200nm).** No matter how many times the images is magnified, the microscope can never resolve objects that are less than **≈0.2µm** apart or reveal details smaller than **≈0.2µm** in size

Samples for light microscopy are usually fixed, sectioned and stained. Specimens for light microscopy are usually fixed with a solution combining alcohol or formaldehyde, compounds that denature most protein and nucleic acids. Usually the sample is then embedded in paraffin or plastic and cut into sections of one or a few micrometers thick using a microtome. Then these sections are stained using appropriate stains.

Transmission Electron Microscopy

The fundamental principles of electron microscopy are similar to those of light microscopy, the major difference is that in electron microscope **electro magnetic lenses** and not optical lenses are used. Also it focuses a high velocity electron beam instead of visible light. The electrons are absorbed by atoms in the air and that is the reason why the entire tube between the electron source and the viewing screen is maintained under an ultra high vacuum.

The TEM directs a beam of electrons through a specimen. Electrons are emitted by a tungsten cathode when it is electrically heated. A condenser lens focuses the electron beam on to the sample objective and projects them on to a viewing screen or on a piece of photographic film.

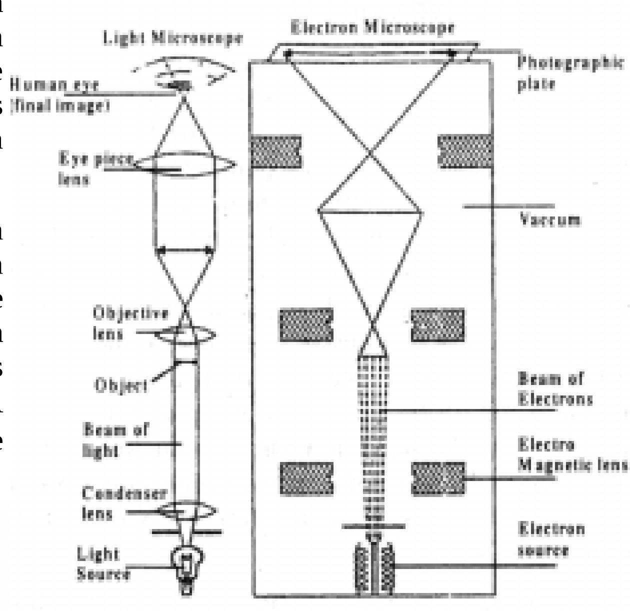


Fig : 2.4. Working principle of light and electron microscope

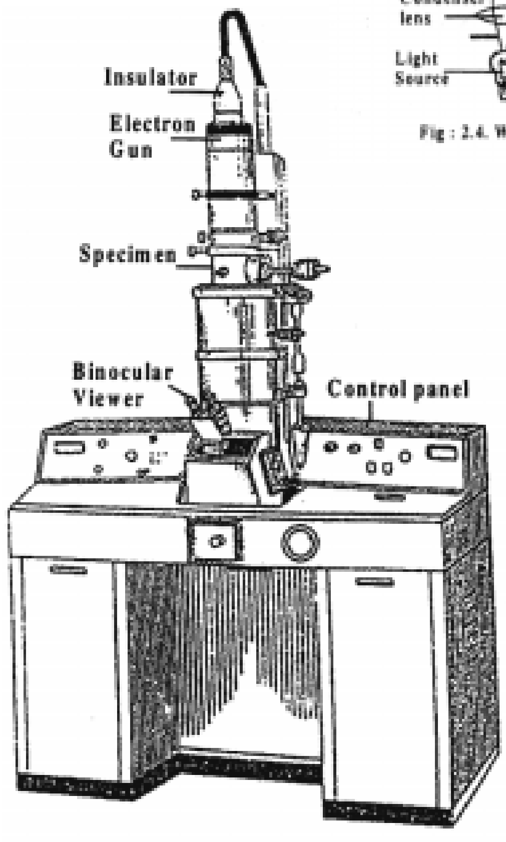


Fig : 2.5. An Electron Microscope

The minimum distance **D** at which two objects can be distinguished is proportional to the wavelength λ of the light that illuminates the objects. Thus the limit of resolution for the electron microscope is theoretically 0.005nm or 40,000 times better than that of unaided human eye. But in reality a resolution of 0.10nm can be obtained with TEM, about 2000 times better than the resolution of light microscopes.

Scanning Electron Microscope

SEM generally has a lower resolving power than the TEM. It is very useful for providing three-dimensional images of the surface of microscopic objects. In this electrons are focused by means of lenses in to a very fine point. The interaction of electrons with the specimen results in the release of different forms of radiation (eg secondary electrons) from the surface of the specimen. These radiations are then captured by an appropriate detector, amplified and then imaged on a television screen.

Other important techniques in EM include the use of ultra thin sections of embedded material; a method of freeze-drying the specimen, which prevents the distortion caused by conventional drying procedure; and the use of negative staining with an electro dense material such as phosphotungstic acid or Uranyl salts. These heavy metal salts provide enough contrast to detect the details of the specimen.

SELF EVALUATION
One Mark
Fill in the blanks

1. The .... value of D, the better will be the resolution.
2. The resolution of a microscope lens is numercally equivalent to ....
3. The purpose of using heavy metals in scanning electron microscopy is to provide enough .... to detect the details of the specimens.
4. The compound microscope uses .... lenses to magnify the objects.

Two Marks

1. Define:resolving power of a microscope

Ten Marks

1. Explain the structure and principle used in light microscope.
2. Explain the structure and principle used in Transmission electron microscope.

5.Cell Wall

The cells of all plants, bacteria and fungi have a rigid, protective covering outside the plasma membrane called **cell wall**. The presence of cell wall in plant cells distinguishes them from animal cells. Among the vascular plants only certain cells connected with the reproductive processes, are naked, all other cells have walls. The cell wall was first observed by **Hooke** in the year 1865 in cork cells. Originally it was thought that the cell wall was a non-living secretion of the protoplasm, but now it is known to be metabolically active and is capable of growth and at least during its growth, contains protoplasmic material.

Formation of the cell wall

During the telophasic stage of mitosis, the **phragmoplast** widens and becomes barrel shaped. At the same time, on the equatorial plane the cell plate i.e the first evident partition between the daughter protoplasts, begins to form inside the phragmoplast. In the area where the cell plate forms, the fibres of the phragmoplast become indistinct and are restricted to the circumference of the cell plate. When the cell plate is completely formed the phargmoplast disappears completely. At this stage thin lamellae are laid down by the daughter protoplasts on both the sides of the cell plate. The cell plate gradually undergoes changes to form the intercellular substances referred to as the **middle lamella.**

Structure of the cell wall

A typical plant cell has the following three parts. 1.**Middle lamella** 2.**Primary wall** 3.**Secondary Wall**

Chemical Composition

The chemical composition of cell wall varies in different kingdoms. In bacteria the cell wall is composed of **peptidoglycan,** in Fungi it is made up of **chitin.** The plant cell wall is made up of **cellulose.** Besides cellulose certain other chemicals such as hemicellulose, pectin, lignin, cutin, suberin, silica may also be seen deposited on the wall.

Middle lamella

It is a thin amorphous cement like layer between two adjacent cells. Middle lamella is the first layer, which is deposited at the time of cytokinesis. It is optically inactive (isotropic). It is made up of calcium and magnesium pectates. In addition to these substances proteins are also present.

Primary wall

It is the first formed wall of the cell which is produced inner to the middle lamella. It is thin, elastic and extensible in growing cells. It is optically active (anisotropic). It grows by addition of more wall material within the existing one. Such a growth is termed as **intussusception.** Some cells like the parenchymatous cells and meristematic cells have only the primary wall. The primary wall consists of a loose network of cellulose **microfibrils** embedded in a gel like matrix or ground substances. In most of the plants the micro fibrils are made up of cellulose. The micro fibrils are oriented variously according to shape and thickness of the wall. The matrix of the primary wall in which the micro fibrils are embedded is mainly composed of water, hemicellulose, pectin and glycoprotein. Pectin is the filling material of the matrix. Hemicellulose binds the microfibrils with the matrix and the glycoproteins control the orientation of the microfibrils.

Secondary Wall

A thick secondary wall is laid inner to the primary wall after the cell has reached maturity. It is laid down is succession of at least three layers often named $\mathbf{S_1}$, $\mathbf{S_2}$ and $\mathbf{S_3}$. It grows in thickness by accretion (apposition) i.e deposition of materials over the existing structures. The central layer ($\mathbf{S_2}$)is usually the thickest layer. In some cells however, the number of layers may be more than three. The formation of secondary wall is not uniform in all the cells. This results in the differentiation of various types of cells, such as parenchyma, collenchyma, fibres and tracheids.

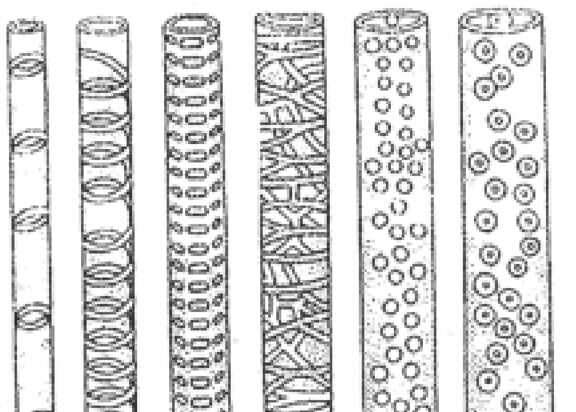


Fig : 2.6. Various types of thickenings in cell wall

The micro fibrils of secondary wall are compactly arranged with different orientation in different layers embedded in a matrix of pectin and hemicellulose. substances like lignin, suberin, minerals, waxes, tannins, resins, gums, inorganic salts such as calcium carbonate, calcium oxalate, silica etc may be deposited in the secondary wall. The secondary wall is very strongly anisotropic and layering can be observed in it.

Fine structure of the cell wall particularly that of the secondary wall, has been intensively studied. This study was stimulated because of its importance to the fibre, paper and other industries. Cell wall is built of a system of microscopic threads the micro fibrils, which are grouped together in larger bundles. the layering seen in the secondary wall is often the result of the different density of the micro fibrils. The secondary wall consists of two continuous interpenetrating systems one of which is the **cellulose micro fibrils** and the other, the continuous system of **microcapillary spaces.** These spaces may the filled with lignin, cutin, suberin, hemicellulose and other organic substances and sometimes even some mineral crystals.

The cellulose molecules consist of long chains of linked glucose residues. The chain molecules are arranged in bundles which are generally termed **micellae.** The

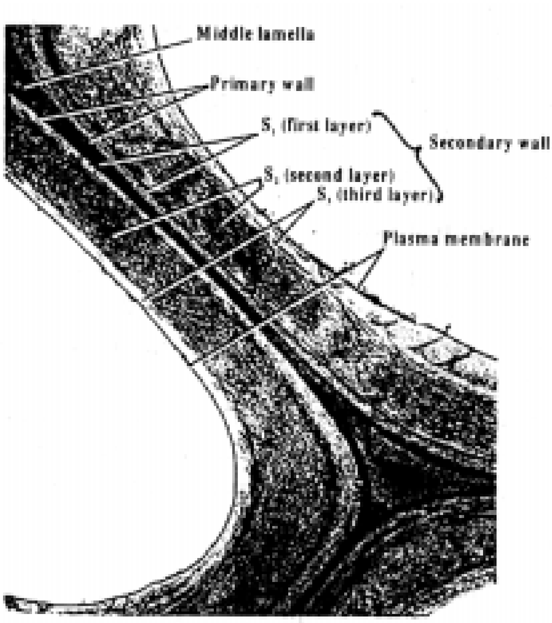


Fig : 2.7. Electron micrograph of a thin section showing parts of the cell walls separating three cells.

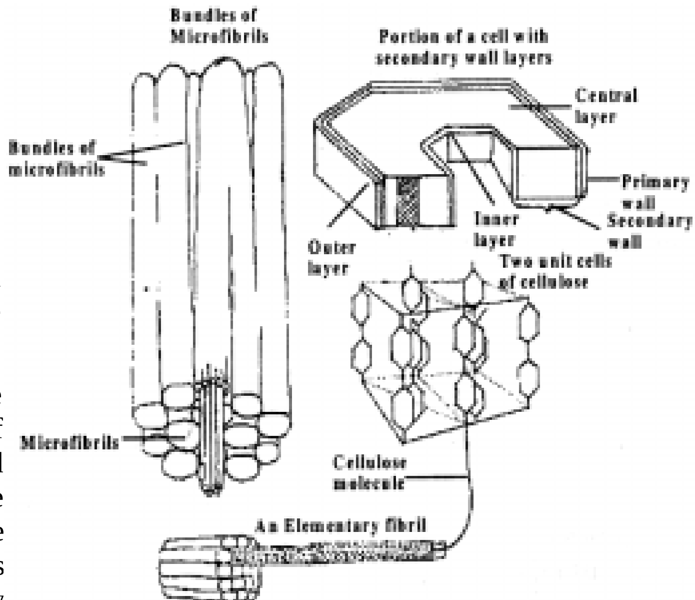


Fig : 2.8. Digrammatic representation of ultrastructure of the cell wall hypothesis of the presence of micellae was proposed by **Nageli.** According to Frey-wyssling and Muhlethaler the thread like cellulose molecules are arranged in bundles. Each such bundle which forms an **elementary fibril** consists of about 36 cellulose molecules. The elementary fibril is mostly crytalline.

Plasmodesmata

The cell wall is not totally complete around the cell. It is interrupted by narrow pores carrying fine strands of cytoplasm, which interlink the contents of the cells. They are called **plasmodesmata.** They form a protoplasmic continuum called **symplast.** It consists of a canal, lined by plasma membrane. It has a simple or branched tubule known as **desmotubule.** Desmotubule is an extension of endoplasmic reticulum. Plasmodesmata serves as a passage for many substances to pass through. It is also believed that they have a role in the relay of stimuli.

Pits

Pits are the areas on the cell wall on which the secondary wall is not laid down. The pits of adjacent cells are opposite to each other. Each pit has a **pit chamber** and a **pit membrane.** The pit membrane consists of middle lamella and primary wall. Pit membrane has many minute pores and thus they are permeable.

Pits are of two types 1.**Simple pits** 2.**Bordered pits.** In simple pits the width of the pit chamber is uniform. There is no secondary wall in the simple pit. In bordered pit the secondary wall partly overhangs the pit. Pits help in the translocation of substances between two adjacent cells. Generally each pit has a **complementary pit** lying exactly opposite to it in the wall of the neighbouring cell. Such pits form a morphological and functional unit called the **pit pair.**

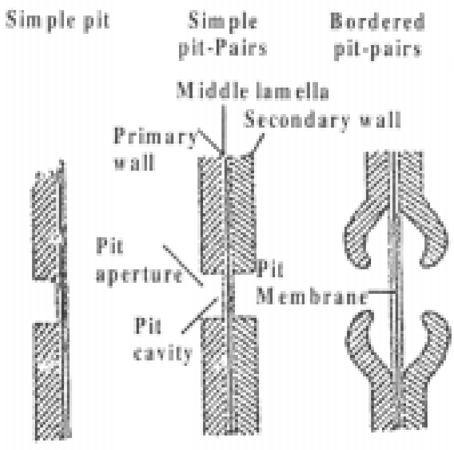


Fig : 2.9. Structure of pits

Functions of cell wall

1. It gives definite shape to the cell.
2. It protects the internal protoplasm against injury.
3. It gives rigidity to the cell
4. It prevents the bursting of plant cells due to endosmosis.
5. The walls of xylem vessels, tracheids and sieve tubes are specialized for long distance transport.
6. In many cases, the cell wall takes part in offense and defense.

SELF EVALUATION

One Mark

Choose the correct answer

1. The addition of wall materials within the existing one is called
   a.accretion   b.intussusception   c.apposition   d.deposition

Fill in the blanks

1. The cell wall of bacterium is made up of ——————
2. The cell wall of a typical plant cell is made up of ——————
3. The cell wall of a fungus is made up of ——————
4. The addition of wall materials over the existing one is called——————

Two Marks

1. Name the three important components of a typical plant cell wall.
2. What is middle lamella?
3. What is meant by growth by intussusception?
4. What are micellae?
5. Name the two continuous interpenetrating systems found in secondary wall.
6. What is a pit membrane?
7. What are bordered pits?
8. Define:symplast.
9. What is desmotubule?

Five Marks

1. What is plasmodesmata? Explain
2. What are pits? Explain their types.
3. Discuss the functions of cell wall.

Ten Marks

1. Describe the fine structure of cell wall.

6. Cell Membrane

All the prokaryotic and eukaryotic cells are enclosed by an elastic thin covering called **plasma membrane.** It is selectively permeable since it allows only certain substances to enter or leave the cell through it. In addition to this eukaryotic cells possess intracellular membranes collectively called cytoplasmic membrane system, that surround the vacuole and cell organelles. Plasma membrane and the sub-cellular membranes are together known as **biological membranes.**

Ultra structure of the cell membrane

Cell membranes are about 75A° thick. Under the electron microscope they appear to consist of 3 layers.

1. an outer electron dense layer of about 20A° thick
2. an inner electron dense layer of about 20A° thick.
3. a middle pale coloured layer about 35A° thick.

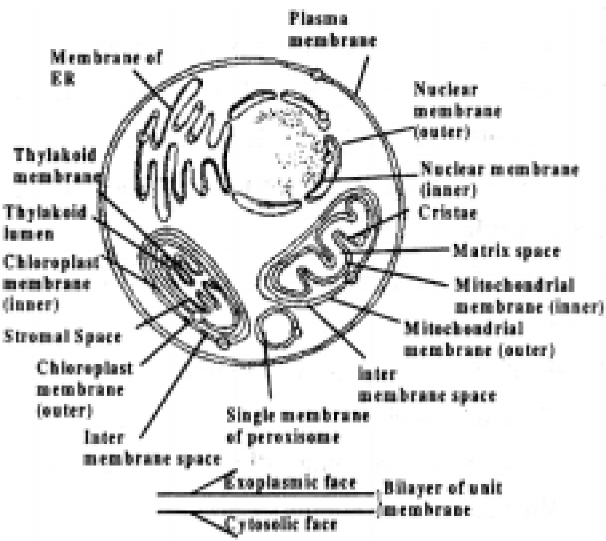


Fig : 2.10. Two faces of bio membrane

The outer and inner layers are formed of protein molecules whereas the middle one is composed of two layers of phospholipid molecules. Such a trilaminar structure is called "Unit membrane" which is a basic concept of all membranes.

Fluid mosaic Model

Many models have been proposed to explain the molecular structure of plasma membrane. Fluid mosaic model was proposed by **Singer and Nicholson** (1972) and it is widely accepted by all. According to this model the cell membrane has **quasifluid** structure. All cellular membranes line closed compartments and have a **cytosolic** and an **exoplasmic** face. Membranes are formed of lipids and priteins. According to this model the membrane is viewed as a two dimensional mosaic of phospholipids and protein molecules.

Lipids

The lipid molecules form a continuous bilayer. The protein molecules are arranged as **extrinsic proteins** on the surface of lipid bilayer and as **intrinsic proteins** that penetrate the lipid bilayer either wholloy or partially. The lipid bilayer is formed of a double layer of phospholipid molecules. They are **amphipathic** molecules i.e. they have a hydrophilic and hydrophobic part. The arrangement of phospholipids forms a water resistant barrier. So that only lipid soluble substances can pass through readily but not water soluble substances.

The phospholipid bilayer forms the basic structure of all biomembranes which also contain proteins, glycoproteins, cholesterol and other steroids and glycolipids. The presence of specific sets of membrane proteins permits each type of membrane to carryout distinctive functions.

Proteins

Proteins are arranged in two forms.

1. **Extrinsic or peripheral proteins:**These are superficially attached to either face of lipid bimolecular membrane and are easily removable by physical methods.
2. **Intrinsic or Integral proteins**:These proteins penetrate the lipid either wholly or partially and are tightly held by strong bonds. In order to remove them, the whole membrane has to be disrupted. The integral proteins occur in various forms and perform many functions.

Functions of plasma membrane

In all cells the plasma membrane has several essential functions to perform. These include transporting nutrients into and metabolic wastes out of the cell preventing unwanted materials from entering the cell. In short, the intercellular and intra cellular transport is regulated by plasma membrane. The plasma membrane maintains the proper ionic composition pH(~7.2) and osmotic pressure of the cytosol. To carry out all these functions, the plasma membrane contains specific trasport proteins that permit the passage of certain small molecules but not others. Several of these proteins use the energy relaeased by **ATP** hydrolysis to pump ions and other molecules into or out of the cell against concentration gradients. Small charged molecules such as ATP and amino acids can diffuse freely within the cytosol but are restricted in their ability to leave or enter it across the plasma membrane.

In addition to these universal functions, the plasma membrane has other important functions to perform. Enzymes bound to the plasma membrane catalyze reactions that would occur with difficulty in an aqueous environment. The plasma membranes of many types of eukaryotic cells also contain **receptor proteins** that bind specific **signalling molecules** like hormones, growth factors, neurotransmitters etc. leading to various cellular responses.

Like the entire cell, each organelle in eukaryotic cells is bounded by a unit membrane containing a unique set of proteins essential for its proper functioning.

Membrane Transport

Based on the permeability a membrane is said to be:

1. **Permeable**: If a substance passes readily through the membrane
2. **Impermeable**: If a substance does not pass through the membrane
3. **Selectively permeable**: If the membrane allows some of the substances to pass through but does not allow all the substances to pass through it.

The permeability of a membrane depends on 1)the size of pores in the Plasma membrane. 2)The size of the substance molecules 3)The charge on the substance molecules.

All the biological membranes are selectively permeable. Its permeability properties ensure that essential molecules such as glucose, amino acids and lipids readily enter the cell, metabolic intermediates remain in the cell and waste compounds leave the cell. In short it allows the cell to maintain a constant internal environment.

Substances are transported across the membrane either by:

1. **Passive Transport** or 2. **Active Transport**

Passive Transport

Physical processes

Passive Transport of materials across the membrane requires no energy by the cell and it is unaided by the transport proteins. The physical processes through which substances get into the cell are 1.**Diffusion** 2.**Osmosis**

Diffusion

Diffusion is the movement of molecules of any substance from a region of it's higher to a region of it's lower concentration (down its own concentration gradient) to spread uniformly in the dispersion medium on account of their random kinetic motion.

The rate of diffusion is directly proportional to

1. the concentration of the substance
2. temperature of the medium
3. area of the diffusion pathway

The diffusion is inversely proportional to

1. the size of the substance molecules
2. the molecular weight of the substance molecule
3. the distance over which the molecules have to diffuse

Diffusion through Biomembranes

Gases and small hydrophobic molecules diffuse directly across the phospholipid bilayer at a rate proportional to their ability to dissolve in a liquid hydro carbon. Transport of molecules takes place **along the concentration gradient** and no metabolic energy is expended in this process. This can be described as **'down hill transport'**. Diffusion through the bio membrane takes place in two ways.

1. Diffusion of fat-soluble substances through plasma membrane simply by dissolving in the lipid bilayer.
2. Diffusion of water soluble substances and ions: This takes place through pores in the membranes.

Diffusion of charged particles water soluble substances and ions such as K^+ Cl^- and HCO_3^- diffuse through the pores in the membranes. An ion diffuses from the side richer in like charges to the side with an excess of opposite charges. The difference of electrical charges between the two sides of a membrance is called electro chemical gradient.

The integral proteins of the membrane act as protein channels extending through the membrane. The movement of gas molecules occurs down its pressure gradient.

Osmosis

It is the special type of diffusion where the water or solvent diffuses through a selectively permeable membrane from a region of high solvent concentration to a region of low solvent concentration.

Role of Osmosis

1. It helps in absorption of water from the soil by root hairs.

2. Osmosis helps in cell to cell movement of water.
3. Osmosis helps to develop the turgor pressure which helps in opening and closing of stomata. (For more about Osmosis see unit 5.4)

Uniporter Catalyzed Transport

The plasma membrane of most cells (animal or plant) contains several uniporters that enable amino acids, nucleosides, sugars and other small molecules to enter and leave cells down their concentration gradients. Similar to enzymes, uniporters accelerate a reaction that is thermodynamically favoured. This type of movement sometimes is referred to as **facilitated transport** or **facilitated diffusion.**

Three main features distinguish uniport transport from passive diffusion. 1. the rate of transport is far higher than predicted 2.transport is specific 3.transport occurs via a limited number of transporter proteins rather than through out the phospholipids bilayer.

Active transport

It is vital process. It is the movement of molecules or ions **against the concentration gradient.** i.e the molecules or ions move from the region of lower concentration towards the region of higher concentration. The movement of molecules can be compared with the **uphill movement** of water.

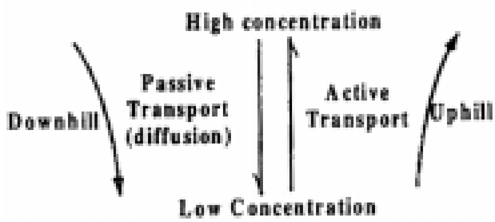


Fig : 2.12. Active transport-a scheme

Energy is required to counteract the force of diffusion and the energy comes from ATP produced by oxidative phosphorylation or by concentration gradient of ions. Thus active transport is defined as athe energy dependent transport of molecules or ions across a semi permeable membrane **against the concentration gradient.**

Active transport takes place with the help of **carrier proteins** that are present in the plasma membrane. In the plasma membrane there are a number of carrier molecules called **permeases** or **translocases** present. For each type of solute molecule there is a specific carrier molecule. It has got two binding sites; one for the **transportant** and other for **ATP** molecule. The carrier proteins bind the transportant molecule on the outer side of the plasma membrane. This results in the formation of **carrier-transportant-complex.** As the ATP molecule binds itself to the other binding site of the carrier protein it is hydrolysed to form ADP and energy is released. This energy brings **conformational change** in the carrier transportant-complex and the transportant is carried through the channel on the other side of the membrane. The carrier molecule regains its original form and repeats the precess.

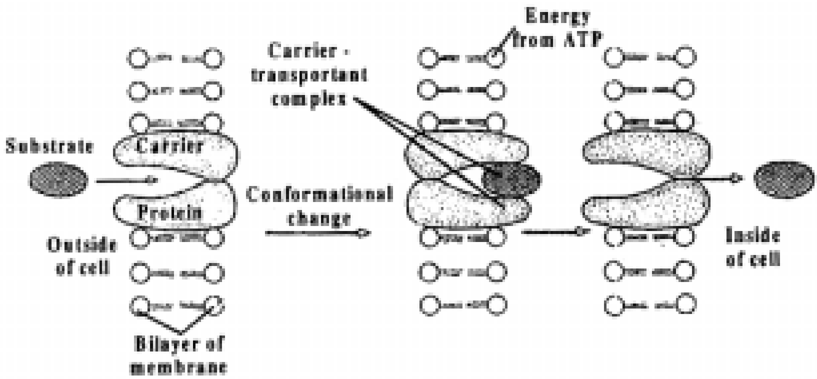


Fig : 2.13. Role of carrier protein in active membrane transport- a schematic representation

There are two forces which govern the movement of ions across selectively permeable membranes, the **membrane electric potential** and **the ion concentration gradient.** ATP driven ion pumps generate and maintain ionic gradients across the plasma membrane.

Endocytosis and exocytosis

Endocytosis and exocytosis are active processes involving bulk transport of materials through membranes, either into cells(endocytosis) or out of cells (exocytosis).

Endocytosis occurs by an in folding or extension of the plasma membrane to form a vesicle or vacuole or vauole. It is of two types.

1. Phagocytosis:(cell eating)-Substances are taken up in solid form. Cells involving in this process are called phagocytes and said to be phagocytic. (eg.) some white blood cells. A phagocytic vacuole is formed during the uptake.

2. Pinocytosis (cell drinking)-Substances are taken up in liquid form. Vesicles which are very small are formed during intake. Pinocytosis is often associated with amoebiod protozozns, and in certain kidney cells involved in fluid exchange. It can also occur in plant cells.

Exocytosis is the reverse of endocytosis by which materials are removed from cells such as undigested remains from food vacuoles.

SELF EVALUATION

One Mark

Choose the correct answer

1. Active transport of molecules take place
   a. along the concentration gradient
   b. along the electric gradient
   c. along the pressure gradient
   d. against the concentration gradient

2. Phagocytosis is also known as
   a. cell eating   b. cell death   c. cell drinking   d. cell lysis

Fill in the blanks

1. All the biological membranes are ————————
2. In passive transport method, transport of molecules takes place——— the concentration gradient.

Two Marks

1. Define: Biological membrane.
2. What are amphipathic molecules?
3. What are extrinsic proteins?
4. What are intrinsic proteins?
5. Define: semi-permeable membrane.
6. Define: Passive transport/Active transport
7. Define: Diffusion/Osmosis
8. Name any two factors on which permeability of a membrane depends on.
9. What is the role of osmosis in plants?
10. What is meant by facilitated transport?
11. Distinguish uniport transport method from passive diffusion.
12. Define: Phagocytosis/Pinocytosis/exocytosis

Five Marks

1. List the functions of plasma membrane.
2. Define diffusion. Discuss the various factors that affect the rate of diffusion.
3. Describe Uniporter Catalyzed transport.
4. Describe active transport of substances across the membranes.

Ten Marks

1. Describe the fluid mosaic model of cell membrane.

7. Cell Organelles

The internal architecture of cells and central metabolic pathways are similar in all plants, animals and unicellular eukaryotic organisma (eg. Yeast) All eukaryotic cells contain a membrane bound nucleus and numerous other organelles in their cytosol. Unique proteins in the interior and membranes of each type of organelle largely determine it's specific functional characteristics.

A Typical plant cell contains the following organelles and parts:

1. Mitochondria

They are bounded by two membranes with the inner one extensively folded. Enzymes in the inner mitochondrial membrane and central matrix carry out terminal stages of sugar and lipid oxidation coupled with ATP synthesis.

2. Chloroplasts

They are the sites of Photosynthesis. They are found only in plant cells. They are surrounded by an inner and outer membrane, a complex system of **thylakoid** membranes in their interior contains the pigments and enzymes that absorb light and produce ATP.

3. Nucleus

It is surrounded by an inner and outer membrane. These contain numerous pores through which materials pass between the nucleus and cytosol. The outer nuclear membrane is continuous with the rough endoplasmic reticulum. The nuclear membrane resembles the plasma membrane in its function. The nucleus mainly contains DNA organized into linear structures called **chromosomes.**

4. Endoplasmic reticulum

These are a network of inter connected membranes. Two types of Endoplasmic Reticulum are recognised. 1.**Rough E.R** 2. **Smooth E.R**

Rough ER

In this kind of ER, ribosomes are present on the surface. The endoplasmic reticulum is responsible for protein synthesis in a cell. Ribosomes are sub organelles in which the amino acids are actually bound together to form proteins. There are spaces within the folds of ER membrane and they are known as **Cisternae.**

Smooth ER

This type of ER does not have ribosomes.

5. Golgi Body or Golgi Apparatus(G.A.) (Dictyosomes)

Golgi body is a series of flattened sacs usually curled at the edges. Proteins which were formed on ribosomes of rough endoplasmic reticulum are processed in G.A. After processing, the final product is discharged from the G.A. At this time the G.A. bulges and breaks away to form vesicle known as **secretory vesicle.** The vesicles move outward to the cell membrane and either insert their protein contents in the membrane or release these contents outside the cell.

6. Vacuoles

The Vacuoles form about 75% of the plant cell. In the vacuole the plant stores nutrients as well as toxic wastes. If pressure increases within the vacuole it can increase the size of the cell. In this case the cell will become swollen. If the pressure increases further the cell will get destroyed.

7. Ribosomes

Ribosomes are found in cells, both prokaryotic and eukaryotic except in mature sperm cells and RBCs. In eukaryotic cells they occur freely in the cytoplasm and also found attached to the outer surface of rough ER. Ribosomes are the **sites of protein synthesis**

8. Plasma Membrane

In all the cells the plasma membrane has several functions to perform. These include transporting nutrients into and metabolic wastes out of the cell. It is formed of lipids and proteins.

9. Microbodies

These are spherical organelles bound by a single membrane. They are the sites of glyoxylate cycle in plants.

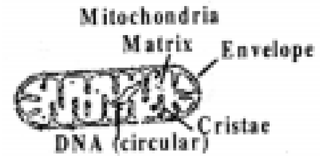
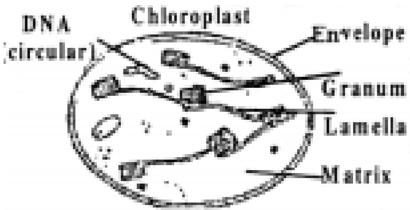
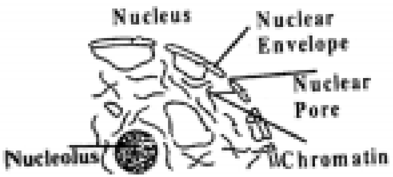
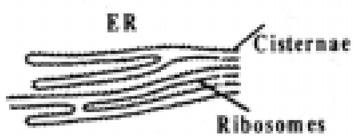
10. Cell wall

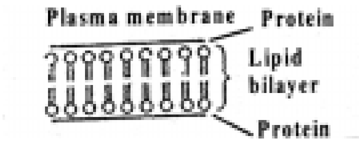
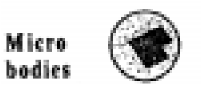
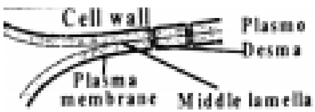
The cells of all plants have cell wall. It has three parts. 1. Middle lamella 2. Primary wall 3. Secondary wall.It gives definite shape to the plant cell.

Nucleus

Nuclus is the largest organelle in eukaryotic cells. It is surrounded by two membranes. Each one is a phospholipid bilayer containing many different types of proteins. The inner nuclear membrane defines the nucleus itself. In many cells the

Table 2.3. Structure and functions of various cell organelles and parts

Diagram	Structure	Functions
	It has an envelope made up of two membranes, the inner is folded to form cristae. Matrix with ribosomes is present. A circular DNA is also there.	ICristae are the sties of oxidative phosphorylation and electron transport. Matrix is the site of Krebs' cycle reactions.
	It has an envelope made up of two membranes. Contains gel like stroma and a system of membranes called grana. Ribosomes and a circular DNA are present in the stroma	Photosynthesis takes place here. It is a process in which light energy is converted into chemical energy.
	It has an envelope made up of two membranes. They have nuclear pores. It contains nucleolus and chromatin.	Nuclear division is the basis of cell replication and thus reproduction. Chromosomes contain DNA, the molecule responsible for inheritance.
	Structure : Consists of membrane - bounded sacs called cisterae.	Smooth ER, (no ribosomes) is the site of lipid synthesis. Rough ER (with ribosomes) transports proteins made by the ribosomes through the cisterae.

	It is formed by a stack of flattened membrane bound sacs, called cisternae.	Often involved in secretion.
Vacuoles	It is bound by a single membrane called the tonoplast. It contains cell sap.	Stores various substances including waste products. It helps in the osmotic properties of the cell.
	It consists of a large and a small sub unit. They are made of protein and RNA. Ribosome are found in mitochondria and chloroplasts also. They may form polysomes i.e. collection of ribosomes strung along messenger RNA.	They are the sites of protein synthesis.
	Two layers of lipid (bilayer) sandwiched between two protein layers.	Being a differentially permeable membrane it controls the exchange of substances between the cell and its environment.
	Spherical organelle bound by a single membrane.	They are the sites of glyoxylate cycle in plants.
	It consists of cellulolose microfibrils in a matrix of hemicellulose and pectic substances. Secondary thickening may be seen	It provides mechanical support and protection.

outer nuclear membrane is continuous with the rough ER and the space between the inner and outer nuclear membrane is continuous with the lumen of the rough ER.

The two nuclear membranes appear to fuse at the nuclear pores. These ring like pores are constructed of a specific set of membrane proteins and these act like channels that regulate the movement of substances between thenucleus and the cytosol.

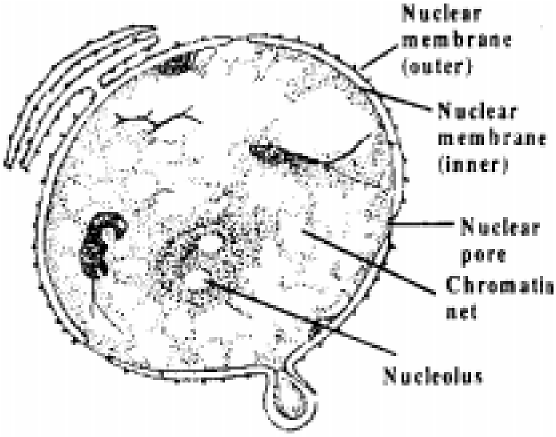


Fig : 2.14. Structure of a nucleus

In a growing of differentiating cell, the nucleus is metabolically active, producing DNA and RNA. The RNA is exported through nuclear pores to the cytoplasm for use in protein synthesis. In 'resting' cells, the nucleus is inactive or dormant and minimal synthesis of DNA and RNA takes place.

In a nucleus that is not dividing, the chromosomes are dispersed and not thick enough to be observed in the light microscope. Only during cell divisons the chromosomes become visible b y light microscopy. **Chromosomes** form the physical basis of heredity. **Genes,** the chemical basis of heredity, are arranged in linear fashion on the chromosomes. A sub organelle of the nucleus, the **nucleolus** is easily recognized under light microscope. Most of the ribosomal RNA of a cell is synthesized in the nucleolus. The finished or partly finished ribosomal sub units pass through a nuclear pore into the cytosol.

The non nucleolar regions of the nucleus is called the **nucleoplasm.** It has very high DNA concentration. Fibrous proteins called lamins form a two dimensional network along the inner surface of the inner membrane giving it shape and apparently binding DNA to it. During the early stages of cell division breakdown of this network occurs.

Functions of Nucleus

1. It controls all the metabolic activities of the cell by controlling the synthesis of enzymes required.
2. Nucleus controls the inheritance of characters from parents to offspring.
3. Nucleus controls cell division.

Mitochondria

A Mitochondrion is also called as the **"Power house of the cell"** because it stores and releases the energy of the cell. The energy released is used to form ATP (Adenosine Triphosphate) Mitochondria are the principal sites of ATP production in aerobic cells.

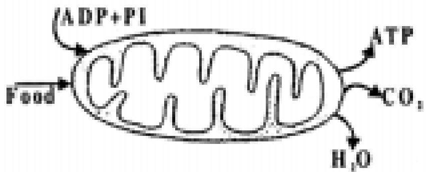


Fig : 2.15. Mitochondria as a powerhouse

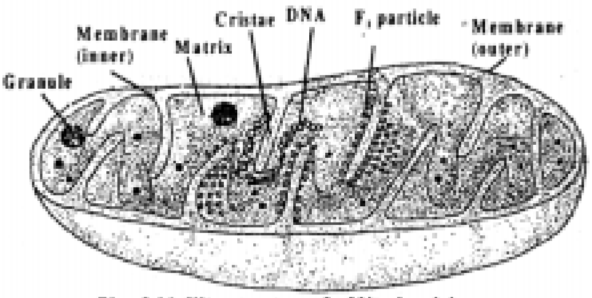


Fig : 2.16. Ultrastructure of a Mitochondrion

Most eukaryotic cells contain many mitochondria, which occupy up to 25 percent of the volume of the cytoplasm. These complex organelles are among the largest organelles generally exceeded in size only by the nucleus, vacuoles and chloroplasts. Typically the mitochondria are sausage-shaped but these may be granular, filamentous, rod-shaped, spherical or thread like.

Mitcohondria contain two very different membranes an outer one and an inner one, separated by the inter membrane space.

The outer membrane is composed of about half lipid and half protein. The inner membrane is less permeable. It is composed of about 20 percent lipid and 80 percent protein. The surface area of the inner membrane is greatly increased by a large number of infoldings, or **cristae** that protrude into the matrix.

Structure of the cristae membrane

The inner of the cristae membrane (i.e the surface towards the matrix) is covered with numerous (infinite) stalked particles. These are called **F1 Particles, elementary particles** or **sub units.** These particles project into the matrix. Each F1 particle has 3 parts, viz, the head piece, the stalk and the base piece. The respiratory chain consists of enzymes and co-enzymes which constitute the **Electron Transport System, (ETS)** in the mitochondrion. These enzymes and co-enzymes of the ETS act as the electron acceptors in the aerobic respiration reaction. (Oxidative Phosphorylation).

In non photosynthetic cells the principal fuels for ATP synthesis are fatty acids and glucose. The complete aerobic degradation of glucose to CO_2 and H_2O is coupled to synthesis of as many as 38 molecules of ATP. In eukaryotic cells, the initial stages of glucose degradation occur in the cytosol, where 2 ATP molecules per glucose molecule are generated. The terminal stages including those involving phosphorylation coupled to final oxidation by oxygen are carried out by exzymes in the mitochondrial matirix and cristae. As many as 36 ATP molecules per glucose molecule are generated in mitochondria although this value can vary because much of the energy released in mitochondrial oxidation can be used for other purposes (e.g heat generation and the transport of molecules into or out of the mitochondrion) making less enery available for ATP synthesis. Similarly, virtually all the ATP formed during the oxidation of fatty acids to CO_2 is generated in the mitochondrion. Thus the mitochondrion can be regarded as the **"Power plant"** of the cell.

Mitochondria as semi-autonomous organelles

Mitochondria are self perpetuating semi autonomous bodies. These arise new by the division of existing mitochondria. These are also regarded as intra cellular parasitic prokaryotes that have established symbiotic relationship with the cell. The mitochondrial matrix contains DNA molecules which are circular and 70s ribosomes, tRNA and enzymes for functioning of mitochondrial genes.

Plastids

Plastids are the largest cytoplasmic organelles bounded by double membrane. These are found in most of the plant cells and in some photosynthetic protists. These are absent in prokaryotes and in animal cells. Plastids are of three types namely **chloroplasts, chromoplasts** and **leucoplasts.**

Chromoplasts are coloured plastids other than green. They are found in coloured parts of plants such as petals of the flower, pericarp of the fruits etc.

Leucoplasts are the colourless plastids. These colourless plastids are involved in the storage of carbothydrates, fats and oils and proteins. The plastids which store carbohydrates are called amyloplasts. The plastids storing fats and oils are called elaioplasts. The plastids storing protein are called proteinoplasts.

Chloroplast

Chloroplasts can be as long as 10ìm and are typically 0.5 - 2.0 ìm thick, but they vary in size and shape in different cells, especially among the algae. Like mitochondrion, the chloroplast is surrounded by an outer and inner membrane. In addition to this, chloroplasts contain an internal system of extensive inter connected membrane-limited sacs called **thylakoids** which are flattened to form disks. These are often grouped in stakes of 20-50 thylakoids to from what are called **grana** and embedded in a matrix called **stroma**.

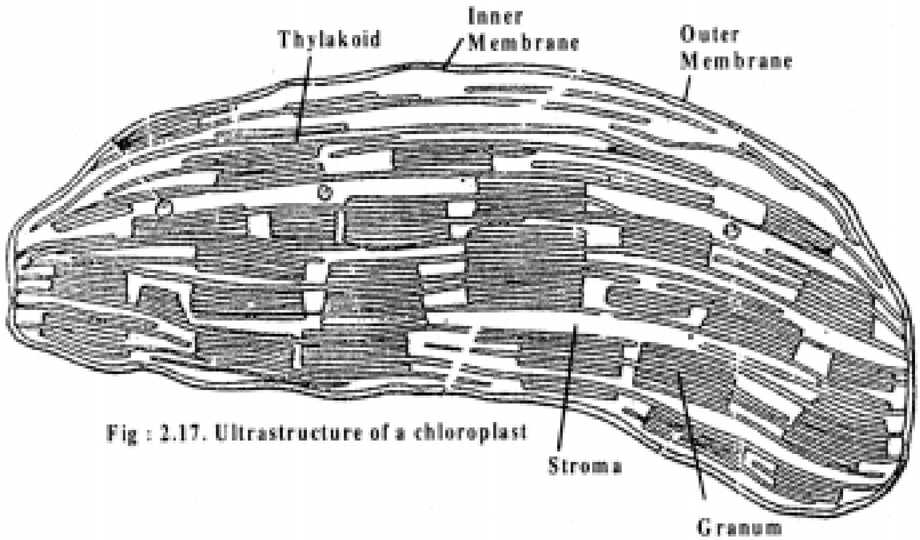


Fig : 2.17. Ultrastructure of a chloroplast

Stroma, a semi fluid, colourless, colloidal complex contains DNA, RNA, ribiosomes and several enzymes. The DNA of chloroplast is circular. The ribosomes are of 70s type. The matrix of higher plant's chloroplasts may contain starch as storage product. Thylakoids may occur attached to the inner membrane of the chloroplast envelop.

About 40-100 grana may occur in a chloroplast. Many membranous tubules called stroma lamellae (intergranal thylakoids) interconnect thylakoids of different grana. Thylakoid membrane contains photosynthetic pigments.

The thylakoid membrane contains green pigments (Chlorophylls) and other pigments and enzymes that absorb light and generate ATP during photosynthesis. Part of this ATP is used by enzymes located in stroma to the convert CO_2 into three carbon (3C) intermediates which are then exported to the cytosol and converted to sugars.

The molecular mechanism by which ATP is formed is very similar in mitochondria and chloroplasts. Chloroplasts and mitochondria have other features also in common. Both migrate often from place to place within cells and both contain their own DNA which code for some of the key organellar proteins. These proteins are synthesized in the ribosomes within the organelle. However, most of the proteins in each of these organelles are encoded in the nuclear DNA and are synthesized in the cytosol. These proteins are then incorporated into the organelles.

Ribosomes

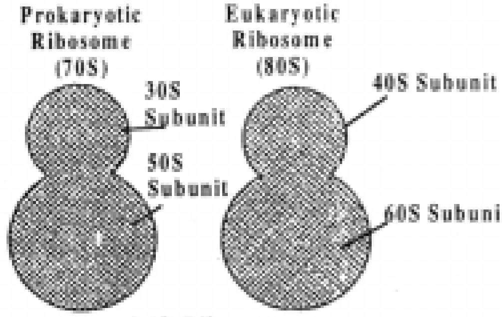


Fig : 2.18. Ribosome

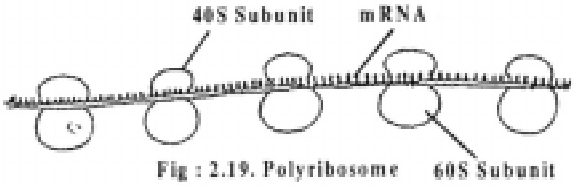


Fig : 2.19. Polyribosome

Ribosomes are small subspherical granular organelles, not enclosed by any membrane. They are composed of ribonucleo proteins and they are the site of protein synthesis.

They occur in large number. Each ribosome is 150-250A in diameter and consists of two unequal sub units, a larger dome shaped and a smaller ovoid one. The smaller sub unit fits over the larger one like a cap.These twosu units occur separately in the cytoplasm and join to form ribosomes only at the time of protein synthesis. At the time of protein synthesis many ribosomes line up and join an mRNA chain to synthesise many copies of a particular polypeptide. Such a string of ribosomes is called **polysome.**

Ribosomes occur in cytoplasmic matrix and in some cell organelles. Accordingly, they are called cytoplasmic ribosomes or organelle ribosomes. The organelle ribosomes are found in plastids and mitochondria. The cytoplasmic ribosomes may remain free in the cytoplasmic matrix or attached to the surface of the endoplasmic reticulum. The attached ribosomes generally transfer their proteins to cisternae of endoplasmic reticulum for transport to other parts both inside and outside the cell.

Depending upon size or sedimentation coefficient(s), ribosomes are of two types. **70s** and **80s. 70s** type of ribosomes are found in all prokaryotic cells and **80s** type are found in eukaryotic cells. **S** is Svedberg unit which is a measure of particle size with which the particle sediments in a centrifuge. In eukaryotic cells, synthesis of ribosomes occurs inside the nucleolus. Ribosomal RNA are synthesized in the nucleolus. The ribosomal proteins are synthesized in the cytoplasm and shift to the nucleolus for the formation of ribosomal sub units by complexing with rRNA. The sub units pass out into the cytoplasm through the nuclear pores. In prokaryotic cells, both ribosomal RNAs and proteins are synthesized in the cytoplasm. Thus the ribosomes act as the **protein factories** of the cell.

Self Evaluation
One Mark
Choose the correct answer

1. The spaces inside the folds of ER membrane are known as
   a. thylakoids b.cisternae c.mesosomes d.periplasmic space
2. These are colourless plastids
   a.chromoplasts b.chloroplasts c.elaioplasts d.leucoplasts
3. The internal system of inter-connected membrane-limited sacs of chloroplasts are called
   a. grana b.stroma c.thylakoids d. cisternae

Fill in the blanks

1. DNA is organized into linear structures called——————
2. The endoplasmic reticulum is responsible for—————— in a cell.
3. ————— are the sites of protein synthesis.
4. —————form the physical basis of heredity.

Match

Power house of a cell	-Chromosomes
Site of protein synthesis	-Genes
Controls all metabolic activities of cell	-Mitochondria
Physical basis of heredity	-Ribosomes
Chemical basis of heredity	-Nucleus

Two Marks

1. What are the main functions of a nucleus?
2. Give reasons: Mitochondria are semi autonomous organelles.
3. Name the three kinds of plastids.
4. Name any two common properties shared by chloroplasts and mitochondria.
5. What is a polysome?
6. Distinguish the ribosomes of prokaryotic cells from that of eukaryotic cells.

Five Marks

1. Draw a plant cell and label it's parts.
2. Explain the ultrastructure of chloroplast.

8. Cell Division

Cell Cycle

As we have discussed in the earlier chapter, the cell cycle amazingly follows a regular timing mechanism. Most eukaryotic cells live according to an internal clock, that is, they proceed through a sequence of phases, called the cell cycle. During the cell cycle DNA is duplicated during the **synthesis(S)** phase and the copies are distributed to the daughter cells during **mitotic(M)** phase. Most growing plant and animal cells take 10-20 hours to double in number and some duplicate at a much slower rate.

A multi cellular organism usually starts it's life as a single cell (zygote). The multiplication of this single cell and it's descendants determine the growth and development of the organism and this is achieved by cell division. Cell division is a complex process by which cellular material is equally divided between daughter cells. Cell division in living things are of three kinds. They are 1.**Amitosis** 2.**Mitosis** 3. **Meiosis.**

Amitosis

It is a simple type of division where the cell contents including nucleus divide into two equal halves by an inwardly growing constriction in the middle of the cell. This type of cell division is common in prokaryotes.

Mitotic cell cycle

It is represented by DNA duplication followed by nuclear division (Karyokinesis) which in turn is followed by cytokinesis. Mitotic cell division was first described by **W. Flemming** in 1882. In the same year, mitosis in plants was described by **Strasburger.**

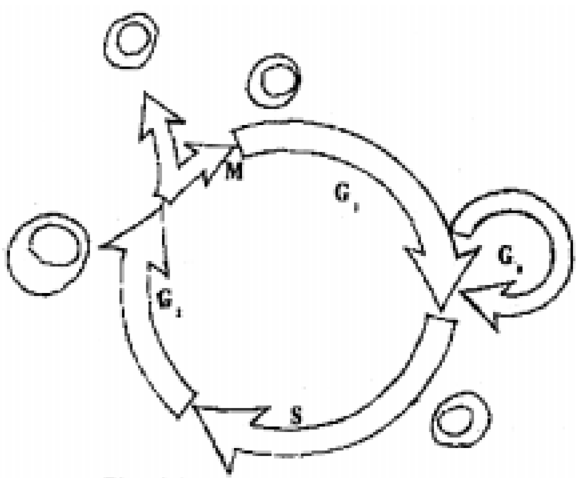


Fig : 2.20. Eukaryotic cell cycle

G_1, S, G_2 } Interphase   M - Mitotic stage

G_0 - Non dividing stage

In plants, active mitotic cell division takes place in apices. In higher animals mitotic cell division is said to be diffused, distributed all over the body.

Mitotic cell cycle consists of long **interphase**(which is sub divided into **G_1, S and G_2** phases), a short **M stage** (or mitotic stage, subdivided into prophase metaphase, anaphase and telophase) and **cytokinesis**. The duration of interphase and M-phase varies in different cells.

Interphase

It is the stage in between two successive cell divisions during which the cell prepares itself for the process by synthesizing new nucleic acids and proteins. Chromosomes appear as chromatin network. Interphase consists of the following three sub stages.

i) G_1 or Gap-1 phase

This phase starts immediately after cell division. The cell grows in size and there is synthesis of new proteins and RNA needed for various metabolic activities of the cell. A non-dividing cell does not proceed beyond G_1 phase. The differentiating cells are said to be in **G_0** stage.

ii) S-or Synthetic Phase

During this phase there is duplication of DNA. Thus each chromosome now is composedof two sister chromatids.

iii) G_2 or Gap-2Phase

The proteins responsible for the formation of spindle fibres are synthesised during this stage.

Mitosis

Mitosis is divided into the following 4 sub stages.

1.Prophase 2. Metaphase 3.Anaphase 4. Telophase

1. Prophase

The chromatin network begins to coil and each chromosome becomes distinct as long thread like structure. Each chromosome at this stage has two chromatids that lie side by side and held together by centromere. The nucleus gradually disappears. The nuclear membrane also starts disappearing.

2. Metaphase

The disappearance of nuclear membrane and nucleolus marks the beginning of metaphase.The chromosomes become shorter by further coiling. Finally, the chromosomes become distinct and visible under compound microscope. The

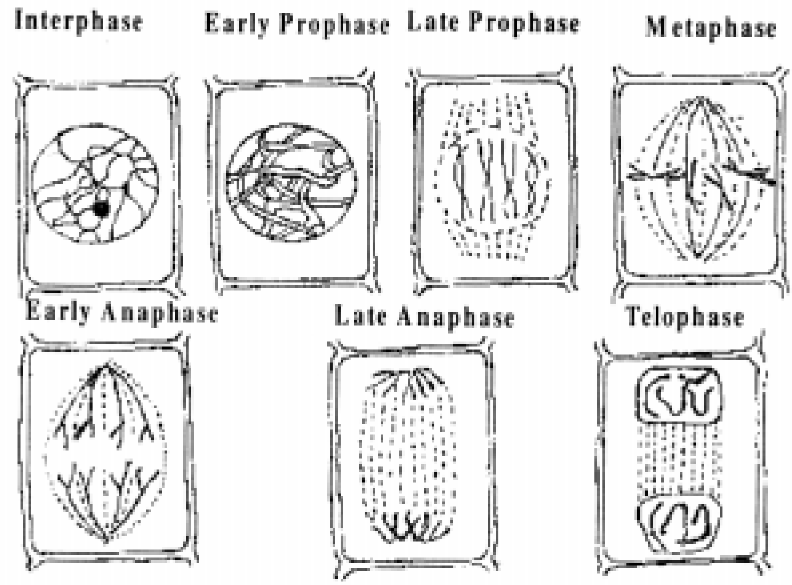


Fig : 2.21. Mitosis - Equational Cell Division

chromosomes orient themselves in the equator of the cell in such a way that all the **centromeres** are arranged in the equator forming metaphase plate or equatorial plate. Out of the two chromatids of each chromosome, one faces one pole and the other one faces the opposite pole. At the same time spindle fibres arising from the opposite poles are seen attached to the centromeres. The fibres are made up of proteins rich in sulphur containing amino acids.

At late metaphase, the **centromeres divide** and now the chromatids of each chromosome are ready to be separated.

3. Anaphase

Division of centromere marks the beginning of anaphase. The spindle fibres start contracting and this contraction pulls the two groups of chromosomes towards the opposite poles. As the chromosomes move toward opposite poles they assume **V or J** or **I** shaped configuration with the centromere proceeding towards the poles with chromosome arms trailing behind. Such variable shapes of the chromosomes are due to the variable position of centromere.

Telophase

At the end of anaphase, chromosomes reach the opposite poles and they uncoil, elongate and become thin and invisible. The nuclear membrane and the nucleouls reappear. thus, two daughter nuclei are formed, one at each pole.

Cytokinesis

The division of the cytoplam is called cytokinesis and it follows the nuclear division by the formation of cell wall between the two daughter nuclei. The formation of cell wall begins as a cell plate also known as **phragmoplast** formed by the aggregation of vesicles produced by Golgi bodies. These vesicles which contain cell wall materials fuse with one another to form cellmembranes and cell walls. Thus, at the end of mitosis, **two identical** daughter cells are formed.

Significance of Mitosis

1. As a result of mitosis two daughter cells which are identical to each other and identical to the mother cell are formed.
2. Mitotic cell division ensures that the daughter cells possess a genetical identity, both quantitatively and qualitatively.
3. Mitosis forms the basis of continuation of organisms.
4. Asexual reproduction of lower plants is possible only by mitosis.
5. Vegetative reproduction in higher plants by grafting, tissue culture method are also a consequence of mitosis.
6. Mitosis is the common method of multiplication of cells that helps in the growth and development of multi-cellular organism.
7. Mitosis helps in the regeneration of lost of damaged tissue and in wound healing.
8. The chromosomal number is maintained constant by mitosis for each species.

Meiosis

Meiosis is a process of cell division of the reproductive cells of both plants and animals in which the diploid number of chromosomes is reduced to haploid.

Meiosis is also known as **reduction division(RD)** since the number of chromosomes is reduced to half. It takes place only in the reproductive cells during the formation of gametes. Meiosis consists of two complete divisions. As a result of this a diploid cell produces four haploid cells. The two divisions of meiosis are **meiosis I** or heterotypic division and **meiosis II** or homotypic division. The first division is **meiotic** or reductional in which the number of chromosomes is reduced to half and the **second division** is **mitotic** or **equational**.

In all the sexually reproducing organism the chromosome number remains constant generation after generation. During sexual reproduction the two gametes male and female, each having single set oof chromosomes (n) fuse to form a zygote.The zygote thus contains twice as many chromosome as a gamete (**n+n=2n**). In these two sets of chromosomes one set is derived from the male parent and the other set from the female parent. This is how diploids come to possess tow identical sets of chromosomes called **homologous chromosomes** Meiosis may take place in the life cycle of a plant during any one of the following events.

1. At the time of spore formation ie. During the formation of pollen grains in anther and megaspores in ovules.
2. At the time of gamete formation
3. At the time of zygote germination.

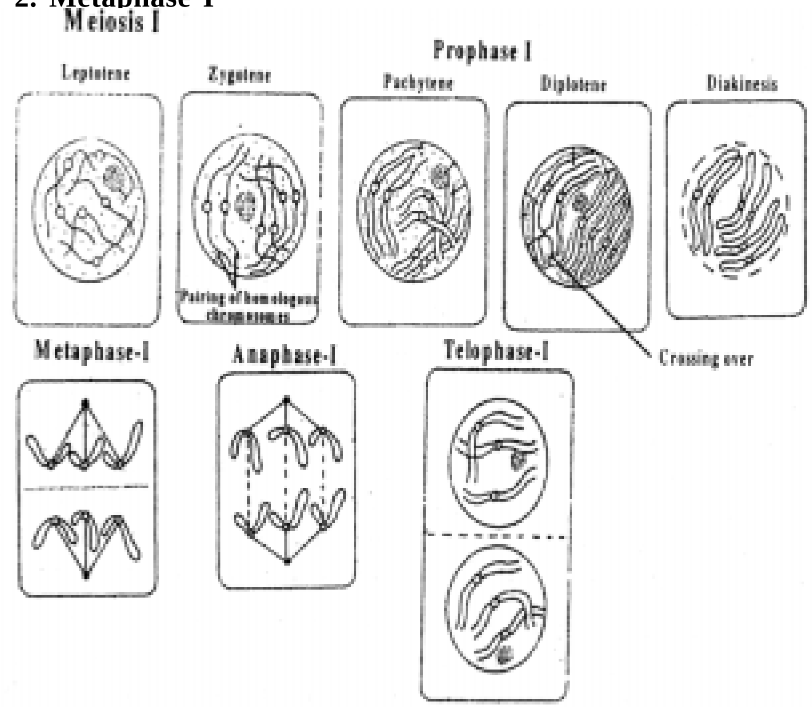
Each meiotic division cycle is divided into same four stages as in mitosis. **Prophase, Metaphase, Anaphase and Telophase.** The name of each stage is followed by **I** or **II** depending on which division of cycle is involved.

Meiosis I

It consists of four stages namely.

1. Prophase I

2. Metaphase I



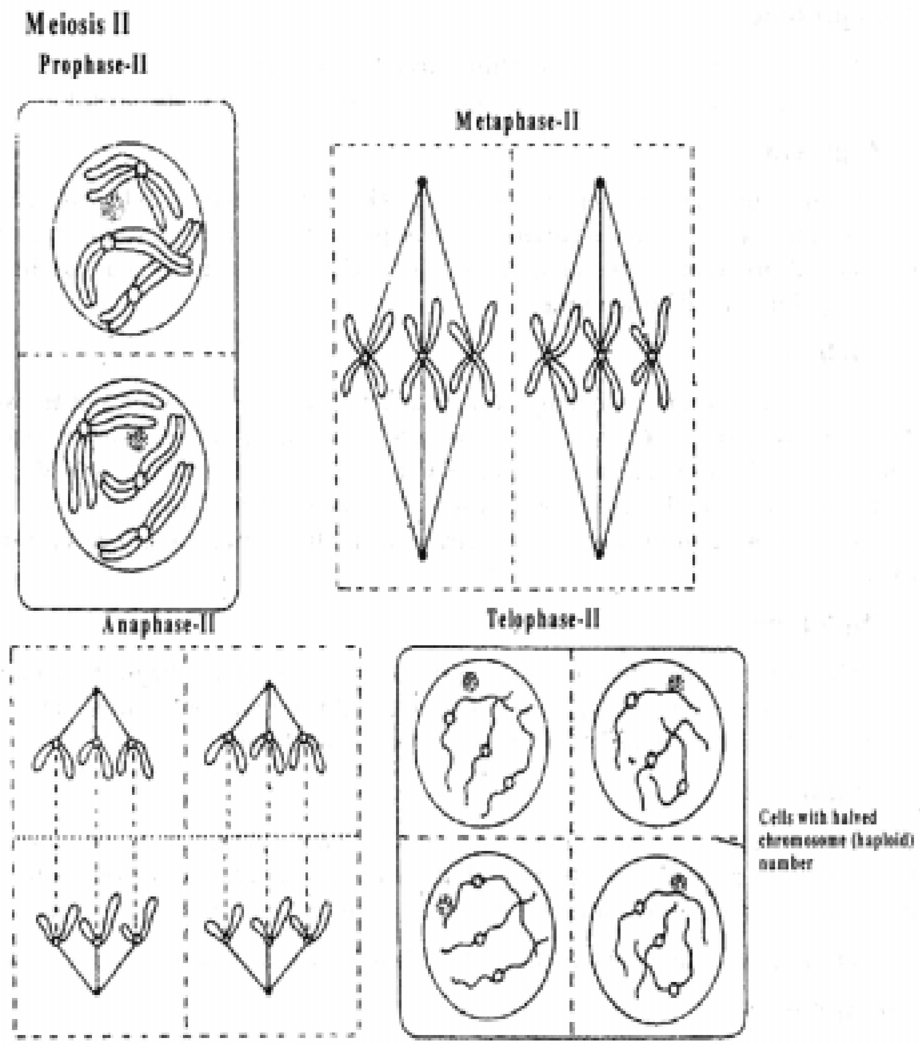


Fig 2.22. Meiosis - Reductional Cell Division

3. Anaphase I

4. Telophase I

Prophase I

It is the first stage of first meiosis. This is the longest phase of the meiotic division. It includes 5 sub stages namely

1.Leptotene 2.Zygotene 3.Pachytene 4.Diplotene 5.Diakinesis

1. Leptotene

The word leptotene means **'thin thread'**. The chromosomes uncoil and become large and thinner. Each chromosome consists of two chromatids.

2. Zygotene

Homologous chromosomes come to-gether and lie side by side throughout their length. This is called **pairing** or **synapsis.** The paired chromosomes are now called **bivalents.** The adjacent non-sister chromatids are joined together at certain posints called **chiasmata.**

3. Pachytene

The chromosomes condense further and become very shorter and thicker. They are very distinct now. The two sister chromatids of each homologous chromosome become clearly visible. The bivalent thus becomes a **tetrad** with four chromatids. In the region of chiasmata, segments of non-sister chromatids of the homologous chromosomes are exchanged and this process is called **crossing over**

4. Diplotene

The homologous chromosomes condense further. They begin to separate from each other except at the chiasmata. Due to this separation the dual nature of a bivalent becomes apparent and hence the name **diplotene.**

5. Diakinesis

The Chromosomes continue to contract. The separation of chromosome becomes complete due to **terminalisation**. The separation starts from the centromeres and goes towards the end and hence the name terminalisation:

The nucleolus and nuclear membrane disappear and spindle formation starts.

Metaphase I

The spindle fibres become prominent. The bivalents align on the equatorial plane. Spindle fibres from opposite poles get attached to the centromeres of homologous chromosomes.

Anaphase I

The two chromosomes of each bivalent (with chromatids still attached to the centromere) separate from each other and move to the opposite poles of the cell. Thus, only one chromosome of each homologous pair reachers each pole.

Consequently at each pole only half the number of chromosomes (haploid) is received. These chromosomes are, however not the same as existed at the beginning of prophase. Each chromosome consists of one of its original chromatids and the other has a mixture of segments of its own and a segment of chromatid from its homologue (due to crossing over).

Telephase I

This is the last stage of meiosis I. Reorganization of the chromosomes at poles occurs to form two haploid nuclei. Nuclear membrane and nucleolus re-appear. The spindle disappears. There is no cytokinesis after meiosis I. The second meiotic division may follow immediately or after a short inter phase. The DNA of the two haploid nuclei does not replicate.

Meiosis II

The second meiotic division is very much similar to mitosis.

Prophase II

The events of prophase II are similar to mitotic prophase. Nucleolus and nuclear membrane disappear. Spindle fibres are formed at each pole.

Metaphase II

Chromosomes move to the centre of the equatorial plane. They get attached to spindle fibres centromere.

Anaphase II

The sister chromatids separate from one another and are pulled to opposite poles of the spindle due to contraction of the spindle fibres.

Telophase II

The chromosomes begin to uncoil and become thin. They reorganize into nucleus with the reappearance of nucleolus and nuclear membrane in each pole. Cytokinesis follows and **four haploid daughter cells** are formed and thus the meiotic division is completed.

Significance of Meiosis

1. Meiosis helps to maintain the **chromosome number constant** in each plant and animal species. In meiosis four haploid daughter cells are formed from a single diploid cell. This is very important in sexual reproduction during the formation of gametes.
2. The occurrence of crossing over results in the **recombination of genes.**

3. The recombination of genes results in **genetic variation.**
4. The genetic variations form raw materials for **evolution**

Self Evaluation

One Mark

Choose the correct answer

1. During this phase there is a duplication of DNA
   a. G_1 Phase b.S phase c. G_2 Phase d. interphase

2. Cytokinesis is the division of
   a.cytoplasm b.nucleus c.chloroplast d.centriole

3. Terminalisation takes place during
   a. pachytene b.zygotene c.leptotene d. diakinesis

Two Marks

1. Define crossing over.
2. What is a tetrad?
3. What is a bivalent?

Five Marks

1. Explain cell cycle
2. Write notes on: significance of mitosis/significance of meiosis

Ten Marks

1. Describe mitosis. Add a note on it's significane.
2. Explain the various stages of **I meiosis/II meiosis**

III. PLANT MORPHOLOGY

1. Root, Stem and Leaf

Morphology is the branch of biology that deals with form, size and structure of various organs of the living organisms. Each and every living organism has a definite form. Study of the external structure or morphology helps us to identify and distinguish living organisms. Knowledge of morphology of plants is also helpful in the study of various other fields such as genetics, plant breeding, genetic engineering, horticulture, crop protection and others.

Morphology of flowering plants or Angiosperms.

The plants which we commonly see in the gardens and road-side belong to the largest group of plants called flowering plants or Angiosperms. (**angio=box**

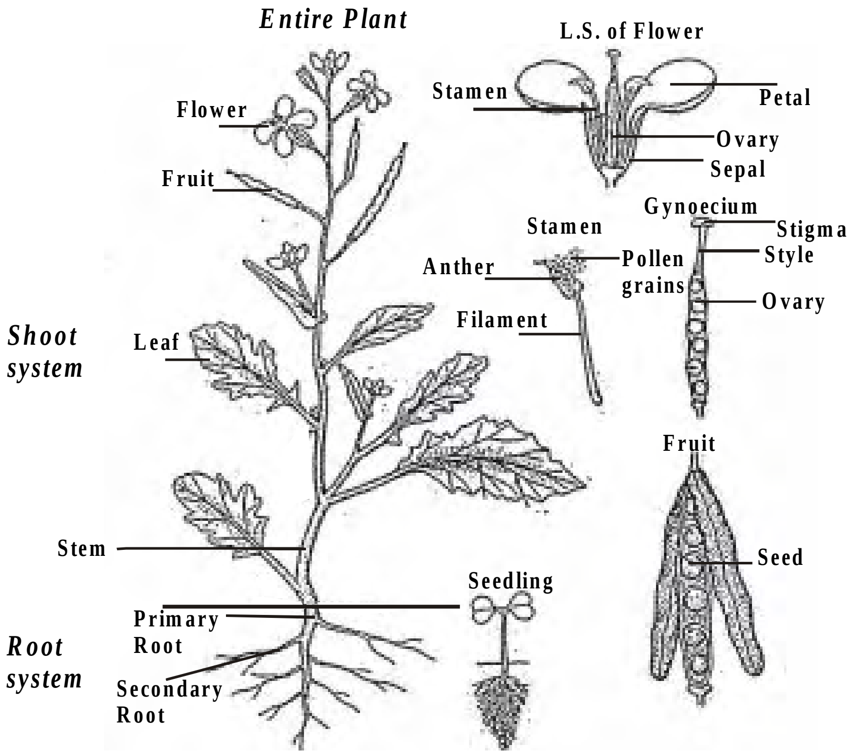


Fig : 3.1. Parts of a typical angiospermic plant (mustard)

sperm=seed). The word derives its origin from the fact that the **ovules** are enclosed in a box like organ called **ovary.** Hence the seeds are enclosed in the fruit. Angiosperms include more than 2,20,000 species exhibiting a wide spectrum of forms and occupying a wide range of habitats. Such a wide range of flowering plants are identified, described and classified based on their morphology and anatomy.

Parts of a Flowering Plant

Any common flowering plant consists of a long cylindrical axis which is differentiated into an underground **root system** and an aerial **shoot system.** The root system consists of **root** and its lateral branches. The shoot system has a **stem,** a system of **branches** and **leaves**. Root, stem and leaves together constitute the **vegetative organs** of the plant body and they do not take part in the process of reproduction. The flowering plants on attaining maturity produce **flowers**, **fruits** and **seeds**. These are called the **reproductive organs** of the plant.

Root System

The root system is typically a non-green underground descending portion of the plant axis. It gives rise to many lateral roots. The roots do not have nodes and internodes.

General Characteristic features of the root

1. Root is positively geotropic and negatively phototropic.
2. Roots are generally non-green in colour since they do not have chlorophyll pigments and hence they cannot perform photosynthesis.
3. Roots do not have nodes and internodes; these do not bear leaves and buds.
4. The lateral branches of the roots are **endogenous** in origin i.e they arise from the inner tissue called pericycle of the primary root.

Regions of a typical root

The following four regions are distinguished in a root from apex upwards.

1. Root Cap: It is a cap like structure that covers the apex of the root. The main function of the root cap is to protect the root apex.

2. Meristematic Zone or Zone of cell division: This is the growing tip of the root. It lies a little beyond the root cap. The cells of this region are actively dividing and continuously increase in number.

3. Zone of elongation: It is a region that lies just above the meristematic zone. The cells of this zone increase in size. This zone helps in the growth in length of the plant root.

4. Zone of cell differentiation : (Cell maturation) This is a zone that lies above the zone of elongation. In this zone the cells differentiate into different types. They form the tissues like the epidermis, cortex and vascular bundles. In this region a number of **root hairs** are also present. The root hairs are responsible for absorbing water and minerals from the soil.

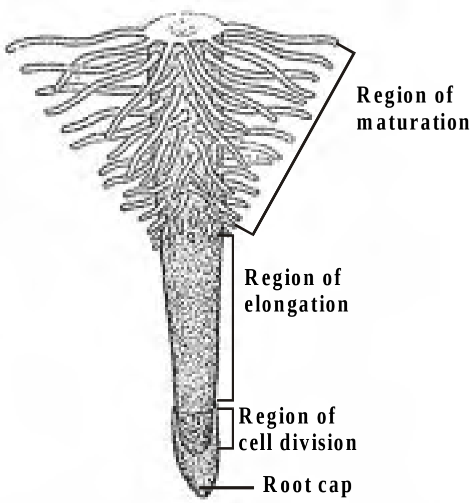


Fig : 3.2. Regions of a typical root

Types of Root System

There are two types of root system

1. Tap root system
2. Adventitious root system

Tap root system

It develops from the radicle of the embryo. The radicle grows in to the **primary or tap root**. It produces branches called **secondary roots**. These branch to produce what are called **tertiary roots**. This may further branch to produce fine **rootlets**. The tap root with all its branches constitutes the tap root system. Tap root system is the characteristic feature of most of the dicot plants.

Adventitious root system

Root developing from any part of the plant other than the radicle is called **adventitious root**. It may develop from the base of the stem or nodes or internodes. The adventitious roots of a plant along with their branches constitute the adventitious root system.

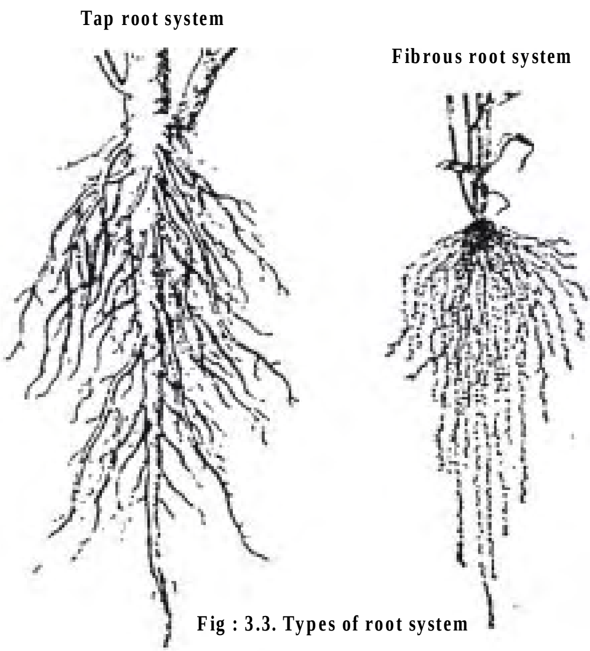


Fig : 3.3. Types of root system

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. They are thread like and are of equal size and length. These are collectively called **fibrous root system**. It is commonly found in monocot plants like **maize, sugarcane and wheat**.

Functions of roots

Roots perform two kinds of function namely primary and secondary function. The primary functions are performed by all the roots in general. In some plants the roots perform certain additional functions in order to meet some special needs. These are called secondary functions of the roots. In order to perform these special functions the roots show modification in their structure accordingly.

Primary functions

1. **Absorption**: The main function of any root system is absorption of water and minerals from the soil with the help of root hairs.
2. **Anchorage**: The roots help to fix the plant firmly in the soil.

Secondary functions:

The following are some of the secondary functions performed by the roots in addition to the primary functions mentioned above.

1. Storage of food 2. Additional support 3. Haustorial function 4. Assimilation 5. Respiration 6. Symbiosis

Root Modifications

Besides primary functions like absorption and anchorage some roots also perform certain additional functions in order to meet some specific needs. These roots are modified in their structure to perform these special functions.

Modification of Taproot

1. Storage Roots:

In some plants the tap root or the primary root becomes thick and fleshy due to the storage of food materials. These are called root tubers or tuberous roots. They are classified in to three types based on their shape.

a. **Conical** : In this type the root tuber is conical in its shape i.e. it is broad at the base and tapers gradually towards the apex. eg. **Carrot**

b. **Fusiform** : The root is swollen in the middle and tapers towards the base and the apex. eg. **Radish**

c. **Napiform**: The root tuber has a top-like appearance. It is very broad at the base and suddenly tapers like a tail at the apex eg. **Beet root**.

2. Respiratory or breathing roots

In plants which grow in marshy places like in ***Avicennia***, the soil becomes saturated with water and aeration is very poor. In these cases erect roots arise from the ordinary roots that lie buried in the saline water. These erect roots are called **pneumatophores**. They have a large number of **breathing pores** or (pheumatothodes) for the exchange of gases.

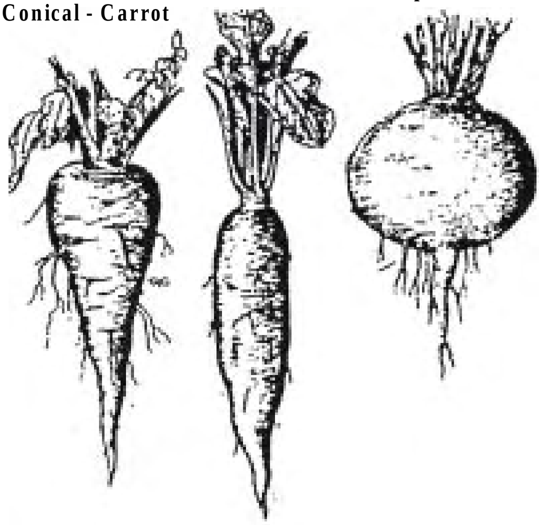


Fig: 3.4. Storage roots

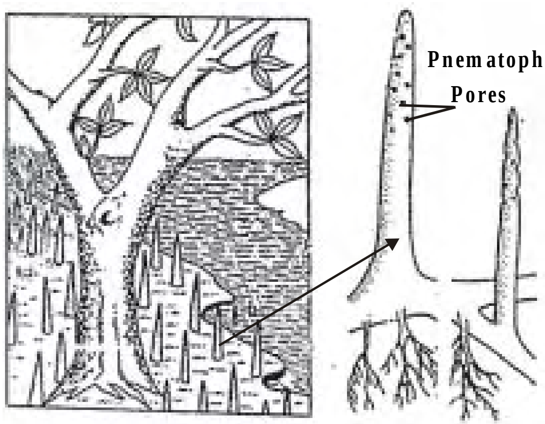


Fig : 3.5. Respiratory Roots (Avicennia)

Modifications of adventitious roots

1. Storage Roots:

In some plants the adventitious roots store food and become fleshy and swollen. It may assume the following shapes.

a. **Tuberous Roots**: These are without any definite shape. Eg. **Sweet Potato**

b. **Fasciculated Root**: In this type the tuberous roots occur in clusters at the base of the stem eg. **Asparagus**, **Dahlia**.

c. **Nodulose Roots**: In this type the roots become swollen near the tips. Eg. **Mango ginger** and **turmeric**

2. Roots modified for additional support

A. Stilt roots: These adventitious roots arise from the first few nodes of the stem. These penetrate obliquely down in to the soil and give support to the plant. eg. **Maize**, **sugarcane** and **pandanus**.

B. Prop roots: These roots give mechanical support to the aerial branches as in banyan tree. These lateral branches grow vertically downwards into the soil. Gradually, the roots become thick and stout and act as pillars.

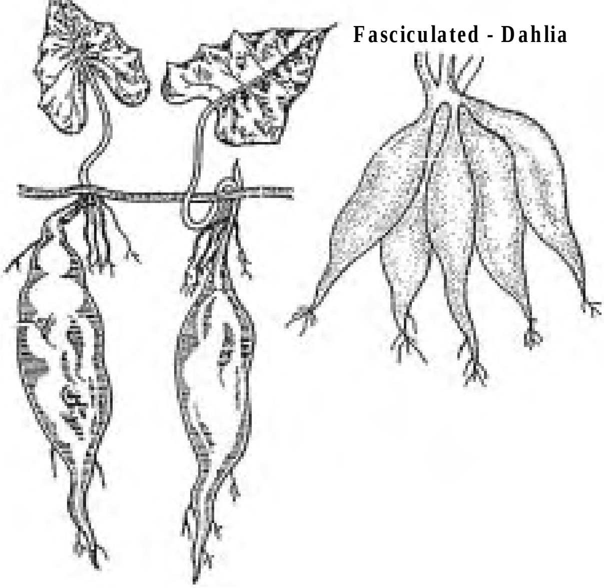


Fig : 3.6. Storage - Adventitious roots

3. Roots modified for other vital functions

a) Epiphytic roots: These are adventitious roots found in some **orchids** that grow as epiphytes upon the branches of other trees. These epiphytes develop special kinds of **aerial roots** which hang freely in the air. These aerial roots possess a special sponge like tissue called **velamen**. Velamen helps in absorbing the atmospheric moisture and stores them since these plants do not have direct contact with the soil.

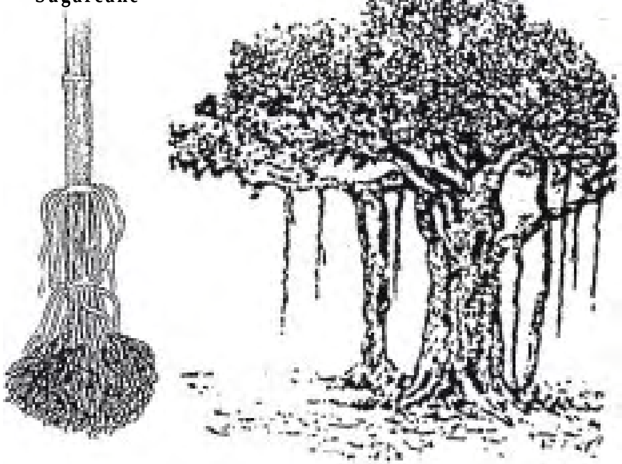


Fig : 3.7. Stilt & Prop roots

b) Photosynthetic or assimilatory roots: In some plants the adventitious roots become green and carry on photosynthesis. These roots are called photosynthetic or assimilatory roots: In ***Tinospora*** roots arise as green hanging threads from the nodes of the stem during rainy season. They assimilate co_2 in the presence of sunlight.

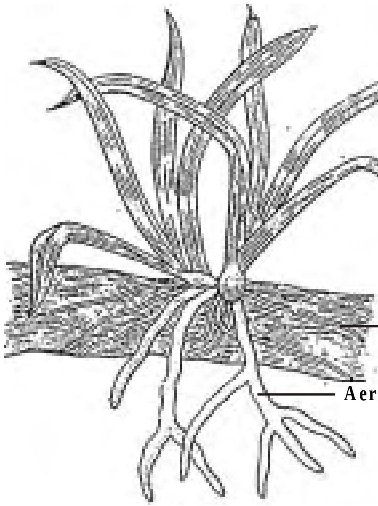


Fig : 3.8. Epiphytic roots

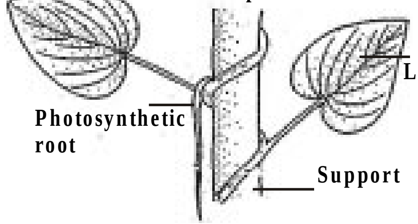


Fig : 3.9. Photosynthetic root

c) **Parasitic roots or haustoria** : These roots are found in non-green parasitic plants. Parasitic plants are those plants which cannot make their own food and they have to obtain their food from the host. Adventitious roots are given out from the nodes of these plants and these penetrate into the host tissue and enter in to its conducting tissue. From the conducting tissues of the host they acquire the required food materials.eg. ***Cuscuta***

Fig : 3.10. Parasitic roots

Shoot System

The **plumule** of the embryo grows into the stem which forms the main axis of the plant. The stem along with the leafy branches constitutes the **shoot system** of the plant.

Characteristic features of the stem

1. The stem is the ascending portion of the main axis of the plant.
2. It is positively phototropic and negatively geotropic.
3. It has well developed nodes and internodes.
4. It has a terminal bud at the apex.
5. The stem bears flowers and fruits.

6. Lateral branches of the stem are **exogenous** in origin i.e they arise from the tissues which are in the periphery of the main axis (cortex)

Buds: Buds are the young shoot, yet to develop. 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.

When a bud is found at the apex of the main stem or branch it is called **terminal bud** or **apical bud**. When a bud arises in the axil of a leaf, it is known as **axillary bud**. Certain buds develop in positions other than the normal. Such buds are known as adventitious buds. e.g. ***Bryophyllum***. In this buds arise on the leaves. These are called epiphyllous buds.

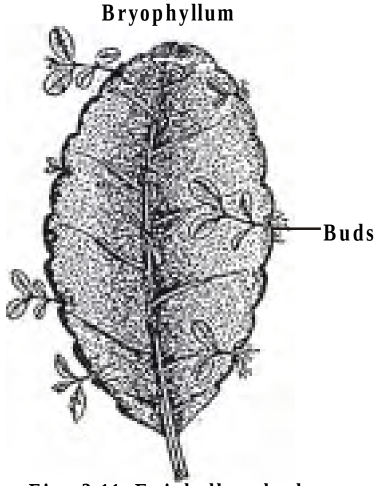


Fig : 3.11. Epiphyllous buds

Functions of Stem: The primary functions of stem is 1. to **support** the branches and leaves. 2. It **conducts** water and minerals from the roots to the leaves and the food materials from the leaves to the roots. The secondary functions of the stem are 1. **Storage** eg. **Potato** 2. **Perennation** e.g. **Ginger** 3. **Vegetative Propagation** e.g **Potato** 4. **Photosynthesis** e.g **Opuntia**

Modifications of stem

In many plants in addition to the normal functions mentioned above the stem performs certain additional functions. In these plants they show structural modifications. The additional functions may be 1. Storage of food 2. Perennation 3. Vegetative propagation 4. Photosynthesis.

Modified stems are grouped into the following three categories.

1. Aerial modifications 2. Sub aerial modifications 3. Under ground modifications

1.Aerial modifications

In some plants, stem undergoes modification to a great degree to perform certain special functions. These are

1. Tendrils 2. Thorns 3. Phylloclade 4. Cladode 5. Bulbil. We will discuss about phylloclade and cladode in detail.

Phylloclade: These are green, flattened or cylindrical stems with nodes and internodes. The leaves are reduced to spines to reduce the loss of water by transpiration since these plants grow in xerophytic conditions. The stem becomes flat like a leaf and performs the functions of photosynthesis. eg. ***Opuntia***. In this the phylloclade i.e. the stem performing the function of leaf becomes succulent due to storage of water and food.

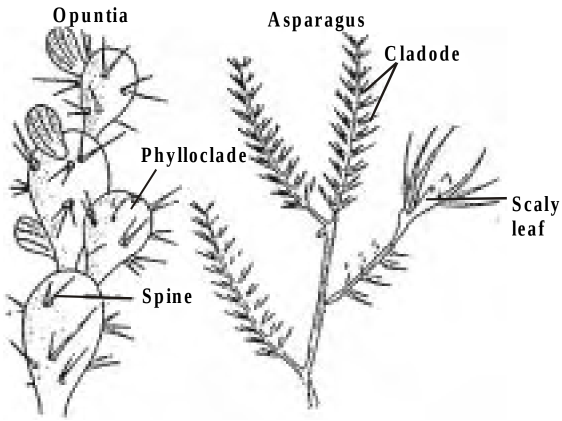


Fig : 3.12. Phylloclade & Cladode

Cladode: These are green, cylindrical or flattened stem branches of limited growth. These are usually of one internode as in ***Asparagus***. Their stem nature is evident by the fact that they bear buds, scales and flowers.

2.Sub-aerial modifications:

This type of modification is found in many herbaceous plants with a thin, delicate and weak stem. In such plants a part of the stem is aerial and the remaining part lives underground. These plants bear adventitious roots and aerial branches at their nodes. They propagate quickly by vegetative methods. Sub-aerial modified stems are of the following types:

1. Runner 2. Sucker 3. Stolon 4. Offset

We will discuss about Runner and Sucker.

1. **Runner** : It has long and thin internodes and the branches creep over the surface of the soil. They develop adventitious roots from the lower sides of the nodes. From the axil of the scale leaves at the nodes arise aerial branches. Runners grow in all directions from the mother plant. On detachment from the mother plant the daughter plant propagate in a similar manner. Thus very soon a whole area is covered by many plants from a single plant. Eg. **Doob grass**, ***oxalis***

2. **Sucker**: It is a modified runner. In this the runner originates as a lateral branch from the underground axillary bud of an aerial shoot. It grows down in to the soil obliquely for some distance and then grows upwards. The sucker has nodes and internodes and in the nodal region it bears scale leaves and axillary buds above and adventitious roots below. Eg. ***Chrysanthemum***

3. Underground modifications:

Some plants develop non-green underground stem which are perennial i.e they live for many years. These store reserve food, and are adapted for perennation. During favorable conditions underground stems give rise to aerial shoots. With the onset of unfavourable conditions the aerial shoots die. During this period the underground stems remain dormant.

These underground stems can be distinguished from the roots by the following.

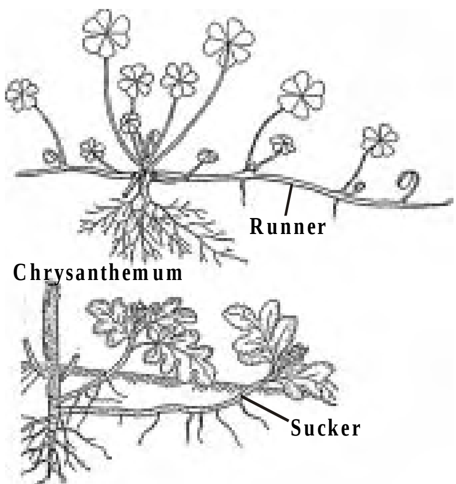


Fig : 3.13. Runner & Sucker

a. Presence of nodes and internodes

b. Presence of scale leaves and adventitious roots arising from the nodes.

c. Presence of axillary and terminal bud.

The four different types of underground stem are 1**. Rhizome 2. Tuber 3. Bulb 4**. **Corm**

a. Rhizome: Rhizomes are horizontal, thick, stout underground stems. They are swollen with the storage of food materials. They have nodes and internodes. The nodes have brown scaly leaves which protect the axillary buds. The nodes bear adventitious roots on the lower side. At the onset of favourable condition the axillary and terminal buds grow into aerial shoots. These aerial shoots die on the approach of unfavourable condition. eg.**Ginger, Turmeric**

Advantages of Rhizomes: Rhizomes are very good means of perennation. They help to tide over the unfavourable conditions like drought etc. They serve as store houses of food which is safely protected from the grazing of animals. Since aerial shoots arise from the buds of the rhizome they are useful in vegetative propagation also.

b. Tuber: Tubers are the swollen tips of special underground branches. They are different from rhizomes in that they are stouter, with slender internodes and the adventitious roots are generally absent. The tuber bears many scale leaves with axillary buds in the nodes. **Potato** is a common example for a tuber. It has got small depressions on it called the **eye of the potato**. It bears the bud. When the tuber is planted in the soil the buds develop into branches

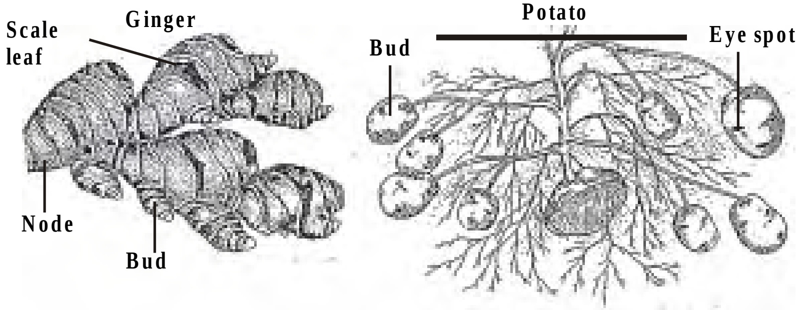


Fig : 3.14. Rizome and Tuber

at the expense of the food material stored in the tuber. Some of these branches become aerial and green and erect while others grow horizontally underground and their tips become swollen with food materials.

Leaf

Leaves are green, thin flattened lateral outgrowths of the stem. They are borne at the nodes of the stem. Leaves are the chief organs of **photosynthesis**. The green leaves of the plant are collectively called as foliage of the plant.

Parts of a Leaf

The three main parts of a typical leaf are 1. **Leaf base** 2. **Petiole** 3. **Lamina**

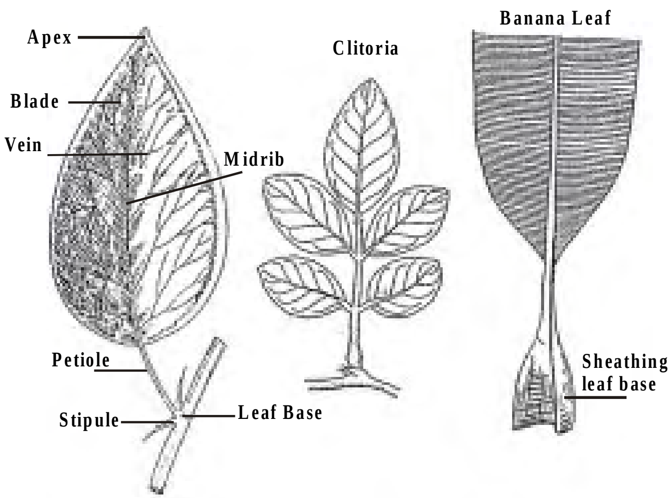


Fig : 3.15. Parts of a typical leaf & Pulvinus & Sheathing leaf base

Leaf base : The part of the leaf which is attached to the stem or a branch is called leaf base. In some plants the leaf has a swollen leaf base. It is known as **pulvinus** eg. The compound leaves of the family **Fabaceae.** In monocots the leaf base is very broad and flat and it clasps a part of the node of the stem as in maize and in banana. It is called sheathing leaf base.

Stipules: In most of the dicotyledonous plants, the leaf-base bears two lateral appendages called the **stipules.** Leaves which have the stipules are called **stipulate**.

The leaves without stipules are called **exstipulate**. The main function of the stipule is to protect the leaf in the bud.

Petiole : Petiole connects the lamina with the stem or the branch. A leaf is said to be **petiolate** when it has a petiole. It is said to be **sessile** when the leaf does not have a petiole.

Leaf blade: It is also known as **lamina**. This is the most important, green part of the leaf which is mainly concerned with the manufacture of food. The lamina is traversed by the **midrib** from which arise numerous lateral **veins** and thin **veinlets**.

Venation

The arrangement of veins in the leaf blade or lamina is called **venation**. It is mainly of two types namely **Reticulate venation** and **Parallel venation**.

1. Reticulate Venation: This type of venation is common in all dicot leaves. In this type of venation there is a prominent vein called the midrib from which arise many small veins which finally form a net like structure in the lamina. It is of two types

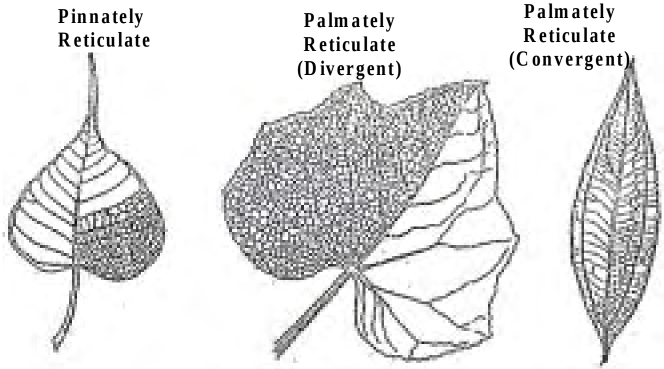


Fig : 3.16. Types of Reticulate Venation

Pinnately reticulate venation : In this type of venation there is only one midrib in the center which forms many lateral branches to form a net work. eg. **Mango**

2. **Parallel Venation**: In this type of venation all the veins run parallel to each other. Most of the monocot leaves have parallel venation. It is of two types.

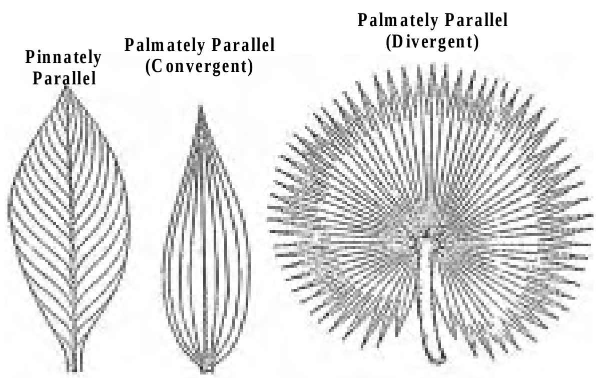


Fig : 3.17. Types of Parallel Venation

VENATION

- Reticulate
  - Pinnately Reticulate
  - Palmately Reticulate
- Parallel
  - Pinnately Parallel
  - Palmately Parallel

a. Pinnateley Parallel venation : In this type, there is a prominent midrib in the centre. From this arise many veins perpendicularly and run parallel to each other eg. **Banana**.

b. Palmately parallel venation : 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. In grass they converge at the apex and hence it is called **convergent**. In **Borassus** (Palmyra) all the main veins spread out towards the periphery. Hence it is called **divergent**.

Phyllotaxy: The arrangement of leaves on the stem or the branches is known as **phyllotaxy**. The purpose of phyllotaxy is to avoid overcrowding of leaves so as to expose the leaves maximum to the sunlight for photosynthesis. The four main types of phyllotaxy are **1. Alternate 2. Opposite 3. Ternate 4. Whorled.**

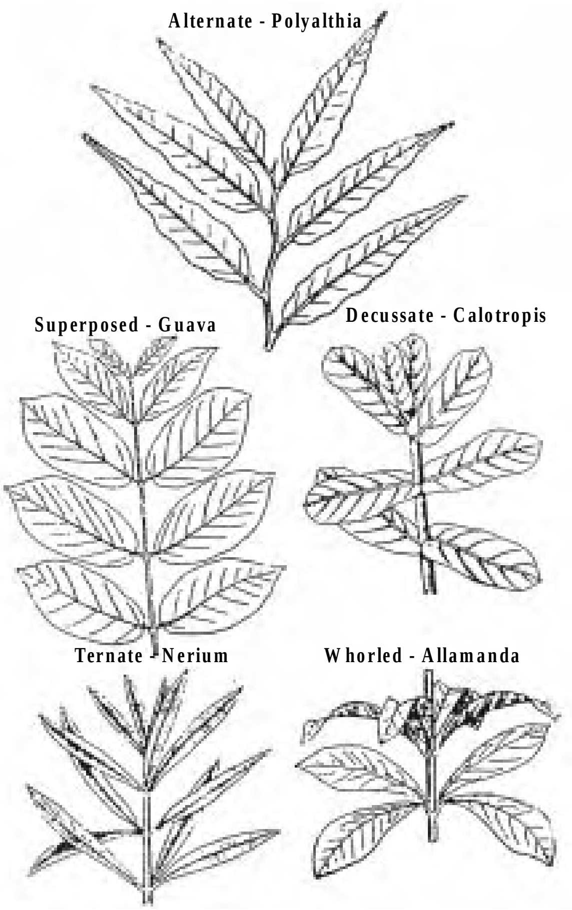


Fig : 3.18. Types of Phyllotaxy

1.Alternate phyllotaxy: In this type the leaves are arranged alternatively in the nodes. There is only one leaf at each node. eg. ***Polyalthia***.

2.Opposite Phyllotaxy: In this type of arrangement two leaves are present at each node, lying opposite to each other. It is of two types:

a) Opposite superposed: The pairs of leaves arranged in successive nodes are in the same direction i.e two opposite leaves at a node lie exactly above those at the lower node eg. **Guava**

b) Opposite decussate: In this type of phyllotaxy one pair of leaves are placed at right angles to the next upper or lower pair of leaves. Eg. ***Calotropis***

3.Ternate Phyllotaxy : In this type there are three leaves attached at each node eg. ***Nerium***

4. Whorled : In this type, more than three leaves are present in a whorl at each node eg. ***Alamanda***.

Simple and compound leaves

Simple Leaf: A leaf is said to be simple in which the leaf blade or lamina is entire. It may be with incision or without incision. e.g. **Mango**

Compound leaf: Here the lamina is divided in to a number of leaf like lobes called the leaflets. The leaflets are borne on a common axis and they do not bear any axillary buds in their axils. The two types of compound leaf are:

1. Pinnately compound leaves 2. Palmately compound leaves

Pinnately compound leaves

In a pinnately compound leaf, the leaflets are borne on a common axis called the rachis. The leaflets are known as the **pinnae**. The pinnately compound leaf may be of the type **1. Unipinnate 2. Bipinnate 3. Tripinnate 4. Decompound**

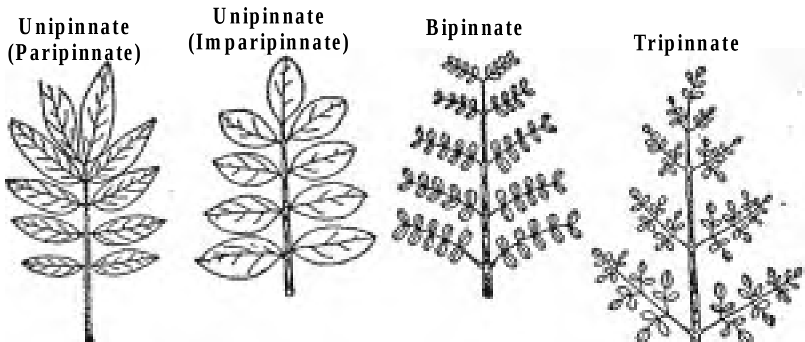


Fig : 3.19. Types of Pinnately compound leaves

1.Unipinnate: In this type the pinnae are borne directly on the rachis. When the number of leaflets is odd, it is said to be **imparipinnate** eg. **Neem** .When the number of leaflets is even it is said to be **paripinnate** eg. **Tamarind**.

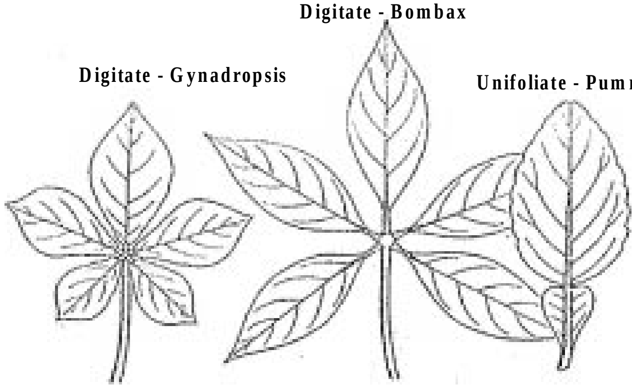


Fig : 3.20. Types of Palmately compound leaves

2.Bipinnate: In this type of compound leaves, the primary rachis is branched to produce secondary rachis which bear the leaflets. eg. ***Acacia***.

3.Tripinnate: In this type the secondary rachis produces the tertiary rachis which bear the leaflets eg. ***Moringa***

4.Decompound : When the compound leaf is more than thrice pinnate it is said to be decompound. eg. **Coriander**

Palmately compound leaf

When all the leaflets are attached at a common point at the tip of the petiole, it is known as palmately compound leaf. According to the number of leaflets present the compound leaf may be 1. **unifoliate** (eg. Lemon) 2. **Bifoliate** (eg.***Zornia diphylla***) 3. **Trifoliate** (eg. ***Oxalis***) 4. **quadrifoliate** (eg. ***Marsilia***) 5. **Multifoliate** (eg. ***Bombax***)

Leaf Modification

The primary functions of leaf are photosynthesis and transpiration. But in many plants the leaves are modified to perform some additional functions. These are called as leaf modifications Some of the leaf modifications are:

Table : 3.1. Differences between a simple leaf and a compound leaf:

Simple Leaf	Compound Leaf
1. Axillary bud is present in the axil of a simple leaf	Axillary bud is present in the axil of a compound leaf. But the leaflets of a compound leaf do not have them.
2. Stipules are present at the base of simple leaves.	Stipules are not present at the base of the Leaflets.
3. The simple leaf may have incisions but these incisions are not deep enough to divide the blade into leaflets.	The compound leaves are divided into distinct parts called leaflets.

1. Leaf tendrils (eg. **Wild pea**) 2. Leaf hooks (eg. ***Bignonia***) 3. Leaf spines (eg. ***Zizyphus***) 4. Phyllode (eg. ***Acacia***) 5. Pitcher (***Nepenthes***) 6. Bladder eg. (**Utricularia**)

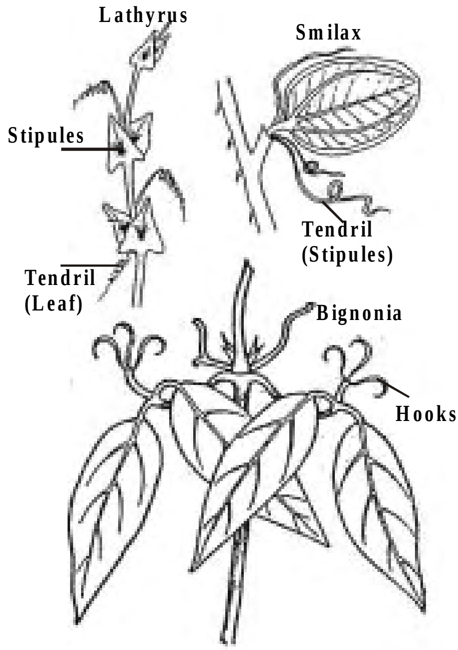


Fig : 3.21. Leaf Tendrils & Leaf Hooks

1. **Leaf tendrils** : Here the stem is very weak and hence they have some special organs for attachment to the support. Tendril is a slender wiry coiled structure which helps in climbing the support. In ***Lathyrus*** the entire leaf is modified into tendril. In ***Smilax*** the stipules become modified into tendril.

2 Leaf hooks: In this the leaves are modified into hooks and help the plant to climb the support. In ***Bignonia unguiscati*** , the three terminal leaflets of the compound leaves become stiff, corved and claw like hooks.

Fig : 3.22. Leaf Spines

3. Leaf-spines : In this type the leaves become wholly or partially modified into sharp pointed structures known as **spines**. This modification helps the plant to cut down transpiration and also protects the plants against the attacks of grazing animals. Any part of the leaf may get modified in to spine. e.g. ***Zizyphus***

4. Phyllode: In Acacia the petiole or any part of the rachis becomes flattened or winged taking the shape of the leaf and turning green in colour. This flattened or winged petiole or rachis is known as the **phyllode**. The normal leaf which is pinnately compound develops in the young stage, but soon falls off. The phyllode then performs all the functions of the leaf. The wing of the phyllode normally develops in the vertical direction so that sunlight cannot fall on its surface; this reduces evaporation of water. There are about 300 species of Australian Acacia, all showing the phyllode.

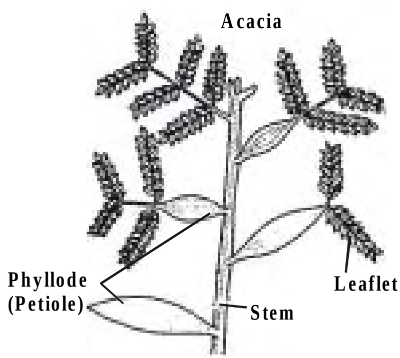


Fig : 3.23. Phyllode

5. Pitcher

In the pitcher plant ***(Nepenthes)*** the leaf becomes modified into a pitcher. There is a slender stalk which coils like a tendril holding the pitcher vertical and the basal portion is flattened like a leaf. The pitcher is provided with a lid which covers the mouth. The function of the pitcher is to capture and digest insets. The lamina is modified into pitcher. The rim of the pitcher is beautifully coloured and it is provided with a row of nectar glands for attracting insects. The inner wall of the pitcher is provided with glands secreting a watery fluid. There are also hairs pointed downwards below the rim. This arrangement prevents the insects entering the pitcher from escaping out. The insects get drowned in the fluid and it is digested by the enzymes secreted by the glands. Thus the plant is able to get nitrogenous food.

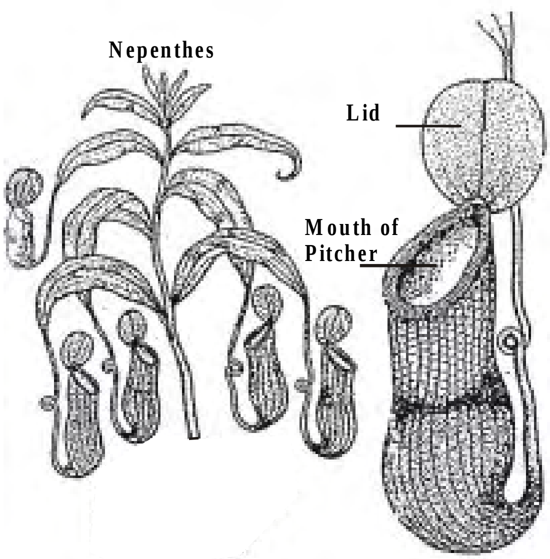


Fig : 3.24. Insectivorous Plant

6. Bladder

In ***utricularia*** some of the much dissected leaves are modified into bladders. These bladders serve as floats for the aquatic plants and for trapping the insects.

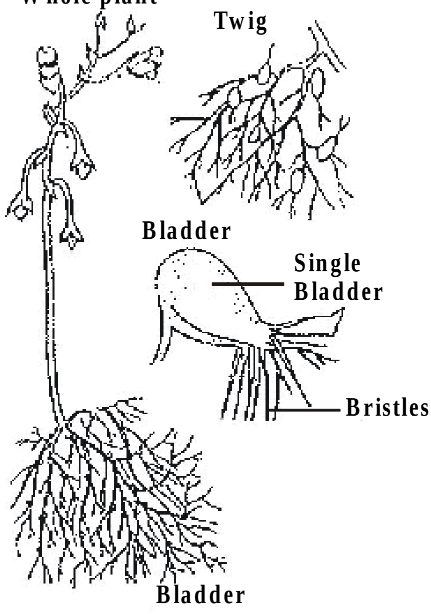


Fig : 3.25. Bladder Plant

SELF EVALUATION

One Mark

Choose the correct answer

1. The type of phyllotaxy found in ***Calotropis*** is

   a. alternate b.opposite decussate c. opposite superposed d. ternate

Fill in the blanks

1. In Bignonia unguiscati___________ become stiff, claw like hooks.
2. In _____________, tuberous roots which have no definite shape are seen.

Match

1. Moringa	- Pneumatophores
2.Lemon	- Tripinnate
3.Acacia	- Bladder
4.Utricularia	- Phyllode
5.Lathyrus	- Unifoliate
6.Avicennia	- Tendril

Two Marks

1. What is meant by exogenous / endogenous origin?
2. Name any two vegetative organs/ reproductive organs of a flowering plant.
3. Write any two characteristic features of root/ shoot.
4. Define: adventitious roots/ root cap/ meristematic zone/ pulvinus/ bud
5. What is an epiphyllous bud?
6. What are the advantages of rhizome?
7. What are pneumatophores?

Five Marks

1. Describe the parts of a typical root.
2. Describe the two types of root system with suitable examples.
3. Write about the functions of roots?
4. Describe phyllode/ phylloclade
5. Describe the pitcher plant.
6. Distinguish a simple leaf from a compound leaf.

Ten Marks

1. Describe the modifications of Tap root system/ adventitious root system/ stem/ leaf.
2. Describe the various types of venation/ phyllotaxy

2. Inflorescence

The reproductive organs of flowering plants are flowers. The flowers are produced after a period of vegetative growth. The flowers may be borne singly or in clusters. When borne singly they are said to be **solitary** (eg) *Hibiscus rosa sinensis* (shoe flower), if in clusters they form an inflorescence.

Inflorescence

When several flowers arise in a cluster on a common axis, the structure is referred to as an **inflorescence**. The common axis is the inflorescence axis which is also called **rachis** or **peduncle**. Several single flowers are attached to the inflorescence axis. In case of plants possessing underground rhizomes, the rachis or peduncle arises directly from the rhizome. Such a rachis is referred to as **scape**. In the case of **lotus**, the scape gives rise to a solitary flower. In plants like **onion**, the scape gives rise to an inflorescence.

Based on the location, the inflorescence may be classified into 3 types. (i) Terminal Inflorescence (ii) Intercalary Inflorescence and (iii) Axillary Inflorescence.

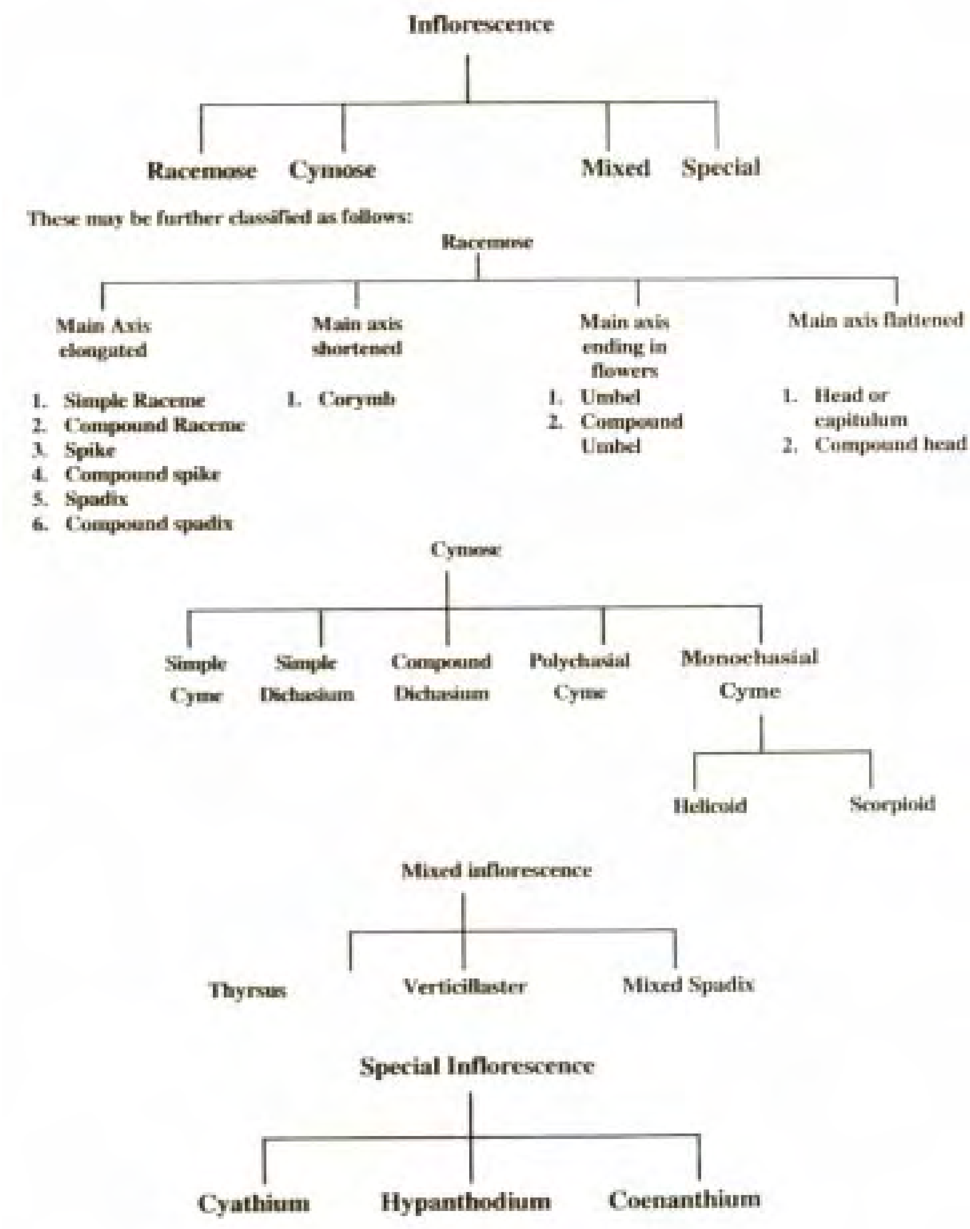
In plants like *Callistemon* the inflorescence is found in between the stem. This is called **intercalary inflorescence**.

Generally, based on the arrangement, structure and organisation of flowers on the axis, inflorescence are classified into various types. There are four major types.

i) Racemose
ii) Cymose
iii) Mixed and
iv) Special types

Racemose Inflorescence

In this type, the inflorescence axis shows **unlimited** growth. Several flowers arise in **acropetal** succession on the axis. The younger flowers are found at the tip and older flowers are found towards the base of the inflorescence axis. The order of opening of flowers is **centripetal** i.e. from the periphery towards the centre. Racemose inflorescence may be sub-divided into various types based on branching of inflorescence axis, length of the axis and presence or absence of pedicels in flowers.



i. Main axis elolngated

Here the inflorescence axis is very much elongated and bears pedicellate or sessile flowers. This may include several types.

Simple Raceme

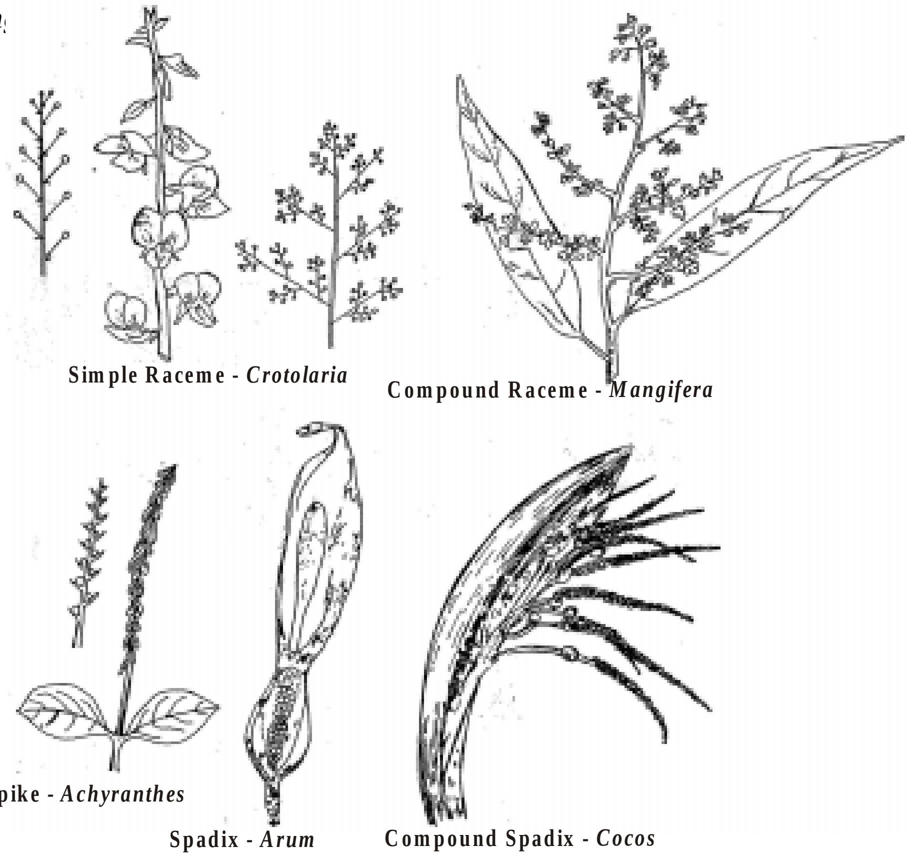
This is a very simple type of inflorescence. The axis shows unlimited growth. Numerous pedicellate flowers are arranged from base to apex in acropetal succession. Each flower arises in the axil of a bract eg. *Crotolaria retusa, Cleome viscosa*.

Compound Raceme or Panicle

In this type, the inflorescence axis is branched. Each branch shows flowers arranged as in a simple raceme i.e. in acropetal sucession. eg. *Mangifera*.

Spike

This inflorescence shows an axis of unlimited growth as in raceme but the flowers are sessile and are arranged in acropetal order eg. *Achyranthes* and *Piper lon*



Main Axis Elongated

Fig : 3.26. Types of Racemose Inflorescence

Compound Spike

The inflorescence axis is branched and each branch is referred to as spikelet. Each spikelet bears a few flowers only. The base of the inflorescence shows a pair of bracts called **glumes**. Each flower has a bract called **lemma** and a bracteole called **palea** eg. *Oryza* (Paddy).

Spadix

The inflorescence axis is swollen and fleshy. Numerous sessile flowers arranged in acropetal order are embedded in the axis. The entire inflorescence is protected and covered by a large bract called **spathe**. The base of the axis bears female flowers, and the sterile flowers and male flowers are borne towards the top. The tip of the inflorescence axis does not bear flowers. eg. *Arum, Colocasia*.

Compound Spadix

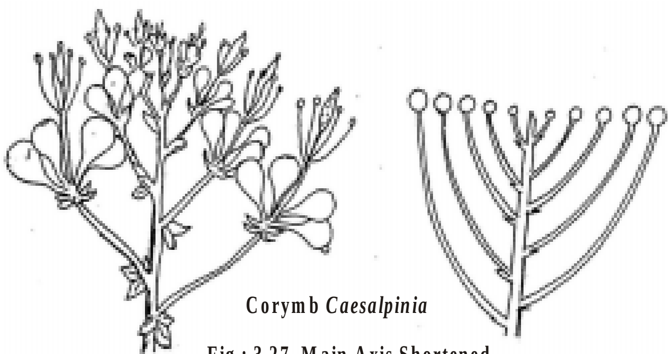
The swollen and fleshy inflorescence axis is branched and bears sessile flowers. There is a thick and large boat-shaped bract called **spathe** covering the inflorescence eg. *Cocos*.

ii. Main Axis Shortened

Here the main axis shows reduced growth and is shortened. Corymb belongs to this type.

Corymb

The inflorescence axis in this type is not elongated as in raceme. The pedicels of the flowers are of unequal length. The older flowers have long pedicels and the younger flowers show short pedicels. So all flowers appear at the same level. eg. *Caesalpinia*.



Corymb *Caesalpinia*

Fig : 3.27. Main Axis Shortened

iii. Main Axis ending in flowers

There are two types under this-umbel and compound umbel.

Umbel

The main axis may be simple or branched. But the vertical growth of the axis is suddenly stopped and a whorl of bracts arise at the tip of the inflorescence. This is called **involucre of bracts** from the axils of which arise flowers having pedicels of equal length. The flowers are in acropetal order and present at the same level. eg. *Allium cepa* (Onion).

Compound Umbel

The main axis of the umbel inflorescence produces an involucre of bracts which give rise to branches called **rays** from their axils. Each ray produces an **involucre of bracts** at its tip from the axils of which arise flowers having pedicels of equal length in acropetal order. Each such umbel is called an **umbellet**. eg. *Daucas carota* (carrot).

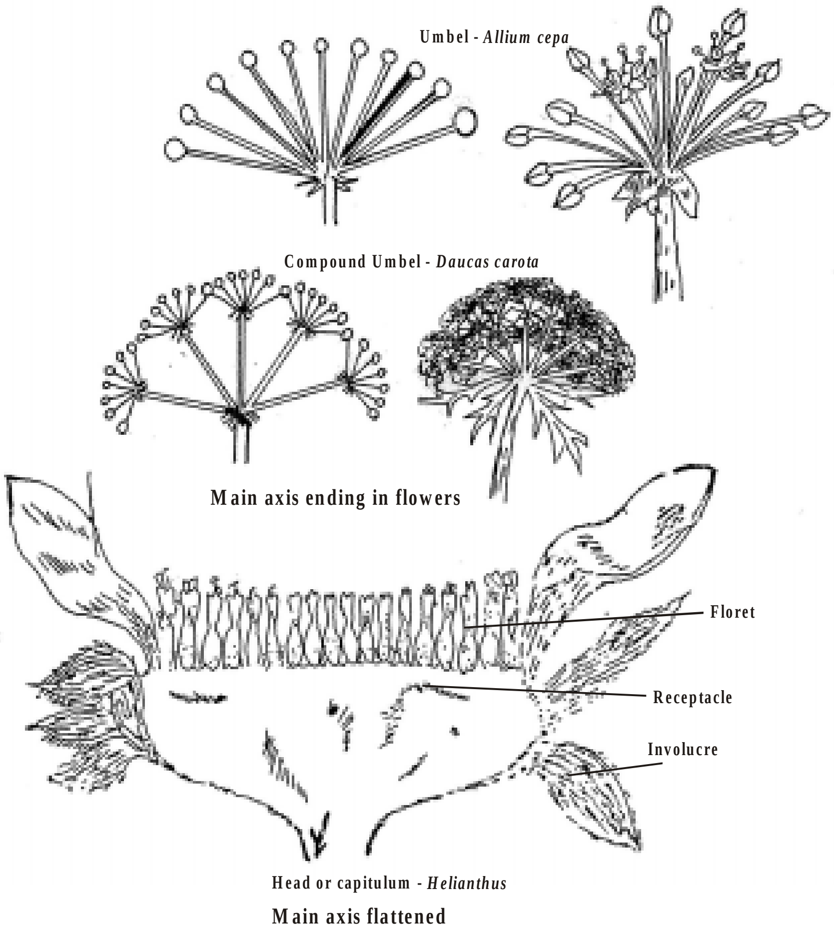


Fig : 3.28. Types of Racemose Inflorescence

Main axis flattened

The main axis is flattened and assumes various shapes. On the flattened axis flowers are arranged.

There are two types under this - head or capitulum and compound head.

Head or Capitulum

The main axis of the inflorescence is flattened and functions as the **thalamus**. This bears numerous **florets** in acropetal order. The inflorescence is surrounded by an **involucre** of bracts which are green in colour and protect the young flowers and fruits.

The florets of the inflorescence are sessile and are of two types. 1. The **tubular or disc** florets and 2. The **ligulate or ray** florets. Based on the type of florets present, the head inflorescence may be of two types **- Homogamous** head and **Heterogamous** head.

Homogamous Head

This type shows florets of a single kind only which may be ray or disc florets eg. *Vernonia* shows only disc florets and *Launaea* shows ray florets only.

Heterogamous Head

The florets present here belong to both ray and disc type. The disc florets are present in the centre of the thalamus while the ray florets radiate outwards from the margins of the thalamus. eg. *Helianthus, Tridax*.

Compound Head

In *Lagasca mollis* the inflorescence axis is branched and each branch bears a head inflorescence.

Cymose Inflorescence

Inflorescence axis shows **limited** growth. The tip of the inflorescence stops growing after producing a flower. The lateral pair of bracts at the base of the flower give rise to lateral branches each of which ends in a flower. Similarly the lateral pair of bracts of each of these branches may also form branches. In this way flowers are formed in **basipetal order** i.e. from **apex to base**. The older flowers is at the tip and younger flower is at the base and the order of opening of flowers is **centrifugal** i.e. from cnetre to periphery. The flowers are few in number.

Cymose inflorescence is of various types.

Simple Cyme

The stem or the axil of leaf may show a single flower which shows a joint on the pedicel. Such flowers are referred to as **terminal solitary cyme** and **axillary solitary cyme** respectively. eg. *Papaver* - Terminal solitary cyme, *Hibiscus* - Axillary solitary cyme.

Simple Dichasium

It is a group of three flowers. The inflorescence axis ends in a flower. the two lateral bracts at the base of the flower give rise to branches ending in a flower. Thus, there are three flowers in the inflorescence and the central flower is the oldest eg. *Jasminum*.

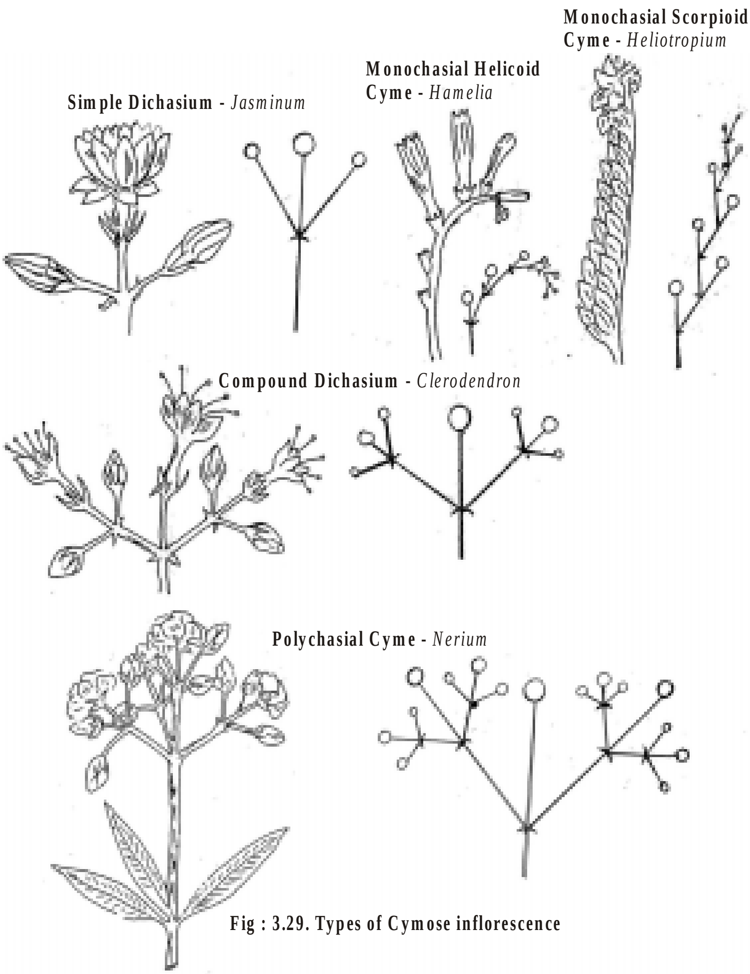


Fig : 3.29. Types of Cymose inflorescence

Compound Dichasium

The tip of the inflorescence ends in a flower. From the lateral bracts of this flower a pair of branches arise, each ending in a flower. Each of the branches bears a pair of bracts and these also give rise to a pair of lateral branches each. Thus symmetrical bunches of three flowers each are formed where the central flower is the oldest. eg. *Clerodendron.*

Monochasial Cyme

The inflorescence axis terminates in a flower. Of the two lateral bracts only one bears flowers. Such a cyme is called a monochasial cyme. This is of two types - **Helicoid** cyme and **Scorpioid** cyme.

Helicoid Cyme

The main axis terminates in a flower. The lateral branches arising from the axile of bracts are on one side only giving rise to a helical appearance. eg. *Hamelia patens*.

Scorpioid Cyme

The main axis stops growing after producing a flower.The lateral branches arising from the axil of bracts are produced alternately to the left and to the right in a zig-zag manner eg. *Heliotropium.*

Polychasial Cyme

The main axis terminates in a flower. The lateral branches formed from the bract continue to branch repeatedly eg. *Nerium.*

III. Mixed Inflorescence

In this type of inflorescence, the axis starts as a racemose inflorescence and shows branching in a cymose fashion. There are different types under this.

Thyrsus

The main axis of the inflorescence shows a number of simple dichasial cymes arranged in a racemose manner eg. *Ocimum.*

Verticillaster

A pair of dichasial cymes arise from the axils of opposite flowers. Later these grow as monochasial scorpioid cymes around the stem eg. *Leucas.*

Mixed Spadix

In *Musa*, several cymose clusters are arranged on the swollen inflorescence axis from base to apex. Each cymose cluster is surrounded by a large bract called **spathe**.

IV. Special Type of Inflorescence

The type of inflorescence which cannot be included in racemose type or cymose type is called special type. There are several kinds of special type inflorescence.

Cyathium

This is found in the genus *Euphorbia*. The inflorescence is reduced to look like a single flower. The bracts are united to form a cup - like structure enclosing a convex receptacle. There are a number of reduced unisexual flowers on the receptacle. There is a single female flower in the centre of the receptacle. It is naked, represented by the gynoecuim only and borne on a long stalk. Around the female flower five groups of naked male flowers are arranged in a monochasial scorpioid cymes. The male flower is represented by a single stamen arising in the axil of a bract. The top of the inflorescence shows the presence of beautiful nectaries. eg. *Euphorbia cyathophora*.

Hypanthodium

Here the receptacle is concave and cup shaped. The

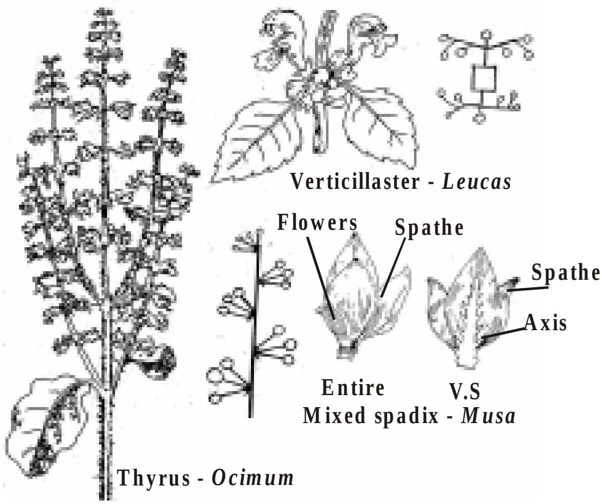


Fig : 3.30. Types of Mixed Inflorescence

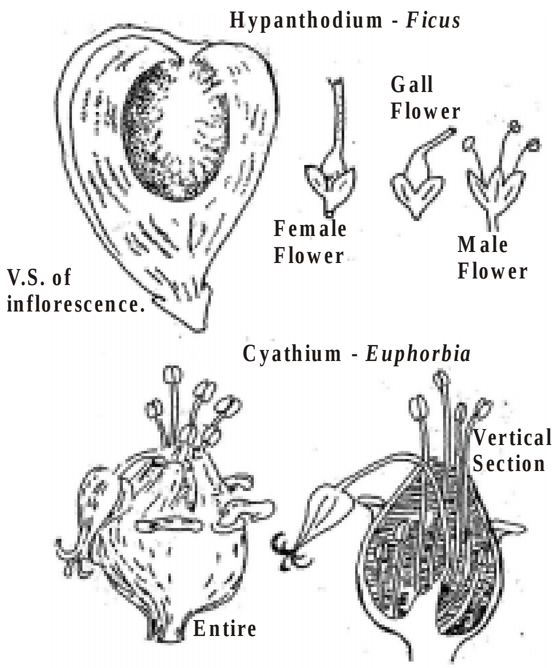


Fig : 3.31. Types of Special Inflorescence upper end has an opening called ostiole, which is protected by scales. Inside the receptacle, three types of flowers are present. Male flowers are present in the upper part, female flowers towards the base and the neutral flowers are found in the middle between the male and female flowers eg. *Ficus*.

Coenanthium

Here the receptacle is fleshy and appears like a circular disc like structure. The centre of the disc contains female flowers and around these are present the male flowers eg. *Dorstenia*.

SELF EVALAUTION

One Mark

Choose the correct anser

1. Spike is a type of
   a. Racemose inflorescence   b. Cymose inflorescence
   c. Mixed inflorescence   d. Special inflorescence
2. **Dorstenia** an example for
   a. raceme   b. panicle   c. spadix   d. coenanthium
3. This is a homogamous head with ray florets
   a. *Vernonia*   b. *Tridax*   c. *Launaea*   d. *Helianthus*
4. *Musa* in an example for
   a. spadix   b. mixed spadix   c. compound spadix   d. none of the above
5. Flowers are unisexual in
   a. cyathium   b. thyrsus   c. verticillaster   d. cyme

Two marks

1. Define : Ligulate floret / Hypanthodium / Corymb / Involucre / Umbellet

Five Marks

1. Describe the different types of mixed inflorescence with examples
2. Give an account of head inflorescence
3. Classify cymose inflorescence and explain any two of them.
4. Give an account of special types of inflorescence.

Ten Marks

1. Give an outline classifications of racemose types of inflorescence.
2. Write an essay on the various types of racemose inflorescence?
3. Describe the various types of cymose inflorescence.

3. Flowers, Fruits and Seeds

Structure and types of flower

A flower is a modified condensed shoot specialized to carry out sexual reproduction in higher plants. Like a branch, it arises in the axil of a small leaf-like structure called **bract**. The terminal part of the axis of a flower, which supports all the floral appendages (i.e., **sepals, petals, stamens and carpels**) is called receptacle (**thalamus or torus**). The receptacle consists of several crowded nodes which are separated by condensed internodes. The internode of the branch that lies below the receptacle is called **pedicel**. A bract is usually situated at the base of pedicel. Sometimes small leaf-like structures are present in the middle of pedicel. They are called **bracteoles**.

FLOWER - A Metamorphosed Shoot

The concept that the flower is a modified or a metamorphosed shoot for the purpose of reproduction is an old one and the concept is gradually developed through the past and is accepted at the present by a majority of morphologists. **Linnaeus** expressed this idea in his **Philosophia Botanica** (1751) by the phrase **"vegetative metamorphosis"**. This concept that floral leaves were a modification of vegetative leaves was further elaborated by **Caspar Wolff** and **Decandolle**.

The 'foliar theory' of the flower of the earlier botanists is held today by many though modified in one form or other by other botanists.

That the flower is a modified shoot, is only a figurative expression, and implies that the floral leaves are vegetative leaves and transformed to do a different function of reproduction, in the place of the ordinary function of photosynthesis.

Evidences to support that flower is a modified shoot

1. The position of flower buds and shoot buds is same, i.e., they are terminal or axillary in position.
2. In some plants, the flower buds are modified into vegetative buds or bulbils, eg. ***Agave***, **Onion,** ***etc***.
3. In some plants, the thalamus elongates to form a vegetative branch or another flower above the first flower, ***e.g.*** **Rose**.
4. In ***Nymphaea*** (Water Lily), the flowers show all transitional stages between a sepal and petal and between a petal and stamen.

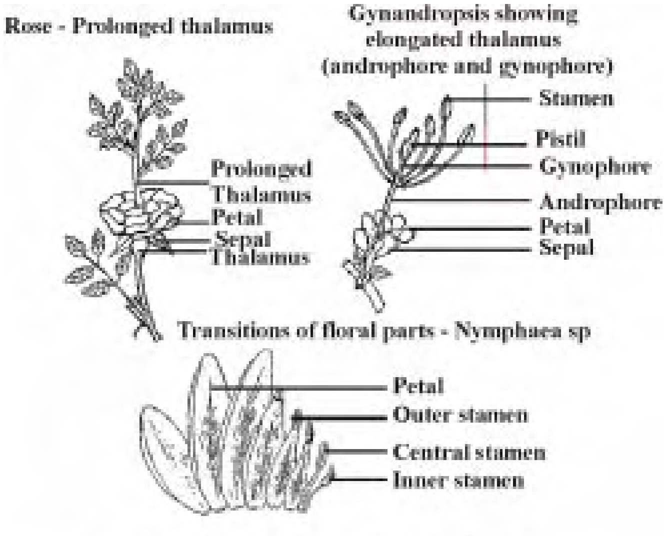


Fig 3.32. Evidences to support that flower is a modified shoot

5. In ***Gynandropsis gynandra***, the thalamus elongates and shows long internodes between the floral organs.

6. In rose, the sepals are similar in morphology to leaves.

7. In ***Degeneria***, the stamens are expanded like leaves and the carpels appear like folded leaves without differentiating into stigma and style.

8. Anatomy of the thalamus, pedicel and stem show close similarities. The vascular supply of different floral appendages resemble the vascular supply of ordinary vegetative leaves.

Position of flower

A flower is usually seen either at the axil of a leaf or at the apices of the stem and its branches. Accordingly, the flower is described as **axillary** and **terminal** respectively.

Flower, whether solitary or in inflorescence, usually has a short stalk called **pedicel**. A flower with stalk is described as **pedicellete** and a flower without stalk is called **sessile**.

Parts of a flower

A typical flower consists of following parts:

1. Bracts and Bracteoles
2. Thalamus
3. Whorls of flower
   a. Calyx
   b. Corolla
   c. Androecium
   d. Gynoecium

Essential and Non-Essential Parts

Of the four parts of a flower, androecium and gynoecium are known as essential organs because they have a direct role in reproduction i.e. pollination and fertilization which lead to development of fruit and seeds from flower. The calyx and corolla do not have a direct role in these processes. Hence they are described as **non-essential** organs or **accessory organs**.

Bracts and Bracteoles

Bracts are special leaves at whose axil flowers develop. For example, in an axillary flower, the leaf from whose axil the flower develops becomes the bract. But bracts are not always present. If a bract is found, the flower is called **bracteate**; if it is absent then the flower is described as **ebracteate**. When bracts are present, they protect flower buds in the young stage. Sometimes small and thin bract-like structures are present on the pedicel between the flower and the bract. These are called **bracteoles**. the bracteoles may be one or two in number. Flowers having bracteoles are described as bracteolate and flowers where bracteoles are absent are called **ebracteolate**.

The receptacle (thalamus)

The thalamus is the short floral axis, with compressed nodes and internodes on which various floral leaves are inserted.

Variation of the Receptacle

In a few cases, internodes become distinct and elongated. The elongated internode between the calyx and corolla is the **anthophore** as in Caryophyllaceae.

The internode elongated between the corolla and the androecium is called the **androphore** eg. ***Passiflora*** (family - Passifloraceae).

The elongated internode between the androecium and the gynoecium is called the **gynophore** as in ***Capparis*** [Capparidaceae] When both androphore and gynophore are present, they are called **gynandrophore** or **androgynophore** e.g. ***Gynandropsis***. When the thalamus is prolongated beyond the ovary, it is called the **carpophore** as in the ***Coriander, Foeniculum*** etc.

Insertion of floral leaves on the thalamus

Hypogyny

When the thalamus is convex or elongated, the carpel occupies the top most position on it. The other floral members (sepals, petals, and stamens) are placed below them. This mode of arrangement is called **hypogyny**. The flower is described as hypogynous. The ovary is known as superior. eg. **Malvaceae, Annonaceae** etc.

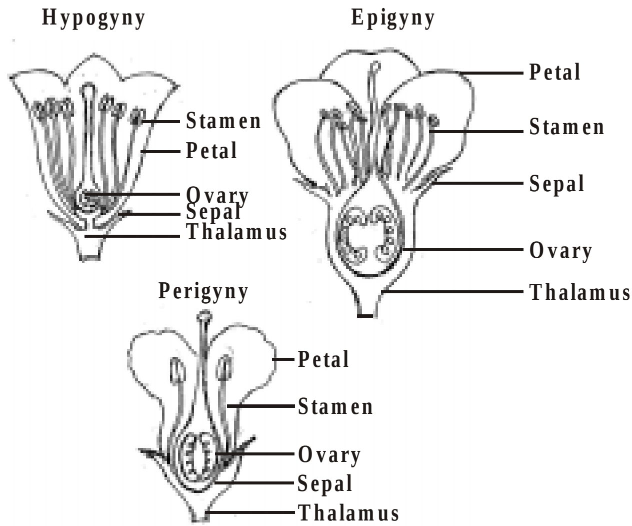


Fig : 3.33. Insertion of floral leaves

Epigyny

When the thalamus is cup shaped, the lower part of the ovary is situated at the bottom of the cup and also fused with the inner wall of thalamus. The other floral members appear to be inserted upon the ovary. This mode on arrangement is called **epigyny**. Then the flower is said to be epigynous. the ovary is said to be inferior. eg. ***Asteraceae, Cucurbitaceae, Rubiaceae*** etc.

Perigyny

In this condition, the receptacle is flat or slightly cup-shaped. The carpels are situated at its centre and other floral members are inserted on its margin. This mode of arrangement is called **perigyny**. The flower is known as perigynous. In this case, the ovary is still described as half inferior. eg. ***Fabaceae, Rosaceae*** etc.

The Perianth

Most flowers of monocot plants have perianth, where there is no difference between calyx and corolla. In families of monocotyledons, the perianth is brightly coloured and highly developed, which is known as Petaloid perianth as in ***Gloriosa superba***. Some families of dicotyledons have also **petaloid** perianth e.g. **Polygonaceae**.

The function of the perianth leaves is to protect the inner part of the flower. When brightly coloured, they attract insects for pollination.

Calyx

The calyx is the outermost whorl of a flower composed of sepals. The sepals are usually green in colour, but sometimes, become brightly coloured then, said to be **petaloid** as in ***Caesalpinia pulcherrima.*** in ***Musseanda frondosa*** the sepals are transformed into large, yellow or white and leafy structure.

The primary function of the calyx is protective. It protects the inner parts of the flower from mechanical injury, rain and excessive sun shine, and from drying out in the bud condition. Green in colour, it can also do the phosynthetic function. When petaloid, it performs the function of attracting insects for pollination. When spiny, its function is defensive and as pappus, it helps in the dispersal of fruit.

The calyx may be regular or irregular. The sepals are free from one another and is said to be **ploysepalous,** when united united, **gamosepalous.**

Variations of calyx

The calyx may sometimes be absent or modified into scaly structure as in Sunflower.

In some cases, it is modified into a bunch of hair - like structures called **pappus** eg. ***Vernonia.***

Duration of Calyx

After the opening of the flower, the calyx usually falls off but it may persist in some cases.

According to its duration, it may be described as follows:

1. **Caducous or Fugacious:**Sometimes the calyx falls off, even before flowers are opened and such a calyx is said to be caducous.eg.***Papaver, magnolia*** etc.
2. **Deciduous:**When it falls off after the opening of the flower, it is said to be deciduous. (eg) Nelumbo
3. **Persistent:** In somw other cases, when the calyx persists (unwithered) even after fruit formation, it is said to be persistent. eg. Brinjal,

4. **Accresent:** Calyx not only persistent but also grows along with development of the fruit. eg. Physalis.

Corolla

The corolla is the second accessory floral whorl consisting of petals.

The petals of the corolla are usually variously coloured and of delicate texture. They may be free (polypetalous) or united (gamopetalous). The primary function of the corolla is to attract insects for polinatioin and also serves to protect the essential organs.

Shape of the petals in the corolla

I. Clawed: The petal is narroe and slender at the base as a claw eg. Petals of Cruciferae.

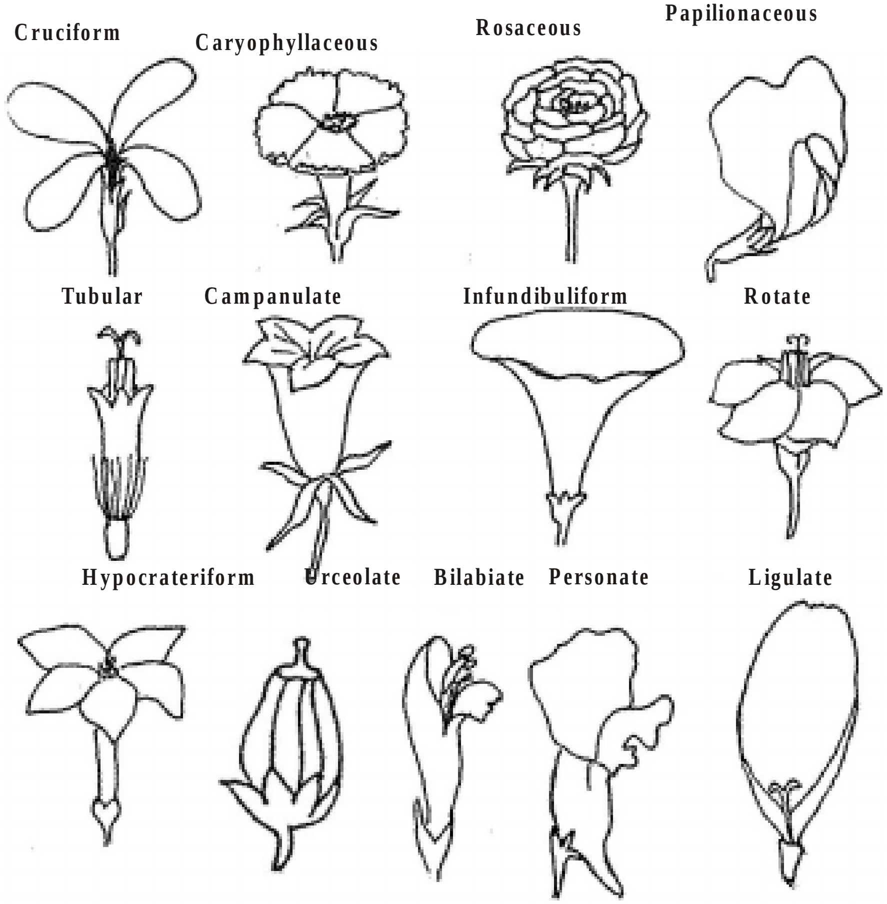


Fig : 3.34. Forms of corolla

II. Filmbriate: Petals fringed with hairy, teeth-like structure_eg. Dianthus

III. Laciniate: Petal divided into several long more or less equal segments.

IV. Spurred: Corola with a long hollow projection called spur eg. Delphinium majus.

V. Saccate: THe lower part of the corrolla tube gets dilated to form a sac-like structure eg. Antirhinum.

Forms of Corolla

A Polytalous and Regular

i. Cruciform: When the corolla consists of four clawed petals arranged at right angles to one another. eg. Brassica, Radish, etc.,

ii. Caryphyllaceaus: when the corolla consists of five clawed petals with spreading limbs; claws and limbs are at right angles to one another. eg. **Carroypyllaceae**

iii. Rasaceous: when the corolla consits of five spreading petals, without any claw eg. **Wild Rose**.

B Polyetalous and Irregular

i. **Papillonaceous**: whent he corolla consists of 5 petals, one large - the vexillum or standard petal which is posteior and outemost, two lateralsalae or wings at the sides and two partially fused structures - the keel or carina. eg. **Pea**, etc. **(Fam. Fabaceae).**

ii. **Orchidaceous**: flowers with a peculiarity of combining calyx and corolla: One member, the petal in from of the stamen and stigma, differs from the rest in shape and in being nectarigerous: It is called a labellum. eg. **Habenaria**.

C Gamopetalous and Regular

I. **Tubular**: Corolla tube is more or less cylindrical. Eg. Disc florests of Helianthis

II. **Companulate**: when the corolla tube is inflated below and winded out at the top. It looks bell-shaped eg. Cucurbita maxima

III. **Infundibuliform**: corolla is funnel-shaped structure. eg. Datura

IV. **Rotate**: When the corolla tube is short with spreading limbs at right angle to it. It looks like a wheel in shape eg. Solanum

V. **Salver-Shaped or Hypocrateriform -** Corolla tube is long and narrow with spreading limbs. eg. Vinca.

VI. **Urceolate**: un-shaped Corolla tube is inflated in the middle but narrow above and below, as inBryphyllum calycinum

D. Gamopetalous and Irregular

i. **Bilabiate:** Limb of the corolla is divided into two projecting lips eg. Ocimum

ii. **Personate:**Corolla shows bilabiate condition with mouth closed by the projecting lip.et.***Antirrhium***

iii. **Ligulate:**Strap-shaped. When the corolla tube is short and tubular at the base but flat above like a strap. eg. **Ray florets of Asteraceae**

Aestivation

The mode of arrangement of either sepals or petals of a flower in bud condition is said to be an Aestivation.

The Aestivation is of the following types

1. Valvate Aestivation

Sepals or petals in a whorl just meet by their edges without overlapping. eg. Sepals of ***Hibiscus.***

2. Twisted Aestivation

In this mode of aestivation one margin of each sepal or petal overlaps the next one, and the other margin is overlapped by a preceding one. Here the over lapping is regular in one direction-clockwise or anticlockwise. eg. ***Petals of Hibiscus***

3. Imbricate

In this type, one sepal or petal is internal or being overlapped on both the margins and one sepal or petal is external with both of its margins overlapping. Of the remaining sepals or petals, one margin is overlapping and the other margin overlapped.

There are two types of imbricate aestivation descendingly imbricate and ascendingly imbricate.

a. **Descendingly Imbricate or Vexillary Aestivation:** In this type of aestivation the posterior petal of overlaps one margin of the two lateral petals.
The other margin of these two lateral petals overlaps the two anterior petals, which are united. Thus the overlapping is in descending order and hence the name eg. **Corolla of Fabaceae**.

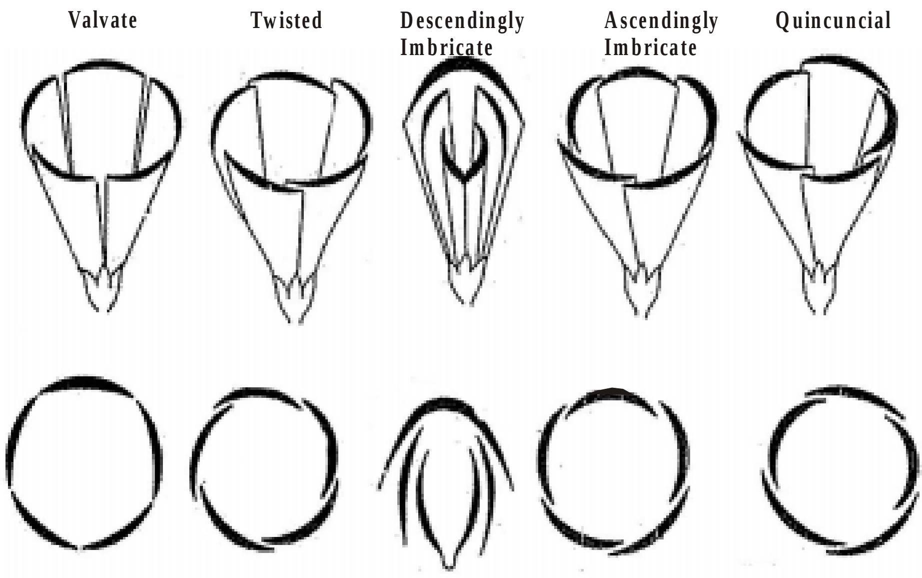


Fig : 3.35. Different types of Aestivation

Ascendingly imbricate aestivation : In this type the posterior odd petal is innermost being overlapped by one margin of the two lateral petals. The other margin of the two lateral petals is overlapped by the two anterior petals. Here the overlapping of petals begins from the anterior side proceeding towards the posterior side. This is just opposite of descendingly imbricate aestivation. eg. **Petals of Caesalpiniaceae**.

4. Quincuncial

It is modification of imbricate aestivation in which two petals are internal, two are external and the fifth one has one margin external and the other margin internal. eg. ***Guava***

Androecium

It is the third whorl of the flower. It is considered as the male part of the flower. The androecium is made up of stamens or microsporophylls. Each stamen has a slender stalk called **filament,** bearing the **anther** (microsporangial sorus). Usually the anther consists of two lobes. The two lobes of an anther are connected by a tissue called **connective**. Each **anther lobe** has **two pollen sacs** (microsporangia). Each pollen sac consists of innumerable **Pollen grains** (microspores).

Sterile stamen or staminode

In some plants, a stamen may not develop any fertile anther. Such sterile stamens are called **staminodes** eg. **Cassia.**

1. Cohesion of Stamens

- **i. Monadelphous**: All the stamens of a flower are united in one bundle by fusion of their filaments only. The anthers are free, eg. ***Hibiscus, Abutilon***, etc.
- **ii. Diadelphous**: All the stamens of a flower are united in two bundles by fusion of their filaments only. The anthers are free, eg. ***Clitoria***
- **iii. Polyadelphous**: Filaments of all the stamens unite to form more than two bundles. The anthers are free, eg. ***Citrus***.
- **iv. Syngenesious**: Anthers of all the stamens of the flower unite to forma cylinder around the style. The filaments are free, eg. ***Asteraceae***.

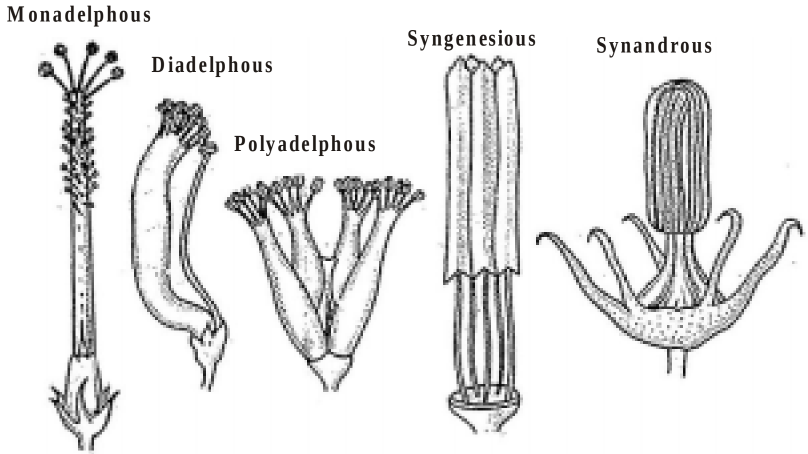


Fig : 3.36. Cohesion of stamens

- **v. Synandrous**: Anthers as well as the filaments are fused throughout their whole length, eg. ***Cucurbitaceae***
- **vi. Polyandrous**: Stamens are indefinite and free, eg. ***Ranunculus***.

2. Adhesion of stamens

- **i. Epipetalous**: Stamens adhre to the petals by their filaments and hence appearing to arise from them, eg. **Solanum, Ocimum**, etc.
- **ii. Epitepalous (Epiphyllous)**: When stamens united with the perianth leaves, the stamens are said to be Epitepalous. eg. ***Asphodelus.*** **(Spider lilly)**

iii. **Gynandrous**: Stamens adhere to the carpels either throughout their length of by their anthers only. eg. ***Calotropis***.

3. Length of stamens

i. **Didynamous**: Out of four stamens in a flower, two are long and two are short, eg. ***Ocimum***

ii. **Tetradynamous**: Out of six stamens in a flower, two outer are short and four inner are long, eg. **Mustard**.

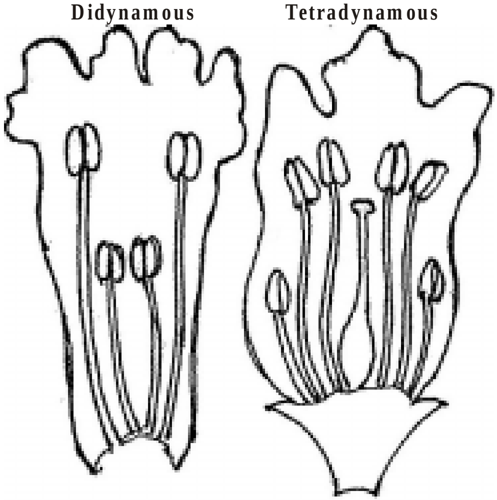


Fig : 3.37. Length of stamens

4. Position of stamens

i. **Inserted**: Stamens shorter than corolla tube.

ii. **Exerted**: Stamens longer than the corolla tube, protruding outwards.

5. Number of antherlobes

i. **Dithecous**: Anthers have two lobes with four microsporangia or pollen sacs.

ii. **Monothecous**: Anthers have only one lobe with two microsporangia.

6. Fixation of anthers

i. **Basifixed (Innate)**: Filament is attached to the base of the anther, eg. ***Brassica***.

ii. **Adnate**: Filament is continued from the base to the apex of anther, eg. ***Verbena***.

iii. **Dorsifixed**: Filament is attached to the dorsal side of the anther, eg. ***Citrus***.

iv. **Versatile**: Anther is attached lightly at its back to the slender tip of the filament so that it can swing freely, eg. **Grass**

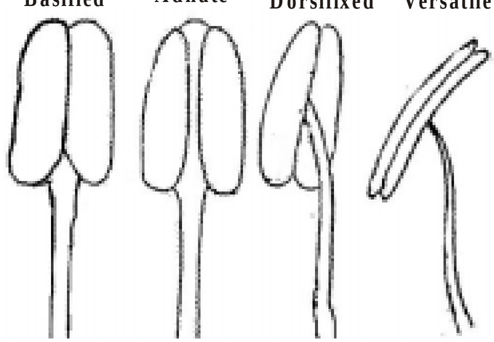


Fig : 3.38. Fixation of anthers

Gynoecium

Gynoecium is the collective term for the innermost central whorl of floral appendages. It is considered as the female part of the flower. A unit of gynoecium is called carpel. Following technical terms and related with gynoecium.

1. Number of Carpel

- **i. Monocarpellary**: Gynoecium consists of a single carpel; eg. **Fabaceae**
- **ii. Bicarpellary**: Ovary consists of two carpels; eg. **Rubiaceae**
- **iii. Tricarpellary**: Ovary consists of three carpels; eg. **Liliaceae**
- **iv. Tetracarpellary**: Ovary comprises of four carpels; eg. **Melia**
- **v. Multicarpellary**: Gynoecium consists of many carpels eg. **Papaver**

2. Cohesion of Carpels

- **i. Apocarpous**: Gynoecium made up of two or more carpels which are free; eg. ***Polyalthia***.
- **ii. Syncarpous**: Gynoecium consists of two or more carpels which are fused; eg. ***Hibiscus***.

3. Number of locules

Depending on the number of chambers, the ovary may be described as unilocular, bilocular, trilocular etc.

Types of Placentation

In Angiosperms, ovules are present inside the ovary. Placenta is a special type of tissue, which connects the ovules to the ovary. The mode of distribution of placenta inside the ovary is known as placentation. Some important types of placentation are as follows:

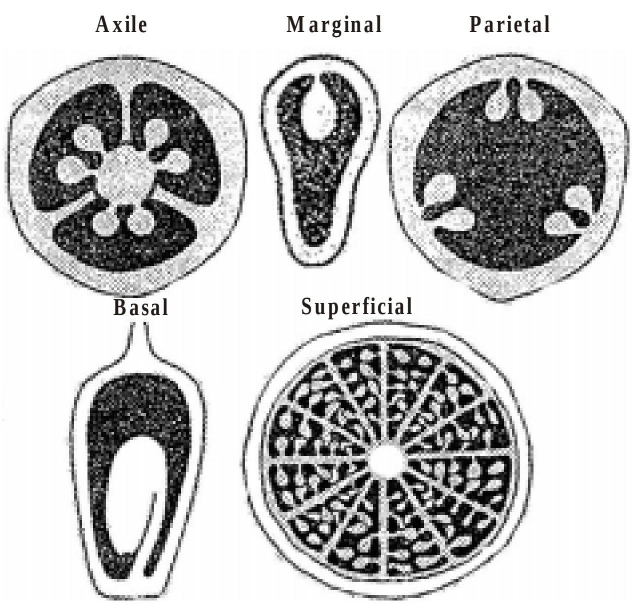


Fig : 3.39. Types of Placentations

1. Axile Placentation

This type of placentation is seen in bi- or multi carpellary, syncarpous ovary. The carpel walls meet in the centre of the ovary, where the lacenta are formed like central column. The ovules are borne at or near the centre on the placenta in each locule. eg. ***Hibiscus***.

2. Marginal Placentation

It occurs in a monocarpellary, unilocular ovary. The ovules are borne along the junction of the two margins of the carpel. eg. ***Fabaceae***

3. Parietal Placentation

This type of placentation is found in multi carpellary, syncarpous, unilocular ovary. The carpels are fused only by their margins. The placenta bearing ovules develop at the places, where the two carpels are fused. eg. ***Cucumber***

4. Basal Placentation

It is seen in bicarpellary syncarpous, and unilocular ovary. The placenta develop directly on the receptacle, which bears a single ovule at the base of the ovary. eg. ***Asteraceae***.

5. Superficial Placentation

This type of placentation occurs in a multicarpellary, multiocular ovary. The ovules are borne on placentae, which develop all round the inner surface of the partition wall eg. ***Nymphaeaceae***

Description of a flower

The following technical terms are used in connection with the description of flower.

1. Floral whorls

1. **Complete**: When all the four whorls. (Calyx, Corolla, Androecium, and Gynoecium) are present in a flower, it is termed complete.
2. **Incomplete**: When one or more whorls are absent the flower is described incomplete.

a. **Monochlamydeous**: Some flowers have only one accessory whorl and they are called **Monochlamydeous**.

b. **Dichlamydeous**: Normally flowers have two outer whorls which are usually differentiated into calyx and corolla. Such flowers are known as dichlamydeous.

c. **Achlamydeous**: There are a number plants, where the flowers have neither calyx nor corolla. Such flowers are described naked or achlamydeous.

2. Sex distribution

- **i.** **Bisexual or Perfect**: When both the essential whorls i.e., androecium and gynoecium are present in a flower, it is called bisexual or perfect.
- **ii.** **Unisexual or imperfect**: A flower having only one of the essential whorls is called unisexual or imperfect. The unisexual flowers may be of two types.
- a) **Staminate**. Male flower with androecium, only
- b) **Pistillate**. Female flower with gynoecium only

Monoecious

If male and female flowers develop in the same plant, it is called Monoecious eg. **Coconut, Maize** etc.

Dioecious

If male and female flowers are borne on separate plants, it is termed dioecious eg. **Palmyrah palm, Papaya, Mulberry** etc.

Polygamous

If a plant develops three kinds of flowers i.e. staminate, pistillate and bisexual flowers, it is called polygamous. eg. **Mango, Cashewnut** etc.

3. Floral Symmetry

The shape, size and arrangement of floral appendages (i.e. Calyx, corolla, androecium and gynoecium) around the axis of a flower is called floral symmetry. The axis to which the flower is attached is called mother axis. The side of flower towards mother axis is called **posterior** side and the side away from it is called **anterior** side.

On the basis of floral symmetry there may be following three conditions of a flower.

- **i.** **Actinomorphic**: A flower with radial symmetry, i.e., the parts of each whorl are similar in size and shape. The flower can be divided into two equal halves along more than one median longitudinal plane, eg. ***Hibiscus, Solanum***, etc.
- **ii.** **Zygomorphic**: A flower with bilateral symmetry, i.e. the parts of one or more whorls are dissimilar. The flower can be divided into two equal halves in only one vertical plane, eg. ***Pisum***

iii. **Asymmetric**: A flower which cannot be divided into two equal halves along any vertical plane, eg. ***Canna***

4. Arrangement of floral organs

i. **Cyclic**: The floral parts are arranged in definite whorls around the axis of flower, eg. ***Brassica, Solanum*** etc.

ii. **Acyclic**: The floral parts are arranged in spirals and not in whorls, eg. ***Magnolia***

iii. **Spirocyclic**: Some of the floral parts are in whorls and others in spirals (Hemicyclic), eg. ***Rose, Ranunculus,*** etc.

5. Number of floral parts

Occurrence of the same number of floral parts in different floral whorls of a flower is called **isomery**. Sometimes, flowers have different number of parts in each whorl. This condition is called **heteromerous**. The isomerous flowers may be of the following types:-

i. Dimerous	**:**	Floral parts in two's or multiplies of two
ii. Trimerous	**:**	Floral parts in three's or multiples of three
iii. Tetramerous	**:**	Floral parts in four's or multiples of four
iv.Pentamerous	**:**	Floral parts in five's or multiples of five

Dicotyledonous flowers are usually tetra, or pentamerous whereas monocotyledonous flowers are trimerous or multiples of three.

Fruit

The fruit may be defined as a fertilized and developed ovary. Fruits and seeds develop from flowers after completion of two processes namely pollination and fertilization. After fertilization, the ovary develops into fruit. The ovary wall develops into the fruit wall called **pericarp** and the ovules inside the ovary develop into seeds. The branch of horticulture that deals with study of fruits and their cultivation is called ***pomology***.

Fertilization acts as a stimulus for the development of ovary into fruit. But there are several cases where ovary may develop into fruit without fertilization. This phenomenon of development of fruit without fertilization is called **parthenocarpy** and such fruits are called parthenocarpic fruits. These fruits are necessarily seedless. eg. ***Banana, grapes, pineapple*** and ***guava*** etc.

The fruits are classified into two main categories, - true and false fruits.

i. **True Fruit**: The fruit, which is derived from ovary of a flower and not associated with any noncarpellary part, is known as true fruit. eg. ***Tomato, Brinjal, Pea, Mango, Banana*** etc.

ii. **False Fruit**: **(Pseudocarp)** The fruit derived from the ovary along with other accessory floral parts is called a false fruit. eg. ***Apple*** (edible part of the fruit is the fleshy receptacle).

Structure of fruit

A fruit consists of two main parts - the seeds and the pericarp or fruit wall. The structure and thickness of pericarp varies from fruit to fruit. The **pericarp** consists of three layers - outer **epicarp**, middle **mesocarp** and inner **endocarp**. The sweet juicy and edible flesh is the mesocarp, the inner most hard covering is the endocarp. These three layers are not easily distinguishable in dry fruits.

The fruits are usually classified into three groups, namely simple, aggregate and multiple or composite fruits.

Simple fruits

When a single fruit develops from a single ovary of a single flower, it is called **simple fruit**. The ovary may be monocarpellary or multicarpellary syncarpous. On the nature of pericarp, simple fruits are divisible into two types

i) Fleshy fruits and ii) Dry fruits

Simple fleshy fruits

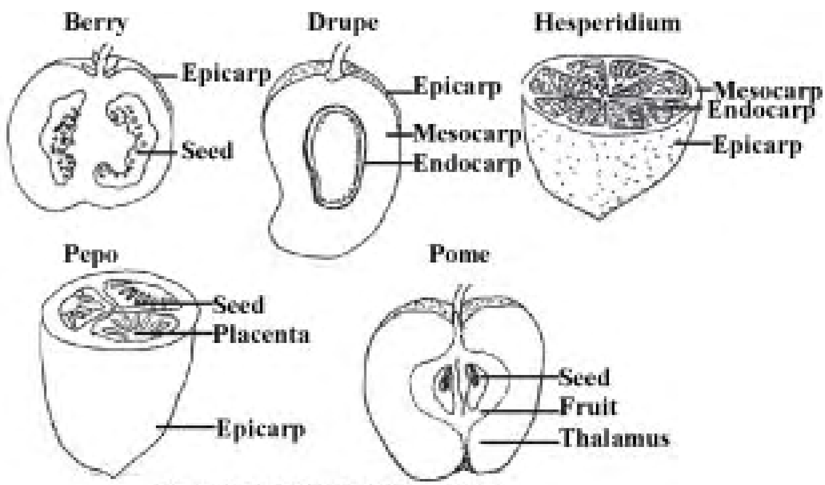


Fig : 3.40. Simple fleshy fruits

In these fruits either the entire pericarp or part of the pericarp is succulent and juicy when fully ripe. Normally the fruit wall may be differentiated into three layers - an outer **epicarp**, a middle **mesocarp** and an inner **endocarp**. As a general rule, the fleshy fruits are indehiscent.

Fleshy fruits are broadly divided into two kinds, **baccate** and **drupaceous**. **Baccate** fruits are fleshy fruits with no hard part except the seeds. **Berry** is an example for the first category while drupe falls under the second type.

1. **Berry**: It is a many seeded fruit. Here the epicarp is thin, the mesocarp and endocarp remain undifferentiated. They form a pulp in which the seeds are embedded. In these fruits, all parts including the epicarp with the seeds are edible eg. ***tomato***

2. **Drupe**: This is normally a one-seeded fruit. In these fruits the pericarp is differentiated into an outer skinny epicarp, a middle fleshy and juicy mesocarp and an inner hard and stony endocarp. Drupes are called **stone fruits** because of the stony hard endocarp. The endocarp encloses a single seed. The edible portion, of the fruit is the fleshy mesocarp eg. ***mango***. In coconut, the mesocarp is fibrous, the edible part is the endosperm.

3. **Hesperidium**: It is a skind of baccate fruit that develops from a superior multicarpellary and syncarpous ovary. The fruit wall is differentiated into three layers - an outer glandular skin or epicarp, a middle fibrous mesocarp, and an inner membranous endocarp. The latter divides the fruit chamber into a number of compartments. The seeds arise on axial placentae and are covered by juicy hairs or outgrowths from the lacentae that are edible.

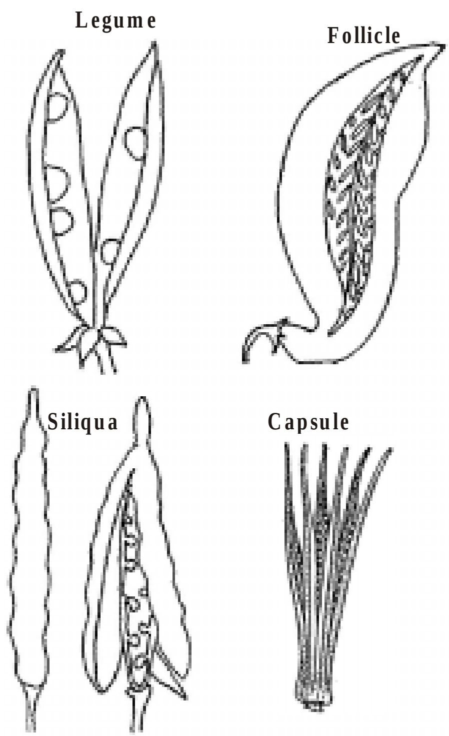


Fig : 3.41. Dehiscent dry fruits

It is characteristic fruit of the genus **Citrus (Fam. Rutaceae)**

4. **Pepo**: A large fleshy fruit developing from a tricarpellary, syncarpous, unilocular and inferior ovary with parietal placentation. The fruit is many seeded with pulpy interior; eg. **Cucumber, Melon, Bottle gourd** etc.

5. **Pome**: It is a fleshy and a false fruit or Pseudocarp. It develops from a multicarpellary syncarpous inferior ovary in which the receptacle also develops along with the ovary to become fleshy and enclosing the true fruit. The true fruit containing seeds remains inside. The edible part is fleshy thalamus. eg. **Apple, Pear** etc.

Simple Dry Fruits

These fruits have dry pericarp, which is not distinguished into three layers. The dry simple fruits are further divided into three types-

a) **Dehiscent**

b) **Schizocarpic** and

c) **Indehiscent**

a) Dehiscent dry fruits

1. **Legume**: A dehiscent dry fruit produced from a monocarpellary, superior ovary, which dehisces from both the sutures into two valves. eg. **Pea**
2. **Follicle**: A dehiscent dry fruit produced from a monocarpellary, superior ovary, which dehisces from one suture only. eg. ***Calotropis***.
3. **Siliqua**: A dehiscent dry fruit produced from a bicarpellary, syncarpous, superior, ovary, which is unilocular but appears bilocular due to false septum. Fruits dehisce along both the sutures from base to apex and large number of seeds remain attached to the false septum called **replum**. eg. ***Brassica***
4. **Capsule**: A dehiscent dry fruit produced from syncarpous, superior or inferior ovary which dehisces along two or more lines of suture in various ways.

   i) **Septicidal** - eg. ***Aristolochia***

   ii) **Loculicidal** - eg. ***Gossypium, Abelmoschus***

b) Schizocarpic dry fruits

1. **Lomentum**: Fruit is similar to a legume but constricted between the seeds. Dehiscing sutures are transverse. The fruit splits into one-seeded indehiscent compartments at maturity; eg. ***Tamarindus, Cassia fistula***.

2. **Cremocarp**: Fruit is produced from a bicarpellary, syncarpous, bilocular and inferior ovary. It is a two-seeded fruit which splits longitudinally into two indehiscent mericarps which remain attached to a thread-like carpophore. eg. **Coriandrum**

3. **Regma**: The fruit is produced from a bi- or multi-carpellary, syncarpous and superior ovary, it breaks up into as many segments or cocci as there are carpels; eg. ***Ricinus***.

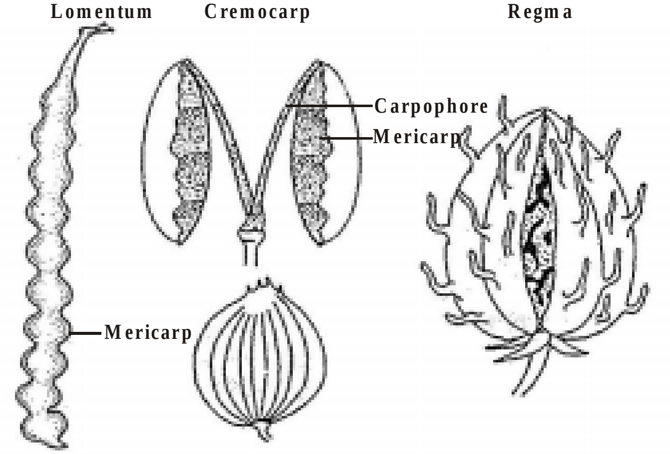


Fig : 3.42. Schizocarpic dry fruits

c) Indehiscent dry fruits

1. **Achene**: A small, indehiscent one seeded fruit developing from a monocarpellary ovary and in which the pericarp is hard, leathery and remains free from seed coat; eg. ***Mirabilis, Clematis***.

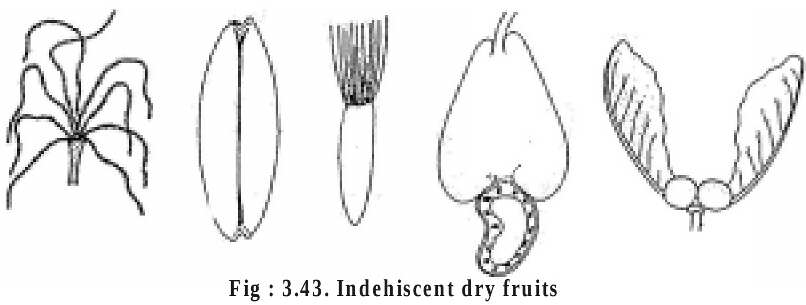


Fig : 3.43. Indehiscent dry fruits

2. **Caryopsis**: A small, indehiscent and one seeded fruit developing from a monocarpellary ovary and in which the pericarp is fused with the seed coat. The seed completely fills the chamber; eg. **Paddy, Maize**

3. **Cypsela**: The fruit is produced from bicarpellary, syncarpous and inferior ovary with persistent calyx forming the 'pappus'. It contains only one seed. The pericarp and seed coat remain free; eg. ***Tridax, Helianthus***.

4. **Nut**: A large, indehiscent, one-seeded fruit that develops from a bi- or multi-carpellary ovary. The fruit wall becomes hard, stony or woody at maturity; etc. **Cashew nut**

5. **Samara**: A dry indehiscent, one-seeded winged fruit developing from bicarpellary, syncarpous ovary. The wing is a modified outgrowth of pericarp; eg. **Acer**

Aggregate fruit

An aggregate fruit develops from a single flower, with multicarpellary, apocarpous, superior ovaries and each of them develops into simple fruitlets. An aggregate fruit, therefore consists of a collection of simple fruits as in ***Polyalthia***. The carpels of the flower unite and give rise to a single fruit as in ***annona squamosa***.

Polyalthia

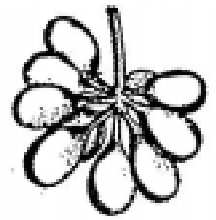


Fig : 3.44. Aggregate Fruit

Multiple or Composite Fruit

Multiple or composite fruit is formed by all the flowers of a whole inflorescence grouped together to give a single big fruit. In a sense, multiple fruits are false fruits.

In Jack, the type of multiple fruit is **sorosis**. The rachis and all the floral parts of the female inflorescence fuse together forming composite fruit. The inflorescence axis and the flowers all become fleshy.

In the centre of the fruit, there is a club-shaped, thick, fleshy central axis, which is the inflorescence axis. The edible part of the fruit represents the perianth, which is fleshy and juicy. The pericarp is bag-like and contains one seed. The spines on the tough rind represent the stigmas of the carpel. The sterile or unfertilized flowers, occur in the form of numerous, elongated, whitish, flat structures in between the edible flakes.

Sorosis - Jack

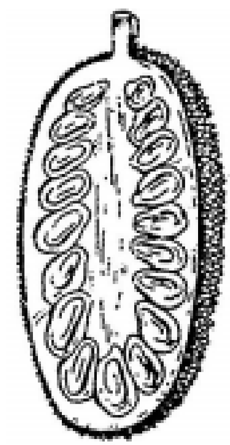
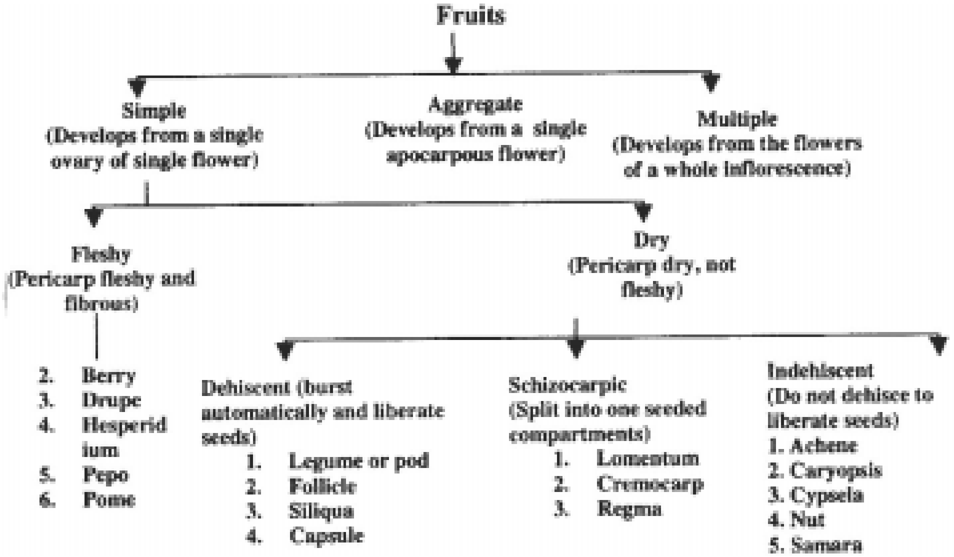


Fig : 3.45. Multiple Fruit

Sorosis: A multiple fruit that develops from a spicateinflorescence. eg. ***Ananas sativus*** **(Pineapple)**.

Pineapple plant is largely cultivated for its fruits. The stem is short and leafy and bears a terminal spicate inflorescence. After fertilization, the axis and the flowers, along with the bracts, become stimulated to grow and unite together into a fleshy compound fruit, the 'Pineapple'. On the surface of the fruit, the hexagonal areas represent the flowers, and the tips of the floral bracts project out. Usually the flowers are sterile and seeds are rarely formed. The inflorescence axis produces a tuft of vegetative leaves, which forms a crown at the top. The vegetative top, if cut and planted, establishes itself in the ground and gives rise to a new plant.



Seed

Seed structure

Seeds vary greatly in size. They can be as small as those of orchids (about two million seeds per gram) or as large as those of coconut. In many plants, the seeds are so peculiar that it helps in identification of a species.

Dicotyledon and Monocotyledon Seeds

On the basis of number of cotyledons in the seed, angiosperms have been divided into two groups:

1. Monocotyledons having embryo with one cotyledon only, eg. **maize, rice, wheat** and **onion**.
2. Dicotyledons having embryo with two cotyledons, eg. **pea, gram, bean** and **castor**.

Structure of gram seed

Gram seed may be taken as an example for the study of the structure of a dicot seed.

The gram seeds are brown in colour. They are pointed at one end and round at the other end. These are contained in a small fruit called, the **pod**. The gram pod is two or three-seeded. The seeds are attached to the wall of the pod by a stalk called the **funiculus**. When the mature seed is detached, the funiculus leaves a scar on the seed called the **hilum**. Just blow the hilum lies the micropyle in the form of a small pore. Water is absorbed through the **micropyle** during the germination of seed. If the soaked seed is squeezed, water is seen to ooze out of the micropyle. The seed is covered by the tough seed coat. The seed coat consists of two layers, outer brownish **testa** and the papery white membranous **tegmen**.

Gram Seed - External Structure

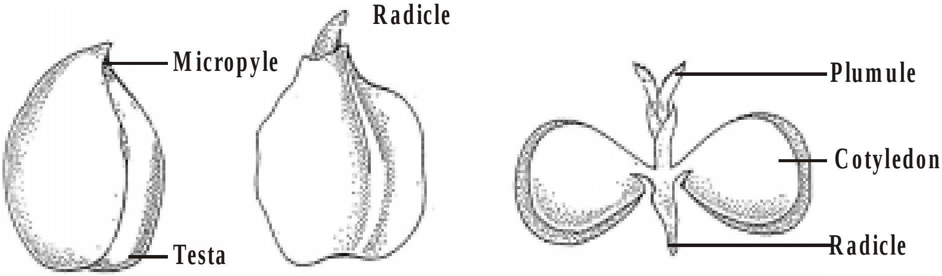


Fig : 3.46. Structure of Dicot seed

The function of seed coat is protective. It protects the seed from desiccation, mechanical injury and extremes of temperature. It also protects the seed from the attack of bacteria, fungi and insects.

On removing the seed coat, two massive and fleshy **cotyledons** are seen. The two cotyledons are attached laterally to the embryonal axis. The embryonal axis projects beyond the cotyledons on either side. The lower pointed end of the axis is the **radicle** which represents the embryonic or rudimentary root. The other end is feathery. It is called the **plumule**. It represents the first apical bud of the future plant and develops into the shoot. The plumule is seen only after separating the two cotyledons. The portion of the axis between radicle and the point of attachment of the cotyledons to the axis is called the **hypocotyl** and the portion between the plumule and the cotyledons is the **epicotyl**. The axis along with the cotyledon constitute the embryo.

2. Structure of Maize Grain

The Maize grain can be taken as an example of monocotyledon seed.

The maize grain is a small one-seeded fruit called the **caryopsis**. In maize grain the seed coat (**testa**) is fused with the fruit wall (**pericarp**). Externally, the maize grain is yellow in colour and somewhat triangular in shape. On one side of the grain is a small, opaque, oval and whitish area in which embryo lies embedded. A longitudinal section of the seed shows the following structures:

1. **Seed coat**: It is formed of a thin layer surrounding the whole grain. This layer is made up of seed-coat and pericarp, i.e. fruit wall.

2. **Endosperm**: When internally examined, maize grain is found consisting of two unequal portions divided by a layer called epithelium. The bigger portion, the endosperm which is yellowish or whitish is the food storage tissue of the grain and is rich in starch. But its outermost layer contains only protein and is called **aleurone layer**. On the other side of the endosperm towards the pointed end lies an opaque body called **embryo**.

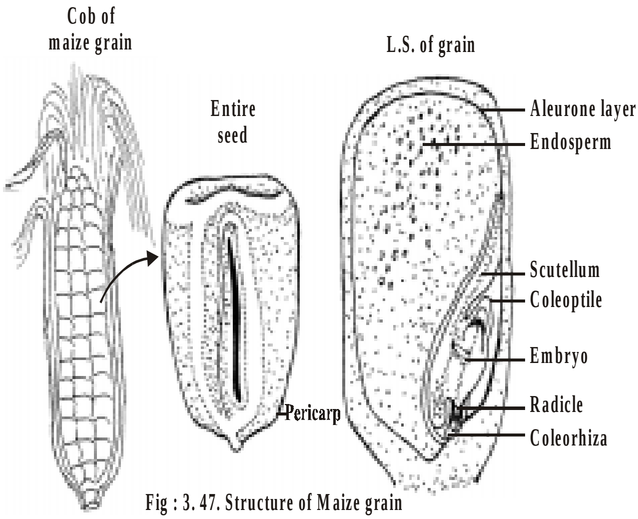


Fig : 3. 47. Structure of Maize grain

3. **Embryo**: It consists of one large and shield shaped **cotyledon**. This is also known as **scutellum** in the case of maize and other cereals. The axis of the embryo lies embedded in the scutellum. The axis consists of a **plumule** at the upper portion and the **radicle** at the lower end. Both radicle and plumule are enclosed in sheath. The sheath covering the plumule is known as **coleoptile** and that covering the radicle is known as **coleorhiza**. The cone-shaped coleoptile has a pore at the apex through which the first foilage leaf emerges during germination.

Types of Seed

Non-endospermic or ex-alubuminous seeds

In gram, pea and bean the cotyledons are thick and fleshy. They store food material for the embryo during germination. Such seeds are known non-endospermic or exalubuminous seeds.

Endospermic or albuminous seeds

However, in seeds like castor, maize and other cereals, the cotyledons are thin and membranous. In such seeds food is stored in the endosperm. Cotyledons act as absorbing organs. They absorb food from the endosperm and supply it to the growing embryo. Such seeds are known as endospermic or albuminous seeds.

SELF EVALUATION

One Mark

Choose the correct answer

1. The most conspicuous and characteristic structure of Angiosperm is
   a. Flower b. Seeds c. Fruits d. Leaves

2. The number of whorls present in a bisexual flower is
   a. One b. Three c. Two d. Four

3. A flower is said to be complete when it has
   a. One whorl b. Three whorls c. Two whorls d. Four whorls

4. Trimerous Flowers are common among
   a. Dicotrs b. Xerophytes c. Monocots d. Gymnosperms

5. In deciduous type of calyx, the sepals fall off
   a. As soon as flower opens b. After fertilization
   c. In the bud condition d. All the above

6. When anthers have two chambers, they are described as
   a. Dioecious b. Dithecous c. Diadelphous d. Dimorphic

7. Gynoecium with united carpels is termed as
   a. Apocarpous b. Multicarpellary
   c. Syncarpous d. None of the above

8. The type of placentation seen in cucumber is
   a. Basal b. Parietal c. Axile d. Marginal

9. Seeds are produced from the
   a. Ovary b. Carpels c. Ovules d. Locules

10. Seedless Grapes are the
    a. Simple Dry fruits b. Multiple fruits
    c. Aggregate fruits d. Parthenocarpic fruits

11. Which is the edible portion in berry?
    a. Epicarp b. Endocarp c. Mesocarp d. All the above

12. Coconut belongs to
    a. Drupe b. Syconium c. Baccate d. Aggregate

13. The type of fruit seen in Jack is
    a. Multiple fruit b. Syconium c. Sorosis d. Aggregate

Fill in the blanks

1. A special leaf at whose axil the flower develops is called ....
2. Thalamus is otherwise called ....
3. .... flower has both androecium and gynoecium
4. A flower having uniform number of all the floral parts is called ....
5. Microsporangia are otherwise called ....
6. After fertilization, the ovary becomes ....
7. Legume is the characteristic fruit of .... family.
8. The edible part of the Jack fruit is ....

I. Match the following

Hypogynyous	-	Petals of Malvaceae
Twisted	-	Superior ovary
Syngenesious	-	Stamens attached to petals
Epipetalous	-	Anthers united, filaments free
Basal Placentation	-	Asteraceae
Caryopsis	-	Pericarp
Unfertilized Ovary	-	Paddy
Ovary Wall	-	True fruit
Fertilized Ovary	-	Aggregate fruit
Apocarpous Ovary	-	Parthenocarpic fruit

Two Marks

1. What are monoecious plants?
2. Define aestivation.
3. What is a bisexual flower?
4. What is a zygomorphic flower? Give Example.
5. Distinguish between monothecous and dithecous anthers.
6. What is meant by monadelphous stamens?
7. Distinguish between apocarpous and syncarpous ovary.
8. Define fruit.
9. What are the three groups of fruits?
10. Define simple fruit.
11. What are dry dehiscent fruits?
12. What are the two processes necessary for the development of fruits?

13. Define aggregate fruits.
14. What is legume? Give an example.
15. How does a fleshy fruit differ from a dry fruit?

Five Marks

1. Explain the hypogynous and epigynous flowers with examples.
2. Explain different types of calyx.
3. How the symmetry of a flower is determined? Briefly describe different types of symmetry seen in flower.
4. Describe aggregate fruit with a suitable example.
5. Describe multiple fruit with a suitable example.
6. Bring out the essential difference in the structure of a dicot and monocot seed by means of labelled diagrams only.

Ten Marks

1. Explain the different types of placentation with example.
2. Given an account of different types of aestivation with example.
3. Describe the essential organs of a flower.
4. Explain different types of fleshy fruits with suitable examples.
5. Describe dry dehiscent fruits with suitable examples.
6. Describe the structure of Maize grain with the help of diagram. How does it differ from a Cicer seed?

IV. GENETICS

1. Concept of Heredity and Variation

The children or offsprings closely resemble their parents and to some extent their grand parents and great grand parents. Still the offsprings of a set of parents differ from each other and from their parents in different degrees. They have certain unique characteristics by which we can understand that they belong to the same family. The Science that deals with the mechanisms responsible for inheritance of similarities and differences in a species is called **Genetics.** It is a branch of biology that encompasses the study of the mechanism of transmission of characters from parents to offsprings. The word "genetics" is derived from the Greek word "genesis" meaning "to grow" or "to become".

The Science of Genetics helps us to differentiate between heredity and variations and seeks to account for the resemblances and differences due to heredity, their source and development.

Heredity refers to the transmission of characters, resemblances as well as differences from one generation to the next. It explains how offsprings in a family resemble their parents.

Variation refers to the differences shown by individuals of the same species and also by offsprings (siblings) of the same parents. It explains why offsprings eventhough born to the same parents differ from each other. They are similar, but not identical (except in identical twins). These similarities and differences are not coincidental.

In brief, genetics is the study of heredity and variation.

Heredity

Heredity refers to the transmission of characters from parents to the offsprings. In the very early ages though improvement of the races of plants and animals were conducted by the Babylonians and Assyrians, it was not known what exactly caused the characters to be passed from one generation to the next.

Some early views of heredity

Many view points were put forward before Mendel to explain the transfer of characters to the subsequent generation.

1. Moist Vapour Theory

This was put forward by the Greek philosopher Pythagoras who believed that each organ of the animal body produced vapours and new organism was formed by combination of different organs.

2. Fluid Theory

This was propounded by Aristotle who was of the view that both male and female produced semen and when these mix the female semen which is not so pure provided the inert substance for the formation of the embryo and the male semen gave form and vitality to the embryo.

3. Preformation Theories

Anton Von Leeuwenhoeck observed human sperms for the first time. This theory according to Swammerdam (1679) postulates that the sex cells either the sperm or egg contained within itself the entire organism in a miniature form called **"homunculus"**. Development was only an increase in size of the miniature. This theory was supported by Malpighi (1673), Delepatius (1694) and Roux (1800).

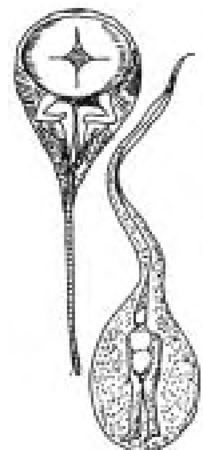


Fig : 4.2 Homunculus as per Preformation Theory

4. Particulate Theory

French biologist Maupertius propounded that the body of each parent gave rise to minute particles for reproduction which blend together to form the offspring.

5. Pangenesis

This theory proposed by Aristotle (384-322 B.C.) holds that the animal body produces minute bodies called **gemmules** or **pangenes** which were carried by blood to the reproductive organs. Here the pengenes from two parents blend to give rise to a new individual.

This theory prevailed for many centuries and was accepted by great biologists such as Charles Darwin (1809 - 1882).

Evidences against the Blending Theory

The individual, according to the views of the Pre-Mendelian era represents the mixture of characters of both parents. This was the **blending theory.** Under this concept the progeny of a black and white animal would uniformly be grey. The progeny from further crossing the hybrids would all remain grey as the characters once blended can never be separated again. But however in daily life it is seen that children of black and white parents may be dark, fair or of a intermediate complexion. So also their children may be dark or fair.

Pattern of inheritance shown by atavism is also against blending inheritance. In atavism, the grandchildren may exhibit a feature of an earlier generation not seen in the parents. The traits of sex (male or female) do not blend in unisexual organisms.

Basic features of Inheritance / Heredity

The Swedish taxonomist **Carolus Linnaeus** and two german plant breeders **Kolreuter** and **Gaertner** performed artificial cross pollination in plants and obtained hybrids. Kolreuter was able to obtain evidence to show the inherited traits remained discrete without blending. Though his results were similar to that of Mendel, he was not able to interpret them correctly.

Mendel's great contribution was that he replaced the **blending theory** with the **particulate** theory. Mendel first presented his findings in 1865, but they were not accepted then and remained unknown for many years. Their rediscovery in 1900 by **de Vries** of Holland, **Carl Correns** of Germany and **Tschermak** of Austria independently, led to the beginning of modern genetics.

Few important characteristics of inheritance are:

i. Every trait has two alternative forms.

ii. One alternative form is more commonly expressed than the other.

iii. Any alternative form can remain unexpressed for many years.

iv. Hidden character may reappear in original form.

v. Characters or traits are expressed due to discrete particulate matter and so do not get blended or modified.

SELF EVALUATION

One mark

Choose the correct Answer

1. Moist vapour theory was given by

   a. Aristotle b.Pythagoras c. Delepatius d. Darwin

2. Blending theory was replaced by particulate theory of

   a. Kolreuter b.Gaertner c. Mendel d.Darwin

3. The grand children may exhibit a feature of an earlier generation not seen in parents. This is called

   a. Homunculus b. Pangenesis c. Atavism d. Blending

Fill in the blanks

1. Polydactyly is the example for ....
2. A group of ramets is called a ....

Two marks

1. Define Heredity / Variation / Homunculus / Parthenogenesis / Pangenes

Five Marks

1. Explain the significance of variation
2. Give the early views of heredity
3. What are basic features of inheritance

Ten Marks

1. Write an essay on the different types of variations

2. Mendel's Laws of Inheritance

Introduction

Gregor Johann Mendel was an Austrian monk, who was the first to explain the mechanism of transmission of characters from the parents to the offsprings. He maintained that there were particles called **factors**, which carried the traits to the subsequent generation. This holds good even today and since he is the pioneer of **modern Genetics**, he is called **The Father of Genetics**.

Biography of Mendel

Gregor Johann Mendel was born in 1822 to a family of poor farmers in **Silisian**, a village in **Heizendorf** which is now a part of Czechoslovakia. After finishing his high school, at the age of 18, he entered the Augustinian monastery at Brunn as a priest. From here he went to the University of Vienna for training in **Physics, Mathematics** and **Natural Sciences**. Here he was influenced by two scientists Franz Unger (a plant physiologist) and Christian Doppler (the physicist who discovered Doppler effect) and he himself became interested in hybridisation experiments.

Mendel returned to the monastery in 1854, and continued to work as a priest and teacher in the high school. In his spare time, he started his famous experiments on garden pea plant (*Pisum sativum*) which assumes great historic importance. He conducted his experiments in the monastery garden for about nine years from 1856 to 1865.

The findings of Mendel and his laws were published in the journal **Annual Proceedings of the Natural History Society of Brunn,** in 1865. The paper was entitled **Experiments in Plant Hybridisation**. But his work was not accepted or lauded by the scientific world at that time because

i. The journal was obscure.

ii. His concept was far ahead of his time.

iii. The scientists were busy with the controversy over Darwin's Theory of Origin of species and

iv. Mendel not being very sure of his findings lacked an aggressive approach.

Later in the year 1900, three scientists **Carl Correns** of **Germany**, **Hugo de Vries** of **Holland** and **Tshermak** of **Austria** independently rediscovered Mendel's findings and brought to light the ingenuity of father Mendel. To recognise his work, it was named as **Mendel's Laws** and **Mendelism**.

Mendel's Experiments

Mendel conducted cross breeding experiments in the garden pea plant (*Pisum sativum*).

He crossed two pea plants with contrasting character traits considering one character at a time. The resulting hybrids were crossed with each other. The data of many crosses were pooled together and the results were analysed carefully.

Reasons for Mendel's Success

A combination of luck, foresight and the aptitude of Maths all contributed to the success of Mendel's experiments.

Selection of Material

He chose the pea plant as it was advantageous for experimental work in many respects such as :

1. It is a naturally self-fertilizing plant and so it is very easy to raise pure-breeding individuals.
2. It has a short life span as it is an annual and so it is possible to follow several generations.
3. It is easy to cross-pollinate the pea plant.
4. It has deeply defined contrasting characters.
5. The flowers are all bisexual.

Therefore the pea plant proved to be an ideal experimental plant for Mendel.

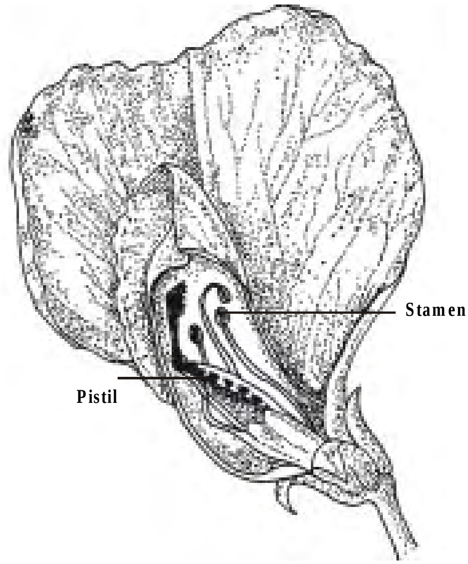


Fig : 4.3. L.S. of *Pisum sativum* flower

Method of Work

1. He conducted hybridisation experiments in true breeding parents (individuals which produce the same type of offsprings for any number of generations when selfed).
2. Mendel worked with seven pairs of contrasting character traits and he considered one pair of contrasting character traits at a time.
3. He carried out his experiments to the second and third generations.
4. He maintained a clear statistical record of his work.

Table 4.1. Contrasting characters of traits chosen by Mendel

S.No.	Character	Dominant	Recessive
1.	Seed shape	Round	Wrinkled
2.	Cotyledon colour	Yellow	Green
3.	Seed coat colour	Grey	White
4.	Pod shape	Inflated	Constricted
5.	Pod Colour	Green	Yellow
6.	Position of Pod or Flower	Axillary	Terminal
7.	Stem length (Height)	Tall	Dwarf

Crossing Techniques

Since garden pea is self pollinating, great care was taken to see that

a. The parents were **emasculated** to prevent self pollination.

b. The anthers were collected from **male parent** and dusted onto the **female parent** and the stigma was bagged.

c. The seeds were collected separately in marked bottles.

d. **Reciprocal crosses**, (by interchanging the male and female parents) were conducted to prove that there was no change in the ratio of the offsprings i.e. sex has no influence on inheritance.

The plants used as parents represent the parental generation designated as P. The resulting progeny from crossing of parents is called first filial generation designated as F_1 and progeny resulting from selfing the F_1 plants was called second filial generation, denoted as F_2.

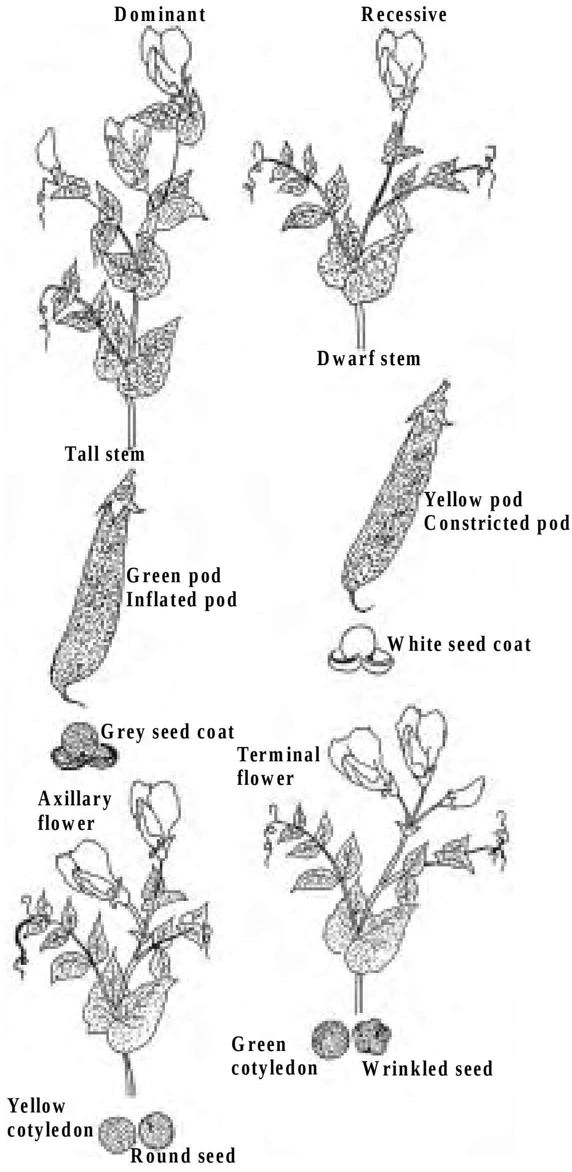


Fig : 4.4. Contrasting characters of traits chosen by Mendel

Crosses involving inheritance of only one pair of contrasting characters are called **monohybrid crosses** and those involving 2 pairs of contrasting characters are called **dihybrid crosses**.

Monohybrid Cross

(Experiments with garden pea for a single pair of contrasting characters)

P TT tt

Tall x Dwarf

Gametes (T) (t)

$\mathbf{F_1}$ Tt Monohybrid

Tall (Selfing)

Gametes **(T)** **(t)**

$\mathbf{F_2}$

	T	t
T	TT	Tt
t	Tt	tt

TT - 1 Homozygous tall

Tt - 2 Heterozygous tall

tt - 1 Dwarf

Tall : Dwarf = 3:1

Mendel's Explanation of Monohybrid Cross

Parental Generation : Mendel selected a pure breeding tall plant and a pure breeding dwarf plant as parents (Homozygous).

$\mathbf{F_1}$ **Generation** : He crossed the parents and from the seeds obtained he raised the first filial generation. Here the plants were all tall and were called monohybrids.

$\mathbf{F_2}$ **Generation**: Mendel allowed selfing of the F_1 monohybrids and he obtained Tall and dwarf plants respectively in the ratio of 3:1. The actual number of tall and dwarf plants obtained by Mendel were 787 tall and 277 dwarf. The ratio of **3:1** is called **Phenotypic ratio** as it is based on external appearance of offsprings.

$\mathbf{F_3}$ **Generation**: By selfing the F_2 offsprings Mendel obtained the F_3 generation. He found that

1. The F_2 dwarf plants always bred true generation after generation whether self or cross pollinated.

2. Of the F_2 tall plants one third bred true for tallness. The rest two thirds produced tall and dwarf in the ratio of 3:1. This meant that the F_2 generation consisted of 3 types of plants.

i.	Tall homozygous (pure)	-	25%
ii.	Tall heterozygous	-	50%
iii.	Dwarf homozygous (pure)	-	25%

Thus based on the constitution of factors the ratio of a Monohybrid cross is **1:2:1** which is called the **genotypic ratio**.

Mendel's Interpretation and Explanation

During Mendel's time structure of chromosomes or the role of meiosis was not known. So he concluded that the inheritance of characters is by particles called **hereditary units** or factors.

He explained the results of Monohybrid cross by making certain presumptions.

i. Tallness and dwarfness are determined by a pair of contrasting factors (now called as genes). A tall plant possesses a pair of determiners (represented by **T**-taking the first letter of the dominant character) and a plant is dwarf because it possesses determiners for dwarfness (represented as **t**). These determiners occur in pairs and may be alike as in pure breeding tall parents (**TT**) and dwarf parents (**tt**). This is referred to as **homozygous**. They may be unlike as in the monohybrid (**Tt**) which is referred to as **heterozygous**.

ii. The two factors making up a pair of contrasting characters are called **alleles** or **allelomorphs**. One member of each pair is contributed by one parent.

iii. When two factors for alternative expression of a trait are brought together by fertilization only one expresses itself, (tallness) masking the expression of the other (dwarfness). The character which expresses itself is called **dominant** and that which is masked is called the **recessive** character.

iv. The factors are always pure and when gametes are formed, the unit factors segregate so that each gamete gets one of the two alternative factors. It means that factors for tallness (T) and dwarfness (t) are separate entities and in a gamete either T or t is present. When F_1 hybrids are selfed the two entities separate and then unite independently forming tall and dwarf plants.

Dihybrid Cross

(Cross involving two pairs of contrasting characters)

Mendel also experimentally studied the segregation and transmission of two pairs of contrasting characters at a time. This was called the **Dihybrid cross** or **Two-factor cross**. He took up the round and wrinkled characters of seed coat along with yellow and green colour of seeds.

Mendel found that a cross between round, yellow and wrinkled green seeds (P) produced only round yellow seeds in the F_1 generation, but in the F_2 generation 4 types of combinations appeared of which two were different from that of the parental combinations, in the following ratio.

These are :

Round Yellow	-	9	Parental
Round Green	-	3	New combination
Wrinkled Yellow	-	3	New combination
Wrinkled Green	-	1	Parental

Therefore the offsprings of the F_2 generation in a dihybrid cross were produced is a ratio of **9:3:3:1**. This ratio is called the **dihybrid ratio**.

In F_2 generation, since all the four characters assorted out independent of the others, he said that a pair of contrasting characters behave independently of the other pair. i.e. seed colour is independent of seed coat. At the time of gamete formation in the F_1 dihybrid, genes for round or wrinkled character of seed coat assorted independently of the yellow or green colour of seed coat. As a result 4 types of gametes with two old and two combinations were formed namely RY, Ry, rY and ry. These 4 types of gametes on random mating produced 16 offsprings in the ratio of 9:3:3:1. The actual number of individuals got by Mendel for each of the four classes were

a. 315 round yellow seeds

b. 108 round green seeds

c. 101 wrinkled yellow seeds

d. 32 wrinkled green seeds

Mendel represented round character of seed as **R** and wrinkled as **r**, and yellow character as **Y** and green character as **y**. So the dihybrid cross was between parents having **factor constitution** as **RRYY** x **rryy**. This cross may be represented as follows:

Round Yellow   Wrinkled Green

P RRYY x rryy

Gametes (RY) (ry)

F_1 RrYy (Dihybrid)

Round Yellow (selfed)

Gametes (RY) (Ry) (rY) (ry)

F_2

	RY	Ry	rY	ry
RY	RRYY Round yellow	RRYy Round Yellow	RrYY Round Yellow	RrYy Round Yellow
Ry	RRYy Round Yellow	RRyy Round Green	RrYy Round Yellow	Rryy Round Green
rY	RyYY Round Yellow	RrYy Round Yellow	rrYY Wrinkled Yellow	rrYy Wrinkled Yellow
ry	RrYy Round Yellow	Rryy Round Green	rrYy Wrinkled Yellow	rryy Wrinkled Green

Laws of Mendel

Based on his experiments of monohybrid and dihybrid cross, Mendel proposed three important laws which are now called Mendel's Laws of Heredity.

i. Law of dominance and recessiveness

ii. Law of segregation or Law of purity of gametes

iii. Law of independent assortment

i. Law of Dominance

The law of dominance and recessiveness states : "When two homozygous individuals with one or more sets of contrasting characters are crossed, the characters that appear in the F_1 hybrid are **dominant** and those that do not appear in F_1 are **recessive** characters".

ii. Law of Segregation or Law of Purity of Gametes

The Law of segregation states that "When a pair of contrasting factors or genes or allelomorphs are brought together in a heterozygote or hybrid, the two members of the allelic pair remain together without mixing and when gametes are formed the two separate out, so that only one enters each gamete".

This law though it was a conception originally and propagated by Mendel, now it has been confirmed by cytological studies. Dominance or no dominance segregation holds good for all cases.

iii. Law of independent Assortment

Law of independent assortment states : "In case of inheritance of two or more pairs of characters simultaneously, the factors or genes of one pair assort out independently of the other pairs".

Mendel gave this law based on his dihybrid cross experiment. Here the total number of individuals in F_2 will be sixteen which occur in a ratio of 9:3:3:1 where two parental classes and two new combinations will be produced.

Back cross and Test Cross

In Mendelian inheritance F_2 offsprings are obtained by selfing the hybrid, but if the F_1 hybrid is crossed to any of the pure breeding parents it is called a **back cross**. If the hybrid is crossed to the dominant parent, all the F_2 offsprings will show dominant character.

If the hybrid is crossed to recessive parent, dominant and recessive phenotypes with appear in equal proportions as shown, which is called a **test cross**.

Monohybrid Back Cross

F_1 Tt x TT

(Back cross)

Gametes (T) (t) (T)

F_2

	T	**t**
T	TT	Tt

All are tall

Monohybrid Test Cross

F_1	Tt	x	tt (Test cross)
Gametes	(T) (t)		(t)

F_2

	T	**t**
t	Tt	tt

Tall : Dwarf = 1: 1

Dihybrid Test Cross

In a dihybrid test cross the four types of phenotypes are obtained in equal proportions as shown. The test cross is used to determine whether segregation of alleles has taken place and to ascertain if hybrid is homozygous or heterozygous.

F_1	RrYy	x	rryy
	dihybird		recessive parent

Gametes (RY) (Ry) (rY) (ry) (ry)

F_2

	RY	**Ry**	**rY**	**ry**
ry	RrYy Round Yellow	Rryy Round Green	rrYy Wrinkled Yellow	rryy Wrinkled Green

RrYy	Rryy	rrYy	rryy
Round Yellow	Round Green	Wrinkled Yellow	Wrinkled Green

1 : 1 : 1 : 1

SELF EVALUATION

One Mark

Choose the correct answer

1. The village where Mendel was born is

   a. Heizendors b.Silisian c. Brunn d. Austria

2. The cross which proves that sex has no influence on inheritance is

   a. Back cross b. Test cross c. Reciprocal cross d. Monohybrid cross

3. The recessive state for seed coat colour is

   a. Green b. Grey c. Yellow d. White

Fill in the blanks

1. The pairs of contrasting character traits of Mendel are called ....
2. The dihybrid test cross ratio is ....

Match

1.	Plant height	- Wrinkled
2.	Position of flower	- Constricted
3.	Colour of pod	- Terminal
4.	Seed shape	- Dwarf
5.	Pod shape	- Yellow

Two Marks

1. Name the three scientists who rediscovered Mendel's work
2. Define true breeding / Monohybrid test cross / Back cross / Alleles / Law of purity of gametes / Dihybrid test cross.

Five Marks

1. Write short notes on the Life History of Mendel.
2. Explain the reasons for Mendel's success.
3. Describe the Monohybrid cross.

Ten Marks

1. Write an essay on Mendel's Dihybrid cross.
2. Give an account of the Laws of Mendel.

3. Chromosomal Basis of Inheritance

The **factors** of Mendel were called **genes** by Johansen 1909, who did not know their exact nature and structure.

Gene Concept

Sutton introduced the gene concept which was elaborated by the studies of **Morgan**, **Bridges** and **Miller**.

The important features of the gene concept are:

i. Genes are transmitted from parents to offsprings and are responsible for the physical and physiological characteristics of the organism which are present inside the nucleus of the cell.

ii. The genes are present on the chromosome.

iii. Since the number of genes far exceeds the number of chromosomes, several genes are located on each chromosome. In man about 40,000 genes are present in 23 pairs of chromosomes.

iv. The genes are present at a specific position on the chromosome called **locus**.

v. Genes are arranged on the chromosomes in a linear order like beads on a string.

vi. A single gene may have more than one functional state or form. These functional states are refered to as alleles.

vii. The alleles may be dominant or recessive but sometimes co-dominance or incomplete dominance may be seen.

ix. Genes may undergo sudden heritable changes called mutations, induced by chemical and physical factors.

x. Due to mutation a gene may come to possess more than two alternative states and these states of the gene are called multiple alleles.

xi. Genes undergo duplication by a phenomenon called replication.

xii. Genes are responsible for the production of proteins called enzymes by which they show their expression which brings about a change in the organism.

xiii. A gene is a particular DNA segment which contains the information to synthesize one polypeptide chain or one enzyme. The information is contained as a sequence of nucleotides which is called **genetic code**. The sequence of three nucleotides that code for an aminoacid is called **Codon**.

Molecular structure of a gene

A gene, is made of DNA. The gene may be subdivided into different units according to Benzer such as Recon, Muton, Cistron and Operon.

Recon

It is that smallest portion of a gene which can undergo crossing over and recombination and may be as small as a single nuclecotide pair.

Muton

It is the smallest unit of a gene that can undergo mutation and can involve a pair of nucleotides.

Cistron

It is the functional unit which can synthesize one polypeptide.

Operon

It is a group of genes having an operator a **structural gene** and other genes in sequence which all function as a unit.

Exons and Introns

In Prokaryotes generally, the genes are continuous segments of DNA occurring collinearly without interruption. But in Eukaryotes, the genes on the DNA strand have coding regions called **exons** interrupted by non-coding DNA segments which do not carry genetic information called **introns**. This led to the concept of **interrupted genes** or **discontinuous genes**. Such genes while producing m-RNA will first form a primary transcript which will then cut off the introns to form the functional m-RNA and this is called **splicing**.

Chromosomal basis of inheritance

The chromosome basis of inheritance was put forth by **Sutton and Boveri independently** in the year **1902**. W.S. Sutton and Theodor Boveri faced and solved the problem of drawing a parallel between chromosomes and genes.

Both had concluded that the genes are contained in chromosomes. Allelic genes present in a heterozygote segregate independently because the chromosomes carrying these genes segregate when the sex cells are formed. This conclusion of Sutton and Boveri was verified extensively by further studies conducted by various geneticists and cytologists.

In order to accept this conclusion we must be able to understand the behaviour of chromosomes in the light of Mendel's assumption.

i) **Individuality of Chromosomes :**Every organisms has a fixed number of chromosomes. The nuclei of gametes contain haploid (n) and those of zygotes have double the number or diploid (2n) number of chromosomes.

ii) **Meiosis :** At the time of meiosis, for the formation of gametes, the pairs of chromosomes of the diploid sets undergo pairing.

iii) The chromosomes of each pair segregate independently of every other pair during their distribution into gametes. This is similar to Mendel's law of independent assortment in the segregation of factors.

iv) During the fusion of haploid gametes, the homologous chromosomes from two parents are brought together to form the diploid zygote. Accordingly Mendel had maintained that maternal and paternal characters mix up in the progeny.

v) The chromosomes maintain the structure and uniqueness during the life time of the individual whether observable or not. Mendel had also demonstrated that the characters are never lost though they are not expressed in a particular generation.

From these points it is evident that a clear parallelism exists between Mendel's factors and chromosomes and so there is a firm basis for Mendel's Laws of heredity in the behaviour of chromosomes during meiosis and fertilisation and therefore the **Chromosomal Theory of Inheritance** has been proposed.

Postulates of the Chromosomal Theory of Inheritance

i. The factors described by Mendel are the genes which are the actual physical units of heredity.

ii. The genes are present on chromosomes in a linear order.

iii. Each organism has a fixed number of chromosomes which occur in two sets referred to as diploid (2n). A pair of similar chromosomes constitute the homologous pair.

iv. Of this, one set is received from the male parent (paternal) and the other from the female parent (maternal).

v. The maternal and paternal chromosomes are contributed by the egg and sperm respectively during zygote formation. But only sperm nucleus is involved proving that chromosomes are present within the nucleus.

vi. The chromosomes and therefore the genes segregate and assort independently at the time of gamete formation as explained in Mendel's law of segregation and Law of Independent Assortment.

Physical and Chemical Basis of Heredity

Physical Basis

Gregor Johann Mendel put forward in 1866 that particles called **germinal units** or **factors** controlled heredity. These were present in both the somatic cells as well as the germinal cells. Though he was not able to actually see these particles, he did explain the pattern of inheritance of genetic characters. It was the gamete which carried these factors to the next generation and so gametes form the **physical basis of heredity.**

Chemical Basis

Now it is known that genes control heredity and these are definite segments of chromosomes and so are particulate bodies. The genes travel from one generation to the next carrying the traits and since gene is composed of DNA and protein, the DNA part functions as the **chemical basis of heredity**.

Self Evaluation

One Mark

Choose the correct Answer

1. The smallest unit of the gene which codes for an amino acid is

   a. Cistron   b. Muton   c. Recon   d. Codon

2. The functional unit of a gene which can synthesize one polypeptide is called

   a. Codon   b. Cistron   c. Muton   d. Recon

3. The gene is present at a specific position on the chromosome called

   a. Locus   b.Nucleotide   c. Nucleoside   d. Allele

4. The chromosomal basis of inheritance was given by

   a. Schleiden & Schwann   b. Sutton & Boveri
   c. Singer & Nicholson   d. Morgan & Bridges

Two Marks

1. Define : Exon / Intron / Splicing / Codon

Five Marks

1. Explain the molecular structure of a gene
2. Give an account of the postulates of the chromosome theory of inheritance

Ten Marks

1. List the important feature of the gene concept.
2. Draw a parallel between Mendel's factors and chromosomes and explain the chromosomal theory of inheritance.

4. Intermediate Inheritance (Incomplete Dominance)

From Mendel's experiments it had been established that when two alleles are brought together from two different pure breeding parents, one of them completely dominates over the other manifesting itself in the hybrid. Researches by many investigators revealed that in a number of living organisms complete dominance was absent, the hybrid exhibited an intermediate character as both the genes of the allelomorphic pair showed partial expression.

Thus in **incomplete dominance** or **partial dominance** or **intermediate inheritance** or **blending inheritance** the F1 hybrid does not resemble either of the parents. A very good example for this is the 4 `O' clock plant *Mirabilis jalapa* studied by Correns in 1906. A similar condition is seen in *Antirrhinum majus*.

In *Mirabilis jalapa*, there are two distinctive types of flower colours namely the red and the white. Both the types are true breeding. When a pure-red flowered (r_1r_1) variety is crossed with a pure white flowered (r_2r_2) one, the F1 hybrids produce pink flower, a character which is intermediate between red and white coloured flowers of the parental generation. This is because neither red flower colour nor white is completely dominant over the other. When F1 hybrids were selfed red, pink and white flowered varieties were obtained respectively in the ratio of 1:2:1. This is the phenotypic ratio. Here the genotypic ratio is also 1:2:1, producing one homozygous red, two heterozygous pink and one homozygous white. The red and the white varieties breed true on self fertilisation of the F_2 individuals but the pink varieties on selfing once again produce a phenotypic ratio of 1:2:1 proving the law of purity of gametes.

Since neither of the parents is completely dominant over the other, the symbol for Red parent is r_1r_1 and the white parent r_2r_2, and so naturally the genotype of the hybrid is r_1r_2.

It has been observed in the given example that there is blending of phenotypes - not genotypes and the alleles of the genes are discrete or particulate. They appear blended in F_1 but have separated out in F_2 generation.

Incomplete dominance is also called blending inheritance because both the characters of the parental plants are mixed to give an intermediate character which is different from that of the parents. But only the characters are mixed with each other and not the alleles. In *Mirabilis* the r_1r_1 always produces red coloured flowers and r_2r_2 produces white coloured flowers, when they are combined, the intermediate colour namely pink is produced. Because of this it is described as blending inheritance.

	Red		White
P	r_1r_1	x	r_2r_2
Gametes	(r_1)		(r_2)
$\mathbf{F_1}$		r_1r_2 (Selfed) Pink	
Gametes		(r_1) (r_2)	

$\mathbf{F_2}$

	r_1	r_2
r_1	r_1r_1	r_1r_2
r_2	r_1r_2	r_2r_2

Red : Pink : White

1 : 2 : 1

r_1r_1 : r_1r_2 : r_2r_2

Self Evaluation

One Mark

Choose the correct answer

1. Incomplete dominance is also called
   a. Intermediate inheritance b. Blending inheritance
   c. Partial dominance d. All the above
2. The phenomenon of intermediate inheritance is observed in
   a. *Lathyrus* b. *Antirrhinum* c. *Cucurbita* d. Maize
3. The phenotypic ratio of incomplete dominance is
   a.1:2:1 b.3:1 c.9:3:3:1 d.1:1

Two Marks

1. Define : Incomplete dominance

Five Marks

1. Why is intermediate dominance also called blending inheritance?

Ten Marks

1. Explain intermediate inheritance in the 4' 0' clock plant.

5. Epistasis

The pioneer work of Gregor Johann Mendel seemed to imply that every character was determined by a single factor or determiner or in other words a pair of genes influenced one trait. Later work by geneticists led to the idea that a character need not necessarily be due to the action of a single factor but may also be due to the action of several factors. These hereditary units or factors are now known as genes.

Gene Interaction

The genes interacting to affect a single trait, if present on different chromosomes will show independent assortment and no interference between the effects of different genes. The condition where one pair of genes reverses or inhibits the effect of another pair of genes by causing the modification of the normal phenotype is called gene interaction.

Types

Gene interaction is of two types

1. Allelic or intragenic interaction

This kind of interaction occurs between alleles of the same gene pair as in the case of incomplete dominance, co dominance and multiple allelism.

2. Non-allelic or intergenic interactions

These interactions occur between alleles of different genes present either on the same or different chromosome and alter the normal phenotype. Complementary gene interaction, supplementary gene interaction, duplicate factors and inhibitory factors are examples of intergenic interactions.

Epistasis

There are two pairs of independent non-allelic genes affecting a single trait.

The suppression of the gene on one locus of a chromosome by the gene present at some other locus is called **epistasis** meaning "standing over". The gene which is suppressed is called hypostatic and the other is the epistatic or inhibiting gene which is also called the suppressing gene.

Epistasis can be of the following types.

1. Due to recessive gene : Recessive gene **a** masks the effect of dominant gene **B**.
2. Due to dominant gene : Dominant gene **A** masks the effect of the dominant gene **B**. Apart from this, the term epistasis refers to all non-allelic interactions involving a pair of genes. Therefore epistasis may be responsible for the production of several modified dihybrid ratios as follows:

1. Duplicate recessive epistasis (9:7)
2. Dominant epistasis (12:3:1)
3. Recessive epistasis (9:3:4)
4. Dominant recessive epistasis (13:3)
5. Duplicate dominant epistasis (15:1)

Duplicate Recessive Epistasis

This type of inheritance is also called **complementary gene interaction** observed in *Lathyrus odoratus* (Sweet pea) by Bateson and Punnett. Inheritance of flower colour was studied.

When two pure breeding white flowered varieties of sweet pea where crossed, the F_1 hybrids were all purple flowered plants. When the F_1 hybrids were selfed, purple and white flowered varieties were produced respectively in the ratio of 9:7.

Explanation

Here two dominant genes C and P interact to produce purple colour. When any one of the genes is present in recessive condition, colour is not produced. Thus both the genes in the recessive state inhibit the formation of purple colour and so this has been referred to as Duplicate recessive epistasis.

Biochemical explanation for production of Flower colour

Dominant gene (C) controls the production of a pigment precursor called chromogen and the dominant gene (P) is responsible for the production of the enzyme which converts the chromogen into the pigment anthocyanin which is responsible for the purple colour.

If gene C is absent there is no formation of chromogen and if gene P is absent chromogen does not get converted to anthocyanin. Thus both the genes have to be in dominant state for production of purple coloured flowers.

White Flowered   White Flowered

P   CCpp   X   cc PP

Gametes   (Cp)   (cP)

$\mathbf{F_1}$ CcPp (Selfed)

Purple Flowers

Cc Pp   x   Cc Pp

Gametes (CP) (Cp) (cP) (cp)

$\mathbf{F_2}$

	CP	**Cp**	**cP**	**cp**
CP	**CCPP Purple**	**CCPp Purple**	**CcPP Purple**	**CcPp Purple**
Cp	**CCPp Purple**	**CCpp White**	**CcPp Purple**	**Ccpp White**
cP	**CcPP Purple**	**CcPp Purple**	**ccPP White**	**ccPp White**
cp	**CcPp Purple**	**Ccpp White**	**ccPp White**	**ccpp White**

Purple : White

9 : 7

Dominant Epistasis - 12:3:1

This type of interaction was studied by Sinnott in summer squash (*Cucurbita pepo*).

In *Cucurbita pepo* there are three common fruit colours white, yellow and green. White colour is produced due to the presence of dominant gene W. In the absence of W, the dominant gene Y produces yellow fruit colour and the double recessive is green. The effect of dominant gene `Y' is masked by dominant gene `W' which is the epistatic gene so this is called **dominant epistasis**.

When pure breeding white fruited variety is crossed with the double recessive green variety, the F1 hybrids are all white. When the hybrids are selfed, white, yellow and green fruited plants arise respectively in the ratio of 12:3:1

White Green

P WWYY X wwyy

Gametes (WY) (wy)

$\mathbf{F_1}$ WwYy (Selfed)

White

WwYy x Ww Yy

Gametes (WY) (Wy) (wY) (wy)

$\mathbf{F_2}$

	WY	**Wy**	**wY**	**wy**
WY	**WWYY White**	**WWYy White**	**WwYY White**	**WwYy White**
Wy	**WWYy White**	**WWyy White**	**WwYy White**	**Wwyy White**
wY	**WwYY White**	**WwYy White**	**wwYY Yellow**	**wwYy Yellow**
wy	**WwYy White**	**Wwyy White**	**wwYy Yellow**	**wwyy Green**

White : Yellow : Green 12:3:1

Recessive epistasis - 9:3:4

In *Sorghum* the dominant gene (P) is responsible for purple colour which is dominant over brown (q).

When both the dominant genes (P and Q) are brought together either in homozygous or heterozygous condition, the purple colour is changed to red.

A cross between purple (PPqq) and brown (ppQQ) results in plants with red colour in F_1 and when the F_1 heterozygotes are selfed, three kinds of phenotypic classes are produced in the ratio of 9:3:4 (9 Red, 3 Purple and 4 Brown).

Thus in this example, the gene `p' is epistatic to the other colour genes.

If the *Sorghum* is pp, it is brown inspite of other genotypes. The expression of the colour genes is masked if pp is present.

The genes for recessive epistasis are also called supplementary genes because the gene P determines the formation of colour. The alleles of the other gene Q and q specify the colour.

If the other gene, P_Q_ occurs, the colour of the glume will be red. When P_qq genotype is present the colour of the glume will be purple. Likewise if pp genotype is present the colour of the glume will be brown.

P PPqq x ppQQ

Purple Brown

Gametes (Pq) (pQ)

F_1 PpQq(Selfed)

Red

Pp Qq x Pp Qq

Gametes (PQ) (Pq) (pQ) (pq)

F_2

	PQ	**Pq**	**pQ**	**pq**
PQ	**PPQQ Red**	**PPQq Red**	**PpQQ Red**	**PpQq Red**
Pq	**PPQq Red**	**Ppqq Purple**	**PpQq Red**	**Ppqq Purple**
pQ	**PpQQ Red**	**PpQq Red**	**ppQq Brown**	**ppQq Brown**
pq	**PpQq Red**	**Ppqq Purple**	**ppQq Brown**	**ppqq Brown**

Red: Purple :Brown
9 : 3 : 4

Table : 4.2. Differences between Epistasis and Dominance

Epistasis	**Dominance**
i. This type of gene interaction involves two non-allelic pairs of genes.	Only one pair of genes is involved, therefore there is no interaction.
ii. One pair of genes masks the effect of another pair of genes	An allele masks the effect of another allele of the same gene pair
iii. Expression of both the dominant and recessive alleles may be suppressed by the epistatic gene	Expression of a recessive allele is masked by the dominant allele
iv. Number of phenotypes in the F_2 generation are reduced	There is no reduction in the number of phenotypes of F_2 generation

SELF EVALUATION

One Mark

Choose the correct answer

1. Inheritance of flower colour in *Lathyrus odoratus* was studied by
   a. Morgan & Bridges   b. Bateson & Punnett
   c. Sutton & Boveri   d. Schleiden & Schwann
2. The inheritance of fruit colour in *Cucurbita pepo* gives a ratio of
   a. 13:3   b. 12:3:1   c.9:7   d.9:3:4
3. A ratio of 15:1 is observed in
   a. Sweet pea   b. *Cucurbita pepo*   c. Rice   d. *Sorghum*

Two Marks

1. Define : Gene interaction / Epistasis / Duplicate factors

Five Marks

1. Explain Duplicate recessive epistasis.
2. Describe the Inheritance of glume colour in *Sorghum.*
3. What is the duplicate factor in rice.
4. Explain dominant recessive epistasis in the inheritance of leaf colour in rice.
5. Explain inheritance of fruit colour in *Cucurbita pepo.*
6. Differentiate between dominance and epistasis.

Ten Marks

1. Write an essay on the various epistatic gene interactions you have studied.

This figure is pertained to Unit 2.
Chapter 6. Cell Membrane

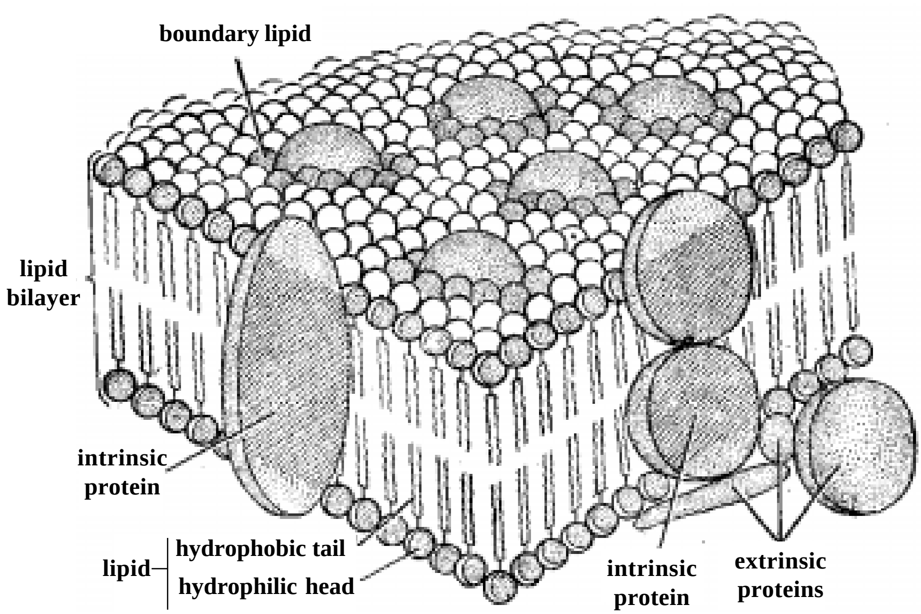


Fig. 2.11 Fluid-mosaic model of the plasma membrane. Proteins floating in a sea of lipid. Some proteins span the lipid bilayer, others are exposed only to one surface or the other.