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.

Means of Transport

Three means of transport in plants:

- Diffusion
- Facilitated Diffusion
- Active Transport

Diffusion

- Movement of molecules from high concentration to low concentration without semi-permeable membrane.
- Slow process
- No expenditure of energy
- Diffusion depends upon: Concentration gradient, Permeability of the membrane, Temperature, Pressure and Size of the substance.

Facilitated Transport

- In facilitated diffusion, the membrane proteins are involved. They provide a site for hydrophilic molecules to pass through the membrane and no energy is required.
- Proteins involved in the process form channels which may always be opened or controlled. Facilitated diffusion is very specific.
- Porins: Proteins that forms huge pores in the outer membranes of plastids, mitochondria, etc. They are different kinds;
- Aquaporins: Proteins that facilitate diffusion of water molecules
- Transport can be of 3 types:
- **Symport** – both molecules move in the same direction
- **Antiport** – both molecules move in opposite directions
- **Uniport** – independent movement of molecules
- When all proteins involved are saturated, it leads to maximum transport.

**Active transport**

- Requires special proteins which are very specific and sensitive to inhibitors.
- Requires energy to pump molecules against the concentration gradient.
- When all proteins involved are saturated, it leads to maximum transport.
Water Potential ($\psi_w$)

- Greater the concentration of water in a system, greater is its kinetic energy and greater is the water potential.
- It is measured in Pascal (Pa)
- If two systems are in contact, then there is movement of water from the solution with greater water potential to lower water potential.
- Solute potential ($\psi_s$) - The magnitude of lowering of water potential due to dissolution of solute is called solute potential ($\psi_s$). Solute potential is always negative. More the solute molecules in the solution lesser the solute potential
- Pressure Potential ($\psi_p$) - pressure greater than atmospheric pressure is applied to pure water or a solution
- Water potential of pure water is zero.
- Solute potential is always negative and water potential is always positive.
- $\psi_w = \psi_s + \psi_p$

Osmosis

- Water diffuses from region of its higher concentration to its lower concentration through semi-permeable membrane.
- Diffusion of water across a semi-permeable membrane
- Direction and rate of osmosis depends upon pressure gradient and concentration gradient.

Osmotic pressure

- External pressure applied to prevent the diffusion of water
- It depends upon solute concentration.
- Numerically, osmotic pressure is equal to osmotic potential
- Osmotic pressure has positive sign. Osmotic potential has negative sign.
Types of Solutions:

- **Isotonic solution**
  Concentration of external solution is equal to Concentration in cytoplasm
  There is no net gain, hence No change in cell size.

- **Hypotonic solution**
  Concentration in cytoplasm is greater than the Concentration of external solution.
  So water enters into the cells and Cells swell.

- **Hypertonic solution**
  Concentration of external solutions is greater than the Concentration in cytoplasm.
  Hence water moves from cells to external solution and Cells shrink.

**Plasmolysis**
- It occurs when cell is placed in hypertonic solution, because water moves out
from cytoplasm and vacuole. Hence cell membrane shrinks away from the cell wall.

- As water moves in, cytoplasm builds up a pressure against the cell wall. This pressure is called **turgor pressure** and cells enlarge.

### Imbibition

- Diffusion in which water is absorbed by solids, causing them to enormously increase in volume.
- Imbibition is along the concentration gradient and depends upon affinity between adsorbent and liquid being adsorbed.
- Examples - swelling of wooden door during rainy season, swelling of raisin when soaked in water, absorption of water by seeds

**Long Distance Transport of Water**: It occurs by three processes, Diffusion, Mass flow system and Translocation through conducting vascular tissues. There are two types of conducting tissues, namely;

**Xylem**: Transports water, salts, nitrogen and hormones. From roots to the other parts and it is unidirectional.

**Phloem**: Transports organic and inorganic solutes. It occurs from the source (leaves) to the sink (storage part) and it is multidirectional.
Absorption of Water by Plants

- Water is absorbed through roots by diffusion.
- Root hairs (slender, thin-walled extensions of root epidermal cells) increase the surface area for absorption.
- Once absorbed by root hairs, water moves into deeper layers by 2 pathways – Apoplast Pathway or Symplast Pathway.

**Apoplast Pathway:**

- Movement occurs through the intercellular spaces or walls of the cells, without entering the cytoplasm. Movement is fast. Most of the water flow in roots occurs via apoplast, except at the casparian strip.

**Symplast pathway:**

- Water enters the cell through the cell membrane and travels intracellularly through plasmodesmata. Movement is slow. At the casparian strip region, water moves through the symplast.

- Most of the water enters through apoplast pathway, endodermis has
casparian strips which are made of suberin, it is impervious to water, so water enters the symplast.

There are two forces which are responsible for transporting the water up in a plant; they are root pressure and transpiration pull.

**Root Pressure**

- Water molecules enter from soil to root hair, then to cortical cells and finally reach xylem vessels.
- Positive pressure created inside the xylem when water transported along the concentration gradients into the vascular system
- *Guttation* - at night and early morning when evaporation is low, and excess water collects in the form of droplets around special openings of veins near the tip of grass blades, and leaves of many herbaceous parts. Such water loss in its liquid phase is known as *guttation*

**Transpiration pull**

- Transpiration is a process of loss of water in the form of water vapours from the surface of leaves.
- Transpiration accounts for loss of 99% of water taken by the plant. Loss is mainly through stomata.
- Pull of water as a result of tension created by transpiration is the major driving force of water movement upwards in a plant.
- There are three physical properties of water which affect the ascent of xylem sap due to transpiration pull.
  - *Cohesion* - Mutual attraction between water molecule
  - *Adhesion* - Attraction of water molecules to polar surface
  - *Surface Tension* - water molecules are attracted to each other in the liquid phase more than to water in the gas phase.

**Transpiration**

- It occurs manly through openings called stomata. Transpiration provides the transpirational pull which is responsible for the upward movement of water in tall plants.
- Stomata:
- Open in the day and close during the night
- Also contribute in the exchange of O₂ and CO₂
- Opening and closing of stomata is influenced by the turgidity of the guard cells.

**Factors affecting transpiration:**

- **External factors**: Temperature, Light, Humidity and Wind speed.
- **Plant factors / Internal factors**: Number of stomata, distribution of stomata, water status in plants.

**Importance of Transpiration**

- Creates transpirational pull for transport
- Supplies water for photosynthesis
- Transports minerals from soil to all parts of a plant
- Cools the surface of the leaves by evaporation.
- Keeps the cells turgid; hence, maintains their shape

**Uptake of Mineral Nutrients**

- Minerals are absorbed from the soil by active transport. They cannot follow passive transport because of two factors;
- They are charged. Hence, they cannot cross the cell membranes.
- Concentration of minerals in soil is lesser than the concentration of minerals in roots. Hence, concentration gradient is not present.
- Certain proteins in the membranes of root hair cells actively pump ions from soil to cytoplasm of epidermal cells.

**Transport of Mineral Nutrients**

- Unloading of mineral ions occur at fine vein endings of the leaves through diffusion.
- Some minerals are also remobilised from old senescing parts N, P K, S. Minerals forming structural components (example Ca) are not remobilised.

- Phloem transports food from source to sink, but this source-sink relationship is reversible depending upon the season. Therefore, phloem transport is bi-directional.

**The Pressure Flow or Mass Flow Hypothesis:**

- This is the well accepted mechanism used for translocation of sugars from the source to the sink.
- Glucose prepared at the source is converted into sucrose. Sucrose is moved to
the companion cells, and then to the living phloem sieve tube cells by active transport. This process of loading creates a hypertonic condition in the phloem.

- Water in the adjacent xylem moves into the phloem by osmosis. Osmotic pressure builds phloem sap.
- As hydrostatic pressure on the phloem sieve tube increases, pressure flow begins and sap moves through the phloem to the sink and stored as complex carbohydrates (starch).

![Diagram of plant translocation](image-url)