BI LOGICAL CLASSIFICATION

FIVE KINGDOM CLASSIFICATION

- ✓ R.H. Whittaker proposed the five-kingdom classification in 1969.
- ✓ This classification was based upon certain characters like mode of nutrition, thallus organization, cell structure, phylogenetic relationships (evolutionary relationship) and reproduction.
- ✓ This five kingdoms include Monera, Protista, Fungi, Plantae and Animalia.

TABLE 2.1 Characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellular (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosyn-thetic and photosynthetic) and Hetero-trophic (sapro-phyte/para-site)	Autotrophic (Photosyn-thetic) and Hetero-trophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosyn-thetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

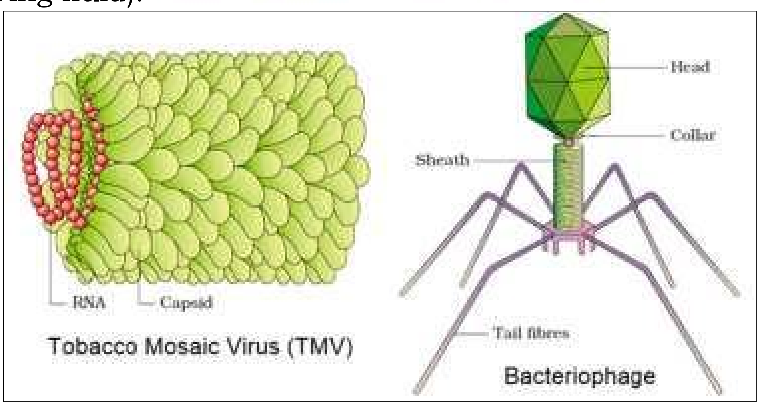
III.KINGDOM FUNGI

- ✓ Fungi are eukaryotic heterotrophic organisms.
- ✓ They show a great diversity in morphology and habitat.
- ✓ Common types include,
- ✓ Yeast (used to make bread and beer)
- ✓ Puccinia (causative organism of wheat-rust disease)
- ✓ Penicillium (Source of antibiotic called penicillin)
- ✓ They are filamentous, with the exception of unicellular Yeasts.
- ✓ The body of fungi consists of long, slender thread-like structures called **hyphae.**
- ✓ The network of hyphae is known as mycelium.
- ✓ Some hyphae are continuous tubes filled with multinucleated cytoplasm. These are called **coenocytic/aseptate hyphae**.
- ✓ Others have **septae** or cross walls in their hyphae they are called **septate hyphae.**
- ✓ Fungal cell wall is made up of chitin & polysaccharides.
- ✓ Most fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called saprophytes.
- ✓ The fungi that depend on living plants and animals for their food are called parasites.
- ✓ Fungi can also live as symbionts in association with algae as lichens and with roots of higher plants as mycorrhiza.

RE RODUCTION IN FUNGI

- Fungi reproduce vegetatively by fragmentation, budding or fission.
- Asexual reproduction takes place through spores called conidia, sporangiospores, aplanospores or zoospores.
- Fungi reproduce sexually through oospores, ascospores, zygospore or basidiospores.
- Sexual cycles involves the following steps
- **lasmogamy**: fusion of protoplasms between two motile or non-motile gametes.
- **Karyogamy:** fusion of two nuclei
- **Meiosis:** zygote undergoes meiosis resulting in haploid spores.
- In higher fungi, karyogamy is delayed and occurs just before meiosis.
- In such cases opposite nuclei remain paired (n+n,**Dikaryon)** before fusion. Such cells are called **dikaryotic cells.**
- Based on the morphology of the mycelium, mode of spore formation and fruiting bodies, the kingdom fungi are classified into 4 classes

- **VIRUS,VIROIDS, RIONS AND LICHENS**
- Five kingdom system of classification do not include Virus, Viroids,Prions and Lichens.
- Viruses are non-cellular organisms having inert crystalline structure outside the living cell.
- Once they enter the living cell, they take over the machinery of living cell to replicate themselves.
- The name **virus** (means venom or poisonous fluid) was given by **asteur.**
- **D.J. Ivanowsky** (1892) recognized certain microbes that cause mosaic disease of tobacco.
- They were smaller than bacteria because they passed through bacteria-proof filters.
- **M.W. Beijerinek** (1898) demonstrated that the extract of the infected plants of tobacco could cause infection in healthy plants and called the fluid as **Contagium vivum fluidum** (infectious living fluid).
- **W.M. Stanley** (1935) showed that viruses could be crystallized and crystals consist largely of proteins.
- In addition to proteins, viruses also contain genetic material (RNA or DNA). No virus contains both RNA & DNA.
- A virus is a nucleoprotein and the genetic material is infectious.
- Usually plant viruses have single stranded RNA; bacteriophages have double stranded DNA and animal viruses have single or double stranded RNA or double stranded DNA
- The protein coat, called **capsid** is made of small subunits called **capsomeres,** protects the nucleic acid.
- These capsomeres are arranged in helical or polyhedral geometric forms.



PL NT KINGDOM

ALGAE

- lgae are chlorophyll-bearing, simple, thalloid, autotrophic and largely aquatic (both freshwater and marine) organisms.
- The important salient features of algae are given below
- The plant body (thallus) is without differentiation.
- The basic form and size of algae is highly variable,They include
  - Microscopic unicellular forms: E.g. Chlamydomonas.
  - Colonial forms: E.g. Volvox
  - Filamentous forms: E.g. Ulothrix and Spirogyra.
  - few marine forms such as kelps, form massive plant bodies. Reproduction
- The algae reproduces vegetatively, asexually and sexually.

i. Vegetative Reproduction

- It occurs by fragmentation. Each fragment gets develop into a new thallus/organism.

ii. Asexual Reproduction

- It occurs by a number of accessory spores, such as zoospores, aplanospores, akinetes,etc.
- The most common being the zoospores, which are flagellated and hence motile.

iii.Sexual reproduction:

- Through fusion of two gametes.
- It is of many types:
- Isogamous: Fusion of gametes similar in size. They may be flagellated (e.g. Chlamydomonas) or nonflagellated (non-motile, e.g. Spirogyra).
- nisogamous: Fusion of two gametes dissimilar in size. E.g. Some species of Chlamydomonas.
- Oogamous: Fusion between one large, non-motile (static) female gamete and a smaller, motile male gamete. E.g. Volvox, Fucus.

ECONOMIC IMPORTANCE OF ALGAE

- t least half of the total carbon dioxide fixation on earth is carried out by them. Increase oxygen level in the environment.
- Many species like Laminaria, Sargassum etc. are used as food.
- gar obtained from Gelidium and Gracilaria are used in ice-creams and jellies and also used to culture bacteria.
- lgin obtained from brown algae and carrageen from red algae used commercially.
- Chlorella and Spirullina are unicellular algae, rich in protein and used as food supplement even by space travelers.

CLASSIFICATION OF ALGAE

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a, d,* phycoerythrin	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

BRYOPHYTES

- They are also called **amphibians of the plant kingdom** because they can live in soil but need water for sexual reproduction.
- They occur in damp, humid and shaded localities.

- heir body is more differentiated than that of algae.
- It is thallus-like and prostrate or erect, and attached to the substratum by unicellular or multicellular **rhizoids**.
- hey lack true roots, stem or leaves. hey may possess root-like, leaf-like or stem-like structures.
- he main plant body is haploid. It produces gametes, hence is called a gametophyte.
- he male sex organ **(antheridium)** produces biflagellate **antherozoids.**
- he female sex organ **(archegonium**) is flask-shaped and produces a single **egg.**
- Antherozoids are released into water where they come in contact with archegonium.
- An antherozoid fuses with an egg to form a zygote.
- Zygotes do not undergo meiosis immediately. It divides and produce a multicellular body called a sporophyte.
- Sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nourishment from it.
- Some cells of the sporophyte undergo meiosis to produce haploid spores.
- hese spores germinate to form new gametophyte.

ECONOMIC IMPORTANCE

- Bryophytes in general are of little economic importance.
- (i) Some mosses provide food for herbaceous mammals, birds and other animals.
- (ii) Species of Sphagnum (a moss), provides peat that have long been used as fuel.
- (iii)Sphagnum has the capacity to hold water and hence it is used as packing material for transshipment of living material.
- Bryophytes are divided into liverworts and Mosses.
- (iv)They have great ecological importance because of their important role in plant succession on bare rocks/soil.
- Mosses along with lichens decompose rocks making the substrate suitable for the growth of higher plants.
- (v) Mosses from dense mats on the soil, they reduce the impact of falling rain and prevent soil erosion.

M RPH L GY F FLOWERING PLANTS

THE R T

- Primary roots are the direct elongation of the **radicle.**
- Primary roots bear lateral roots of several orders that are referred to as secondary, tertiary roots, etc.
- Primary roots along with lateral roots forms the Tap root system. Example: Mustard, Gram, etc.
- In monocot plants, primary root is short lived after seed germination.
- It is replaced by large number of roots at the base of the stem. Such roots constitute the Fibrous root system. Eg. Wheat, rice etc.
- The roots that arise from any parts of the plant other than radicle are called **adventitious roots.** Example- Grass, Banyan tree, Maize, etc.

Functions of root system

- 1.Absorption of water and minerals from the soil
- 2. Storage of food materials.
- 3.Providing a proper anchorage to the plant parts.
- 4.Synthesis of plant growth regulators

M DIFICATI N F R TS

- Roots are modified for storage, nitrogen fixation, aeration and support.
- Tap root of carrot, turnip and adventitious root of sweet potato get swollen to store food.
- Prop root of Banyan and Stilt root of maize and sugarcane are, supporting roots coming out from lower node of stems.
- In Rhizophora, roots come out of the ground and grow vertically upwards, These roots are called **Pneumatophores.**
- They help to get oxygen for respiration as it grows in swampy areas.

THE STEM

- Stem is the aerial part of the plant and develops from plumule of the embryo.
- Stem bears nodes and internodes.
- The region of stem where leaves are born are called nodes and portion between two **nodes** are called **internodes.**
- The stem has **axillary buds** or terminal buds.
- The main function of stem is spreading branches bearing leaves, flowers and fruits.
- Stem arranges leaves in a way that it gets direct sunlight to perform photosynthesis.
- It also conducts water and minerals from root to leaves and product of photosynthesis from leaves to other parts.
- Some stem perform special functions like storage of food, support, protection and vegetative propagation.

M DIFICATI N F STEMS

- Underground stem of potato, ginger and turmeric are modified to store food.
- They also act as organ of perennation in unfavorable conditions.
- **Stem tendril** help plants to climb as in cucumber, pumpkins, and grapes.
- Axillary buds of stem may modify into woody, straight and pointed **thorns** as in Citrus and Bougainvillea.
- Plants of arid regions modify their stem to flattened (Opuntia), fleshy cylindrical (Euphorbia) stem called **phylloclade.**
- They help in photosynthesis and storage of water.
- In some plants, a slender lateral branch arises from the base of the main axis and after growing aerially for some time arch downwards to touch the ground **(Stolons**). Example- mint and jasmine
- A lateral branch with short internodes and each node bearing a rosette of leaves and a tuft of roots is found in aquatic plants **(ffset).** Example- Pistia and Eichornia
- In some plants lateral branches originate from the basal and underground portion of the main stem.
- These branches grow horizontally beneath the soil and then come out obliquely upward giving rise to leafy shoots (Sucker). Example- banana, pineapple

TH LEAF

- Leaf is a green,lateral flattened outgrowth which is borne on the node of a stem.
- Each leaf bears a bud in its axil called as the axillary bud, which later develops into a branch.
- Leaves are specialized organs for photosynthesis.
- Leaves originate from shoot apical meristem and are arranged in an acropetal order.
- A typical leaf consists of three parts- **Leaf base, Petiole, Lamina**.
- Leaf is attached with stem by Leaf Base which may bear two small leaf like structure called **stipule.**
- In leguminous plants the **leaf base** may become swollen, which is called the **Pulvinus.**
- The structure that holds the leaf is called petiole.
- The green exposed part of the leaf is known as lamina. ϖ Lamina bears the veins or veinlets .Middle prominent vein is called midrib.
- Veins provide rigidity to the leaf blade and act as channel for transport of water and minerals.

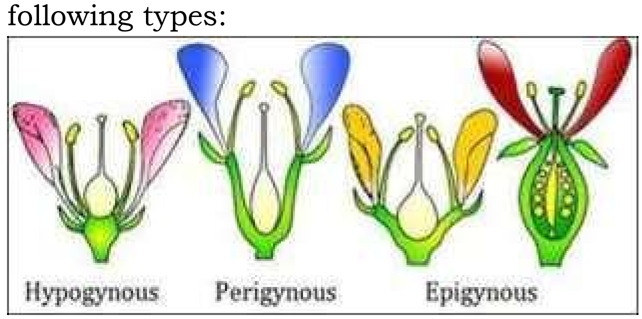
INFLOR SCENCE

- During the flowering season, the vegetative apex of the stem gets converted into a floral meristem.
- The arrangement of flowers on the floral axis is termed as inflorescence.
- Based on whether the floral axis continues to grow or end in a flower,infloresence are of 2 main types , racemose and cymose.

Racemose	**Cymose**
The main axis continuous to grow. Flowers are borne laterally in an acropetal succession. Example- Radish, Mustard.	Main axis terminates in flower having limited growth. Flowers are borne in a basipetal succession. Example- Jasmine, Bougainvillea

THE FLOWER

- Flower is the part of angiosperm plants for sexual means of reproduction.
- Stalk of the flower is called **pedicel**
- A typical flower has four whorls arranged on a swollen end of pedicel called t**halamus/ receptacle.**
- They are **Calyx, Corolla, Androecium and Gynoecium**.
- In flower like lily, the calyx and corolla are not distinct and are called **perianth**
- When a flower has both androecium and gynoecium, the flower is called **bisexual.**
- A flower having either androecium or gynoecium only is called **unisexual**.
- When a flower can be divided into two equal halves in any radial plane passing through the centre, it is said to be actinomorphic (radial symmetry) as in Mustard, Datura, and Chili.
- When flower can be divided into two similar halves only in one vertical plane it is **zygomorphic** as in Pea, Gulmohar, Cassia etc.
- A flower is asymmetric (irregular) if it cannot be divided into two equal halves by any vertical plane passing through the centre.
- Example- canna
- When Floral appendages are in multiple of 3,4 or 5 the flowers are said to be **trimerous, tetramerous** and p**entamerous** respectively.
- Flower with bracts are called **bracteates** and without it is **ebracteate**.
- Based on the position of ovary with respect to other floral part on thalamus, flowers are of following types:



- **Hypogynous flower**– Ovary occupies the highest position. The ovary in such case is called superior. Eg. Mustard, brinjal and china rose.

- ✓ **Perigynous** flowers-If the gynoecium is situated at the centre and other parts are on the rim at same height. Ovary is called half-inferior.
- ✓ **Epigynous flowers**- The margin of thalamus grows to completely cover the ovary. Ovary is said to be inferior.

PARTS OF A FLOWER

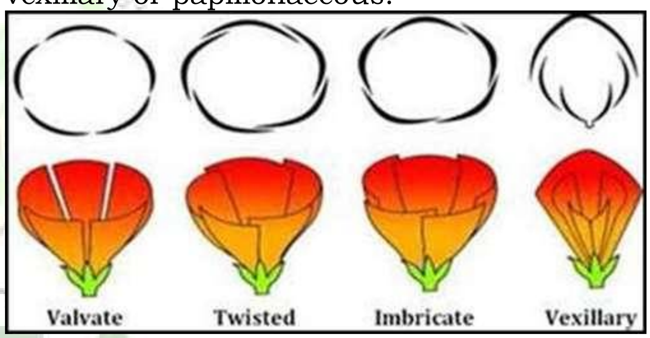
- ✓ **Calyx** is the outermost whorl of the flower; its members are called sepals.
- ✓ They are generally green and leafy; protect the flower in bud stage.
- ✓ It may be **gamosepalous** (sepals united) or **polysepalous** (sepals free).
- ✓ **Corolla** is composed of petals.
- ✓ **Petals** are brightly coloured to attract the insects for pollination.
- ✓ They may be **Polypetalous** (petals are free) or **Gamopetalous** (petals are united or fused).

AESTIVATION

- ✓ The mode of arrangement of sepals or petals in floral bud with respect to other members of the same whorl is called aestivation.
- ✓ **Valvate**
- ✓ sepals or petals in a whorl just touch one another at the margin, without overlapping. E.g. Calotropis.
- ✓ **Twisted** :
- ✓ One margin of the appendage overlaps that of the next one. E.g. china rose.
- ✓ **Imbricate** :
- ✓ The margin of sepals or petals overlap one another but not in any particular direction as in Cassia and gulmohur.

Vexillary

- ✓ In pea and bean flowers, there are five petals- the largest (standard) overlaps the two lateral petals (wings) which in turn overlap two smallest anterior petals (keel).
- ✓ This type of aestivation is known as vexillary or papilionaceous.



THE ANDROECIUM

- ✓ Androecium represent the male reproductive parts of flower and consists of **stamens.**
- ✓ Each stamen consists of a stalk or **filament** and an **anther.**
- ✓ Pollen grains are produced in pollen sacs of the anther.
- ✓ Sterile stamen is called **Staminode.**
- ✓ When stamens are attached with petals,such stamens are called epipetalous (Brinjal).
- ✓ A stamen is called Epiphyllous when it is attached to the perianth. E.g. lily
- ✓ If Stamens in a flower are free,they are called polyandrous.
- ✓ Stamens may be united in one bundle (**monoadelphous),** two bundles **(diadelphous),** more than two (**polyadelphous).**

THE GYNOECIUM

- ✓ Female reproductive part of flower is made up of one or more carpels.
- ✓ Each carpel has stigma,style and ovary.
- ✓ Ovary is the enlarged basal part on which lies the elongated tube, the style.
- ✓ The stigma usually at the tip of the style.It receives pollen grain.
- ✓ When more than one carpel is present, it may be free (apocarpous) as in lotus and rose or fused together (syncarpous) as in mustard and tomato.
- ✓ After fertilisation, ovules change into seeds and ovary mature into fruits.

PLACENTATION

- ✓ The arrangement of ovules within the ovary is called placentation.
- ✓ Marginal: Ovules are arranged along the fused margins of ovary.

- ✓ Axile: Margins of carpels fuse to form central axis.The ovules are attached to placenta in a multilocular ovary .
- ✓ Parietal: Ovules develop on inner wall of ovary.
- ✓ Free central: Ovules borne on central axis, lacking septa.
- ✓ Basal: Placenta develops at the base of ovary.

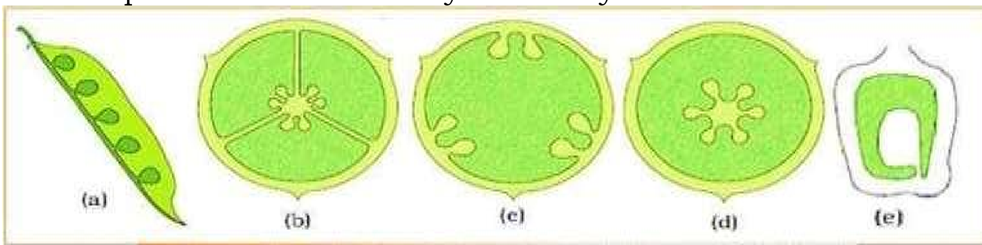


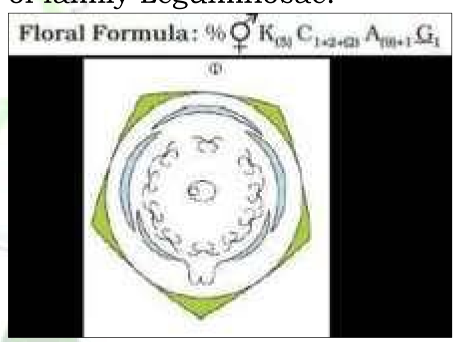
Fig: Placentation: (a) Marginal (b) Axile (c) Parietal (d) Free central (e) Basal

SEMI -TECHNICAL DESCRIPTION OF A TYPICAL FLOWERING PLANT

- ✓ The plant is described beginning with its habit, vegetative characters and then floral characters(inflorescence and flower parts).
- ✓ The floral formula is represented by some symbols.
- ✓ In the floral formula, **Br** stands for bracteate **K** stands for calyx , **C** for corolla, **P** for perianth, **A** for androecium and **G** for Gynoecium.
- ✓ Fusion is indicated by enclosing the figure within bracket and adhesion by a line drawn above the symbols of the floral parts.
- ✓ A floral diagram gives information about number and fusion of floral parts,their arrangement and relation.

Family Fabaceae-

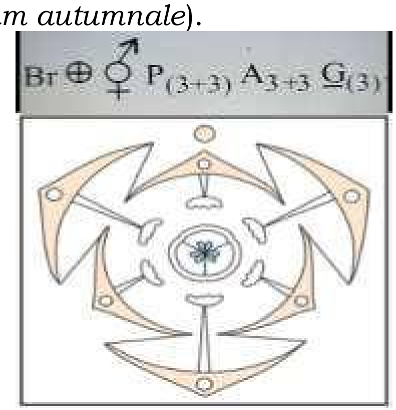
- ✓ This family was earlier called Papilonoideae, a subfamily of family Leguminosae.
- ✓ **Economic importance**
- ✓ Flower: bisexual, zygomorphic
- ✓ Corolla: petals five, polypetalous, papilionaceous, consisting of a posterior standard, two lateral wings, two anterior ones forming a keel (enclosing stamens and pistil), vexillary aestivation
- ✓ Androecium: ten, diadelphous, anther dithecous
- ✓ Plants belonging to this family are sources of pulses like Gram, Arhar, Bean. Pea etc. and edible oils like groundnut, soybean, etc.



- ✓ Some plants belonging to the family are sources of dye like indigofera,fibre like sunhemp,fodder like Sesbania, Trifolium.
- ✓ Ornamentals plants like Lupin and Sweet pea are also belongs to fabaceae .

Family Liliaceae

- ✓ Commonly called the 'Lily family' and is a characteristic representative of monocotyledonous plants.
- ✓ **Floral characters**
- ✓ Inflorescence: solitary / cymose; often umbellate clusters
- ✓ Flower: bisexual; actinomorphic
- ✓ Perianth tepal six (3+3), often united into tube; valvate aestivation
- ✓ Androcium: stamen six, (3+3)
- ✓ Gynoecium: tricarpellary, syncarpous, ovary superior, trilocular with many ovules; axile placentation
- ✓ It includes ornamental plants (Tulip), Medicine (Aloe) ,vegetable (Asparagus) and colchicine (*Colchicum autumnale*).



- ✓

ANATOMY OF FLOWERING PLAN S

Tissue

- ✓ A tissue is group of cells having common origin and performing a common function.
- ✓ There are two types of issues in plants
- ✓ a) Permanent tissue and b) meristematic tissue
- ✓ **MERISTAMATIC TISSUES**
- ✓ Growth in plants is largely restricted to specialised regions of active cell division called **meristems.**
- ✓ Based on its position in the plant body, the meristem is divided into three types – apical meristem, intercalary meristem and lateral meristem.

• Apical meristem	• Intercalary meristem	• Lateral meristem
• Occurs at the tips of roots and shoots • Primary meristem • Increase the length of plant	•Occurs between mature tissue at nodal region • Primary meristem • Help the grasses to regenerate parts removed by grazing herbivores.	•Present along the sides of the plant body • Secondary meristem •Appears later stage of growth and responsible for increase in thickness .

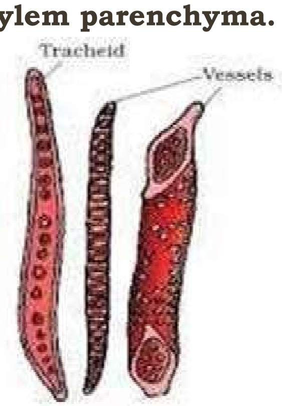
- ✓ Both apical meristems and intercalary meristems are primary meristems because they appear early in life of a plant and contribute to the formation of the primary plant body.
- ✓ **Axillary bud** : he buds which are present in the axils of leaves and are responsible for forming branches or flowers.

COMPLEX TISSUES

- ✓ Complex tissue consists of different types of cells but perform same function.
- ✓ Xylem and phloem constitute the complex tissues in plants and work together as a unit.

XYLEM

- ✓ Xylem functions as tissue for transport of water and minerals from roots to the stem and leaves.
- ✓ Xylem is composed of four different types of elements, namely, **tracheids, vessels, xylem fibres** and **xylem parenchyma.**



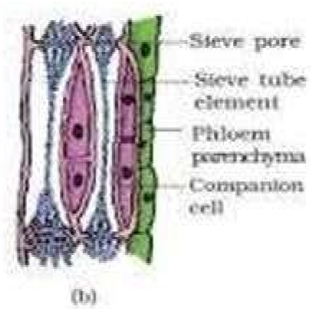
- ✓
- ✓ **Protoxylem & metaxylem**
- ✓ Primary xylem is of two types – **protoxylem and metaxylem.**
- ✓ The first formed primary xylem elements are called **protoxylem** and the later formed primary xylem is called **metaxylem**

- ✓ Tracheids are elongated or tube like cells with thick and lignified walls and tapering ends.
- ✓ Vessel is a long cylindrical tube-like structure made up of many cells called vessel members.
- ✓ Gymnosperms lack vessels in their xylem.
- ✓ Vessel members are inter-connected by perforations in their common walls.
- ✓ In flowering plants tracheids and vessels are the main water transporting elements.
- ✓ Xylem fibers are dead cells with lignified cell wall and central lumen.
- ✓ Xylem parenchyma are living and thin-walled cells, and their walls are made up of cellulose.
- ✓ Radial conduction of water takes place by specialise **ray parenchyma cells.**
- ✓ In stems, the protoxylem lies towards the centre (pith) and the metaxylem lies towards the periphery of the organ, this type of primary xylem is called **endarch**.
- ✓ In roots, the protoxylem lies towards periphery and metaxylem lies towards the

centre, such arrangement of primary xylem is called **exarch**

PHLOEM

- ✓ Phloem transports food materials, usually from leaves to other parts of the plant.
- ✓ Phloem in angiosperms is composed of sieve tube elements, companion cells, phloem parenchyma, and phloem fibres.



- ✓ Instead of sieve tubes and companion cells Gymnosperms have **albuminous cells** and **sieve cells.**
- ✓ Sieve tube elements are also long, tube-like structures, arranged longitudinally and are associated with the **companion cells**.
- ✓ Their end walls are perforated in a sieve-like manner to form the sieve plates.
- ✓ A mature sieve element possesses a peripheral cytoplasm and a large vacuole but lacks a nucleus.
- ✓ The functions of sieve tubes are controlled by the nucleus of **companion cells.**
- ✓ The companion cells are specialised parenchymatous cells, which are closely associated with sieve tube elements.
- ✓ Phloem parenchyma is made up of elongated, cylindrical cells which have dense cytoplasm and nucleus.
- ✓ Phloem parenchyma is absent in most of the monocotyledons.
- ✓ Phloem fibres (bast fibres) are made up of sclerenchymatous cells.
- ✓ These are generally absent in the primary phloem but are found in the secondary phloem.
- ✓ Phloem fibres of jute, flax and hemp are used commercially.
- ✓ The first formed primary phloem consists of narrow sieve tubes and is referred to as **proto phloem.**
- ✓ Later formed phloem has bigger sieve tubes and is referred to as **meta phloem.**

THE TISSUE SYSTEM

- ✓ On the basis of their location and function all the tissues of a plant can be classified in to three tissue systems.

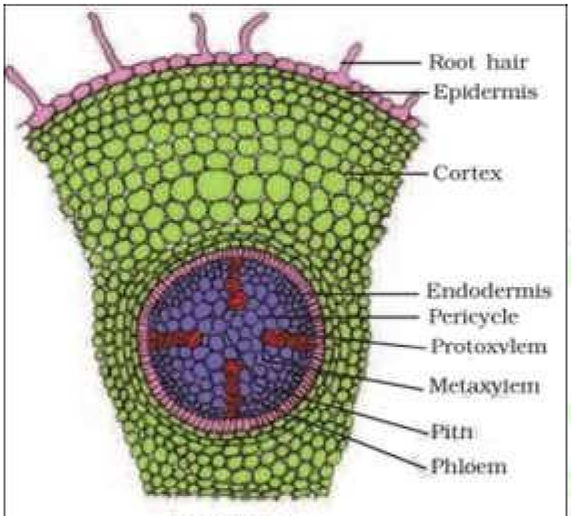
EPIDERMAL TISSUE SYSTEM

- ✓ It forms the outermost covering of whole plant body, which consists of epidermal cells, stomata, epidermal appendages (trichomes and hairs).
- ✓ Epidermis forms outermost protecting layer made up of is single layered parenchyma cells.
- ✓ The outside of the epidermis is often covered with a waxy thick layer called the **cuticle** which prevents the loss of water.
- ✓ Cuticle is absent in roots.
- ✓ Stomata are structures present in the epidermis of leaves.
- ✓ Stomata regulate the process of transpiration and gaseous exchange.
- ✓ Each stoma is composed of two bean shaped cells known as **guard cells** which enclose stomatal pore.
- ✓ Epidermal cells adjacent to the guard cells become specialised in their shape and size and are known as **subsidiary cells**.
- ✓ The stomatal aperture, guard cells and the surrounding subsidiary cells are together called **stomatal apparatus.**
- ✓ The root hairs are unicellular elongation of epidermal cells and help in absorption of water and mineral nutrients.
- ✓ **Trichomes** are multicellular hairs present on the stem.

VASCULAR TISSUE SYSTEM

- ✓ The vascular system consists of complex tissues, xylem and phloem that together form **vascular bundles.**
- ✓ the arrangement of xylem and phloem are different in roots and stem.
- ✓ In roots the xylem and phloem seen in different radii. Such vascular bundles are called **radial vascular bundles**.(Roots)
- ✓ In stem the xylem and phloem are arranged in the same radius. Such vascular bundles are called **conjoint** (stem and leaves).
- ✓ Conjoint vascular bundles may be open or closed
- ✓ In open vascular bundle **cambium** (a meristem) is seen in between xylem and phloem as in dicot stem
- ✓ In closed vascular bundle cambium is absent as in monocot stem.

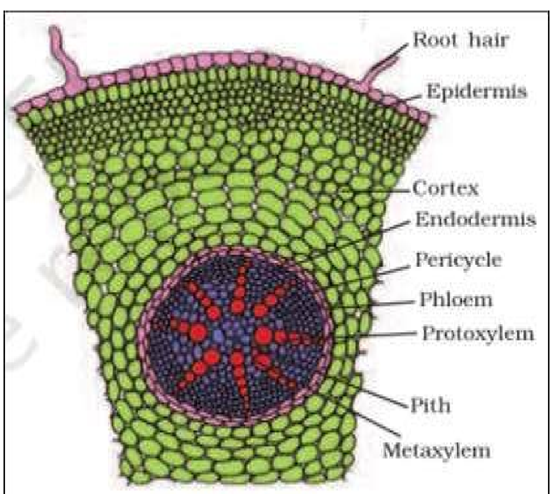
✓ ANATOMY OF DICOT ROOT



Dicot Root

- ✓ The outermost layer of dicot root is **epiblema** containing unicellular root hairs.
- ✓ The cortex consists of several layers of thin-walled parenchyma cells.
- ✓ The innermost layer of cortex is called **endodermis,**
- ✓ Endodermal cell wall has thick deposition of waxy material suberin,which is impermeable to water,it is called **casparian strip.**
- ✓ Inner to endodermis lies a few layers of thick-walled parenchyomatous cells referred to as pericycle.
- ✓ Xylem and phloem groups are limited in number .Xylem elements are polygonal in outline.
- ✓ The parenchymatous cells which lie between the xylem and the phloem are called conjuctive tissue.
- ✓ All tissues on the inner side of the endodermis such as pericycle, vascular bundles and pith constitute the stele.

ANATOMY OF MONOCOT ROOT

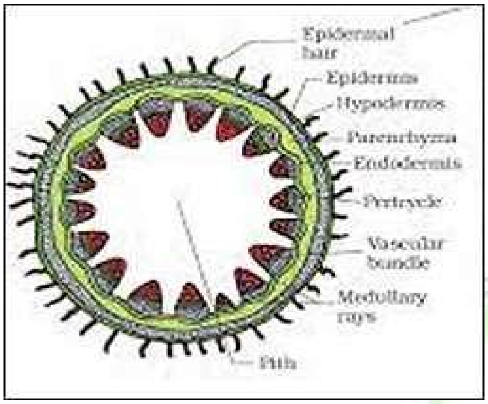


Monocot Root

- ✓ The anatomy of the monocot root is similar to the dicot root in many respects.
- ✓ It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith.
- ✓ Xylem and phloem groups are more in number than dicot root.
- ✓ Pith is large and well developed.

✓ Dicot Root	✓ Monocot Root
1. Cortex is comparatively narrow	1. Cortex is very wide.
2. Endodermis is less thickened casparian stripes are more prominent	2. Casparian strips are visible only in young Roots
3. The xylem and phloem bundles varies from 2 to 6	3. Xylem and phloem are more than 6. (polyarch).
4. Pith is reduced or sometimes absent	4. Well developed and large pith is present.
5 .Secondary growth takes place with the help of cambium.	5. Secondary growth is absent.

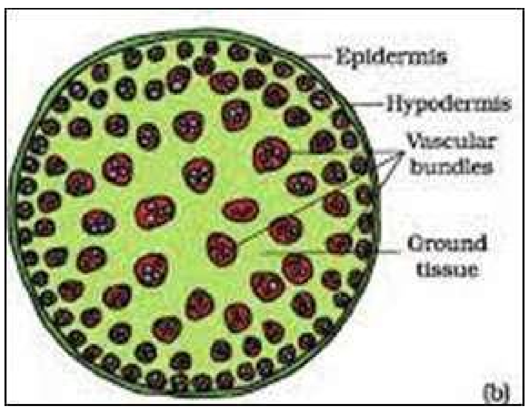
✓ **ANATOMY OF DICOT STEM**



- ✓ Epidermis forms the outermost protective layer of the stem.
- ✓ The multiple layers of cells arranged in between epidermis and pericycle constitute the **cortex**.
- ✓ It has three sub-zones
- ✓ **Hypodermis:** Layers of collenchymatous cells just below the epidermis, which provide mechanical strength to the young stem.
- ✓ Cortical layers: Layers of round thin walled parenchymatous cells with intercellular spaces.
- ✓ **Endodermis:** The innermost layer of the cortex rich in starch grains and hence called **Starch sheath**
- ✓ **Pericycle** is present on the inner side of the endodermis and above the phloem.
- ✓ Vascular bundles limited in number and arranged in a ring form.
- ✓ Vascular bundles are **conjoint and open**.
- ✓ Paren-chymatous tissue seen in between vascular bundles constitute **medullary rays**.
- ✓ A large number of rounded, paren-chymatous cells occupy the central portion of the stem constitute the **pith.**
- ✓ Conjoint vascular bundles may be open or closed
- ✓ In open vascular bundle cambium (a meristem) is seen in between xylem and phloem as in dicot stem.

ANATOMY OF MONOCOT STEM

- ✓ The hypodermis is made up of sclerenchyma.
- ✓ Vascular bundles are **conjoint and closed**.
- ✓ Vascular bundles are numerous and scattered in the ground tissue
- ✓ Each vascular bundle is surrounded by a sclerenchymatous bundle sheath.
- ✓ Phloem parenchyma is absent in monocot stem and they have water-containing cavities within the vascular bundles.



Dicot Stem	**Monocot Stem**
1. The ground tissue is differentiated into cortex, endodermis, pericycle and pith.	1. The ground tissue is made up of similar cells. (Homogeneous)

2. The vascular bundles are arranged in a ring	2. The vascular bundles are scattered in the ground tissue.
3. Vascular bundles are open, without bundle sheath.	3. Vascular bundles are closed,and surrounded by sclerenchymatous bundle sheath.
4. The stem shows secondary growth.	4. Secondary growth is absent.

ANATOMY OF DOSIVENTRAL (DICOT) LEAF

- ✓ The leaf lamina of a dorsiventral leaf has 3 parts: **epidermis, mesophyll** and vascular system.
- ✓ The upper epidermis is called **adaxial epidermis** and lower one is called **abaxial epidermis**.
- ✓ More number of stomata are present on the abaxial epidermis.
- ✓ There are two types of cells in the mesophyll,upper layer called palisade parenchyma and lower spongy parenchyma.
- ✓ There are numerous large spaces and air cavities between the cells of spongy parenchyma.
- ✓ Vascular bundles can be seen in the midrib and veins.
- ✓ Vascular bundles are surrounded by a layer of thick-walled **bundle sheath cells**.

CELL .THE UNIT OF LIFE

INTRODUCTION

- Cell is the fundamental structural and functional unit of all living organisms.
- **Antony Von Leeuwenhoek** first saw and described a live cell.
- Robert Brown discovered nucleus.
- All organisms are composed of cells.
- Some organisms are composed of a single cell and are called **unicellular organisms.**
- Others composed of many cells,they are called **multicellular organisms.**

PROKARYOTIC CELLS

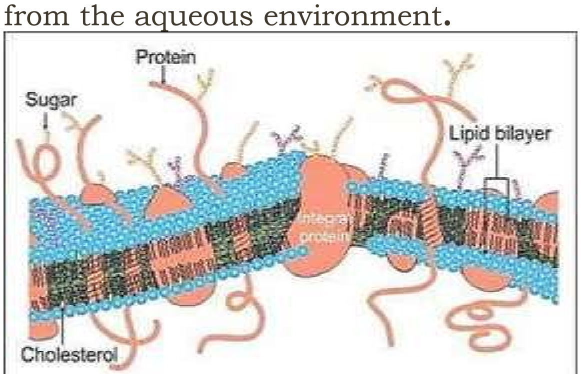
- Represented by bacteria, blue-green algae, **mycoplasma and PPLO.**
- Smaller and multiply more rapidly than eukaryotic cells.
- The four basic shapes of bacteria are bacillus (rod shaped) coccus (spherical), vibrio (comma shaped) and spirillum (spiral).
- All prokaryotes have a cell wall that surrounds the plasma membrane.
- There is no well defined nucleus and hence the genetic material is basically naked .
- A specialized differentiated form of cell membrane called **mesosome** is present.

EUKARYOTIC CELLS

- Eukaryotic cells are present in Protista, plants, Animals and Fungi.
- The cells contain well organized nucleus with nuclear membrane.
- The genetic materials are arranged in chromosomes.
- Plants cells differ in having cell wall, plastids and large central vacuole as compared to animal cells.
- Animal cells have centrioles, which are absent in plant cell.

CELL MEMBRANE

- The cell membrane is composed of lipids that are arranged in a bilayer.
- The lipids are arranged within the membrane with the polar head towards the outer sides and the hydrophobic tails towards the inner part.
- This arrangement ensures that the nonpolar tail of saturated hydrocarbons is protected from the aqueous environment.



- The lipid component is mainly composed of phosphoglycerides.
- Later it was found that protein is also present in cell membrane.
- Ratio of protein and lipids varies in different cells.
- Membrane protein may be integral or peripheral. Integral protein remains buried in membrane but peripheral protein lies on the surface.
- Singer and Nicholson (1972) proposed **fluid mosaic model**.
- According to this model the quasi-fluid nature of lipid enables lateral movement of protein within the bilayer of lipids.
- The main function of plasma membrane is the transport of molecules across it.
-

ACTIVE TRANSPORT	PASSIVE TRANSPORT
1.The transport involves an expenditure of energy by the cells.	1. The cells do not spend energy in passive transport.

Prepared by
Ismail Parambath,KKM.Govt.HSS,Orkatteri,Kozhikkode

It occurs against the concentration gradient. It is a rapid process.	This transport is always along the concentration gradient. It is comparatively slow process.

MITOCHONDRIA

- ✓ Mitochondria is double membrane bound structure with the outer membrane and inner membrane dividing its lumen in two compartments.
- ✓ The inner membrane forms a number of infoldings called **cristae** towards the matrix.
- ✓ Mitochondria are sites for aerobic respiration.
- ✓ They produce cellular energy in form of ATP so, they are called power house of the cells.
- ✓ The matrix of mitochondria also contain circular DNA molecules, a few RNA molecules, ribosomes and components of protein synthesis.

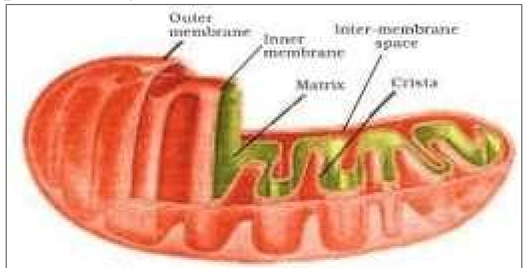
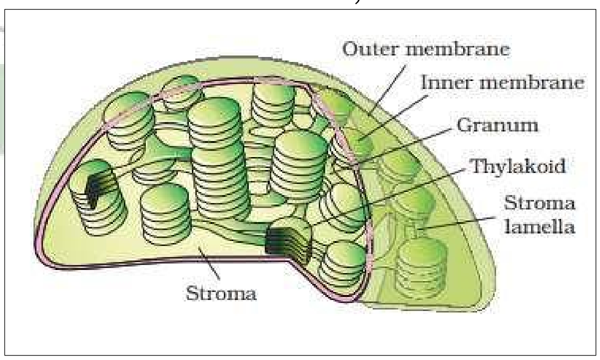


Diagram of Mitochondria

PLASTIDS

- ✓ Found in plant cells and in euglenoides
- ✓ Based on the type of pigments plastids can be classified into chloroplasts, chromoplasts and leucoplasts.
- ✓ The chloroplasts contain chlorophyll and carotenoid pigments which are responsible for trapping light energy essential for photosynthesis.
- ✓ In the chromoplasts, fat soluble carotenoid pigments like carotene, xanthophylls etc. are present.
- ✓ Leucoplasts are colourless plastids that store food.
- ✓ There are three types of leucoplasts
- ✓ **I) Eliaoplast**–stores oil and fat **ii) Amylopast–**stores starch **iii) Aleuroplast** –stores protein
- ✓ Chloroplasts of the green plants are found in the mesophyll cells of the leaves.
- ✓ Chloroplasts are double membrane structures.
- ✓ The space limited by the inner membrane of the chloroplast is called the **stroma.**
- ✓ A number of organised flattened membranous sacs called the **thylakoids.**
- ✓ Thylakoids are arranged in stacks like the piles of coins called **grana.**
- ✓ There are flat membranous tubules called the stroma lamellae connecting the thylakoids of the different grana.
- ✓ The stroma contains enzymes, double stranded DNA molecules, ribosomes



- ✓ Function : Site of photosynthesis, and imparts colours to fruits and flowers.

RIBOSOMES

- ✓ Ribosomes are granular structure first observed by George Palade (1953).
- ✓ Non-membranous cell organelles made up of ribonucleic acid (RNA) and proteins.
- ✓ Eukaryotic ribosomes are 80S while the prokaryotic ribosomes are 70S.

'S' (Svedburg unit)stands for sedimentation coefficient.(measure of density and size).

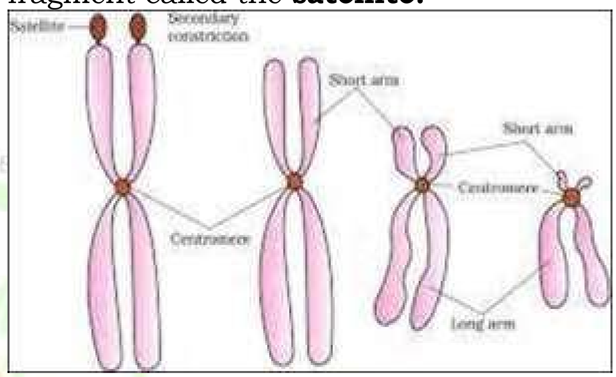
- ✓ Both 70S and 80S ribosomes consists of two subunits.
- ✓ Primary function is protein synthesis hence called protein factory of the cell.

NUCLEUS :

- ✓ Nucleus as a cell organelle was first described by Robert Brown in 1831.
- ✓ The interphase nucleus has highly extended and elaborates nucleoprotein fibres called

chromatin.

- ✓ The nucleus also contains nuclear matrix and spherical bodies called **nucleolus.**
- ✓ Nucleolus is the site of active ribosomal RNA synthesis.
- ✓ Nuclear envelope consists of two membranes –outer and inner with a space between them called the perinuclear space.,
- ✓ Minute openings on the nuclear envelop (Nuclear pore) allow the movement of RNA and protein in both directions.
- ✓ The nuclear matrix or nucleoplasm contains nucleolus and **chromatin.**
- ✓ Chromatin contains DNA and some basic proteins called histones, some non-histone proteins and RNA.
- ✓ During cell division the chromatins condensed to form chromosomes.
- ✓ A single human cell contains approximately two meter long thread of DNA in 46 chromosomes.
- ✓ Each chromosome essentially has a primary constriction or the **centromere.**
- ✓ On each side of centromere there is disc shaped structures called **kinetochores.**
- ✓ Based on the position of the centromere chromosomes are classified into four types.
- ✓ **i)Metacentric:** centromere at the middle with two equal arms.
- ✓ **ii)Sub-Metacentric**: centromere near the centre with one short arm and one long arm.
- ✓ **iii)Acrocentric**: centromere near the tip with one extremely short arm and a very long arm.
- ✓ **iv)Telocentric:** with terminal centromere.
- ✓ A few chromosomes have non-staining secondary constrictions at a constant location.
- ✓ This gives the appearance of a small fragment called the **satellite.**



CELL CYCLE AND CELL DIVISION

- **INTRODUCTION**
- Growth and reproduction are characteristics of living cells.
- The mechanisms of division and multiplication of cells together constitute **cell reproduction**
- The cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

PHASES OF CELL CYCLE

- The duration of cell cycle can vary from organism to organism.
- Cell cycle is divided into two basic phases: **Interphase** and **M phase**
- The **M Phase** represents the phase when the actual cell division or mitosis occurs and the
- **interphase** represents the phase between two successive M phases.
- The M Phase starts with the nuclear division, corresponding to the separation of daughter chromosomes known as **karyokinesis** and usually ends with division of cytoplasm

G1 PHASE

- G1 phase corresponds to the interval between mitosis and initiation of DNA replication.
- Cell is metabolically active and grows in size but does not replicate its DNA.

G2 PHASE

- Cell growth continues.
- Synthesis of RNA and proteins continues and cell is prepared for mitosis phase.
- **G0 PHASE**
- Some cells do not show division. E.g. heart cells.
- Many other cells divide only occasionally to replace damaged or dead cells.

CELL CYCLE

- Cell division, DNA replication, and cell growth have to take place in a coordinated way to ensure correct division and formation of progeny cells.
- It is the life period of a cell during which a cell synthesizes DNA (replication), grows in size and divides into two daughter cells.

known as **cytokinesis**

- The interphase, commonly called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner.
- The interphase is divided into three further phases:
  - G1 phase (Gap 1)
  - S phase (Synthesis)
  - G2 phase (Gap 2)

S PHASE

- During S or synthesis phase, the amount of DNA per cell doubles, but there is no increase in the chromosome number.
- In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm.
- The cells that do not divide further exit G1 phase and enter an inactive stage called **quiescent stage (G0).**
- In animals, mitotic cell division is seen only in the diploid somatic cells.
- In plants mitosis takes place in both haploid and diploid cells

MITOSIS

- It is a process of cell division where chromosomes replicate and get equally distributed into two daughter cells. Hence, it is also called equational division.
- The process of mitosis keeps the chromosome number equal in daughter as well as parental cell.
- Mitosis usually takes place in somatic cells.
- Mitosis is divided into four stages of nuclear division (Karyokinesis):
- 1.Prophase 2.Metaphase
- 3.Anaphase 4.Telophase

1.PROPHASE

- ✓ Prophase is the first stage of mitosis, which follows the S and G2 phases of interphase.
- ✓ The centrosome moves towards opposite poles of the cell.
- ✓ Each centrosome radiates out microtubules called **asters.**
- ✓ The two asters together with spindle fibres forms mitotic apparatus.
- ✓ Chromosomal material condenses to form compact mitotic chromosomes.
- ✓ Chromosomes are seen to be composed of two chromatids attached together at the centromere.

2.METAPHASE

- ✓ Metaphase chromosome is made up of two sister chromatids, which are held together by the centromere.
- ✓ Small disc-shaped structures, where spindle fibres attach to the surface of the centromeres are called **kinetochores.**
- ✓ Chromosomes are arranged at the centre of the cell with the help of spindle fibres.
- ✓ This arrangement is called metaphase plate formation.
- ✓ The plane of alignment of the chromosomes at metaphase is referred to as the **metaphase plate.**

ANAPHASE

- ✓ Centromere splits and daughter chromosomes move towards two opposite poles.
- ✓ The centromere of each chromosome is towards the pole with the arms of the chromosome trailing behind.

TELOPHASE

- ✓ Chromosomes finally reach their respective poles.
- ✓ The chromosomes begin to de-condense and return into a undifferentiated mass.
- ✓ Nuclear envelope assembles around each chromosome clusters.
- ✓ Golgi bodies and ER complex, which had disappeared after prophase start to reappear.

CYTOKINESIS

- ✓ Cytokinesis involves the division of cytoplasm of a cell.
- ✓ In animal cells, a furrow develops in the plasma membrane, which gradually deepens and ultimately joins in the centre dividing the cell cytoplasm into two.
- ✓ It is achieved in plant cell by cell plate formation.
- ✓ The formation of the new cell wall begins with the formation of a simple precursor, called cell-plate that represents the middle lamella between the walls of two adjacent cells.
- ✓ When karyokinesis is not followed by cytokinesis, a multinucleated condition arises. This is called **Syncytium**.
- ✓ Example- liquid endosperm in coconut.

MEIOSIS

- ✓ The cell division that reduces the number of chromosome into half and results in the production of haploid daughter cells..
- ✓ It helps in production of haploid phase in the life cycle of sexually reproducing organism.
- ✓ It involves following events.
- ✓ Two sequential cycles of nuclear and cell division called **meiosis I** and **meiosis II** but single cycle of DNA replication.
- ✓ It involves pairing of homologous chromosome and recombination of them.
- ✓ Four haploid daughter cells are formed at the end of meiosis II.
- ✓ The phases of meiosis are as shown below

MEIOSIS-I

1.Prophase I

- ✓ It comprises of 5 stages:

LEPTOTENE

- ✓ During Leptotene, the chromosome becomes distinct and visible under microscope.
- ✓ Compaction of chromosome continues throughout the leptotene phase.

ZYGOTENE

- ✓ Pairing of homologous chromosomes called **synapsis** occurs.
- ✓ A pair of synapsed homologous chromosomes is called **bivalent**.
- ✓ Synapsis occurs with help of complex cytochemical substance called synaptonemal complex.

PACHYTENE

- ✓ Exchange of genetic material between non-sister chromatids of homologous chromosome occurs **(crossing over).**
- ✓ The crossing over is enzyme – mediated process which involves enzyme recombinase.

DIPLOTENE

- ✓ It is recognized by dissolution of synaptonemal complex and tendency to separation of bivalent except at the site of crossing over.
- ✓ The X-shaped structures formed during separation are known as **chiasmata.**

DIAKINESIS

- ✓ **Terminalisation** of chiasmata can be observed.
- ✓ By the end of this stage, the nucleolus disappears and the nuclear envelope breaks.
- ✓ **Metaphase I**
- ✓ The bivalents align at the equatorial plate.
- ✓ Microtubules from the opposite poles attach to the pairs of homologous chromosomes.

Anaphase I

- ✓ The two chromosomes of each bivalent separate and move to the opposite ends of the cells.
- ✓ The sister chromatids are attached to each other.

Telophase

- ✓ Nuclear membrane and nucleolus reappears and cytokinesis follows.
- ✓ This is called as diad of the cells.
- ✓ The stage between two meiotic divisions is called **interkinesis** and it is short lived, that follows Meiosis II.

MEIOSIS II

Prophase II

- ✓ The chromosomes begin to condense accompanied by the dissolution of the nuclear membrane and the disappearance of the Golgi apparatus and ER complex.

Metaphase II

- ✓ Chromosomes align at the equator.
- ✓ Spindle fibres attach to kinetochores of sister chromatids at each pole.

Anaphase II

- ✓ Chromatids separate by splitting of centromere.
- ✓ As a result, chromatids move towards their respective poles in the cell.

Telophase II

- ✓ The two groups of chromosomes get enclosed by a nuclear envelope.
- ✓ Cytokinesis follows resulting in the formation of tetrad of cells i.e., four haploid daughter cells.

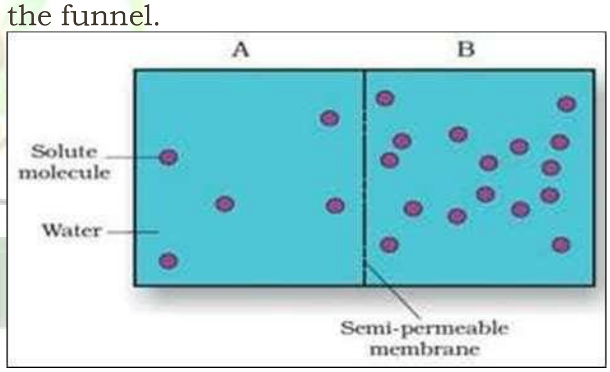
TRANSPORT IN PLANTS

WATER POTENTIAL (Ψ)

- It is a concept fundamental to the understanding of water movement.
- Water potential is determined by solute potential (**Ψ**s) and pressure potential (**Ψp**).
- Water molecules possess kinetic energy.
- The greater the concentration of water in the system, the greater is its kinetic energy or water potential.
- So pure water has greatest water potential.
- Water potential is denoted by Greek symbol Psi (**Ψ**) and is expressed in pressure unit Pascal (Pa).
- Water pressure of pure water is taken as zero at standard temperature and pressure.
- A solution has less water potential due to less water concentration.
- The magnitude of lowering of water potential due to dissolution of solute is called solute potential.
- Solute potential is always negative. More the solute molecules in the solution lesser the solute potential.
- For a solution at atmospheric pressure (water potential) Ψw = (solute potential) Ψs .
- If a pressure greater than atmospheric pressure is applied to pure water or solution, its water potential increases.
- Pressure can build up in a plant system,when water enters a plant cell due to diffusion. it makes the cell **turgid.**
- Pressure potential is usually positive. Pressure potential is denoted as (**Ψp**).
- Water potential of a cell is affected by both solute and pressure potential.
- The relationship between them is as follows: **Ψw = Ψs + Ψp**

OSMOSIS

- The plant cell is surrounded by a cell membrane and a cell wall.
- The cell wall is freely permeable to water and substances in solution hence is not a barrier to movement.
- In plant cells, the cell membrane and the membrane of the vacuole, **the tonoplast** together are important determinants of movement of molecules in or out of the cell.
- Osmosis is the diffusion of water across a semi-permeable membrane. .
- The net direction and rate of osmosis depends upon the pressure gradient and concentration gradient.
- ater will move from its region of higher concentration to region of lower concentration until equilibrium is reached.
- Solute A has more water and less solutes so high water potential in comparison to the solution in B container.
- Osmosis is demonstrated by **Thistle funnel experiment**.
- Semi permeable membrane fixed at mouth region of thistle funnel separates pure water in the beaker and concentrated solution in the funnel.
- Water in the beaker will move into the funnel, resulting in rise in the level of the solution in the funnel.



-
- This will continue till the equilibrium is reached.
- External pressure can be applied from the upper part of the funnel such that no water diffuses into the funnel through the membrane.
- This pressure required to prevent water from diffusing is the **osmotic pressure.**
- It is the function of the solute concentration(osmotic potential), more the solute concentration, greater will be the pressure required to prevent water from diffusing in.
- Numerically osmotic pressure is equal to osmotic potential but sign is opposite.
- Osmotic pressure is the positive pressure while osmotic potential is negative

PLASMOLYSIS

- The behaviour of the plant cells with regard to water movement depends on the surrounding solution
- If the surrounding solution balances the osmotic pressure of cytoplasm, the solution is called **isotonic.**
- If the external solution is more dilute than cytoplasm, it is **hypotonic** and If the external solution is more concentrated than cytoplasm, it is **hypertonic.**
- Cells swell in hypotonic solutions and shrink in hypertonic ones.
- Plasmolysis is the shrinkage of the cytoplasm of the cell away from its cell wall under the influence of hypertonic solution.
- When the cell is placed in an isotonic solution, there is no net flow of water towards the inside or outside.
- The process of plasmolysis is usually reversible.
- When the cells are placed in a hypotonic solution (higher water potential or dilute solution as compared to the cytoplasm), water diffuses into the cell causing the cytoplasm to build up a pressure against the wall, that is called **turgor pressure.**
- The pressure build up against the wall due to movement of water inside is called **turgor pressure.**
- The pressure exerted by the protoplasts due to entry of water against the rigid walls is called pressure potential Ψp
- It is responsible for enlargement and extension growth of cells

IMBIBITION

- Imbibition is a special type of diffusion when water is absorbed by solid (colloids) causing them to increase in volume.
- For example absorption of water by seeds and dry woods.
- Imbibition is the initial step in seed germination.
- Imbibition is also a kind of diffusion because movement of water is from higher concentration to lower concentration.
- Water potential gradient between the absorbent and liquid imbibed is essential for imbibition.
- For any substance to imbibe any liquid, affinity between the adsorbant and the liquid is also a pre-requisite.

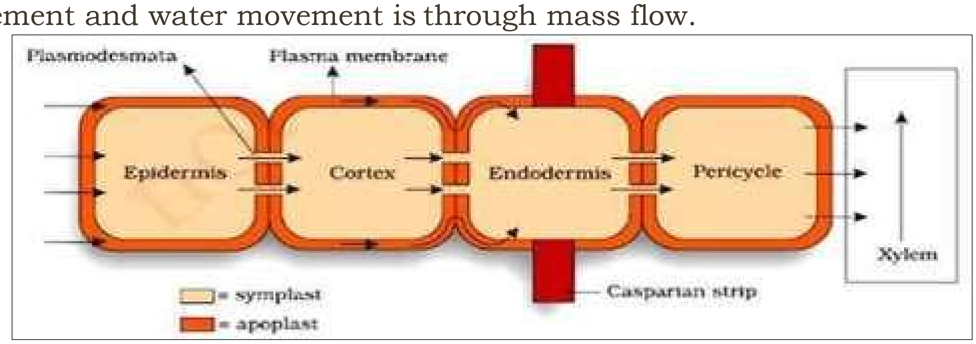
ABSORPTION OF WATER

- Water is absorbed along with mineral solutes by root hairs by diffusion.
- Root hairs are thin-walled slender extensions of root epidermal cells that greatly increase the surface area for absorption.

1.apoplast pathway 2.symplast pathway

APOPLAST AND SYMPLAST PATHWAY

- The apoplast is the system of adjacent cell walls, that is continuous throughout the plant, except at the casparian strips of the endodermis in the roots.
- The inner boundary of cortex, endodermis is impervious to water due to suberised matrix called Casperian strip.
- The apoplastic movement of water occurs exclusively through the intercellular spaces and the walls of the cells.
- Movement through the apoplast does not involve crossing the cell membrane.
- The apoplast does not provide any barrier to water movement and water movement is through mass flow.
-



- The **symplastic system** is the system of interconnected protoplasts.
- Neighbouring cells are connected through cytoplasmic strands that extend through plasmodesmata.
- During symplastic movement, the water travels through the cells–their cytoplasm;intercellular movement is through the plasmodesmata.
- Endodermis prevents water or any solutes dissolved in water from passing through the layer via **apoplastic pathway.**
- Water can pass through the endodermis by crossing the membrane of the endodermis.
- That is water moves through the symplast and crosses a membrane to reach the cells of the xylem.
- The movement of water through the root layers is ultimately symplastic in the endodermis.
- Some plants have additional structures associated with roots that help in water and mineral absorption
- A **mycorrhiza** is the symbiotic association between a fungus and angiospermic roots.
- The fungal filaments forms a network around the young root to have large surface area that help to absorb mineral ions and water from the soil.
- The fungus provide minerals and waters and roots in turn provide organic and nitrogen containing compounds.
- Pinus seeds cannot germinate and establish without the presence of **mycorrhizae.**

TRANSPIRATION PULL

- Water is mainly 'pulled' through the plant body due to driving force of transpiration from the leaves.
- It is termed as cohesion – tension – transpiration pull model of water transport.
- **Transpiration** is evaporative loss of water from plant leaves.
- It occurs mainly through **stomata (**sing. **: stoma).**
- Besides the loss of water vapour in transpiration, exchange of oxygen and carbon dioxide in the leaf also occurs through these stomata.
- Normally stomata are open in the day time and close during the night.
- The opening and closing of stomata is because of turgidity of **guard cells.**
- The inner wall of each guard cell, towards the pore or stomatal aperture,is thick and elastic.
- When turgidity increases within the two guard cells flanking each stomatal aperture or pore, the thin outer walls bulge out and force the inner walls into a crescent shape.
- When the guard cells lose turgor, due to water loss, the elastic inner walls regain their original shape, the guard cells become flaccid and the stoma closes
- Transpiration is affected by several external factors: temperature, light, humidity, wind speed.
- Plant factors that affect transpiration include number and distribution of stomata, per cent of open stomata, water status of the plant, canopy structure etc.
- The transpiration driven ascent of xylem sap depends on physical properties of water, which are as follows:
- **Cohesion** – mutual attraction between water molecules.
- **Adhesion** – attraction of water molecules to polar surfaces (such as the surface of tracheary elements).
- **Surface Tension**– water molecules are attracted to each other in the liquid phase more than to water in the gas phase.
- These properties give water **high tensile strength**, i.e,(an ability to resist a pulling force) and

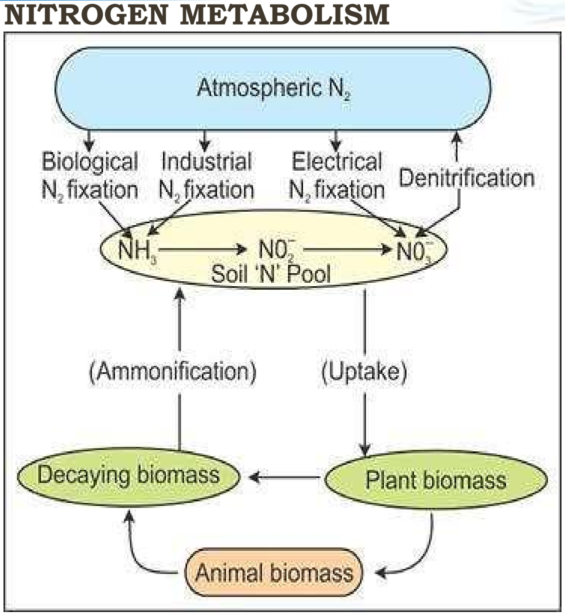
  high capillarity, i.e., the ability to rise in narrow tubes.
- In plants capillarity is aided by the small diameter of the tracheary elements – the tracheids and vessel elements.
- The process of photosynthesis requires water and the system of xylem helps in the supply of water from roots to leaf veins.
- During this process, the evaporation of water takes place via stomata, thin film of water result in pulling effect in leaves from xylem.
- Because of lower concentration of water vapor in atmosphere in comparison to sub-stomatal cavity and intercellular spaces, water gets diffused in the surroundings and creates a "*Pull*".

MINERAL NUTRITION

CRITERIA FOR ESSENTIALITY

- The criteria for essentiality of an element are given below:
- The element must be absolutely necessary for supporting normal growth and reproduction. In the absence of the element the plants do not complete their life cycle.
- The requirement of the element must be specific and not replaceable by another element..
- The element must be directly involved in the metabolism of the plant.
- Based upon the above criteria only a few elements have been found to be absolutely essential for plant growth and metabolism.
- These elements are further divided into two broad categories based on their quantitative requirements. **(i) Macronutrients, and (ii) Micronutrient**
- **Macronutrients**are generally present in plant tissues in large amounts (in excess of 10 mmole Kg^{-1} of dry matter).
- The macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium and magnesium.
- **Micronutrients or trace elements**, are needed in very small amounts (less than 10 mmole Kg^{-1} of dry matter).
- These include iron, manganese, copper, molybdenum, zinc, boron, chlorine and nickel.
- Essential elements can also be grouped into four broad categories on the basis of their diverse functions.
- Essential elements as components of biomolecules and hence structural elements of cells (e.g., carbon, hydrogen, oxygen and nitrogen).
- Essential elements that are components of energy-related chemical compounds in plants (e.g., magnesium in chlorophyll and phosphorous in ATP).
- Essential elements that activate or inhibit enzymes, For example- Mg^{2+} is an activator for both Rubisco and PEPcase.
- Some essential elements can alter the osmotic potential of a cell. Potassium plays an important role in the opening and closing of stomata.

NITROGEN METABOLISM



- Nitrogen is the most prevalent element in living world along with C, H and O.
- It is the main constituent of proteins, nucleic acids, fats, hormones, enzymes etc.
- Nitrogen exists as two nitrogen atoms joined by a very strong triple covalent bond (N ≡ N).
- The process of conversion of nitrogen to ammonia is called **nitrogen fixation.**
- In nature lightening and ultraviolet radiation provide energy to convert atmospheric nitrogen into nitrogen oxide **(NO, NO_2 and N_2O).**
- Decomposition of organic nitrogen of dead plants and animals into ammonia is called **ammonification.**
- Ammonia is first oxidized to **nitrite** by bacteria *Nitrosomonas* or *NitrococcUs* which is further oxidized to **nitrate** with help of bacteria *Nitrobactor*.
- These processes are called **nitrification.**
- These nitrifying bacteria are chemoautotrophs.

$2NH_3 + 3O_2 \rightarrow 2NO^- + 2H^+ + 2H_20$

$2N0^- + O_2 \rightarrow 2N0^-3$

- The nitrate thus formed is absorbed by plants and is transported to the leaves.

- ✓ In leaves, it is reduced to form ammonia that finally forms the amine group of amino acids.
- ✓ Nitrate present in the soil is also reduced to nitrogen by the process of **denitrification.**
- ✓ **Denitrification** is carried by bacteria like *Pseudomonas* and *Thiobacillus.*

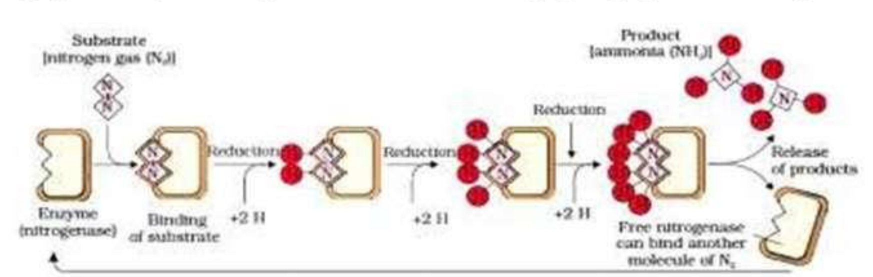
BIOLOGICAL NITROGEN FIXATION

- ✓ Reduction of nitrogen to ammonia by living organisms is called **biological nitrogen fixation (BNF).**
- ✓ The enzyme **nitrogenase**, present in prokaryotic organism is capable for nitrogen fixation.
- ✓ Nitrogen fixing microbes (Nitrogen fixers) may be Aerobic free living bacteria like *Azoospirillum and Beijerinckia*
- ✓ Anaerobic free living forms like *Rhodospirillum.*
- ✓ Free living cyanobacteria such as Anabaena and Nostoc

SYMBIOTIC BIOLOGICAL NITROGEN FIXATION

- ✓ Most common symbiotic nitrogen fixation is observed in Legume-Rhizobium relationship.
- ✓ Rhizobium forms root nodules in leguminous plants, and ***Frankia*** produces nitrogen-fixing root nodules on the roots of non-leguminous plants.
- ✓ The nodules are small outgrowths on the roots.
- ✓ Central portion of nodule is pink or red due to presence of leguminous haemoglobin or **leg- haemoglobin**
- ✓ Both Rhizobium and Frankia are free living in soil, but they can fix atmospheric nitrogen only in a symbiotic association.
- ✓ **Nodule formation** involves sequence of interaction between root and Rhizobium as follows-
- ✓ Rhizobia multiply and colonise epidermis of roots.
- ✓ Root hairs curls and bacteria invade it.
- ✓ An **infection thread** is formed that carries the bacteria into cortex of root.
- ✓ Nodule formation starts in cortex of root.
- ✓ Bacteria is released from thread to cells which leads to formation of specialized nitrogen fixing cells.
- ✓ Nodules establish **direct vascular connection** with host for exchange of nutrients.
- ✓ Nodule contains all necessary biochemical components like enzyme nitrogenase and leg-haemoglobin.
- ✓ Enzyme nitrogenase is a **Mo-Fe protein** and catalyses the conversion of atmospheric nitrogen into ammonia.
- ✓ The reaction is as follows-
- ✓ The enzyme nitrogenase is highly sensitive to molecular oxygen and needs anaerobic condition.
- ✓ To protect this enzyme from oxygen, the nodules contain an **oxygen scavenger called leg- haemoglobin.**
- ✓ The ammonia synthesized by nitrogenase enzyme requires high amount of energy (8 ATP for each NH3 produced).
- ✓ It is interesting to note that these microbes live as aerobes under free-living conditions (where nitrogenase is not operational), but during nitrogen-fixing events, they become anaerobic.

$$N_2 + 8e^- + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$$

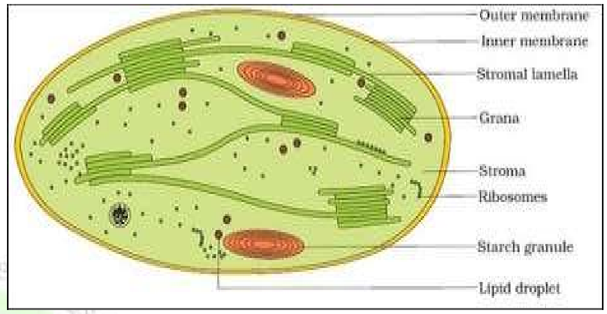


Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

PHOTOSYNTHESIS IN HIGHER PLANTS

SITE OF PHOTOSYNTHESIS

- ✓ Generally photosynthesis takes place in the green leaves of plants.
- ✓ The mesophyll cells in the leaves, have a large number of chloroplasts.
- ✓ Usually the chloroplasts align themselves along the walls of the mesophyll cells.
- ✓ Chloroplasts are **green plastids** which function as the site of photosynthesis in eukaryotic **photoautotrophs.**
- ✓ Within the chloroplast there is a membranous system consisting of **grana**, the **stroma lamellae** and the fluid, **stroma.**
- ✓ The membrane system is responsible for synthesizing light energy for the synthesis of ATP and NADPH.
- ✓ The stroma has enzymes, which are responsible for the reduction of carbon dioxide into carbohydrates and formation of sugars..
- ✓ The reaction in which light energy is absorbed by grana to synthesis **ATP** and **NADPH** is called **light reaction**.
- ✓ The later part of photosynthesis in which is reduced to sugar, light is not necessary and is called **dark reaction**.



✓

PIGMENTS IN PHOTOSYNTHESIS

- ✓ Pigments are substances that have an ability to absorb light, at specific wavelengths.
- ✓ The colour of the leaves is due to four pigments such as
  - Chlorophyll a (bright or blue green in the chromatogram),
  - chlorophyll b (yellow green),
  - xanthophylls (yellow) and
  - carotenoids (yellow to yellow-orange)
- ✓ Chlorophyll a absorb lights of different wavelengths and it is the chief pigment .
- ✓ **Absorption spectrum** shows the ability of chlorophyll-a to absorb lights of different wavelength.
- ✓ Maximum absorption by chlorophyll a occurs in **blue and red** regions of visible spectrum.
- ✓ Major part of the photosynthesis takes place in the blue and red regions, while some of the photosynthesis takes place at other wavelengths also(**Action spectrum)**
- ✓ Other thylakoid pigments, like chlorophyll b, xanthophylls and carotenoids, also absorb light and transfer the energy to chlorophyll a. Hence they are called **accessory pigments/antennae molecules.**
- ✓ These pigments help to make photosynthesis more efficient by absorbing different wavelengths of light.
- ✓ They also protect chlorophyll a from photo-oxidation

LIGHT REACTION

- ✓ Light reactions or the 'photochemical' phase include light absorption, water splitting, oxygen release, and the formation of high-energy chemical intermediates, ATP and NADPH..
- ✓ The pigments are organised into two discrete photochemical light harvesting complexes (LHC) within the Photosystem I (PS I) and Photosystem II (PS II).
- ✓ The LHC are made up of hundreds of pigment molecules bound to proteins.
- ✓ Each photosystem has all the pigments (except one molecule of chlorophyll a) forming a light harvesting system (**antennae molecule).**
- ✓ The single chlorophyll a molecule forms the **reaction centre.**
- ✓ **In PS I the reaction centre ,chlorophyll a has an absorption peak at 700 nm, hence is called P700, while in PS II it has absorption maxima at 680 nm, and is called P680.**

THE ELECTRON TRANSPORT SYSTEM

- The photosynthetic electron transport chain initiates by the absorbance of light by the photosystem-I
- Reaction centre of photosystem II absorbs light of 680nm in red region and causing electron to become excited.
- These electrons are picked by an electron acceptor and pass on to electron transport system consisting of **cytochromes.**
- The electrons are passed on to the pigments of photosystem PS I, and the movement of electrons are downhill.
- Electron in the PSI also get excited due to light of wavelength 700nm and are transferred to another accepter molecule having a greater redox potential.
- The electrons then are moved downhill to a molecule of energy-rich NADP+ and the addition of these electrons reduces NADP+ to NADPH + H+.
- The whole scheme of transfer of electron is called **Z-scheme** due to its shape.

SPLITTING OF WATER

- In this process the water splits into protons, electrons and oxygen.
- The complex for water splitting is associated with the photosystems-II that is located on the inner side of the thylakoid membrane.
- Photolysis of water release electrons that provide electron to PS II. Oxygen is also released during this process.

CYCLIC AND NON-CYCLIC PHOTO-PHOSPHORYLATION

- Phosphorylation is the process through which, ATP is synthesised by cells (in mitochondria and chloroplasts) is named phosphorylation.
- **Photophosphorylation** is the synthesis of ATP from ADP and inorganic phosphate in the presence of light.
- Non-cyclic photophosphorylation is the type of photophosphorylarion in which both the photosystems (PS-I and PS-II) cooperate in light driven synthesis of ATP.
- During this cycle, the electron released from PS-II does not return to it hence, it is known as non-cyclic photophosphorylation
- Both ATP and NADPH + H^+ are synthesised by this kind of electron flow.

CYCLIC PHOTO-PHOSPHORYLATION

- It is the type of photophosphorylation in which only PS-I is taking part and the electron released from the reaction centre P_{700} returns to it after passing through a series of carriers
- The cyclic photophosphorylation takes place in the stromal lamellae of the chloroplast.
- This happens because the stromal lamellae does not possess enzyme NADP reductase (essential for reducing NADP+ to NADPH) and PS-II.
- The cyclic flow hence, results only in the synthesis of ATP, but not of NADPH + H+ .
- Cyclic photophosphorylation also occurs when only light of wavelengths beyond 680 nm are available for excitation.

CHEMI-OSMOTIC HYPOTHESIS

- This hypothesis was given by Peter Mitchell (1961) in order to explain the ATP synthesis in photosynthesis.
- The synthesis of ATP is directly linked to the development of a **proton gradient** across the thylakoid membranes of a chloroplast.
- The development of proton gradient results due to the reasons given below
  (i) As the water molecule splits into the inner side of the membrane the protons or hydrogen ions that are produced by the water splitting gets accumulate within the thylakoids lumen.
  (ii) Transportation of protons takes place across the membrane when the electron moves through the photosystems.
- The primary acceptor of electron is located towards the outer side of the membrane, which transfers electron to the proton (H+) carrier and not to the electron carrier.
- So, this molecule, while transporting an electron removes a proton from the stroma, thus, release of proton takes place into the inner side, i.e., on the lumen of the membrane.
- (iii) The enzyme NADP reductase is present on the stromal side of the membrane.
- Thus, along with the electrons that comes from the acceptor of electrons of PS-I,

protons are also necessary to reduce $NADP^+$ to NADPH + H^+

- ✓ Hence, within the chloroplast, protons in the stroma decrease in number, while in the lumen there is accumulation of protons.
- ✓ This creates a proton gradient across the

ATPsynthaase Enzyme

- ✓ The enzyme ATPsynthase consists of the following two parts

F_0 Particle

- ✓ This portion remains embedded in the membrane and forms a transmembrane channel, which carries out facilitated diffusion of protons across the membrane.

F_1 Particle

- ✓ This portion protrudes towards the outer surface of the thylakoid membrane which faces the stroma.
- ✓ Conformational change occurs in F_1 particle

thylakoid membrane as well as a measurable decrease in pH in the lumen.

- ✓ The gradient is broken down due to the movement of protons across the membrane to the stroma through the transmembrane channel of the F_0 of the ATPsynthase.

of ATPsynthase, which caused due to the breakdown of the gradient, which allows the enzyme to synthesise several molecules of ATP.

- ✓ Thus, Chemiosmosis requires a membrane, a proton pump, a proton gradient and ATP synthase.
- ✓ The ATP thus, produced will be used immediately in the biosynthetic reaction (in stroma), responsible for the fixing of CO2 and synthesis of sugar.

CALVIN CYCLE (C3-PATHWAY)

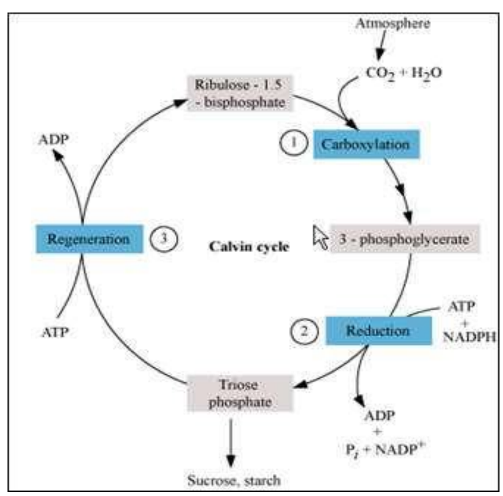
- ✓ This is a cycle biochemical pathway of reduction of CO_2 or photosynthetic carbon, cycle, which was discovered by Melvin Calvin.
- ✓ The Calvin cycle runs in all photosynthetic plants, no matter they shows C3, C4 or any other pathways.

Primary Acceptor of CO2 in C3 Pathway

- ✓ After a long research and conducting many experiments it was concluded by the scientists that in C3 pathway, the acceptor molecule is a 5-carbon ketose sugar, i.e., Ribulose Bis phosphate (RuBP).
- ✓ Calvin cycle can be described under three stages: **carboxylation, reduction and regeneration.**
- ✓ **Carboxylation** is the fixation of CO_2 into 3-phosphoglyceric acid (3-PGA).
- ✓ Carboxylation of RuBP occurs in presence of enzyme **RuBP carboxylase-oxygenase (RuBisCO)** which results in the formation of two molecules of 3-PGA.
- ✓ **Reduction** is series of reaction that leads to formation of glucose.
- ✓ Three molecules of ATP and two molecules of NADPH are required for reduction of one molecules of CO_2.
- ✓ Hence, the fixation of 6 molecules of CO2 and 6 turns of the cycle are required in order to release one molecule of glucose from the

pathway.

- ✓ **Regeneration** is the generation of RuBP molecules for the continuation of cycle. This process require one molecules of ATP.
- ✓ Hence, for every CO2 molecule that- enters the Calvin cycle, required are 3 molecules of ATP and 2 molecules of NADPH.
- ✓ The cyclic phosphorylation takes place in order to meet the difference in the number of ATP and NADPH used in the dark reaction.
- ✓ Thus, in order to produce one molecule of glucose through the Calvin pathway, 18 ATPs and 12 NADPHs are required.



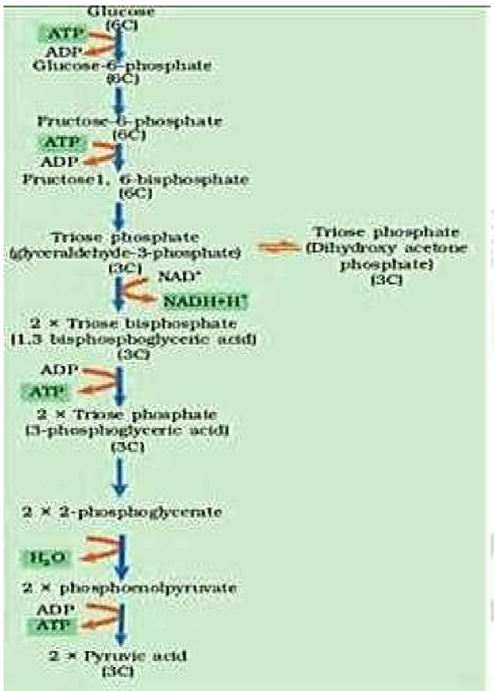
#############

RESPIRATION IN PLANTS

GLYCOLYSIS

- Glycolysis is a step-wise process by which one molecule of **glucose (6C)** breaks down into two molecules of **pyruvic acid (3C).**
- The scheme of glycolysis was given by Gustav Embden, Otto Meyerhof and J Parnas and is often referred as the **EMP pathway.**
- It is a common pathway in both aerobic and anaerobic modes of respiration.
- But in case of anaerobic organisms, it is the only process taking place during respiration.
- Glycolysis is the process in which glucose, derived from sucrose, undergoes partial oxidation to form two molecules of pyruvic acid.
- In plants this glucose is derived from sucrose (end product of photosynthesis) or from storage carbohydrates.
- e is converted into glucose and fructose by the enzyme, invertase, and these two monosaccharides readily enter the glycolytic pathway.

STEPS INVOLVED IN GLYCOLYSIS.



- Glucose and fructose are phosphorylated to give rise to glucose-6- phosphate by the activity of the enzyme hexokinase.
- Isomerisation of this phosphorylated glucose-6-phsophate takes place to form **fructose-6-phosphate** with the help of an enzyme **phosphohexose isomerase**
- This fructose-6-phosphate is again phosphorylated by ATP in order to form **fructose 1, 6-bisphosphate** in the presence of an enzyme **phosphofructokinase and Mg2+.**
- Splitting of fructose 1, 6-bisphosphate takes place into two triose phosphate molecules, i.e., **dihydroxyacetone phosphate** and **3-phosphoglyceraldehyde (i.e., PGAL).**
- Each molecule of PGAL removes two redox equivalents in the form of hydrogen atom and transfer them to a molecule of NAD+ (This NAD+ forms NADH + H^+).
- Glyceraldehyde 3-phosphate is converted to **1,3- bisphosphoglyceric acid** by the enzyme glyceraldehyde 3- phosphate dehydrogenase
- 1,3-bisphosphoglyceric acid is converted to **3-phosphoglyceric acid** by the enzyme phosphoglycerate kinase.
- 3-phosphoglyceric acid is converted to **2-phosphoglycerate** by the enzyme phophoglyceromutase.
- 2-phosphoglycerate is converted to **Phosphoenol Pyruvate(PEP)** with the release of one molecule of water
- Pyruvate kinase converts phosphoenol pyruvate to pyruvate.

Metabolic Fate of Glycolysis

- ATP is utilised at two steps: first in the conversion of glucose into glucose 6-phosphate and second in the conversion of fructose 6-phosphate to fructose 1, 6-bisphosphate.
- When 3-phosphoglyceraldehyde (PGAL) is converted to 1, 3-bisphosphoglyceric acid (BPGA), NADH + H^+ is formed from NAD+.
- Conversion of 1,3-bisphosphoglycerate to 3-phosphoglycerate and phospho-enol pyruvate to pyruvate, are energy-yielding process, where energy is trapped by the formation of **ATP.**
- The overall reaction of glycolysis can be

depicted as

Glucose + 2Pi + 2ADP + $2NAD^+$ —> 2 Pyruvate + 2ATP + $2NADH+H^+$

- Two molecules of NADH+H+ on oxidation produce 6 molecules of ATP. Therefore, a net gain of 8ATP molecules occurs during glycolysis.
- There are three major ways in which different cells handle pyruvic acid produced by glycolysis.
- These are **lactic acid fermentation, alcoholic fermentation** and **aerobic respiration.**
- Fermentation takes place under anaerobic conditions in many prokaryotes and unicellular eukaryotes.
- For the complete oxidation of glucose to CO_2 and H_2O, organisms follow **Krebs' cycle**,which is also called as aerobic respiration.

FERMENTATION

- Fermentation is the incomplete oxidation of glucose under anaerobic conditions by sets of reactions.
- Fermentation is of two types
- **1.Alcoholic fermentation 2.Lactic acid fermentation.**
- In alcohol fermentation, pyruvic acid is converted to CO_2 and ethanol by pyruvic acid decarboxylase and alcohol dehydrogenase.
- It is done under two steps
- (a) Pyruvic acid is first de-carboxylated to acetaldehyde in the presence of enzyme pyruvic acid decarboxylase.
- (b) This acetaldehyde is further reduced to ethyl alcohol or ethanol in the presence of enzyme, i.e., alcohol dehydrogenase.
- During lactic acid fermentation, organisms like some bacteria produces lactic acid as an end product from pyruvic acid.
- In some animal cells(muscles during exercise) when oxygen is inadequate for cellular respiration pyruvic acid is reduced to lactic acid by lactate dehydrogenase.
- In the alcoholic and lactic acid fermentation, $NADH+H^+$ is the reducing agent which is oxidized to NAD^+.
- The energy released in both the processes is not much and the total sum of ATP molecules produced during fermentation is 2 ATP.
- In both lactic acid and alcohol fermentation not much energy is released.
- i.e., not more than 7% of the energy is released from glucose and not all of it is trapped as high energy bonds of ATP.
- The fermentation processes are proved to be hazardous in nature because either acid or alcohol is produced on oxidation.
- Apart from this, yeasts may also poison themselves to death if the concentration of alcohol reaches about 13%.
- In eukaryotes complete oxidation of glucose take place within the mitochondria and this requires O_2.
- Aerobic respiration is the process that leads to a complete oxidation of organic substances in the presence of oxygen, and releases CO_2 , water and a large amount of energy present in the substrate.

AEROBIC RESPIRATION

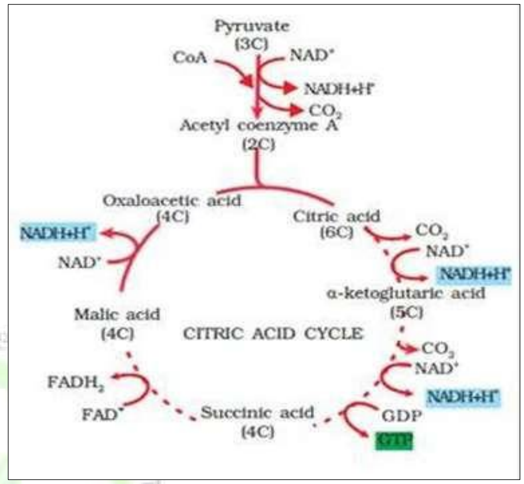
- The complete breakdown of glucose molecules in the presence of oxygen to release energy is called aerobic respiration.
- For aerobic respiration, pyruvate is transported from the cytoplasm into the mitochondria.
- The crucial events in aerobic respiration are:
  1.The complete oxidation of pyruvate by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO_2 .
  2.The passing on of the electrons removed as part of the hydrogen atoms to molecular O2 with simultaneous synthesis of ATP
- First event takes place in the matrix of the mitochondria while the second process is located on the inner membrane of the mitochondria.
- In mitochondria, Pyruvate undergoes oxidative decarboxylation by a complex set of reactions catalysed by pyruvic dehydrogenase with the participation of several coenzymes, including NAD^+ and Co-enzyme A.

$$\text{Pyruvic acid} + \text{Co-A} + NAD^{+} \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{acetyl Co-A} + CO_2 + NADH + H^{+}$$

- Two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid.
- The acetyl CoA then enters a cyclic pathway, **tricarboxylic acid cycle**, more commonly called as **Krebs' cycle** after the scientist **Hans Krebs** who first elucidated it.

TRICARBOXYLIC ACID CYCLE

- The TCA cycle starts with the condensation of acetyl Co-enzyme A with oxaloacetic acid (OAA) and water to yield citric acid.
- The reaction is catalysed by the enzyme citrate synthase and one molecule of CoA is released.
- Citrate is then isomerised to isocitrate.
- It is followed by two successive steps of decarboxylation, leading to the formation of α-ketoglutaric acid and then succinyl-CoA.
- In the next step Succinyl-CoA is oxidised to OAA allowing the cycle to continue.
- During the conversion of succinyl-CoA to succinic acid a molecule of GTP is synthesised.This is a substrate level phosphorylation.
- In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP.



Output of Krebs' Cycle or Citric Acid Cycle

- During this cycle of reactions, 3 molecules of NAD+ are reduced to NADH + H^+, and one molecule of FAD^+ is reduced to FADH2.
- uring this one molecule of ATP is reduced directly from GTP (by substrate level phosphorylation).
- For continuous oxidation of acetyl Co-A, continued replenishment of oxalo acetic acid is necessary.
- In addition to this regeneration of NAD+ from NADH and FAD+ from FADH2 are also required.

$$\textbf{Pyruvic acid} + 4NAD^{+} + FAD^{+} + 2H_2O + ADP + Pi \longrightarrow 3CO_2 + 4NADH + 4H^{+} + FADH_2 + ATP$$

- At the end, glucose has been broken down to release CO_2 and 8 molecules of NADH+H^+, two $FADH_2$ are synthesised and just two molecules of ATP.

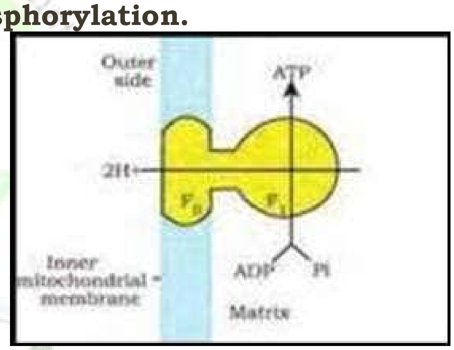
ELECTRON TRANSPORT SYSTEM (ETS) AND OXIDATIVE PHOSPHORYLATION

- These reactions in the respiratory process are to release and utilise the energy stored in NADH+H+ and FADH2.
- The metabolic pathway through which the electron passes from one carrier to another, is called the **electron transport system (ETS)** and it is present in the inner mitochondrial membrane.
- This is accomplished when they are oxidised through the electron transport system and the electrons are passed on to O_2 resulting in the formation of H_2O.
- Electrons from NADH produced in the mitochondrial matrix during citric acid cycle are oxidised by an NADH dehydrogenase (complex I), and electrons are then transferred to ubiquinone located within the inner membrane.
- Ubiquinone also receives reducing equivalents via FADH2 (complex II) that is generated during oxidation of succinate in the citric acid cycle.
- The reduced ubiquinone (ubiquinol) is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc1 complex (complex III).
- Cytochrome c is a small protein attached to the outer surface of the inner membrane and acts as a mobile carrier for transfer of electrons between complex III and IV.
- Complex IV refers to cytochrome c oxidase complex containing cytochromes a and a3 , and two copper centres.

- When the electrons pass from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase (complex V) for the production of ATP from ADP and inorganic phosphate.

OXIDATIVE PHOSPHORYLATION

- When the electrons pass from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase (complex V) for the production of ATP from ADP and inorganic phosphate.
- The electron transport and movement of protons creates a proton gradient across the mitochondrial membrane.
- The protons are pumped through a membrane protein called **complex-V.**
- This complex consists of two major components, **F_1 and F_0**.
- The F_1 headpiece is a peripheral membrane protein complex and contains the site for synthesis of ATP from ADP and inorganic phosphate.
- F_0 is an integral membrane protein complex that forms the channel through which protons cross the inner membrane.
- The energy derived from the proton pumping is used for the synthesis of ATP.
- For each ATP produced, $2H^+$ passes through F_0 from the intermembrane space to the matrix down the electrochemical proton gradient.
- The number of ATP molecules synthesised depends on the nature of the electron donor.
- Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while that of one molecule of FADH2 produces 2 molecules of ATP.
- Although the aerobic process of respiration takes place only in the presence of oxygen, the role of oxygen is limited to the terminal stage of the process.
- The presence of oxygen is vital, since it drives the whole process by removing hydrogen from the system.
- Oxygen acts as the final hydrogen acceptor.
- During respiration ,the energy of oxidation-reduction utilised for the phosphorylation and hence the process is called **oxidative phosphorylation.**



-

PLANT GROWTH AND DEVELOPMENT

PLANT GROWTH REGULATORS

- The plant growth regulators (PGRs) are small, simple molecules of diverse chemical composition.
- Examples- Indole compounds (indole-3-acetic acid, IAA); adenine derivatives (N6-furfuryl- amino purine, kinetin), derivatives of carotenoids (abscisic acid, ABA); terpenes (gibberellic acid, GA3); gases (ethylene, C_2H_4).
- The PGRs can be broadly divided into two groups based on their functions,**Plant growth promoter** and **Plant growth inhibitor**
- Plant growth promoters are involved in growth promoting activities, such as cell division, cell enlargement, pattern formation.
- Major growth promoters include auxins, gibberellins and cytokinin.
- Plant growth inhibitors are involved in various growth inhibiting activities such as dormancy and abscission.Example- abscisic acid
- Ethylene acts as both promoter and inhibitor, though it is largely an inhibitor of growth activities.

PHYSIOLOGICAL EFFECTS OF PLANT GROWTH REGULATORS

1.Auxins

- The term 'auxin' is applied to the indole-3-acetic acid (IAA), and to other natural and synthetic compounds having certain growth regulating properties.
- They are generally produced by the growing apices of the stems and roots.
- IAA and indole butyric acid (IBA) have been isolated from plants(natural) and NAA (naphthalene acetic acid) and 2, 4-D (2, 4-dichlorophenoxyacetic) are synthetic auxins.
- They help to initiate rooting in stem cuttings, promote flowering, prevent fruit and leaf drop at early stages, induce parthenocarpy (example- tomato).
- Auxin help to prevent fruit and leaf drop at early stages but promote the abscission of older mature leaves and fruits.
- Auxin also controls xylem differentiation and helps in cell division.
- Auxin promotes **apical dominance.**
- In most higher plants, the growing apical bud inhibits the growth of the lateral (axillary) buds, a phenomenon called **apical dominance.**
- Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations, hedge-making.
- Auxins are widely used as herbicides. Example- 2, 4-D is widely used to kill dicotyledonous weeds.

2.Gibberellins

- All gibberellins are acidic and are denoted as GA_1, GA_2,GA_3 ...and so on.
- Gibberellic acid (GA_3) was one of the first gibberellins to be discovered.
- Their ability to cause an increase in length of axis is used to increase the length of grapes stalks.
- They help to elongate and improve shape of fruits, delay senescence,
- Spraying sugarcane crop with gibberellins increases the length of the stem, thus increasing the yield
- Gibberellins also promotes bolting (internode elongation just prior to flowering) in beet, cabbages and many plants with rosette habit.
- Gibberellins also promotes bolting, defined as internode elongation just prior to flowering, in beet, cabbages.

3.Cytokinins

- Cytokinins were discovered as kinetin (a modified form of adenine, a purine) from the autoclaved herring sperm DNA.
- Zeatin is a natural cytokinin isolated from corn-kernels and coconut milk.
- Natural cytokinins are synthesised in regions where rapid cell division occurs, for example, root apices.
- Cytokinin helps to produce new leaves, chloroplasts in leaves, lateral shoot growth and adventitious shoot formation.

- Cytokinins help overcome the apical dominance and promote nutrient mobilisation which helps in the delay of leaf senescence.

4.Ethylene

- Ethylene is a simple gaseous plant growth regulator synthesized by tissues undergoing senescence and in ripening fruits.
- Influences of ethylene on plants include horizontal growth of seedlings, swelling of the axis and apical hook formation in dicot seedlings.
- Ethylene promotes senescence and abscission of plant organs,and ripening of fruits.
- It enhances the respiration rate during ripening of the fruits.This rise in rate of respiration is called **respiratory climactic**.
- Ethylene breaks seed and bud dormancy, initiates germination in peanut seeds, sprouting of potato tubers.
- Ethylene promotes rapid internode/petiole elongation in deep water rice plants. It helps leaves/ upper parts of the shoot to remain above water.
- Ethylene also promotes root growth and root hair formation, thus helping the plants to increase their absorption surface.
- Ethephon is the most widely used compound as a source of ethylene in agricultuer.
- Ethephon in an aqueous solution is readily absorbed and transported within the plant and releases ethylene slowly.
- Ethephon hastens fruit ripening in tomatoes and apples and accelerates abscission in flowers and fruits.
- It promotes female flowers in cucumbers thereby increasing the yield.

5.Abscisic Acid

- Abscisic acid (ABA) was discovered for its role in regulating abscission and dormancy.
- ABA inhibits seed germination.
- ABA stimulates the closure of stomata and increases the tolerance of plants to various kinds of stresses. Therefore, it is also called the **stress hormone.**
- ABA plays an important role in seed development, maturation and dormancy.
- By inducing dormancy, ABA helps seeds to withstand desiccation and other factors unfavourable for growth .
- ABA acts as an antagonist to Gibberellin.

Interaction between Plant Growth Regulators

- For every phase of growth, differentiation and development of plants, one or the other PGR has some role to play.
- These can either act synergistically or antagonistically.
- Similarly many functions in the plant body are controlled by more than one planr growth regulator.Eg. dormancy in seeds/ buds, abscission, senescence, apical dominance, etc

PHOTOPERIODISM

- The response of plants to periods of day/night is termed photoperiodism
- The effects of **photoperiods** or daily duration of light periods (and dark periods) on the growth and development of plants, especially flowering is called **photoperiodism**.
- The site of perception of light/dark duration are the leaves.
- (i) **Short day plants (SDP):** These plants initiate flowering when the day length(Photoperiod) become shorter than a certain critical period .Eg. *ChrysanthEMUm*, sugarcane
- (ii) **Long day plants (LDP) :** These plants begin flowering when the day length exceeds a critical length.
- The critical duration is different for different plants.
- (iii) **Day neutral plants :** These plants can flower in all possible photoperiods. The day neutral plants can blossom throughout the year. *e.g.,* cucumber, cotton, sunflower, tomato

################