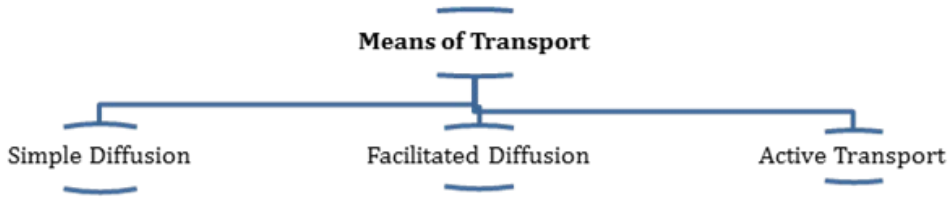
TRANSPORT IN PLANTS

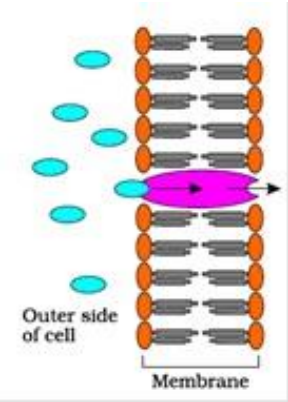
Plant transport various substances like gases, minerals, water, hormone and organic solutes to short distance (one cell to another) or long distance as water from roots to tips of stem.

- Long distance transport occurs through vascular system, xylem and phloem called **translocation** through mass flow.
- The direction of translocation may be unidirectional as in case of water and multidirectional as in minerals and organic solutes.



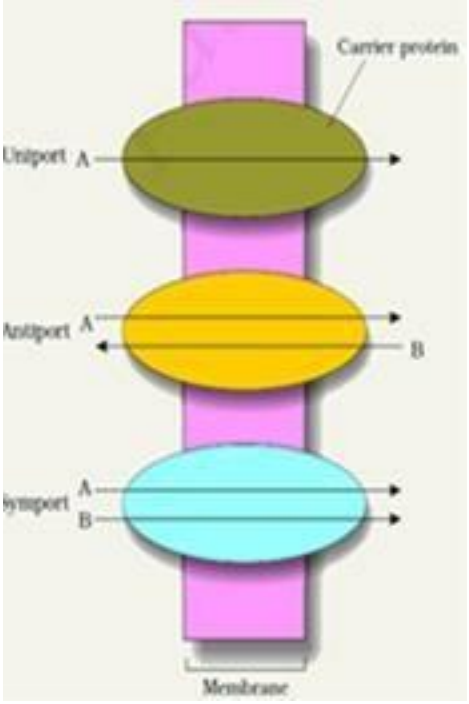
Simple Diffusion-

- Movement by diffusion is passive and slow along the concentration gradient through permeable membrane.
- No energy expenditure takes place. It occurs in liquid and gases.
- Rate of diffusion are affected by gradient of concentration, permeability of membrane, temperature and pressure.



Facilitated Diffusion-

- Lipid soluble particles easily pass through cell membrane but the hydrophilic solutes movement is facilitated.
- For facilitated diffusion, membrane possesses aquaporins or water channels. **Aquaporins** are membrane proteins for passive transport of water soluble substances without utilization of energy.
- The protein forms channels in membrane for molecules to pass through. The **porins** are proteins that forms huge pores in the outer membrane of the plastids, mitochondria etc.
- Water channels are made up of eight different types of aquaporins.



Symport, Antiport and Uniport-

- In **Symport**, both molecules cross the membrane in the same direction.
- In **Antiport**, both molecule moves in opposite direction.
- When a molecule moves across a membrane independent of other molecules, the process is called **uniport**.

Active Transport

- Uses energy to pump molecules against the concentration gradient. It is carried out by membrane proteins.
- In active transport movable carrier proteins are called **pumps.**
- The pumps can transport substance from low concentration to high concentration. The carrier proteins are very specific in what it carries across the membrane.

Comparison between Transport mechanisms-

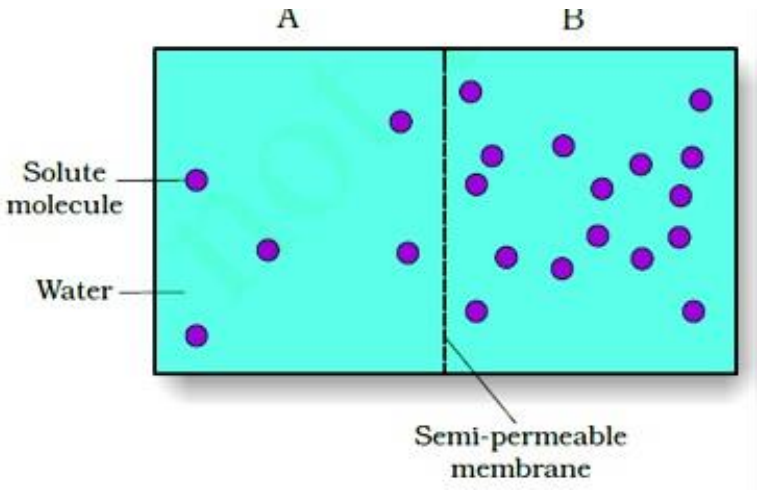
Simple diffusion	**Facilitated diffusion**	**Active transport**
Special membrane protein is not required.	Special membrane protein is required.	Special membrane protein is required.
Not selective	Highly selective	Highly selective
Transport do not saturate	Transport saturate	Transport saturate
No uphill transport	Uphill transport	Uphill transport
No ATP energy is required.	No ATP energy is required.	ATP energy is required.

Plant Water Relationship

- Water is essential for all physiological activities of plants along with all living organisms. It provide medium for most substances to dissolve in it.
- Protoplasm of cells contains water in which different molecules are dissolved and suspended.
- Terrestrial plants take lot of water and release most of it in form of water vapour by the process of transpiration.
- Water is the limiting factor for plant growth and productivity in both agricultural and natural environments.

Water Potential (Ψ_w)- is a concept fundamental to the understanding of water movement. Water potential is determined by solute potential (Ψ_s) and pressure potential (Ψ_p).

- 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** (Ψ_s). Solute potential is always negative. More the solute molecules in the solution lesser the solute potential.
- If a pressure greater than atmospheric pressure is applied to pure water or solution, its water potential decreases. Pressure potential is usually positive. Pressure potential is denoted by (Ψ_p).
- Water potential of a cell is affected by both solute and pressure potential. The relationship is as follows.



$\Psi_w = \Psi_s + \Psi_p$

$$\Psi_w = \Psi_s + \Psi_p$$

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. Water 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.
- Osmotic potential is the pressure required to prevent water from diffusing. More the solute concentration greater will be the pressure required to prevent water from diffusing it.
- Numerically osmotic pressure is equal to osmotic potential but sign is opposite. Osmotic pressure is the positive pressure while osmotic potential is negative.
- 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**. The cells swell up when placed in hypotonic solution.
- If the external solution is more concentrated than cytoplasm, it is **hypertonic**. Cell will shrink in hypertonic solution.
- **Plasmolysis** is the shrinkage of the cytoplasm of the cell away from its cell wall under the influence of hypertonic solution. The pressure of plasmolysis is usually reversible when the cell is placed in hypotonic solution.
- The pressure build up against the wall due to movement of water inside is called **turgor pressure**. It is responsible for enlargement and extension growth of cells.
- **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 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.

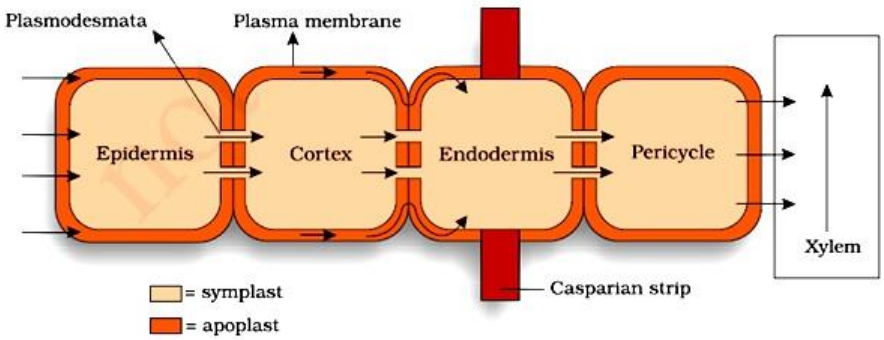
- Long distance transport of water in plants takes place by **mass or bulk flow system**. It is the movement of substance in bulk from one point to another as a result of pressure difference between two points.
- The bulk movement of substances through the conducting or vascular tissue of plants is called **Translocation**. Xylem is associated with translocation of water and mineral salts, some organic nitrogen and hormone from roots to aerial parts of plants.
- Phloem transport organic and inorganic solutes from leaves to other part of plants.

Absorption of water by plants

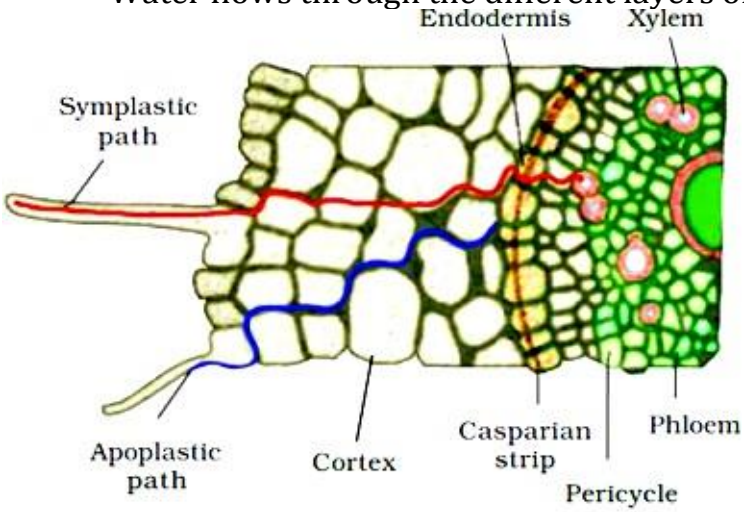
- Water is absorbed along with mineral solutes by root hairs by diffusion. The absorbed water passes to deeper layer by two pathways.

Apoplast pathway	Symplast pathway
1. It consists of nonliving parts of plants body such as cell wall and intercellular spaces. 2. There is little resistance in movement of water. 3. It is faster. 4. Metabolic state of root does not affect apoplast pathway.	1. It consists of living parts of plant body such as protoplast connected to plasmodesmata. 2. Some resistance occurs in the movement of water. 3. It is slightly slower. 4. Metabolic state of root directly affect symplast pathway.

- Most of the water flows in roots via apoplast pathway because cortical cells are loosely packed and offers no resistance to water movement.



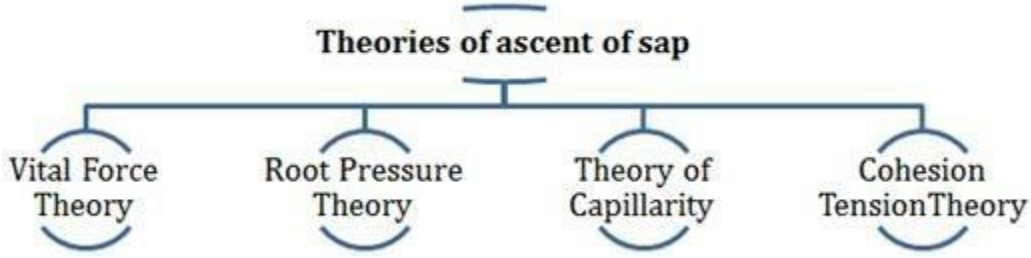
- The inner boundary of cortex, endodermis is impervious to water due to suberised matrix called **Casperian strip**. Water molecules are directed through wall regions that are not suberised.
- Water flows through the different layers of roots to reach the xylem tissues as follows-



- 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.

Ascent of saps (Translocation of water)

The upward movement of water from roots towards the tips of stem, branches and their leaves is called ascent of sap.



- **Vital force theory** was forwarded by J.C.Bose in 1923. This theory believes that the innermost cortical cells of the root absorb water from the outer side and pump the same into xylem channels.

- Root **pressure theory** was forwarded by Priestley in 1916. Root pressure is positive pressure that develops in the xylem sap of the root of plants. It can be responsible for pushing up water to small heights in plants.
- Loss of water in liquid phase by herbaceous plants from the tips of leaf blades is known as **guttation.**
- Water rises in tubes of small diameters, kept in vessels having water due to force of surface tension. Similarly water rises up in the walls of xylem channels due to adhesion and cohesion. This theory is called **Theory of Capillarity**.
- Cohesion **Tension theory** was put forwarded by Dixon and Joly in 1894. According to this theory water is mostly pulled due to driving force of transpiration from the leaves. The water molecules remain attached with one another by cohesion force. The water molecule does not breaks in vessels and tracheid due to adhesive force between their walls and water molecules. On account of tension created by transpiration, the water column of plant is pulled up passively from roots to great heights.
- Transpiration is the loss of water in the form of water vapour from aerial parts of plants. The following purpose is fulfilled by transpiration-

1. Creates **transpirational pull** for absorption and transport in plants.
2. Supplies water for photosynthesis.
3. Transport minerals and salts from soil to other parts of plant.
4. Cool the leaves and maintain their shape and size.

- Photosynthesis is limited by available water. C_4 plants are twice as efficient as C_3 plants in term of fixing carbon. Although C_4 plants uses half as much water as C_3 plants for the same amount of CO_2 fixed.

Uptake and transport of mineral nutrients

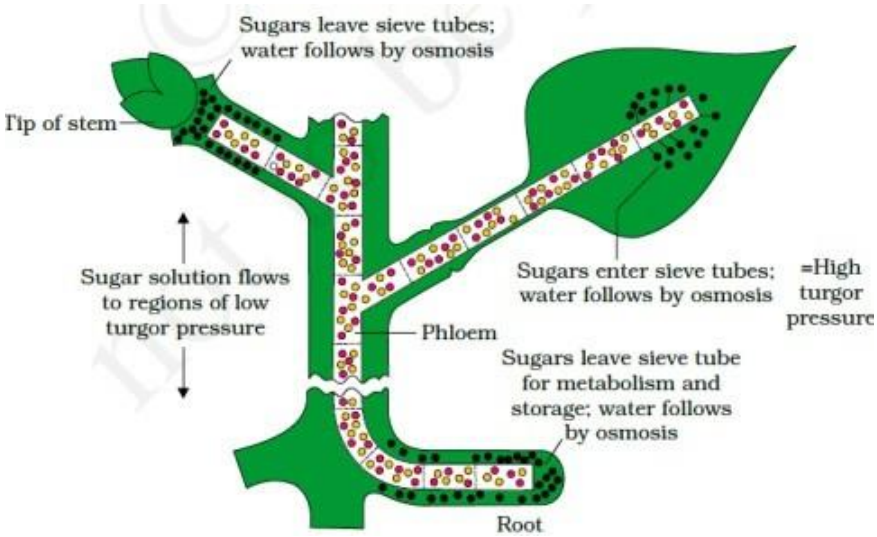
- Most of the minerals enter the roots by **active absorption** into the cytoplasm of epidermal cells because-

1. Minerals are present in the soil as charged particles (ions) which cannot move across cell membranes.
2. The concentration of ions in soil is usually lower than concentration in roots.

- Active absorption needs energy in form of ATP. Active uptake of ions is also responsible for water potential gradient in roots.
- Transport proteins of epidermal cells are control point where quantity and type of solutes that reach the xylem is adjusted.
- The ions that reaches to xylem by active or passive transport moves further upward along with transpirational pull.
- The chief **sink** of mineral elements are growing region of plants like apical meristem,young leaves, growing flower and fruit, and the storage organs.
- Minerals are frequently remobilized from older senescing part of the plants to young growing parts of plant.
- The elements most readily mobilized include phosphorus, sulphur, nitrogen and potassium. The element like calcium is not mobilized as it is the structural components of plant body.

Phloem transport: Flow from Source to Sink

- Food (sucrose) is transported by phloem from source to sink. The part of plant that synthesize the food is called source and part where food is used or stored is called sink.
- The source and sink can be reversed by the plants depending upon the season or plant's need. So, the direction of movement in the phloem is bi-directional.
- Phloem sap is mainly water and sucrose but other sugars, hormones and amino acids are also translocated through it.



Pressure flow or Mass flow hypothesis

- It is the most accepted theory for the translocation of sugar from source to sink. Glucose is prepared at source by photosynthesis which is converted into disaccharides (sucrose). Sucrose moves into companion cells and then into sieve tube cells by active transport.
- Loading of phloem at source creates a water potential gradient that facilitates the mass movement in the phloem.
- Sieve tube cells of phloem forms a long column with holes in their wall called sieve plates. Cytoplasmic strands pass through the hole in the sieve plates to form continuous filament. Hydrostatic pressure developed in sieve tube cells moves the sap in the phloem.
- At sink, incoming sugar is actively moved out of the phloem as complex carbohydrates. The loss of solute produces a high water potential in the phloem and water passes out and returning into xylem.