# Transport in Plants Class 11 Notes Biology Chapter 11

In flowering plants, a complex movement of materials take place in different directions. This is despite the fact that plants do not bear any circulatory system. Water taken up by the roots has to reach all the parts of the plant, up to very tip of the growing stem, where photosynthesis and growth are going on. Leaves manufacture food, which has to be supplied to all parts of the plant including the roots.

Materials also move over short distances, i.e., inside the cell, across the membranes or even cell to cell. The substances transported are water, mineral, nutrients, organic nutrients and plant growth regulators. Over short distances the substances move by diffusion and cytoplasmic streaming supplemented by active transport while, the long distance transport takes place through xylem and phloem and is called translocation.

**Topic 1 Transport and Plant Water Relations**

In rooted plants, water and mineral transport in xylem is unidirectional (roots to stems). However, translocation of organic and inorganic nutrients is multi directional. Organic compounds synthesised in the leaves are transported to all parts including storage organs. The storage organs later re-export these organic compounds when required. Important nutrients are also withdrawn from plant parts undergoing senescence and are supplied to the growing parts. Hormones and plant growth regulators are present in very minute quantities and are often transported in polarised (unidirectional) manner.

**Means of Transport**

Transport in plant is an important phenomenon. It can either be unidirectional or bidirectional. There are mainly three important methods of transport of materials into and out of cells, i.e., diffusion, facilitated diffusion and active transport. These process are given below in details

**1. Diffusion**

It is a physical process in which passive transport of solvent molecules or solute ions occur without the expenditure of energy. It is a slow process and is independent of living system. During the process, the molecules or ions flow in a random fashion from the region of higher concentration to region of lower concentration be it a gas, liquid or solids. Rate of diffusion is mainly affected by

(a) Concentration gradient of diffusing substance.
(b) Permeability of the membrane separating them.
(c) Temperature
(d) Pressure
(e) Density

**Note:**

* Diffusion rate is inversely related to square root of relative density of the diffusing substance. This is known as Graham's law of diffusion.

$$D \propto \frac{1}{\sqrt{d}}$$

where, $D$ = diffusion

$d$ = density

* Diffusion is a very important phenomenon in plants as it is the only means of transport of gases in them.
* Tendency of different substances to diffuse according to their own partial pressures or concentration is called independent diffusion.

**2. Facilitated Diffusion**

A favourable concentration gradient of molecules is essential for difiusion. The rate of difiusion depends on the size of the substances, i.e., smaller the substance, the faster it will diffuse and on its solubility in lipids (major constituents of membrane), i.e., more the substance is soluble in lipid, more faster it will diffuse through the membrane.
Transport of substances (having hydrophilic moeity) is facilitated by transport proteins. These protein do not create any concentration gradient by themselves; a concentration gradient is already present.
This process is called facilitated difiusion. Facilitated diffusion does not allow net movement of molecules from low to high concentration because it will require input of energy. The rate of transport finally reaches the maximum when all transporters of proteins are utilised. Facilitated diffusion is very specific, i.e., allows uptake of only selected substances.

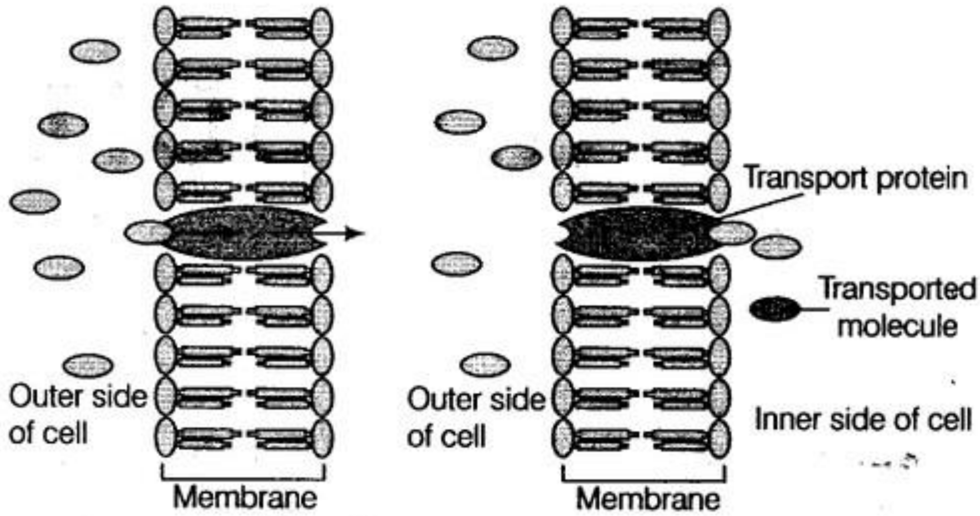


**Fig. 11.1** Facilitated diffusion

There are two different types of transport proteins, i.e., carrier proteins and channel proteins. Carrier proteins bind the particular solute to be transported and deliver the same to the other side of the membrane.
The channel proteins form channels in the cell membrane so s that molecules can easily get transported. This is called channel mediated facilitated difiusion. Out of these channels, some always remain open while, the others are controlled. The large transporter proteins, which create huge pores in the outer membranes of the plastids, mitochondria and bacteria to cross a variety of molecules up to the size of small proteins are called porins.
During transportation, the extracellular molecule binds to the transport protein which then rotates towards the intracellular matrix and releases the molecule inside the cell, e.g., Water channels made up of eight different types of aquaporins.

**Note:**

Aquaporin are membrane proteins for passive transport of water. They enhance the rate of transport of water across the membrane without altering the direction of transport.

**Passive Symports and Antiports**

In relation to facilitated diffusion, some carrier or transport proteins allow the movement of molecules only if two molecules move together. This type of movement is known as co-transport.

**It can be of following three types**

**a. Symport**

In this, both molecules cross the membrane in the same direction.

**b. Antiport**

In this both molecules cross membrane in opposite directions.

**c. Uniport**

In this type, the molecules moyes across a membrane independent of any other molecules

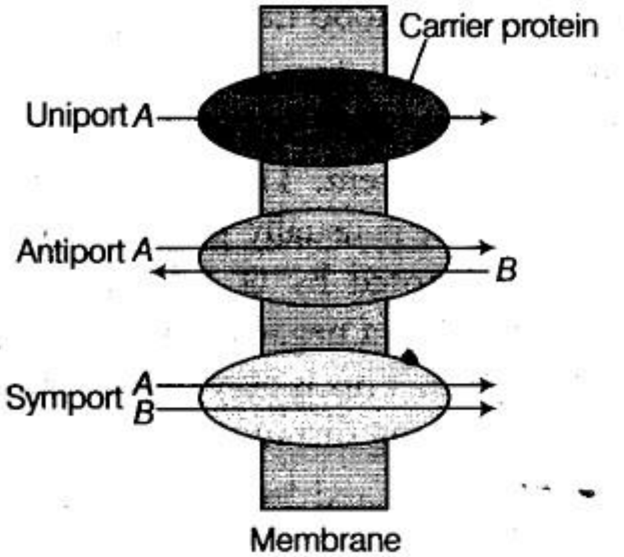


**Fig. 11.2** Facilitated diffusion

**3. Active Transport**

Active transport uses energy in the form of ATP to pump molecules or ions against a concentration gradient (i.e., uphill transport low concentration to high concentration). This is carried out by the carrier proteins in the plasma membrane. "When the transporters become saturated or are used up the rate of transport reaches its maximum level.

These carrier proteins are very specific in carrying protein across . the membrane. The ions once transported inside the membrane cannot return back to the outer space. While the carrier protein returns back to its original state in order to pick new ion or a molecule. These carrier proteins are very sensitive to inhibitors or other substances, which have the property of reacting with side chains of the proteins.

**Comparison of Different Transport Processes**

Out of the transport mechanisms discussed above, diffusion (whether facilitated or not) takes place along a concentration gradient without the utilisation of energy. However, both facilitated diffusion and active transport are mediated through membrane proteins.

Protein transporters are highly selective in nature, liable to get saturated, respond to inhibitors and are under hormonal regulation.

**Comparison of Different Transport Process**

| Property | Simple Diffusion | Facilitated Diffusion | Active Transport |
|---|---|---|---|
| Requires special membrane proteins | No | Yes | Yes |
| Highly selective | No | Yes | Yes |
| Transport saturates | No | Yes | Yes |
| Uphill transport | No | No | Yes |
| Requires ATP energy | No | No | Yes |

**Plant Water Relations**

Before discussing how absorption and transportation of water takes place in plants. It is necessary to understand some basic facts about water. Without the constant supply of water, the plant could not carry on any of its physiological activities.

**Some useful functions of water are given below**

(i) Water carries the nutrients from the soil to the plants.

(ii) Water acts as a major component of all living cells, i.e., a medium in which all substances are dissolved and undergo various types of reaction, e.g., protoplasm of cells is nothing but water containg several different molecules or suspended particles.

(iii) It acts as an excellent solvent and also acts as cooling system in plants.

(iv) Every plant whether herbaceous or woody consists of water but its amount varies, e.g., Herbaceous plant has 10-15% of its fresh weight as dry matter watermelon has 92% of water while woody plants has relatively very little water .

(v) It also acts as a major component of seeds (for their survival and respiration) although they appear dry.

(vi) It acts as a limiting factor for growth and productivity of plant in both agricultural and natural environments because of high demands of water by plants.

**Note:**

* A mature corn plant absorbs almost three litres of water in a day, while a mustard plant absorbs water equal to its own weight in about 5 hrs.

* Terrestrial plants take up huge amount water daily but most of it is loss to the air through transpiration (i.e., evaporation from the leaves).

* To understand plant water relation an understanding of action standard terms like water potential, solute potential, pressure potential etc

**Water Potential**

Potential is the way of representing free energy. All living organisms require free energy to grow, maintain metabolism and reproduce. As water molecules possess kinetic energy, they are in random motion (in both liquid and gaseous form) which is rapid and constant.

Thus, water potential is the difference between the free energy of water molecules in pure water and the energy of water in any other system. It is denoted by (psi) and expressed in pressure unit i.e., pascals (Pa). Greater the concentration of water in a system, greater will be its kinetic energy or water potential, i.e., pure water will have greatest water potential.

The best way to express spontaneous movement of water from one region to another is in terms of differences in the free energy of water between two region, i.e., one with the higher energy to one with the lower energy.

Thus, water will move from the system containing water with higher potential to the one having lower potential (down the gradient). Hence, this movement of water is called diffusion.

**Note:**
* The term water potential was first used by Slatyer and Taylor.
* By convention, the water potential of pure water at standard temperatures, which is not under any pressure, is taken to be zero.
* Water potential is always regarded as the tendency of water to leave a system.

**Solute Potential**

The magnitude by which water potential is reduced due , to the presence of a solute in pure water is known as solute potential. When solute or some substance is dissolved in pure water, the concentration of water decreases and solution will have fewer free water. It infers that the presence of solute particles in water reduces the free energy of water due to which water potential also decreases.

Solute potential is denoted by \J/S and is always negative (or has value less than zero).
Hence,
More number of solute molecules = Lower solute potential (more — ve).
At atmospheric pressure for a solution

$$\underset{\text{(Water potential)}}{\Psi_w} = \underset{\text{(Solute potential)}}{\Psi_s}$$

**Pressure Potential**

If a pressure more than atmospheric pressure is applied to pure water or a solution (containing solute), the water potential increases. This is equal to pumping water from one place to another such as our heart buildup pressure for the circulation of blood in the body. When water enters a plant cell through diffusion, it becomes turgid due to building up of pressure against the cell wall in a plant system. This leads to increase in the pressure potential. It is usually positive known a turgor pressure and is denoted by fp. Loss of water during transpiration produces a negative hydrostatic pressure or tension in the xylem. This is very important in transport (Asent of sap) over long distances in plants.

Water potential is affected by both solute and pressure potential.

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

**Osmosis**

A plant cell is surrounded by both cell wall and cell membrane. The cell wall is freely permeable, i.e., it does not act like a barrier to the movement of water and other substances. The cell membrane and membrane of vacuole, the tonoplast are responsible for determination of water or other molecules in or out of the cell.

The large central vacuole and its contents (vacuolar sap) contributes to the solute potential of the cell.

Osmosis may be defined as the net movement of solvent molecules (water molecules) across a differentially or semipermeable membrane.

Osmosis takes place very spontaneously in response to a driving force.

The movement of solvent, in osmosis occurs due to the differences of water potential on two sides, i.e., water will move from a region of higher chemical potential to a region of lower chemical potential until the state of equilibrium is reached.

**The net direction of molecules and rate of osmosis depends on two factors**

(i) Pressure gradient
(ii) Concentration gradient.

Osmosis is a passive process and does not require any input of energy. Discovery of osmosis was made by Pfeffer.

**Illustration of Osmosis**

Phenomenon of osmosis can he easily understood on the basis of the diagram given below

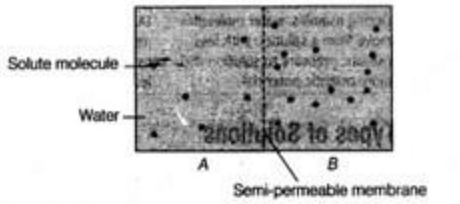


**Fig.11.3** Two chambers *A* and *B* containing solutions separated by a semi-permeable membrane

**On the basis of this following observations are made**

(i) Solution in chamber B has a lower water potential (as it contains more number of solute particles
than A).

(ii) Solution in chamber A has a lower solute potential (as it has less number of solute particles, than B chamber) and B chamber has higher solute potential (as it contains high solute particles and less solvent, i.e., water).

(iii) Osmosis will takes place from chamber A —> B because as explained earlier osmosis always occurs from its region of higher chemical potential to a region of lower chemical potential.

One must not be confused with the movement of solvent (water) and movement of solute (water + solute particles) as solute always moves from a region of lower concentration to higher concentration and vice-versa in the case with solvent

(iv) At equilibrium, both chambers will have same water potential (i.e., neither A and B will have lower or higher water potential).

**Note:**

Endosmosis and Exosmosis The inflow of solvent (water) into a cell from outside when placed in distilled water, is called endosmosis in which cells swell up due to the entry of water and become turgid.

On the other hand, the outward flow of water from cell when placed in hypertonic solution like sugar solution, the cell tends to shrink and becomes flaccid. This outward flow of water in solution is called exosmosis.

**The Funnel Experiment**

This is another experiment, which is performed in the laboratory through which phenomenon of osmosis can be easily demonstrated.

**Following steps are performed during this experiment**

(a) A beaker is taken and filled with pure water.

(b) A thisde funnel is filled with sucrose solution and kept inverted in a beaker containing water (level is noted).

(c) The inverted funnel is separated from a pure water through a semi-permeable membrane.

(d) Level of the sucrose solution will rise into the funnel as water will move into the funnel as shown in fig (a).

(e) Water will continue moving till an equilibrium state is achieved.

If sucrose will diffuse out through the membrane, the equilibrium will not be reached ever, because for the state of equilibrium the concentration or gradient potential should be equal in both the chambers, i.e., funnel and beaker.

(f) External pressure is applied from the upper part of the funnel as in fig.(b) to stop the water movement into the funnel through the membrane.

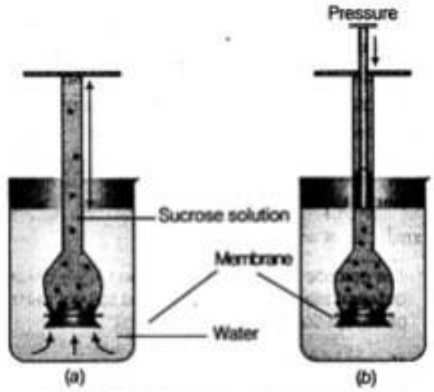

**Fig. 11.4** Demonstration of osmosis
A thistle funnel is filled with sucrose solution and kept inverted in a beaker

**Differences between Diffusion and Osmosis**

| Diffusion | Osmosis |
| --- | --- |
| It is the movement of molecules or ions from a zone of high to low concentration or from a zone of their higher free energy to a zone of lower free energy, until they are evenly spread in the media. | It is the movement of solvent (water) molecules from a zone of higher free energy to a zone of lower free energy through a semipermeable membrane. |
| Can occur in any type of medium solid, liquid or gaseous. | Occurs only in liquid medium. |
| Semipermeable membrane not involved. | Semipermeable membrane is involved. |
| It is just dependent on the free energy of diffusing molecules. | It is dependent upon the free energy of solvent molecules present on both sides of the membrane. |

**Significance of Osmosis**

**Osmosis is helpful in many ways as given below**

(i) It helps in maintenance of cell turgidity.
(ii) Plays a vital role in stomatal movement during transpiration.
(iii) It helps in the movement of liquids across biological membranes.
(iv) It also have effects on absorption of water by roots.

Osmotic Pressure

It is that pressure of a solution, which must be applied to the solution in order to allow passage of solvent due to osmosis. This is also the function of solute concentration; i.e., more the concentration of a solute, greater will be the amount of pressure applied in order to prevent water from diffusing. Osmotic pressure is numerically equal to the osmotic or solute potential but osmotic potential has a negative sign, while osmotic pressure is always a positive pressure.

*i.e.,* $\psi_s = -\pi$

where, $\psi_s$ = solute potential

and $\pi$ = osmotic pressure

The osmotic pressure of a solution largely depends upon the ratio between the number of solute and solvent particles present in a given solution.

**Note:**

* Instrument used for measuring osmotic pressure is called osmometer, eg., Berkeley and Hartleys osmometer.

* Reverse osmosis is expulsion of pure water from solution through a semipermeable membrane under the influence of external pressure, higher than OP of solution.

**Differences between Osmotic Pressure and Osmotic Potential**

| Osmotic Pressure | Osmotic Potential |
|---|---|
| It is the pressure which must be applied in order to prevent the passage of solvent due to osmosis. | It is the amount by which water potential is reduced as a result of presence of solutes. |
| Its unit is bars with positive sign. | Its unit is bars with negative sign. |
| Osmotic pressure of pure solvent (water) is zero. The value increases due to addition of solute particles. | The value of pure solvent (water) is also zero. Addition of solute particles makes the value of the osmotic potential more negative. |
| During osmosis, water molecules move from a solution with less osmotic pressure to solution with more osmotic potential. | During osmosis, water molecules move from a solution with more osmotic potential to solution with less water potential. |

**Types of Solutions**

The plant cells or tissues behave according to the movement of water depending upon the surrounding solution. Thus, on the basis of concentration of cell sap (cellular solution found in large central vacoule of a living plant cells).

The solutions are of following three types (i) Isotonic Solution It is a type of solution, which has a similar concentration as the cell sap of the cells, i.e., No change occurs in a cell after placing it in isotonic solution.

(ii) Hypotonic Solution It is a type of solution which has lower concentration (more diluted) than the cell sap. The cell swells up when placed in this solution.

(iii) Hypertonic Solution It is a type of solution which has higher concentration than the cell sap of cells. The cells shrink, when placed in hypertonic solution.

Note:

The term ‘Diffusion Pressure Deficit’ (DPD) was coined by BS Meyer in 1938. The amount by which diffusion pressure of a solution is lower than that of its pure solvent is known as diffusion pressure deficit.

$$DPD = OP - TP\ (WP)$$

Fully turgid cell

$$DPD = O$$

$$OP = TP$$

fully flaccid cell

$$TP = O$$

$$DPD = OP$$

**Plasmolysis**

This phenomenon occurs when water moves out of the cells and the cell membrane of a plant cell shrinks away from its cell wall when placed in a hypertonic solution (having more concentration). During the process the hypertonic solution causes exosmosis (outward movement of water).

The water first moves out from the cytoplasm and then from the central vacoule. This withdrawal of water through diffusion into the extracellular fluid causes the cell to shrink in size, due to which cell moves away from the walls. The cells is said to be plasmolysed.

The space between the cell wall and the shrunken protoplast is occupied or filled by the eternal solution.

At limiting plasmolysis the pressure of external solution balances the osmotic pressure of the cytoplasm. Thus, during this state of equilibrium when flow of water into and out of the cell is same, the cells are called flaccid.

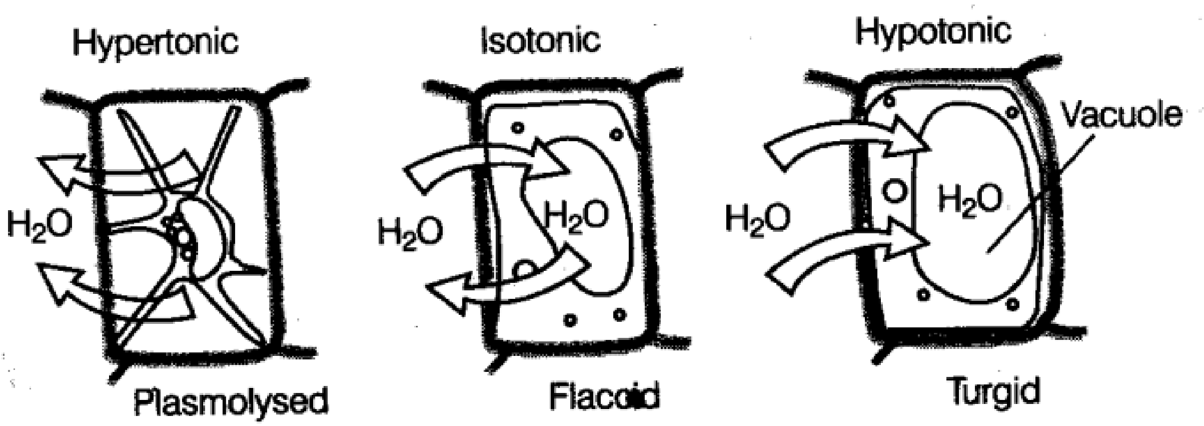


**Fig. 11.5** Plant cell plasmolysis

**Deplasmolysis**

The process in which the plasmolysed cell when placed in pure water or hypotonic solution, builds up a turgor pressure (in which water enters the cell and cause the cytoplasm to build up a pressure against the wall). It is mainly responsible for enlargement and extensive growth of the cells. During this stage, water enters due to endosmosis and cell again becomes turgid when protoplast attains its original shape and size. As cell wall is rigid, the cell do not rupture. The pressure exerted against rigid wall due to the entry of water by the protoplasts is called pressure potential, i.e., fp .

(i) Deplasmolysis should be followed immediately after plasmolysis otherwise the cell protoplast becomes damaged permanently.

(ii) Pressure potential of a flaccid cell is zero because there is no net movement of water in and out of the cell.

(iii) Cell wall is found in bacteria, fungi, algae some archea and plant cells (animals and protozoans do not have cell wall).

**Differences between Plasmolysis and Deplasmolysis**

| Plasmolysis | Deplasmolysis |
|---|---|
| It occurs when a tissue is placed in hypertonic solution. | Deplasmolysis occurs when freshly plasmolysed cells are kept in hypotonic solution or pure solvent. |
| Plasmolysis is a result of exosmosis. | Deplasmolysis is a result of endosmosis. |
| Plasmolysis involves shrinkage of protoplast from the cell wall. | It is swelling of shrunken protoplast so as to come in contact with cell wall. |
| Plasmolysis is not reversible after a long interval of time. | Deplasmolysis is reversible even after an interval. |

**Significance of Plasmolysis**

(i) It allows a plant cell to lose water without dying, it can shrink or increase in size as water is available within the constraints of the cell wall.

(ii) It is shown by living cells. By this we can determine whether a cell is living or dead.

(iii) It helps in determining osmotic pressure of plants.

(iv) It proves that cell wall is elastic and permeable.

**Imbibition**

It is a special phenomenon in which water or any other liquid is absorbed by the solid particles (colloids) of a substance. This leads them to increase enormously in volume. The solid particles which imbibe water or any other liquid are called imbibants. The liquid, which is imbibed is known as imbibate. It is also a type of diffusion because movement of water occur along concentration gradient as in diffusion. During imbibition, water molecules get tightly adsorbed and becc immobilised.

**Note:**

* During imbibition water molecule lose most of their kinetic energy in the form of heat. This is called heat of hydration or heat of wetting

* Imbibition can be best explained and seen in absorption of water by seeds and drywood which acts as absorbents to imbibe water and swell.

**Imbibition Pressure**

The pressure developed by solid particles, which adsorbs water or any other liquid when submerged in pure imbibing liquid is called imbibition pressure. It is due to this pressure in plants that seedlings emerge out of the soil and establish themselves.

Conditions necessary for imbibition to take place are

(i) Affinity between the adsorbant and the liquid imbibed is essential.

(ii) Water potential gradient between the absorbent and the liquid imbibed.

The phenomenon of imbibition is also influenced by several factors like temperature (increases with rise in temperature), pressure (decreases if pressure is against imbibant), pH (depends on change of imbibant) electrolytes (decreases) and texture of imbibant (increases if it is loose, decreases if it is compact in nature).

**Importance of Imbibition**

**Imbibition plays following major roles**
(i) Helps seedlings to come out of soil.
(ii) Acts at the initial stage in germination of the seeds.
(iii) Helps of seeds.
(iv) In older times, the imbibition pressure was used in breaking the rocks and stones.
(v) It is dominant in the initial stage of water absorption by roots.

**Differences between Imbibition and Diffusion Imbibition Diffusion**

| Imbibition | Diffusion |
|---|---|
| In this the absorption of solvent or water takes place by a solid substances. | It is the movement of substances from the region of their higher concenteration to the region of their lower concentration. |
| It always results in the release of heat (called heat of wetting or heat of hydration). | It does not involve the release of heat. |
| The molecules of water or any other liquid are adsorbed to the surface of hydrophilic colloids (e.g., cellulose, starch, proteins, polypeptides, etc). | The diffusing particles/molecules distributed uniformaly throughout the available space. |
| The imbibant swells up but the swelling is less than volume of imbibate. | No overall change in volume is seen |
| It occurs only when an adsorbant ( imbibant) is present. | There is no requirement of any adsorbant. |
| It develops a very high pressure (up to 1000 atm). | It develops less pressure comparatively (upto 100 atm). |

**Note:**
Adsorption is property of colloids. Hence, material which have high proportion of colloids are good imbibants. eg., wood, is good imbibant as it contains proteins, cellulose and starch as colloidal substances.

**Topic 2 Long Distance Transport of Water**

Long distance transport of substances cannot take place by the process of diffusion alone. Diffusion accounts for only those molecules that move for short distance and it is a very slow process. For instance, the movement of a molecule across a typical plant cell (about 50 pm) takes approximately 2.5 second. At this rate, the movement of molecules over a distance of 1 m would take approximately 32 years by diffusion alone.
In large and complex organisms, sites of production or absorption and sites of storage are far away from one another thus, the substances to be transferred have to follow a long path and move across very large distances.
Hence, some special long distance transport systems are necessary in order to transfer substances across long distances at much faster rate.
The movement of water, minerals and food across long distances is generally done by a mass or bulk flow system, which operates due to difference between the pressure of two points, i.e., the source and the sink. The substances whether dissolved or suspended in solution, are carried at a same speed. Such a movement is different from diffusion where different substances move independent of each other depending upon concentration gradients of their own. Mass or bulk flow movement occurs through vascular tissues, xylem and phloem of plants. The bulk movement of substances through conducting or vascular tissues of plant is called translocation.

**There are generally two types of vascular tissues in plants which are responsible for translocation**
(i) Xylem It is responsible for translocation of water with mineral salts, some organic nitrogen and hormones mainly from roots to aerial parts of plants.
(ii) Phloem It is responsible for translocation of organic and inorganic substances from leaves to other parts of the plant. Bulk flow can operate either due to positive hydrostatic pressure

gradient (like a garden hose) as in phloem or a negative hydrostatic pressure gradient (like suction through a straw) as in xylem.

**Absorption of Water by Plants**

Plants absorb water through roots. However, the area of young roots where most absorption of water and minerals takes place is root hair zone. Root hairs are thin walled, slender extension of root epidermal cell present at the tip of the roots in millions. These are very delicate structure, which do not last for more than days or a week. They have very sticky walls that help in tight adhesion to the soil particles.

Tracheids and trachea of xylem transport water in plants.

Water once absorbed by file root hairs enter epidermis from where, it moves deeper into the root layers and finally reaches xylem following two pathways, i.e., apoplast and symplast.

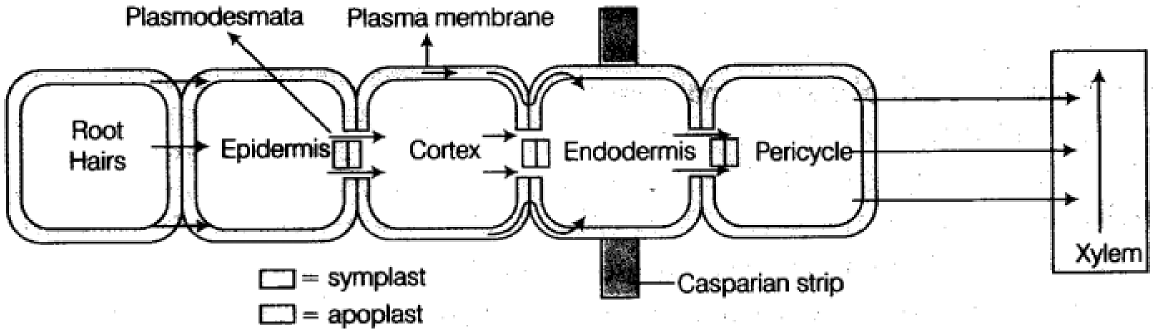


**Fig. 11.6** Pathway of water movement in the root

**Apoplast Pathway**

Apoplast is the system of adjacent cell walls (i.e., interconnecting cell walls, intercellular spaces, cell wall of endodermis) that occur continuously throughout the plant, except at the casparian strips of endodermis in roots. In this pathway, the movement of water molecules takes place through intercellular spaces and the walls of the cells only. The water movement takes place along the gradient" from root hairs to xylem through the walls of intervening cells without crossing any membrane or cytoplasm.Thus, it does not provide any barrier to the movement of water, which occur through mass flow , due to adhesion and cohesion of water molecules.

There is no involvement of osmosis in the apoplast pathway.

**Symplast Pathway**

This system includes the living part of the plant cells made up of interconnected protoplasts of neighbouring cells and connected through cytoplasmic strands extending through plasmodesmata.

The water that enters into the cell sap of root hair as a result of active absorption, moves into the underlying cortex cells bounded by a continuous selectively permeable membrane through plasmodesmata.

The movement is relatively slower as water enters the cells through the cell membrane. The movement is again down the potential gradient. This pathway is aided by cytoplasmic streaming, which helps in quicker movement across individual cells. Thus, facilitating transport.

Cytoplasmic Streaming is an autonomous vital movement that occurs in eukaryotic cells continuously, e.g., around the central vacuole. Also known as cyclosis. It can be easily observed in the cells of Hydrilla leaf. The movement of chloroplast due to streaming is easily seen under microscope.

It is generally believed that both apopiast and symplast pathways are operative in plants but apopiast pathway offers less or no resistance. Thus, water continue to move through apopiast in the roots.

As the apopiast pathway is bfbcked by the bond of a suberised matrix called the casparian strip in the inner boundary of the cortex, the endodermix is imperious to water.
Therefore, the movement of water by and the endodermis occurs by the symplast pathway, i.e., water from the cell walls enter the cell cytoplasm and moves from one cell cytoplasm to another cell cytoplasm crossing the cell membrane through plasmodesmata and finally reaches the xylem elements.

**Mycorrhizal Absorption**

Instead of using root hairs for absorption many plants use mycorrhiza for water absorption. Mycorrhiza is a symbiotic association between a fungus and a young root system of a plant. Fungal hyphae have a very large surface area and extend into soil for sufficient distance, where a root cannot reach.
They absorb both mineral ions and water from the soil and provide these substances to the roots. The roots in turn provides sugar and N-containing compound to the mycorrhizae. The mycorrhizal association is obligate in many cases, e.g., seeds of Pinus and many orchid cannot ’ germinate properly without the development of mycorrhizal association.

**Water Movement up a Plant (Ascent of sap)**

Translocation of water or ascent of sap is usually upwards from the roots toward the top of the plant via stem, i.e., to the leaves and growing points or apical meristems and other aerial plant parts. It occurs through the tracheary elements of xylem. Many theories have been put forward to explain the upward movement of water.

**Two of them are given below**

**Boot Pressure**

It is believed that all plants absorb excess of water by an active process and tends to build up a positive hydrostatic pressure within the root system known as root pressure. Due to this activity the water is pushed upward along the length of the stem to a small height. The pressure inside the xylem is caused due to the diffusion pressure gradient and is maintained by the activity of living cells.

**Demonstration of Root Pressure in Plants**

At the start of the experiment, choose a plant having soft stem on a day when there is plenty of moisture in the atmosphere. Early in the morning cut the stem horizontally near the base, i.e., just above the soil with a sharp blade. The moment cut is made, few drops of solution start oozing out of the cut stem, which is due to the positive root pressure. Now in order to determine the rate of exudation (substances that oozes out) and the composition of the exudates (like sap, germs, latex, etc.), fix a vertical glass tuBe filled with water, with the help of a rubber tube to the cut end the stem. A column of sap is seen to ripe in the tube, which will be the measure of the root pressure.
Root pressure is inhibited or reduced during reduced aeration, low or high temperature, drought, etc.
Root pressure is maximum during early morning of spring and – rainy season when the level of evaporation is low or minimum and decreases with the advancement of day.
The magnitude of root pressure is about two bars or atmospheres.

**Guttation**

* When the amount of root pressure is high and rate of itranspiration is low, many herbaceous plants tend to loose small quantities of water or liquid in the form of drops from the hydathodes (small pores) or water glands. These are present on the margins of the leaves or where the main vein ends and near the tips of blades of some vascular plants like i i grasses and small herbaceous plants (rose, strawberry, tomato, etc).
* This phenomenon water loss in its liquid phase is called guttation. It takes place usually in early morning. The water that oozes out contains organic-and inorganic substances.

**Contribution of Root Pressure**

As root pressure contribute a modest push in the overall water transport. The enormous tension developed by transpiration, breaks the continuous chains of water molecules in the xylem which gets re-establish by the root pressure. In this way root pressure provides a great contribution in the transport of water.

**Limitations to Root Pressure**

Root pressure cannot account for the translocation of water or ascent of sap due to the following reasons

(i) It cannot lift sufficient amount of water upward to meet the requirement of water.

(ii) It fails to play a role in water movement in tall trees like gymnosperms, etc.

(iii) The amount of the fluid transported by the root pressure is not enough in measuring the movement of water in xylem in many trees.

(iv) Root pressure seems to be absent in summer when the requirements of water are high.

Although it plays a major role in the transport of water through xylem in some plants and some seasons but it does not account for majority of water transport due to which most plants fulfil their needs by transpiratory pull.

**Transpiration Pull**

Plants have a continuous water column in their xylem channels that starts at the base, i.e., roots and continues up to leaves from where water is lost through the process of transpiration. Thus, despite the absence of a circulatory system in plants, the flow of water upward through the xylem in plants achieve fairly high rates up to 15 meters per hour.

The water molecules in the water column remain attracted by the cohesive force and cannot be separated easily from one another. Thus, there is attraction between water molecules and the inner wall of xylem ducts. Hence, water column cannot be pulled away from the walls of xylem ducts due to strong adhesive and cohesive forces. This maintains the continuity of water column from roots to leaves.

Water is lost from mesophyll cells to the inter cellular spaces as a result of transpiration and develops a strong negative water potential. There are very large number of leaves and each leaf has thousands of transpiring mesophyll cells, which withdraw water from the xylem. This leads to a negative pressure in the water column, which exerts an upward pull over the water column. This pull is known as transpirational pull.

This tension or pull is transmitted up to the roots in search for more water. The water column (formed in the xylem elements of roots) now moves upward under the influence of transpirational pull.

Thus, the cohesive, adhesive forces and transpiration pull all help in lifting up of water through xylem elements and because of the critical role of cohesion the transpiration pull is also called cohesion-tension transpiration pull model of water transport.

**Note:**

Cohesion-tension theory was originally proposed by Dixon and Jolly in 1894 and further improved by Jolly in 1914.

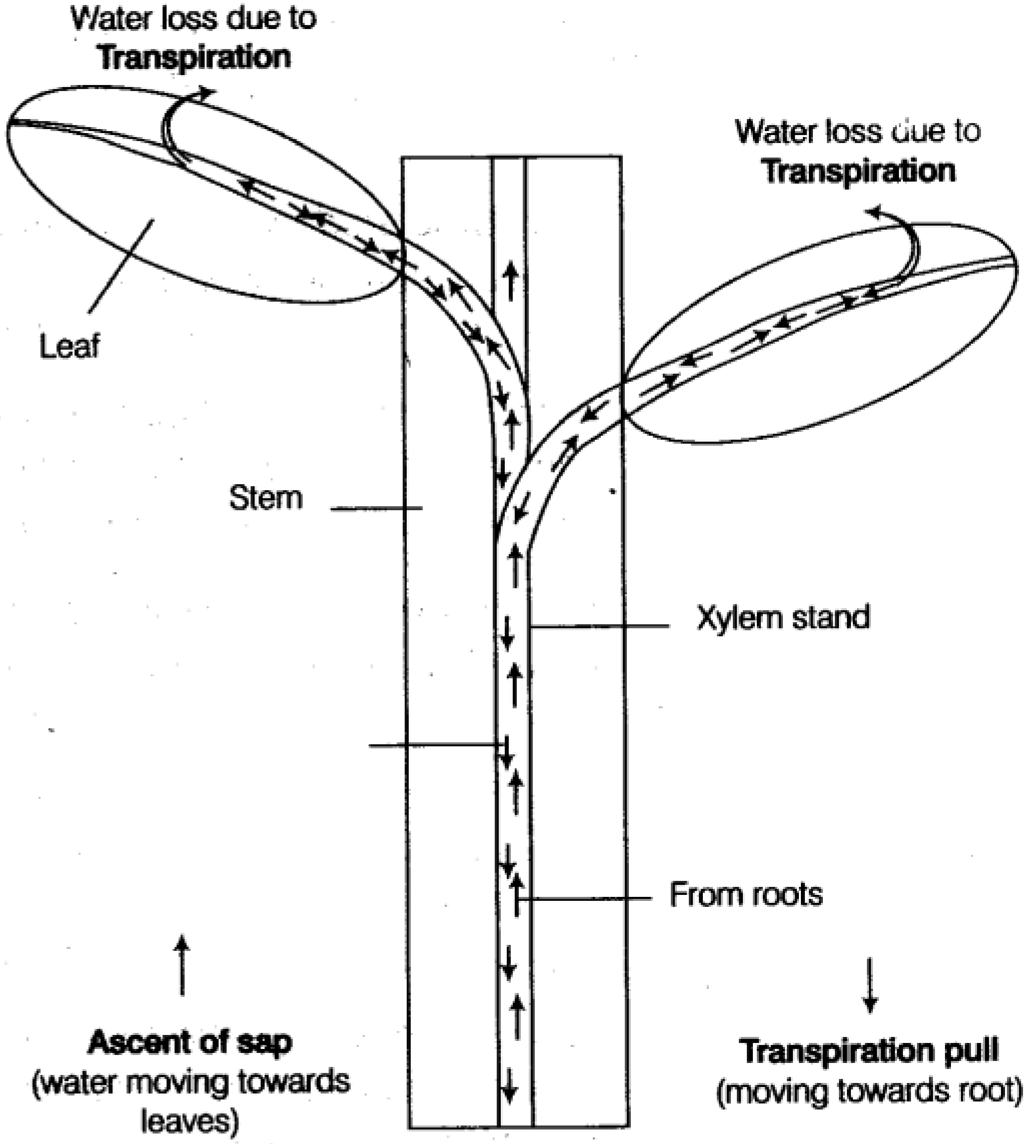


**Fig. 11.7** Transpiration pull (tension) and ascent of sap