

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- From **SENESCENT** plant parts nutrients are withdrawn and moved to growing plants.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 |

- Diffusion is the only means for gaseous movement within the plant body.
- Porins** are proteins that form large pores in outer membrane of Plastids, Mitochondria and some Bacteria.
- 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.

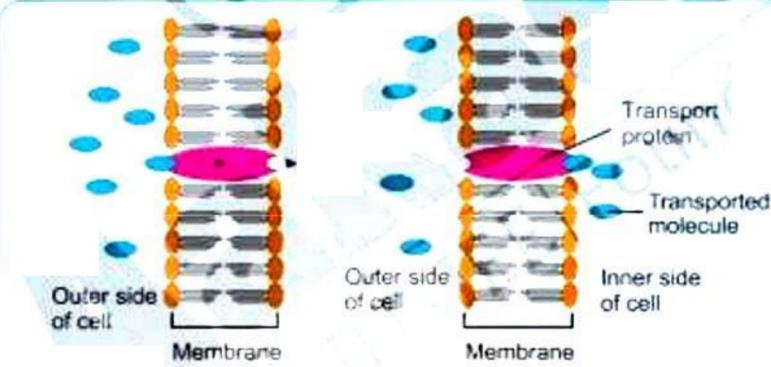


Fig. : Facilitated diffusion

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.

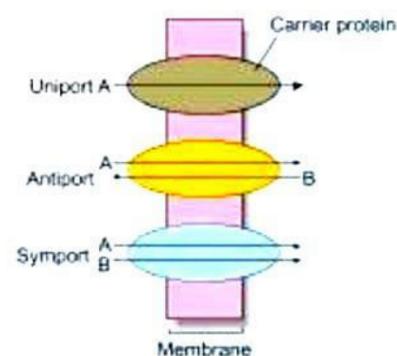


Fig. : Facilitated diffusion

3 PLANT-WATER RELATIONS

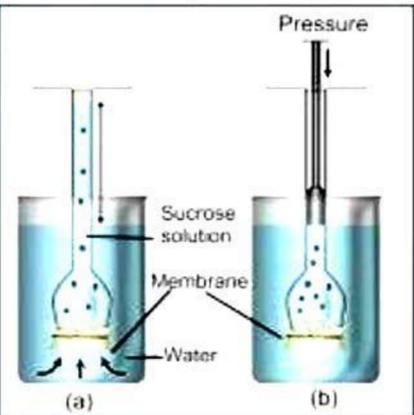
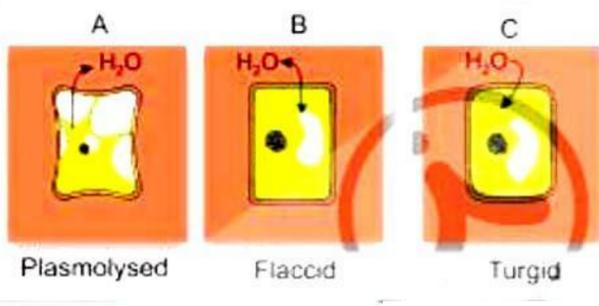
Water is essential for all physiological activities of plant. Because of its high demand water is often the limiting factor for plant growth and productivity.

Terms :

- 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.
 - Pure water has the greatest water potential.
 - Water moves from a system at higher water potential to the one having low water potential.
 - It is denoted by Ψ_w or Ψ and expressed in pascals.
 - Water potential of pure water at standard temperature which is not under any pressure, is taken as zero.
- Solute Potential** : The magnitude of lowering of water potential due to dissolution of solute is called solute potential or Ψ_s .
 - Ψ_s is always negative.
 - More the solute molecules, the lower is the Ψ_s .
- For a solution at atmospheric pressure.

(Water potential) $\Psi_w = \Psi_s$ (Solute potential)
- Numerically osmotic pressure is equivalent to the osmotic potential but the sign is opposite.
- Osmotic pressure is the positive pressure applied, while osmotic potential is negative.
- 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**.
 - It is usually positive.
 - Though negative potential or tension in xylem plays a major role in water transport.
- Water Potential** is affected by both solute and pressure potential.

The relationship is : $\Psi_w = \Psi_s + \Psi_p$

| OSMOSIS | PLASMOLYSIS | IMBIBITION |
|--|--|---|
| <ol style="list-style-type: none"> 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.  <p>Fig.: Demonstration of osmosis-Thistle funnel experiment</p> | <ol style="list-style-type: none"> 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.  <p style="text-align: center;">A B C Plasmolysed Flaccid Turgid</p> | <ol style="list-style-type: none"> 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. <p>Example : Absorption of water by seeds and dry wood</p> <p>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.</p> |

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.

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**.

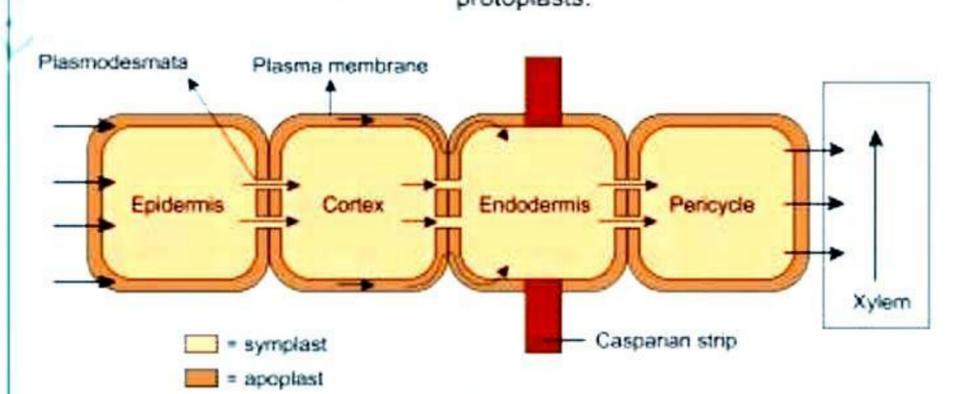
5 WATER MOVEMENT UP A PLANT

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.

↓

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

↓



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.

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

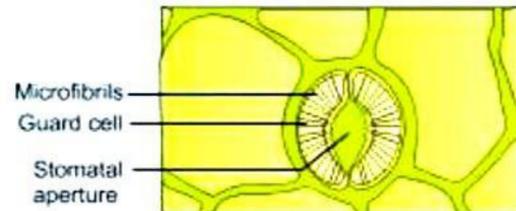


Fig. : Stomatal aperture with guard cells

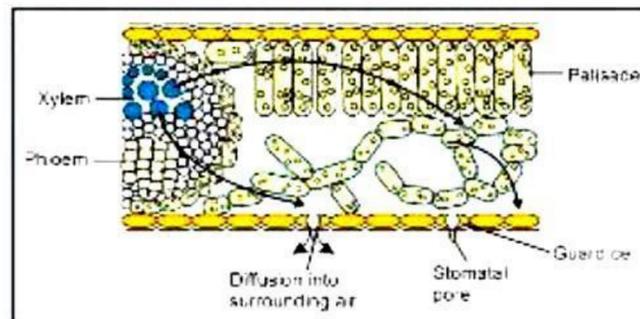


Fig. : Water movement in the leaf

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 REMOBLISED 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

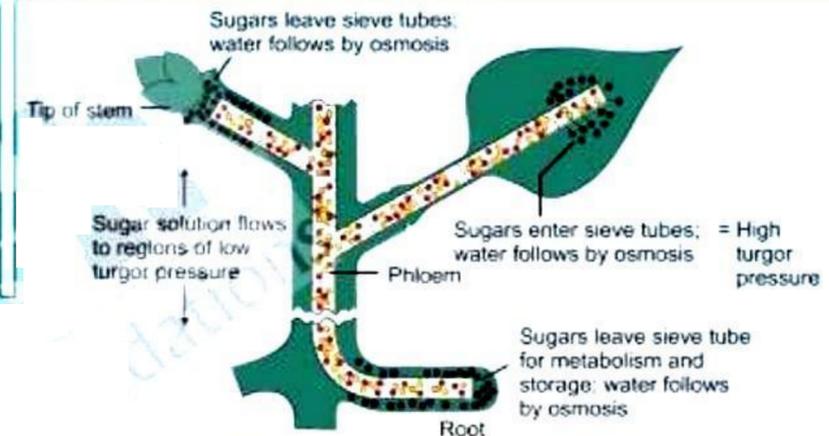


Fig. : Mechanism of translocation

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 | → | Sucrose | → | Companion cell |
| (Prepared at the source) | | (Converted to disaccharide) | | ← Loading (Active transport) |
| | | | | ↓ |
| | | | | Living phloem sieve tube cells |
| | | | | ↓ |
| | | | | Builds osmotic pressure |
| | | | | ↓ |
| | | | | Water from xylem |
| | | | | ↓ |
| | | | | Sink (used or stored) |
| | | | | ←←←←← |
| | | | | Unloading (Active transport) |
3. Loading and unloading are active processes.



Sharpen Your Understanding

1. Select the **odd** one out w.r.t passive transport. [\[NCERT Pg. 192\]](#)
 - (1) Nutrients move across membrane by diffusion
 - (2) It is always down the concentration gradient
 - (3) It requires energy
 - (4) It is always a uphill movement
2. Phloem sap is mainly : [\[NCERT Pg. 190\]](#)
 - (1) Water and sucrose
 - (2) Glucose and water
 - (3) Amino-acids and water
 - (4) Hormones only
3. Which of the following element is not remobilized in plants? [\[NCERT Pg. 190\]](#)
 - (1) Nitrogen
 - (2) Calcium
 - (3) Potassium
 - (4) Phosphorus
4. Root endodermis has the ability to actively transport ions in one direction only because of the layer of : [\[NCERT Pg. 189\]](#)
 - (1) Lignin
 - (2) Cutin
 - (3) Algin
 - (4) Suberin
5. The plant factor that affect transpiration is: [\[NCERT Pg. 187\]](#)
 - (1) Humidity
 - (2) Wind speed
 - (3) Canopy structure
 - (4) Light

6. Water loss in its liquid phase, in the form of droplets around special openings of veins near the tip of grass blades is due to [\[NCERT Pg. 186\]](#)
 - (1) Guttation
 - (2) Transpiration
 - (3) Root pressure
 - (4) Both (1) and (3) are correct
7. Symplastic system is the system of [\[NCERT Pg. 185\]](#)
 - (1) Inter connected protoplasts
 - (2) Dead tissues
 - (3) Adjacent cell walls
 - (4) Mass flow of water
8. The bulk movement of substances through the vascular tissues of plant is called [\[NCERT Pg. 184\]](#)
 - (1) Facilitated diffusion
 - (2) Active transport
 - (3) Translocation
 - (4) Translation
9. In the mycorrhizal association of a fungus and the root system of plants, the plants provide to the fungi: [\[NCERT Pg. 186\]](#)
 - (1) Minerals
 - (2) Water
 - (3) N-containing compounds
 - (4) Lipids

NCERT Based MCQs

10. Seedlings have been able to emerge out of the soil into the open and are able to establish due to : [\[NCERT Pg. 183\]](#)
 - (1) Root pressure
 - (2) Guttation
 - (3) Transpiration
 - (4) Imbibition
11. When the external solution balances the osmotic pressure of the cytoplasm, it is said to be [\[NCERT Pg. 182\]](#)
 - (1) Hypotonic
 - (2) Hypertonic
 - (3) Isotonic
 - (4) Plasmolysed
12. What occupies the space between the cell wall and the shrunken protoplast in the plasmolysed cell? [\[NCERT Pg. 182\]](#)
 - (1) Hypertonic solution
 - (2) Hypotonic solution
 - (3) Isotonic solution
 - (4) Pure water
13. Leaf surfaces are cooled, sometimes 10 to 15 degrees, due to evaporative cooling, by the process of [\[NCERT Pg. 189\]](#)
 - (1) Photosynthesis
 - (2) Transpiration
 - (3) Root pressure
 - (4) Guttation
14. By convention, the water potential of pure water at standard temperatures, which is not under any pressure is taken to be [\[NCERT Pg. 179\]](#)
 - (1) Minimum
 - (2) Negative
 - (3) Positive
 - (4) Zero

15. Solute potential for a solution is always:
[NCERT Pg 179]

- (1) Zero
- (2) Negative
- (3) Positive
- (4) Equal to other solutions

16. If a pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential :

[NCERT Pg 179]

- (1) Increases
- (2) Decreases
- (3) Remains unaffected
- (4) Becomes positive

17. Active transport is [NCERT Pg 178]

- (1) Downhill transport
- (2) Non-selective
- (3) Not dependent on ATP
- (4) Uphill movement

18. Molecules move across a membrane independent of other molecules in one direction in the

[NCERT Pg 177]

- (1) Symport
- (2) Antiport
- (3) Uniport
- (4) Co-port

19. Select the **odd** one out w.r.t. diffusion?
[NCERT Pg 176]

- (1) A slow process
- (2) Dependent on a living system
- (3) Affected by temperature
- (4) It is a passive process

20. In rooted plants, transport of water and minerals in xylem is essentially

[NCERT Pg 175]

- (1) Bi-directional
- (2) Multi-directional
- (3) Uni-directional
- (4) Non-directional

Thinking in Context

1. The more the solute molecules _____ is the solute potential. [NCERT Pg 179]

2. If the external solution is more dilute than the cytoplasm, it is called _____ solution.

[NCERT Pg 181]

3. The pathways of adjacent cell-walls that is continuous throughout the plant, except at the casparian strips of the endodermis in the roots, is the system of _____

[NCERT Pg 185]

4. The inner wall of each guard cell, towards the stomatal aperture is _____

[NCERT Pg 187]

5. Usually the lower surface of leaf has a greater number of stomata in _____

[NCERT Pg 187]

6. The evolution of the C₄-photosynthetic system is probably one of the strategies for maximizing the availability of CO₂ while minimizing _____. [NCERT Pg 189]

7. The chief sinks for mineral elements are the growing regions of the plant, such as the _____

[NCERT Pg 190]

8. Ions are absorbed from the soil by both _____ transport. [NCERT Pg 189]

9. Measurements reveal that the forces generated by transpiration can create pressures sufficient to lift a xylem sized column of water over _____.

[NCERT Pg 188]

10. Less than _____ of the water reaching the leaves is used in photosynthesis and plant growth. [NCERT Pg. 187]
11. The translocation in phloem is explained by _____. [NCERT Pg. 193]
12. The most acceptable model to explain the transport of water in plants is _____. [NCERT Pg. 192]
13. The potential energy of water molecules which helps in the movement of water is called _____. [NCERT Pg. 192]

14. On the trunk of a tree, a ring of bark up to a depth of the phloem layer, can be carefully removed, this is called _____. [NCERT Pg. 192]
15. _____ maintains the shape and structure of the plants by keeping cells turgid. [NCERT Pg. 189]
16. *Pinus* seeds cannot germinate and establish without the presence of _____. [NCERT Pg. 186]

□ □ □

17. We can study water loss from a leaf using _____. [NCERT Pg. 187]
18. Movement of chloroplast in the cells of the *Hydrilla* leaf is due to _____. [NCERT Pg. 185]
19. Water is absorbed along with mineral solutes by the root hairs purely by _____. [NCERT Pg. 184]
20. Numerically osmotic pressure is equivalent to the _____. [NCERT Pg. 181]