Transport in Plants

1 INTRODUCTION

- In a flowering plant the substances that would need to be transported are water, mineral nutrients, organic nutrients and plant growth regulators.
- Water and mineral nutrients are taken up by roots and food is synthesised in the leaves.
- But plants do not have a circulatory system.
- So in plants, there are two broad strategies for transport, short-distance and long-distance.
- Short-distance movement is through-diffusion, cytoplasmic streaming and active transport; and transport through longer distances is through vascular system (xylem and phloem) and is called TRANSLOCATION.
- Transport in xylem is essentially UNIDIRECTIONAL (of water and minerals) from roots to leaves through the stems.
- Organic and mineral nutrients undergo MULTIDIRECTIONAL transport.
- From SENESCENT plant parts nutrients are withdrawn and moved to growing plants. So the transport is complex but orderly. Each organ is receiving some substances and giving out some other.

2 SHORT DISTANCE MOVEMENT

Property	Simple Diffusion	Facilitated Diffusion	Active Transport
1. Need special membrane proteins	No	Yes	Yes
2. Highly selective	No	Yes	Yes
3. Transport saturates	No	Yes	Yes
4. Uphill movement	No	No	Yes
5. Need ATP	No	No	Yes

1. Diffusion is the only means for gaseous movement with in the plant body.
2. **Porins** are proteins that form large pores in outer membrane of Plastids, Mitochondria and some Bacteria.
3. In facilitated diffusion extracellular molecule is bound to transport protein which then rotates and releases the molecule inside the cell, e.g., water channels-made of 8 different types of aquaporins.

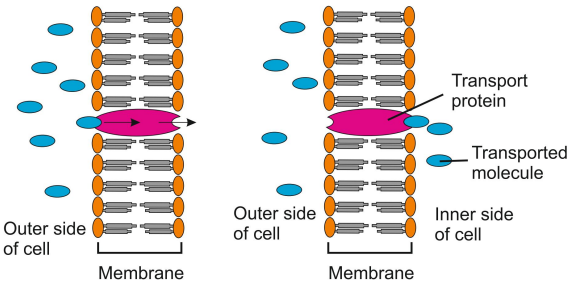


Fig. : Facilitated diffusion

4. Passive symports and antiports
   - In symport two molecules move together in the same direction and in opposite direction in antiport
   - In uniport a molecule moves across a membrane independent of other molecules in one direction.

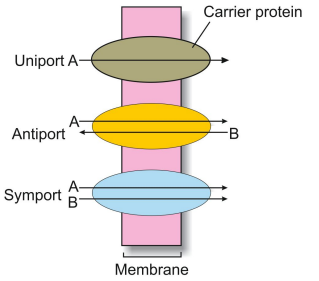


Fig. : Facilitated diffusion

3 PLANT-WATER RELATIONS

Water is essential for all physiological activities of plant. Because of its high demand water is often the limiting factor for plant growth and productivity.

Terms :

1. **Water Potential :** water molecules possess kinetic energy. The greater the concentration of water in a system, the greater is its kinetic energy or water potential.
   (i) Pure water have greatest water potential
   (ii) Water moves from a system at higher water potential to the one having low water potential.
   (iii) It is denoted by Psi or Ψ and expressed in pascals.
   (iv) Water potential of pure water at standard temperature. Which is not under any pressure, is taken as zero.
2. **Solute Potential :** The magnitude of lowering of water potential due to dissolution of solute is called solute potential or Ψ_S
   (i) Ψ_S is always negative.
   (ii) More the solute molecules, the lower is the Ψ_S
3. For a solution at atmospheric pressure.
   (Water potential) $\Psi_W = \Psi_S$ (Solute potential)
4. Numerically osmotic pressure is equivalent to the osmotic potential but the sign is opposite.
5. Osmotic pressure is the positive pressure applied, while osmotic potential is negative.
6. **Pressure Potential :** Pressure builds up in a plant system when water enters a plant cell due to diffusion, it makes the cell **turgid**, this increases the **pressure potential**.
   (i) It is usually positive
   (ii) Though negative potential or tension in xylem plays a major role in water transport.
7. **Water Potential** is affected by both solute and pressure potential.
   The relationship is : $\Psi_W = \Psi_S + \Psi_P$

OSMOSIS

1. Refer specifically to the diffusion of water across a differentially or selectively permeable membrane.
2. Net direction and rate of osmosis depends on both pressure gradient and concentration gradient.
3. Water moves from higher chemical potential to region of lower chemical potential until equilibrium is reached.

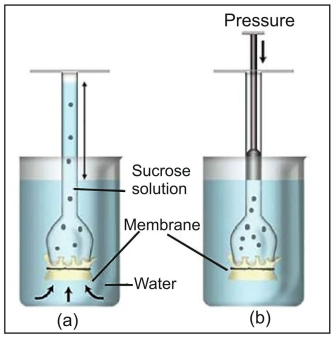
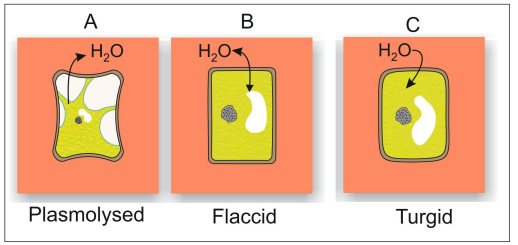


Fig.: Demonstration of osmosis-Thistle funnel experiment

PLASMOLYSIS

1. Occurs when water moves out of the cell and cell membrane of plant cell shrinks away from its cell wall.
2. This happens when a cell or tissue is placed in hypertonic solution.
3. The process of plasmolysis is reversible. When cells are placed in hypotonic solution the cell regains its shape.
4. When water flow into the cell and out of the cells are in equilibrium, the cells are said to be flaccid.



IMBIBITION

1. Special type of diffusion when water is absorbed by solids-colloids causing them to increase in volume
2. Water potential gradient between the absorbent and the liquid imbibed is essential for imbibition.
3. For any substance to imbibe any liquid, affinity between the adsorbant and the liquid is also a pre-requisite.

Example : Absorption of water by seeds and dry wood

Watermelon has over 92% water, herbaceous plants have only 10 to 15% of fresh weight as dry wt. A seed many appear dead but it still has water.

1. Transport proteins of endodermal cells are control points, where a plant adjusts the quantity and types of solutes that reach xylem
2. Root endodermis because of suberin, actively transports ions in one direction.

5 WATER MOVEMENT UP A PLANT

1. Root Pressure : Only provide a modest push in overall process of water transport. They do not play a major role in water movement up tall plants.
   - The greatest contribution of root pressure is to re-establish the continuous chains of water molecules in xylem.
   - In many herbaceous plants, grass blades, root pressure is the cause of loss of water in the form of liquid droplets called GUTTATION.
2. **TRANSPIRATION PULL :** Cohesion-tension-transpiration pull model of water transport accomplishes water movement in tall plants.

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Transpiration is the evaporative loss of water by plants through stomata.

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4 LONG DISTANCE TRANSPORT

1. Diffusion is a slow process. It can account for only short distance movement.
2. Long distance movement of water and minerals and food generally occur by mass or bulk flow.
3. Mass flow is en masse movement due to pressure differences between the two points.
4. Bulk movement is through vascular tissues called TRANSLOCATION.
5. Xylem mainly translocates WATER, MINERAL SALTS, some ORGANIC NITROGEN and HORMONES.
6. PHLOEM translocates a variety of organic and inorganic solutes.
7. Water is absorbed by two distinct pathways :
   - **Apoplast :** A system of adjacent cell wall except at casparian strips of endodermis. This movement is dependent on the gradient.
   - **Symplast:** A system of interconnected protoplasts.

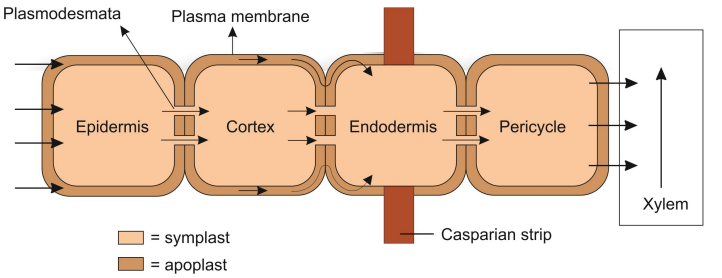

Fig.: Pathway of water movement in plants

7. In some plants symbiotic **mycorrhizal** association of fungus with root system help in water and mineral absorption eg. *Pinus* seeds.

The opening of stomata is caused due to change in turgidity of guard cells.

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Opening is also aided by radial orientation of cellulose microfibrils in cell wall of guard cell.

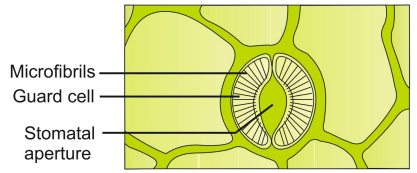

Fig. : Stomatal aperture with guard cells

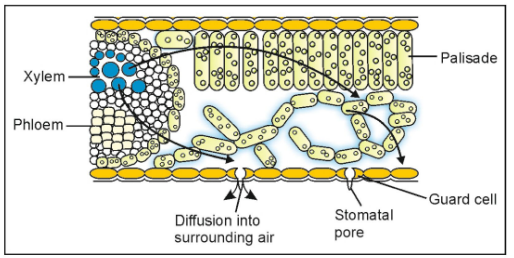

Fig. : Water movement in the leaf

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Transpiration driven ascent of xylem sap depends mainly on physical properties of water.

6 TRANSPIRATION & PHOTOSYNTHESIS- A COMPROMISE

1. An actively photosynthesising plant has an insatiable need for water
2. Photosynthesis is limited by available water which can be swiftly depleted by transpiration.
3. A C_4 plant loses only half as much water as a C_3-plant for the same amount of CO_2 fixed.
4. Temperature, light, humidity and wind speed affect transpiration.
5. Plant factors like number and distribution of stomata, percent of open stomata, water status of plants, canopy etc. affect transpiration.

7 UPTAKE AND TRANSPORT OF MINERAL NUTRIENTS

1. Plants obtain their carbon and most of their oxygen from CO_2 in the atmosphere. However, their remaining nutritional requirements are obtained from water and minerals in the soil.
2. Most minerals must enter the root by active absorption into the cytoplasm of epidermal cell.
3. The active uptake of ions is partly responsible for the water potential gradient in roots and therefore for the uptake of water by osmosis.
4. Some ions also move into epidermal cells passively.
5. Mineral ions are frequently REMOBILISED from older, senescing, dying parts (leaves) to younger leaves.
6. Elements most readily mobilised are phosphorus, nitrogen and potassium. Some elements like calcium are not remobilised.

8 PHLOEM TRANSPORT : PRESSURE FLOW OR MASS FLOW HYPOTHESIS

1. Food, primarily SUCROSE, is transported by vascular tissue phloem from source to sink.
2. **Source :** Leaf (synthesise food), roots (storage)
3. **Sink :** Where needed or stored (buds of trees)
4. Since source - sink relation is variable, so direction of movement of phloem can be bi-directional.
5. Phloem sap is mainly water and sucrose, but other sugars, hormones and amino-acids are also translocated through phloem.
6. GIRDLING EXPERIMENT
   (i) Identifies the tissues through which food is transported.
   (ii) It shows that phloem is the tissue responsible for food translocation.
   (iii) And transport takes place in one direction, i.e. towards the roots

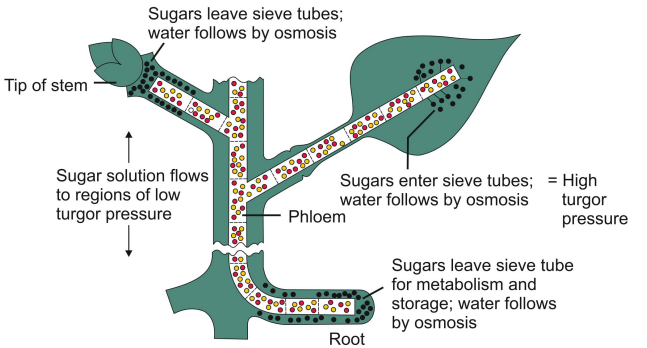

Fig. : Mechanism of translocation

MASS FLOW HYPOTHESIS

1. The accepted mechanism used for the translocation of sugars from source to sink is called the pressure flow hypothesis.
2. Glucose (Prepared at the source) → Sucrose (Converted to disaccharide) → Companion cell ← Loading (Active transport) → Living phloem sieve tube cells → Unloading (Active transport) → Builds osmotic pressure → Sink (used or stored) ← Water from xylem
3. Loading and unloading are active processes.