UNIT-I: PLANT WATER RELATIONS

1) Importance of water in plant life

- Water is a constituent of protoplasm
- It helps to maintain turgidity of cells and plant organ
- Water helps to maintain the turgidity of cell walls. Water helps in cell enlargement due to turgor pressure and cell division which ultimately increase the growth of plant
- Water is essential for the germination of seeds
- Water regulates the temperature and cools the plant.
- Water plays a significant role in movement of asexual spore and gametes
- Water plays a significant role in opening and closing of stomata
- Water plays a significant role in fruit dehiscence and seed dispersal
- Water plays a significant role in dehiscence of sporangia and dispersal of spores
- Water also helps in pollination in aquatic plants
- To activate enzyme water is essential
- Water help in translocation of enzymes and hormones in plant
- They are used for photosynthesis and the end product is also conveyed through water to various plant parts
- Water helps in the transpiration, which is very essential for maintaining the absorption of nutrient from the soil.
- Water is essential in hydraulic process in the plant. It helps in the conversion of starch to sugar
- Water dissolves the nutrients present in the soil which is then transported to the various parts of the plant.
- Water provides a medium for transportation of food and minerals within the plant.
- Water is also a reactant in the hydrolysis of plant food reserves such as starch.

Different bio-physico-chemical phenomenon: Permeability, Diffusion, Osmosis,Plasmolysis and Imbibition.

1- Permeability,

Defination-

The ability of a substance to pass through a membrane is also called as permeability A membrane may be freely permeable for one substance, moderately permeable for the second one and may be completely impermeable for the third one.

On this basis following types of membranes have been recognized:

1- Freely permeable membrane

2- Impermeable membrane

3- Semi-permeable membrane

1-Freely permeable membrane:

This type of membrane allows free movement (passage) of various substance, such as water, other solvents, various ions and dissolved solutes, e x – Cell wall.

2- Impermeable membrane:

This type of membrane does not allow any kind of movement through it., e.g., – cultinized cell wall.

3-Semi-permeable membrane:

A membrane that is selectively permeable, i.e. being permeable to only certain molecules and not to allmolecules.

This type of membrane allows only solvent particles to pass through it. It does not allow the movement of solute particles, e.g., egg membrane, animal bladder, parchment membrane. These can be prepared artificially also.

4-Selectively permeable membrane or differentially permeable membrane:

These membranes allow only some selected molecules (of solute and solvent) to pass through it. Most of the biological membranes, such as cell membrane, tonoplast (vacuolar membrane) and the membrane surrounding the sub-cellular organelles are selectively permeable These membranes give a differential treatment to different kinds of molecules. Some molecules move very rapidly, some move very slowly, while rest other do not move at all. A nonliving selectively permeable membrane is cellophane.

2- Diffusion,

Def-The tendency of molecules of liquid, solid or gas move a place of higher concentration to place of lower concentration. or Diffusion is the movement of ions, atoms or molecules of solutes, liquids or gases form the region of their higher concentration to a region of their lower concentration till an equilibrium is attained

Examples-

a) Open bottle of ammonia or perfume in a room. The fumes or perfumes will spread all over the room in short time this is diffusion of gases
b) Place a crystal of copper sulphate in a beaker containing water. The copper sulphate slowly dissolve in the water and its molecules moves form the surface of the crystal to remaining part of water. This is example of diffusion of solid.

-The direction of migration is always form region where the molecules are in higher concentration to a region where their concentration is less.

-Diffusion pressure (DP) is the potential ability of solid, liquid or gas to diffuse form an area of its greatest concentration to an area of lesser concentration. The diffusion pressure of pure solvent is always more.

Types of Diffusion

Simple diffusion

A process in which the substance moves through a semipermeable membrane without any help from transport proteins. For example, bacteria deliver small nutrients, water, and oxygen into the cytoplasm through simple diffusion.

Facilitated diffusion

Facilitated diffusion is a passive movement of molecules across the cell membrane from the region of higher concentration to the region of lower concentration by means of a carrier molecule.

Diffusion pressure

It is a hypothetical term coined by Meyer (1938) to denote the potential ability of the molecules or ions of any substance to diffuse from an area of their higher concentration to that of their lower concentration. DP is directly proportional to the diffunsing particles.

Law of diffusion –

The process of diffusion of gases is governed by Grahams Law. It states that if other condition remaning same the rate ofdiffusion of gases are inversely proportional to the square roots of their density i.e. heavy gas will diffuse more slowly than of lighter gas

$$\frac{r1}{r2} \propto \sqrt{\frac{d2}{d1}}$$

d1 and d2- relative density of two gases

r1 and r2 – rate of diffusion

Ex. The hydrogen(molecular weight 2) and oxygen(molecular weight 32)

The rate of diffusion of H2 will be 4 time more than the rate of diffusion of O2 under ideal conditions

$$\frac{rH}{rO} \propto \sqrt{\frac{32}{2}} \quad = \frac{16}{1} = 4$$

Importance of diffusion of plants

- The exchange of gases like O2 and CO2 during photosynthesis and respiration takes place through stomata by diffusion
- During transpiration water vapours through intercellular spaces diffuse through stomata
- The diffusion of ions of mineral salts during passive absorption takes place
- Diffusion also helps in absorption of water through roots.

Osmosis

Def-Osmosis is the transfer of solvents (Water molecules) from a region of higher concentration to a region of lower concentration through semi-permeable membrane. Or diffusion of water or any solvent through a semi permeable membrane is called osmosis. Or ***Osmosis is a process by which the molecules of a solvent pass from a solution of low concentration to a solution of high concentration through a semi-permeable membrane."***

If the solutions of different concentration are separated by a semipermeable membrane, the membrane being selectively permeable not allow to pass solute molecules where as the solvent molecules will pass through it.

Osmotic Pressure

Osmotic pressure is the pressure required to stop water from diffusing through a membrane by osmosis. Or The pressure developed by water molecules on semi-permeable membrane is called osmotic pressure (O.P) or Osmotic pressure is defined as the minimum pressure applied to a solution to stop the flow of solvent molecules through a semipermeable membrane.

It is determined by the concentration of the solute. Water diffuses into the area of higher concentration from the area of lower concentration. When the concentration of the substances in the two areas in contact is different, the substances will diffuse until the concentration is uniform throughout.

Osmotic pressure can be calculated using the equation:

$\Pi = MRT$

where Π denotes the osmotic pressure,

M is the molar concentration of the solute,

R is the gas constant,

T is the temperature

Osmotic Solutions

There are three different types of solutions:

- Isotonic Solution
- Hypertonic Solution
- Hypotonic Solution

An **isotonic solution** is one that has the same concentration of solutes both inside and outside the cell.

A **hypertonic solution** is one that has a higher solute concentration outside the cell than inside.

A **hypotonic solution** is the one that has a higher solute concentration inside the cell than outside.

Types of Osmosis

Osmosis is of two types:

- **Endosmosis**– When a substance is placed in a hypotonic solution, the solvent molecules move inside the cell and the cell becomes turgid or undergo deplasmolysis. This is known as endosmosis.or Movement of water molecules into the cell when the cell is placed in hypotonic solution
- **Exosmosis**– When a substance is placed in a hypertonic solution, the solvent molecules move outside the cell and the cell becomes flaccid or undergo plasmolysis. This is known as exosmosis.or Movement of water molecules out of the cell when the cell is placed in concentration solution

Demonstration of osmosis

Potato Osmoscope

Demonstration of osmosis in a living system can be one using the potato osmoscope.A potato is peeled and one side is flattened which serves as the base. A cavity is made in the potato and is filled with concentrated sugar solution and a pin mark is made to indicate the initial level. This potato is then placed in a beaker containing coloured water for some time.It is observed that the sugar solution in the cavity of the potato becomes coloured and level rises.This proves the entry of water into the sugar solution through the potato tissues which serve as the selective permeable membrane.

U- Shaped tube –

Take a U shaped tube in the middle portion of the membrane form sheeps bladder is stretched. Fill the right limb of U tube with water and left limb is with 10% sugar solution(90%water +10% sugar solution). Thus right limb has 100% water and left limb has 90%water after some time water molecules from right limb will move into solution in the left limb. As a result of the diffusion of water the level of the solution in the left limb increases. This causes lowering of concentration in left limb and lowering level of the water in the right limb. such a type of membrane that allows water to pass freely but prevents passage of solutes is called semipermeable membrane.

Importance or Significance of Osmosis

- Osmosis influences the transport of nutrients and the release of metabolic waste products.
- It is responsible for the absorption of water from the soil and conducting it to the upper parts of the plant through the xylem.
- It stabilizes the internal environment of a living organism by maintaining the balance between water and intercellular fluid levels.
- It maintains the turgidity of cells.
- It is a process by which plants maintain their water content despite the constant water loss due to transpiration.
- This process controls the cell to cell diffusion of water.
- Osmosis induces cell turgor which regulates the movement of plants and plant parts.
- Osmosis also controls the dehiscence of fruits and sporangia.
- Higher osmotic pressure protects the plants against drought injury.

Plasmolysis

Def-Plasmolysis is defined as the process of contraction or shrinkage of the **protoplasm** of a plant cell and is caused due to the loss of water in the cell

Plasmolysis-

in normal plant cell protoplasm is tightly pressed against the cell wall. If this normal cell is placed in concentrated solution(Hypertonic) water comes out form the cell sap into the outer solution due to exosomosis, because of permeability of cell wall. Protoplasm shrinks or contracts from the cell wall. This is called as incipient plasmolysis. If the outer hypertonic solution is more concentrated as compared to cell sap protoplasm contracts or shrinks more and more due to exosmosis. The

protoplasm gets separated from the plant cell wall. It becomes spherical in form. This phenomenon is called as plasmolysis and the tissue or cell is called as plasmolysed cell. In plasmolysed cell, outer space is occupied by hypertonic solution

Deplasmolysis

When the plasmolysed cell is placed in a hypotonic solution, (the solution in which solute concentration is less than the cell sap), the water travels into the cell due to the higher concentration of water outside the cell. Then the cell swells and becomes turgid. This is known as deplasmolysis..Deplasmolysis is caused due to endosmosis.

Stages of Plasmolysis

The complete process of Plasmolysis take place in three different stages:

1. Incipient plasmolysis: It is the initial stage of the plasmolysis, during which, water starts flowing out of the cell; initially, the cell shrinks in volume and cell wall become detectable.
2. Evident plasmolysis: It is the next stage of the plasmolysis, during which, the cell wall has reached its limit of contraction and cytoplasm gets detached from the cell wall attaining the spherical shape.
3. Final plasmolysis: It is the third and the final stage of the plasmolysis, during which, the cytoplasm will be completely free from the cell wall and remains in the centre of the cell.

Types of Plasmolysis

There are two different types of plasmolysis and this classification is mainly based on the final structure of the cytoplasm.

Concave Plasmolysis

During the concave plasmolysis, both the cell membrane and protoplasm shrink away and begins to detach from the cell wall, which is caused due to the loss of water. Concave plasmolysis is a reversible process and it can be revised by placing the cell in a hypotonic solution, which helps calls to regain the water back into the cell.

Convex plasmolysis

During the convex plasmolysis, both the cell membrane and protoplasm lose so much water that they completely get detach from the cell wall. Later, the **cell wall** collapses and results in the destruction of the cell. Alike concave plasmolysis, convex plasmolysis cannot be reversed, and this happens when a plant wilts and dies from lack of water. This type of plasmolysis is more complicated compared to convex plasmolysis.

Examples of Plasmolysis

Plasmolysis is more common and happens in extreme cases of water loss. Some real-life examples of Plasmolysis are:

- Shrinkage of vegetables in hypertonic conditions.
- Blood cell shrinks when they are placed in the hypertonic conditions.
- Spraying of weedicides kills weeds in lawns, orchards and agricultural fields. This is due to the natural phenomena-Plasmolysis.

- When more amount of salt is added as the preservatives for food like jams, jellies, and pickles. The cells lose water due to higher concentration outside and become less conducive to support the growth of microorganisms.

Importance of Plasmolysis:

1. It is a vital phenomenon as it explains the process of osmosis.

2. Plasmolysis demonstrates the permeability of the cell wall and the semipermeable nature of the protoplasm.

3. It helps to detect whether a particular cell is living or dead as the plasmolysis does not take place in a dead cell.

4. Osmotic pressure of a cell can be determined by plasmolytic method.

5 . Plasmolysis is also used to check the growth of fungi and bacteria in jams and jellies.

6. Used to prove the permeability of cell wall and selectively permeable nature of plasma membrane.

Imbibition

Def- Adsorption of water by the dry hydrophilic colloids is called as Imbibition or The absorption of water by the solid particles of an adsorbent without forming a solution is called Imbibition. orThe adsorption of liquid, usually water, into the ultramicroscopic spaces or pores found in materials such as cellulose, pectin, and cytoplasmic proteins in seeds.

-Imbibition is one of the physical process available to the plant for uptake of water. If a small quantity of seeds were placed in water they absorb water they swell and there is an increases in the volume of seeds.

- example -Gum is placed in water it quickly takes up water and swells. This is because the gum is a dry hydrophilic colloid. It has a great affinity or attraction for water and water molecules becomes adsorbed on the surface of the colloidal particles of the gum. Such and adsorption of water by the dydrophillic colloids is scalled imbibitions

-example- when some pieces of grass or dry wood or dry seeds are placed in water they absorb the water quickly and swell up considerably so that their volume is increased

- In plants, the hydrophilic colloids viz., protein and carbohydrates, starch, cellulose and pectic substances have strong attraction towards water

- when piece of dry wood or dry seeds are placed in water they absorb the water quickly and swell up considerably so that their volume is increased. It is made up of cellulose lignin, pectin and other polysaccharide substances, which are also hydrophilic colloids

- The seeds contain storage resave food such proteins, carbohydrates,starch which have strong attraction towards water which are also hydrophilic colloids.

The substance which imbibes water is called imbibant. During imbibitions the the imbibant increases in volume and if the imbibant is tightly enclosed then great pressure is devolped and this is called imbibitions pressure

Although the volume of imbibant increases the final volume of the imbibant plus the volume of water decreases is less than what it was before the starting of imbibitions. This is because water molecules are tightly adsorbed on the colloids and are packed closely together. Becauses of this tight adsorption a part of free energy of the molecule is liberated as heat. Therefore temperature increases when imbibitions takes place

Imbibition Pressure:

When the imbibing substance is kept in a confined space, pressure is developed due to the increase in the volume of the imbibant. This is called imbibition pressure. It develops due to the matric potential of the imbibant, hence called matric potential and is denoted as Ψ_m (= psi) Ψ_m measured in bars or mega pascals (MPa). Now a days, the term imbibition pressure is replaced by the new term matric potential.

Role of Imbibition In Plants:

(i) Imbibition is the first step in the absorption of water by the roots and cells,

(ii) Imbibition of water by cell walls helps to keep the cells moist, and

(iii) Imbibition pressure is helpful in seed germination, growth of seedling through the soil, ascent of sap in plants, etc

Significance of Imbibition:

1. It is the dominant and first step of water absorption.

2. Imbibition is the first step of seed germination.

3. Seedling is able to come out of soil due to development of imbibitional pressure.

Factors Influencing Imbibition:

(a) Texture of the imbibant

(b) Affinity of the imbibant for the imbibate

(c) Temperature

(d) Pressure

Ascent of sap: Introduction and mechanism (transpiration pull theory)

Def-The upward movement of water is called as ascent of sap or The transport of water from root to other aerial parts like stem and leaves against gravity.

The water after being absorbed by the roots is distributed to all parts of the plant (excess of which is lost through transpiration). In order to reach the topmost parts of the plant, the water has to move upward through the stem. This upward movement of water is called as Ascent of Sap.

Mechanism-

- water is absorbed by the roots moves upwards till it is transpired. Plants which transpire slowly, water enters into the root hair from the soil by imbibitions and osmosis then from there it passes radially inwards by cell to cell by osmotic diffusion and is ultimately injected into the xylem elements of the root under pressure

- The movement of water is rapidly transpiring plants is form the soil to the root xylem across root epidermis and cortex in a continuous stream.

- This movement of water is due to the negative tension developed in the lower end of the sylem ducts which pulls the water form the soil across the root cells.

- From the root xylem the upward movement of water in vessels and tracheids of the root and stem takes place due to forces such as root pressure capillalry force, cohesion of water and pumping activity of the living cortical cells

- Some of the water in the xylem of the stem and older parts of root diffuses radially ouwards by osmosis into the epidermis through the cells of the medullary rays and cortex a part of it being transpired through the stomata and the cuticle.

- The ascent of water continues through the xylem of the petiole into the veins of the leaf blades.the water passes form the xylem into the cell of the mesophyll and epidermis by osmosis and a result of diffusion pressure gradient.

- A part of this water saturates the wall of the mesophylls cells, water is evaporated into the inter cellular spaces form where it diffuse into the outer air through the stomata. Some water is also lost by transpiration form the epidermis through the cuticle and in some cases by guttation form the ends of the vein.

Path▸ water mover from---- soil -----Root hairs-----imbibition and osmosis-----root cell , root epidermis, root cortex----xylem elements of root-----stem xylem---stem cell -----petiole----venin of leaf----mesophyll cell of leaf-----traspiration-------stomata and cuticle ----remove outside

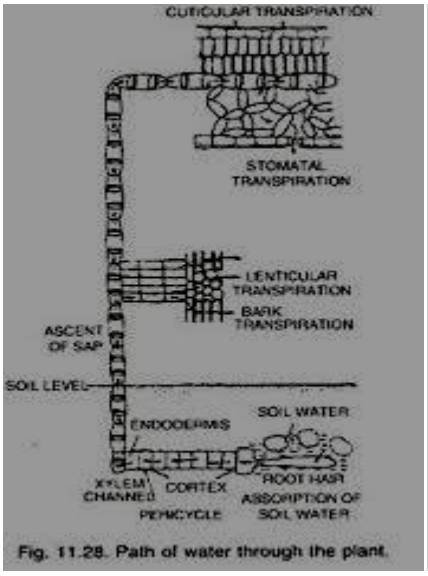


Fig. 11.28. Path of water through the plant.

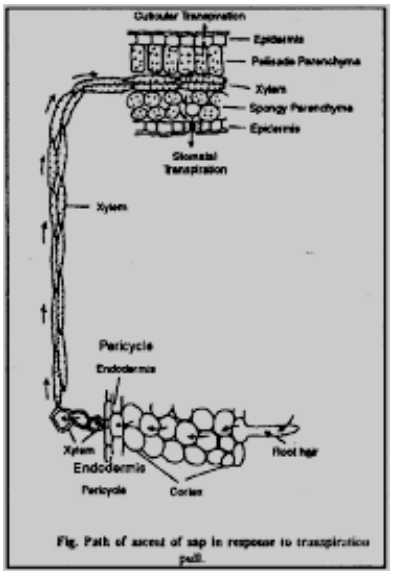


Fig. Path of ascent of sap in response to transpiration pull.

<u>Trasnspiration pull theory or Cohesion theory</u>

This theory was originally proposed by Dixon and Joly (1894) and greatly supported and elaborated by Dixon (1914, 1924).

This theory is based on the following features:

(i) Cohesive and Adhesive properties of water molecules to form a continuous water column in the xylem.

(ii) Transpiration pull exerted on this water column.

<u>Cohesive and Adhesive properties of water molecules to form a continuous water column in the xylem.</u>

- There is a continuous column of water from root through the stem and into the leaves. The water column is present in tracheary elements. The latter do operate separately but form a continuous system through their un-thickened areas.

- Water molecules remain attached to one another by a strong mutual force of attraction called cohesion force. The mutual attraction is due to hydrogen bonds formed amongst adjacent water molecules On account of cohesion force, the water column can bear a tension or pull of up to 100 atm.

- Therefore, the cohesion force is also called tensile strength

- Water column does not further break its connection from the tracheary elements (vessels and tracheids) because of another force called adhesion force between their walls and water molecules.

Transpiration pull exerted on this water column.

- Intercellular spaces present amongst mesophyll cells of the leaves are always saturated with water vapours. The latter come from the wet walls of mesophyll cells. The intercellular spaces of mesophyll are connected to the outside air through stomata. Outside air is seldom saturated with water vapours. It has a lower water potential than the moist air present inside the leaf.

- Intercellular spaces present amongst mesophyll cells of the leaves are always saturated with water vapours. The latter come from the wet walls of mesophyll cells. The intercellular spaces of mesophyll are connected to the outside air through stomata. Outside air is seldom saturated with water vapours. It has a lower water potential than the moist air present inside the leaf.

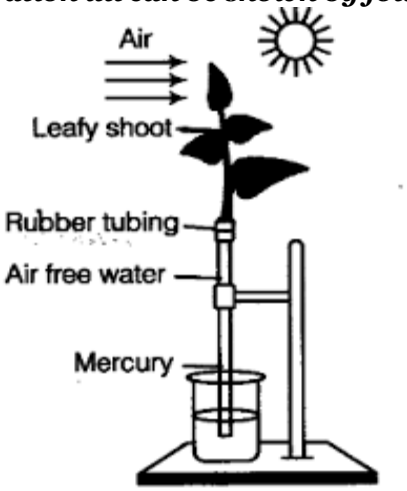
- Therefore, water vapours diffuse out of the leaves. The mesophyll cells continue to lose water to the intercellular spaces. As a result curvature of meniscus holding water increases resulting in increase in surface tension and decrease in water potential, sometimes to -30 bars. The mesophyll cells withdraw water from the deeper cells as its molecules are held together by hydrogen bond

- The deeper cells in turn obtain water from the tracheary elements. The water in the tracheary elements would, therefore, come under tension. A similar tension is felt in millions of tracheary elements lying adjacent to the transpiring cells.

- It causes the whole water column of the plant to come under tension. As the tension develops due to transpiration, it is also called transpiration pull

According this theory as a result of transpiration pull pressure is exerted on the column of water in the wood vessels foromabove. The water vapour evaporates through stomata, the stomatal cells with draw water from the surrounding mesophyll cells, which in turn will draw water from the vacuoles of the cell. Thus the turgour pressure decreases and the osmotic pressure increases, resulting increases of suction pressure. Thus a gradient of suction pressure is developed up to leaf veins. In leaves this force may be of 10-15 atmosphere.

The evidence of transpiration ull can be shown by following experiment



A narrow vertical glass tube filled with water is placed in a mercury dish. At the open upper end a branch is fitted and made air tight with the help of polythene sheet. As transpiration takes place due to suction pressure developed mercury is drawn in to the tube thus water is drawn up form the tube due to trasnpirational pull. During hot and dry days the rate of transpiration is high and the transpiration pull is also high.

Transpiration Definition

"Transpiration is the biological process by which water is lost in the form of water vapour from the aerial parts of the plants." Or The evaporation of water fom the surface of the aerial part of the plant is called Transpiration

Types of Transpiration

Transpiration mainly takes place through surface of leaves. It is known as Foliar transpiration (more than 90%). Transpiration occurs through young or mature stem is called as Cauline transpiration.

Depending on the organ that performs transpiration, the different types are:

- ***Stomatal transpiration***: Water vapour diffuses out through minute pore (stomata) present in soft aerial part of plant is known as Stomatal Transpiration. It is the evaporation of water through stomata. Stomata are specialized pores in the leaves. Stomatal transpiration is commonly found in leaves and stem of young plants. Stomata ar more number on lower than uppr epidermis. The maximum loss of water neary of 85-90% take place thorugh stomatal trasnpiratino only
- ***Cuticular transpiration***: The trasnpiration take place by direct evaporation of water through cuticle is called cuticular transpiration. Cuticle is an impermeable covering present on the leaves and stem.The water loss by cuticular transpiratio is not much when coparied to over all rate of transpiration. Cuticuar trasnpiration is only 3-5 % of the total transpiration. The rate of cuticular trasnpiration is depend on thickness of cuticle. Cuticular transpiration is lesser in xerophytes because they have thicker cuticles.
- ***Lenticular Transpiration***: It is the evaporation of water through lenticels. Lenticels are the tiny openings present on the woody bark. Some time in the wood bark stem small lenticells are present they contain loosly arranged cells some amount of water is loss through lenticel. It is very negliglibe because amount of water lost through lenticel may be about.1% of the total loss.

Structure of Stomata

Stomata was discovered by Pfeffer & name 'stomata' was given by Malphigii. Stomata cover 1-2% of leaf area. It is minute pore present in soft aerial parts of the plant. Algae, fungi and submerged plants do not possess stomata.

(a) Stomata are minute pores of eliptical shape, consists of two specialized epidermal cell called guard cells.

b) The guard cells are kidney shape in dicotyledon and dumbell shape in monocotyledon.

The inner wall of the guard cell towards the stomata is thicker as compared to the outer walls.

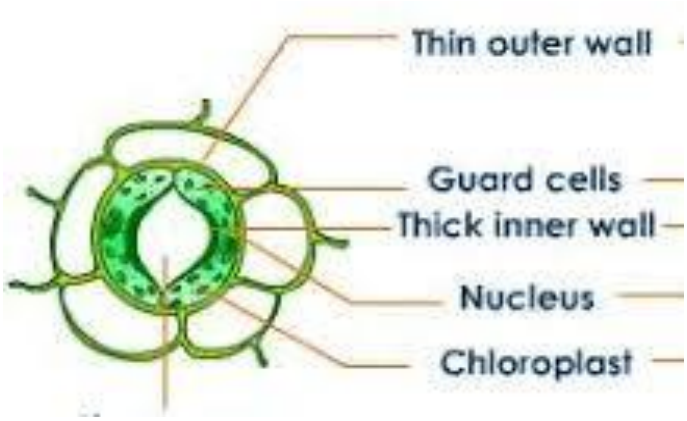
The interior wall of the guard cells present towards the aperture is dense and flexible. The stomata open when the turgidity of the guard cells increases. The exterior walls bulge out, and the interior walls form a crescent shape.

(d) Each guard cell has a cytoplasmic lining, central vacuole. It cytoplasm contains single nucleus and number of chloroplast. The chloroplast of guard cell are capable of very poor photosynthesis, because the absence of RUBISCO enzyme.

(e) Guard cells are surrounded by modified epidermal cells, known as subsidiary cells or accessory cells, which supports in the movement of guard cells.

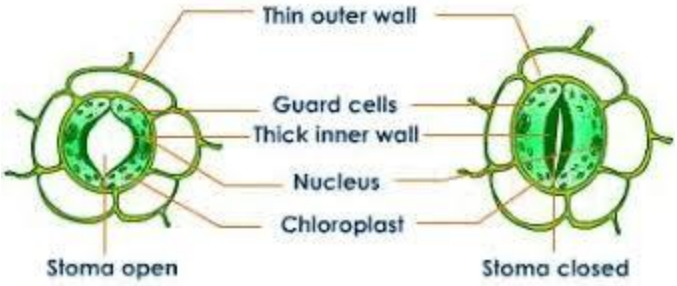
(f) The Size and shape of stoma and guard cell vary from plant to plant. When fully open, the stomatal pore measures 3-12 in width and 10-40 in length.

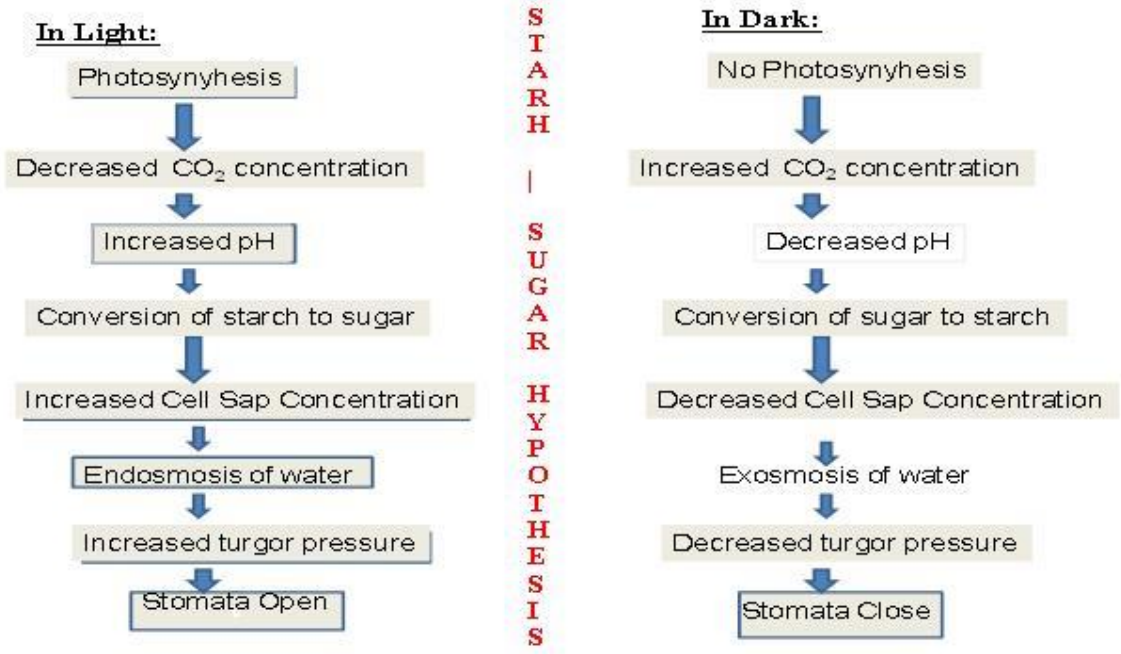
In a dorsiventral dicotyledonous leaf, the number of stomata on the lower surface is higher when compared to the upper surface. This adaptation helps in reducing the evaporation of water. In isobilateral leaf in a monocotyledonous plant, the number of stomata is equal on both the surfaces.

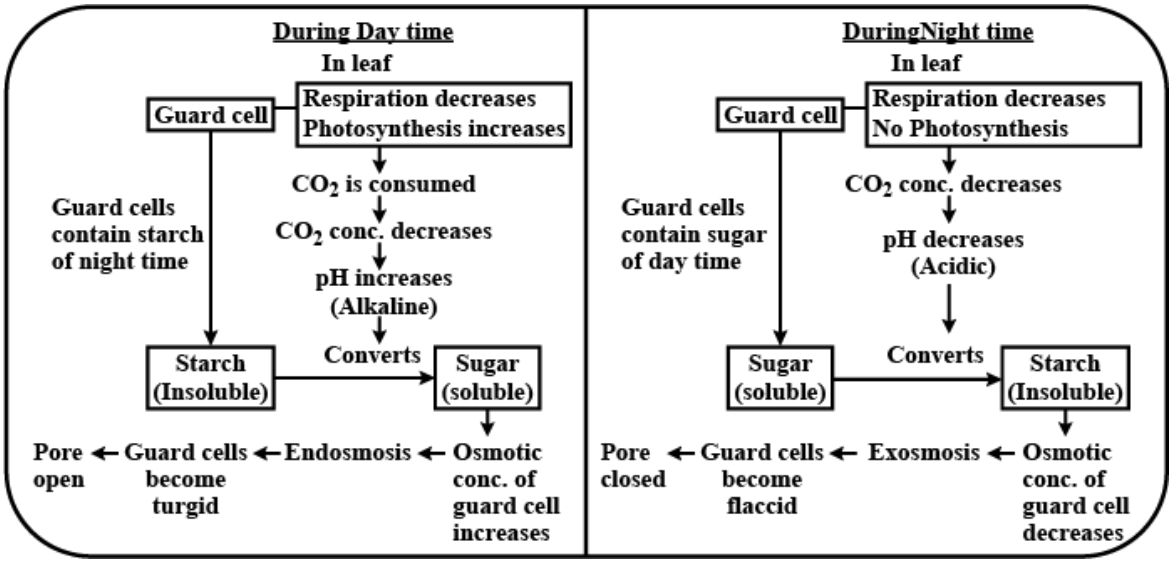


Mechanism of opening and closing of stomata (starch-sugar theory and K+ pump theory)

-Opening and closing of stomata takes place due to changes in turgor of guard cells. Generally stomata are open during the day and close at night.The turgor changes in the guard cells are due to entry and exit of water into and out of the guard cells.







-When the guard cell absorbed water from the surrounding cells or subsidary cells it expands and become turgid this exerts pressures causing the thin outer wall to pull outward this causes the inner thick wall to be pulled apart becoming concave and results n the opening of the stomata. When the

guard cell loss their turgidity and become contracted or flaccid the inner thick wall come back to their original position i.e. move inward and finally close the stomata

The mechanism of the closing and opening of the stomata depends upon the presence of sugar and starch in the guard cells. During day time or in the presence of light, the guard cells of the stomata contain sugar synthesized by their chloroplasts.

In day sugar is soluble and increases the concentration of the sap of guard cells. This bring about an increase in the osmotic pressure of the guard cell and causes entry of water form subsidiary cell to guard cell and guard cell turgid resulting in the opening of stomata.

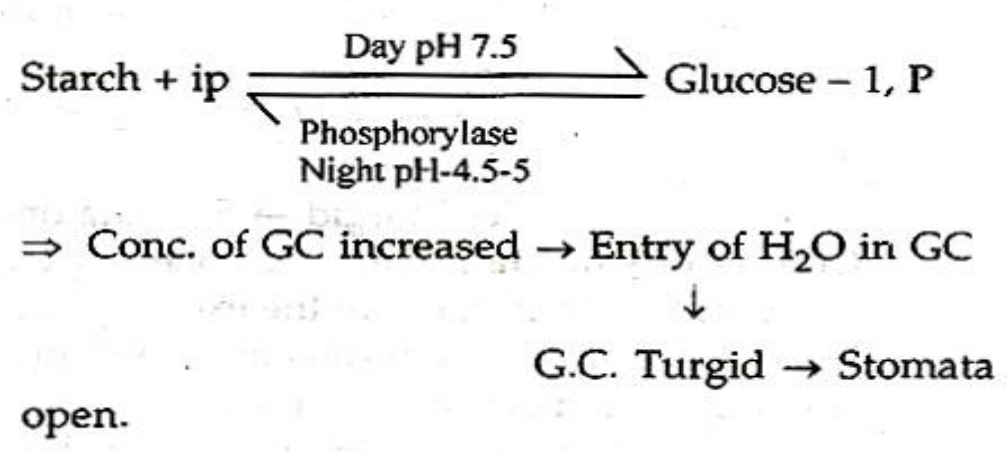
In night sugar decreases in guard cell(In the night or in the absence of light the sugar present in guard cells converts into the starch.). The starch is insoluble thus osmotic pressure become lower than the surrounding cell causes the water to flow form guard cell into subsidiary or surrounding cell. The guard cell contract and become flaccid resulting in the closing of stomata.

The conversion of sugar into starch during night and vice-versa in day time depends upon the acidity (pH) and alkalinity of the cell sap of guard cells. During night there is no photosynthesis and the carbon dioxide accumulates in the guard cells, converting the cell sap into weak acidic starch.

During day time the carbon dioxide is used in the process of photosynthesis, the cell sap becomes alkaline and the starch converts into sugar.

Theory of opening and closing of stomata

1. **The Starch - Sugar interconversion** Theory: This theory was put forward by Steward in 1964. According to him, during day time phosphorylase enzyme converts the starch into sugar due to which osmotic potential of guard cell increased and allow the entry of water into the cell. During the night same reaction occur in reverse direction which closes the guard cell i.e. stomata is closed during night.



2. **Proton - Potassium Pump Hypothesis**:
   This theory is called Malate hypothesis. According to theory In presence of light malic acid is produced probably from starch during respiration in the guard cells.
   Levit in 1974 combined the points in Scarth's and Steward's hypothesis and gave a modified version of the mechanism of stomatal movement which was called the proton - potassium

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

- Under the influence of light Malic acid produced In the chloroplast of the guard cells is excreted into its cytoplasm. Malic acid being a week acid dissociated into malate ions and H+ ions. These released H+ ions are enter in the guard cells. This ions exchange at the plasma membrane is an active process involving expenditure of metabolic energy. K + ions react with the malate ions present in the guard cells to form potassium malate. The accumulation of K+ Malate ions, increase the osmotic pressure of the guard cell. This result in the flow of water into the guard cells. Which become turgid resulting into the opening of stomata
- At night the dissociation of potassium malate takes place. H+ ions enter and K+ ions leaves the guard cell. Malate and H ions combine to form malic acid. which is used in respiration. This leads to decrease in osmotic pressure of guard cells, loose their turgidity and results in the closer of stomata

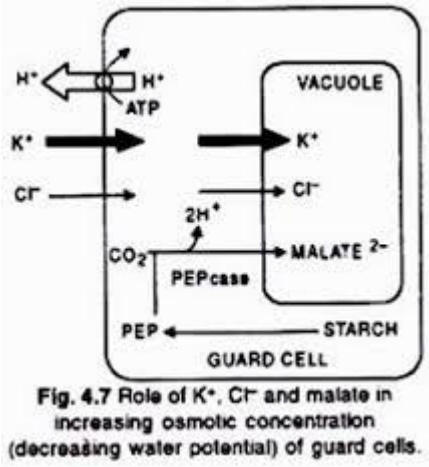


Fig. 4.7 Role of K^+, Cl^- and malate in increasing osmotic concentration (decreasing water potential) of guard cells.

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

Significance of Transpiration in Plants

The significance of transpiration is explained below:

1. Transpiration helps in the conduction of water and minerals to different parts of the plants.
2. Due to the continuous elimination of water from the plant body, there is a balance of water maintained within the plant.
3. It maintains osmosis and keeps the cells rigid.
4. A suction force is created by transpiration that helps in the upward movement of water in the plants.

5. Certain hydrophilic salts are accumulated on the surface of the leaves, which keeps the leaves moist.
6. It maintains the turgidity of the cells and helps in cell division.
7. Optimum transpiration helps in the proper growth of the plants.
8. The cooling effect of a tree is due to the evaporation of water from its leaves.

In addition to the significance, transpiration has a few drawbacks:

- Transpiration slows down if the transpired water is not compensated by absorption from the soil.
- A lot of energy is released during transpiration.
- Plenty of unnecessary water is absorbed by the plants during the process.

Plant movements: Introduction, classification, paratonic and nastic movements.

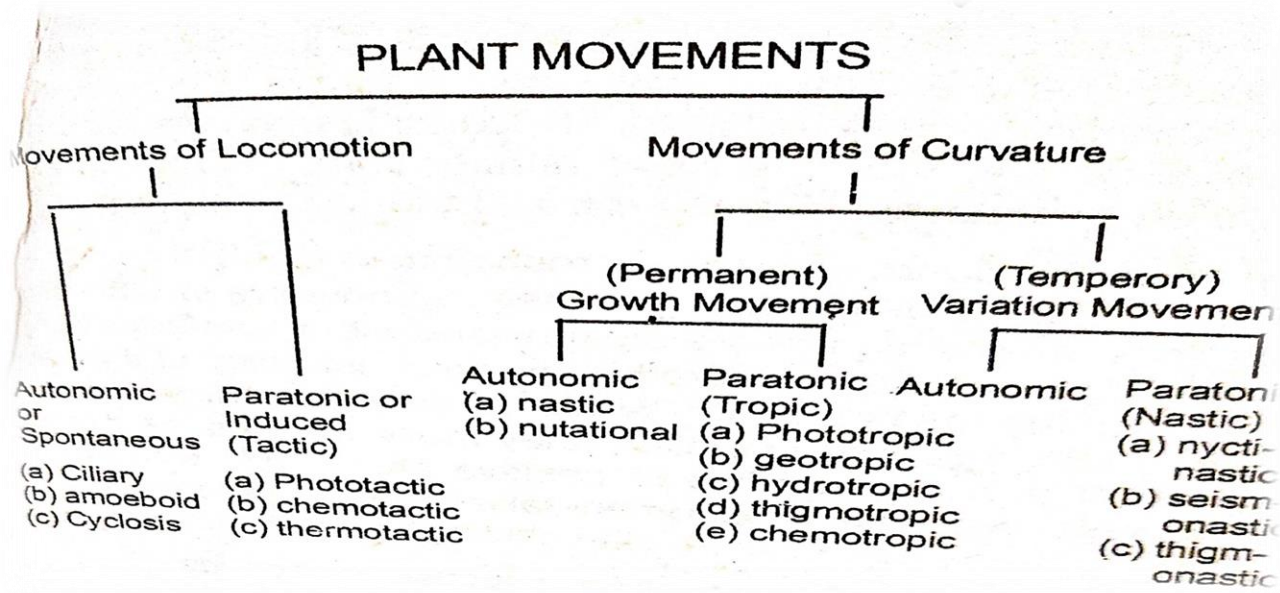
Defination- The change in position of an organism with respect to its surrounding.

-The movement which takes place spontaneously without the effect of external stimuli are termed spontaneous or autonomic movement.

- The movement which are caused by external stimuli are termed as induced or paratonic movement.

- Plant movement is classified into to two types 1- Movement of locomotion 2- Movement of curvature. In movement of locomotion the plant or the plant structure moves physically form one place to another place. In movement of curvature the plant is fixed and the movement is in the form of slight bending or curvature of a portion of the plant.

-Movement of curvature is of two types. 1- growth movement 2- Variation movements. In growth movement the curvature is of permanent nature. In variation movement the curvature id simply a temporary change in the position of certain plant organs.



1-Movement of locomotion –

Movement of locomotion is of two types i.e. Autonomic movement or spontaneous. Paratonic or induced movement (Tactic movement)

A) Autonomic movement or spontaneous.-

The Autonomic movement or spontaneous is of three types a) ciliary movement b) amoeboid movement c) cyclosis

a) ciliary movement- The movement is take place by using cilia or flagella. ciliary movement are important in mobility of zoospores, mobility of gametes and mobility of some algae. These structures are move from one place to another with the help of cilia .such movement is called ciliary movement Ex. Chlamydomonas, volvax and zoospores of some algae.

b) amoeboid movement-the movement is take place by pseudopodia. These are seen in plasmodia of Myxomycetes which are naked masses of protoplasm. They move over the surface of the substratum by putting out pseudopodia. The naked mass of protoplasm moves by producing pseudopodia like processes and hence called amoeboid movement.

c) cyclosis-The movement of cytoplasm with in a cell is a cyclosis. Theses are two types i.e. rotation and circulation. In rotation the protoplasm is move around single central vacuole in either clockwise or anticlock wise manner ex. Leaf cell of Hydrilla and Vallisneria. In circulation movement of protoplasm occurs in different vacuoles in different direction with in the cell ex. Stamina hairs of Tradescantia.The rotation and circulation are collectively known as cyclosis.

B) Paratonic or induced movement of locomotion (Tactic movement)

This movement is induced by some unidirectional external stimuli. Depending upon the nature of the stimuli like light, chemicals, temperature the movement are termed as phototactic, chemotactic and thermostatic.

a) Phototactic movement-These tactic movement are in response to unidirectional light. Some algae, zoospores and gametes are with light sensitive eyes spot. The eye spot is attracted by weak intensity of light and repelled strong light. Free swimming algae, zoospores gametes when swim towards the light intensity of light said to be positive phototactic and when they move away form the strong light they are called negatively phototactic.

b) Chemotactic movement- The unidirectional movements of locomotion in response to certain chemicals is called chemotactic movement. The movement of antherozoids of bryophytes and pteridophytes towards egg due to chemicals. The archegonia secrete certain organic substancelike malic acid which attract the anthrozoids ex zoospores of saprolegina.

c) Thermotactic movement- The movement of locomotion in response to certain unidirectional temperature stimulus. The ciliated algal structures have been observed to move from a colder to a warmer place, if a glass vessel containing chlamydomonas in cold water is warmed on one side, the

algae move to the warm side in response to the heat stimuli, however, if the temperature becomes very high they move back from that side.

2- Movement of curvature

The movement of curvature are of two types

A-Growth movement B- movement of variation

A-Growth movement - these movement again are of two types i.e. autonomic movement and paratonic movement.

a) autonomic movement or spontaneous movement-

i) Nastic movement- this type of movement are to be found in leaves, flowers, petals, buds scales etc. in such structures at some stage in the development, growth of one surface is more than the growth of the other surface. If the upper or the inner surface has more growth the movement is termed as epinasty. The opening of the flower and the dropping of bud are examples of epinastic movement . if the growth is more on the lower surface the movement is termed hyponasty. The folding in of a plant part are the examples of hyponastic movement .

ii) Nutational movement- the growth of the shoot tip of certain species takes lace in a zigzag manner. this is because of the alternate change in growth rates on opposite sides of the apex. Such movements are very slow and cannot be easily seen. This type of growth movement is known as nutation. When more growth posses round the growing tips this movement is termed as circum nutation.

b) Paratonic movement.(induced or tropic movement)- in many cases growth movement are induced by certain external stimuli. The stimuli are however effective in causing growth movements. Only when they are unilateral. External stimuli like light, gravity, water, touch and chemical play vital role in movement.

i) Phototropism- this is tropic movement occur in response to an external unilateral light stimulus. If the movement occurs towards the light is called positively phototropic and if away form light known as negatively phototropic. Stem shows a positively phototropic and root shows a negatively phototropic movement.

ii)Geotropism- geotropic movement which occur in response to the gravity stimulus. The phenomenon called geotropism. The stem is negatively geotropic whereas the root is positively geotropic .

iii) Hydrotropism- the movement of the plant organs in response to unilateral stimulus of water is referred to hydrotropic movement. This also results in curvature of the organs concerned due to unequal growth on its two sides. Roots are positively hydrotropic. The young root always grow toward water.

iv) Chemotropism-the movement caused due to unilateral stimulus of some chemical. The pollent tube in many cases which moves through the style towards ovary due to chemical stimulus. The

fungal mycelium which when grown in culture medium moves and grows towards the region of the medium where more nutrients are concenetrated.

v) Thigmotropism- the movement occurs in response to unilateral stimulus of touch or contact. This type of movement is occur in many twinners and climbers. Whenever the supporting organ touches a support it makes a curvature movement to catch hold of the object and tightens its hold ex. Leaf tip of Gloriosa superb and leaf stalk of Clematis,

B- movement of variation – the movement variation are of two types i.e. Autonomic movement of variation and Paratonic movement of variation.

a)Autonomic movement of variation- this movement is commonly found in Desmodium gyrans. During the day the two lateral leaflets of the leaf are always in a state of rotator movement. The leaflets make a dancing movement, as it were in different planes and sometimes make anangle of 180^0 . the movement is normally in an ellipsoidal orbit. One such movement takes about two minutes to complete.

b)Paratonic movement of variation- the variation movement are brought about by certain external stimuli like light temperature and touch. Such movements are termed nastic. Nastic movement unlike the tropic movement are brought about by stimuli which are not directional but diffuse.

i) Nyctinastic or sleep movement-the diurnal variation in the position of flowers and leaves of many plants in day and night is called nyctinastic or sleep movement. If nyctinastic movement is caused by the presence of or absence of light is called as photonastic. If it is caused by the change in temp of the surrounding it is termed as termonastic. The photonastic movements are exhibited by flowers and leaves which open in the morning and close at night . flowers of certain plants open in evening and close during day . flowers of crocus and tulip exhibit termonastic movement, since they open at high temp and close at low temp.

ii) Seismonastic-The movement is response to touch and shock.

This type of movement is commonly found in Mimosa pudica leaf. The plant is herbaceous with bipinnate compound leaves. A large pulvinus is present ate the base of the petiole. Smaller pulvinules are present at the base of the petiole. Smalle pulvinules are present at the base of leaflets. If a terminal pinnule is touched the stimulus is conduced to its base and then to other pinnules. The pinnules droop down in succession with the passage of the stimulus and ultimately the leaflets droop down.

iii) Thigmonastic movement- in the leaves of certain insectivorous plants like Drosera and Dionea the tentiacles exhibit variation movement on coming in contact with and insect. The touch stimulus imparted by the insect is transmitted to the entire leaf and all the tentacles bend over the insect.