BIOLOGY

BOTANY

CLASS - XI

SYLLABUS : HIGHER SECONDARY - FIRST YEAR
BIOLOGY : PART-A BOTANY

Unit 1 : Biodiversity (12 Hours)

Systematics : Two Kingdom and Five Kingdom systems - Salient features of various Plant Groups : Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms - Viruses - Bacteria.

Unit 2 : Cell Biology (8 Hours)

Cell as the basic unit of life - Cell Theory - Prokaryotic and Eukaryotic Cell (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, Plastids, Ribosomes - Cell Divisions : Amitosis, Mitosis & Meiosis and their significance.

Unit 3 : Plant Morphology (8 Hours)

Structure and Modification of Root, Stem and Leaf - Structure and Types of Inflorescences - Structure and Types of Flowers, Fruits and Seeds.

Unit 4 : Genetics (12 Hours)

Concept of Heredity and Variation - Mendel's Laws of Inheritance - Chromosomal basis of Inheritance - Intermediate Inheritance (Incomplete Dominance) - Epistasis.

Unit 5 : Plant Physiology (18 Hours)

Cell as a Physiological Unit : Properties of Protoplasm - Water relations - Absorption and movement : Diffusion, Osmosis, Plasmolysis, Imbibition - Permeability, Water Potential - 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 - Mineral Nutrition : Functions of minerals - Essential Major elements and Trace elements - Deficiency symptoms of elements - Theories of Translocation - Translocation of Solutes - Nitrogen Metablosim and Biological Nitrogen Fixation.

Unit 6 : Reproduction Biology (10 Hours)

Modes of Reproduction in Angiosperms : Vegetative propagation (natural and artificial) - Micropropagation - Sexual Reproduction - Pollination: Types - Double Fertilization - Germination of seed : Parts of seed - Types of germination - Abscission, Senescence.

Unit 7 : Environmental Biology (10 Hours)

Organisms and their environment - Factors : Air, Water, Soil, Temperature, Light and Biota - Hydrophytes, Mesophytes, Xerophytes and their adaptations - Natural Resources - types, uses and misuse Conservation of water (RWH).

CONTENTS

BIO - BOTANY CHAPTERS

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.

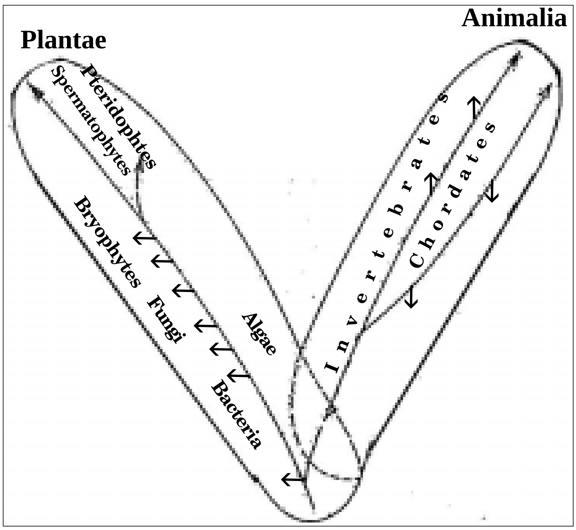


Fig: 1.1. Diagrammatic representation of Two Kingdom System

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 saprotrophic 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.

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

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.

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. 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 19^{th} 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**.

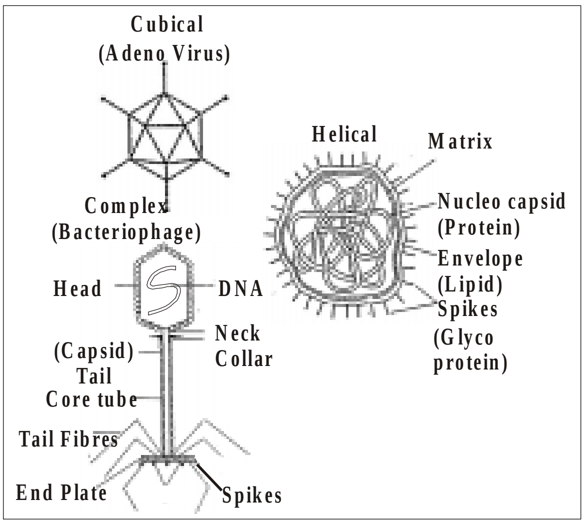


Fig : 1.2 Different shapes of Viruses

Structure of a virus

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.

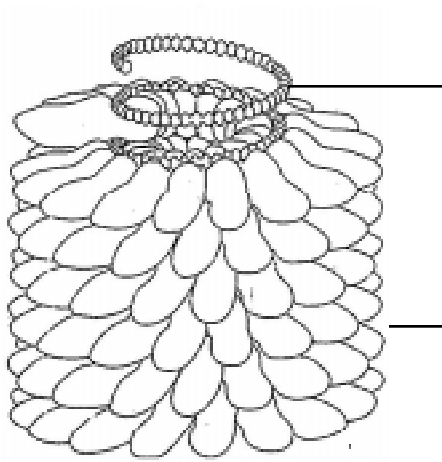


Fig.1. 3 Basic components of a virus (TMV)

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

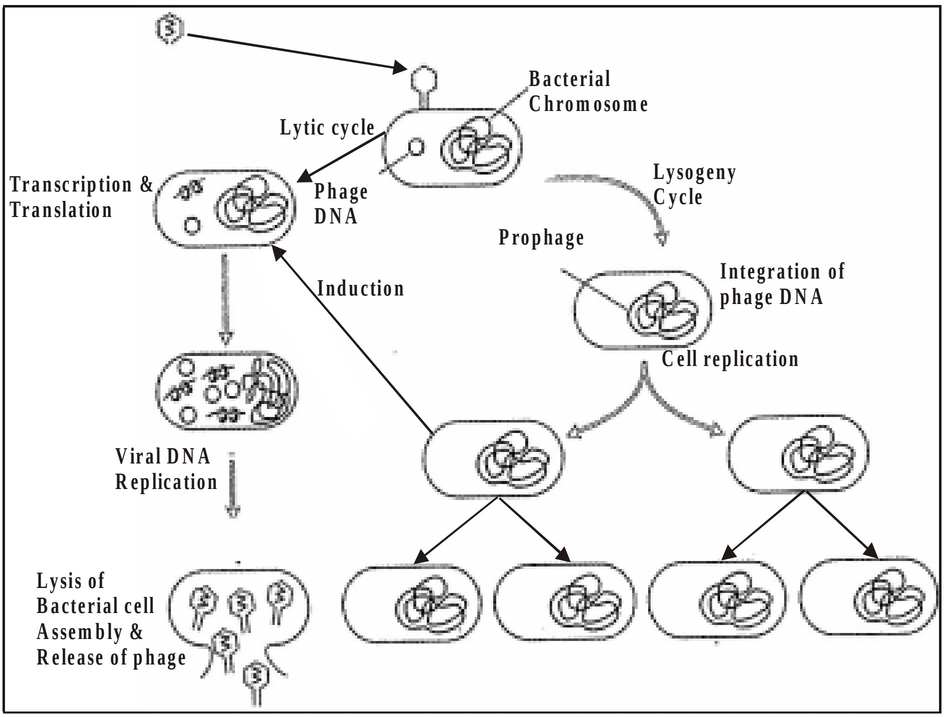


Fig.1.4 Lytic and Lysogenic cycle of a phage

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.

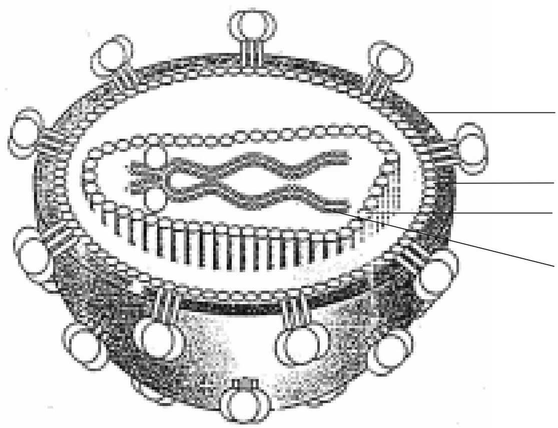


Fig : 1.5 Human Immuno Deficiency Virus

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.

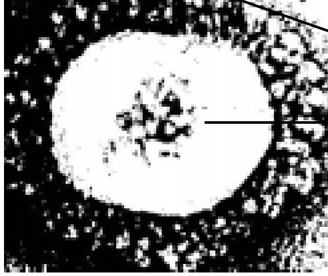


Fig: 1.6 Human CoronaVirus

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**

3. 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 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.

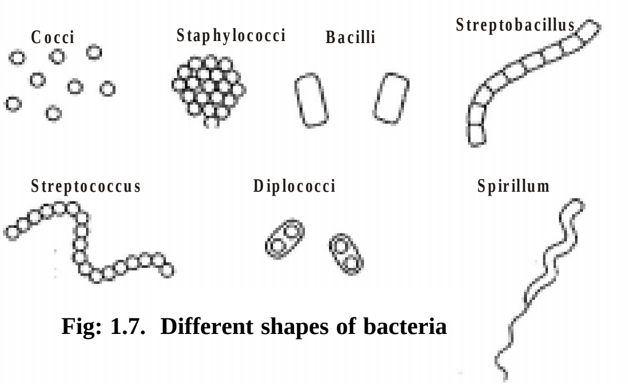


Fig: 1.7. Different shapes of bacteria

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:

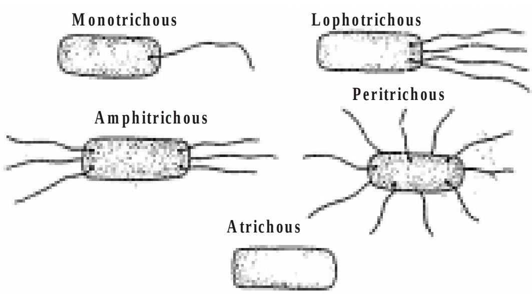


Fig: 1.8. Flagellar arrangement in Bacteria

- **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**

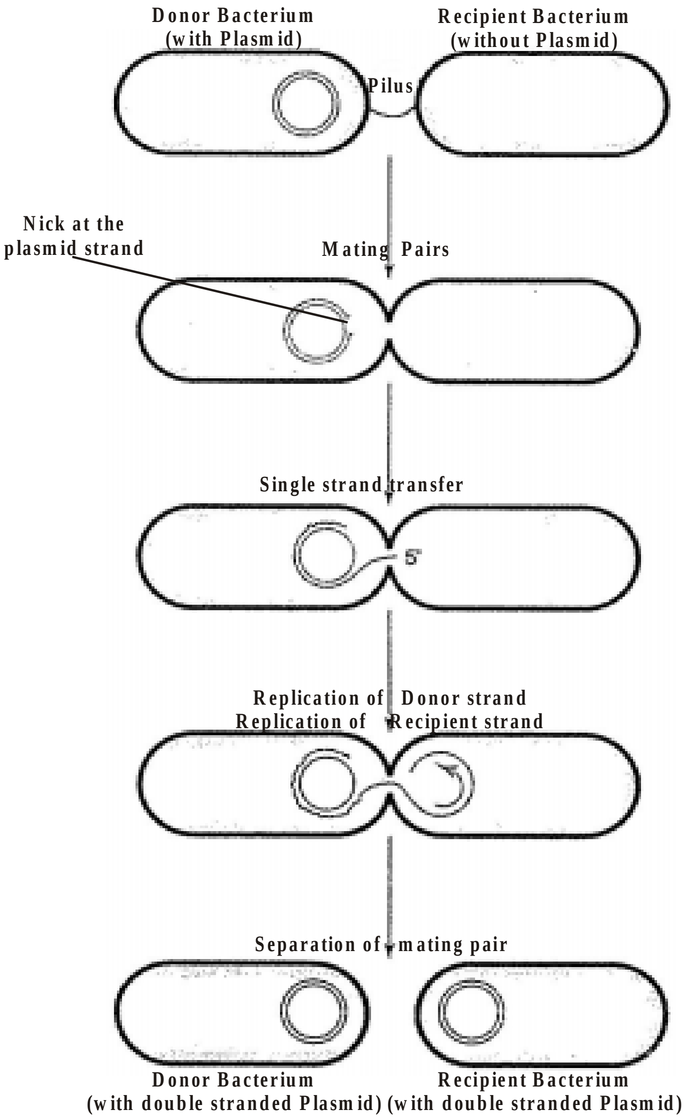


Fig: 1.9. Conjugation in Bacteria

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 20th 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.

4. Salient Features of Various Groups

4.1 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

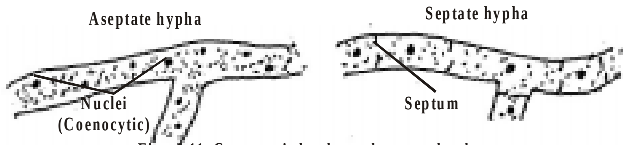


Fig : 1.11. Coenocytic hypha and septate hypha

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.

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 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.

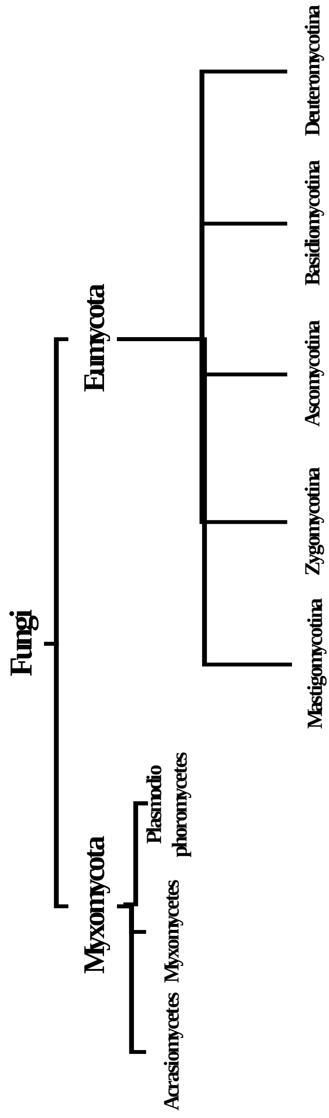


Fig. 1.12. Classification of Fungi by Ainsworth

Classification of Fungi

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

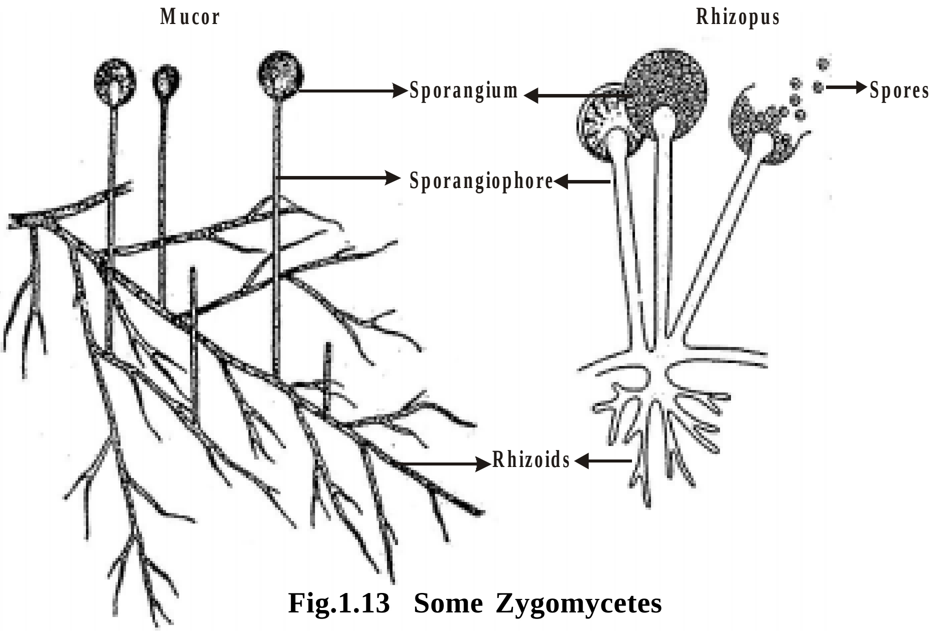


Fig.1.13 Some Zygomycetes

Mucor belong to this group. Rhizopus is a very common saprotroph similar in appearance to Mucor, but more widespread.

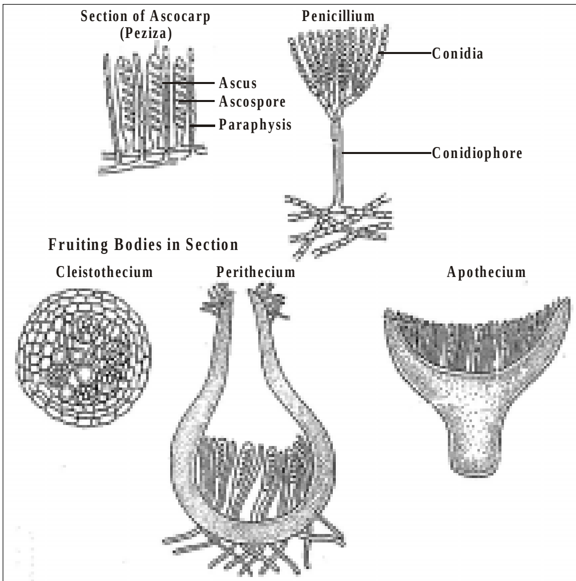


Fig : 1.14. Some Ascomycetes and their Ascocarps

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.

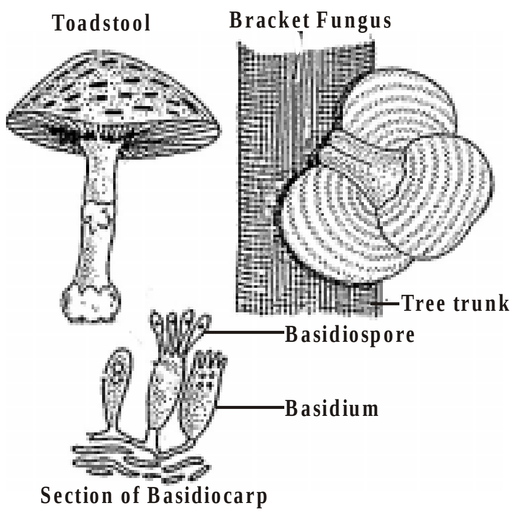


Fig : 1.15. Some Basidiomycetes and their Basidiocarps

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.

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.

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***

"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 (**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.

4.2 Algae

Salient Features

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.

Algae are autotrophic organisms and they have chlorophyll. They are 0_2 producing photosynthetic organisms that have evolved in and have exploited an aquatic environment. The study of Algae is known as **Algology** or **phycology.**

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*.

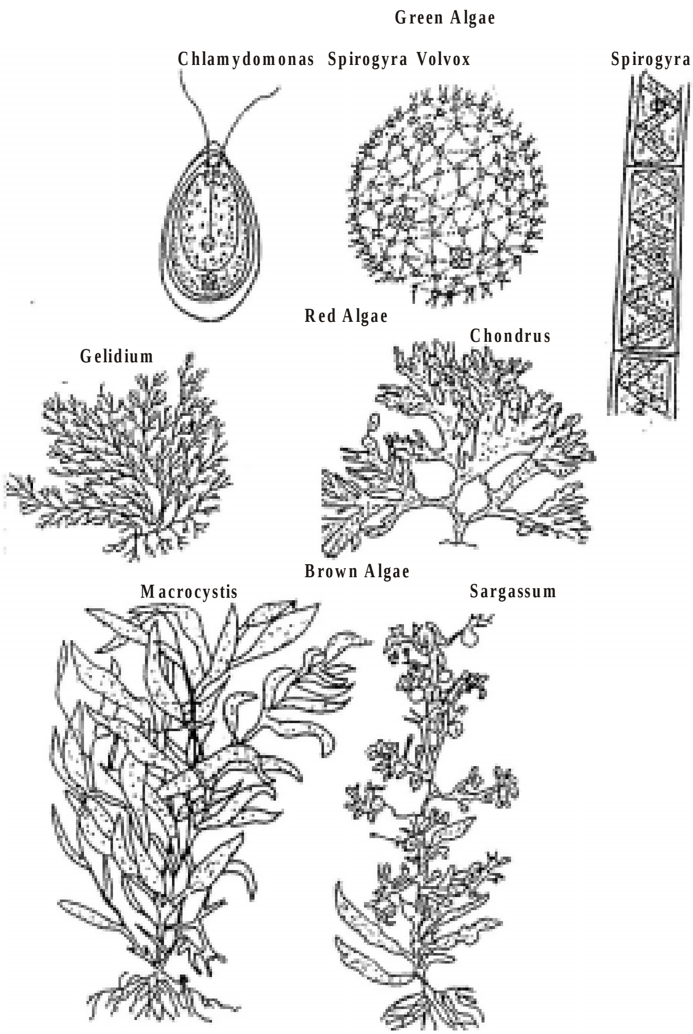


Fig: 1.16. Thallus Organization in Algae

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).

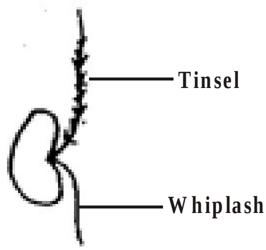


Fig: 1.17. Types of Flagella

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 ***Gracillaria*.**

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 ***Spirulina*** 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 ***Spirullina*** 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.

4.3. 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.

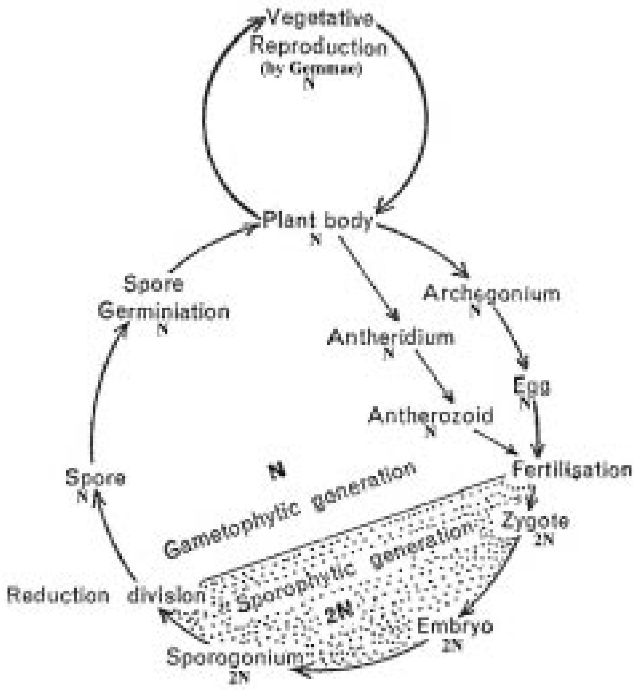


Fig : 1.18. Generalised life cycle of a Bryophyte plant showing alternation of generation

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.

Classification

Bryophyta is divided into three major classes.

BRYOPHYTA

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

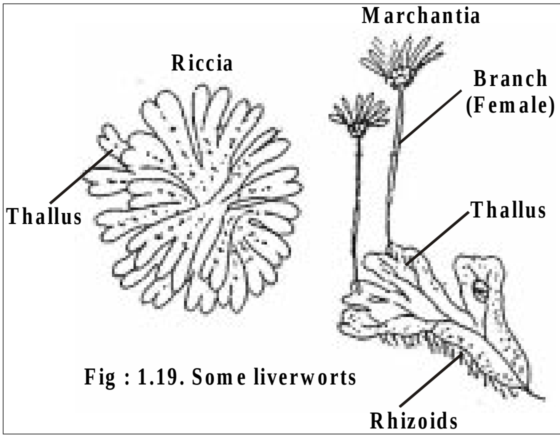


Fig : 1.19. Some liverworts

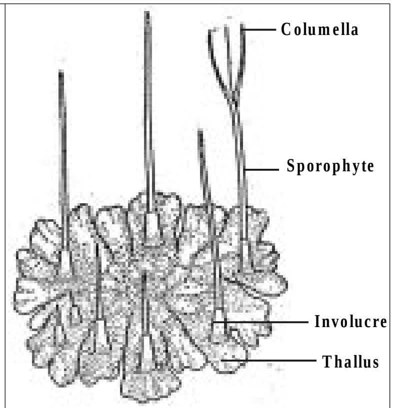


Fig: 1.20. Hornwort-Anthoceros

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.***

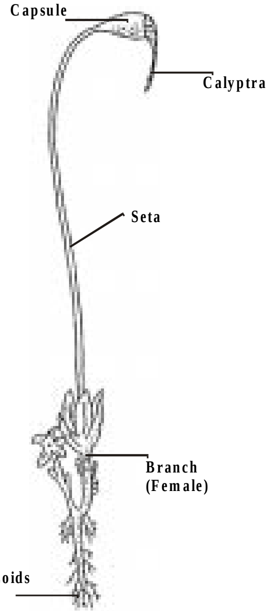


Fig : 1.21. Moss - Funaria

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 classification of Bryophyta.

4.4. 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.

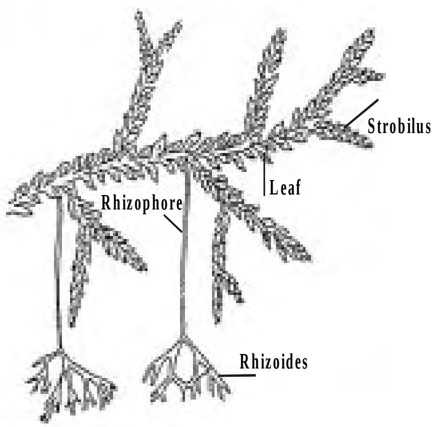


Fig: 1.22. Microphyllous Pteridophyte - Selaginella

15. Fertilized egg i.e zygote develops into embryo.

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

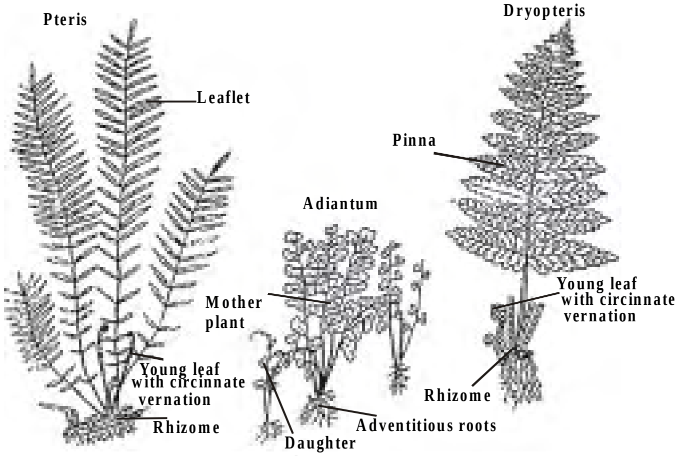


Fig: 1.23. Ferns

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.**

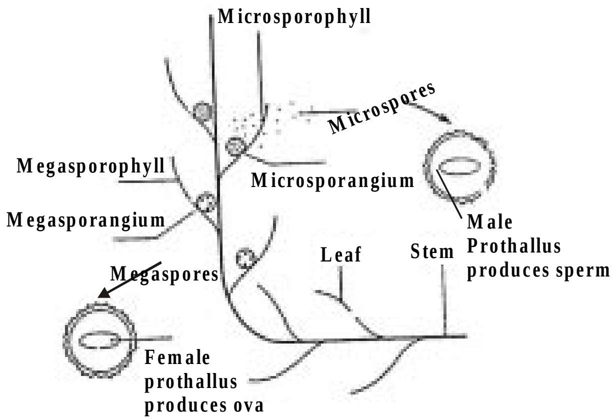


Fig : 1.24. Diagramatic representation of heterospory

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.

4.5. 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.**

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.

Classification and Characteristic of Spermatophytes

Division : Spermatophyta (seed bearing plants)

General Characteristics

Heterosporous– microspore = 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.

GYMNOSPERMS

Salient features of Gymnosperms

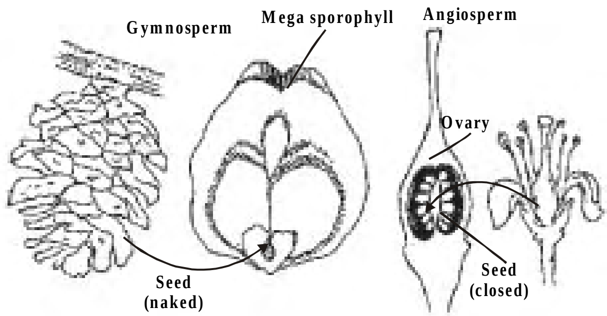


Fig : 1.25. Seeds of Gymnosperm and Angiosperm compared

Gymnosperms represent a primitive group of seed bearing plants (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.

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

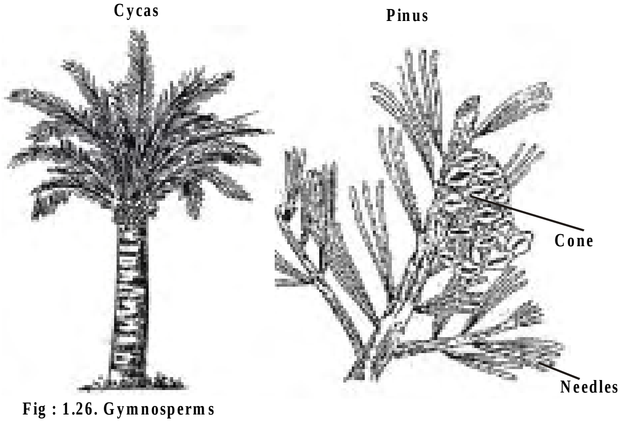


Fig : 1.26. Gymnosperms

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.
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.
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 is 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.

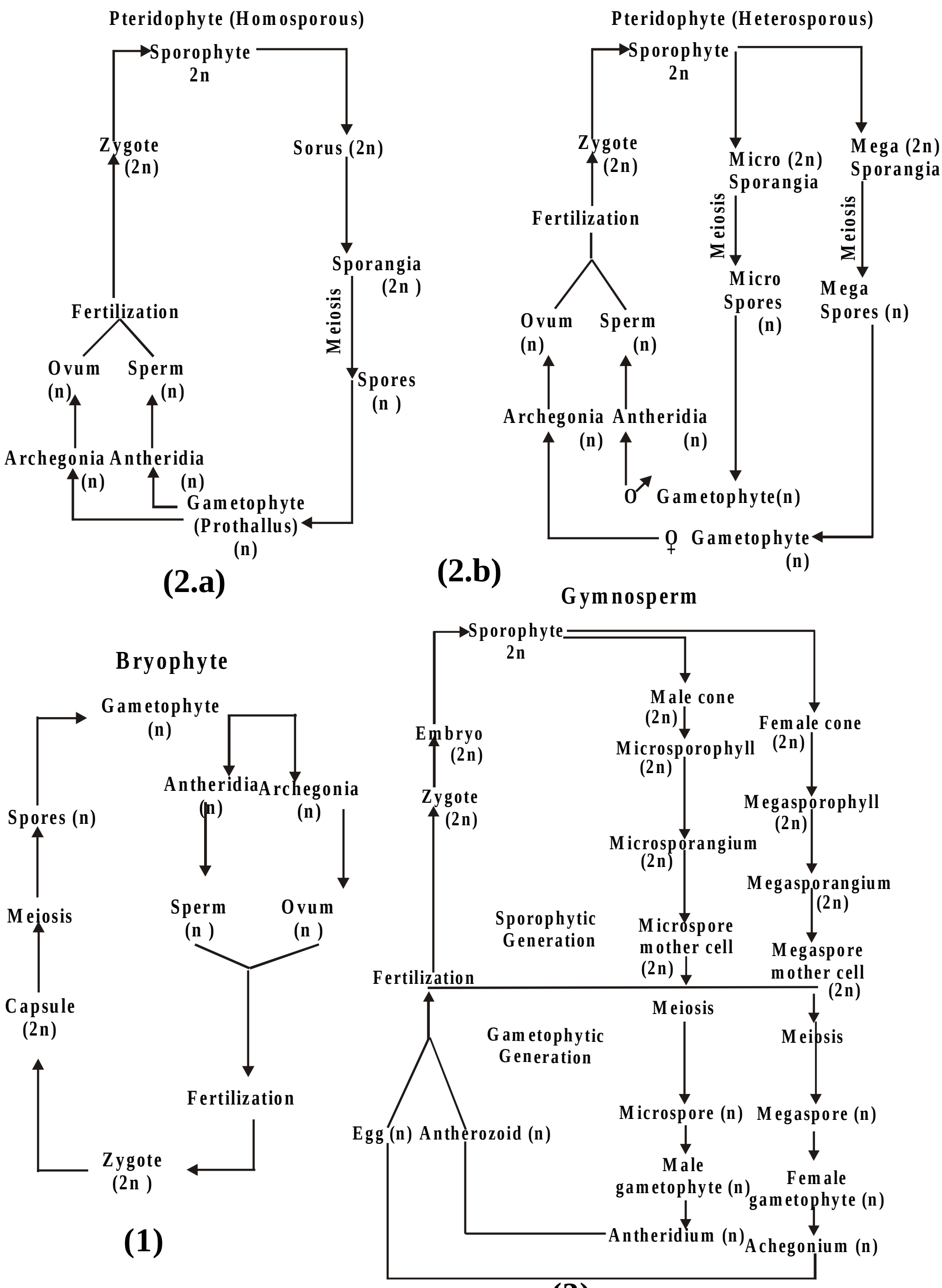


Fig : 1.26. Graphical representation of life cycles of various plant groups.

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.

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 compound 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 organelles 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.,

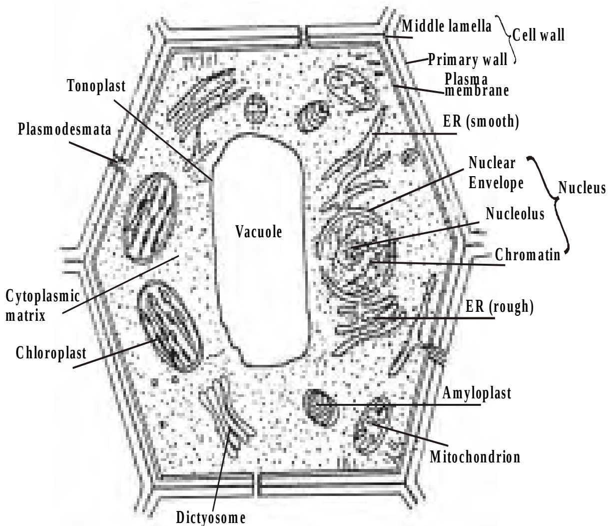


Fig : 2.1. Diagrammatic representation of eucaryotic Plant Cell

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 aspects of cellular life.

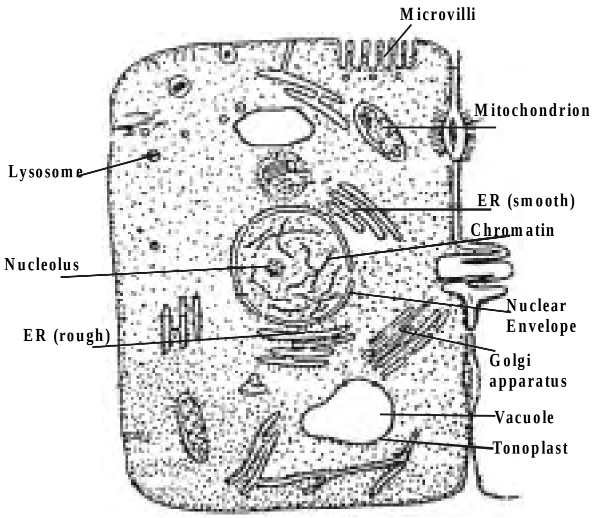


Fig : 2.2. Diagrammatic representation of eucaryotic Animal Cell

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 given cell will grow and divide is a highly regulated decision of

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 these 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.

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. To 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 unnecessary 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 protozoans 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 sieve tube cells 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 function of the cell are controlled by DNA.
7. Some times 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.fungi   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 circular DNA molecule, in the central region of the cell. This region is often referred to 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 maintain 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

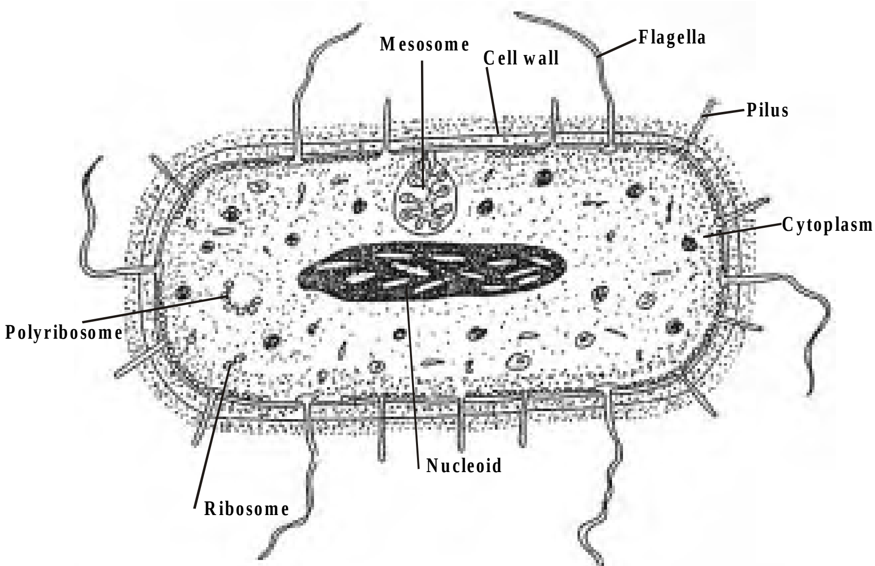


Fig : 2.3. Ultra structure of a prokaryotic Cell (Bacteria)

complex; it contains peptidoglycan, polysaccharides, lipid and protein molecules. One of the most abundant polypeptides, 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 metabolites (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 1mm 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 proteins.

The single chromosome or the DNA molecule is circular and at one point it is attached to the plasma membrane and it is believed that this attachment may help in the separation of two chromosomes after DNA replication.

In addition to a chromosome, certain bacteria contain a small, extra-chromosomal 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 blue-green 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 systems, 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 50μm.	Most are large cells (10-100μm).some are larger than 1mm.
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 70 s 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. mesosome 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 **100x** 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 x 10**).

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

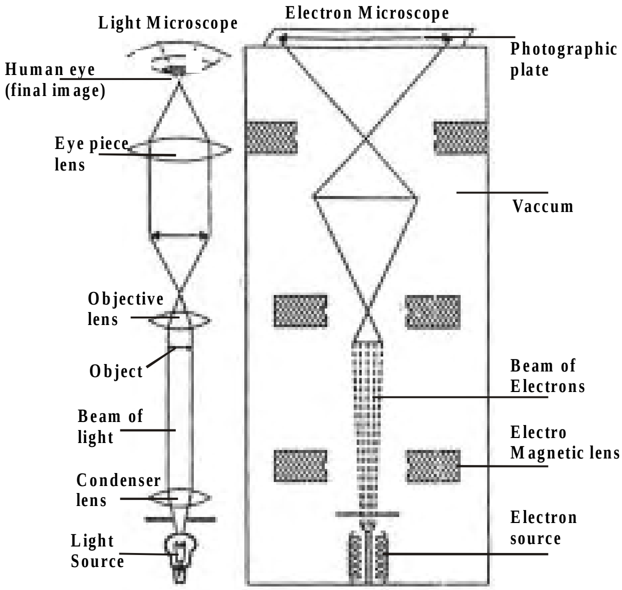


Fig : 2.4. Working principle of light and electron microscope

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.

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 0.005 nm or 40,000 times better than the resolution of the light microscope and 2 million 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

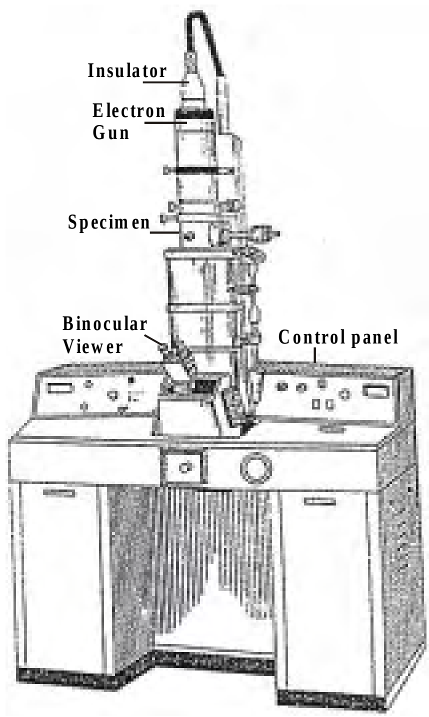


Fig : 2.5. An Electron Microscope

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 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 numerically 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.
3. Explain the principle used in Scaning 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 phragmoplast 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 **peptidoglycon,** 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.

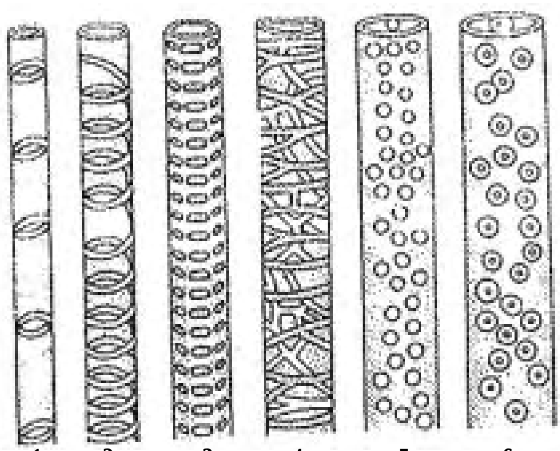
Primary wall

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, hemi-cellulose, pectin and glycoprotein. Pectin is the filling material of the matrix. Hemi-cellulose binds the microfibrils with the matrix and the glycoprotein 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 in 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, sclerenchyma, fibres and tracheids.

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, and calcium oxalate, silica etc



1 2 3 4 5 6

1. Annular 2. Spiral 3. Scalariform 4. Reticulate 5. Simple pits 6. Bordered pits

Fig : 2.6. Various types of thickenings in cell wall

may be deposited in the secondary wall. The secondary wall is very strongly anisotropic and layering can be observed in it.

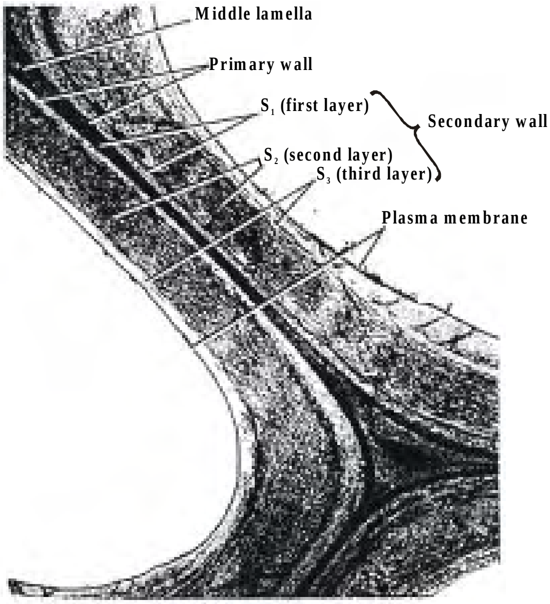


Fig : 2.7. Electron micrograph of a thin section showing parts of the cell walls separating three cells.

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, hemi-cellulose and other organic substances and sometimes even some mineral crystals.

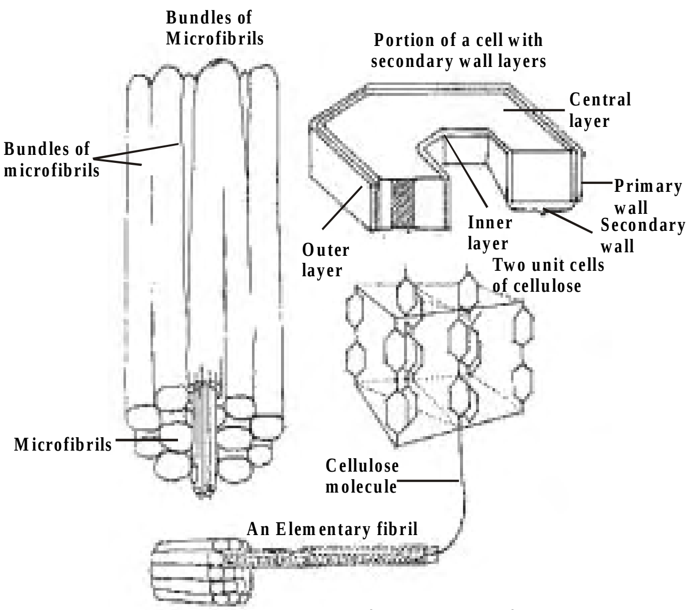


Fig : 2.8. Digrammatic representation of ultrastructure of the cell wall

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

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**.

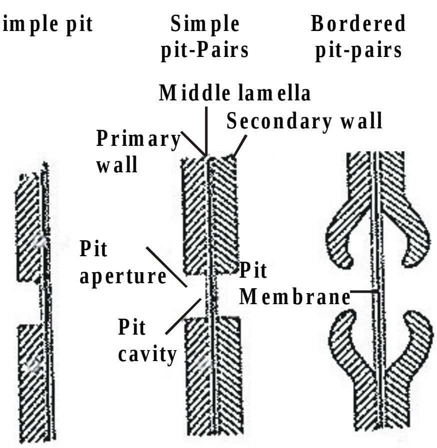


Fig : 2.9. Structure of pits

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

Filll 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 a 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^0 thick. Under the electron microscope they appear to consist of 3 layers.

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

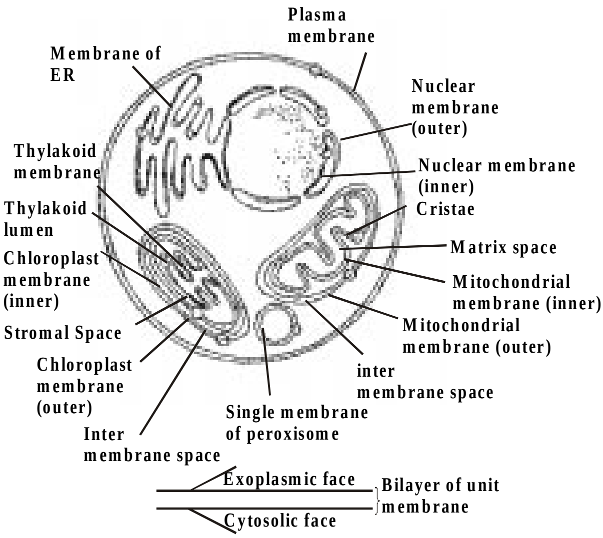


Fig : 2.10. Two faces of bio membrane

The outer and inner layers are formed of protein molecules whereas the middle one is composed of two layers of phospho lipid 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 proteins. 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 wholly 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 carry out 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 transport proteins that permit the passage of certain small molecule but not others. Several of these proteins use the energy released 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 function, 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 **signaling 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 membrane is called electric 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 a 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.

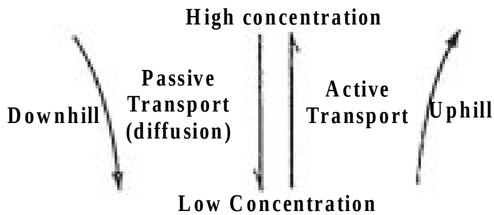


Fig : 2.12. Active transport-a scheme

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 the 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 though the channel on the other side of the membrane. The carrier molecule regains its original form and repeats the process.

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.

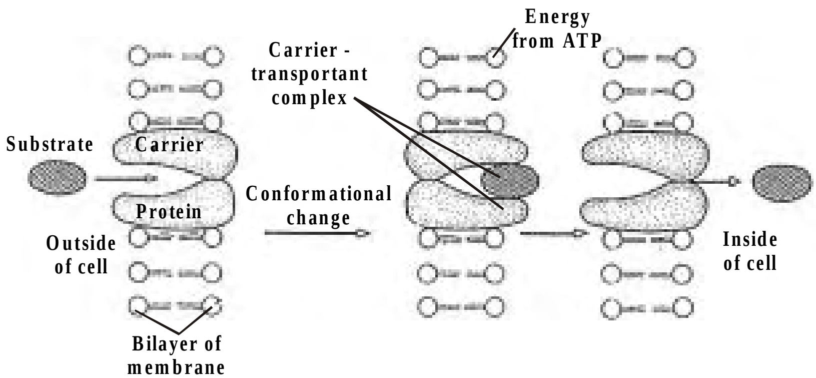


Fig : 2.13. Role of carrier protein in active membrane transport- a schematic representation

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. 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 amoeboid protozoans, 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 palce _______ 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 organisms (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(GA) (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 GA. After processing, the final product is discharged from the G.A. At this time the G.A. buges and breaks away to form a 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 out side 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 all 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.

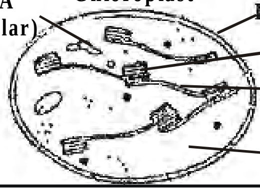
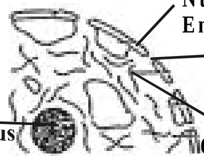
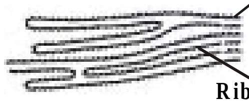
10. Cell wall

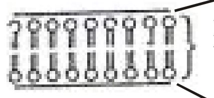
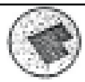
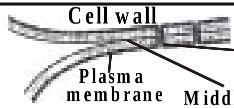
The cells of all plants have cell wall. It has three parts 1. Middle lamella 2. Primary wall 3. Secondary wall. It gives definite shape to the plant cell.

Nucleus

Nucleus 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

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.	Cristae 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 cisternae.	Smooth ER, (no ribosomes) is the site of lipid synthesis. Rough ER (with ribosomes) transports proteins made by the ribosomes through the cisternae.

	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.
Ribosomes 	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
Micro bodies 	Spherical organelle bound by a single membrane	They are the sites of glyoxylate cycle in plants.
	It consists of cellullose microfibrils in a matrix of hemicellulose and pectic substances. Secondary thicking may be seen.	It provides mechanical support and protection.

the 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 the nucleus and the cytosol.

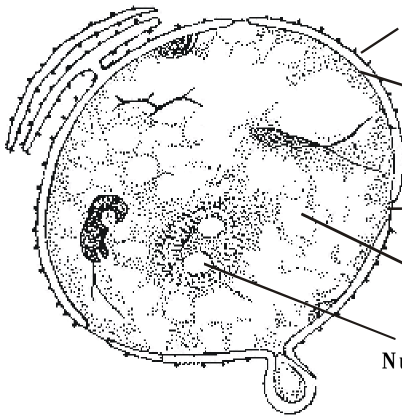


Fig : 2.14. Structure of a nucleus

In a growing or 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 divisions the chromosomes become visible by 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.

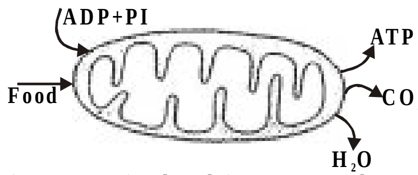


Fig : 2.15. Mitochondria as a powerhouse

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.

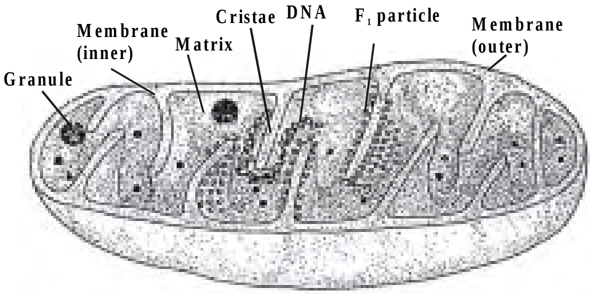


Fig : 2.16. Ultrastructure of a Mitochondrion

Mitochondria 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 in folding, or **cristae** that protrude into the matrix.

Structure of the cristae membrane

The inner surface the cristae membrane (i.e the surface towards the matrix) is covered with numerous (infinite) stalked particles. These are called **F_1 Particles**, **elementary particles** or **sub units**. These particles project into the matrix. Each F_1 particle has 3 parts, viz ,the head piece, the stalk and the base piece. The respiratory chain is situated in the cristae membrane where the F_1 particles are present. The 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 enzymes in the mitochondrial matrix and cristae. As many as 34 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 energy 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, t RNA 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 carbohydrates, 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 10mm and are typically 0.5 - 2.0mm 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 form what are called **grana** and embedded in a matrix called **stroma.**

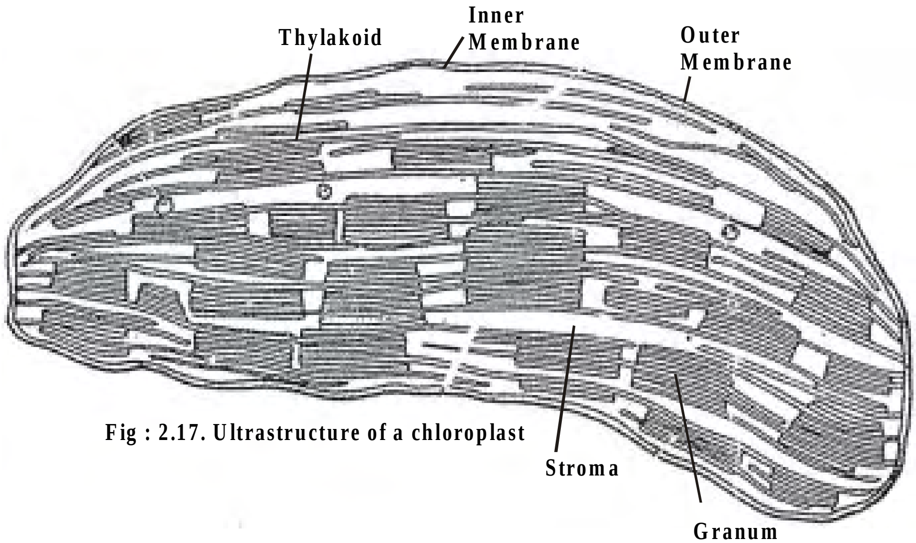


Fig : 2.17. Ultrastructure of a chloroplast

Stroma, a semi fluid, colourless, colloidal complex contain DNA, RNA, ribosomes and several enzymes. The DNA of chloroplast is circular. The ribosomes are 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) inter connect 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 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 organelle.

Ribosomes

Ribosomes are small sub-spherical granular organelles, not enclosed by any membrane. They are composed of ribonucleoproteins and they are the site of protein synthesis.

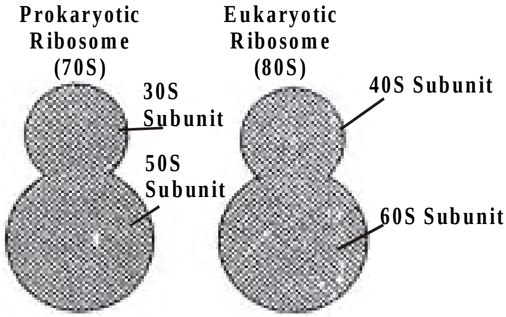


Fig : 2.18. Ribosome

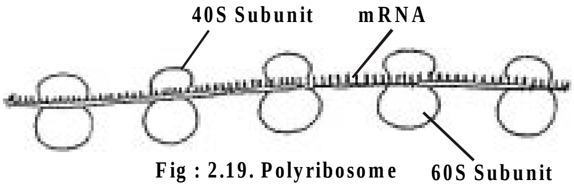


Fig : 2.19. Polyribosome

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 two sub 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**.

In plants, active mitotic cell division takes place in

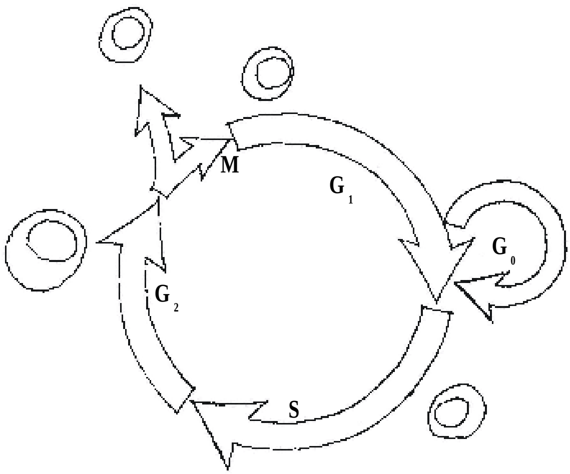


Fig : 2.20. Eukaryotic cell cycle

G_1, S, G_2 } **Interphase** **M - Mitotic stage**

G_0 - Non dividing stage

shoot and root 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 composed of two sister chromatids.

iii) G_2 or Gap –2 Phase

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

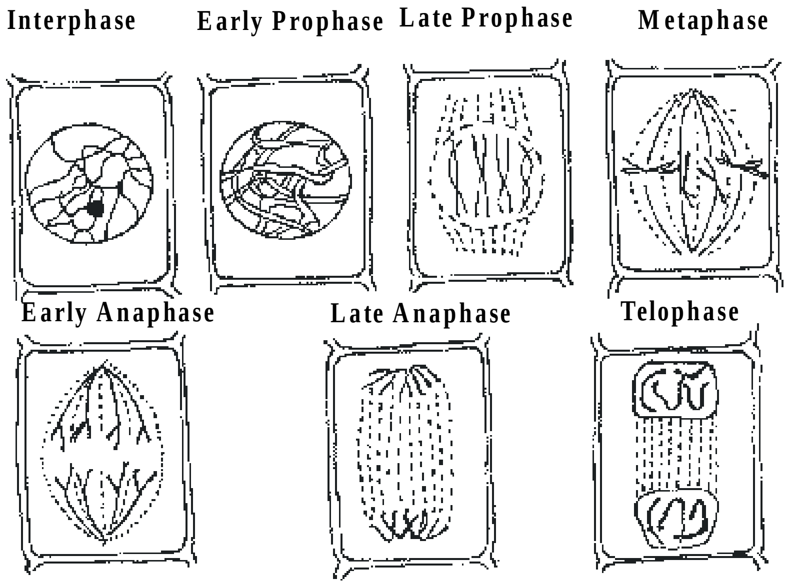


Fig : 2.21. Mitosis - Equational Cell Division

chromosomes become distinct and visible under the compound microscope. The 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 nucleolus reappear. Thus, two daughter nuclei are formed, one at each pole.

Cytokinesis

The division of the cytoplasm 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 cell membranes 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 or 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 of 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 two 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.

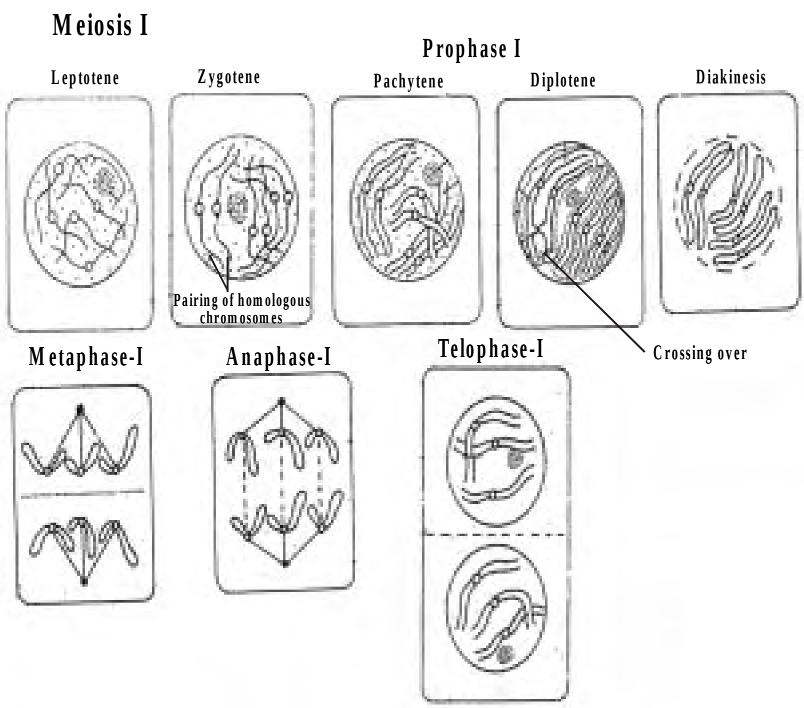
Each meiotic division cycle is divided into same four stages as in mitosis. **Prophase, Metaphase, Anaphase and Telophase**. The name of each stage is followed by **I** or **II** depending on which division of cycle is involved.

Meiosis I

It consists of four stages namely

1. Prophase I

2.Metaphase I



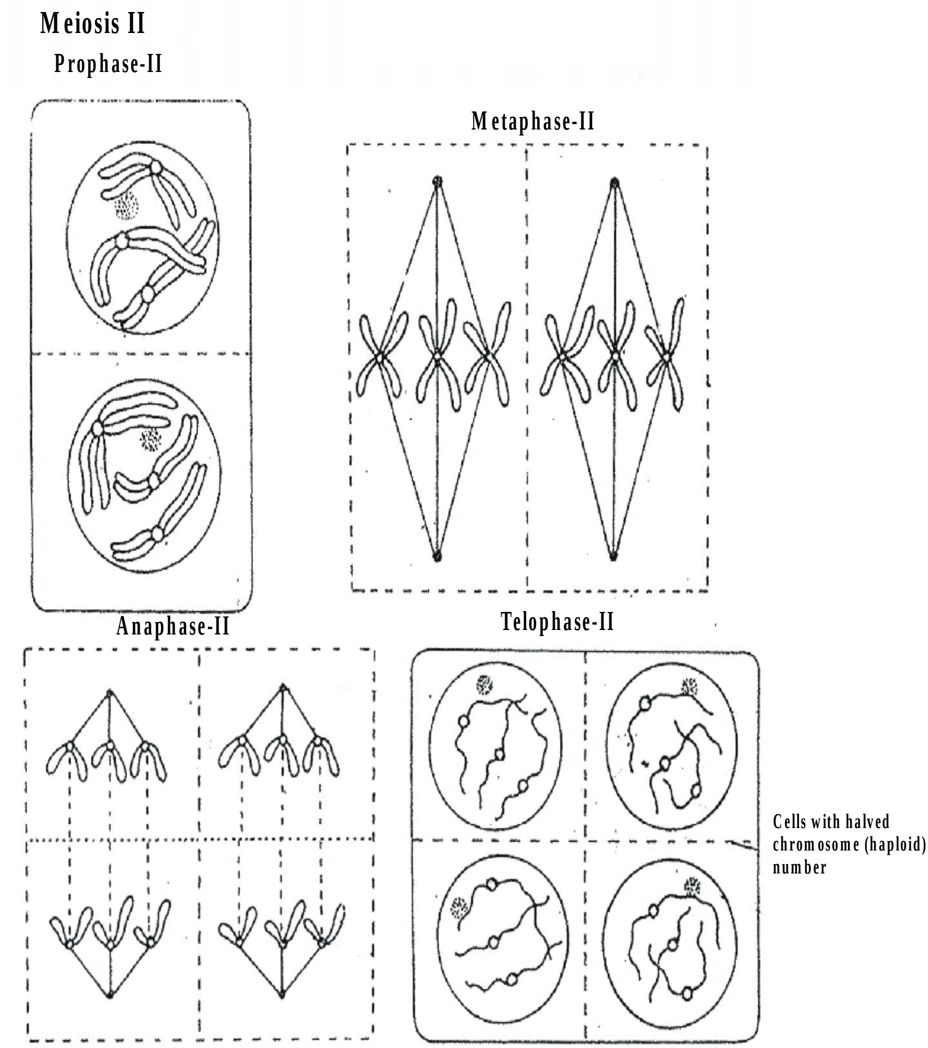


Fig 2.22. Meiosis - Reductional Cell Division

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 points 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 bivalent 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 reaches 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).

Telophase I

This is the last stage of meiosis I. Reorganization of the chromosomes at poles occurs to form two haploid nuclei. 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 at 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, 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

2. 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 significance.
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**

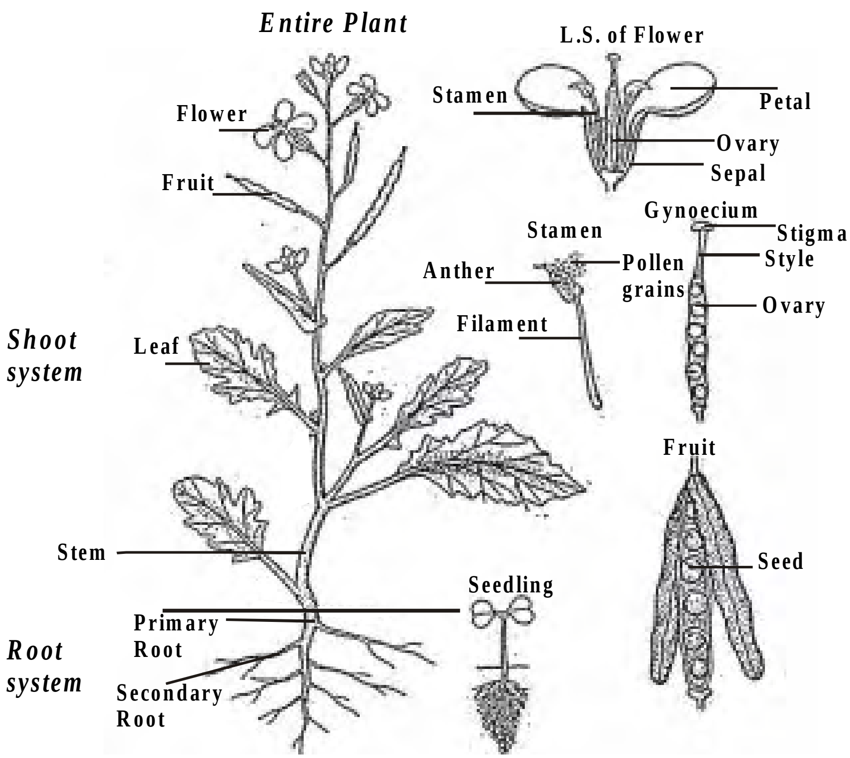


Fig : 3.1. Parts of a typical angiospermic plant (mustard)

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.

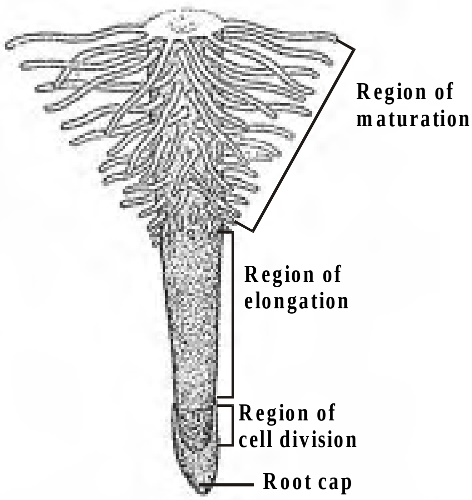


Fig : 3.2. Regions of a typical root

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.

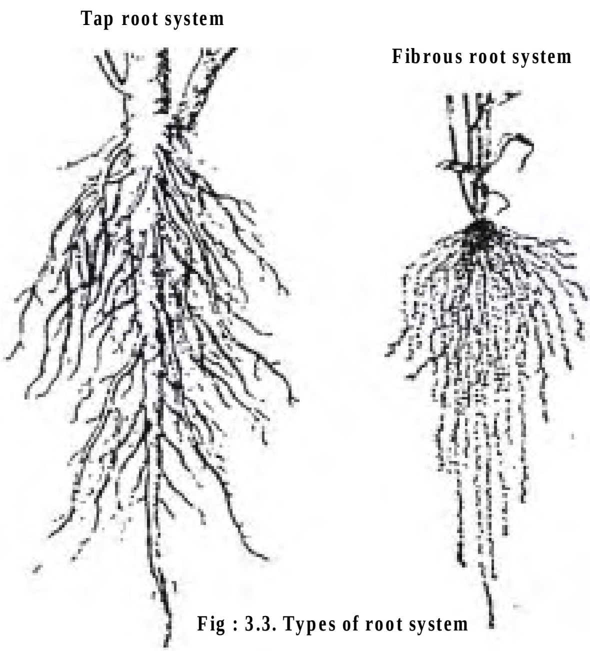


Fig : 3.3. Types of root system

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.

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.

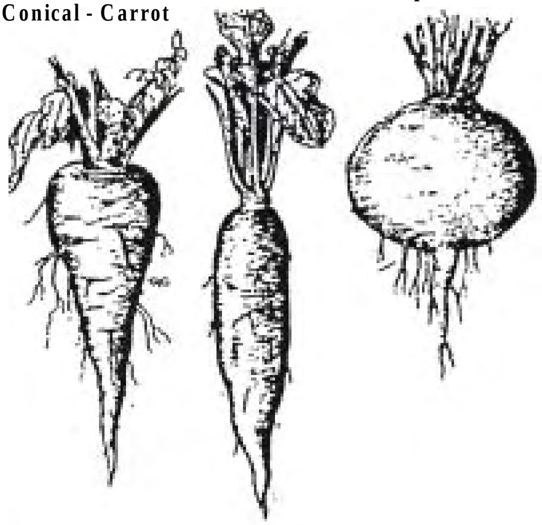


Fig: 3.4. Storage roots

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.

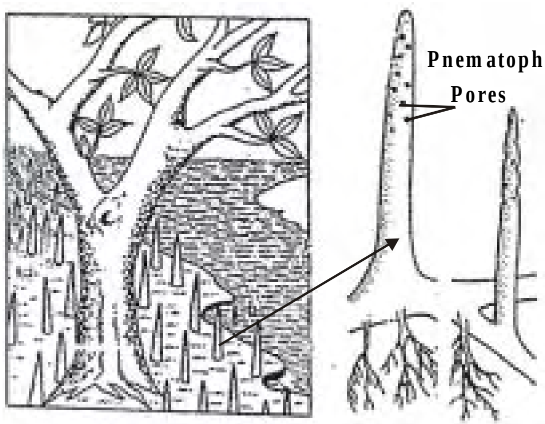


Fig : 3.5. Respiratory Roots (Avicennia)

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.

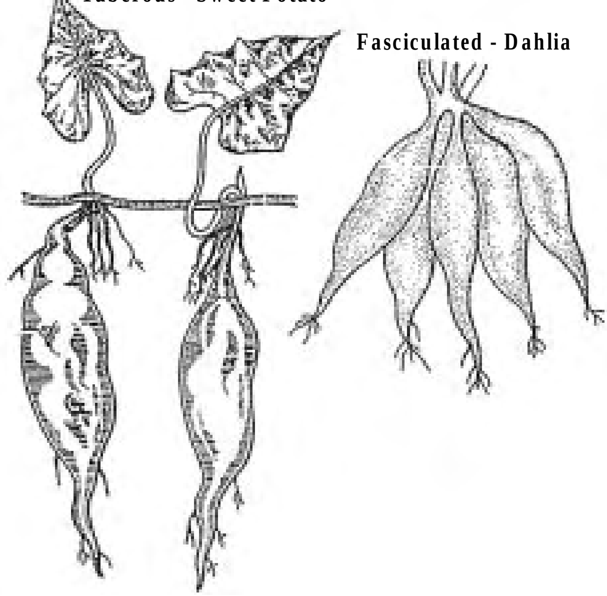


Fig : 3.6. Storage - Adventitious roots

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.

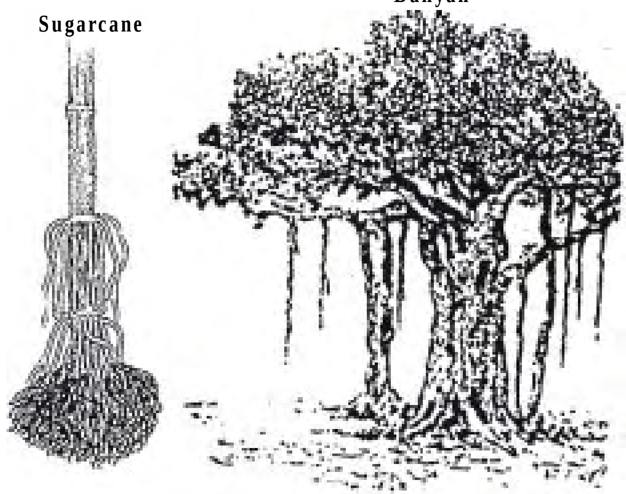


Fig : 3.7. Stilt & Prop roots

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.

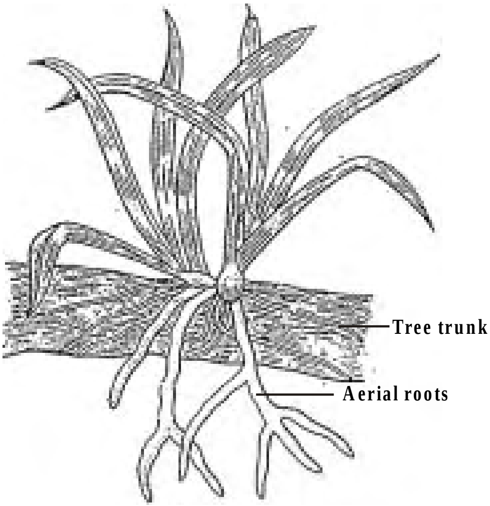


Fig : 3.8. Epiphytic roots

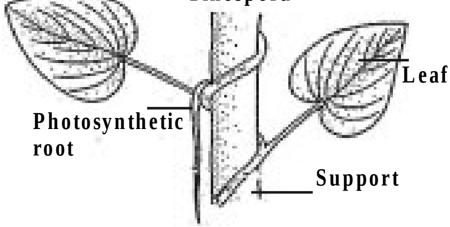


Fig : 3.9. Photosynthetic root

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 its 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.

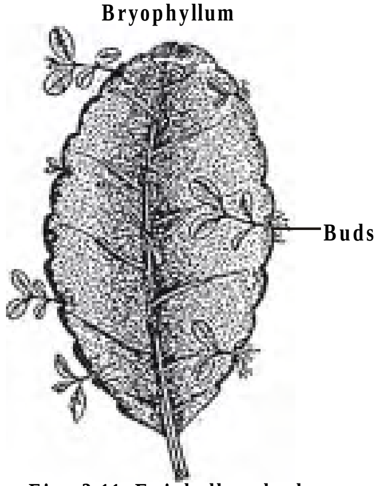


Fig : 3.11. Epiphyllous buds

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.

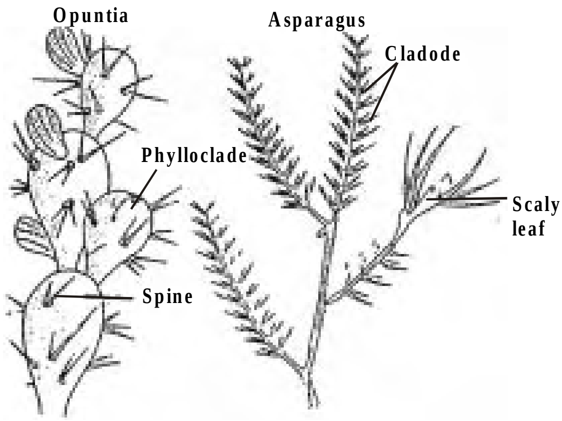


Fig : 3.12. Phylloclade & Cladode

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:

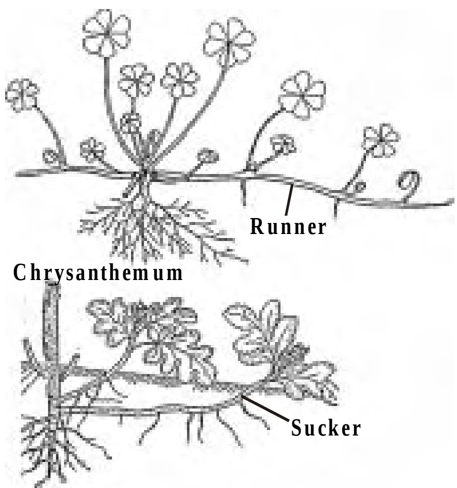


Fig : 3.13. Runner & Sucker

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.

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

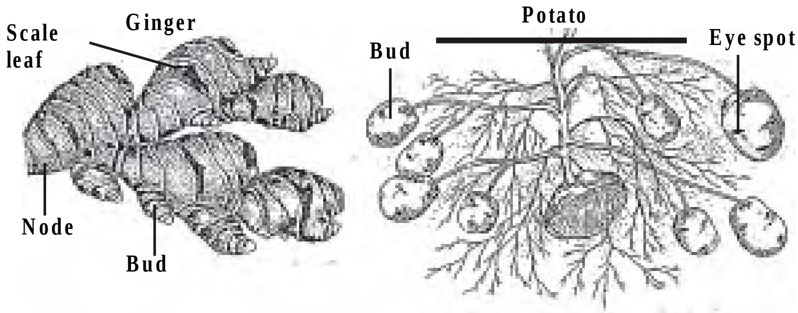


Fig : 3.14. Rizome and Tuber

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**

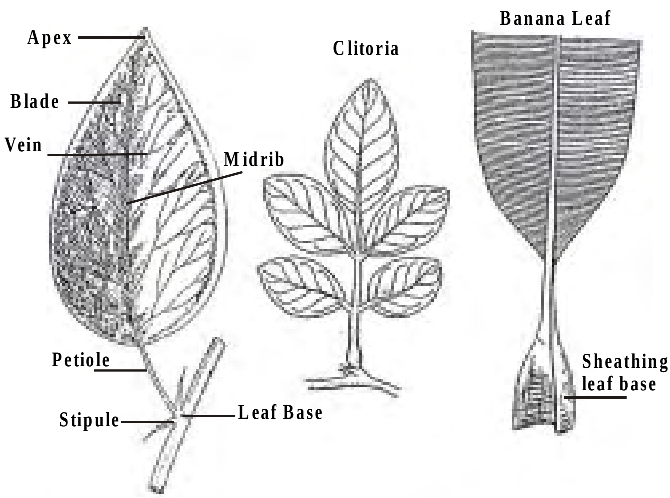


Fig : 3.15. Parts of a typical leaf & Pulvinus & Sheathing leaf base

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

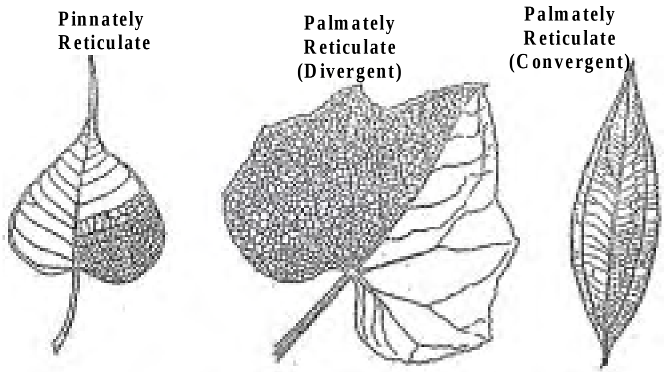


Fig : 3.16. Types of Reticulate Venation

a. 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.

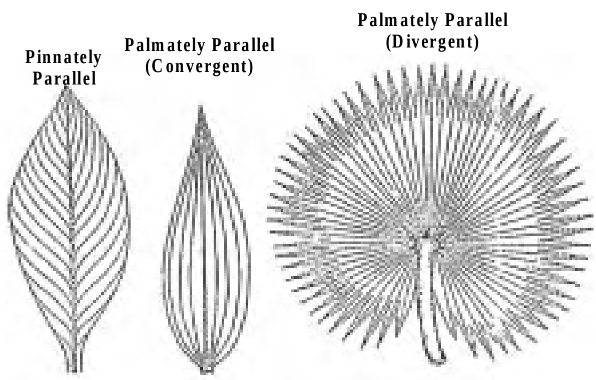


Fig : 3.17. Types of Parallel Venation

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**

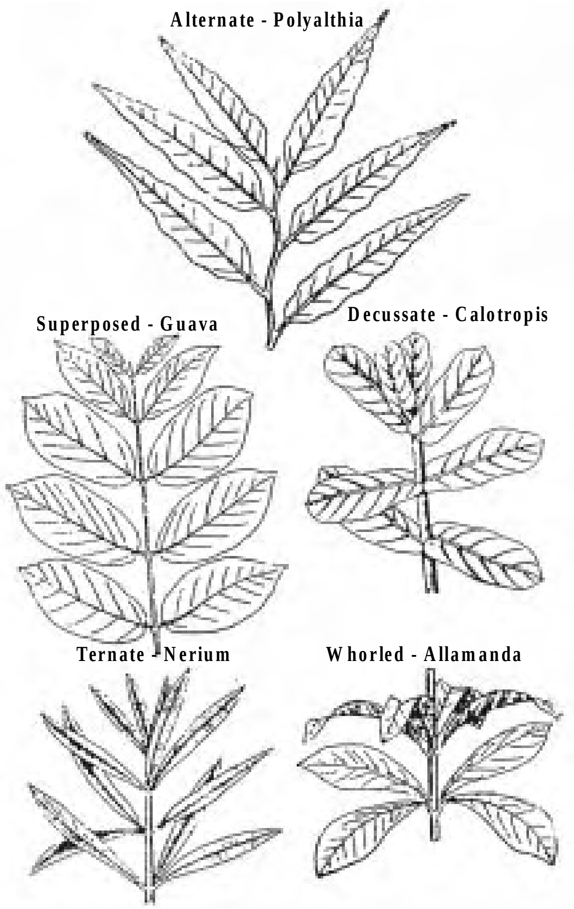


Fig : 3.18. Types of Phyllotaxy

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**

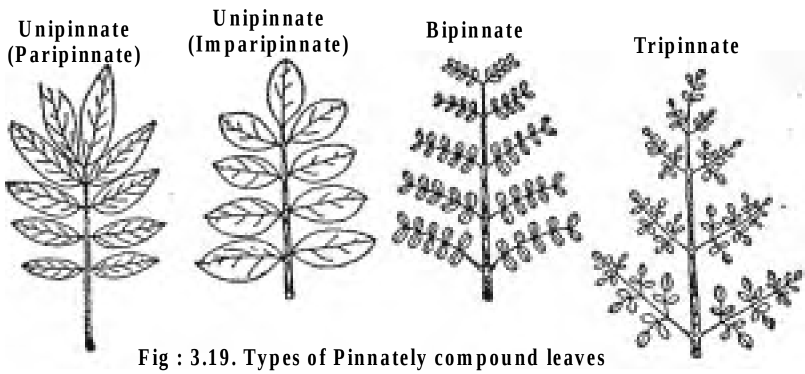


Fig : 3.19. Types of Pinnately compound leaves

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**.

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**

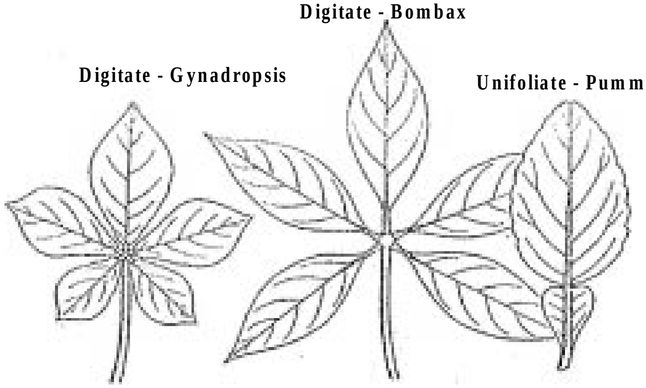


Fig : 3.20. Types of Palmately compound leaves

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**)

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.

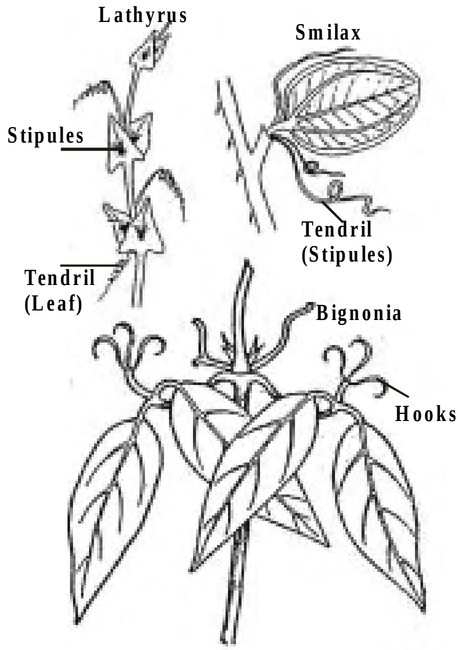


Fig : 3.21. Leaf Tendrils & Leaf Hooks

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***

Fig : 3.22. Leaf Spines

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.

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

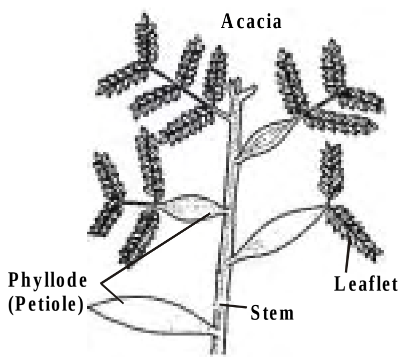


Fig : 3.23. Phyllode

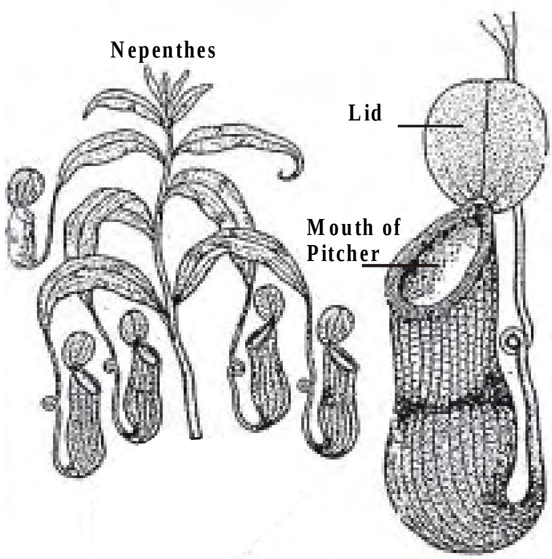


Fig : 3.24. Insectivorous Plant

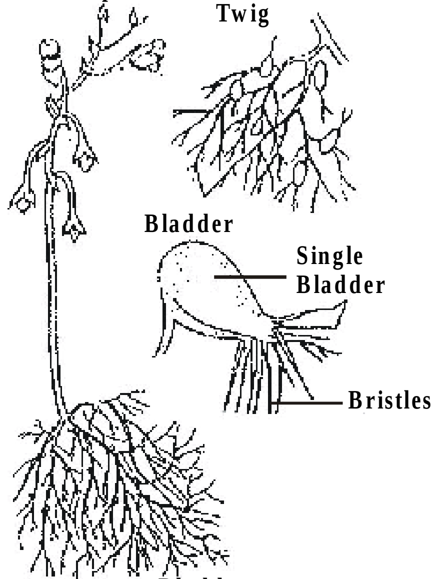


Fig : 3.25. Bladder Plant

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.

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.

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 the flowers. Flowers are produced after a period of vegetative growth. The flowers may be borne singly or in clusters. Flowers when borne singly 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 as **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, inflorescences 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.

Inflorescence

- **Racemose**
- **Cymose**
- **Mixed**
- **Special**

These may be further classified as follows:

Racemose

- **Main Axis elongated**
  1. Simple Raceme
  2. Compound Raceme
  3. Spike
  4. Compound spike
  5. Spadix
  6. Compound spadix
- **Main axis shortened**
  1. Corymb
- **Main axis ending in flowers**
  1. Umbel
  2. Compound Umbel
- **Main axis flattened**
  1. Head or capitulum
  2. Compound head

Cymose

- Simple Cyme
- Simple Dichasium
- Compound Dichasium
- Polychasial Cyme
- Monochasial Cyme
  - Helicoid
  - Scorpioid

Mixed inflorescence

- Thyrsus
- Verticillaster
- Mixed Spadix

Special Inflorescence

- Cyathium
- Hypanthodium
- Coenanthium

i. Main axis elongated

Here the inflorescence axis is very much elongated and bears pedicellate or sessile flowers. This may include several types.

Simple Raceme

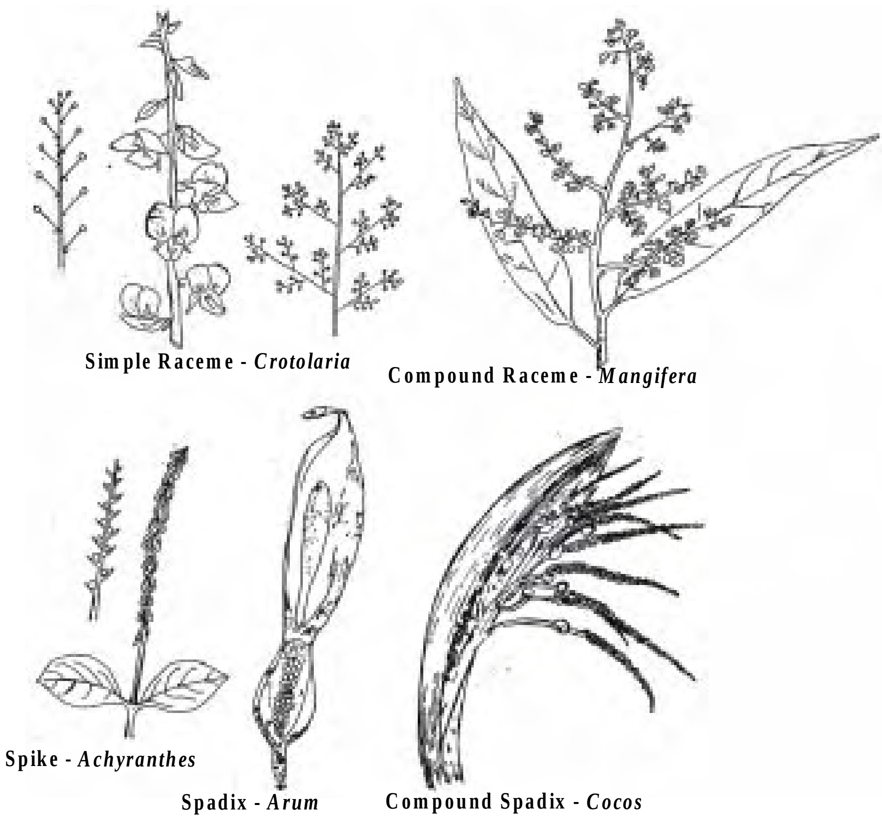
This is a very simple type of inflorescence. The axis shows unlimited growth. Numerous pedicellate flowers are arranged from base to apex in acropetal succession. Each flower arises in the axil of a bract eg. *Crotolaria retusa*, *Cleome viscosa*.

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 succession. 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 longum*.



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

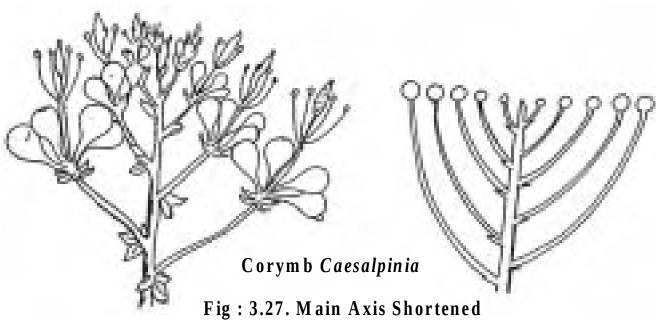
The swollen and fleshy inflorescence axis is branched and bears sessile flowers. There is a thick and large boat shaped bract called **spathe** covering the inflorescence eg. *Cocos.*

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 the 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 **involucel 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)

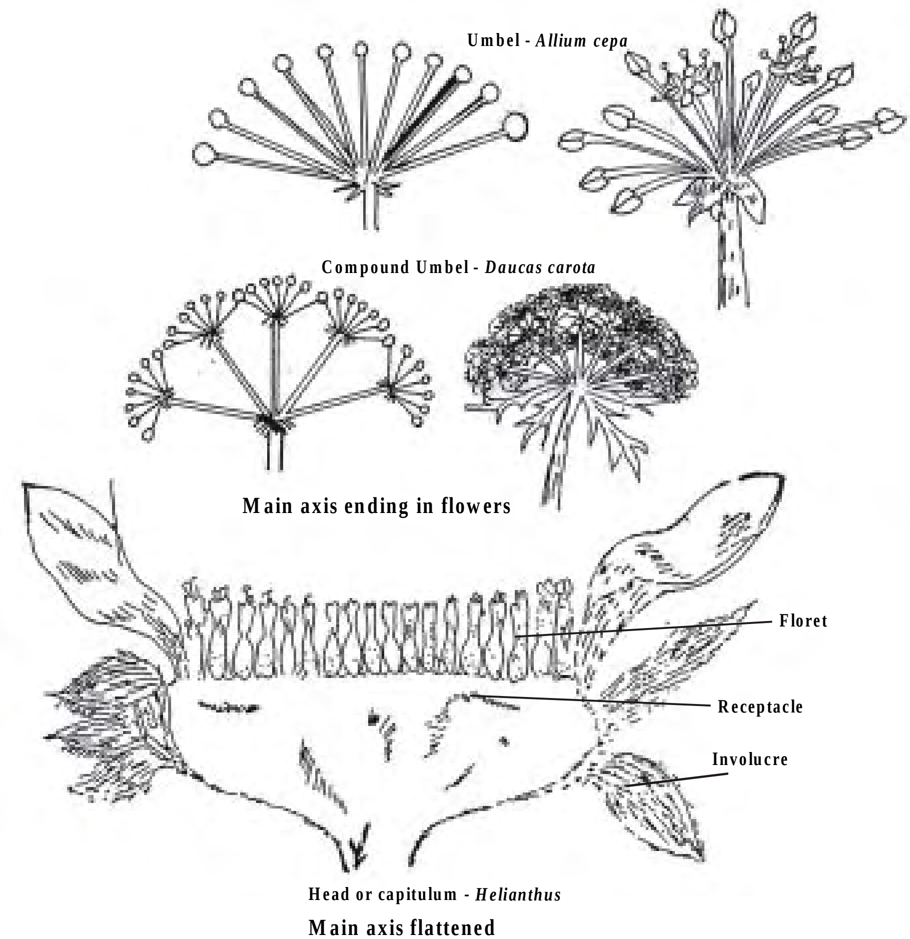


Fig : 3.28. Types of Racemose Inflorescence

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 inflo-rescence 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.

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 flower is at the tip and younger flower is at the base and the order of opening of flowers in **centrifugal** i.e. from centre to periphery. The flowers are few in number.

Cymose inflorescence is of various types.

Simple Cyme

The type of the stem or the axil of the 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*.

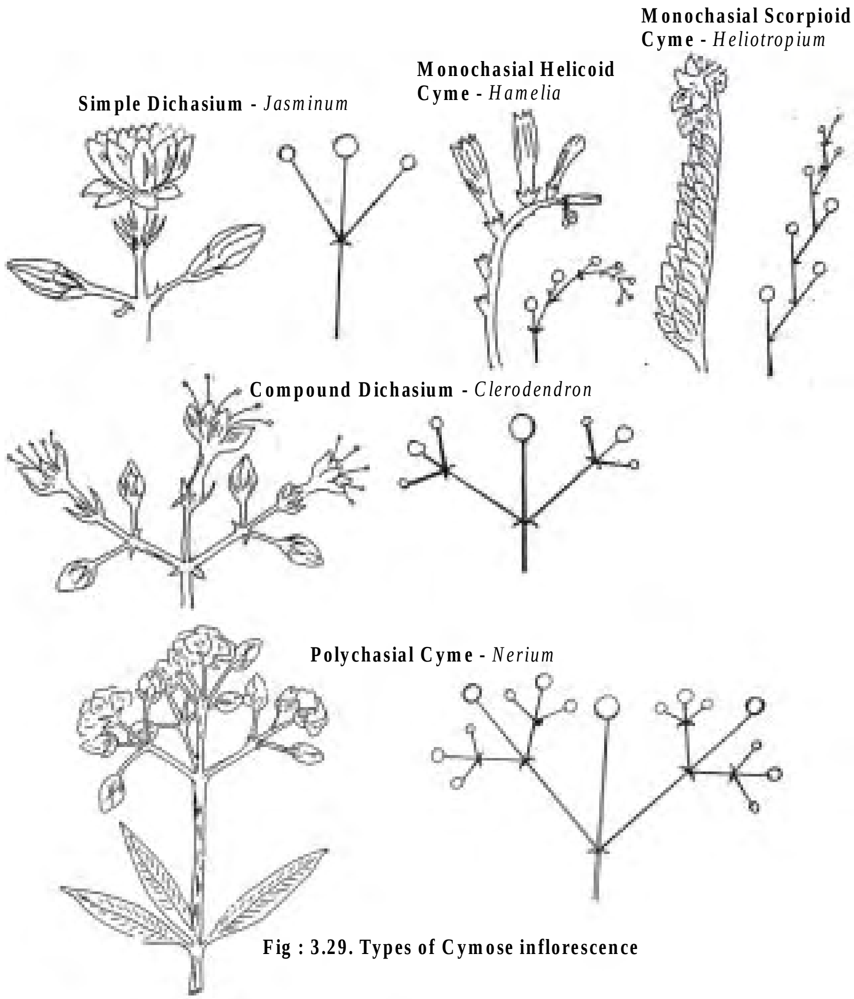


Fig : 3.29. Types of Cymose inflorescence

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. Thus a branched simple dichasium forms a compound dichasium eg. *Clerodendron.*

Monochasial Cyme

The inflorescence axis terminates in a flower. Of the two lateral bracts only one branches further. Such as 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 bracts are on one side only giving rise to a helical appearance. eg. *Hamelia patens*.

Scorpioid Cyme

The main axis stops growth after producing a flower. The lateral branches arising from the bracts are produced alternately to the left and to the right in a zig-zag manner e.g. *Heliotropium*.

Polychasial Cyme

The main axis terminates in a flower. The lateral branches formed from the branch 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.

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 inflorescences.

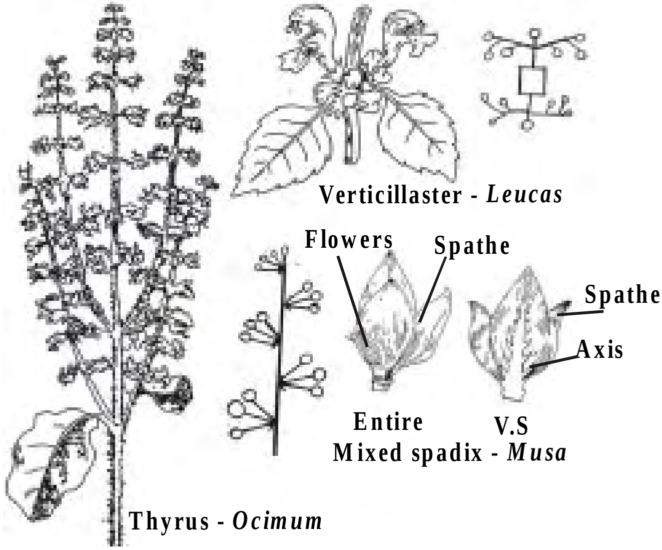


Fig : 3.30. Types of Mixed Inflorescence

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 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*.

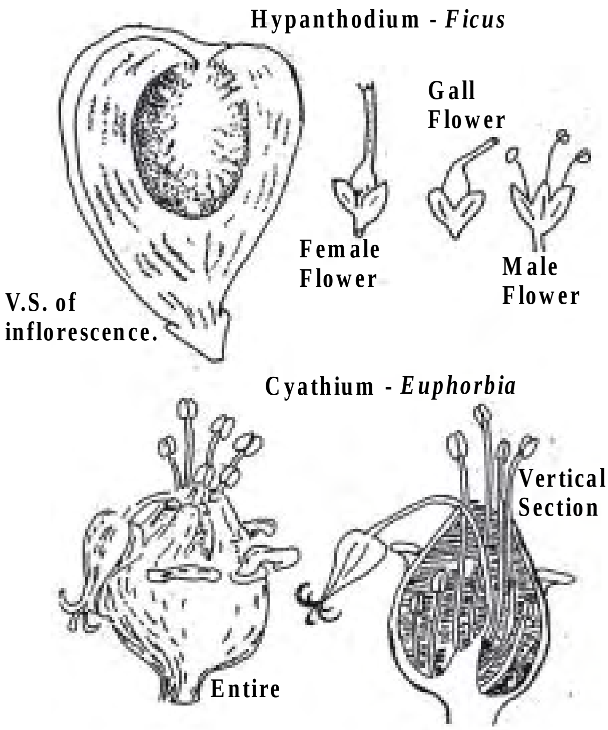


Fig : 3.31. Types of Special Inflorescence

Hypanthodium

Here the receptacle is concave and cup shaped. The 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 EVALUATION

One Mark

Choose the correct answer

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 the **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**.

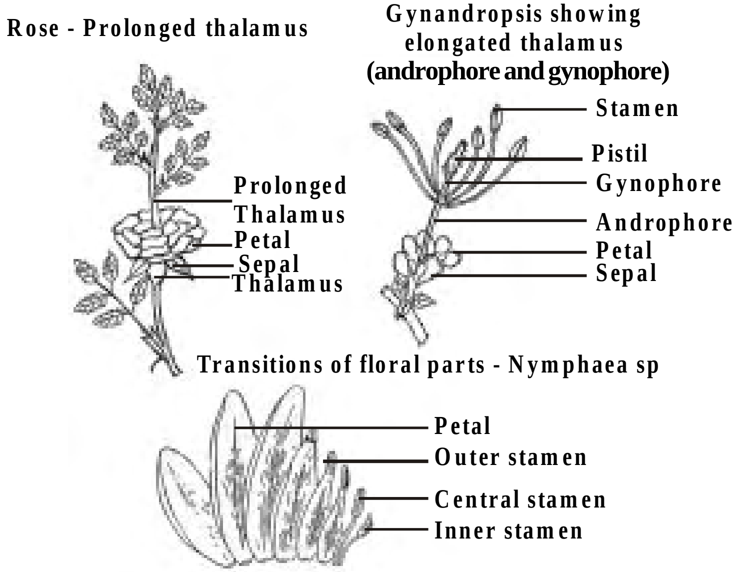


Fig 3.32. Evidences to support that flower is a modified shoot

4. In ***Nymphaea*** (Water Lily), the flowers show all transitional stages between a sepal and petal and between a petal and stamen
5. In ***Gynandropsis gynandra***, 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 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 **pedicellate** and a flower without stalk is called **sessile.**

Parts of a flower

The 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 *C**oriander, 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

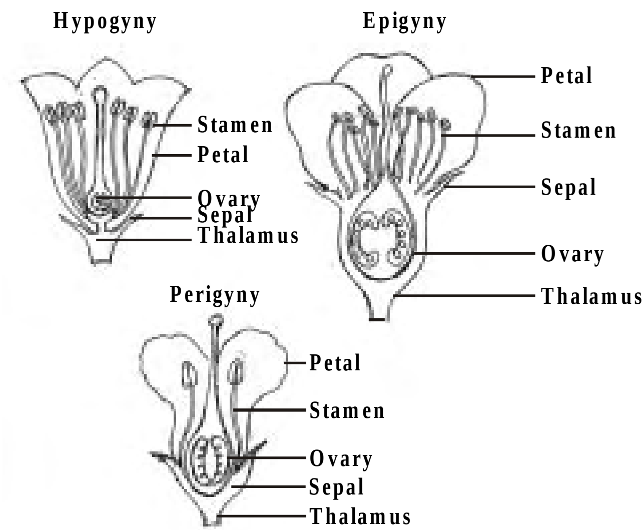


Fig : 3.33. Insertion of floral leaves

described as hypogynous. The ovary is known as superior. eg. **Malvaceae, Annonaceae** etc.

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 a 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 ***Mussaenda 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 the 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 **polysepalous**, when 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 the **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 some other cases, when the calyx persists (unwithered) even after fruit formation, it is said to be persistent. eg. **Brinjal,**
4. **Accrescent**: 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 pollination and also serves to protect the essential organs.

Shape of the petals in the corolla

I. **Clawed :** The petal is narrow and slender at the base as a claw eg. ***Petals of Cruciferae.***

II. **Fimbriate:** Petals fringed with hairy, teeth like structure_ eg. ***Dianthus***

III. **Laciniate:** Petal divided into several long more or less equal segments.

IV. **Spurred:** Corolla with a long hollow projection called spur eg. ***Delphinium majus***

V. **Saccate :** The lower part of the corolla tube gets dilated to form a sac- like structure eg. ***Antirrhinum.***

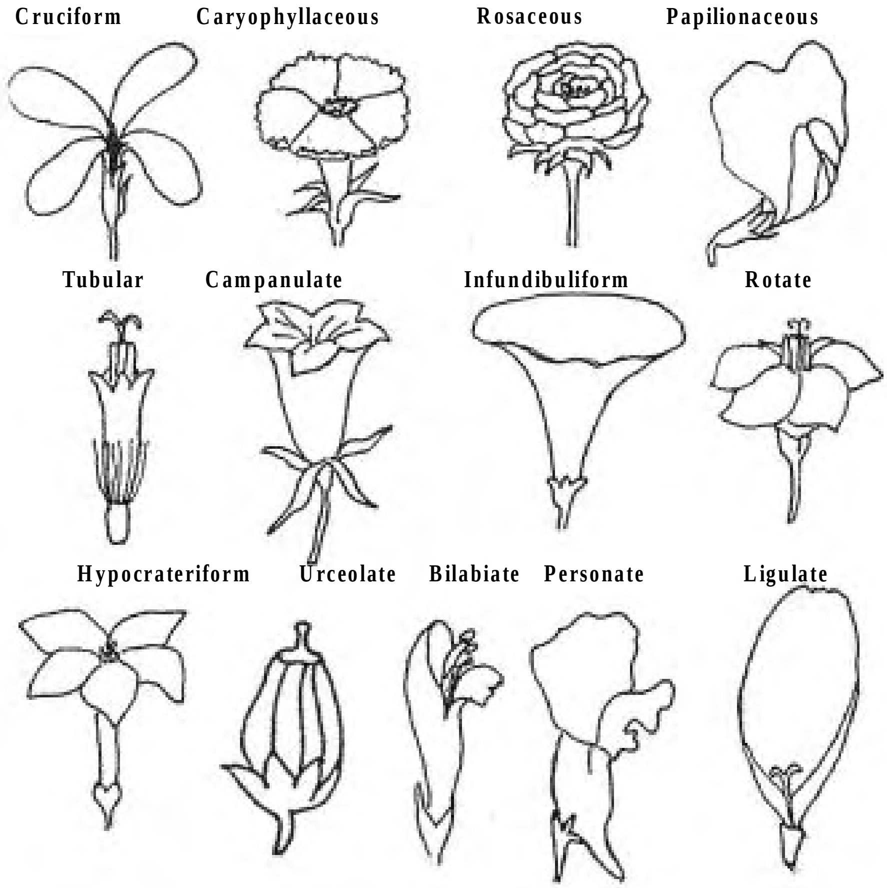


Fig : 3.34. Forms of corolla

Forms of Corolla

A Polypetalous and Regular

i. Cruciform : When the corolla consists of four clawed petals arranged at right angles to one another. eg. ***Brassica*, Radish, etc.,**

ii. Caryophyllaceous : When the corolla consists of five clawed petals with spreading limbs; claws and limbs are at right angles to one another. eg. **Caryophyllaceae**

iii. Rosaceous : When the corolla consists of five spreading petals, without any claw eg. **Wild Rose**

B Polypetalous and Irregular

i. **Papilionaceous** : When the corolla consists of 5 petals, one large – the **vexillum** or **standard** petal which is posterior and outermost, two laterals **–alae** 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, combining calyx and corolla: One member, the petal in front of the stamen and stigma, differs from the rest in shape and in being nectariferous: it is called a labellum. eg. ***Habenaria.***

C Gamopetalous and Regular

I. **Tubular :** Corolla tube is more or less cylindrical. **Eg. *Disc florets of Helianthus***

II. **Campanulate :** When the corolla tube is inflated below and widened out at the top. It looks bell shaped. e**g. *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 wheel in shape eg. ***Solanum***

V. **Salver-Shaped or Hypocrateriform** – Corolla tube is long and narrow with spreading limbs. eg. ***Vinca.***

VI. **Urceolate :** Urn-shaped. Corolla tube is inflated in the middle but narrow above and below, as in ***Bryophyllum 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. eg. ***Antirrhinum***

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 like descendingly imbricate and ascendingly imbricate.

a. **Descendingly Imbricate or Vexillary Aestivation :** In this type of aestivation the posterior petal overlaps one margin of the two lateral petals.

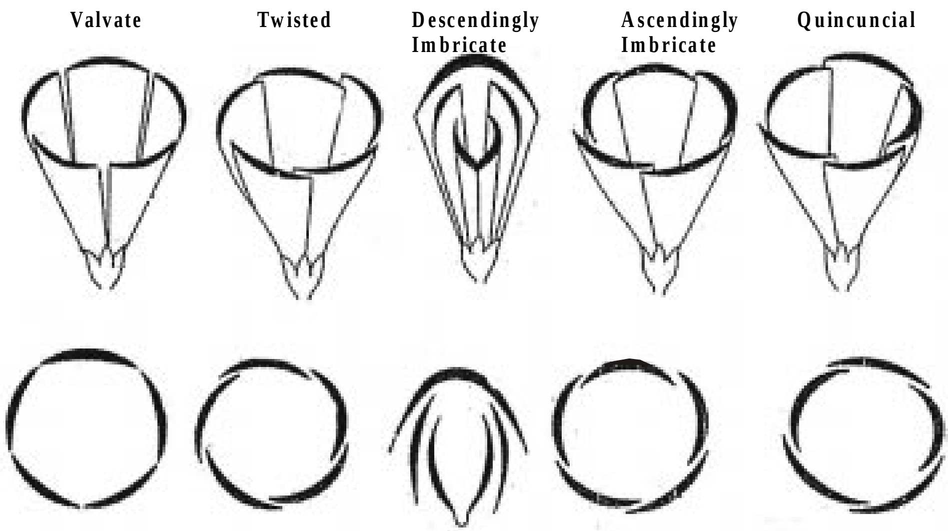


Fig : 3.35. Different types of Aestivation

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**

Ascendingly imbricate aestivation : In this type the posterior odd petal is innermost being over lapped 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 a 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 conncted 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 form a cylinder around the style. The filaments are free, eg. ***Asteraceae*** .

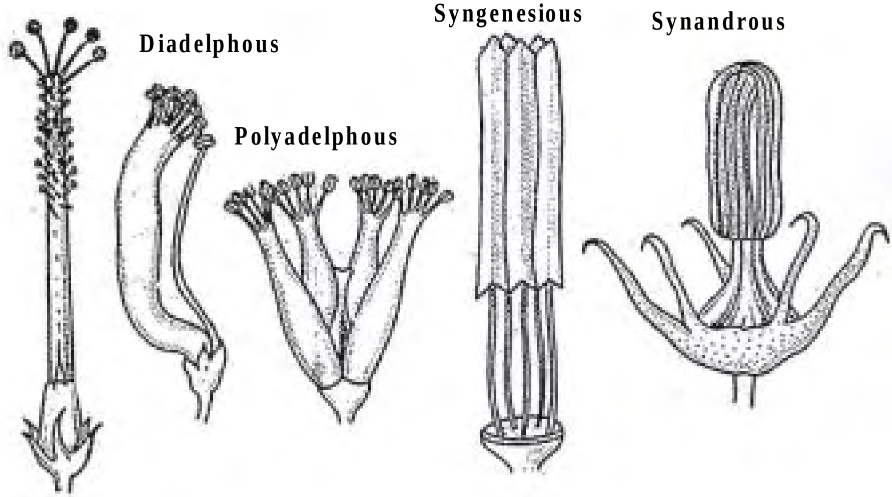


Fig : 3.36. Cohesion of stamens

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 adhere 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 or 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.**

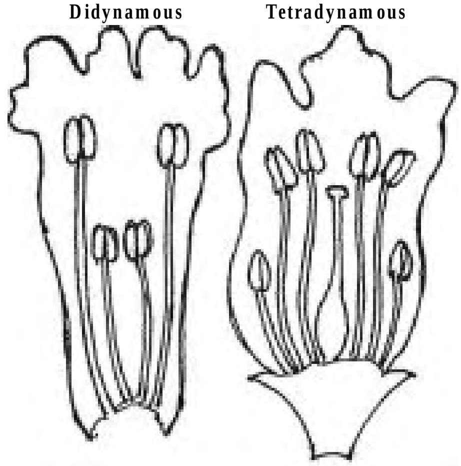


Fig : 3.37. Length of stamens

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 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**

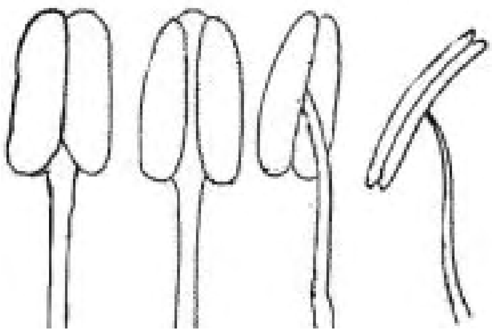


Fig : 3.38. Fixation of anthers

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 are related with gynoecium.

1. Numbr 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:

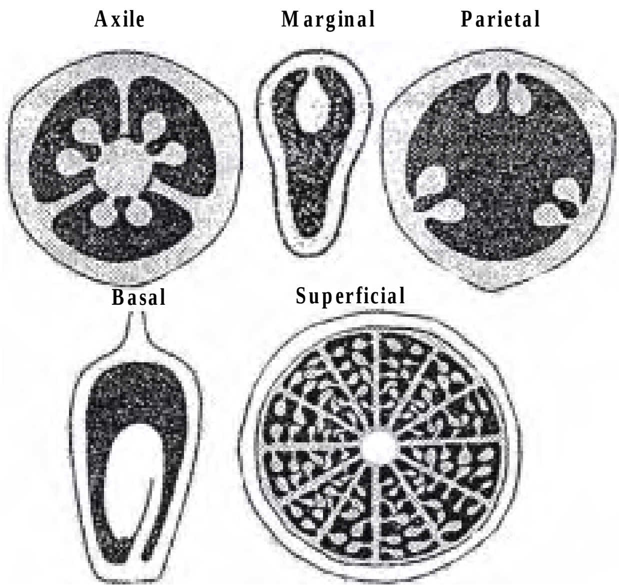


Fig : 3.39. Types of Placentations

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 placenta 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, multilocular 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.

I. Floral whorls

1. **Complete:** When all the four whorls. (Calyx, Corolla, Androecium, and Gynoecium) are present in a flower, it is termed as complete.
2. **Incomplete:** When one or more whorls are absent the flower is described as 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 of plants, where the flowers have neither calyx nor corolla. Such flowers are described as naked or achlamydeous.

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 as 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, Cashew nut** 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, ie. 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 the 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 multiples 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 fives 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 s 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

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.

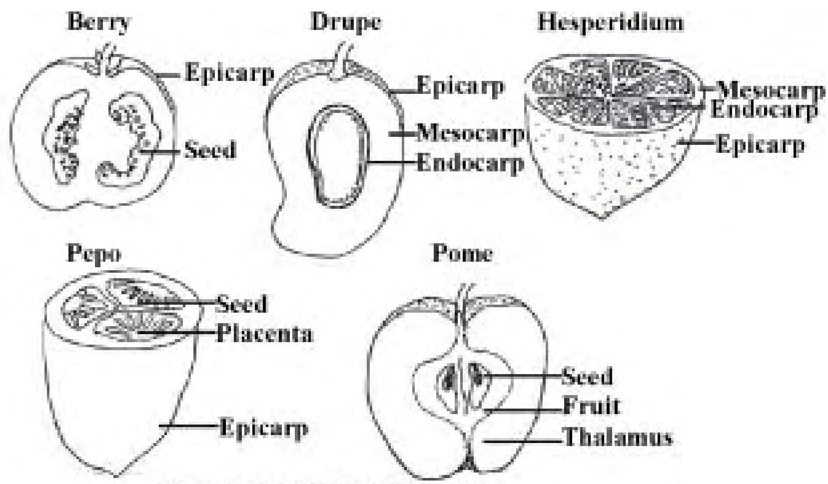


Fig : 3.40. Simple fleshy fruits

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 kind 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 placentae, that are edible.

It is a 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 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**.

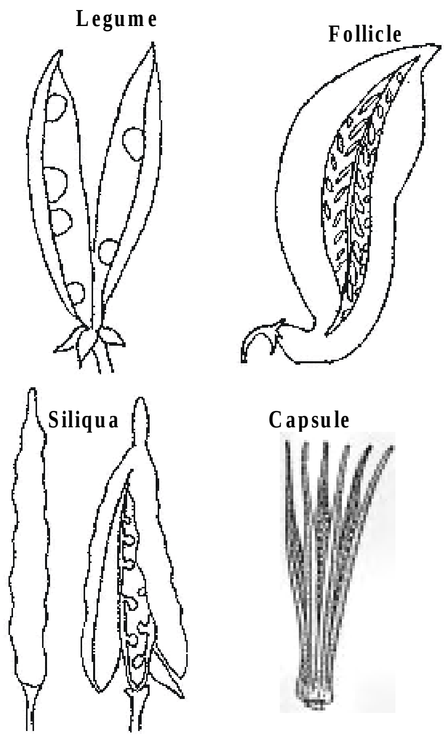


Fig : 3.41. Dehiscent dry fruits

(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***

(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 multicarpellary, syncarpous and superior ovary, It breaks up into as many segments or cocci as there are carpels; eg. ***Ricinus,***

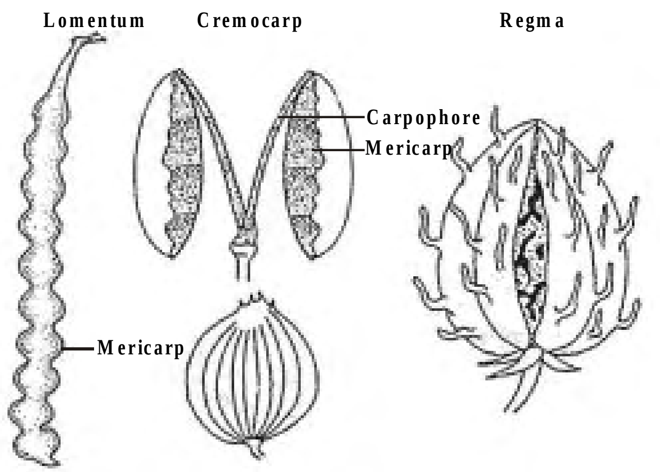


Fig : 3.42. Schizocarpic dry fruits

c. Indehiscent dry fruits

1. **Achene:** A small, indehiscent one

Fig : 3.43. Indehiscent dry fruits

seeded fruit developing from a monocarpellary ovary and in which the pericarp is hard, leathery and remains free from seed coat; eg. ***Mirabilis, Clematis*.**

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 multicarpellary 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 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***.

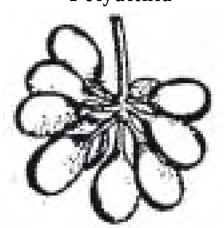


Fig : 3.44. Aggregate Fruit

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 sigmas of the carpel. The sterile or unfertilized flowers, occur in the form of numerous, elongated, whitish, flat structures in between the edible flakes.

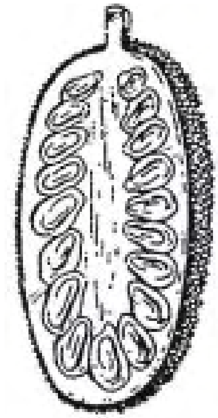


Fig : 3.45. Multiple Fruit

Sorosis: A multiple fruit that develops form a spicate inflorescence. 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.

Fruits

- **Simple (Develops from a single ovary of single flower)**
  - **Fleshy (Pericarp fleshy and fibrous)**
    - **2. Berry**
    - **3. Drupe**
    - **4. Hesperidium**
    - **5. Pepo**
    - **6. Pome**
  - **Dry (Pericarp dry, not fleshy)**
    - **Dehiscent (burst automatically and liberate seeds)**
      1. **Legume or pod**
      2. **Follicle**
      3. **Siliqua**
      4. **Capsule**
    - **Schizocarpic (Split into one seeded compartments)**
      1. **Lomentum**
      2. **Cremocarp**
      3. **Regma**
    - **Indehiscent (Do not dehisce to liberate seeds)**
      1. **Achene**
      2. **Caryopsis**
      3. **Cypsela**
      4. **Nut**
      5. **Samara**
- **Aggregate (Develops from a single apocarpous flower)**
- **Multiple (Develops from the flowers of a whole inflorescence)**

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 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**. The function of seed coat is protective. It protects the seed from desiccation,

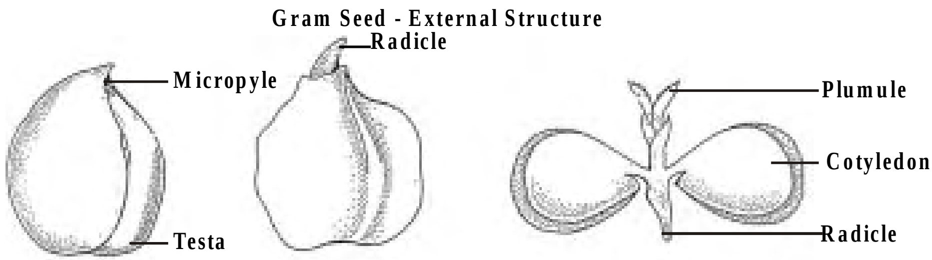


Fig : 3.46. Structure of Dicot seed

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**.

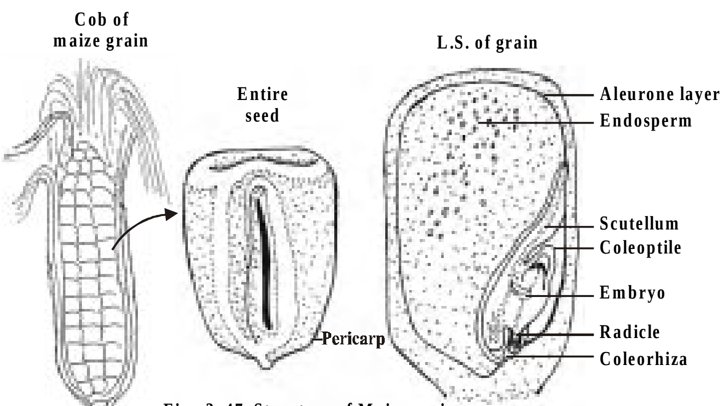


Fig : 3. 47. Structure of Maize grain

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. Axis consists of a **plumule** at the upper portion and the **radicle** at the lower end. Both the radicle and the 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 these of embryo during its 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 allbuminous 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. Timerous Flowers are common among
   a. Dicots 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. Syconus c. Baccate d. Aggregate
13. The type of fruit seen in Jack is
    a. Multiple fruit b. Syconus 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 the different types of calyx.
3. How the symmetry of a flower is determined? Briefly describe the 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 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 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).

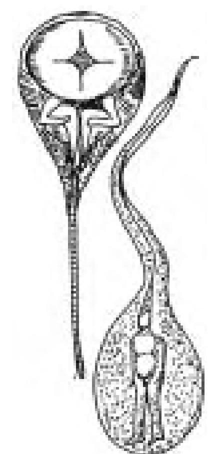


Fig : 4.2 Homunculus as per Preformation Theory

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.

Some 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.

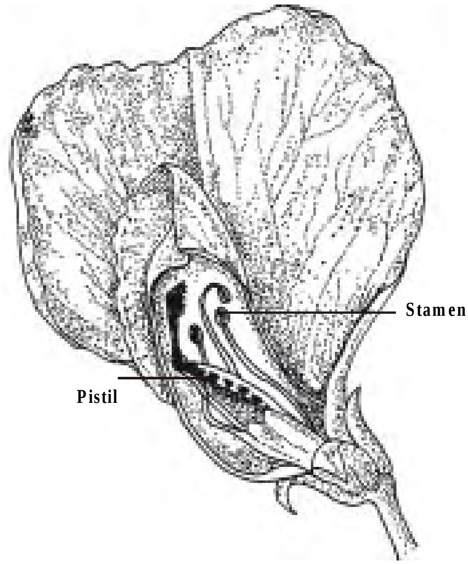


Fig : 4.3. L.S. of *Pisum sativum* flower

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.

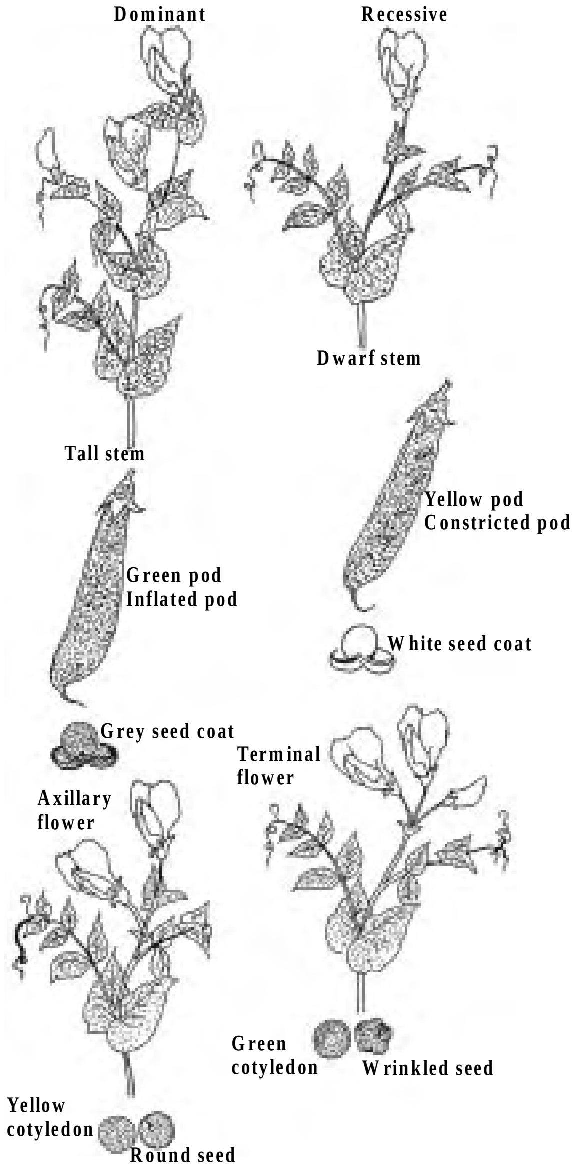


Fig : 4.4. Contrasting characters of traits chosen by Mendel

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 x tt

Tall x Dwarf

Gametes (T) (t)

F_1 Tt Monohybrid

Tall (Selfing)

Gametes **(T)** **(t)**

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).

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.

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.

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 dihybird	x	rryy 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)
F_1		r_1r_2 (Selfed) Pink	
Gametes		(r_1) (r_2)	

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)

F_1 WwYy (Selfed)

White

WwYy x Ww Yy

Gametes (WY) (Wy) (wY) (wy)

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)

$\mathbf{F_1}$ PpQq(Selfed)

Red

Pp Qq x Pp Qq

Gametes (PQ) (Pq) (pQ) (pq)

$\mathbf{F_2}$

	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 : 4.3. 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. Describe the Inheritance of glume colour in *Sorghum.*
2. Explain inheritance of fruit colour in *Cucurbita pepo.*
3. Differentiate between dominance and epistasis.

Ten Marks

1. Write an essay on the various epistatic gene interactions you have studied.

V. PLANT PHYSIOLOGY

1. Cell as a Physiological Unit

Living organisms are made up of structural and functional units called cells. Every cell is made up of several biomolecules and organelles. The organelles are membrane - bound structures involved in specific functions. The organelles are absent in prokaryotic cells; yet a prokaryotic cell also can carry out all the physiological functions required for its metabolism.

The plant cell can be referred to as a physiological unit as it has the capabilities of carrying out physiological functions as a single entity.

The cell wall is a non-living outer limiting layer of the plant cell which provides shape and rigidity to the cell.

The cell wall is followed by the plasma membrane or cell membrane which is selectively permeable involved in the absorption of water by osmosis, and other substances like ions and low molecular weight biomolecules.

The protoplasm which is the physical basis of life includes cytoplasm, nucleus and cellular organelles which are involved the various physiological phenomena taking place within the cell. The protoplasm is a water retentive colloid holding 90% of water which is a universal solvent.

The plant cells are characterised by a prominent vacuole holding the cell sap and functioning as an osmo-regulatory organelle of the cell.

The cell is the principal seat of metabolic events.

Nutrition

Among the cell organelles, the **Chloroplast** is the most important structure unique to plant cells and involved in the most important physiological process called **Photosynthesis**. This process is the source of food for life on earth.

Respiration

The organelle of the plant cell involved in cellular respiration is the mitochondrion. This organelle is concerned with the oxidation of food substances to release CO_2 , water and energy in the form of Adenosine Tri Phosphate (ATP).

Protein Synthesis

The synthesis of proteins and their transport is carried out by the ribosomes and the endoplasmic reticulum.

Secretion

Cell secretion takes place by the organelle called the **Golgi body** which is referred to as the **dictyosome** in plants.

The plant is thus able to co-ordinate the physiological activities of the various organelles and behaves as a perfect physiological unit.

Thus the cell is the seat of important physiological functions.

1.a. Properties of Protoplasm

The protoplasm is the living component of the plant cell and involves four parts (i) the cytoplasm (ii) the vacuoles, (iii) a number of organelles and (iv) the nucleus.

In young cells, the vacuoles are many, small and scattered, whereas in a mature cell, there is a single large vacuole occupying the centre of the cell and the cytoplasm forms a thin peripheral layer around the vacuole.

The Physical Nature of Protoplasm

Many theories have been put forth to explain the physical nature of the protoplasm.

The Alveolar foam Theory

Butschili in 1882, said that the protoplasm is a semi-transparent, viscous and slimy substance, essentially a liquid possessing a foaming or alveolar structure.

Colloidal Theory

Wilson Fischer (1894) considered the protoplasm as a polyphase colloidal system.

This theory is a widely accepted one as the protoplasm is seen to exhibit the properties of colloids.

Properties

i. Colloidal System

The protoplasm forms a colloidal system composed of a water phase in which mineral matter is dissolved, also having a protein phase, a fat phase and many minor phases. So it is said to be a **polyphase colloidal** system.

ii. Solation and Gelation

The protoplasm exists mostly as a sol (which is semi-liquid) but sometimes it becomes rigid and is viewed as a gel (which is semi-solid)

$$\text{Sol} \underset{\text{Solation}}{\overset{\text{Gelation}}{\rightleftharpoons}} \text{Gel}$$

iii. Brownian Movement

The particles of the protoplasm show an erratic zig-zag movement. This **random** motion, caused by the uneven bombardment of particles is called Brownian movement.

iv. Tyndall Effect

The scattering of a beam of light by the particles of a colloid is termed **tyndall effect**. This is a property of the protoplasm also.

v. Ultrafiltration

The particles of the protoplasm cannot be filtered through ordinary filter paper but can be filtered through ultrafilters such as millipore filters.

vi. Electrical Properties

The particles of the colloid carry an uniform electric charge.

vii. Flocculation or Co-agulation

When the particles of a colloid lose their charges they tend to aggregate and increase in size. As a result they fall out and get precipitated. In other words protoplasm loses its living property.

These properties of the protoplasm indicate that it is a living substance and has rightly been termed as the physical basis of life.

Chemical Nature of Protoplasm

The major constituent of the protoplasm is water which makes up 90% of it. The dry matter has several organic and inorganic substances. Proteins and other nitrogen - containing compounds constitute the bulk of organic matter. Liquids like fats and oils are also present in small amounts. Compounds consisting of chlorides, phosphates, sulphates and carbonates of magnesium, potassium, sodium, calcium and iron are also present.

Since the protoplasm contains all the chemical constituents required for life, it has been called the **"Physical and Chemical Basis of Life"**.

1.b. Water relations

Water is the most important substance required for the sustenance of life. The protoplasm which is the physical and chemical basis of life has 90% of water. Thus the dispersion medium of the protoplasmic colloid is water. Water has a number of special properties by which it becomes the most suitable medium for the organisation of a variety of life's functions rather very easily. Absorbing of substances from the environment, transporting these within and across the cells, mediating important chemical reactions and properly maintaining the shape and forms of organs to bring about their effective functioning are all advantages, the protoplasm possesses due to the presence of water in it. At molecular level water is the donor of electrons / hydrogen in photosynthesis and it is the end product in respiration Thus it is clear that any factor causing loss of water and subsequent coagulation of protoplasm will eventually lead to death.

As far as plant cells are concerned water absorption for photosynthesis is one of the most essential activities. So water relations in a plant cell are of greater significance and form the fundamental process for the proper functioning of the plant cell.

A typical plant cell consists of cell wall, a central large vacuole filled with an aqueous solution called cell sap, and the cytoplasm. When a plant cell is subjected to movement of water, many factors start operating and these will ultimately determine, a property called water potential of the cell sap. It is the water potential which controls movement of water into and out of the cells.

1.c. Absorption and Movement

Absorption of water

Absorption of water occurs in plants through roots. The zone of water absorption in root is about 20 - 200mm from the root tip and this is the **root hair zone**. The ultimate units of water absorption are the root hairs. The root hair is a unicellular tubular extension bound by an outer cell wall followed by plasma membrane, enclosing the protoplasm inside. The cytoplasm of the root hair contains a large central vacuole filled with cell sap.

Absorption of water by plants takes place due to the process, osmosis, which is a passive diffusion.

Path of water across the root

The root hairs are unicellular extensions of the roots found extending into the pore spaces of the soil particles. The pore spaces contain water and dissolved minerals in the form of **soil solution**. This water first gets adsorbed to the wall of the root hair, by imbibition thus wetting it. This forms a channel for further absorption of water by the living cells of the root in an active manner. From the root hair water reaches the cells of the rhizodermis, then through the cortical layers the water reaches the **passage** cells of the endodermis which are opposite to the **protoxylem points.** The water then passes through the parenchymatous pericycle and reaches the **protoxylem**.

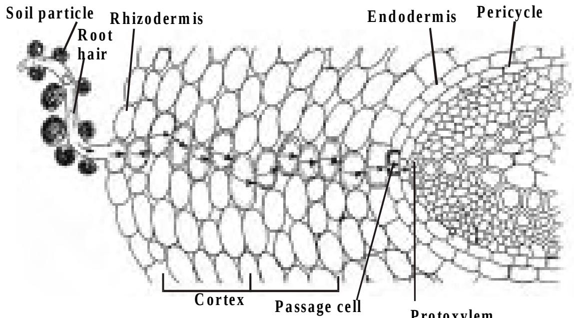


Fig : 5.1. Path of water across the root

The path of water is in a lateral direction and so is called **lateral transport** of water. Once the water reaches the xylem, it has to be transported in an upward direction to the shoot system and from there to the leaves. This is referred to as **Ascent of Sap.**

Imbibition

Imbibition is the uptake of water or other solvents by non-living substances such as gum, starch or wood causing swelling of these substances. Such substances are called **imbibants**. The phenomenon of imbibition creates a force called **imbibitional force** between the imbibant and the solvent. In plant cells, the cell wall is the imbibant which absorbs water and forms a channel for movement of water into the cell by diffusion and osmosis. Imbibition plays a very important role in most of the activities especially seed germination which involves absorption of water by seed coats, their swelling and rupture causing the emergence of the **radicle** and **plumule**.

Diffusion

Diffusion is the flow of matter, solid, liquids and gases from a region of higher concentration to a region of lower concentration until equilibrium is attained. Examples of diffusion are the smell of perfume, when we open a perfume bottle and the spread of colour when a crystal of potassium permanganate is put into a beaker of water.

When a substance undergoes diffusion, its particles start moving. When the moving particles counter a surface, the surface offers resistance to the impact of diffusing particles. This leads to development of pressure called **diffusion pressure**. Always diffusion occurs from a level of higher diffusion pressure to a level of lower diffusion pressure. A pure solvent has maximum diffusion pressure and addition of solutes lowers the diffusion pressure. The amount by which the diffusion pressure of a solution is lower than that of the pure solvent is called **Diffusion Pressure Deficit** (DPD). But the recent trend is to use the term water potential to explain diffusion of water.

Osmosis

Osmosis is a special type of diffusion of liquids. When two solutions of different concentrations are separated by a selectively permeable membrane, diffusion of water or solvent molecules takes place from the solution of lower concentration to the solution of higher concentration. This process is called **Osmosis**. In other words Osmosis is the diffusion of water or solvent from a region of its higher concentration to a region of its lower concentration through a selectively permeable membrane. This can also be expressed as the movement of water from a region of higher free energy of water or water potential to a region of lower free energy of water potential through a selectively permeable membrane.

Hypertonic, Hypotonic and Isotonic solutions

Imagine a system in which an aqueous solution **A** with high concentration of solute is seperated by a selectively permeable membrane from an aqueous solution **B** with a low concentration of solute. Solution A is said to be **hypertonic** to solution B, and solution B **hypotonic** to solution A. In this situation, there will be a net movement of water or solvent molecules through the membrane from the hypotonic solution to the hypertonic solution by osmosis. This will continue until equilibrium in reached, at which point there is no further movement of water and the two solution are described as **isotonic.**

Demonstration of Osmosis

The process of osmosis may be demonstrated by the simple osmometer which is also called the thistle funnel experiment.

Potato Osmoscope

Demonstration of osmosis in a living system can be done using the potato osmoscope.

A potato is peeled and one side is flattened which serves as the base. A cavity is made in the potato and is filled with concentrated sugar solution and a pin mark is made to indicate the initial level. This potato is then placed in a beaker containing coloured water for some time.

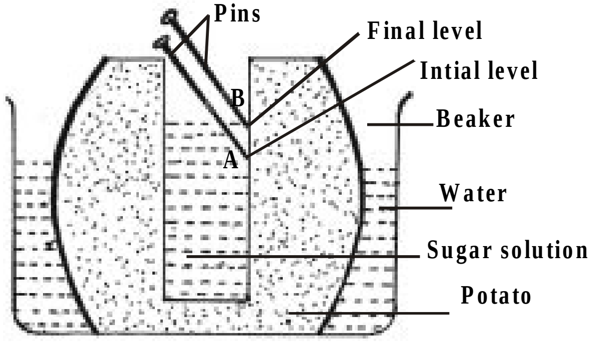


Fig : 5.2. Potato osmoscope

Observation

It is observed that the sugar solution in the cavity of the potato becomes coloured and level rises.

Inference

This proves the entry of water into the sugar solution through the potato tissues which serve as the selectively permeable membrane.

Plasmolysis

When a plant cell is placed in hypertonic solution, the process of exosmosis starts and water from the cell sap diffuses out into the solution of external medium. This causes a reduction in the tension of the cell wall and brings about the contraction

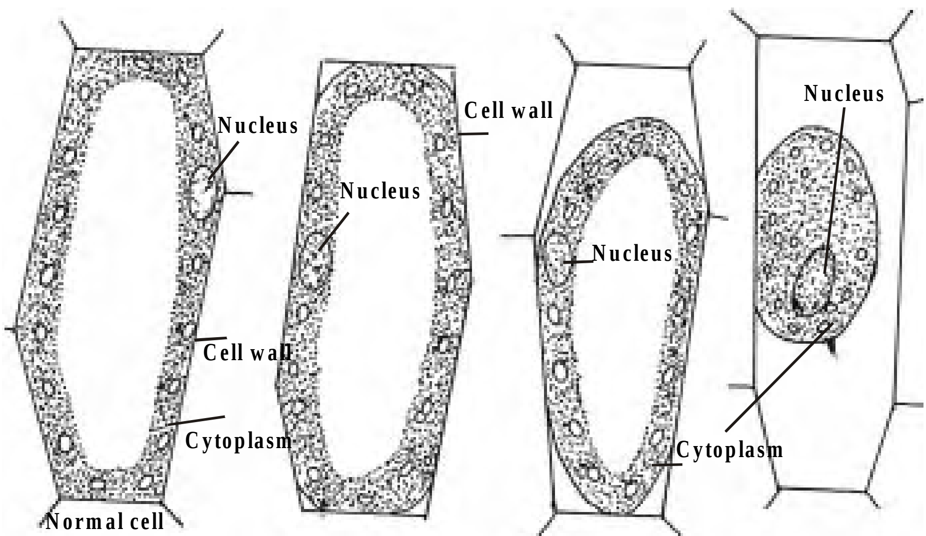


Fig : 5.3. Various stages of plasmolysis in a cell of protoplasm due to the continuous loss of water. The protoplasm becomes rounded in shape due to contraction and such a cell is said to be **plasmolysed** and the phenomenon is referred to as **plasmolysis**. The initial stage of plasmolysis where the protoplasm just starts leaving the cell wall is called **incipient plasmolysis**.

When a completely plasmolysed cell is again placed in water or a hypotonic solution, endosmosis takes place and the protoplasm regains its original state and shape. ie., the cell becomes fully turgid. This phenomenon is the reverse of plasmolysis and is called **deplasmolysis**.

Significance of Plasmolysis

1. Helps to understand the living nature of a cell.
2. Helps to preserve meat, jellies and used in pickling as their salting kills bacteria by plasmolysis.
3. Used to prove the permeability of cell wall and selectively permeable nature of plasma membrane.

Osmotic Pressure

Osmotic pressure of a solution is the pressure which must be applied to it in order to prevent the passage of solvent due to osmosis. In other words, it is that pressure which is needed to check the process of osmosis. The term **osmotic potential** is also used in place of osmotic pressure.

Turgor Pressure

When the plant cell is placed in water, it will swell but will not burst. Due to the negative osmotic potential of the cell sap, water moves into the cell and causes the plasma membrane to press against the cell wall. This pressure responsible for pressing the plasma membrane against cell wall is called **turgor pressure**.

Turgor pressure may also be defined as the hydrostatic pressure developed inside the cell on the cell wall due to **endosmosis**.

Wall Pressure

As a result of turgor pressure on the cell wall, the rigid cell wall exerts an equal pressure in the opposite direction called **wall pressure**. Under these conditions, the plant cell is said to be turgid.

When wall pressure becomes equal to turgor pressure, entry of water into the cell stops and the water potential (Psi denoted as Ψ) becomes equal to that of the environment.

Diffusion Pressure Deficit (DPD) or Suction Pressure

The pressure exerted by diffusing particles is called diffusion pressure. When solute is added, the diffusion pressure of a solution is lowered. The amount by which diffusion pressure of a solution is lower than that of its pure solvent is known as **diffusion pressure deficit** which was described as **suction pressure** by Renner (1915). Recently a new term called water potential is used for DPD but with a negative value.

1.d. Permeability and Water Potential

Permeability

The entry and exit of water into and out of the plant cells is due to a phenomenon called **permeability** of the plasma membrane. The plasma membrane is considered to be selectively permeable because it allows the solvent, water and a few selected molecules and ions to pass through it.

Water Potential

The plant being multiphase system, here the movement of water is expressed in terms of free energy. Water will flow from a region of higher free energy to a region of lower free energy. Free energy is the thermodynamic parameter which determines the direction along which physical and chemical changes should occur and may be defined as the sum of the energy of a system capable of doing work.

Based on free energy, water potential may be defined as the difference between the free energy of water molecules in pure water and the free energy of water in any other system (eg) water in a solution or water contained in the plant cell. Water potential is denoted by the Greek letter *psi* Ψ and is measured in bars. Thus, water potential is the chemical potential of water. The water potential of pure water is zero bar and water potential in a plant tissue is always less than zero bar and hence a negative number.

Table: 5.1. Differences between diffusion and osmosis

Diffusion	Osmosis
Movement of solid, liquid or gas molecules from a region of higher concentration to a region of lower concentration	Movement of solvent molecules from a region of higher solvent concentration to a region of lower solvent concentration.
A selectively permeable membrane is not involved.	Takes place through a selectively permeable membrane.

Components of Water Potential

When a typical plant cell containing cell wall, vacuole and cytoplasm is placed in a medium containing pure water, there are a number of factors which determine the water potential of the cell sap. These are called the components of water potential and are named as

(i) Matric potential, (ii) Solute potential and (iii) Pressure potential

Matric Potential

The term `matric' is used for surfaces which can absorb water such as cell walls, protoplast and soil particles. Matric potential is the component influenced by presence of a matric and possesses a negative value and denoted as Ψ_m.

Solute Potential

It is a component of water potential which is also called Osmotic potential which represents the amount of solute present and is denoted as Ψ_s. Ψ_s of pure water is zero and so Ψ_s values are negative.

Pressure Potential

The cell wall exerts a pressure on the cellular contents inwards called **wall pressure** causing a hydrostatic pressure to be exerted in the vacuole called **turgor**

Table : 5.2. Differences between Diffusion Pressure Deficit and Water Potential

Diffusion Pressure Deficit (DPD)	Water Potential
1. DPD was originally called suction pressure.	It is called ψ_w where ψ is psi and the chemical potential of water equivalent to DPD with a negative sign.
2. It is measured in atmospheres.	It is measured in bars.
3. DPD is the difference between the diffusion pressure of a solution and pure solvent.	Water potential is the difference between free energy of water molecules in pure water and solution.
4. DPD = OP - TP where OP = Osmotic pressure and TP = Turgor pressure.	$\psi_w = \psi_m + \psi_s + \psi_p$ where ψ_m = Matric potential; ψ_s = Solute potential; ψ_p = Pressure potential
5. Water moves from lower DPD to higher DPD.	Water moves from higher water potential to lower water potential.

pressure which is equal and opposite to wall pressure. Pressure potential which is denoted as Ψ_p is equivalent to either the wall pressure or turgor pressure. Water potential $\Psi = \Psi_m + \Psi_s + \Psi_p$.

Water potential is thus the sum of the three potentials.

Thus the plant cell acts as an osmotic system having its own regulatory control over absorption and movement of water through the concerted effect of phenomena such as imbibition, diffusion and osmosis.

SELF EVALUATION

One Mark

Choose the correct answer

1. The protoplasm was considered as a polyphase colloidal system by

   a. Altmann b. Hemming c. Wilson Fisher d. Butschili

2. The movement of water into and out of cells is controlled by

   a. Water potential b. Endosmosis c. Exosmosis d. Plasmolysis

3. Flow of matter from a region of higher concentration to a region of lower concentration is called

   a. Imbibition b.Osmosis c. Diffusion d. Plasmolysis

4. The principle used in pickling is

   a. Imbibition b. Endosmosis c. Plasmolysis d. None of the above

Two Marks

1. Define : Tyndall effect / Brownian movement / Imbibition / Diffusion / DPD / Osmosis / Hypertonic solution / Hypotonic solution / Isotonic solution / Plasmolysis / Osmotic pressure / Turgor pressure / Wall pressure / Water potential / Permeability.

Five Marks

1. Why is the cell called a physiological unit?
2. Explain the physical nature of protoplasm.
3. Describe the properties of protoplasm.
4. Explain the components of water potential.
5. Explain plasmolysis and bring out its significance.
6. Differentiate between DPD and water potential.

Ten Marks

1. Explain osmosis with an experiment.
2. Write an essay on the physical nature and properties of protoplasm.

2. Water Transport

The water absorbed by the root hairs is translocated upwards through the xylem. The mystery of the upward movement of water is yet to be solved in a satisfactory way. The upward transport of water in plants which are 400 feet high still poses a serious problem as it has not been satisfactorily explained till date.

Though the mechanism for upward movement of water or **ascent of sap** is not clear, it has been proved that ascent of sap takes place through xylem.

The **girdling experiment** was done in a plant with thick stem where the outer layer of phloem was removed. Still it was found that ascent of sap continued to take place proving that ascent of sap takes place through the xylem.

A young tomato or balsam seedling was taken and kept in a beaker containing water coloured with eosin. After sometime it was seen that streaks of red colour were running up the stem. When a cross section of the stem was taken, it was found that xylem was coloured proving that ascent of sap takes place through the xylem tissue.

Mechanism of Ascent of sap

A number of theories have been put forward at various times to explain the mechanism of ascent of sap. These are (i) Vital theories (ii) Root Pressure theory and (iii) Transpiration pull.

Vital Theories

These theories had been given very early and have only historical importance. **Godslewski** gave the **relay pump theory**. According to this theory the pumping of water takes place upwards due to the vital activities of xylem parenchyma and xylem rays.

J.C. Bose has put forward the **pulsation theory**. According to this theory water is pumped up due to the contraction and expansion of innermost cortical cells which creates a pulsation causing upward movement of water.

2.a. Transpiration Pull Theory

This is also called as **cohesion-tension theory** put forward by **Dixon** and **Joly** (1894) and supported by **Renner, Curtis** and **Clark**. This theory is based on a number of features.

Cohesion and Adhesion

Mutual attraction between water molecules is called **cohesion** and this force may have a value as high as 350 atmospheres.

The wall of the tracheids and vessels which transport water are made up of lignin and cellulose and have high affinity for water and this is called **adhesion.**

Xylem vessels have perforated end walls and form a tubular structure from roots to the shoot tip. This provides a continuous channel for movement of water which cannot be pulled away from xylem wall due to cohesive and adhesive properties.

Transpiration Pull

The transpiration taking place through leaves causes negative pressure or tension in xylem sap which is transmitted to the root. This is called **transpiration pull** which is responsible for the movement of water column upward.

Objections and Explanation

Air bubbles may enter the water column due to atmospheric pressure variations. Dixon explained that the water continuity is maintained by network of tracks of water due to interconnections between longitudinal vessels.

Septa in xylem vessels may check the flow of water. But the suction force or negative tension developed by transpiration pull is sufficient to overcome resistance developed by septa.

Experiment to Demonstrate Cohesion - Tension Theory

A young transpiring twig is fixed to a glass tube filled with water. The lower end of the tube is kept dipping in a dish containing mercury. As transpiration occurs in the twig the level of mercury rises in the tube due to the suction force created.

Instead of the transpiring twig, if a porous dry pot filled with water is used, the same results are got.

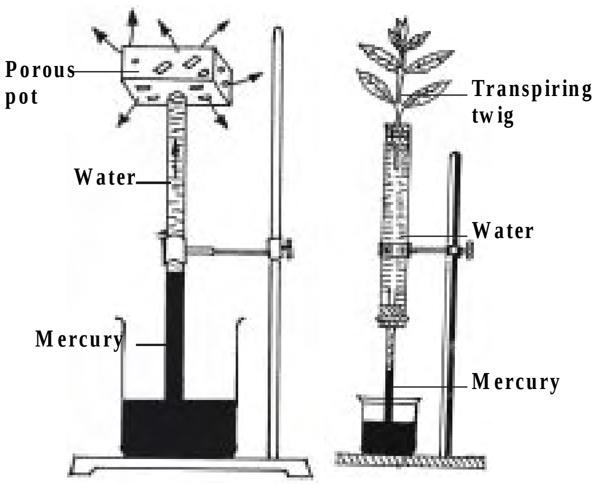


Fig : 5.5. Experiment to demonstrate transpiration pull

Thus the cohesion - tension or transpiration pull theory best explains the ascent of sap as it stands today but still this theory is also not completely accepted.

2.b. Factors Affecting Rate of Transpiration

The process of transpiration is influenced by a number of factors which may be broadly classified as External factors and Internal factors.

External Factors

These include conditions of the environment which affect the rate of transpiration. The external factors are humidity, wind, atmospheric pressure, temperature, light and water.

Humidity

Humidity refers to the amount of water vapour present in the atmosphere. If humidity is high, rate of evaporation is low and so the rate of transpiration is slow.

Wind

Wind is air in motion which enhances the rate of evaporation. Wind increases the rate of transpiration. But winds at high velocity bring about closure of stomata and thus reduce the transpiration rate.

Atmospheric Pressure

Low atmospheric pressure increases the rate of transpiration. Water vapour from transpiring surfaces rapidly moves into the atmosphere which is at low pressure.

Temperature

Increase in temperature increases the rate of transpiration as high temperature causes the water in intercellular spaces to vaporize at a faster rate.

Light

Light influences opening of stomata and so rate of transpiration is high in light and less in darkness.

Water

Less amount of soil water decreases the rate of transpiration. If the rate of transpiration exceeds the rate of absorption, the stomata get closed the cells lose their turgidity and the plant wilts. If the plant regains the turgidity, it will regain its original position and this called **incipient wilting**. If the wilting is **irreversible** it is called **permanent wilting**.

Internal Factors

These are factors prevailing within the plant which are inherent properties of the plant itself and include leaf structure, root-shoot ratio and age of plants.

Leaf Structure

In xerophytes, the rate of transpiration is reduced due to structural modifications such as less surface area, thick cuticle with hard and leathery surface, leaf rolling, sunken stomata, waxy coating, lower stomatal frequency, hairy covering and development of mechanical tissue. In the case of the plants such as *Opuntia* and *Asparagus* the leaf is modified into thorns and the stem becomes flattened and green to perform the function of the leaf. Such a structure is called a **Cladode**.

Root - Shoot Ratio

Transpiration shows a direct relation with the amount of water absorbed by the roots and the water lost through leaves. Therefore the increase in the root-shoot ratio will also increase the rate of transpiration.

Age of Plants

Germinating seeds generally show a slow rate of transpiration. It increases with age and becomes maximum at maturity. But rate of transpiration decreases during senescence.

Plants absorb water through the root system and only 2% is needed by the plant for the various metabolic activities. The rest of the water is lost through the aerial parts of the plant by a process called **transpiration**.

The loss of water in the form of vapour from the aerial parts of the plant is referred to as **transpiration**.

Types of Transpiration

Transpiration in plants is essentially of three types.

a. Cuticular

b. Lenticular

c. Stomatal

a. Cuticular Transpiration

Cuticular transpiration takes place through outer covering of the epidermis called **cuticle** made up of substance called **cutin**. Only a very little part of transpiration takes place by this process.

b. Lenticular Transpiration

Lenticels are regions on the bark having loosely arranged cells called **complementary cells**. A very little amount of water is lost by transpiration through lenticels.

c. Stomatal Transpiration

Stomata are minute openings on the epidermis of leaves and stems. Most of the water lost by transpiration (about 95%) takes place through the stomata.

Structure of Stoma

A stoma is a minute pore on the epidermis of aerial parts of plants through which exchange of gases and transpiration takes place.

Each stoma in surrounded by a pair of kidney shaped **guard cells**. Each guard cell is a modified epidermal cell showing a prominent nucleus, cytoplasm and plastids. The wall of the guard cell is differentially thickened. The inner wall of

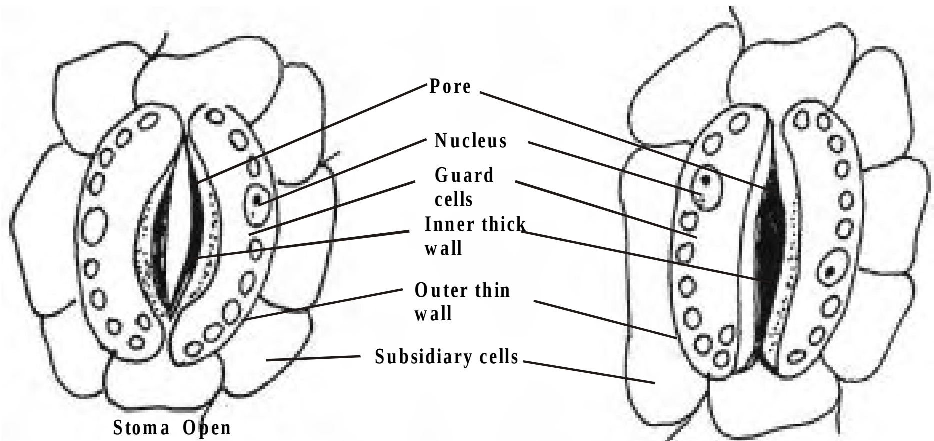


Fig : 5.6. Structure of Stomata

each guard cell facing the stoma is concave and is thick and rigid. The outer wall is convex and is thin and elastic.

The guard cells are surrounded by a variable number of epidermal cells called **subsidiary cells**.

2.c. Mechanism of Stomatal Opening and Closing

Opening and closing of stomata takes place due to changes in turgor of guard cells. Generally stomata are open during the day and close at night.

The turgor changes in the guard cells are due to entry and exit of water into and out of the guard cells. During the **day**, water from subsidiary cells enters the guard cells making the guard cells fully turgid. As a result, the thin elastic convex outer walls are bulged out causing the thick and rigid concave inner walls to curve away from each other causing the stoma to open.

During **night** time, water from guard cells enters the subsidiary cells and as a result, the guard cells become flaccid due to decrease in turgor pressure. This causes the inner concave walls to straighten up and the stoma closes.

The actual mechanism responsible for entry and exit of water to and from the guard cells has been explained by several theories.

The most important theories are

i. The starch-sugar interconversion theory of Steward

ii. Active K^+ transport of Raschke

iii. pH theory of Scarth

iv. Proton-potassium pump theory of Levitt.

i. The Starch - Sugar interconversion Theory

Steward (1964) holds that during the day the enzyme **phosphorylase** converts starch to sugar, thus increasing osmotic potential of guard cells causing entry of water. The reverse reaction occurs at night bringing about closure.

$$\text{Starch (stoma opens)} \underset{\text{night}}{\overset{\text{Phosphorylase (day)}}{\rightleftharpoons}} \text{Sugar (stoma closes)}$$

iv.Proton - Potassium Pump Hypothesis

Levitt in 1974 combined the points in Scarth's and Steward's hypothesis and gave a modified version of the mechanism of stomatal movement which was called the **proton - potassium pump hypothesis**.

According to this hypothesis K+ ions are transported into the guard cells in the presence of light. The sequence of events taking place are

i. Under the influence of light, protons formed by dissociation of malic acid move from cytoplasm in to the chloroplasts of guard cells.

ii. To counter the exit of protons, K+ ions enter the guard cells from the surrounding mesophyll cells.

iii. K+ ions react with the malate ions present in the guard cells to form potassium malate.

iv. Potassium malate causes increase in the osmotic potential of guard cells causing entry of water into the guard cells as a result of which the stoma opens.

v. At night the dissociation of potassium malate takes place and K+ ions exit out of guard cells causing loss of water from guard cells and so the stoma closes.

Noggle and Fritz (1976) supported this theory and gave a scheme for opening of stomata.

Light
↓
Starch
↓
Production of Malic acid
↓
Dissociation into H^+ and Malate
↓
Exit of H^+ and entry of K^+ ions
↓
Formation of Potassium malate
↓
Increase of OP of guard cells
↓
Entry of water into guard cells
↓
Increase in turgor of guard cells
↓
Stoma opens

This theory is the widely accepted one as Levitt was able to demonstrate rise in K+ ion level during the day and the formation of organic acids like malic acid with the unused CO_2 present in the guard cells.

2.d. Factors Affecting Stomatal Movement

There are a number of factors which influence stomatal movements. These include light, temperature, potassium chloride, organic acid, carbondioxide concentration, water and abscissic acid.

Light

Light greatly influences the opening and closing of stomata as it stimulates production of malic acid due to conversion of starch to sugar. Stomata do not open in U-V light and green light but remain opened in the blue and red regions of the spectrum.

Temperature

Stomata open with rise in temperature and close at lower temperature as light and temperature are directly related. But higher temperatures also cause stomatal closure.

Potassium Chloride

Accumulation of potassium chloride causes opening of stomata.

Organic Acid

The increase of organic acid content in the guard cells causes the stomata to open.

Carbondioxide Concentration

Stomatal movement is influenced by the concentration of carbondioxide. At low concentrations of CO_2, the stomata open. With increase in the concentration of CO_2, the stomata begin to close and when CO_2 concentration of cells is higher than its concentration in the air, the stomata completely close.

Stomatal movement is always influenced by the CO_2 concentration of the intercellular spaces of the leaf and not the concentration of the air.

Water

Water is responsible for causing changes in the turgor of the guard cells. Guard cells become flaccid on losing water and so the stomata close. Similarly the guardcells become fully turgid on gaining water and the stomata open. Under conditions of water scarcity also, the stomata close.

Abscissic Acid

Abscissic acid accumulates in the leaves when the plants experience water stress or water deficit. It has been observed, that ABA (Abscissic acid) stimulates closure of stomata under these conditions.

SELF EVALUATION

One Mark

Choose the correct answer

1. During the day the guard cells experience

   a. exosmosis b. endosmosis c. fall in turgor d. loss of water

2. The starch -sugar interconversion theory was given by

   a. Steward b. Scarth c. Levitt d. Raschke

3. The relay pump theory was put forward by

   a. Godslewski b. J.C.Bose c. Stocking d. Dixon.

4. J.C. Bose gave the

   a. relay pump theory b. root pressure theory
   c. pulsation theory d. cohesion - tension theory.

5. Lignin and cellulose have affinity for water. This is called

   a. adhesion b. cohesion c. root pressure d. none of the above

6. The transpiration pull theory was supported by

   a. Renner b. Curtis c. Clark d. All the above

Two Marks

1. Define : Stomata / Transpiration / Starch - sugar interconversion.
2. Define : Root pressure / Transpiration pull / Cohesion / Vital theories.

Five Marks

1. Explain the mechanism of stomatal opening and closing.
2. Describe the Proton - potassium pump hypothesis.
3. Give an experiment to demonstrate cohesion - tension theory.
4. Give an account of the inherent properties of the leaf which affect the rate of transpiration.

Ten Marks

1. Write an essay on the theories explaining mechanism of stomatal movement.
2. Give an account of the factors influencing stomatal movement.
3. Explain the postulates of the cohesion - tension theory. Add a note on the objections and explanation.
4. List and explain the factors affecting transpiration.
5. Give an account of the various theories explaining the ascent of sap.

3. Mineral Nutrition

Mineral nutrition of plants was a phenomenon known from very ancient times. Woodward (1699) observed for the first time that plants grow better in muddy water than rain water. Later it was proved that minerals have specific functions in plant metabolism.

When an oven-dried plant material is ignited at 400-600^{o}C, all the organic materials are oxidized and incombustible matter remains as plant ash. When this ash was analysed it was found to contain 40 elements besides C, H, O, N and S which were oxidized. All these are not essential for plant nutrition but on analysis the important essential elements have been identified and based on their role in plant metabolism and requirement, they have been classified as major elements and trace elements.

The functions of the various minerals in general depends on the role of the mineral in plant metabolism.

Criteria for Essentiality of a Mineral Element

Essential elements should have the following characteristics

i. Normal growth and reproduction must be dependent on particular mineral elements.

ii. An essential element must have direct influence on the plant.

iii. Essential elements must be indispensable and their substitution by other elements must be impossible.

iv. Some elements are required in very low quantities and the status of essentiality or non essentiality is doubtful. For example **silicon.**

3.a. Functions of Minerals

i) Mineral elements are constituents of the various parts of plant body such as calcium which is found in the middle lamella, nitrogen and sulphur in proteins, phosphorus in nucleic acids.

ii) The mineral elements influence the osmotic pressure of the plant cell.

iii) The mineral elements absorbed from the soil affect the pH of the cell sap.

iv) Elements like Fe, Cu, Mn and Zn act as catalysts in various enzymatic processes.

v) Elements like Ca, Mg, Na and K or their salts neutralize the toxic effects of other elements in the cell.

vi) Elements like As, Cu, and Hg show toxic effects at certain stages of the plant.

vii) Deposition of ions like K^+ and Ca^{++} on cell membrane change its permeability.

Hydroponics

The term **hydroponics** has been used for growth of plants in water and sand culture. This may also be referred to as **soil-less agriculture, test-tube farming, tank farming** or **chemical gardening**.

Commercially hydroponic cultures are maintained in large shallow concrete, cement, wood or metal tanks in which gravel and nutrient solutions are taken. The tanks are provided with pumps and empty auxiliary tanks to pump out and circulate the growth solution and to maintain proper aeration of the nutrient solution.

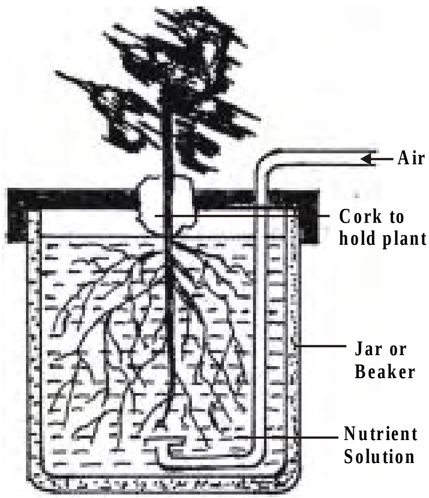


Fig : 5.7. Hydroponics

The technique of hydroponics is employed to know which mineral element is essential for the growth and development of the plant. Commercially the application of hydroponics involve the production of **horticultural** and **floricultural** crops. This method may be used to increase yield of ornamentals such as gladioli, snapdragon, roses and vegetables such as carrot, radish, potatoes, tomatoes and lettuce.

Advantages of Hydroponics

i. It is possible to provide the desired nutrient environment.

ii. The acid-base balance can be easily maintained.

iii. Mulching, changing of soil and weeding are eliminated.

iv. Proper aeration of nutrient solution is possible.

v. Labour for watering of plants can be avoided.

vi. Tilling is not necessary.

Disadvantages of Hydroponics

i. Production is limited when compared to field conditions.

ii. Technical skill is required to design equipment.

iii. If a disease appears all plants in the container will be affected.

3.b. Essential Major Elements and Trace Elements

The plant ash reveals the presence of 40 elements but all are not essential for plant nutrition, only a few are essential for growth and development of plants. These are called the **essential elements**. The essential elements may be grouped as **major elements** or **macronutrients** and **trace elements** or **micro nutrients,** based on their requirement by plants.

Major Elements or Macro Nutrients

These elements are required in large amounts and form the plant constituents. The major elements are otherwise known as **macronutrients**. These include **carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium** and **sulphur**. These elements form an integral part of complex organic molecules. Some of these elements help in the functioning of enzyme systems. The sources of macronutrients are generally the soil or the atmosphere. **Carbon** is got from carbodioxide of the atmosphere. **Oxygen** is derived from water and atmospheric oxygen. **Nitrogen** is present in the atmosphere as an inert substance which is brought to the soil and converted to soluble nitrates either by asymbiotic or symbiotic nitrogen fixation. **Phosphorous** and **sulphur** are derived from rocks during weathering. The source of **hydrogen** is water.

Trace elements or Micronutrients

Elements like **iron, boron, manganese, copper, zinc** and **molybdenum** are required for plants only in very small amounts but these are indispensable for the normal growth and development of plants.

3.c. Physiological Role and Deficiency Symptoms of Mineral Elements

Macro Nutrients

1. Carbon, hydrogen and oxygen

These are not mineral elements in the true sense but have been included because these elements form the composition of all organic compounds present in plants. They are a part of carbohydrates, proteins, and fats. Thus these elements have a role to play in the general metabolism of plants.

Deficiency symptoms

Deficiency of these elements is very rare because the plants have a steady supply of these through water and gaseous exchange. Deficiency affects the normal growth and development of plants.

2. Nitrogen

Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules such as chlorophyll. Nitrogen also forms a constituent of various hormones, coenzymes and ATP.

Deficiency symptoms

i) Stunted growth
ii) Chlorosis
iii) Reduction in flowering
iv) Excessive colouring in apple and peach and reduction in fruit size
v) Decrease in protein contents
vi) Change in the pigmentation pattern

3. Phosphorus

It is present in plasma membrane, nucleic acids, nucleotides, many co-enzymes and organic molecules. It plays an important role in energy metabolism. Phosphorus promotes healthy root growth and fruit ripening.

Deficiency symptoms

i. Loss of older leaves
ii. Reduction in growth
iii. Increase in phosphatase enzyme activity
iv. Causes accumulation of carbohydrates in soyabean

4. Potassium

Potassium is required in the meristematic regions and regions of cell differentiation. It accumulates in older leaves. Though it does not have a structural role, it is involved in stomatal opening and closing. It is an activator of many enzymes and has a role in protein and carbohydrate metabolism.

Deficiency symptoms

i. Leaf tips curve downward
ii. Causes mottled chlorosis
iii. Development of chlorosis at tips and margins of leaves.
iv. Shortening of internodes and stunted growth.

5. Sulphur

Sulphur is the constituent of certain vitamins such as **thiamine** and **biotin**. It is constituent of **coenzyme - A** playing an important role in respiration. It forms the sulphydryl group in many enzymes and is a constituent of sulphur containing aminoacids such as **cystine, cysteine** and **methionine.**

Deficiency symptoms

i. Causes inhibition of protein synthesis.
ii. Younger leaves show chlorosis first
iii. Chloroplasts of mesophyll show a decrease in stroma lamellae but grana increase.

6. Magnesium

Magnesium is a constituent of chlorophyll molecule which cannot be formed without magnesium. It has a vital role in carbohydrate metabolism and the binding of ribosomal sub-units. Magnesium is the activator of many enzymes involved in DNA and RNA synthesis. It acts as a phosphorus carrier and activates enzymes such as PEP carboxylase and RuBP carboxylase.

Deficiency symptoms

i. Interveinal chlorosis takes place.
ii. Anthocyanin pigment deposition takes place after chlorosis.
iii. Necrotic spots appear in acute cases.

7. Calcium

Calcium forms an important constituent of the cell wall occurring in the middle lamella as calcium pectate. It has an important role in the formation of plasma membrane. Calcium plays a role in mitotic cell division and is a constituent of enzymes like **phospholipase** and **adenyl kinase** where it acts as an activator.

Deficiency symptoms

i. Affects the carbohydrate metabolism.

ii. The process of respiration is badly affected as number of mitochondria are decreased.

iii. Meristematic tissues are affected and leaf and root tips die.

iv. Cell wall may become brittle or rigid.

Micro Nutrients

8. Iron

Soil is generally not deficient in iron. Iron is a constituent of various flavoproteins and forms a part of enzymes such as **catalases, peroxidases** and **cytochromes**. It plays an important role in the electron transport system of photosynthesis being part of cytochrome and ferredoxin.

Deficiency symptoms

i. Causes interveinal chlorosis and the leaves become yellow or white.

ii. Impairs aerobic respiration and related processes.

iii. Fruit trees particularly show sensitivity to iron deficiency.

9. Boron

Leaves and seeds require boron. It is necessary for uptake and utilisation of Ca^{++} ions, pollen germination, cell differentiation and translocation of carbohydrates. It plays a role in nitrogen metabolism, hormone and fat metabolism.

Deficiency symptoms

i. It causes **brown heart-rot disease** in beetroots.

ii. In apple internal tissues become corky.

iii. Causes leaf to curl and become brittle.

iv. Premature fall of fruits and flowers.

10. Manganese

Manganese is required by leaves and seeds. It is an activator of enzymes like **carboxylases, oxidases, dehydrogenses** and **kinases**.

Deficiency symptoms

i. Causes **grey spot disease** in oat.

ii. Poor development of root system.

iii. Interveinal chlorosis occurs.

11. Copper

This is required in all plant parts. Copper forms a component of enzymes such as phenolases and tyrosinase. Copper being a constituent of plastocyanin plays a role in photophosphorylation. Copper maintains the carbohydrate - nitrogen balance.

Deficiency symptoms

i. Causes **die back of shoots** especially in *Citrus*.

ii. A disease called **`exanthema'** causes the yield of gums on the bark.

iii. **Reclamation disease** is caused in plants growing on newly reclaimed soil where seed formation is affected.

12. Zinc

Zinc is involved in the synthesis of indole acetic acid by activating the enzyme **tryptophan synthetase**. It plays a role in protein synthesis. It acts as an activator of many other enzymes such as **carbonic anhydrase, alcohol dehydrogenase, hexokinase** and so on.

Deficiency symptoms

i. Causes distortion of growth.

ii. Leaves become very small and resetted called as **little leaf disease**.

iii. Interveinal chlorosis and stunted growth of stems is seen.

13. Molybdenum

Molybdenum has an important role to play in the **metabolism of nitrogen**. It affects the synthesis of ascorbic acid. It activates the enzymes involved in nitrogen metabolism.

Deficiency symptoms

i. It leads to mottling and wilting of leaves at the margins causing **"yellow spot" disease** of *Citrus*.

ii. **"Whiptail" disease** in cauliflowers causing narrowing of leaf blades and their rugged appearance due to distortion.

Table : 5.3. Physiological Role and Deficiency Symptoms of important Mineral Elements

S. No	Element	Physiological Role	Deficiency Symptoms
1. 2. 3.	**Carbon** **Hydrogen** **Oxygen**	General metabolism of plants	Affect normal growth and development.
4.	**Nitrogen**	Constituent of proteins, nucleic acids, coenzymes and ATP.	Chlorosis, stunted growth and reduction in flowering.
5.	**Phosphorus**	Constituent of plasma membrane, coenzymes and nucleotides.	Reduction in growth, increase of phosphatase activity.
6.	**Potassium**	Required in meristematic regions and in stomatal movement.	Mottled chlorosis, shortening of internodes.
7.	**Sulphur**	Constituent of thiamine and biotin coenzyme-A, cystine and cysteine.	Inhibition of protein synthesis and chlorosis of young leaves.
8.	**Magnesium**	Constituent of chlorophyll, activator of PEP and RuBP carboxylases.	Internveinal chlorosis and deposition of anthocyanin pigments.
9.	**Calcium**	Constituent of cell wall and plasma membrane, helping in mitosis.	Carbohydrate metabolism affected, meristematic tissues affected.
10.	**Iron**	Constituent of flavo proteins, catalases, peroxidases and cytochromes.	Sensitivity in fruit trees, interveinal chlorosis, impairs aerobic respiration.
11.	**Boron**	Necessary for uptake and utilisation of Ca^{2+}, pollen germination and translocation of carbohydrates.	Brown heart rot disease in beetroot, corkiness of internal tissues of apple, premature fall of fruits and flowers.
12.	**Manganese**	Required by seeds and leaves, activating enzymes like oxidase, carboxylase and kinase.	Grey spot disease in oats, poor development of root system.
13.	**Copper**	Component of enzymes like phenolase, tyrosinase and plastocyanin.	Die back of shoots in *Citrus,* Exanthema-producing gums on bark, Reclamation disease - affecting seed formation.
14.	**Zinc**	Activates enzymes like tryptophan, synthetase, carbonic anhydrase and alcohol dehydrogenase.	Rosetted leaves causing little leaf disease, stunted growth of stems.
15.	**Molybdenum**	Plays a role in nitrogen metabolism and synthesis of ascorbic acid.	Yellow spot disease of *Citrus,* Whiptail disease in cauliflowers causing narrowing of leaf blades.

SELF EVALUATION

One Mark

Choose the Correct Answer

1. Hydroponics is otherwise called

   (a) soil-less agriculture (b) tank farming

   (c) chemical gardening (d) all the above

2. This element is a constituent of chlorophyll

   (a) Manganese (b) Magnesium
   (c) Potassium (d) Zinc

Fill in the blanks

1. Exanthema is a disease caused due to deficiency of ....
2. Deficiency of Molybdenum cause .... of cauliflower
3. Sulphur containing amino acids are ....and ....

Match

Boron - Thiamine

Sulphur - Reclamation

Copper - Stomatal Movements

Potassium- Translocation of Carbohydrates

Two Marks

1. Define Hydroponics / Exanthema / Reclamation

Five Marks

1. Explain the advantages and disadvantages of Hydroponics.
2. Describe the technique of hydroponics with a diagram.
3. Describe the criteria for essentiality of an element
4. Explain the role and deficiency symptoms of any three macronutrients.
5. Describe the deficiency symptoms of copper, boron and molybdenum.

Ten Marks

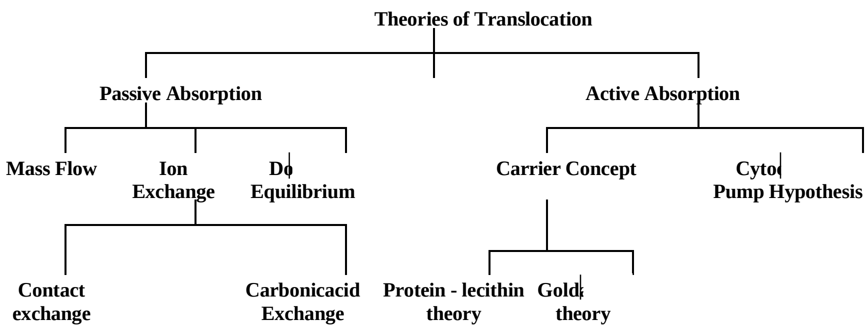
1. Write an essay on the role and deficiency of macro and micronutrients.

3.d.Theories of Translocation

Plants absorb minerals from the soil and translocate them to other parts of the body. Minerals are absorbed in the form of **soil solution** contained in the pore spaces between the soil particles and the root hair. The soil solution contains the mineral salts in the dissolved state. Several theories have been put forth to explain the mechanism of translocation of mineral salts. These theories can be placed under two headings (i) **Passive absorption** and (ii) **Active Absorption** which can be further subdivided as follows.

i. Passive Absorption

When the movement of mineral ions into the roots occurs by diffusion without any expenditure of energy in the form of ATP it is called **Passive Absorption**. This form of absorption is not affected by temperature and metabolic inhibitors. Rapid uptake of ions is observed when a plant tissue in transferred from a medium of low concentration to a medium high concentration. Various theories have been put forward to explain mineral salt uptake by passive absorption.



(a) Ion exchange theory

Mineral elements are absorbed in the form of ions. The anions and cations within the plant cells are exchanged with the anions and cations of equivalent charge from the external medium in which the cells are kept. This mechanism can be explained by two theories.

(i) Contact exchange theory

This was put forward by Jenny and Overstreet (1939). According to this theory ions are transferred from soil particles to root or *vice versa* without passing into solution. The ions are electrostatically adsorbed to surface of root cells or clay particles and held tightly. These ions oscillate within a small volume of space called **oscillation volume.** When the oscillation volume of two ions of same charge overlap, one is exchanged for the other. This is called **contact exchange.**

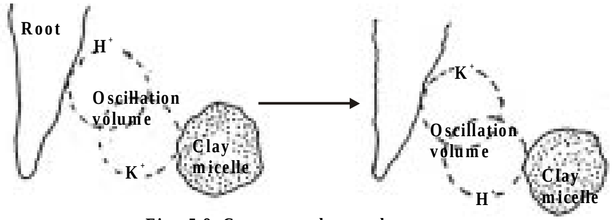


Fig : 5.8. Contact exchange theory

(ii) Carbonic acid exchange theory

According to this theory the soil solution plays an important role in exchange of ions by providing a medium. CO_2 released during respiration combines with water to form **carbonic acid** (H_2CO_3) which dissociates as H^+ (Hydrogen ions) and HCO_3^- (bicarbonate ions). A cation adsorbed on clay micelle may be exchanged with the H^+ of soil solution and this cation diffuses into the root in exchange for H^+ ion.

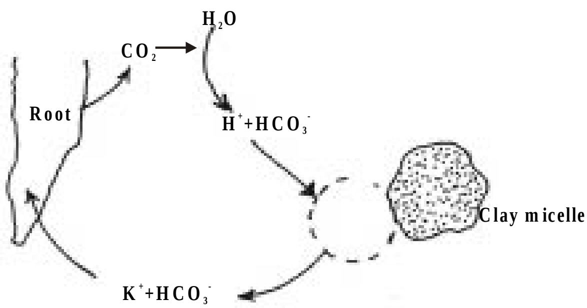


Fig : 5.9. Carbonic acid exchange theory

(b) Donnan Equilibrium

This was proposed by **F.G. Donnan** in which the **fixed** or **indiffusible** ions play an important role. These ions are present on the inner side of the cell and cannot diffuse out. When a cell having fixed anions is immersed in salt solution, anions equal in number and charge to the fixed ions move into the cell. To balance the negative charges of the fixed ions additional cations also move into the cell and the cell sap cation concentration becomes higher than the external medium. This is called **Donnan Equilibrium**.

In the same way if there are fixed cations, additional anions will accumulate from the external medium.

II. Active Absorption

The absorption of ions against the concentration gradient with the expenditure of metabolic energy is called **active absorption**. In plants, the vacuolar sap shows accumulation of anions and cations against the concentration gradient which cannot be explained by the theories of passive absorption. The mechanism of active absorption of salts can be explained by several theories.

(a) Carrier Concept

The cell shows the presence of **carriers** or **transporters** which are highly specific for a particular ion. The carrier picks up an ion from external medium to form a carrier-ion complex, undergoes rotation at 180°, moves across the membrane and releases the ions on the inner side of membrane and returns to pick up another ion. The carrier may be an enzyme or a protein. Metabolic energy is expended in this process. This concept is supported by **Isotopic exchange** using radioactive isotopes, **saturation effect** and **specificity of carriers**. The carrier concept is explained by two theories:

(i) Protein-Lecithin as carrier

(ii) Goldacre's theory

Protein - Lecithin as carrier

Bennet - Clark proposed that the carrier can be a protein associated with a phosphatide e.g. Lecithin which carries both anions and cations and forms a **lecithin-ion complex**. This moves to the inner side of membrane, releases the ion by hydrolysis forming phosphatidic acid and choline due to the action of the enzyme **lecithinase.** Lecithin is regenerated with the help of enzymes **Choline esterase** and **choline acetylase.** This requires expenditure of metabolic energy.

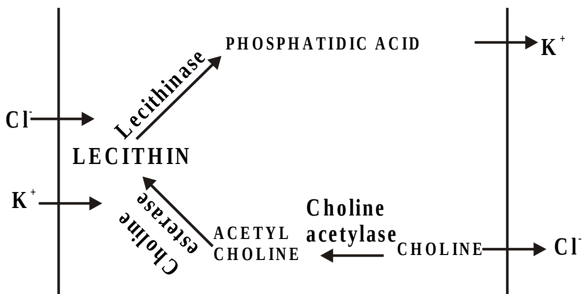


Fig : 5.10.a. Protein - Lecithin as carrier

(b) Cytochrome Pump Theory or Electron Transport Theory

This theory was proposed by H. Lundegardh (1954) who suggested that anions could be transported across the membranes by cytochrome system utilising energy released by direct oxidation of respiratory intermediates.

The important postulates are:

i) Only anions can be actively transported.

ii) Cytochromes act as carriers in absorbing anions.

iii) Oxygen gradient helps in oxidation at outer surface and reduction at the inner surface.

iv) Transport of cations can be along the electrical gradient created by ion accumulation.

v) Selectivity in ion absorption cannot be explained and

vi) This is absent in plants respiring anaerobically.

Therefore this theory explains respiration due to anion absorption which was called **anion respiration** or **salt respiration**.

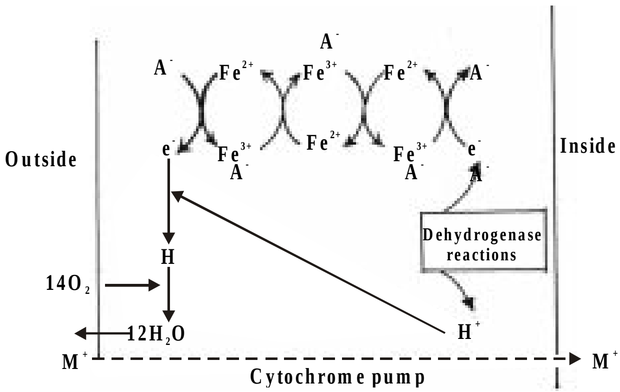


Fig : 5.11. Cytochrome pump

3.e. Translocation of Solutes

In higher plants food is synthesised only in the green leaves which are the sites of Photosynthesis. From here the food is translocated to the different parts of the plant in the soluble form. The process by which the synthesized food from the leaves is translocated to the different parts of the plant depending on their requirement is called **translocation of food**. The food materials in excess than the required amount are stored in insoluble form in the various storage organs and are translocated in solution or soluble form. Therefore this is also referred to as translocation of solutes.

Direction of translocation

Translocation of food occurs in the downward upward and lateral directions.

Downward translocation

Downward trnaslocation takes place from the leaves downwards to the stem, roots and storage organs.

Upward translocation

In some stages of plant life such as seed germination, emergence of new shoots from underground storage organs and development of buds, flowers and fruits, the food materials are translocated upward.

Lateral translocation

In certain parts of stem and roots food is translocated in lateral direction through medullary rays.

Ringing experiment to demonstrate downward translocation

Take a plant and remove all the tissues outer to xylem and pith in the form of ring at any place on the stem. The portion from where tissues are removed is sealed with melted wax. After 7 or 8 days the epidermis and cortex of upper portion of the ring become very much swollen and from this swollen part the adventitious roots emerge out. It happens because the food material translocated from the leaves does not pass through the ring and is stored in the upper portion.

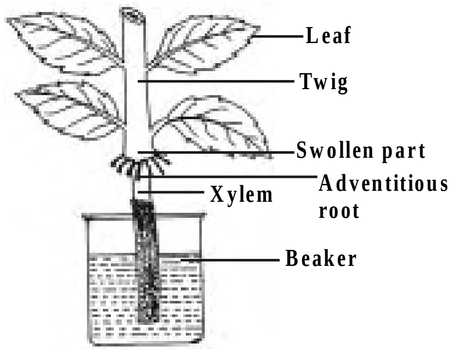


Fig : 5.12. Ringing experiment

Mechanism of Translocation

Following theories were proposed to explain the mechanism of translocation of solutes.

Munch's "Mass Flow" Hypothesis

A few scientists believe that the soluble food material in the phloem move just like the blood which moves in the blood vessels. Based on this Munch in 1930 proposed a hypothesis according to which the soluble food materials in the phloem show mass flow. The fundamental idea behind this hypothesis is that the sugars synthesized by mesophyll cells of leaves increase the osmotic pressure (OP) of these cells causing entry of water into mesophyll due to absorption of water by the xylem cells of root. In other words a turgor pressure gradient exists through phloem, between the **source** which is the mesophyll cell and the **sink** which refers to regions of requirement.

As a result, the turgor pressure of mesophyll cells increases on the upper side which forces the solutes dissolved in water to flow *en masse* into the phloem of stem and finally into the roots.

This can be explained by a physical system. It consists of a glass tube bent at right angles. At the two ends differentially permeable membranes are tied. Thus there are two osmometers x and y.

The osmometer x has concentrated sugar solution while y has dilute sugar solution. The two osmometers are kept in two separate water containers connected with each other through a tube.

Osmosis will take place and water enters both the osmometers **x** and **y** but the water entering **`x'** is more and as a result of turgor pressure developed, water will move out of **x** and will enter **y**. Here the solute molecules are carried to **y** *en masse* with the flow of water explaining Munch's hypothesis.

The most important objection for this hypothesis is that it explains only unidirectional flow of solutes.

Importance of Munch's hypothesis

This forms basis of the principle of **phloem loading** and **unloading.**

Phloem loading is caused by movement of photosynthates from mesophyll to phloem. Unloading of phloem is caused by movement of photosynthates from phloem to other parts where required. This is the source-sink relationship.

3.f. Nitrogen Metabolism

Nitrogen is an inert gas which constitutes 78% of the atmosphere. It is an important mineral present in the bodies of living organisms. It forms a component of proteins and aminoacids and is also present in nucleic acids, cytochromes, chlorophyll, vitamins, alkaloids and so on.

Nitrogen cannot be used directly and is converted to Nitrites, Nitrates and Ammonia by a process called Nitrogen Fixation. There are many free living organisms like bacteria and blue-green algae which are involved in nitrogen fixation. The ammonia and urea present in the soil are directly absorbed by plants.

Nitrogen Cycle

The atmosphere is the source of elemental nitrogen which cannot be used directly by plants. The atmospheric nitrogen is converted to ammonia, nitrite, nitrate or organic nitrogen in the soil.

The death and decay of organic systems causes cycling of ammonia from amino acids, purines and pyrimidines. Some of these forms may also be converted to Nitrogen gas and may be cycled back into the atmosphere.

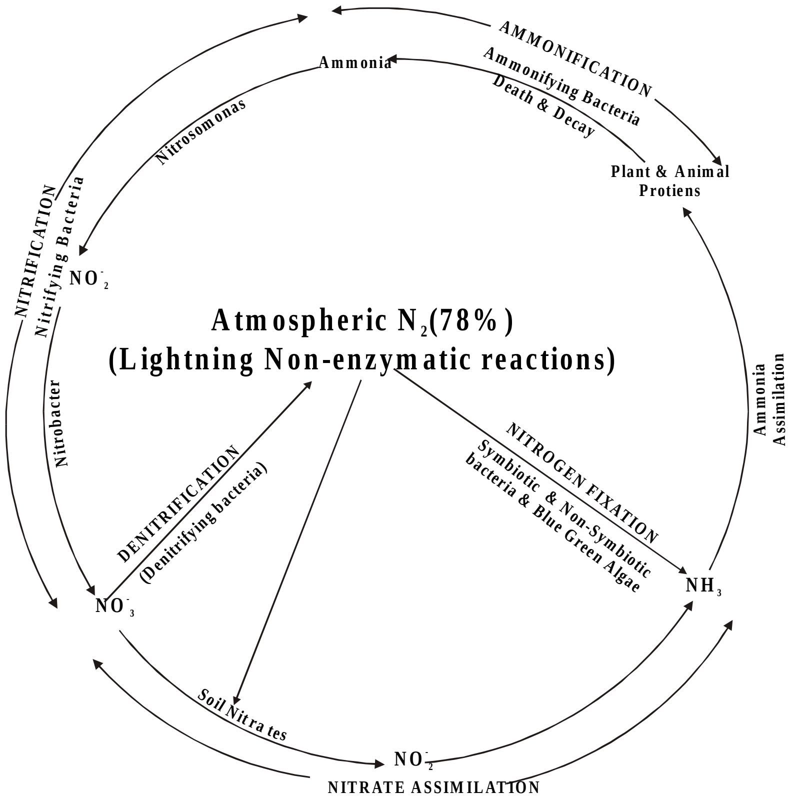


Fig : 5.14. Nitrogen Cycle

The process by which these forms get inter converted to maintain a constant amount of nitrogen in atmosphere, by physical and biological processes is called **nitrogen cycle**. The cycle includes 5 stages.

i. Ammonification

ii. Nitrification

iii. Nitrate assimilation

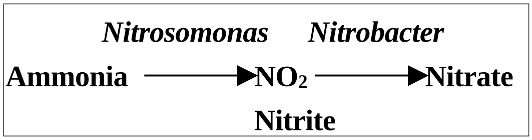
iv. Denitrification and

v. Nitrogen fixation

(i) Ammonification

This involves conversion of organic nitrogen to ammonium ions by microbes present in the soil. The sources of organic nitrogen in the soil are animal excreta and dead and decaying plant and animal remains which are acted upon by ammonifying saprotrophic bacteria such as ***Bacillus ramosus, Bacillus vulgaris,*** certain soil fungi and actinomycetes.

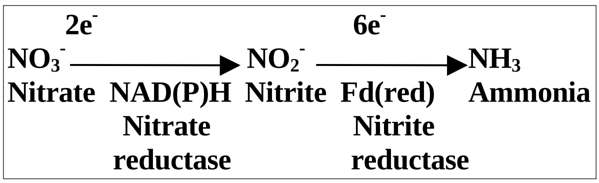
(ii) Nitrification



In warm moist soils having a temperature of 30-35°C and neutral pH, ammonia gets oxidized to nitrite (NO_2^-) and then nitrate (NO_3^-) by the process of nitrification. Nitrifying bacteria like *Nitrosomonas* convert ammonia to nitrite and another bacterium called *Nitrobacter* converts nitrate to nitrate.

(iii) Nitrate Assimilation

The nitrate present in the soil is absorbed by plants through the root system in the form of NO_3^- ions. But it cannot be used by plants directly. So it is first reduced to nitrite by the enzyme **nitrate reductase**. Nitrite is then converted to Ammonia by the enzyme **nitrite reductase** series of steps requiring a total of eight electrons provided by reduced NAD and Ferredoxin (Fd). This reduction of Nitrate to Ammonia and its incorporation into cellular proteins by aerobic micro organisms and higher plants is called **Nitrate assimilation**.



(iv) Dentrification

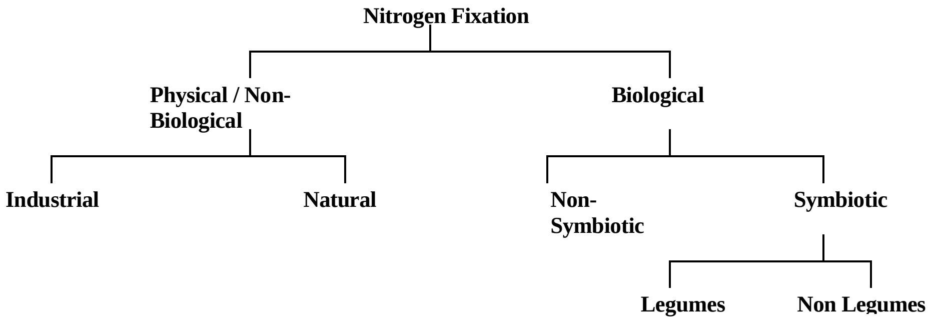
The process of conversion of nitrate and nitrite into ammonia, nitrogen gas and nitrous oxide (N_2O) is called **denitrification**. This process ends in the release of gaseous nitrogen into the atmosphere and thus completes the nitrogen cycle. A number of bacteria such as *Pseudomonas denitrificans*, *Bacillus subtilis* and *Thiobacillus dentrificans* are involved in this process.

(v) Nitrogen fixation

Nitrogen fixation refers to the conversion of elementary dinitrogen (N≡N)into organic form to make it available for plants. Nitrogen fixation is essentially of two types-

(i) Non-Biological or Physical and

(ii) Biological Nitrogen Fixation



Non-Biological or Physical Nitrogen Fixation

This involves fixation of nitrogen by chemical process in industry or naturally by electrical discharges such as lightning.

Biological Nitrogen Fixation

Nitrogen fixation taking place by living things is called biological nitrogen fixation. These include the bacteria and blue-green algae, which have acquired the capacity to fix atmospheric nitrogen during the evolutionary process by possessing a set of genes called `nif' (Nitrogen fixing) genes. They fix Nitrogen in the following reaction.

$$N_2 \xrightarrow[\text{Fd(red) / NADPH}_2 \text{ Nitrogenase}]{(6e^-)} NH_3$$

These organisms may be freeliving which are otherwise called **non-symbiotic nitrogen fixers** and may form symbiotic associations when they are called **symbiotic nitrogen fixers**.

Non-Symbiotic Nitrogen Fixation

This is carried out by free living organisms in the soil such as Bacteria and blue green algae.

Bacteria include aerobic bacteria such as *Azotobacter* and anaerobic bacteria such as *Clostridium, Chlorobium* and *Chromatium.*

Blue green algae include *Chroococcus, Rivularia, Anabaena, Tolypothrix* and *Nostoc*.

These organisms contain an enzyme system called **Nitrogenase** which is a Mo-Fe (Molybdenum-ferredoxin) protein. This progressively reduces the dinitrogen molecules to form ammonia, with the help of Ferredoxin and energy from ATP.

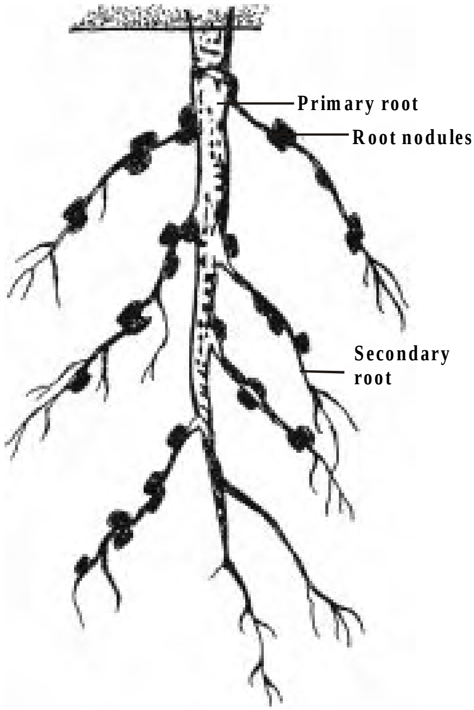


Fig : 5.15. Nodulated root

Symbiotic Nitrogen Fixation

This involves nitrogen fixation by micro organisms living in symbiotic association with higher plants which are commonly legumes, but non-legumes may also be involved. A symbiotic association is a mutually beneficial relationship between two living organisms which are called **symbionts.**

Nitrogen fixation in non-legumes

An actinomycete like *Frankia* establishes a symbiotic relationship with roots of higher plants such as *Alnus*. Blue-green algae like *Nostoc* establish symbiotic relationships in the corolloid roots of *Cycas*, or thalli of *Anthoceros*.

Nitrogen fixation in legumes

This is the commonest type of symbiotic nitrogen fixation which has been elaborately studied. A soil bacterium called *Rhizobium* infects roots of leguminous plants (belonging to Family Leguminosae) and forms the root nodules.

These are involved in nitrogen fixation. The bacteria living in the soil enter the root hair and penetrate the root cortex through an infection thread. When the bacteria enter the cortical cells of roots, the latter get stimulated to divide vigorously and form nodules on the root. The bacteria come to occupy the nodules, and at this stage lack a rigid cell wall being called **bacteroids**. These make use of the food substances of the root cells and secrete a pinkish pigment called **leg-hemoglobin** which is an oxygen carrier like hemoglobin.

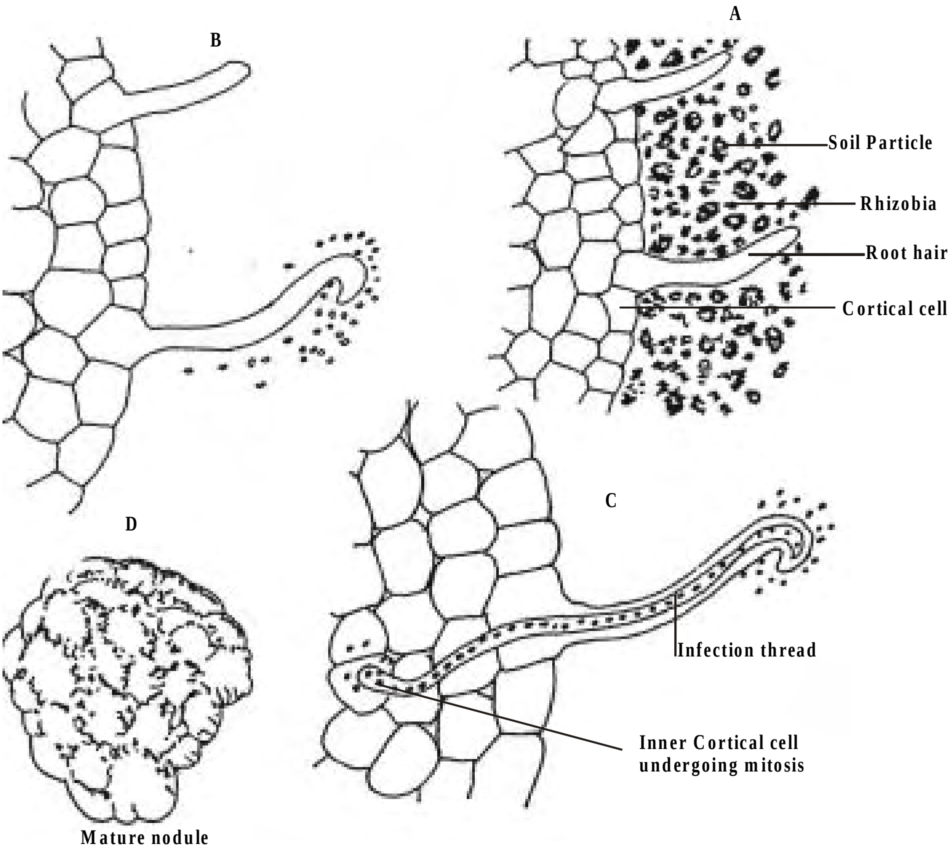


Fig : 5.16. Mode of development of root nodule

The *Rhizobia* in the form of bacteroides contain the enzyme **nitrogenase** which is responsible for fixation of Nitrogen thus benefitting the host plant. Leghemoglobin is supposed to protect the nitrogenase enzyme as it can function only under anaerobic conditions.

Table : 5.1. Major Nitrogen-fixing Biological Systems.

I Free-living (asymbiotic) microorganisms		
Bacteria		
Aerobic,	Species of *Azotobacter*	
Aerobic, non-photosynthetic	Species of *Clostridium*	
Aerobic, photosynthetic	Species of *Rhodospirilhum*	
Cyanobacteria	Species of *Nostoc, Anabaena* and others	
II Symbiotic systems		
Host	Microorganisms	Location
1. Angiosperms		
Leguminous	Species of *Rhizobium*	Root Nodules
Non-leguminous		
Alnus, Casuarina	Species of actinomycetes	Root Nodules
Psychotria	*Klebsiella*	Leaf Nodules
2. Gymnosperms		
Certain Cycads	Certain unidentified species of bluegreen algae	Symbiotic relation-not well documented
3.Ferns		
Azolla	*Anabaena*	Leaf pockets
4. Non-vascular plants		
Lichens	Fungi and algae	

SELF EVALUATION

One Mark

Choose the correct answer

1. The theory explaining passive absorption of mineral salts is :

   a. Ion exchange — b. Carrier Concept
   c. Cytochrome pump theory — d. None of the above.

2. Contact exchange theory was put forward by :

   a. Jenny and Overstreet — b. Hylmo and Kramer
   c. Bennet and Clark — d. De Vries and Curtis

Fill in the Blanks

1. The bacterium involved in symbiotic nitrogen fixation is ....
2. The nitrifying bacteria are .... and ....

Match

Bacillus ramosus	- Yeast
Pseudomonas aeruginosa	- Ammonification
Bennet & Clark	- Denitrification
Rhodotorula	- Carrier concept
Goldacre	- Protein - lecithin carrier

Two Marks

1. Define Translocation of solutes / Ammonification / Denitrification / Donnan equilibrium.

Five Marks

1. Explain Munch's mass flow hypothesis.
2. Explain the theories of active transport of mineral salts.
3. Describe the transports of mineral by ion exchange.
4. Write notes on the cytochrome-pump hypothesis of mineral salt transport.
5. Describe the ringing experiment to demonstrate translocation of solutes.

Ten Marks

1. Write an essay on the theories of mineral salt absorption.
2. Describe the Nitrogen cycle.
3. Explain biological Nitrogen fixation.

VI. REPRODUCTION BIOLOGY

1. Reproduction in Angiosperms

1.(a) Vegetative Propagation

Generally Angiosperms propagate by producing seeds, which is the result of sexual reproduction. However they resort to other methods of reproduction, such as vegetative propagation.

Plants belonging to this category propagate by a part of their body other than the seed. The structural unit that is employed in place of seed is called propagule.

Lower plants reproduce vegetatively through budding, fission, fragmentation, gemmae, resting buds, spores etc.

Methods of vegetative propagation have been further divided into two types.

A) Natural vegetative propagation and

B) Artificial vegetative propagation

A. Natural Methods of Vegetative Propagation

Vegetative Propagation by Roots

Some modified tuberous roots can be propagated vegetatively, when planted in soil. The buds present on the roots grow as leafy shoots called slips above ground and adventitious roots at their bases. Each slip gives rise to a new plant. eg. Sweet potato, Topioca, yam, Dahlia and Tinospora.

Adventitious buds develop on the ordinary roots of Dalbergia sisoo, Populus, Guava, Murraya sp, etc. which grow to form new plants.

Vegetative Propagation by Stem

In many plants, stem is modified to perform different functions. The modified stems perform three distinct functions (a) perennation, (b) vegetative propagation and (c) storage of food.

Modified stems which help in propagation can be classified into following three categories:

1. Underground
2. Subaerial
3. Aerial.

Propagation by Underground Stem

These plants develop non-green, under ground perennial stems. These store reserve food, propagate vegetatively and are adapted for perennation. They give rise to aerial shoots that grow actively during favourable conditions. On the approach of unfavourable conditions, the aerial shoots die. The underground stems remain dormant during the unfavourable conditions. Once the conditions become favourable, they produce new aerial shoots.

The various types of underground stems are

1. Rhizome, 2. Tuber, 3. Bulb, 4. Corm

Bulb

The stem is shortest and somewhat disc-like and does not contain any food material. Stem is covered by numerous thickened, overlapping leaves or leaf bases (usually called scales). The whole structure takes the form of a bulb. The short and reduced stem bears numberous adventitious roots at its base:

(a) **Tunicated bulbs**: In this case, the fleshy scales completely surround the reduced stem forming the concentric layers around stem forming the concentric layers around one another. On the outside they are covered by a few dry scales forming a membranous covering, called the tunic. The fleshy scales are bases of the foliage leaves, eg., **Onion, etc.**

(b) **Scaly bulbs**: Here, the leaves are small and scale-like and only overlap at the margins. There is also no outer tunic. The scaly bulbs are found in lilies, garlic, etc.

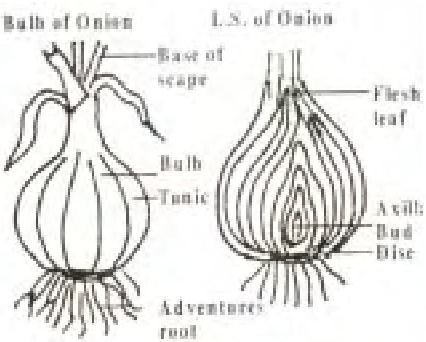


Fig : 6.1. Bulb

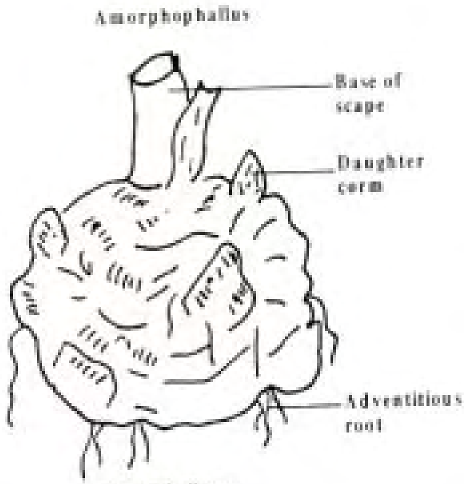


Fig : 6.2. Corm

In both the above types, axillary buds frequently develop in the axil of the fleshy scales. These develop into new bulbs or on separation from the parent bulb develop into new plants. They serve both for food storage and vegetative propagation.

Corm

It is more or less a condensed form of rhizome. It is a short, stout, solid and fleshy underground stem growing in the vertical direction. It is more or less rounded in shape or often somewhat flattened from top to bottom. It contains excessive deposits of food material and grows to a considerable size. It bears one or more buds in the axil of scale leaves and some of these buds grow up into aerial flowering shoots and from the base adventitous roots pass into the soil. Food materials get stored in the basal portion and in this way a new corm is formed. eg. Colocasia, Amorphophalus etc.

Propagation by Modified Subaerial Stem

These modifications are found in many herbaceous plants with a thin, delicate and weak stem. In such plants a part of the stem lives under-ground whereas remaining part of the stem is aerial. These plants bear adventitious roots and aerial branches at nodes. Such plants propagate quickly with the help of fragments of special branches. Subaerial modified stems are of the following types:

1. Stolon, 2. Offset.

Fig : 6.3. Stolon

Stolons

These develop from underground stems. They grow horizontally outwards and bear nodes and internodes. They resemble the runners except that they are produced just below the surface of the soil, eg., Strawberry, Vallisneria etc.

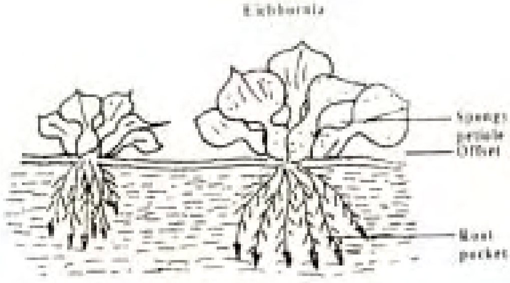


Fig : 6.4. Offset

Offset

These are also known as condensed runners. These originate as short, more or less thickened, horizontal branches in the axil of lower leaves of the main shoots. Unlike a runner, an offset produces a tuft of leaves above and a cluster of roots below. On breaking off from the parent plant, each branch forms an independent plant. eg., *Pistia, Eichhornia* etc.

Propagation by Leaves

Leaves are not a common means of vegetative propagation in nature. However, *Bryophyllum* is known for its remarkable ability to reproduce by leaves. In *Bryophyllum* plantlets develop from the buds present on the marginal notches of the intact leaves. These plantlets become detached and develop into independent plants.

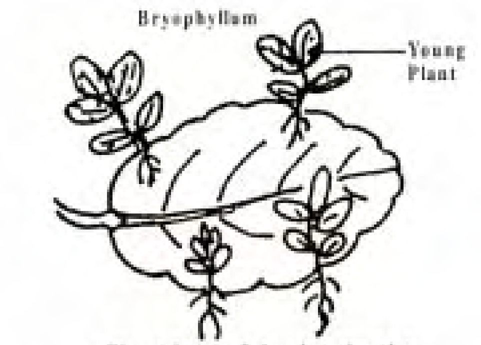


Fig : 6.5. A leaf showing plant lets

Propagation Through Bulbils

These are spherical multicellular, fleshy buds produced in the axil of foliage leaves in the place of axillary buds. They grow to form new plants, when shed and fall on the ground. eg. *Dioscorea, Oxalis, Pine apple*, etc.

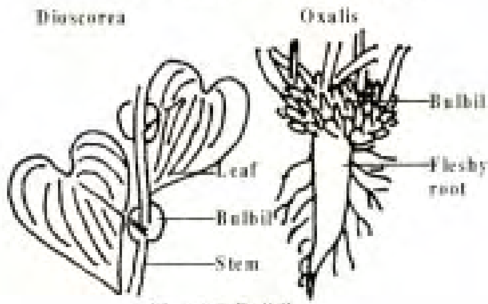


Fig : 6.6. Bulbils

Propagation by Turions

These are special type of fleshy buds that develop in aquatic plants. Eg. *Potamogeton, Utricularia*, etc. for vegetative propagation.

Horticultural importance of Natural vegetative propagation

Agriculturists and horticulturists use various means of natural vegetative propagation explained above for raising crops and garden plants for commercial purposes.

The chief advantage of vegetative propagation is the perpetuation of the desirable features of a selected plant. We are familiar with the fact that potatoes are propagated by whole tubers or their pieces, *ginger* and *banana* by the division of rhizomes, *Colocasia* and *Crocus* by the pieces of *corms, onion* and *garlic by bulbs, mint* and *chrysanthemum* by suckers and sweet potatoes by the pieces of tuberous roots.

B. Artificial Method of Vegetative Propagation

In addition to the natural methods of vegetative propagation as described above, several artificial methods of vegetative propagation are practised. Following are the important artificial methods of vegetative propagation.

Cuttings

The portion of any plant organ such as stem, root or leaf, used for vegetative propagation is called cutting. Stem cuttings are most commonly used for this purpose. Factors such as the optimum length and diameter of the cutting, age of the parent plant and season are to be considered, while selecting a cutting for each species.

Some of the plants propagated by stem cuttings are sugarcane, rose, *Bongainvillaea, Moringa, Hibiscus, Thepesia* etc.

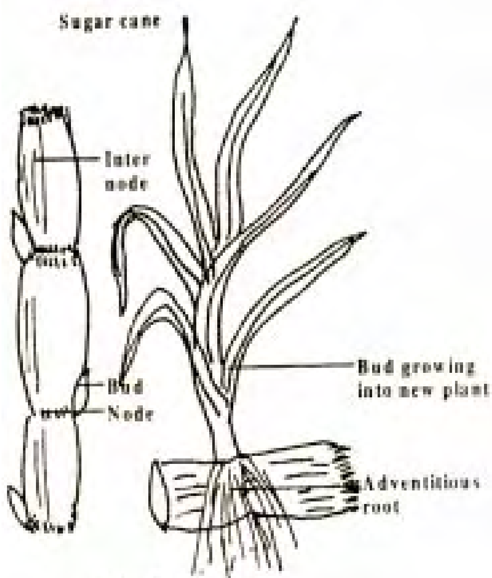


Fig : 6.7. Cutting

Grafting

It is the most common method of vegetative propagation. In this method part of two plants are joined in such as way that they grow as one plant. Grafting is done between the two closely related dicotyledonous plants having vascular cambia. The rooted supporting portion of one plant, called stock is joined with a twig of another plant called scion.

Advantages of Vegetative propagation

Vegetative propagation has a number of advantages. Some of these are as follows:

1. Vegetative propagation is a more rapid, easier and a less expensive method of multiplying plants which have either poor viability or prolonged seed dormancy.
2. It also helps us to introduce plants in new areas where seed germination fails to produce plants due to change in the soil and environmental conditions.
3. Plants like Bermuda grass or doob grass (Cynodon dactylon), which produce only a small quantity of seeds are mostly propagated vegetatively.

4. Vegetative propagation is the only known method of multiplication in plants like *banana*, seedless *grapes* and *oranges*, *rose* and *jasmine* that have lost their capacity to produce seeds through sexual reproduction.
5. Grafting permits the physical and physiological joining of separate individuals for the best economic advantage i.e. good qualities of two varieties can be combined in one composite plant.
6. The good qualities of a race or variety can be preserved indefinitely.
7. The greatest advantage of vegetative propagation is that all plants produced will have the same characters and hereditary potential as the parent plants. It is not possible in the plants raised from seeds, since it contains blended characters of both the parents.

SELF EVALUATION

One Mark

Choose the correct answer

1. In Hibiscus vegetative reproduction takes place by

   a. Stem b. Bud c. Rhizome d. Leaf.

2. The plant which propagate with the help of its leaves is

   a. Onion b. Cactus c. Potato d. Bryophyllum

Fill in the blanks

1. During grafting the part that becomes the supporting portion is called as ....
2. A piece of potato tuber can form a new plant if it has ....

Two Marks

1. What is grafting?
2. What is a bulbil?
3. Differentiate between stolon and sucker.
4. Why is grafting not possible in monocot plants?

Five Marks

1. Discuss the significance of vegetative propagation
2. What is vegetative propagation?

Ten Marks

1. Give a brief account of vegetative propagation
2. Describe different means of natural vegetative propagation.

1. (b) Micropropagation

Micro propagation is a rapid method of vegetative multiplication of valuable plant material for agriculture, horticulture and forestry. In this process, a large number of plantlets are produced from a small mass of explanted plant tissue by the tissue and cell culture technique. The ability of every living plant cell to produce the entire plant is called totipotency. This is being exploited industrially to multiply plants which are difficult to propagate by conventional means.

Procedure for micropropagation

In this method, a small segment of explant is cultured in a nutrient medium; the explant may be a meristametic tissue of a stem tip, an inflorescence etc. The explant tissue produces callus during the period of incubation. After the production of enough amount of callus tissue, the callus is sub-cultured in a fresh M.S. Medium containing growth hormones auxin and cytokinin.

The sufficiently developed calluses are then transferred to regeneration medium where the calluses are induced to produce roots and shoots. After the proper development of roots and shoots, the individual planets are transferred to pots in a green house for further existence.

Sometimes the callus tissue can be homogenised and the homogenate is directly plated on the medium. The cell masses of the homogenate grow and produce new plantlets.

1. Multiple Shootlet Production

This process is adapted to produce multiple copies of a desirable plant by making use of shoot tips. The desirable plant is multiplied for being a rare hybrid or a sterile plant with unusual features or for obtaining individual plants of only one sex. In this process multiple buds are formed from the cultured shoot tips without intervention of a callus in response to specific treatments. These buds are grown into shoots and are subsequently induced to produce roots with the rooting hormones. The shoots are then planted in the soil to develop into new plants. The chief advantage of this technique is the large scale cloning of plants throughout the year in a very small space. More examples of micropropagation on a commercial scale have been reported in ***Potato, Bananas, Begonias, Chrysanthemums***, etc.

2. Somatic Embryogenesis

Somatic cells are cultured in electric shakers to obtain single cell suspensions. After sometime when the number of cells has increased to a maximum depending upon the amount of the nutrient medium, the culture is made stationary. Each cell starts differentiating into an embryo and proceeds through globular heart-shaped and torpedo shaped stages resembling the development of sexually produced embryos. Since these embryos develop from the somatic calls, they are called as **embryoids**. Thousands of somatic embryos (embryoids) can be produced in a small volume of the nutrient medium contained in a culture tube. Each of these embryoids can form a complete plant with a normal tap root system. Success has been achieved in ***Carrot, Celery*** and ***Alfalfa***

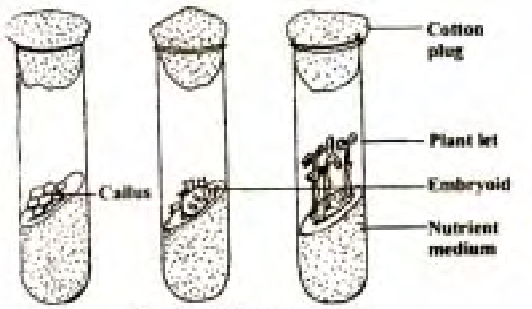


Fig : 6.8. Micropropagation

Micropropagation can be practiced in plants for many reasons

1. In some plants, seed production may be difficult or impossible. In such cases micro propagation is an effective technique for producing a large number of identical clones.
2. In some plants, normal sexual reproduction can take place, but only a small number of hybrids show the desired characters. The individuals resulting from micropropagation are all identical; they show a number of desired characters.
3. Sometimes a plant of desirable genotype may be required for planting. In plants like oil palms, identical clones are produced through micropropagation.
4. It is a standard multiplication method by which all the individuals produced are protected against mutation.
5. Till 1986, more than sixty species of forest trees were bred by using micro propagation.

SELF EVALUATION

Two Marks

1. Define totipotency.
2. What is Micropropagation?

Ten Marks

1. Write an essay on Micropropagation.

2. Sexual Reproduction

2.a. Pollination

The process of transfer and deposition of pollen grains from the another to the stigmatic surface of the flower is called pollination. It is an essential event in the sexual reproduction of seed bearing plants. Pollination is a pre-requisite for ensuring seed set and perpetuation of a species. Pollination is direct in Gymnosperms and indirect in Angiosperms.

There are two main types of pollination - self pollination and cross pollination.

I. Self Pollination

It is the process of transfer of pollen grains from the another to the stigma of either the same flower or another flower borne on the same plant. Accordingly, self pollination is of two types: autogamy and geitonogamy.

(A) Autogamy: (Gk. Auto = self, gamos = marriage):

It is a kind of pollination in which the pollen from the anthers of a flower are transferred to the stigma of the same flower. It occurs by three methods.

(i) Cleistogamy: (Gk. Kleisto = closed. Gamos = marriage):

Some plants never open to ensure complete self-pollination. This condition is called cleistogamy, eg. ***Commelina bengalensis***, ***Oxalis***, ***Viola***, etc. The cleistogamous flowers are bisexual small, inconspicuous, colourless and do not secrete nectar.

(ii) Homogamy

Anthers and stigma of the bisexual flowers of some plants mature at the same time. They are brought close to each other by growth, bending or folding to ensure self pollination. This condition is called homogamy, eg., ***Mirabilis (Four O. clock), Catharanthus (Vinca), Potato, Sunflower***, etc.

(iii) Bud Pollination

Anthers and stigma of the bisexual flowers of some plants mature before the opening of the buds to ensure self-pollination, eg., ***Wheat, Rice, Pea***, etc.

(B) Geitonogamy (Gk, geiton = neighbour, gamos = marriage).

It is a kind of pollination in which the pollen grains from the anthers of one flower are transferred to the stigma of another flower borne on the same plant. It usually occurs in plants which show monoecious condition (unisexual, male and female flowers are borne on the same plant).

Advantages of self-pollination

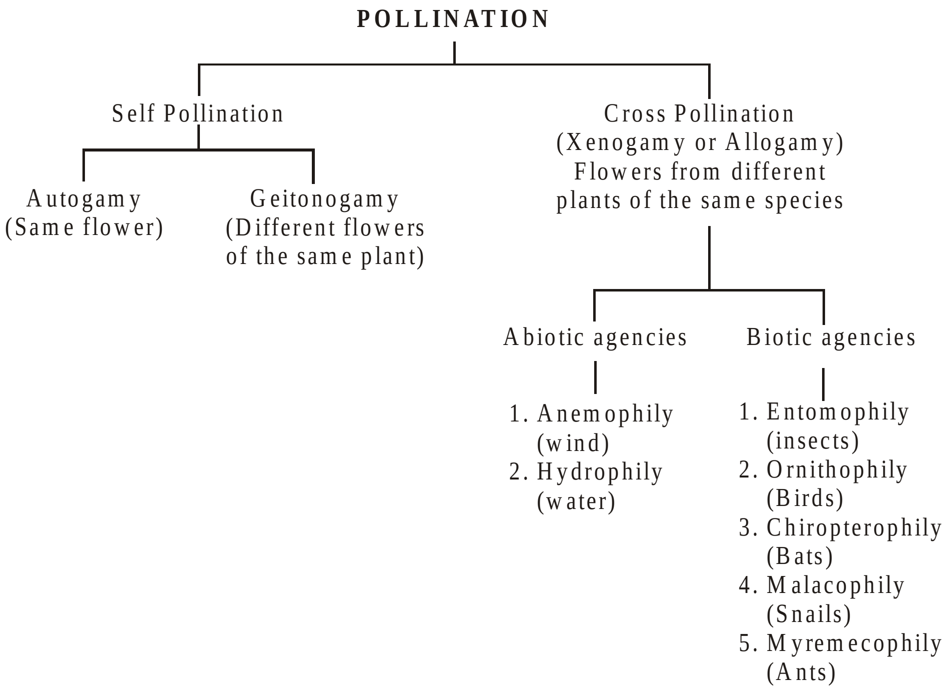
1. Chances of pollination are more.
2. Self-pollination maintains purity of the race and avoids mixing.
3. It need not produce a large number of pollen grains.
4. Flower need not possess devices such as large and showy petals, presence of scent and nectar, etc. to attract pollinators.

Disadvantages of self-pollination

1. Progeny continuously gets weaker after every generation.
2. Less chances of the production of new species and varieties.

II. Cross Pollination (Xenogamy, Allogamy)

Cross Pollination involves the transfer of pollen grains from the flower of one plant to the stigama of the flower of another plant. It is also called Xenogamy.



(Gk. Xenos = Strange, gamos = marriage) or allogamy (gk, allos = other, gamos = marriage. The main floral characteristics which facilitate cross pollination are

i) Herkogamy

Flowers are bisexual but the essential organs, the stamens and stigmas, are arranged in the flower, in such a way that self pollination becomes mechanically impossible. eg., ***Hibiscus sps; Gloriosa superba, etc.***

Hibiscus : The stigmas project far above the stamens.

Gloriosa superba : The style is reflexed away from the stamens.

ii) Dichogamy

Pollen and stigma of the flower mature at different times to avoid self-pollination. It is of two types.

a. Protography

Gynoecium matures earlier than androecium eg. ***Bajra, Aristolochia*** etc.

b. Protandry

Androecium matures and shed pollen gynoecium eg. **maize**.

iii) Self-incompatibility

In some plants, when the mature pollen fall on the receptive stigma of the same flower, it fails to bring about self pollination. It is called self incompatibility. Under such conditions, the cross pollination is the only option.

iv) Male sterility

The pollen grains of some plants are not functional. Such plants set seeds only after cross pollination.

v) Dioecism

Cross pollination always occurs when the plants are unisexual and dioecious. i.e. male and female flowers occur on separate plants. eg., ***Papaya***, some ***cucurbits*** etc.

vi) Heterostyly

The flowers of some plants have different lengths of stamens and styles so that self pollination is not possible eg. ***Primula, Linum***, etc.

Agents of pollination

Pollination is effected by many agents like wind, water, insects etc. On the basis of the agents that bring pollination, the mode of pollination is as follows :

1. Anemophily (Wind)
2. Hydrophily (Water)
3. Entomophily (Insects)
4. Ornithophily (Birds)
5. Chiropterophily (Bats)
6. Myrmecophily (Ants)

1. Anemophily (Wind pollination) (Gk, anemos = wind, philein = to love)

It is a mode of pollination or transfer of pollengrains from anther to stigma through the agency of wind. The flowers which are wind pollinated are called anemophilous. The anemophilous flowers are characterized by the following adaptations :

(i) Flowers are small colourless, inconspicuous, odourless and nectarless.

(ii) Calyx and corolla are either reduced or absent. Anthers are usually versatile.

(iii) When flowers are unisexual, male flowers are more abundant than female flowers. In bisexual flowers, the stamens are generally numerous.

(iv) Pollen grains are small, light, dry, dusty and sometimes winged (or saccate) so that they are easily blown away to long distances (upto 1300 km).

(v) Pollen grains of anemophilous flowers are produced in huge quantities. For example, a single flower of *Cannabis* produces, 5,00,000 pollengrains.

(vi) The flowers are well exposed in the air. In certain plants, they are produced above the foliage before the appearance of new leaves.

(vii) The stigmas are large, well-exposed, hairy, feathery or branched to catch the air-borne pollen grains.

(viii) In some plants, (eg., ***Urtica***), the anthers burst suddenly to throw the pollen grains into the air (gun-powder mechanism)

The common examples of wind pollinated flowers are **- *grasses, sugarcance, bamboo, coconut, palm, date palm, cannabis (bhang), maize*** etc. fig.

2. Hydrophily (Water Pollination) : (Gk, Hydro = water, Philein = to love)

Hydrophily occurs only in a few aquatic plants. Hydrophily is of two types, hypohydrophily and epihydrophily.

i) **Hypohydrophily** is true hydrophily which occurs below the surface of water. It occurs in totally submerged plants and their pollen grains are water borne. eg., ***Zostera marina, Ceratophyllum***, etc.

a. Ceratophyllum desnersum

In **Ceratophyllum** desnersum (a submerged fresh water plant), the male flower bears 30-45 stamens. The mature anthers break at the base, rise to the surface of water and dehisce there. The liberated pollen germinate and sink in water. While sinking, they come in contact with stigma of female flowers to effect pollination.

b. Zostera marina

In Zostera marina, the pollen grains are elongated (upto 2,500 mm), needle like and without exine. They have the same specific gravity as that of water, therefore float below the surface of water. When they reach the stigma, they oil around it and germinate.

3. Entomophily (insect Pollination)

The important pollinating insects are bees, butterflies, moths, wasps, bettles etc. The insects visit the flowers for nectar, edible pollen grains or shelter. Bees are the chief visitors of flowers and they obtain both nectar and pollen from the flowers. They have **pollen sacs** or **pollen baskets** for collecting pollen. The important characteristics of insect pollinated flowers are as under.

1. The flowers are large or if small they are grouped into inflorescence
2. The flowers are usually brightly coloured and have specific odour.
3. The flowers usually possess nectar or edible pollen.
4. They produce fewer pollen grains.
5. Anthers and stigmas are commonly inserted.
6. Stigmas are usually unbranched and may be flat or lobed.

A detailed study of the inter-relationship between the structure of flower and insect pollinators clearly indicates that some angiospermous plants are dependent upon a particular type of insect for pollination. Some classic examples are as follows :

a. Pollination in Salvia

The genus ***Salvia*** belongs to family Labiatae (Mint family) in which the gamopetalous corolla is two-lipped (bilabiate). The lower lip provides platform for the visiting insect and the upper lip is just like a hood which protects the floral organs. The flowers are protandrous. Each flower has two epipetalous stamens located in anterio-lateral position. Each stamen has a short filament and an elongated curved connective. The anther has two parts - one half is sterile and another half is fertile. Both the parts of anther are separated apart due to elongation of connective. The elongated connective has two unequal arms. The upper arm is long and curved. It bears the fertile lobe of anther. The lower arm of connective is short and bears the sterile lobe of anther. The two sterile lobes jointly form a sterile plate of tissue which is placed at the mouth of corolla tube and partly blocks the path of the visiting insect. The upper fertile lobes are sheltered in the upper lip of corolla. As a bee visits the young flower and moves inward in search of nectar, its head pushes the sterile plate which brings down the fertile anther lobes to strike against its back. The pollengrains are deposited upon the back of the bee. When the pollen-dusted bee visits older flower (with protruded bilipped stigma), its back rubs against the mature stigma bringing about the pollination.

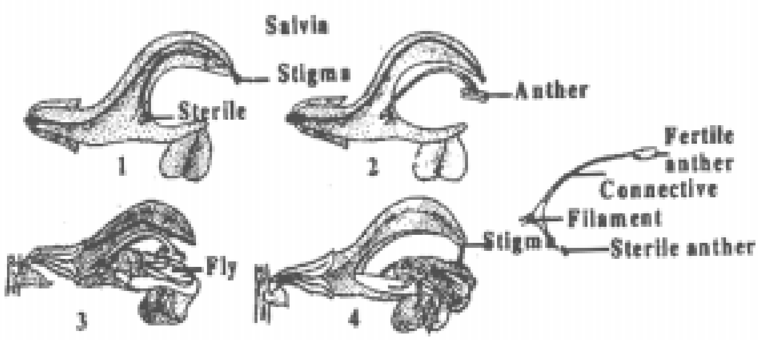


Fig : 6.10. Pollination by insect

Since the bisexual flowers of *Salvia* are protandrous, (anthers mature earlier than the gynoecium), cross pollination occurs only when pollen-dusted bee visits older flowers with mature gynoecium.

4. Ornithophily (Pollination by birds)

Ornithophily (Gk. Ornis = bird, philein = to love) is a mode of pollination performed by birds. The act of pollination is not performed by all the birds except a few. The most common bird pollinators are Sun bird, Humming bird, Crow, Bulbul, Parrot, Mynah, etc. The birds visit a large variety of flowers such as ***Bombax*** (Red Silk Cotton), ***Erythrina*** (Coral Tree), ***Callistemon*** (Bottle Brush), ***Bignonia, Agave, ete***. Over about 100 species of Australian plants are pollinated by birds. Humming bird pollinates while hovering over the flowers and sucking nectar. The bird can derive about half of its body weight of nectar in a single day. The nectar is chiefly made of sugars and provides a sweetdrink to the bird.

The ornithophilous flowers are characterized by the following adaptations:

i) The flowers are usually large in size. They have tubular or funnel-shaped corollas.

ii) The flowers are brightly coloured (such as red, yellow, orange, blue, etc.) which attract the birds from long distances.

iii) The flowers produce abundant watery nectar.

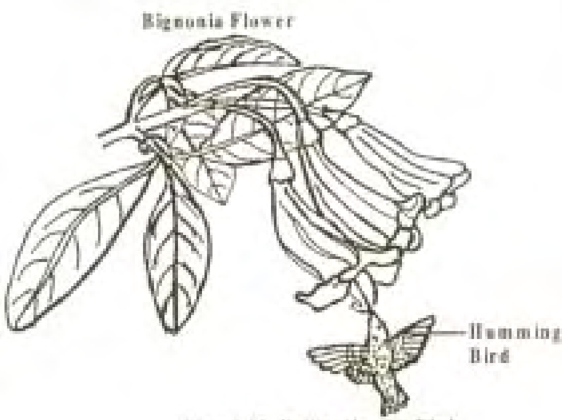


Fig : 6.13. Pollination by Bird

5. Chiropterophily (Bat Pollination)

It is a mode of pollination performed by bats. The bats are nocturnal flying mammals which move swiftly and transport pollen grains to long distances, sometimes over 30 kms. The flowers they visit are large, dull-coloured and have a strong scent. Chiropterophilous flowers produce abundant pollen grains and secrete more nectar than the ornithophilous flowers. Some of the common chiropterophilous plants are - ***Kigelia pinnata*** (Sausage Tree), ***Adansonia*** (Baobab Tree), ***Bauhinia megalandra, Anthocephalus*** (Kadam Tree), etc. Each flower of ***Adansonia*** (Baobab Tree) has 1500-2000 stamens.

6. Myrmecophily

Sometimes ants take their food or shelter on some trees such as ***Mango, Litchi, South American Acacia*** and so on. These ants act as body guards of the plants against any disturbing agent and also helps in pollination.

The pollination performed by any type of animal is called **Zoophily**.

Advantages of cross pollination

i) Cross pollination brings about genetic recombination and production of new varieties (variations).

ii) Cross pollination results in healthy and stronger offsprings due to phenomenon of hybrid vigour.

2.b. Double fertilization

The fusion of the male and female gametes is called fertilization. The process was first discovered by **Strasburger** (1884) in ***Monotropa***

Siphonogamy

In seed plants, the male gametes arebrought to the eff containing female gametophyte by a pollen tube, the phenomenon is called **siphonogamy.**

Type of pollen entry

The pollen tube enters the ovule either through the micropyle **(Porogamy** eg. Lily), Chalaza (**Chalazogamy** eg. **Cauarinas**) or the integuments (**Mesogamy-** eg. *cucurbita) and* and discharges the two male gametes or sperms into the embryo sac. The pollen tube bores through nucellus and finally penetrates the wall of the embryo sac. It passes between a synergid and the egg cell or penetrates between the two synergids. Later one or both of the synergids degenerate. Inside the embryo sac, the pollen tube ruptures and the two male gametes are set free near the egg apparatus.

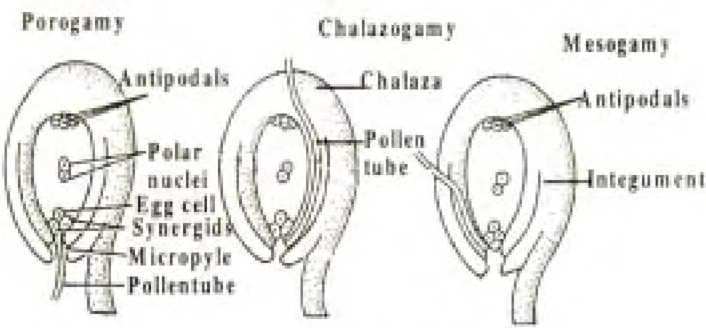


Fig.6.14. Entry of pollen tube into the ovule

Syngamy or true fertilization

Out of the two male gametes, one fuses with the egg nucleus and forms a diploid **zygote.** This process of gametic fusion is called **syngamy** or **true fertilization.** It is also known as **generative fertilization.**

Triple fusion

The second male gamete moves further the central cell and fuses with the two haploid polar nuclei or diploid secondary nucleus to form a triploid **primary endosperm nucleus.** This process involving the fusion of three necle is called **triple fusion.** It is also called **vegetative fertilization**. The central cell is now called **primary endosperm cell.**

The whole phenomenon of fertilization involving the fusion of one male gamete with the egg. together with the fusion of second male gamete with the

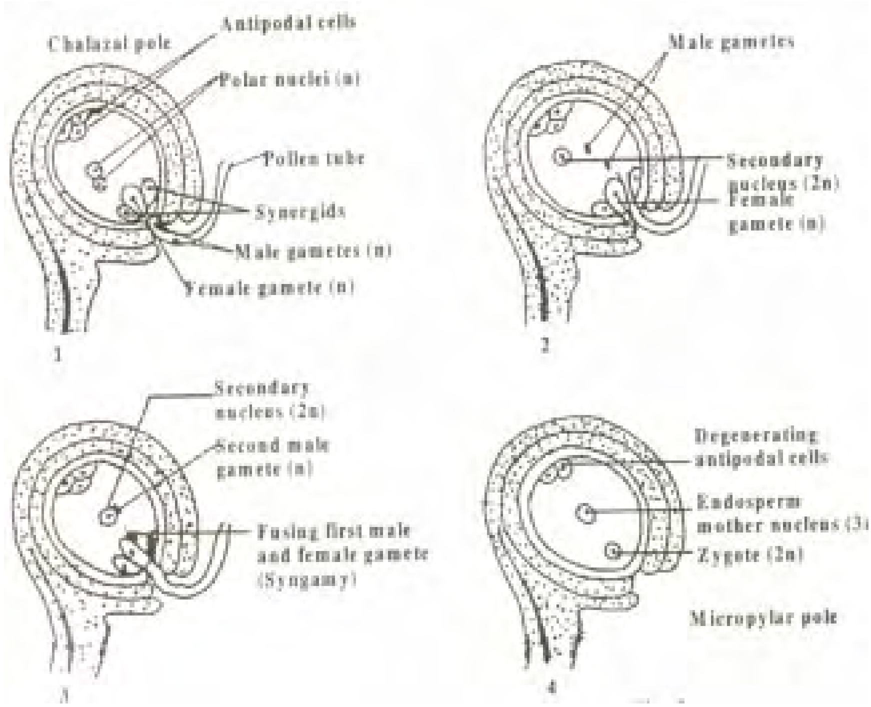


Fig.6.15 L.S. of ovule showing different stages of double fertilization

polar nuclei is called double fertilization. It involves both syngamy and triple fusion. Double fertilization is a unique feature of angiosperm and is necessary and is necessary for the production of viable seeds in the flowering plants. It was first observed by **Nawaschine(1898)** in **Fritillaria** and **Lillium.**

Significance of double fertilization

Double fertilization is found to be universal occurrence among angiosperms. It must occur within the ovule for the setting of viable seeds. Following are the significance of double fertilization.

1. In angiosperms the growth of the embryo sac (female gametophyte) stops at 8 nucleate or 7 celled stage. The fusion of second male gamete with the polar nuclei or secondary nucleus, provides stimulus to one of its cells to resume growth and form the nutritive tissue or endosperm.

2. Double fertilizationensures that the nutritive tissue or endosperm is formed only when the formation of embryo has been confirmed by fertilization of egg. If fertilization fails due to some reason, no endosperm will be formed. Thus no energy of the plant will be wasted on this account in angiosperms.

3. It provides characteristics tonutritive tissue called endosperm.

Post fertilization changes

After fertilization the sepals,petals, stamens, styles and stigma usually wither and fall off. The calyx may persis(e.g. tomato, brinjal) and even show growth (eg. **Physalis).** The zygote undergoes a number of mitotic divisions and forms a multicellular **embryo.**The primary endosperm nucleus also undergo mitotic division to form a food laden tissue called endosperm. The ovules mature into seeds and the ovary containing the ovules enlarges and forms the fruit.

Parts before fertilization	**Parts after fertilization**	
1. ovary	-fruit	
2. ovary wall	-pericarp	
3. ovule	-seed	
4. funicle	-stalk of the seed	
5. hilum	-hilum	
6. nucellus	-perisperm	
7. outer integument	-testa	Seed coat
8. inner integument	-tegmen	
9. micropyle	-micropyle	
10.Fertilized egg	-Emdosperm	
11.Synergids	-Degenerate	
12.Fertilized Secondary nucleus		
13.Antipodal cells	-Degenerate	

SELF-EVALUATION

One Mark

Choose the correct answer

1. The embryo sac in a typical dicot at the time of fertilization is

   a. 8 celled   b. 6 celled   c. 7 celled   d. 5 celled

2. Process of fusion between male and egg nuclei are

   a.Syngamy   b.Conjugation   c.Double fertilization   d. Triple fusion

Fll in the blanks

1 Double triple fusion. What is the product of this process?

2. What is double fertilization?

Ten Marks

1. Describe the process of endosperm and embryo formation in flowering plants.

3. Germination of Seed

3.a. Parts of Seed

Seed is aripened ovule which contains the embryo or the miniature of plant body. Seeds of different plants vary in their size and shape. However, the general plan of structural organization of seed remains almost the same.

Part of a seed

Every seed an outer covering called seed coat. It develops from the integuments of the ovule. The outer coat is called **testa** and the inner layer is called tegmen. If only one covering is present in the seed, it is called testa. The testa is hard andleathery whereas **tegmen** is thin and membranous. Sometimes tegmen remains fused with the testa. The outer surface of seed shows a scar or mark of attachement with the seed stalk. It is called**hilum.**There is a small pore, called **micropyle,** which represents the micropyle of ovule. Some seeds also show the place of origin of seed coats (**chalaza**) and the part of funiculus fused with seed wall (**raphe**).

The seed coat encloses an embryo which is differentiated into **radicle, plumule** and **cotyledons**. The radicle, when elongated, gives rise to primary root whereas the plumule gives rise to aerial shoot.

The number of cotyledons or seed leaves may be one as in monocotyledons or two as in dicotledons.sometimes, they store reserve food materials eg. Gram, Pea, Almond, Cashewnut, etc. or serve as photosynthetic organs in young seedling. the part of embryonic axis between the radicle and the point of attachment of cotyledons is called **hydocotyl.** Similarly, the part of embryonic axis between the plumule and the point of the attachment of cotyledons is called **epicotyl.**

Example for Dicot seed is Bean, Cicer, Tramarind etc. (Fig-3.46)

Example for monocot seed is paddy, maize etc. (Fig-3.47)

SELF-EVALUATION

One Mark

Choose the correct answer

1. Micropyle occurs in
   a. Ovary b.Seeds c.Ovule d. Both (a) and (c)

2. The Micropyle in a seed helps in the entry of
   a. Water b. Male gamete c. Pollen tube d. None of these

3. Single cotyledon of a monocot seed is
   a.Plumule b. Epicotyl c. Scutellum d. Coleorrhiza

Fill in the blanks

1. Triple fusion occurs between male gamete and ....
2. the outer coat of seed is called ....

Two Marks

1. What is meant by tegmen?
2. What is cotyledon?

Five Marks

1. Differentiate dicot seed from monocot seed.

3.b. Types of Seed Germination

The process by which the dormant embryo of the seed become active growth and forms a seedling or a young plant capable ofindependent existence is called seed germination.

Process of seed germination

Most seeds geminate, when they are provided with water, oxygen and their dormancy is over. The main step of seed germination are described below.

1. Imbibition

The first step in germination is imbibition or uptake of water by the dehydrated seed. The seeds, when placed in moist soil, absorbs water through micropyle. Imbibition causes the seed to swell as the cellular constituents are dehydrated. Imbibition takes place iwth great force. It ruptures the seed coat and enables the radicle to emerge. It causes swelling of seeds and development of the great force called imbibition pressure. Dry seeds packed in a bottle containing water can crack it as they imbibe water and swell.

2. Respiration

Imbition makes the embryo cells active and causes resumption of metabolic activities. Their respiration isinitially anaerobic. The cells possess some simple polysaccharides for functioning as respiratory substrate. When the anaerobic respiration reaches a peak,mitochondria differentiate in the embryo cells. The respiration now becomes aerobic as oxygen starts entering the seed coats.

3. Mobilization of reserve food

The activated embryo cells induce the production of hormones and digestion of reserve food. Depending on the nature of seed, the resouce may be stored chiefly in the endosperm(e.g.castor, cereal grains and other monocots) or in the cotyledons(eg. many dicotyledonssuch as pea, gram, bean etc.) The cells which are rich in proteins produce and secretes hydrolyzing enzymes. These enzymes bring about the digestion of the reserve foods. The latter are changed into sugars, amino acids and other soluble substances. They are translocated to the embryo.

4. Growth of embryo

On the receipt of soluble food, the cells of embryo axis undergo division and expansion. the radicle end of the embryo axis is the first to enlarge. It grows out of the seed coats and passes downwardly into the soil toestablish itself as the primary root. The plumule also comes out of the seed and soil to establish itself as shoot.

Types of seed germination

It is of two types.Epigeal and hypogeal.

Epigeal germination

In this type of germination, the cotyledons are brought above the ground due to rapid elongation of hypocotyl. Epigeal germination seen inmany dicotyledon seeds such as bean, castor, sunflower, gourd, cucumber etc., During this germination the hyphocotyl grows actively and become curved. It brings the seed above the soil. After coming above the surface of the soil, the hypocotyl straightens. The loosened seed coat fall down and the cotyledons become green. Now, the epicotyl grows and plumule gives rise to green leaves. The cotyledons fall down ultimately.

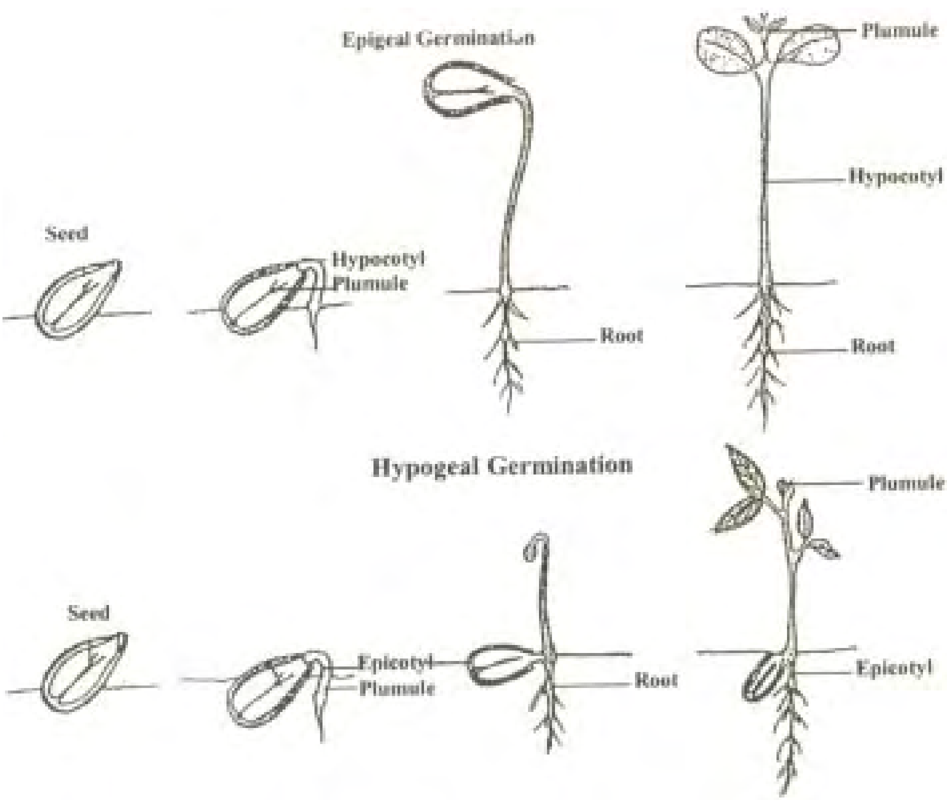


Fig.6.16 Types of seed germination

Hypogeal germination

In this type of germination, the cotyledons remain below the soil due to rapid elongation of epicotyl. It is found in many dicotyledonous seeds and monocotyledonous seeds. During this germination, the epicotyl elongates and become curved. It brings the plumule above the soil. Cotyledons remain underground. In case of monocotyledonous seeds like maize, the coleoptile (plumule covering) grows straight into the soil and comes out to form the green tube. Plumle elongates as well and comes out of the soil while contained in the coleoptile. the plumle ruptures the coleoptile with further growth. The coleorrhiza (covering of radicle) along with radicle grows downwards. After sometimes coleorrhiza ruptures due to further growth of the radicle. The radicle forms the primary root which is soon replaced by fibrous foot.

Special type of Germination

Vivipary

Vivipary is the special type of seed germination. During germinatin, seed is till attached to parent plant and nourished by it. Vivipary generally occurs in mangrove plant. The mangrove plants are generally medium sized tree which grow in salty marshes of sea coasts. (eg.***Rhizophora, Sonneratia, Avicennia***).The seeds of mangrove plants cannot germinate on themarshy habitat because of the excessive saltconcentration and lack of oxygen. The embryo of the seed continues growth while stillattached to parentplant. The radicle of the plant elongates considerably and projects out of the fruit. The lower part of the radicle becomes thick and swollen. Finally, dart like seedling breaks off the parent plant due to its incresing weight and gets embedded into the marsh in such a position that the plumule remains outside the satish water. The radicle immediately formsnew roots and establishes the seedling as a new plant.

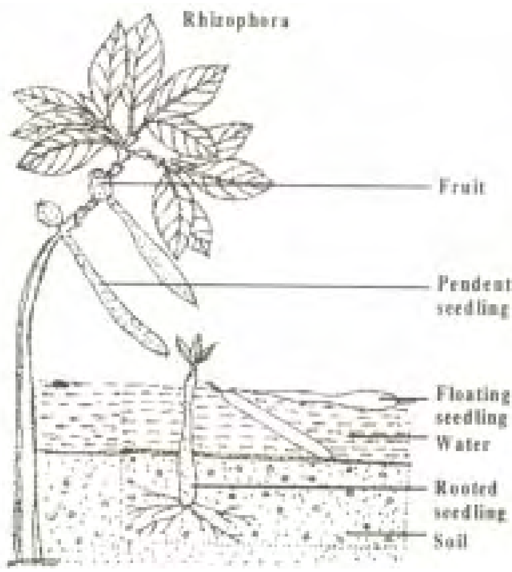


Fig.6.17 Vivipary

Factors necessaryf for seed gamination

A number of factors are required for the process f germination . They are of two types-external and internal.

External factors.

1. Water

Seeds are generally highlly dehydrated with only 6-15% of water content in their cells.Therefore they have low physiological activity. Water provides sufficent hydration to the concentrated protoplasm of the transport gases, a cause hydrolysis of reserve food nd its trnansport and allow embryo cells to grow in size.

2. Oxygen

Oxygen is essential for aerobic respiration to release energy for the metabolic activities. Therefore, with the exception of the few plants. (eg. rice, Typha etc) seeds usually require oxygen or good aeration for their germination.

3. Temperature

Seeds require a definite temperature range withinwhich they germinate. Commonly seeds germinate within temperature range of 5^0C to 40^0C. However, the optimum temperature or seed germination lies between 25-30^0C for most of the species.

4. Light

Light is not an essential factor for the germination of most of the seeds. However some are light sensitive and their germination is influenced by the presence or absence of light.

Internal factor

1. **Maturity of embryo:** The seeds of some plants, when shed, contain immature embryo. Such seeds germinate only after maturation of their embryo.
2. **After ripening:** The freshly shed seeds of some plants may not possessthe required hormones for the growth of embryo, such seeds germinate only after the maturation of their embryo.
3. **Viability:**Usually seeds remain viable or living only for a particular period. The viability of seeds range from a few days (eg. Oxalis) to more than one hundred years. (eg. Trifolium). Maximum viability (i.e., 1000 years) has been recorded in lotus seeds. Seeds germinate only within the period of viablity.

4. **Dormancy:** Seeds of many plants are dormant at the time of shedding. Seed dormancy may be due to various reasons like impermeability, toughness of seed coats, presence of growth inhibitors etc. Such seeds germinate only after natural breakage of dormancy.

SELF -EVALUATION

One Mark

Choose the best answer

1. Hypogeal germination ofalbuminous seed is seen in

   a.Maizeb.Castor c.Gram d.Bean

2. Vivipary is a characteristic feature of

   a.Mesophytes b.Halophytes c.Xerophytes d.Hydrophytes.

3. Germination of the seed is promoted by

   a. Green light b.Red light c.Blue light d.Infra red light

Fill in the blanks

1. The phenomenon of germination of seeds inside the fruit itself is called........
2. The inner thin, membranous, whitish integument seen in dicotyledonous seed is known as ....
3. Albuminous seeds store food materials in.............

Two Marks

1. What is funicle?
2. What is hypocotyl?
3. Define epicotyle.

Five Marks

1. Write the difference between epigeal and hypogeal germination.

Ten Marks

1. Describe the epigeal type of seed germination.
2. Describe the hypogeal of seed germination.

3.c. Abscission,Senescence

The process of separation of leaves, flowers, and fruits from the plant is called abscission. It is essential, when these parts are removed that the plant seals off its vascular system to prevent loss of water and nutrients and to exclude bacteria, fungal sporesand other pathogens. An abscission zone, a layer of specialized cells is formed at the base of each part before it is lost, to separate it form the main body. The cells in this layer die and become hardened by the deposition of ligning and suberin. So, by the time the leaf or fruit drops, the vascular system has been sealed off.

Mechanism of Leaf abscission

It takes place at the base of the petiole which is internally marked by a distinct zone of few layers of thin-walled cells arranged transversally across the petiolar base. This zone is called as the **abscission zone** or **abscission layer** (Fig). The cells of the abscission layer is separate from each other due to the dissolution of middle lamella and also the primary cellulose walls under the influence of the increased of the increased activity of the enzymes **pectinase** and **cellulase.** At this stage the petiole remains attached to the stem only by vascular elements and very soon due

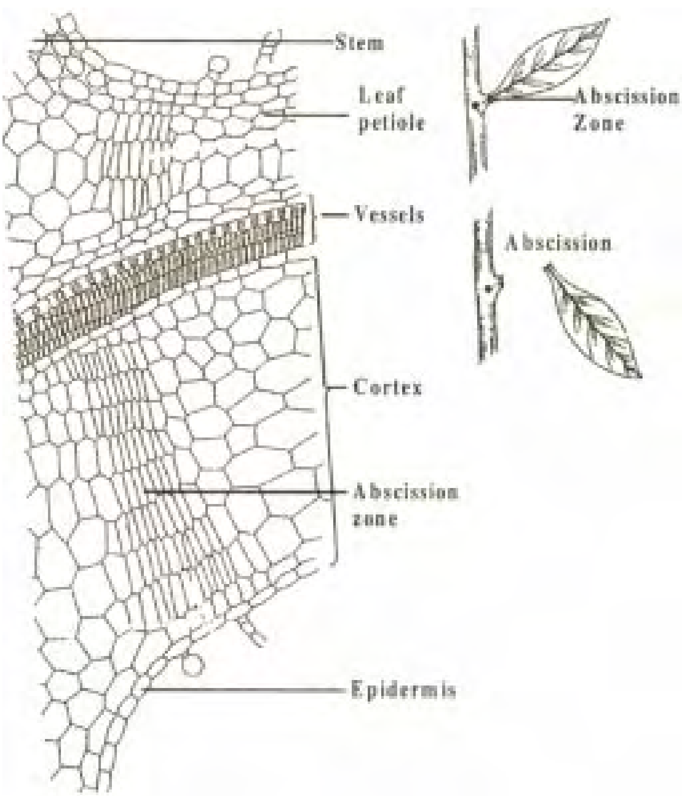


Fig.6.18 A leaf petiole showing the abscission zone

to its own weight and pressure of wind, is detached from the stem. The broken vascular elements are soon plugged with tyloses or gums.

Abscission is controlled by **abscisic acid** (ABA), a growth regulator synthesized primarily in chloroplasts. It is a general inhibitor of many processes, and the abscission layer forms and hardens under its direction.

Importance of Abscission

1. Itsheds off the senescent and dead parts of the plants.
2. It also sheds off ripe fruits, which helps in their dispersaland further life cycle of the plant.
3. In lower plants, shedding of vegetative parts, such as gemmae or plantlets helps in vegetative propagation.

Senescence

As the young plant grows, it undergoes ageing and develops into mature plant in an orderly fashion. The later part of the developmental process which ultimatelyleads to death is called senescence.

Senescence may be defined as the period between reproductive maturity and death of a plant or a part of it. It is characterized by a collective, progressive and deteriorative developmental process which ultimately leads to completeloss of organization and function of the plant or parts of it. The study of plant senescence is called **phytogerontology.**

Types of Senescence

Leopold(1961) has recognized 4 types of senescence patterns, which are as follows:-

1. Whole plant senescence
2. Shoot Senescence
3. Sequential senescence of Organ senescence
4. Simultaneous senescence

1. Whole plant senescence

It is found in monocarpic plants which produce flower and fruit only once in their life cycle. The plants may be annual(e.g. **rice, wheat, gram, mustard** etc.), biennials(e.g.**cabbage, henbane**) or perennials (e.g. certain **bamboos**). The plant dies soon after ripening of seeds.

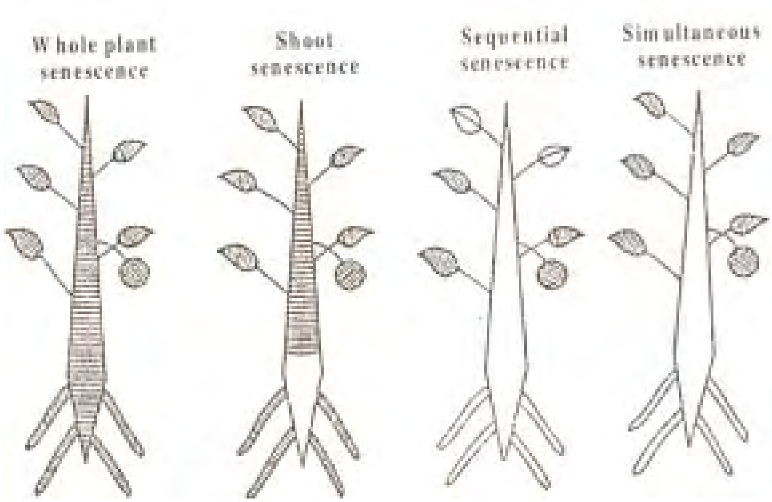


Fig.6.19 Types of senescence

2. Shoot senescence

This type of senescence is found in certain perennial plants which possess underground perennating structures like rhizomes, bulbs, corm etc. The above ground part of the shoot dies each year after flowering and fruiting, but the underground part (stem and root) survives and puts out new shoots again next year. E.g.**banana, gladiolus, ginger** etc.

3. Sequential Senescence

This is found inmany perennial plants in which the tips of main shoot and branches remaining a meristematic state and continue to produce new buds and leaves. The older leaves and lateral organs like branches show senescence and die. Sequential senescence is apparent in evergreen plants. e.g.***Eucalyptus, Pinus*** etc.

4. Simultaneous or Synchronous senescence

It is found in temperate deciduous trees such as **elm** and **maple**. These plants shed all their leaves in autumn and develop new leaves in spring. Because of this shedding of leaves, autumn season is also called fall. Such a senescence of leaves or plant organs is called synchronous.

Physiology of senescence

The process of senescence involves a number of structural and physiological changes in the senescing organs. Some of the important changes are:

i) Cells undergo reduction in their size.
ii) The membrane bound sub-cellular inclusions are disrupted.
iii) Photosynthesis is reduced and starch content decreases in the cells.
iv) Breakdown of chlorophy II is accompanied by synthesis and accumulation of anthocyanin pigments.
v) Protein synthesis is decreased and protein break down enhances.
vi) Amino acids are withdrawn from senescing leaves and transported to the growing regions.
vii) RNA content is decreased.
viii) Chromatin material changes its property and DNA molecules degenerate.

Importance of senescence
Biologically senescence and death have following advantages

1. It maintains efficiency since the old and inefficient organs are replacedby young efficientparts like leaves, buds, flowersand fruits. etc.,
2. During senescence, the celluar breakdown results in release of many nutrients including amino acids, amides, nnucleotides, simple sugars and minerals. The same are withdrawn from the senescing organs into the main trunk and later utilized in the growth and development of new parts.
3. Shoot senescence is a mechanism to help the plants perennate during the unfavorable periods.
4. Simultaneous or synchronous leaf fall occursin autumn prior to winter. It reduces transpiration, which is essential for survival in winter, when the soil is frozen and roots cannot absorb water.
5. Liter of fallen leaves and twigs is an important source of humus and mineral replenishment for the soil.

Self-evaluation
One Mark
Choose the correct answer

1. Which one of the following generally increases during senescence?
   a.Protein b.Chlorophyll c.Photosynthesis d.Respiration
2. Senescence of detached leaves can be delayed by the use of
   a.Auxin b.Giberellin c.Cytokinin d.Ethylene

3. Yellowing and shedding of leaves in autumn in many trees is an example of
   a.Over all senescence   b.Deciduous senescence
   c.Top senescence   d.Progressive Senescence

Fill in the blanks

1. Cytokinins can ....ageing of plant organs.
2. Leaf fall starts, when the amount of .... decreases.

Two Marks

1. Define senescence in plants.
2. What are the four kinds of senescence?
3. What is the significance of senescence in the life of a plant?
4. What is abscission?

Five Marks

1. Describe various types of senescence

Ten Marks

1. Describe the anatomical and biochemical changes taking place during abscission of a leaf.

VII. ENVIRONMENTAL BIOLOGY

1. Organisms and their Environment

The living organisms and the environments in which they live play a complex interdependent and interrelated role. Ecology deals with the various principles that govern the relationships between the organisms and environment. The term **Ecology** (Gk. Oikos-house or place to live, logos-study or discourse) was first introduced, by **Reiter** (1885). **E. Haeckel** (1886) a zoologist defined ecology as 'the study of the reciprocal relationships between organisms and their environment'.

The term 'environment' means surroundings, in which the organisms live. Any constituent or condition of the environment which affects directly or indirectly the form or functioning of the organism in any specific way is called environmental or ecological factor. The environment consists of different types of environmental factors such as light temperature, humidity, precipitation, wind, physical and chemical nature of soil, plants, animals. etc.

The adaptations of the organisms allow them to live in perfect harmony with their surroundings.

Environmental factors

All living organisms, including human beings live in some sort of abiotic component of environment, that contains matter and energy. Various environmental factors can be divided into following two groups:

1. Climatic factors 2. Edaphic factors 3. Biotic Factors. The former two factors are abiotic components that contain matter and energy.

I. Climatic Factors

These are related to the aerial environment of the organisms e.g. light, precipitation, temperature, atmospheric humidity, wind, etc.

II. Edaphic Factors

They include the factors related to the soil. e.g. soil composition, organic matter, soil water, soil air, soil organisms etc.

1. Climatic Factors

i) Light

Light is a factor of great physiological importance. It affects structure, growth and activities of organisms

Sunlight is the source of energy for all organisms. Light is essential for photosynthesis, a process by which green plants synthesise their food on which rest of the living world depends.

Development of photosynthetic pigments, pigments for floral colour, red – far red absorbing phytochrome pigments which regulate morphogenetic processes, induction and regulation of many enzymes are all light regulated processes. "Photoperiod" is an important factor in the flowering of plants.

ii) Temperature

Most living organisms can survive only in a narrow range of temperature (5^0-35^0C). However, there are notable exceptions to it. Certain bacteria, cyanobacteria (blue green algae), seeds, spores and encysted protozoans can occur in hot springs or in very low temperature. Many organisms have developed physiological and behavioural adaptations to avoid extremes of temperature.

Temperature varies in various quarters of the earth according to latitute and altitude. It is also influenced by plant cover, atmospheric humidity, water reservoirs, air current and snow. According to the change of temperature with the increase of latitude, various vegetation zone have been recognized. Similarly , on the basis of change in temperature due to altitude, many vegetation zones can be observed.

iii) Water

Water is an essential requirement of life. No life can exist without water. The protoplasm of the cell contins 80-90% of water. The requirement of water varies from organism to organism. The distribution of organisms depend upon the extent of the need and special **adaptations** for conserving water. Plants of dry area are called **xerophytes**. They develop modifications to increase water absorption, reduce transpiration and store absorbed water.

Plants of aquatic habitats are called **hydrophytes**. They possess aerenchyma (air containing parenchyma) to support themselves in water. The depth, salt content, clarity and water currents determine the growth and distribution of plants in water.

iv) Air

Air currents determine the weather conditions and also affect living organisms, particularly plants. Wind helps in pollination and dispersal of fruits and seeds of many plants. It increases transpiration, which may lead to desiccation and wilting of many plants. Strong winds uproot the plants and cause lodging (flattening of plants on the ground) of many crops. Areas frequented by unidirectional winds develop flag trees, which have branches on one side only. Persistent strong winds restrict the height of plants due to excessive loss of water by transpiration. The plants of such areas usually possess strong spreading roots and strong but flexible shoots.

II. Edaphic Factors

i) Soil

Soil is the upper weathered and humus (organic matter) containing layer of the earth, which sustains plant life and contains numerous living organisms along with their dead remains. Soil provides water, mineral salts and anchorage to plants. The characteristics of soil such as its constitution, origin, temperature range, water holding capacity, aeration, minerals, etc. determine flora and fauna of a particular place.

A productive, well aggregated soil is composed of mineral matter (derived from parent rocks as a result of weathering), organic matter, water and air.

ii) Mineral Matter

The physical attributes of the soil are due to the size of the soil particles. The different particles which are present in the soil vary in their size and depending on this as the soils have been classified into sandy soils (sand with poor representation of silt and clay), loam soils (fine sand with well representation of silt and clay), silt soils (more silt than sand and clay) and clay soils (soils with high percentage of clay).

Sandy soils are porous and hence well aerated but they have very little water holding capacity and are chemically inert. Clay soils have a greater capacity of retaining water and are rich in nutritive salts. They are, however badly aerated. The loam soils are ideally suited for plant growth because they possess appreciable porosity or aeration, sufficient nutritive salts and good water retaining capacity.

iii) Organic Matter

The organic matter (humus) is highly important for all types of soils because it increases both aeration and hydration. It maintains the structure of the soil and also provides inorganic salts and some growth promoting substances to the soil.

iv) Soil Water

Soil water is of paramount importance in the physiology of plants. It occurs in various forms, such as gravitational, capillary, hygroscopic and combined water. Rain is the principal source of water for the soil. Water which flows down due to the force of gravity is known as **gravitational water**. The gravitational water is not available to the plants. However, it is a big soil water reservoir and is trapped out through tube wells.

A certain amount of rain water is retained within the intercellular spaces of the soil particles in the form of a capillary network. It is called **capillary water** and is used by the plants. Some water molecules form a thin sheet of water around soil particles. It is called **hygroscopic water** (water of imbibition). The hygroscopic water is also not absorbed by the plants. The water, which is bound up in chemicals is called **combined water** or crystalline water. (e.g. $MgSo_4.7H_2O$). It is not available to plants.

The total water present in the soil is called as **field capacity**. Addition of water beyond field capacity causes water logging. It excludes soil air and thus inhibits plant growth. The soils that have poor water holding capacity, cannot afford luxuriant vegetation. In such soils, the plants generally show wilting of their leaves.

v) Soil Air

It is essential for the growth of root and micro-organisms. A badly aerated or water-logged soil will have more of carbon dioxide and lesser amount of oxygen.

vi) pH (Hydrogen ion concentration).

Most organisms thrive in an optimal pH range, pH of soil and water has a strong influence on the distribution of organisms. Some plants and aquatic animals require acidic conditions, others need neutral or alkaline conditions.

vii) Mineral elements.

A number of minerals are essential for normal growth of organisms. Their availability and concentration control the distribution of microbes, plants, and animals. Deficiency or absence of anyone, results in abnormal growth. Excess of mineral is equally harmfull. Plants growing in nitrogen deficient soils have developed special adaptations for obtaining it. For example, leguminous plants harbour nitrogen fixing bacteria in root nodules and the insectivorous plants have devices to trap insects and absorb nitrogen from their bodies. The salts of calcium, magnesium and phosphorus are most important for aquatic forms. Salinity of soil and water greatly affects the distribution of organism..

III. Biotic factor

The biotic factor deals with interaction among living organisms. This along with abiotic component, forms the overall ecosystem.

Under natural situations, organisms live together influencing each other's life directly or indirectly. Vital processes such as growth, nutrition and reproduction depend very much upon the interactions between the individuals of same species and different species. Pollination, seeds and fruits dispersal, grazing, parasitism and symbiosis are the common examples of such interactions.

Relationships among Organisms

Most of the ecologists are in favour of the use of the term **symbiosis,** which literally means 'living together', in its broader sense.

Odum (1971) used the term 'symbiosis' in its broader sense and preferred to group all the types of symbiotic interactions into two major groups. These are:

1. Positive Interactions

A type of interaction, where populations help one another, the interaction being either one-way or reciprocal. Their benefit may be in respect of food, shelter, substratum, transport etc. These include (i) commensalisms (ii) Protocooperation and (iii) Mutualism.

2. Negative Interactions

Where members of one population may live at the expense of members of the other population compete for foods, excrete harmful wastes, etc. These include (i) Competition, (ii) Predation, (iii) Parasitism, and (iv) Antibiosis.

Positive Interactions

1) Mutualism

Here both the species derive benefit. The two populations enter into some sort of physiological exchange. The following are some common examples of mutualism.

i) Symbiotic Nitrogen fixers

This is a well known example of mutualism, where the bacterium **Rhizobium** form nodules in the roots of leguminous plants, and lives symbiotically with the host. Bacteria obtain food from the higher plant and in turn fix gaseous nitrogen, making it available to plant.

ii) Mycorrhizae

A symbiotic association between a fungus and a root of a higher plant is called Mycorrihza, which may be (i) **Ectotrophic**, where fungal hyphae are natural substitute of root hairs absorbing water and nutrients from soil e.g. Pines and Oaks or (ii) **Endotrophic**, where fungi occur internal to root tissue. e.g. Orchids and members of Ericaceae

iii) Lichens

These are examples of mutualism where contact is close and permanent as well as obligatory. Their body is made up of a matrix formed by a fungus, within the cells of which an alga is embedded. Usually the fungal groups are from Ascomycetes or Busidiomycetes and the algal groups are species of blue greens. The algal groups takes up the photosynthetic function. The fungal groups are concerned with reproduction. The fungus makes moisture as well as minerals available, whereas alga manufactures food. Neither of the two can grow alone independently in nature. Lichens grow abundantly on bare rock surfaces.

2) Commensalism:

Commensalism refers to association between members of different species only. One is benefited without any effect on the other. Some common examples are:

i) Lianes

Lianes are common in dense forests of moist tropical climates. They maintain no direct nutritional relationship with the trees upon which they grow. On the basis of the type of device used for climbing their support, lianes may be leaners, thorn lianes, twiners or tendril lianes. Common lianes are species of ***Bauhinia, Ficus*** and ***Tinospora.***

ii) Epiphytes

Epiphytes are plants growing perched on other plants. They use other plants only as support and not for water or food supply. They differ from lianes in that they are not rooted into the soil. Epiphytes may grow on trees, shrubs, or larger submerged plants. They grow either on the trunks or leaves. Epiphytes are most common in tropical rain forests. Many ***orchids, Usnea*** and ***Alectoria*** are well known epiphytes.

iii) Epizoics

Some plants grow on the surfaces of animals. For example, green algae grow on the long, grooved hairs of the sloth. Similarly, ***Basicladia*** (Cladophoraceae) grows on the backs of freshwater turtles.

Negative Interactions

These include the relations, in which one or both the species are harmed in any way during their life period. Some (Clarke, 1954) prefer to call such types of associations as 'antagonism'. Such negative interactions are generally classified into three broad categories, as **exploitation, antibiosis** and **competition** which are discussed in detail as follows:

I) Exploitation

Here one species harms the other by making its direct or indirect use for support shelter, or food. Thus exploitation may be in respect of shelter or food.

1. Shelter

The so-called 'parasitic birds' as cuckoo and cowbird never build their own nests and female lays eggs in the nest established by birds of another usually smaller species.

2. Food

The various relationships in respect of food may belong to:

a) Parasitism

A parasite is the organism living on or in the body of another organism and deriving its food more or less permanently from its tissues.

There are some parasitic vascular plants. Species of ***Cuscuta*** (total stem parasites) grow on other plants on which they depend for nourishment. Young stem twines around the host stem from which adventitious roots develop that finally penetrate the stem of the host, establishing relationship with its conducting elements. The specialized roots are called **haustoria.**

Other examples of such association are total root parasites as ***Orabanche,*** and ***Epifagus*** (Orobanchaceae) which are found on roots of higher plants***. Rafflesia*** is found on roots of ***Vitis.*** Members of the family Loranthaceae *(Viscum album, Loranthus sp)* are partial stem parasites. They grow rooted in branches of host trees. Others like ***Santalum album,*** are partial root parasite. Their roots are attached to host plants. Majority of parasites are microorganisms, of which fungi, bacteria, mycoplasmas, rickettsias and viruses parasitise plants as well as animals.

b) Carnivorous Plants

A number of plants as ***Nepenthes, Darlingtonia, Drosera, Utricularia, Dionaea*** consume insects and other small animals for their foods. They are also known as insectivorous plants. They are adapted in remarkable ways to attract, catch and digest their victims. Their leaves or foliar appendages produce proteolytic enzymes for digestion of the insects. The carnivorous habit in plants is said to be an incidental feature of their nutrition, since they possess green leaves and carryout photosynthesis.

II) Antibiosis

The term 'antibiosis' generally refers to the complete or partial inhibition or death of one organism by another through the production of some substance or environmental conditions as a result of metabolic pathways. Here none of them derives any benefit. These substances and or conditions are harmful (antagonistic) to other organism. The phenomenon of antibiosis is much common among microbial world. Production of chemicals that are antagonistic to microbes – the **antibiotics** is well known.

Bacteria, actinomycetes and fungi produce a number of antimicrobial substances which are widespread in nature. Antagonistic substances are also reported in some algae, as for example in cultures of ***Chorella vulgaris,*** some substance accumulates which inhibits the growth of the diatom, ***Nitxschia frustrulum***. Pond 'blooms' of blue-green algae especially ***Microcystis*** are known to produce toxins such as hydroxylamine which causes death of fish and cattle.

The term antibiosis would also include such phenomena as **hypersensitive reactions** that involve the interaction between microorganisms, particularly pathogenic ones, and harmful to one or both.

III) Competition

Competition occurs when individuals attempt to obtain a resource that is inadequate to support all the individuals seeking it, or even if the resource is adequate, individuals harm one another in trying to obtain it. The resources competed for can be divided into two types :

(i) Raw material such as light, inorganic nutrients, and water in autotrophs and organic food and water in heterotrophs.

(ii) Space to grow, nest, hide from predators. etc.

The competition may be

(i) Intraspecific: Occurring between members of the same species of the population.

(ii) Interspesific: Occurring between different species of population. Competition thus is usually between members of the same trophic level.

SELF EVALUATION

One Mark

Fill in the blanks

1. Light is necessary for plants to do _____________
2. Soil provides water and _______to plants.

Two marks

1. Write short note on soil water.
2. What is symbiosis?
3. What are Mycorrhizae?
4. What are lichens?
5. What is competition?

Five marks

1. Describe the effects of edaphic factors on the living organisms.
2. Give an account of the effect of light and temperature on the plants.

2. Hydrophytes, Mesophytes and Xerophytes

The living organisms live in habitats which provide them with what they need. The organisms have to be well fitted to their environments in which they live. Any characteristic that is advantageous to a particular organism or population is an adaptation. The term 'adaptation' can be defined as *' the structural and functional characteristics of the living organisms which develop over a period of time and enable them to survive and reproduce in a particular environment or habitat.'* The living organisms live in three main types of habitats- **water, land** and **air,** and exhibit various types of adaptations.

Warming (1909) classified the plants on the basis of their water requirement into three ecological groups. They are

1. Hydrophytes
2. Xerophytes
3. Mesophytes

Hydrophytes

Hydrophytes are plants that grow in regions, where, there is plenty of water supply (ie. Pond, pool, lake, river and marshes) or wet soils.

The organisms found in aquatic habitats i.e. sea (**marine** habitat), lakes and ponds (**lentic** habitats) and streams and rivers (**lotic** habitats) experience a variety of physical factors. These include, the availability of oxygen and light, pressure fluctuations, resistance to motion, salt concentration, etc. To adjust to the prevailing conditions, aquatic plants have various types of adaptations.

Classification of Hydrophytes

According to their relation to water and air, the hydrophytes are grouped into four categories.

1. Free floating hydrophytes.
2. Floating but rooted hydrophytes.
3. Submerged hydrophytes (floating and rooted).
4. Amphibious hydrophytes.

1. Free floating hydrophytes

These plants float freely on the surface of water but are not rooted in the soil. These plants are in contact with both water and air **(e.g. *Eichhornia, Pistia, Wolffia, and Lemna*)**

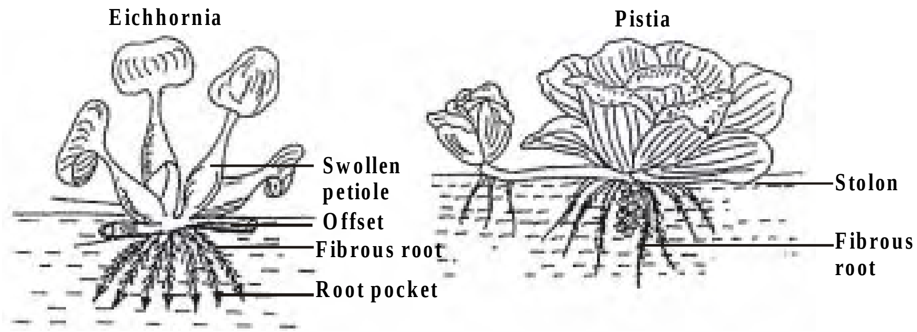


Fig : 7.1. Free-floating hydrophytes

2. Floating but rooted hydrophytes

These hydrophytes are rooted in the mud but their leaves and flowering shoots float on the water surface. **E.g. *Victoria regia, Nymphaea, Nelumbium and Marsilea*.**

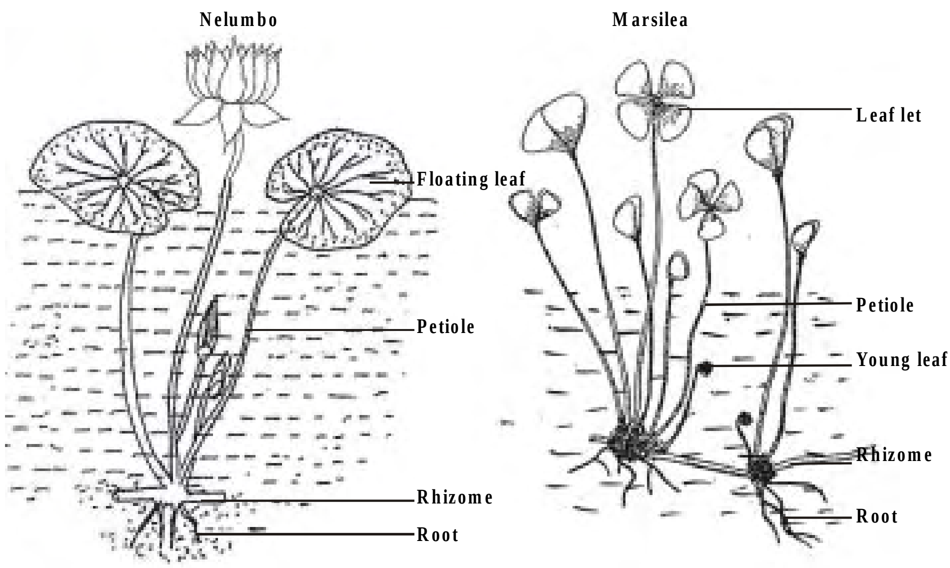


Fig : 7.2. Rooted hydrophytes with floating leaves

3. Submerged hydrophytes (floating)

Plants which grow below the water surface and not in contact with atmosphere are called free floating submerged hydrophytes. E.g. ***Ceratophyllum,*** and ***Utricularia*.**

Submerged hydrophytes (Rooted)

These plants are completely immersed in water and rooted in the mud. E.g. ***Hydrilla, Vallisneria, Potamogeton*** **etc.,**

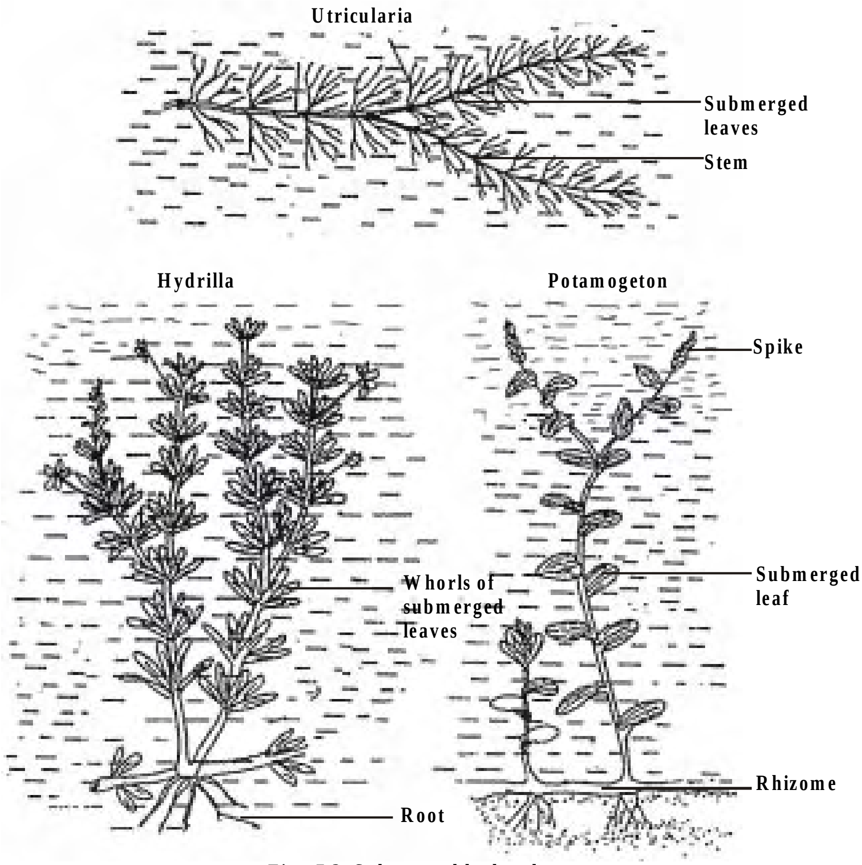


Fig : 7.3. Submerged hydrophytes

4. Amphibious Hydrophytes

These plants grow in shallow waters. Their roots, some part of stems and leaves are submerged in water. But some flowering shoots spring well above the water surface.

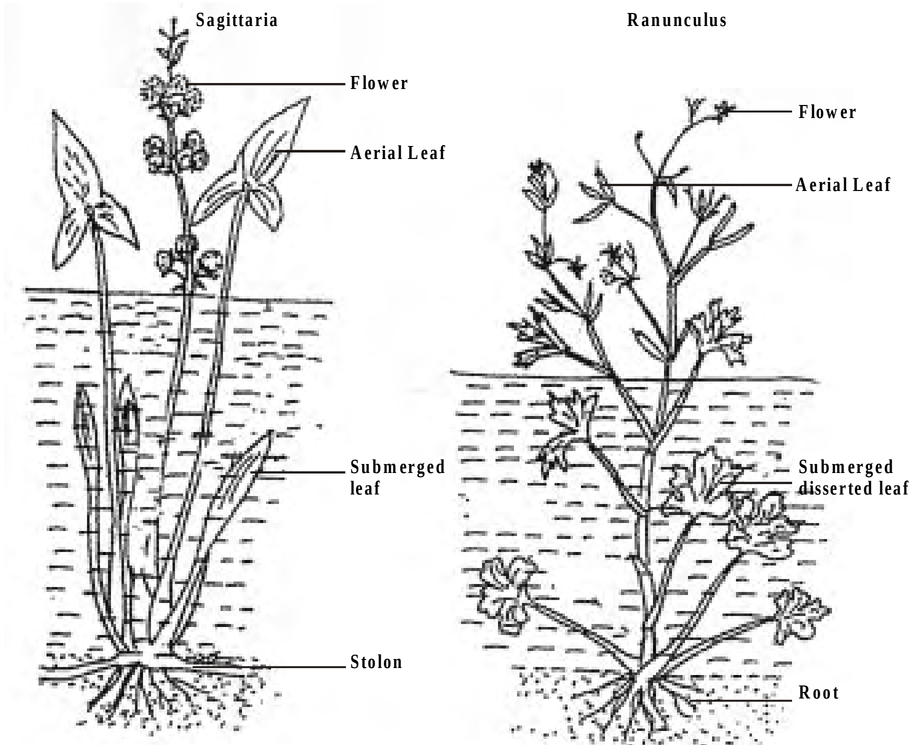


Fig : 7.4. Amphibious Hydrophytes

These plants are adapted to both aquatic and terrestrial modes of life. The aerial parts of these amphibious plants show mesophytic characters, while the submerged parts develop true hydrophytic characters. e.g. ***Limnophylla heterophylla, Typha, Sagittaria*** **etc.,**

Morphological adaptations

1. Root system is poorly developed.
2. Roots of floating hydrophytes show very poor development of root hairs, absence of true root caps, with root pockets to protect their tips from injuries. (e.g. ***Eichhornia*****)**
3. Rooted hydrophytes like ***Hydrilla, Vallisnera, Elodia*** derive their nourishment through their body surfaces. More plants partly depend on their roots for the absorption of minerals from the soil. Roots are totally absent in ***Ceratophyllum, Salvinia, Azolla, Utricularia*** **etc.,**
4. In ***Jussiaea repens*** two types of roots develop. Some of them are normal, while others are negatively geotropic, floating roots, spongy in nature and keep the plants afloat.

5. In free floating hydrophytes, the stem is thick and short, floating on the surface of water (e.g.) ***Eichhornia.***
6. In ***Nymphaea*** and ***Nelumbium*** the stem is a rhizome. These rhizomes live for many years and produce leaves every year.
7. In rooted plants with floating leaves, the leaves are large, flat and entire (e.g.) ***Nymphaea, Victoria regia.*** Their upper surface is coated with wax. The wax coating protects the leaves from mechanical and physical injuries and also prevents clogging of stomata by water.
8. In floating plants of ***Eichhornia, Trapa*** **etc.,** the petioles become characteristically swollen and become spongy, providing buoyancy.
9. Plants such as ***Limnophylla heterophylla, Sagittaria, Ranunculus, Salvinia, Azolla*** etc show heterophylly, with submerged dissected leaves offering little resistance against the water currents, and absorbing dissolved carbon-di-oxide from water. The aerial leaves show typical mesophytic features. It acts as foliage leaf.
10. Pollination (e.g. Vallisneria) and dispersal of fruits and seeds are accomplished by the agency of water.

Anatomical adaptations

1. The root and shoot systems show common features such as cuticle which is very thin or absent.
2. Epidermis is usually a single layer of thin walled cells, not protective in function.
3. Cortex is well developed. It has numerous air chambers. It helps in buoyancy and rapid gaseous exchange.
4. Mechanical tissues are generally absent.

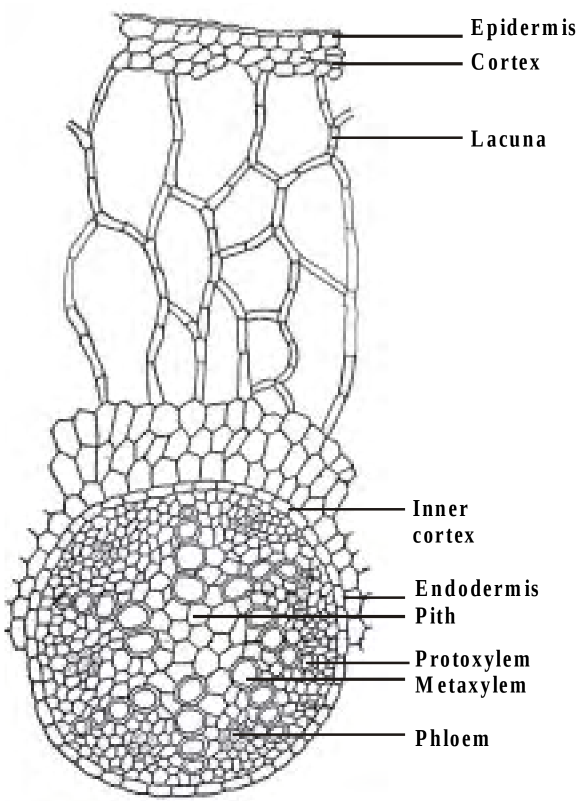


Fig : 7.5. T.S. of Nymphaea root

5. In the vascular tissue, xylem vessels are less common. Only tracheids are present in submerged forms.
6. In amphibious form, the xylem and phloem are well developed (e.g.) ***Limnophylla heterophylla*** or vascular bundles may be aggregated towards the centre. (e.g. ***Jussiaea***)
7. Epidermal cells of leaves contain chloroplasts and they can function as photosynthetic tissue, especially where the leaves and stems are very thin. eg. ***Hydrilla***

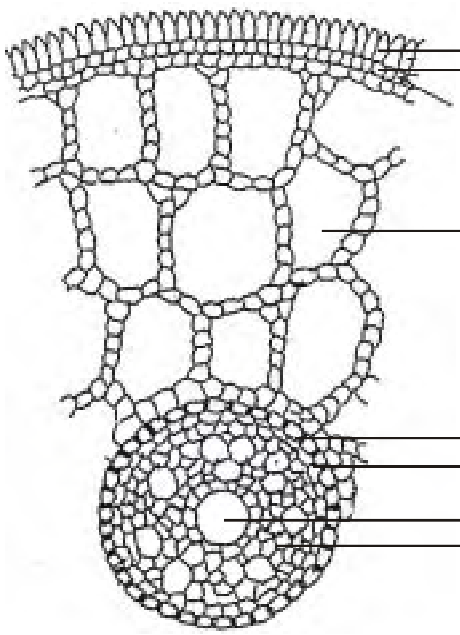


Fig : 7.6. T.S. Hydrilla Stem

8. Stomata are totally absent in submerged, but in floating leaves, stomata are confined only to the upper surface. In amphibious plants stomata may be scattered on all the aerial parts.
9. In submerged leaves, air chambers are filled with respiratory and other gases and moisture.
10. In Water Lilly (***Nymphaea***) and some other plants, special type of star shaped lignified cells called **asterosclereids** are developed. It gives mechanical support to the plants.
11. The aquatic plants exhibit a low compensation point and low osmotic concentration of cell sap.
12. Mucilage cells and mucilage canals secrete mucilage to protect the plant body from decay under water.

Xerophytes

Plants, which grow in dry habitats or xeric conditions, are called **xerophytes**. Places where available water is not present in adequate quantity are termed xeric habitats, which may be of three types.

1. Physically dry habitats

Where water retaining capacity of the soil is very low and the climate is dry **e.g. D*esert, Rock surface* etc.**

2. Physiologically dry habitats

Places where water is present in excess amount, but it is not absorbed by the plants easily.

3. Physically and physiologically dry habits e.g. **Slopes of mountains.**

Daubenmire (1959) defined xerophytes as "plants which grow on substrate that usually become depleted of water to a depth of at least two decimeters during normal growth season."

Xeric habitats are characterized by

1. High temperature of atmosphere and soil
2. Deficiency of water and minerals
3. Presence of water deep in the soil.
4. High intensity of light

On the basis of morphology, physiology and life cycle patterns, xerophytes are classified into three categories.

1. Drought escaping plants

They are also called as **Drought evaders.** They are mostly found in arid zones. They are annuals, which complete their life cycles within a very short period of 6-8 weeks and thus escape dryness (e.g.) ***Solanum xanthocarpum, Argemone mexicana, Cassia tora* etc.**

2. Drought Enduring Xerophytes (Succulents)

These plants suffer from dryness in their external environment only. Their succulent, fleshy organs (stems, leaves, roots) serve as water storage organs which accumulate large amount of water during the brief raining reason. e.g ***Agave, Aloe, Euphorbia, Opuntia, Asparagus.***

Fleshy Xerophytes

In some plants, stem becomes succulent which are called the **"Fleshy Xerophytes"** as in ***Opuntia*** and ***Euphorbia***.

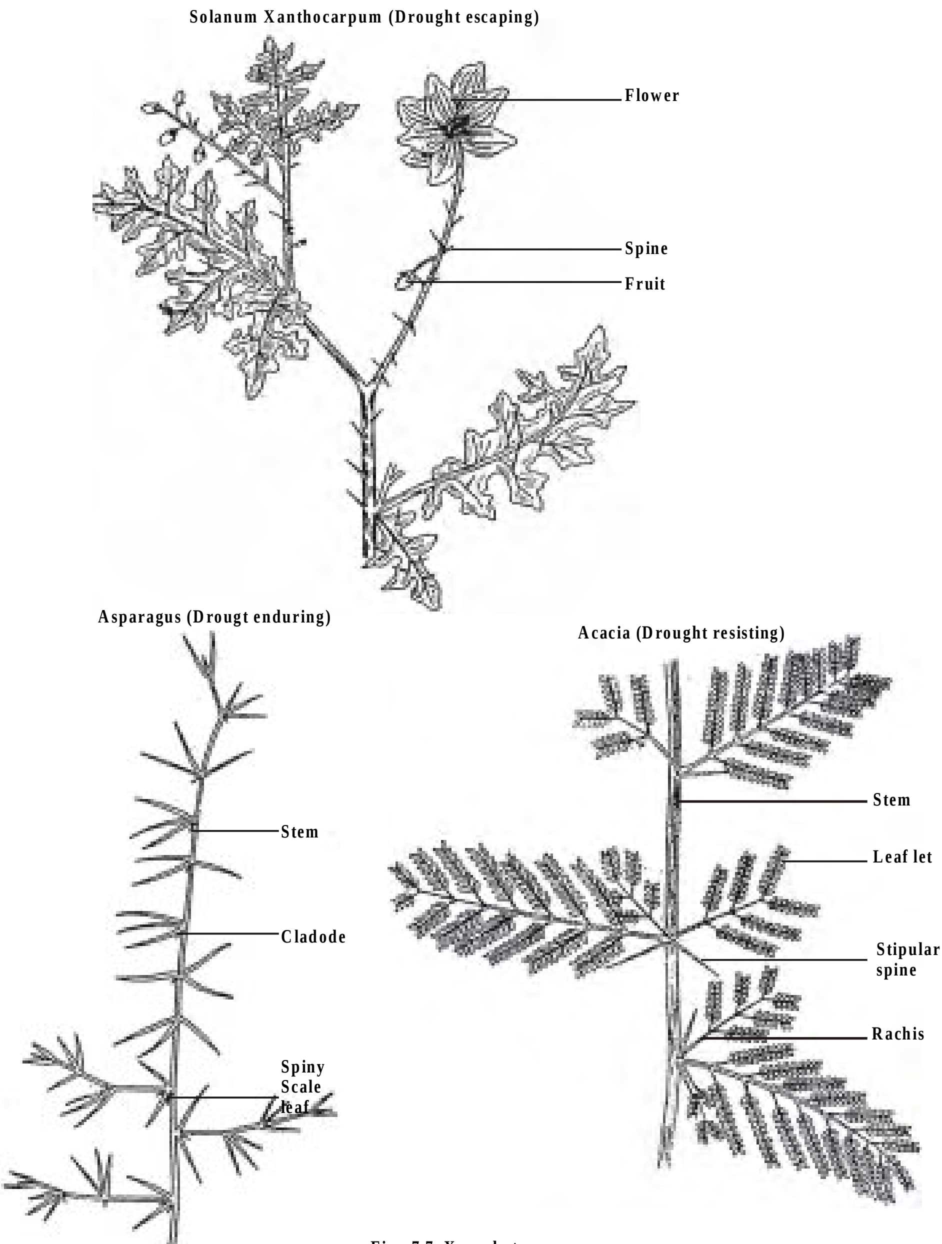


Fig : 7.7. Xerophytes

Opuntia dilleni

It is a wild spiny shrub of a rid places. The flattenned, green stem segments called **phylloclades** are thick and fleshy and carry out the function of photosynthesis. The phylloclades contain lot of mucilage, which help in retaining water for long a item.

In plants like ***Opuntia dilleni,*** stems are flat without leaves and perform photosynthesis.

3. Drought resisting plants (Non- succulent perennial)

The drought resisting plants are the true xerophytes. They possess a number of morphological, anatomical and physiological characteristics, which enable them to withstand critical dry condition. Thus they suffer from dryness both in their internal as well as external environments. e.g ***Calotropis procera, Acacia nilotica, Zizyphus jujuba, Capparis aphylla, Casuarina, Nerium, Saccharum*** etc.

Morphological Adaptations

1. The root system is very well developed with root hairs and root caps. e.g. ***Calotropis*.**
2. The roots are fasciculated as in ***Asparagus***.
3. Stems are stunted, woody, dry, hard, ridged, and covered with thick bark, may be underground, e.g. ***Saccharum***. In ***Opuntia*** phylloclade is covered with spines.
4. Stem is covered with thick coating of wax and silica in ***Equisetum*** or dense hairs as in ***Calotropis***.
5. Stems may be modified into a thorn e.g. ***Ulex*** or cladodes e.g. ***Asparagus.***
6. Leaves are very much reduced, small scale-like, appearing only for a brief period (Caducous) sometimes modified into spines or scales as in ***Casuarina, Ruscus, Asparagus***.
7. Lamina may be narrow or needle like as in ***Pinus*** or divided into many leaflets as in ***Acacia*** or succulents as in ***Aloe***.
8. In ***Euphorbia*** and ***Zizyphus jujuba*** stipules become modified into spines.
9. Xerophytes like ***Calotropis*** have hairy covering on the leaves and stems to check transpiration.

Anatomical Adaptations

1. Root hairs and root caps are well developed in ***Opuntia***.
2. Roots may become fleshy to store water as in ***Asparagus***

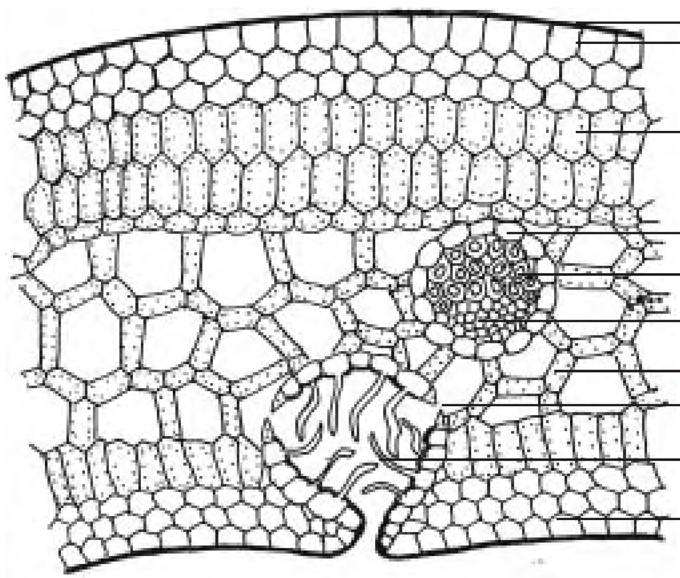


Fig : 7.8. T.S> of Nerium leaf

3. In succulent xerophytes, stems possess a water storage region (thin walled parenchyma cells)
4. Stems of non-succulent xerophytes show a very thick cuticle, well developed epidermis with thickened cell wall, several layered and sclerenchymatous hypodermis e.g. ***Casuarina***.
5. The stems have sunken stomata and well developed vascular and mechanical tissues.
6. Leaves show well developed cuticle, succulent leaves in ***Aloe***, multilayered epidermis in ***Nerium***, sclerenchymatous and several layered hypodermis in ***Pinus***, bulliform cells in Sugarcane.
7. Mesophyll is well differentiated and vascular tissues and mechanical tissues are well developed.

Physiological Adaptations

1. The stomata of these plants open during night hours and remain closed during the day. This unusual feature is associated with metabolic activities of these plants.
2. In xerophytes, the chemical compounds of cell sap are converted into wall forming compounds (eg) Cellulose, Suberin etc.

3. Some enzymes, such as catalases, perioxidases are more active in xerophytes than in mesophytes.
4. The capacity of xerophytes to survive in long period of drought is due to the resistance of the hardened protoplasm to heat and desiccation.
5. The Xerophytes have very high osmotic pressure, which increases the turgidity of the cell sap.

Mesophytes

Mesophytes are common land plants, which grow in situations that are neither too wet nor too dry. These plants can neither grow in water or waterlogged soils nor can they survive in dry places. In other words, mesophytes are the plants of those regions where climates and soils are favourable. Vegetations of forests, meadows and cultivated fields belong to this category. The simplest mesophytic community comprises of grasses and herbs, richer communities have herbs and bushes, and the richest ones have trees (rain-forest in tropics).

Mesophytes can be classified into two main community groups:

1. Communities of grasses and herbs.
2. Communities of woody plants.

Adaptations of plants to mesic habitats. The plants which grow in moderately moist and cool habitats are called **mesophytes** e.g. majority of crop plants. The mesophytes have following morphological and physiological features.

i. Root system is well developed. Roots are generally fairly branched with root caps and root hairs.

ii. The stems are generally aerial, solid and freely branched.

iii. Leaves are generally large, broad and moderately thick. They are without hairs or waxy coating.

iv. The stomata are distributed on both surfaces of the leaves.

v. The mesophyll in leaves is differentiated into palisade and spongy parenchyma, with many intercellular spaces.

vi. The aerial parts possess moderately developed cuticle.

vii. Mechanical and vascular tissues are fairly developed and well differentiated.

SELF EVALUATION

One Mark

Choose the best answer

1. Finely dissected leaves are common in

   a. Submerged plants   b. Amphibious plants
   c. Free floating plants   d. Rooted floating plants

2. The root pockets are present instead of root caps in

   a. Utricularia   b. Eichhornia   c. Hydrilla   d. Limnophylla

Fill in the blanks

1. Plants that are growing in water are called _____________
2. Plants that are seen in xeric conditions are known as _______________

Two marks

1. What are hydrophytes?
2. What are the three ecological groups of plants?
3. Define : Xerophytes

Five marks

1. List out the different kinds of hydrophytes with examples.
2. Explain the basis for the classification of xerophytes.

Ten marks

1. List out the adaptations of xerophytes with suitable examples.

3. Natural Resources

Man lives in nature and depends on the resources of nature. The progress of mankind depends upon the exploitation of different natural resources. The utilization of soil, water, coal, electricity, oil, gas and nuclear energy is very important for the development of a nation. These resources have changed the living standards of man. India contains the world's largest resource of coal and third and fourth largest resource of manganese and iron.

The world is facing an ecological crisis and is degrading her natural resources day by day, due to over exploitation. India is no exception.

Food, shelter and clothing are the primary requirements of man. Early human society has used natural resources, relatively in much less quantity to cover its wants.

Natural resources

The word 'resource' means a source of supply or support that is generally held in reserve. The natural resources are the components of lithosphere, hydrosphere and atmosphere. They include energy, air, water, soil, minerals, plant and animals. For man resources are those materials and sources of energy which are needed for survival and comforts.

The nature of resources varies from society to society.

Types of natural resources

Natural resources are classified in different ways. i.e. on the basis of chemical composition, availability and distribution.

A. Natural resources are of three types on the basis of their chemical composition

1. **Inorganic Resources.** eg. *air, water and minerals*
2. **Organic Resources** eg. *plants, animals. micro-organisms and fossil fuels*.
3. **Mixture of Inorganic and Organic Resources,** eg. *soil*

B. Natural resources are of two types depending upon their availability and abundance.

1. Inexhaustible Resources

They are not likely to be exhausted by man's use. They are air, clay, sand, tidal energy etc. Although the air is available in exhaustible quantity, it can be degraded, if its pollution is not checked.

2. Exhaustible Resources

They are likely to be exhausted by human use. They are further of two types- renewable and non-renewable.

a. Renewable Resources

They have inherent capacity to reappear or replenish themselves by quick recycling, reproduction and replacement within a reasonable time. Soil and living organisms are the main renewable resources.

b. Non- Renewable Resources

They lack the ability for recycling and replacement. The substances with a very long recycling time are also regarded as non-renewable resource e.g. fossil fuels like coal, petroleum and natural gas and minerals.

It is important to note that underground water, forests and wild life are regarded renewable resources but become non-renewable, if they are not used properly.

Energy resources

Source: Ecologically man is only a part of energy flow in nature. Man requires energy for his daily needs. The major energy sources are fuel wood, fossil fuels such as coal, petroleum and natural gas. Apart from these, the other direct energy resources are sunlight, hydroelectric and wind power, tidal, geothermal and nuclear energy.

Energy Requirement: During early stages of human civilization, the daily per capita need for energy was just 2,000-4,000 kilo calories. During the agricultural stage, the muscular energy of domestic animals was used for work. The per capita energy consumption gradually increased. In nineteenth century, during the industrial stage of human civilization, the use of fossil fuel started and the per capita energy requirement increased to 70,000 kilo calories per day.

Today we need energy for agriculture, industry, transport, communication, comfort and defence. The per head energy consumption varies from country to country

Depletion of fossil fuels

Today the world's energy resources have reached critical stage. Most of the world's human population uses fossil fuels (coal, petroleum and natural gas). The fossil fuel resources are being rapidly depleted. As a result these resources may last only another few centuries. The dwindling stocks of fuels has led to the search of alternate sources of energy.

Sources of Energy

Some alternative sources of fuel are solar energy, hydro-electric energy, geo-thermal energy, wind power, tidal energy, energy from garbage, dung energy and nuclear energy. They are generally called renewable/ non- conventional sources of energy.

1. Solar Energy

Sun is an inexhaustible and pollution free source of energy. Solar equipments have been developed to harness sun-rays to heat water, cook meals, light our houses and run certain machines.

2. Nuclear Energy

It is generated by fusion of the atoms of certain elements such as Uranium - 235. The processes results in the release of enormous amount of energy. Fission of 1 amu (atomic mass unit) of Uranium – 235 can generate energy equivalent to that obtainable from burning of 15 metric tons of coal or about 14 barrels of crude oil. In our country atomic power stations have been set up in Tarapur (Bombay), Narora (Uttar Pradesh), Kota (Rajasthan) and Kalpakkam (Tamil Nadu).

3. Wind Power

It has been used for centuries to run the wind-mills for grinding grains and pump water in certain areas. But the wind does not blow with required intensity all the year round and in all areas. Therefore, wind power can be used only in certain areas and on certain days.

4. Dung Energy

Cattle dung is widely used as fuel in rural areas of our country. This deprives our fields of valuable organic manure. Now cattle dung is used in **Biogas** or **Gobar Gas Plant** to produce an odourless, low pressure gas. This gas can be used for cooking and heating. The residue is used as manure.

5. Energy from garbage

The garbage of houses contains waste paper, plastics and several other materials. It can be used to produce electricity.

6. Tidal Energy

Tidal waves of the sea can be used to generate electricity.

7. Geo-thermal Energy

In some places, the heated water comes to the earth's surface as hot springs. It can be used for heating water and building and for generating electricity.

8. Hydro-electric Energy

It is produced from the kinetic energy of water falling from height. A number of power stations have been established on many rivers in our country.

Conservation of Energy

The present critical energy position demands an organized effort at all levels from individual to international action. A considerable amount of energy can be saved by reducing wastage and using energy efficient devices. Following measures can help in this effort:

1. Development of technology for the use of solar energy in appliances and transport vehicles
2. Development of efficient and smokeless **Chulhas** or wood stoves
3. Development of non-conventional energy sources and less dependence on fossil fuels.
4. Planned programme for raising fuel wood, trees and shrubs under the control and maintenance of local communities especially in developing countries.
5. Effective use of agricultural and animal wastes to obtain biogas and manure.
6. Improvement of engine and pump designs to increase fuel efficiency.
7. Development of effective techniques to trap wind and tidal energy.

Forest Resources

Forest is an important natural resource. It is most important natural habitat for wild life. It is also utilized by farmers for commercial and recreational purposes. Many herbivores find shelter and carnivores their prey in the forest. Besides this, forest plays most important role from commercial point of view. Forest based cottage industries, such as bee-keeping, bamboo mat and basket making provides small-scale industry to the tribal people. Sal is a most important source for timber industries. It also provides raw materials for pulp and plywood industry.

Green plants of the forest are food-producing organisms and are primary producers of the “food chain”. These foods are stored in the form of fruits, nuts, seeds, nectar and wood. Therefore, forest serves as an energy reservoir, trapping energy from sunlight and storing it in the form of a biochemical product.

Forest plays a most important role in keeping the atmospheric balance by consuming CO_2 and releasing O_2, the latter which is essential for animal life. So removal of plants and trees would disturb the composition of natural air. An acre of forest absorbs four tonnes of carbonic acid gas and recycles eight tonnes of oxygen into environment.

If a forest is cut down, energy stored in the wood is lost and also most of the nutrients of the system are lost. Such deforestation leaves a poor soil which can support agriculture for only a short time, because the harvesting of the first few crops removes the remaining nutrients and renders it useless. Deforestation causes soil erosion.

The reduction of forests later affects rainfall and thereby restricts the availability of a most important natural resource, the rain water. In natural forests, the tree roots bind the soil and about 90 per cent of the water falling on the forests is retained either in humus or in the plant tissue. The forest thus acts as a soaking device and plays a vital role in the hydrological cycle. It has been estimated that in India 60,000 million tonnes of top soil is carried away annually by rain water from deforested area.

Now-a-days the tendency of deforestation is increasing day by day. Man is cutting forest to get temporary benefits but there is a tremendous loss in due course of time.

Social Forestry

The National Commission on Agriculture is giving serious thought to the problem of deforestation and recommended introduction of “ Social Forestry”. Social forestry may be defined as an additional aid to wild life conservaion. According to K.M. Tewari (President, Forest Research Institute, Dehradun) “Social forestry is a concept, a programme and a mission which aims at ensuring ecological, economic and social security to the people, particularly to the rural masses especially by involving the beneficiaries right from the planning stage to the harvesting stage".

Different components of social forestry programme are

1. Protection and afforestation of degraded forests .
2. Creation of village wood lots on community lands and government waste lands.
3. Block plantation.
4. Argo-forestry (trees along with agricultural crops) on marginal and sub-marginal farm lands.
5. Tree planting around habitation area and field boundaries
6. Tree planting in urban and industrial areas for aesthetic purposes,
7. Control of erosion by planting trees or shrubs.
8. Strip plantation along road sides, canals and rail lines.

Conservation of Forests

Following measures should be adopted to conserve forests:

1. A tree removed from the forest for any purpose must be replaced by a new tree. Thus tree felling should be matched by tree planting programmes as early as possible.
2. Afforestation should be done in areas unfit for agriculture, along highways and river banks around play grounds and parks. A special programme of tree plantation called Van Mahotsav is held every year in our country. It should be made popular and effective.
3. Maximum economy should be observed in the use of timber and fuel wood minimising by the wastage.
4. The use of fire wood should be discouraged and alternative source of energy for cooking such as biogas, natural gas etc., should be made available.
5. Forest should be protected from fire. Modern fire fighting equipment should be used to extinguish accidental forest fire.
6. Pests and diseases of forest trees should be controlled by fumigation and aerial spray of fungicides and through biological method of pest control.
7. Grazing of cattles in the forests should be discouraged.

8. Modern methods of forest management should be adopted. These include, use of irrigation, fertilizers, bacterial and mycorrhizal inoculation, disease and pest management control of weeds, breeding of elite trees and tissue culture techniques.
9. Technique of improvement cutting and selective cutting should be done. The improvement cutting includes the removal of old dying trees, non commercial trees, damage tree and diseased trees. Selective cutting involves cutting of mature timber trees and crowded trees.

Conservation of Water

Water Resources

Underground water is available in the crevices of rocks, and between the soil particles. The layers of earth which contain such water form the underground water table. Only certain depth under the earth will be filled with underground water. The upper surface of such stagnant water is called underground water level. The underground water level will vary from 1-100 mts depending upon the place. The water taken out from the water table is compensated every year through monsoon rain.

Importance of Rain Water

The Rainwater plays a vital role in the water cycle of the earth. Rainwater is the main source for rivers, lakes, and underground water. Nowadays, we depend mainly on the above said water resources for our water needs. In such as situation, the importance of rainwater is not realised much. Rainwater Harvest means understanding the importance of rainwater and using the same in all the catchment areas without wasting.

Reasons for water scarcity

1. The water sources are used to the maximum level in order to meet the needs of the growing population of the cities.
2. The increasing buildings, tar and cement roads occupy the open space and these prevent the percolation of natural rainwater into the earth.
3. The failure of monsoon rains brings about increased water scarcity.
4. Usage of underground water becomes more during poor rainfall.
5. Excessive pumping of underground water reduces the water level and the wells become dry.
6. Rainwater is the only source for all the available water.

Thus, in order to maintain the underground water resources, we have to conserve rainwater in the underground water table. Rainwater Harvest is the only solution to overcome water scarcity.

Rain Water Harvesting

Types of Harvesting Rainwater

Collection of rainwater during rainy season and allowing this water to percolate into the soil is known as rain water harvesting.

1. Rainwater can be harvested in two ways, depending on the rate of rainfall.
   2. We can collect the rainwater directly in big troughs and the same when we used when needed.
   3. The underground water resources can be improved by introducing special rainwater harvesting systems into the earth.

Rainwater harvesting depends upon the annual rainfall, area of rainwater harvesting and the amount of rainwater that may percolate into the soil.

The average rain fall in Chennai	- 1200mm (1.2 m)
The rain fall in a housing plot of 2400 sq.ft.	- 223 x 1.2 = 267 (cubic metre)
	2,67,000 litres.
Of this the rate of rainwater sent into the earth	- 1,60,000 lit. (per year)

We can avoid water scarcity by sending back 1,60,000 litres of rainwater into the earth through rain water harvesting.

Rainwater can be harvested from the following;

i. The rainwater falling on the open terrace

ii. The rainwater falling on the open space around the buildings.

iii. If a house has well or borewell, the rainwater from the open terrace can be harvested very easily.

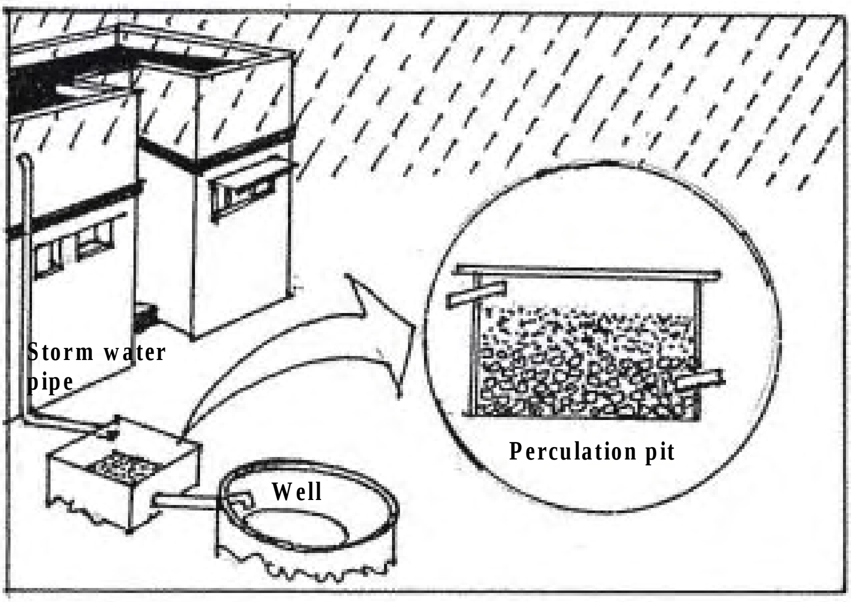


Fig : 7.9. Rain water harvesting from a building

iv. The rainwater from the open space can be harvested through a proper rainwater harvesting system.

I. Collection of Rainwater from terrace and open spaces.

a. To collect through open wells.

b. To collect through bore wells.

Method of collecting

1. Method of water soaking pits
2. Water soaking pits with perforation
3. Water soaking beds (trenches)
4. Shallow water supplying well
5. Deep water supplying well.

Method to Harvest Rainwater from thatched Roofs/Tiled Roofs

1. The water from the roof can be brought through pipes and sent through sand filters.
2. Polythene sheets can be spread over thatched huts and the water from it can be collected.
3. The water cleaned through sand filter can be saved in troughs and used.

Rain water harvest through open wells

Water falling on the open terrace can be collected through pipes and let into the well or earth level storing trough.

1. The filtering trough should be made as follows.
2. Broken bricks or pebbles are to be laid one feet height at the bottom.
3. The top level of the trough must be filled with river sand.
4. The trough can be closed with a cement slab if necessary.

Rainwater Harvest through Bore Wells

The water falling on the open terrace can be sent into the bore well through pipes and filtering pit.

The filtering trough is to be made as indicated in the diagram.

The overflowing rainwater can be let into the soaking pit

Rainwater also can be harvested through the bore well which are not under use.

Rainwater penetrating level will be lower in the bore well than the open well.

Seepage pit – construction

It can be constructed in the open space around the house.

Pits can be in the form of square / rectangle or a circle.

The pits are to be filled with broken bricks, pebbles and river sand.

This method is suitable for sandy areas.

One such pit is needed for every 300 sq.ft. area.

Seepage pits with perforation

At the centre of the above said soaking pit, a bore well is to be erected.

The bore well must be of 150 – 300 mm radius and 10-15 feet depth.

It is to be filled with the broken bricks and pebbles

This method is suitable for area with clayey soil

One such pit is needed for 3000 sq.ft. area.

Water Soaking Trench

This pit is made in lengthwise direction

Length 3 to 15 feet

Breadth 1 to 3 feet

Depth 3 to 4.5 feet

The Trench is to be filled with broken bricks, pebbles and river sand.

This is suitable for sandy areas.

SELF EVALUATION

One Mark

Choose the correct answer.

1. Deforestation may reduce the chances of

   a. Rainfall b. Land slides c. Soil erosion d. Frequent cyclones

2. Soil erosion can be checked by

   a. Wind screen alone b. Restricted human activity
   c. Checking movement of animals d. Good plant cover

3. Common sources of energy used in Indian villages is

   a. Electricity b. Sun c. Coal d. Wood and animal dung

4. Which of the following is non- renewable?

   a. Water b. Coal c. Forests d. Wild life

Two Marks

1. Define conservation?
2. How do forests protect the environment?
3. What is meant by resources?
4. What are the main sources of energy in the world today?

Five Marks

1. What steps would you suggest for the conservation of forests?
2. What is the economic importance of forest?
3. What is a natural resource? Give an account of different types of natural resources?
4. What are the objectives of conservation of natural resources?
5. Give an account of non-conventional energy sources.
6. Explain seepage pit construction method.

Ten Marks

1. Describe the methods of harvesting rain water.

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This figure is pertained to Unit 2.
Chapter 6. Cell Membrane

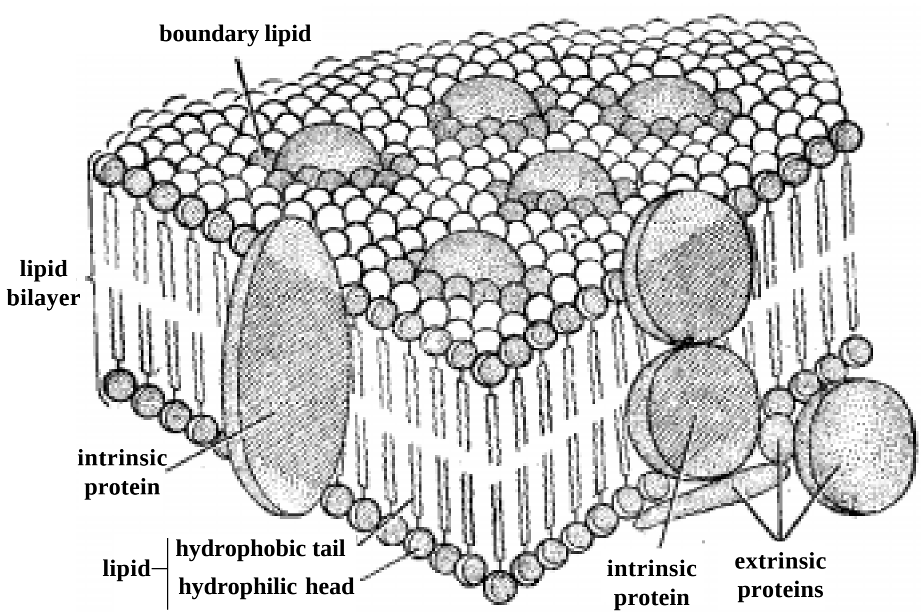

Fig. 2.11 Fluid-mosaic model of the plasma membrane. Proteins floating in a sea of lipid. Some proteins span the lipid bilayer, others are exposed only to one surface or the other.