SOIL – WATER PLANT RELATIONS AND TRANSLOCATION OF ORGANIC SOLUTES

INTRODUCTION

Plant physiology (*Physis* = nature of life; *logas* = study) is the branch of botany which deals with the study of life activities of plants. It include the functional aspects of its processes both at cellular as well as sub-cellular level.

Life process or physiological process may be defined, as any chemical or physiological change occuring within a cell and organism and any exchange of substances between the cell or organism and its environment.

According to the definition of physiological process, imbibition, osmosis, diffusion, plasmolysis, water potential, water conduction, ascent of sap, transpiration, solute absorption and translocation, transport of radiant energy, photomorphogenetic responses, etc. are considered as physiological processes.

3.1 CONCEPT OF WATER RELATION

Water is the most important constituent of plants and is essential for the maintenance of life, growth and development. Plants lose huge amount of water through transpiration. They have to replenish this lost water to prevent wilting. Water is mainly absorbed by the roots of the plants from the soil, than it moves upward to different parts and is lost from the aerial parts, especially through the leaves. Before taking up the absorption and movement of water in plants, it is worthwhile to understand the phenomenon of imbibition, diffusion and osmosis involved in the water uptake and its movement in the plants.

(1) **Imbibition :** The process of adsorption of water by solid particles of a substance without forming a solution is called 'imbibition'. It is a type of diffusion by which movement of water take place along a diffusion gradient. The solid particles which adsorb water or any other liquid are called **imbibants**. The liquid which is imbibed is known as imbibate. Cellulose, pectic substances, protoplasmic protein and other organic compound in plant cells show great power of imbibition.

(i) **Characteristics of imbibition :** The phenomenon of imbibition has three important characteristics :

(a) **Volume change :** During the process of imbibition, imbibants increase in volume. It has been observed that there is an actual compression of water. This is due to arrangement of water molecules on surface of imbibant and occupy less volume than the same molecules do when are in free stage in the normal liquid. During the process of imbibition affinity develops between the adsorbant and liquid imbibed. A sort of water potential gradient is established between the surface of adsorbant and the liquid imbibed.

e.g. If a dry piece of wood is placed in water, it swells and increases in its volume. Similarly, if dry gum or pieces of agar agar are placed in water, they swell and their volume increases. Wooden doors and windows adsorb water in humid rainy season and increase in their volume so that they are hard to open or close, in gram and wheat the volume increase by adsorption of water, in plant systems are adsorption of water by cell wall.

(b) **Production of heat :** As the water molecules are adsorbed on the surface of the imbibant, their kinetic energy is released in the form of heat which increase the temperature of the medium. It is called heat of wetting (or heat of hydration). *e. g*., during kneading, the flour of wheat gives a warm feeling due to imbibition of water and consequent release of heat.

(c) **Development of imbibitional pressure :** If the imbibing substance (the imbibant) is confined in a limited space, during imbibition it exerts considerable pressure. The bursting of seed coats of germinating seeds is the result of **imbibition pressure** developed within the seeds as they soak the water. **Imbibition pressure** can be defined as the maximum pressure that an imbibant will develop when it is completely soaked in pure water. Imbibition pressure is also called as the **matrix potential** because it exists due to the presence of hydrophilic substances in the cell which include organic colloids and cell wall.

Resurrection plants of *Selaginella*, lichens, velamen roots and dry seeds remain air dry for considerable periods because they can absorb water from the slight downpour by the process of imbibition.

(ii) **Factors influencing the rate of imbibition**

(a) **Nature of imbibant :** Proteins are the strongest imbibants of water, starch less strong, cellulose being the weakest. That is why proteinaceous pea seeds swell more than the starchy wheat seeds. During seed germination seed coat rupture first because it is made up of cellulose (weak imbibant) and kernel is made up of protein, fat and starch (strong imbibant).

(b) **Surface area of imbibant :** If more surface area of the imbibant is exposed and is in contact with liquid, the imbibition will be more.

(c) **Temperature :** Increase in temperature causes an increase in the rate of imbibition.

(d) **Degree of dryness of imbibant :** If the imbibant is dry it will imbibe more water than a relatively wet imbibant.

(e) **Concentration of solutes :** Increase in the concentration of solutes in the medium decreases imbibition due to a decrease in the diffusion pressure gradient between the imbibant and the liquid being imbibed. It is due to the fact that imbibition is only a special type of diffusion accompanied by capillary action. If some solute is added into the liquid which is being imbibed, its diffusion pressure decreases and the process of imbibition slows down.

(f) ***pH* of imbibant :** Proteins, being amphoteric in nature, imbibe least in neutral medium. Towards highly acidic or highly alkaline *pH*, the imbibition increases till a maximum is reached, there after it starts slowing down.

(iii) **Significance of imbibition**

(a) The water is first imbibed by walls of root hairs and then absorbed and helps in rupturing of seed coat (made up of cellulose).

(b) Water is absorbed by germinating seeds through the process of imbibition.

(c) Germinating seeds can break the concrete pavements and roads etc.

(d) The water moves into ovules which are ripening into seeds by the process of imbibition.

(e) It is very significant property of hydrophilic surfaces.

(2) **Diffusion :** The movement of the molecules of gases, liquids and solutes from the region of higher concentration to the region of lower concentration is known as diffusion.

Or

Diffusion is the net movement of molecules or ions of a given substance from a region of higher concentration to lower one by virtue of their kinetic energy.

Or

It is the movement of molecules from high diffusion pressure to low diffusion pressure.

Phenomenon of diffusion can be observed everyday.

It may occur between gas and gas (*e.g.,* diffusion of ammonia into air), liquid and liquid (*e.g.*, diffusion of alcohol into water), or solid and liquid (*e.g.*, diffusion of sugar into water). The diffusion of one matter is dependent of other. That is why many gases and solutes diffuse simultaneously and independently at different rates in different direction at the same place and time, without interfering each other. From soil, water and ions of simple inorganic salts pass into plants through the root cells by a process which is basically diffusion, though greatly modified by other factors. The water and solutes pass through the dead and living vessels and also from cell to cell by diffusion. When a crystal of copper sulphate is placed in a beaker containing water, a dense blue colour is seen around the crystal.

(i) **Diffusion pressure :** It is a hypothetical term coined by **Meyer** (1938) to denote the potential ability of the molecules or ions of any substance to diffuse from an area of their higher concentration to that of their lower concentration. Alternatively, it may also be defined as the force with which the diffusing molecules move along the concentration gradient.

(ii) **Diffusion pressure deficit (DPD) or Suction pressure (SP) :** The term diffusion pressure (DP) and diffusion pressure deficit (DPD) were putforth by B.S. Meyer in 1938. Originally, the DPD was described by the term *suction force* (*Saugkraft*) or *suction pressure* (*SP*) by Renner (1915). Now a days, the term *water potential* (ψ) is used which is equal to DPD, but negative in value.

Each liquid has a specific diffusion pressure. Pure water or a pure solvent has the maximum diffusion pressure. If some solute dissolved in it, the water or solvent in the resulting solution comes to attain less diffusion pressure than that of the pure water or pure solvent. In other words, diffusion pressure of a solvent, in a solution is always lower than that in the pure solvent. 'The amount by which the diffusion pressure of water or solvent in a solution is lower than that of pure water or solvent is known as *diffusion pressure deficit* (*DPD*)'. Because of the presence of diffusion pressure deficit, a solution will always tend to make up the deficit by absorbing water. Hence, diffusion pressure deficit is the water absorbing capacity of a solution. Therefore, DPD can also be called **suction pressure (SP).**

(iii) **Factors influencing rate of diffusion**

(a) **Temperature :** Increase in temperature leads to increase in the rate of diffusion.

(b) **Pressure :** The rate of diffusion of gases is directly proportional to the pressure. So the rate of diffusion increases with increase of pressure. Rate of diffusions $\propto$ pressure.

(c) **Size and mass of diffusing substance :** Diffusion of solid is inversely proportional to the size and mass of molecules and ions.

Rate of diffusion $\propto \frac{1}{\text{Size} \times \text{Mass of particles}}$

(d) **Density of diffusing substance :** The rate of diffusion is inversely proportional to the square root of density of the diffusion substance. Larger the molecules, slower will be the rate of diffusion. This is also called **Graham's law of diffusion**.

$D \propto \frac{1}{\sqrt{d}}$ (D = Diffusion and *d* = Density of diffusing substance).

According to the density the diffusion of substances takes place in following manner –

Gas > Liquid > Solid

The vapours of volatile liquids (sent or petrol) and solids (camphor) also diffuse like gases.

(e) **Density of the medium :** The rate of diffusion is slower, if the medium is concentrated. Thus, a gas would diffuse more rapidly in vacuum than in air. Substances in solution also diffuse but at a much slower rate than gases. Substances in solution diffuse more rapidly from regions in which their concentration is higher into regions of low concentration. If two solutions of sugar (or of any other substance) of different concentrations are in contact, sugar molecules diffuse from the higher to the lower concentrations of sugar and water molecules diffuse from the higher to the lower concentrations of water, until equilibrium is attained when the two solutions become of equal concentration.

(f) **Diffusion pressure gradient (DPG) :** The rate of diffusion is directly proportional to the difference of diffusion pressure at the two ends of a system and inversely proportional to the distance between the two.

(iv) **Significance of diffusion**

- Gaseous exchange during the processes of photosynthesis and respiration takes place with the help of diffusion.
- The process of diffusion is involved in the transpiration of water vapours.
- Aroma of flowers is due to diffusion of volatile aromatic compounds to attract pollinating animals.
- During passive salt uptake, the ions are absorbed by process of diffusion.

- Diffusion helps in translocation of food materials.
- Gaseous exchange in submerged hydrophytes is takes place by general surface of the cells through diffusion.

(3) **Permeability :** Permeability is the degree of diffusion of gases, liquids and dissolved substances through a membrane. Different types of membranes may be differentially permeable to different substances. Normally, permeability of a given membrane remains unchanged, but it may change with alteration in the environmental conditions of the cell.

(i) Types of membranes on the basis of permeability

(a) **Permeable membrane :** These membranes allow free passage of solvent (water) and most of the dissolved substances. *e.g.*, cell wall in plant cells. Filter paper is made up of pure cellulose it also functions as permeable membrane.

(b) **Impermeable membrane :** This type of membranes with deposite of waxy substances like cutin and suberin, do not allow the entry of water, dissolved substances and gases. *e.g.*, suberized walls of cork cells, cuticle layer of leaf.

(c) **Semi-permeable membrane :** These membranes permit the movement of solvent molecules only through them, but prevent the movement of solute particles. *e.g.*, egg membrane, animal plasma membrane, parchment membrane, copper ferrocyanide membrane, membranes of collodion.

(d) **Selectively or Differentially permeable membrane :** This type of membranes allow selective passage of solutes along with solvent, through them. *e.g.,* Osmotic diffusion of water through selectively permeable membrane start from higher water potential to lower water potential. Many biological membranes such as cell membrane (plasmalemma), tonoplast (vacuolar membrane) and the membranes surrounding the sub-cellular organelles are selectively permeable. A non-living selectively permeable membranes is cellophane.

(ii) **Theories of cell permeability :** Following theories are given for cell permeability :

(a) **Sieve theory :** Rhouhland and Hoffman described that, small pores are found on membranes.

- The molecules which are small in size than pores of membrane are only passed through these membranes.
- So the molecules of glucose diffused faster as comparatively sucrose (bigger size) molecules.

(b) **Solubility theory :** According to Overtone, formation of membranes take place by fats. Therefore membranes are permeable for those molecules, which are dissolve easily in it.

On the basis of this theory, the permeability of fat insoluble substances like sugar, minerals and amino acids cannot explained.

(c) **Electro capillary theory :** Michaelis, Scorth and Loyad proposed modified theory of sieve theory.

- According to this theory pores found on membranes are surrounded by charged proteins.
- Permeability depends upon the size of charged particles present on pores, size of pore and the charge present on pores.
- So if ionizing substance are smaller than pores, it can pass through membrane.
- In the same way both positive and negative ions pass through the uncharged pores. But positive ions moves through negatively charged pores and negative ions moves through positively charged pores.

(d) **Carrier concept :** According to this concept, movement of substances through membrane required two types of carriers called carrier particle and carrier vesicles.

Carrier particles : These type of particles attached with solutes and forms carrier solute complex. Because it shows chemical affinity to solutes.

- After reaching on inner surface of membrane this carrier, solute complex breakdown.
- Solute enters into the cell and carrier transferred to outer surface.

Carrier vesicles : Wheeler and Hanchey (1971) described that the transportation of substances in higher plants take place by the means of pinosomes.

- Pinosomes originate by infoldings of cells. It shows bulk transportation.

(4) **Osmosis :** Osmosis (Gr. *Osmos* = a pushing or impulse) was discovered by Abbe Nollet in 1748 and also coined the term 'osmosis'. First of all Traube (1867) use copper ferrocyanide and develop semipermeable membrane to show its utility in the osmosis of plant physiology. First time Pfeffer in (1887) develop osmoscope by using semipermeable membrane.

Osmosis is special type of diffusion of a liquid, when solvent moves through a semipermeable membrane from a place of higher diffusion pressure to a place of lower diffusion pressure.

Or

It is the migration of solvent from a hypotonic solution (of lower concentration) to hypertonic solution (of higher concentration) through a semi-permeable membrane to keep the concentration equal. In osmosis, the water (or solvent) molecules moves as follows :

From the region of	**To the region of**
Pure solvent (water)	Solution
Dilute solution	Concentrated solution
High free energy of water molecules	Low free energy of water molecules
Higher chemical potential (or water potential)	Lower chemical potential (or water potential)
Higher diffusion pressure of water	Lower diffusion pressure of water

- In formalin preserved *Spirogyra* filament, selective permeability of plasmamembrane is lost and hence no effect on placing in hypertonic solution.
- If salt presents in higher concentration in a cell than outer side, water will enter in the cell by osmosis.

(iv) **Differences between diffusion and osmosis**

S.No.	Diffusion	Osmosis
(1)	It is the movement of particles, molecules or ions from the region of their higher free energy to the region of their lower free energy.	It is the movement of solvent of water from the area of its higher free energy or chemical potential to the area of its lower free energy or chemical potential through a semi-permeable membrane.
(2)	It can occur in any type of medium.	It occurs only in liquid medium.
(3)	The diffusing molecules may be solids, liquids or gases.	It involves the movement of solvent molecule only.
(4)	It does not require a semi-permeable membrane.	A semi-permeable membrane is required for the operation of osmosis.
(5)	It is purely dependent upon the free energy of the diffusing substance only.	It depends upon the free energy chemical potential of the solvent present on the two sides of the semi-permeable membrane.
(6)	An equilibrium in the free energy of diffusing molecules is achieved in the end.	An equilibrium in the free energy of solvent molecule is never achieved.

(v) **Osmotic pressure (OP) :** Pfeffer coined the term osmotic pressure.

Osmotic pressure of a solution is the pressure which must be applied to it in order to prevent the passage of solvent due to osmosis.

Or

Osmotic pressure is that equivalent of maximum hydrostatic pressure which is produced in the solution, when this solution is separated from its pure solvent by a semipermeable membrane.

It can also be defined as "the excessive hydrostatic pressure which must be applied to it in order to make its water potential equal to that of pure water". Osmotic pressure is equal to the pressure which is needed to prevent the passage of pure water into an aqueous solution through a semi-permeable membrane. In other words, it is that pressure which is needed to check the process of osmosis.

(i) **Types of osmosis :** Depending upon the movement of water into or outward of the cell, osmosis is of two types.

(a) **Endosmosis :** The osmotic inflow of water into a cell, when it is placed in a solution, whose solute concentration is less than the cell sap, is called endosmosis *e.g.,* swelling of raisins, when they are placed in water.

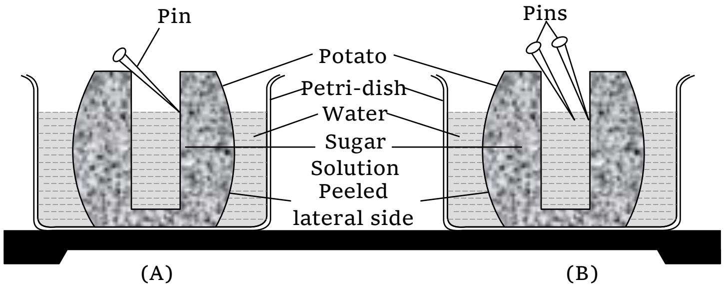
- ❑ When a fish of marine water kept in fresh water than it will be die due to endosmosis.
- ❑ An animal cell placed pure water will swell up and brust.
- ❑ Pollen grains of some of plants germinate on stigma soon but they burst in water or dilute sugar solution.

(b) **Exosmosis :** The osmotic outflow of water from a cell, when it is placed in a solution, whose solute concentration is more than the cell sap, is called exosmosis. *e.g.,* <u>shrinkage of grapes, when they are placed in strong sugar solution</u>.

(ii) **Demonstration of osmosis**

(a) **Thistle funnel experiment to show osmosis :** Tie the mouth of a thistle funnel with an egg membrane or animal bladder which are semi-permeable in nature. Put sugar solution (hypertonic solution) inside the thistle funnel. Thistle funnel is dipped in water with the help of a stand. A rise in level is noticed after some time. This is due to the diffusion of water into thistle funnel through semi-permeable membrane by the process of osmosis.

(b) **Demonstration of osmosis by potato osmoscope :** Peel of the skin of large sized potato with the help of scalpel. Cut its one end to make the base flat. Make a hallow cavity in the potato almost up to the bottom. Put sugar solution into the cavity and mark the level by inserting a pin in the wall of the cavity of tuber. Place the potato in beaker containing water. After some time, it will be noticed that level in cavity rise. It is due to phenomenon of osmosis. The experiment demonstrates that living cells of potato act as differentially permeable membrane.



Osmosis cannot be demonstrated by a potato osmoscope using a solution of *NaCl* instead of sugar because the potato tissue is permeable to salt solution.

(iii) **Osmotic concentrations (Types of solutions) :** A solution can be termed as hypotonic, hypertonic and isotonic depending upon its osmotic concentration, with respect to another solution or cell sap.

(a) **Hypotonic solution** (*hypo* = less than). A solution, whose osmotic concentration (solute potential) is less than that of another solution or cell sap is called hypotonic solution. If a cell is placed in such a solution, water start moving into the cell by the process of endosmosis, and cell become turgid.

(b) **Hypertonic solution** (*hper* = more than). A solution, whose osmotic concentration (solute potential) is more than that of another solution or cell sap is called hypertonic solution. If a cell is placed in such a solution, water comes out of the cell by the process of exosmosis and cell become flaccid. If potato tuber is placed in concentrated salt solution it would become shrink due to loss of water from its cell.

(c) **Isotonic solution** (*iso* = the same). A solution, whose osmotic concentration (solute potential) is equal to that of another solution or cell sap, is called isotonic solution. If a cell is placed in isotonic solution, there is no net changes of water between the cell and the solution and the shape of cell remain unchanged. The normal saline (0.85% solution of $NaCl$) and 0.4 m to 0.5 m solution of sucrose are isotonic to the cell sap.

- Osmotic concentration of a solution may governed by concentration of solute, temperature of solution, ionization of solutes and hydration of the solute molecules.

- In xerophytes, the osmotic concentration of cell sap is more than normal. *e.g.,* A molar solution of sucrose separated from pure water by such a membrane has an OP of approximately 22.4 atmospheres at 0°C. The osmotic pressure of given solution can be calculated by using the following relationship.

Osmotic pressure = CST

Where, C = Molar concentration of solution, S = Solution constant, which is 0.082 and T = Absolute temperature *i.e.,* 273°C.

Sucrose is non-ionizing substance while $NaCl$ is ionizing substance. Osmotic pressure of a solution of ionizing substance is greater than that of equimolar concentration of non-ionizing substance. *e.g.,* 0.1M sucrose solution has an OP of 2.3 bars while 0.1M sodium chloride solution has value of 4.5 bars.

(vi) **Significance of osmosis in plants**

(a) The phenomenon of osmosis is important in the absorption of water by plants.

(b) Cell to cell movement of water occurs throughout the plant body due to osmosis.

(c) The rigidity of plant organs (*i.e.,* shape and form of organism) is maintained through osmosis.

(d) Leaves become turgid and expand due to their OP.

(e) Growing points of root remain turgid because of osmosis and are thus, able to penetrate the soil particles.

(f) The resistance of plants to drought and frost is brought about by osmotic pressure of their cells.

(g) Movement of plants and plant parts, for example, movement of leaflets of Indian telegraph plant, bursting of many fruits and sporangia, etc. occur due to osmosis.

(h) Opening and closing of stomata is affected by osmosis.

(5) **Osmotic relation of cell :** In a plant cell, however, two membranes are present between the cell sap and the surroundings the cell-wall is a permeable membrane that does not interfere with the movement of water and solutes into or out of the cell. The plasma membrane and vacuolar membrane (tonoplast) with the thin layer of cytoplasm between them behave as differentially permeable membrane. Cell sap of a cell is a mixture of water and soluble substances. Water absorption in root hair from soil is depends on the concentration of cell sap. So a cell behave as a osmotic system in which endosmosis generate following pressures –

(i) **Turgor pressure (TP) :** The plant cell, when placed in pure water, swells but does not burst. Because of negative osmotic potential of the vacuolar solution (cell sap), water will move into the cell and will cause the plasmalemma be pressed against the cell wall. The actual pressure that develops that is the pressure responsible for pushing the membrane against cell wall is termed turgor pressure.

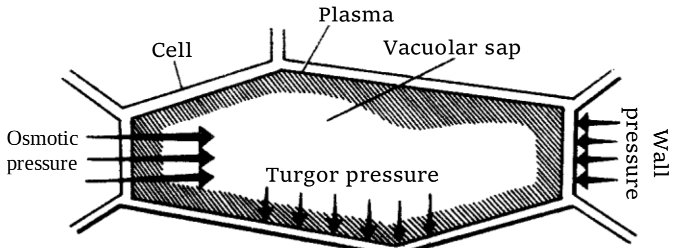


Fig : A cell showing turgor pressure, wall pressure and osmotic pressure

In other words, we can say that when water enters the living cell, a pressure is developed within the cell due to turgidity. The hydrostatic pressure developed inside the cell on the cell wall due to endosmosis is called turgor pressure. It is responsible for growth of young cells.

Significance of turgidity in plants

- It provides stability to a cell.
- Turgidity keeps the cell and their organelles (mitochondria, plastids and microbodies) fully distended. This is essential for plants to live and grow normally.
- Turgor pressure helps in cell enlargement, consequently in stretching of the stems and in keeping leaves erect and fully expanded.
- The turgid cells provide mechanical support necessary for the non woody tissues (maize, sugarcane, banana etc.).
- Loss of turgidity leads to wilting of leaves and drooping of shoots.
- The opening and closing of stomata are regulated by the turgidity of the guard cells.
- Leaf movements (seismonastic movement) of many plants (such as bean, sensitive plant *Mimosa pudica*) are controlled by loss and gain of cell turgor.
- Due to turgid pressure plumule and radicles force out from seeds at the time of seed germination.

(ii) **Wall pressure (WP) :** Due to turgor pressure, the protoplast of a plant cell will press the cell wall to the outside. The cell wall being elastic, presses back the protoplast with a pressure equal in magnitude but opposite in direction. This pressure is called **wall pressure**. Wall pressure (WP) may, therefore, be defined as '*the pressure exerted by the cell wall over the protoplast to counter the turgor pressure*. Normally wall pressure is equal and opposite to turgor pressure (WP =TP) except when the cell become flaccid. The value of the two forces continue to rise with the continued entry of water, till the cell becomes fully turgid.

(6) **Interrelationship of DPD, OP and TP (WP) :** DPD indicates the sucking power of suction pressure. As water enters into the cell the TP of the cell is increased. Cell wall exerts equal and opposite WP against TP. The actual force responsible for entry of water will be therefore OP–TP

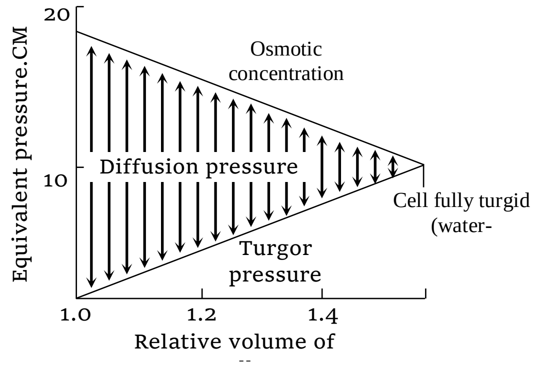


Fig : Relationship between diffusion pressure deficit and other pressure

i.e., DPD = OP – WP (As WP = TP)

DPD = OP – TP

Consider that a plant cell with OP = 10 atm. is immersed in pure water. In the beginning TP inside the cell is zero *i.e.*

DPD = OP = 10 atm.

When water enters into the cell, TP increases. Turgidity increases and cell wall develops equal and opposite WP. At the stage of equilibrium TP = 10 atm. and DPD will become zero. It is important to note that OP was same when cell was flaccid and turgid.

DPD = OP – TP

= 10 – 0 = 10 (when flaccid)

= 10 – 10 =0 (when turgid)

The entry of water in cell to cell depends up on the DPD and not on OP and TP. This can be examplified as follows :

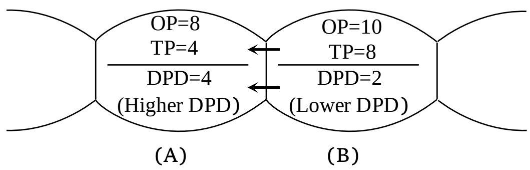


Fig : Relation between diffusion pressure deficit and entrance of water in the cell

A cell (A) with OP = 8 and TP = 4 is surrounded by the cells (B) with OP = 10 and TP = 8.

Then for cell **A**, DPD = OP – TP

= 8 – 4

= 4

Similarly for cell **B**, DPD = OP – TP

= 10 – 8 = 2

Since the DPD of cell **A** is more, it has less water and, therefore water would diffuse from cell **B** into the cell **A** (because that DPD of cell **B** is less than that of **A** or it has more water than cell **A**). The entry of water into the cell **A** would stop when DPD of both the cells becomes equal. In this way water moves from a cell with less DPD into the cell with more DPD. Thus, DPD is the osmotic parameter, which determines the flow of water from one cell to another.

Under given suitable conditions, the DPD more than OP when TP is negative. DPD of a cell mainly depends upon OP. If two cells have the same OP but differ in TP, the direction of the movement of water from higher TP to lower TP.

(7) **Plasmolysis (Gr. *Plasma* = something formed; *lysis* = loosing) :** If a living plant cell is placed in a highly concentrated solution (*i.e.* hypertonic solution), water comes out of the cell due to exosmosis, through the plasmamembrane. The loss of water from the cell sap causes shrinkage of the protoplast away from the cell wall in the form of a round mass in the centre. "*The shrinkage of the protoplast of a living cell from its cell wall due to exosmosis under the influence of a hypertonic solution is called plasmolysis*". The stage of plasmolysis, when the protoplast just begins to contract away from the cell wall is called **incipient plasmolysis**. The stage when the cell wall has reached its limit of contraction and the protoplast has detached from cell wall attaining spherical shape is called **evident plasmolysis**. In a plasmolysed cell, the space between the contracted protoplast and the cell wall remains filled with external solution. If a cell with incipient plasmolysis is placed in a hypertonic solution it will show more plasmolysis.

If a plasmolysed cell is placed in pure water or hypotonic solution, endosmosis takes place. The protoplast attains its original shape and the cell regains its original size. "*The swelling up of a plasmolysed protoplast due to endosmosis under the influence of a hypotonic solution or water is called deplasmolysis*'. Deplasmolysis is possible only immediately after plasmolysis otherwise the cell protoplast becomes permanently damaged. Leaf of *Tradescantia* is used for demonstration of plasmolysis in laboratory. The value of TP becomes zero at the time of limiting plasmolysis and below zero during incipient and evident plasmolysis.

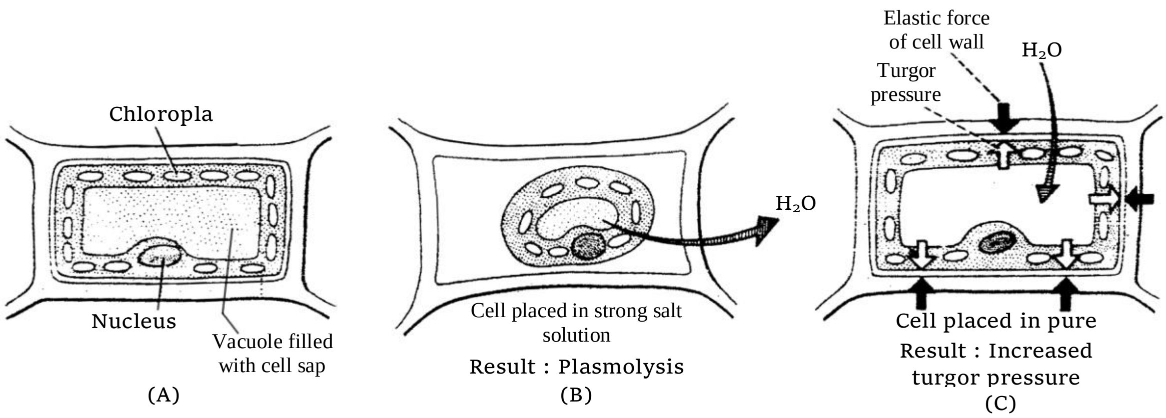


Fig : Plasmolysis and deplasmolysis (A) Normal cell (B) Plasmolysed cell (C) Deplasmolysed cell and increased turgor pressure

Significance of plasmolysis : It proves the permeability of the cell wall and the semipermeable nature of the protoplasm.

- The OP of a cell can be measured by plasmolysis. The OP of a cell is roughly equal to the OP of a solution that causes incipient plasmolysis in the cell.

- Salting of pickles, meat, fishes etc. and addition of sugar to jams, jellies, cut fruits etc., prevent their decay by microbes, as the latter get killed due to plasmolysis or due to high concentration of salt or sugar.

- By salting, the weeds can be killed from tennis courts and the growth of plants can be prevented in the cracks of walls.

- Plasmolysis is helpful in determining whether a particlular cell is living or dead as plasmolysis does not occur in a dead or non living cell.

(8) **Water potential (ψ) :** The movement of water in plants cannot be accurately explained in terms of difference in concentration or in any other linear expression. The best way to express spontaneous movement of water from one region to another is in terms of the difference of free energy of water between two regions. Free energy is the thermodynamic parameter, that determine the direction in which physical and chemical changes must occur. The potential energy of water is called water potential. *e.g.,* water is stored behind a dam. When the water runs downhill, its potential energy can be converted to electrical energy. This conversion of energy of water is due to gravity. The other source that provides energy to water is pressure. The increasing pressure increases the free energy there by increasing water potential.

Water running downhill due to gravity can be made to run uphill by overcomming the water potential (energy) by applying pressure. This means that water moves from the point, where water potential is greater to the other, where water potential is less. The difference in water potential between two points is a measure of the amount of work or energy needed to move water from one point to the other. Thus, based on the concept of water potential, the direction of water movement can be predicted. Water potential is measured in terms of pressure.

Measurement unit of water potential is **pascal**, Pa (1 mega pascal, Mpa = 10 bars). It is represented by Greek letter, **Psi (ψ)**. Water potential ψ_w is the difference between chemical potential of water at any point in a system ($\mu\omega$) and that of pure water under standard conditions ($\mu\omega^\circ$). The value of water potential can be calculated by formula :

$$\psi_w = (\mu\omega) - (\mu\omega^\circ) = RT\ 1\ n\ e/e^\circ$$

where ψ_w = water potential, R is gas constant, T is absolute temperature (K), *e* is the vapour pressure of the solution in the system at temperature T, and e° the vapour pressure of pure water at the same temperature.

The direction in which water will move from one cell to another cell depends on water potential in two regions. Water potential is measured in bars. A bar is a pressure unit which equals 14.5 lb/in^2, 750 *mm Hg* or 0.987 *atm.*

Water potential of pure water at normal temperature and pressure is zero. This value is considered to be the highest. The presence of solute particles reduces the free energy of water and thus decreases the water potential. Therefore, water potential of a solution is always less than zero or has negative value. External pressure increases the water potential. If a pressure greater than atmospheric pressure is applied to pure water, the water potential can be raised from zero to a positive value. The water potential is equal but opposite in sign to the diffusion pressure deficit (DPD). In terms of DPD, the movement of water takes place from the region of lower DPD to the region of higher DPD, while in terms of water potential (ψ), the flow of water occurs from the region of higher water potential (less negative) to the region of lower water potential (more negative). The movement of water continue till the water potential in two regions becomes equal.

(i) **Component of water potential :** When a cell is subjected to the movement of water, many factors begin to operate which ultimately determine the water potential of cell sap. For solutions, such as contents of cells, water potential is determined by three major sets of internal factors *viz*., matric potential ($\psi\ m$), solute potential ($\psi\ s$) and pressure potential ($\psi\ p$). The water potential (ψ) in a plant cell or tissue can be written as the sum of the matric potential ($\psi\ m$) due to binding of water to cell walls and cytoplasm, the solute potential ($\psi\ s$) due to concentration of dissolved solutes, which by its effect on the entropy components reduces the water potential and the pressure potential ($\psi\ p$) due to hydrostatic pressure, which by its effect on the energy components increases the water potential :

$$\psi = \psi\ m + \psi\ s + \psi\ p \quad \ldots\ldots (1)$$

Each component potential is discussed separately below :

(a) **Matric potential ($\psi\ m$) :** Matric is the term used for the surface (such as, soil particles, cell walls, protoplasms, etc.) to which water molecules are adsorbed. The matric potential ($\psi\ m$) is the component of water potential influenced by the presence of a matrix. It has got a negative value. In case of plant cells and tissues, the matric potential is often disregarded because it is not significant in osmosis. Thus, the above equation (1) may be simplified as follows :

$$\psi = \psi\ s + \psi\ p \quad \ldots\ldots (2)$$

In normal cells of mesophytes and hydrophytes it is almost negligible due to presence of large vacuole which leaves little space for matrix in the cell. In herbaceous plants it has been calculate to be only – 0.1 bar by Wiebe (1966). Its value, however, is quite high (–100 to –200 bars) in xeropytes and dryseeds.

(b) **Solute potential ($\psi\ s$) :** Solute potential is also known as *Osmotic potential*. It is defined as the amount by which the water potential is reduced as a result of the presence of solute. Solute potentials or osmotic potentials ($\psi\ s$) are always in negative values (number). The term solute potential takes the place of osmotic pressure (π; Pi) expressed in bars with a negative sign.

$$\psi_s = -\pi$$

(c) **Pressure potential ($\psi\ p$) :** Plant cell wall is elastic and it exerts a pressure on the cellular contents. As a result of inward wall pressure, hydrostatic pressure is developed in the vacuole termed as turgor pressure. The pressure potential is usually positive and operates in plant cells as *wall pressure* and *turgor pressure*.

Its magnitude varies between +5 bars (during day) and +15 bars (during night).

(ii) **Physical states of cell :** Three physical states of cell, according to their water potential, are as follows :

(a) **In case of fully turgid cell :** In case of fully turgid cell, the net movement of water into the cell is stopped. The cell is in equilibrium with the water outside. The water potential in such a case will be zero (0).

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi s + \psi p$$

A cell at full turgor has its osmotic potential and pressure potential equal but opposite in sign. Therefore, its water potential will be zero. For example, supposing a cell has its ψs of –10 bars and ψp of 10 bars the resultant water potential will be zero as follows :

$$\psi = \psi s + \psi p$$

$$\psi = -10 \text{ bars} + 10 \text{ bars}$$

$$\psi = 0 \text{ bars}$$

(b) **In case of flaccid cell :** When a plant cell is flaccid, its turgor becomes zero (corresponding to a turgor pressure of a 0 bars). Zero turgor is approached under natural conditions when a tissue is severely wilted. A cell at zero turgor has an osmotic potential (ψs) equal to its water potential (ψ). For example, supposing a flaccid cell has an osmotic potential of –10 bars and pressure potential (ψp) of 0 bars.

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi s + \psi p$$

$$\psi = -10 \text{ bars} + 0 \text{ bars}$$

$$\psi = -10 \text{ bars}$$

The water potential of the cell will be –10 bars, which is less as compared to the water potential of pure water (0 bars).

(c) **In case of plasmolysed cell :** When the vacuolated parenchymatous cells are placed in solutions of sufficient strength the protoplast decreases in volume to such an extent that they shrink away from the cell wall. The cells are plasmolysed. Such cells have negative value of pressure potential (negative turgor pressure). The resultant water potential will be more negative, as for example, a plasmolysed cell has osmotic potential of –10 bars and pressure potential of –2 bars the water potential of the cell will be –12 bars.

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi s + \psi p$$

$$\psi = -10 + (-2)$$

$$\psi = -12 \text{ bars}$$

(iii) **Movement of water between two adjacent cells :** Suppose A and B are two adjacent plant cells where osmotic movement of water can occur. Cell A has osmotic potential (ψs) of –16 bars and pressure potential of 8 bars. The cell B has osmotic potential of –12 bars and pressure potential of 2 bars. The movement of water will be as follows :

Cell A	Cell B
$\psi s = -16$ $\psi p = 8$ →	$\psi s = -12$ $\psi p = 2$
$\psi = \psi s + \psi p$ $= -16+8 = -8.$	$\psi = \psi s + \psi p$ $= -12+2 = -10.$

Cell A has osmotic potential of –16 bars and pressure potential of 8 bars. The water potential will be –8 bars.

$$\psi = \psi s + \psi p = -16 + 8 = -8$$

Cell B has osmotic potential of – 12 bars and pressure potential of 2 bars. The water potential will be –10 bars.

$$\psi = \psi s + \psi p = -12 + 2 = -10$$

Since water moves from higher water potential to lower water potential, the flow of water will be from cell A (–8 bars) to cell B (–10 bars).

Differences between diffusion pressure deficit and water potential

S.No.	Diffusion Pressure Deficit (DPD)	Water Potential (ψ)
(1)	The DPD was originally described by the term suction force (*Saugkraft*) by Renner. Other synonyms of the term are suction pressure (SP), enter tendency (E) and osmotic equivalent (E).	Water potential is the chemical potential of water which is equivalent to DPD with negative sign. The term water potential was coined by Slatyer and Taylor (1960).
(2)	The diffusion pressure deficit is abbreviated as DPD. The term was coined by Meyer (1938).	The symbol for water potential is a Greek letter *psi*, which is designated as ψ.

(9) **Wilting :** A plant usually fails to survive if it is conditioned to water deficiency. The symptoms appear in the plant, plant part or in the cells due to scarcity of water are termed as wilting. It is loss of turgidity causing folding and drooping of leaves and other soft aerial parts of the plant. It is of three types :

(i) **Incipient wilting :** There is no external symptoms but the mesophyll cells lose a part of their water content during midday due to transpiration.

(ii) **Temporary wilting :** It occurs during midday and is visible externally due to drooping of leaves and young shoots. At noon the rate of transpirations is quite high as compared to water absorption. Which decreases further due to depletion of water around rootlets. It is corrected in the afternoon when transpiration decreases.

(iii) **Permanent wilting :** It is the last stage in wilting when the aerial parts do not regain turgidity even if placed in water saturated atmosphere. It is caused by decrease in water content of the soil which increases TSMS (Total soil moisture stress) or resistance to absorption to such an extent that plant roots are unable to absorb water. **Permanent Wilting Percentage (PWP)** is the percentage of water on the dry weight basis of the soil that is present in the soil when the plants growing in it first touch the condition of permanent wilting. This value varies between 1–15% and depends upon the texture of the soil *e.g.*, clay has higher PWP than sand.

Important Tips

- Stephen Hales is known as father of plant physiology. Coined the term root pressure.
- The kinetic energy or free energy possessed by the molecules of a substance is called chemical potential. The chemical potential of water is called water potential.
- The osmotic pressure of a solution can be measured with the help of a apparatus called osmometer.
- **Molar solution :** 1gm mole of solute plus 1 litre / 1000 cc of solution.
- **Molal solution :** 1gm mole of solute plus 1 litre / 1000 cc of solvent.
- 0.1M solution containing any solute has water potential of –2.3 bars.
- The value of water potential of solution is lower than that of water.
- In a pure solvent the value of osmotic potential is zero.
- Plants wilt when turgor pressure inside the cells of such tissue go down below zero.
- **Pressure chamber** is used for measuring water potential of whole leaves, shoots etc.
- The value of osmotic pressure of the soil solution in a well watered soil is less than 1 atmosphere.
- The basic driving force in osmosis is the difference in the free energy of water on the two sides of membrane.
- **Cryoscopic osmometer** measures the osmotic potential of solution by measuring its freezing point.
- **Equimolar concentration** of two solution of non-ionising substances will have same osmotic pressure.
- In evident plasmolysis, cytoplasm withdraws itself from cell wall.
- O.P. does not increase by addition of insoluble solute in the solution.
- D.P.D. can become zero (fully turgid cell). T.P. can also become zero (flaccid cell). However O.P. of a cell can never be zero.

- **Plant imbibants**. Agar agar imbibes maximum –99 times its weight of water. Other pectic compounds also possess good imbibition capacity. They are followed by proteins (some of them 15 times their volume), starch and cellulose. Seeds swell more if they are protein rich than starchy seeds. During seed germination the seed coat ruptures because protein/starch rich kernel swells up more than cellulose seed coat.
- Wilting in plant occur when xylem is blocked.
- **Osmotic pressure/Osmotic potential :** It is measured in atmospheres or bars. Osmotic pressure has a positive value while osmotic potential has a negative value. 1gm mole of a nonelectrolyte develops an osmotic potential of –22.4 atm or osmotic pressure of 22.4 atm (or 22.7 bars) at 0°C and 24 atm (= 24.3 bars) at 20°C. It increases due to hydration of solutes and ionisation of solute particles.
- Young cells and young fruits absorb a part of their water through imbibition.
- In hypertonic solution a cell water potential is decrease.
- Under given suitable conditions, the DPD will be more than OP when TP is negative.
- In the process of osmosis in the cell only outer layer of protoplasm act as a membrane.
- Heating kills the cell membrane which lose their selective or differential permeability and become freely permeable to solute as well as solvent.
- Wilting of leaves in hot weather is due to excess of transpiration as compared to water absorption.
- Surface tension doesn't help in molecule transport.

3.2 Absorption of water

(1) **Component of soil :** Soil is the superficial layer of the weathered earth crust, which support plant life. Generally soil is the combination of various component such as mineral matter (inorganic component), organic matter, soil water, soil atmosphere and soil organisms. On an average the ratio and proportion of the above mentioned components is as follows :

Mineral matter	:	40% of volume
Organic matter	:	10% of volume
Soil water	:	25% of volume
Soil atmosphere	:	25% of volume
Soil organisms	:	Some

(i) **Mineral matter :** The soil is produced by the breakdown of parent rocks by a process called *weathering*. Weathering is a result of three kinds of processes physical, chemical and biological. Physical weathering involves fragmentation of rocks due to freezing and thawing, movement of earth (as earth-quakes) and other mechanical processes. Chemical weathering involves reactions between *e.g.*, carbonic acid ($H_2O + CO_2 \rightarrow H_2CO_3$) with minerals of rocks. Biological weathering is due to action of living organisms specially microbes.

The characteristic of soil depend on its texture and structure.

(a) **Soil texture :** Texture depend upon the size of particles in a soil. On the basis of texture, soils are usually classified as gravel, sand, silt and clay. Clay particles are tiny and sticky in nature, hence holding capacity is highest in clay soil.

(b) **Soil structure :** The arrangement of particles in a soil is called **soil structure**. The smaller particles become crowded into spaces between the larger and colloids form coatings over all the larger particles, binding them together into various types of structural units.

(ii) **Organic matter :** Both plants and animals contribute to the organic matter of the soil. Some of the material is derived from dead roots and soil organisms and is therefore well distributed through the soil from the beginning. On the other hand much organic matter is deposited upon the soil surface as leaves, twigs, etc., and becomes incorporated into the mineral matter only through the activities of micro organisms.

After the normal biological processes of decay, decomposition of litter through the above stages, the resultant production becomes incorporated into the mineral soil imparting a dark colour to it. Such finely divided amorphous organic matter as has become mixed with the mineral materials is called **humus** and the process leading to its formation **humification**. Humus usually is homogenous, dark coloured and odourless. Humus and clay the two colloidal components of the soil are called 'colloidal complex' of soil. This complex increases water holding capacity of sandy soil.

(iii) **Soil water :** The chief source of soil water is rain. In soil water found in different forms. various terms have been used for soil water according to its availability and non availability to the plants. The total amount of water present in the soil is called **holard**, of this the available to the plant is called **chesard** and the water which cannot be absorbed by the plants is called **echard**.

Water occurs freely deep in the soil and above the parent rock, it is called ground water. Broadly we can recognise five stages of water in the soil which differ in their availability to plants. These are briefly described below :

(a) **Gravitational water :** When the water enters the soil and passes the spaces between the soil particles and reaches the water table, the type of soil water is called gravitational water. In fact gravitational water is surplus to the water retaining capacity of soil and drains from it to reach in deep saturated zone of earth *i.e.*, ground water, upper surface of which is called **water table**.

(b) **Capillary water :** It is the water which is held around soil particles in the capillary space present around them due to force like cohesion and surface tension. This is the water which can be utilised by the plants. It is also called growth water. It occurs in the form of films coating smaller soil particle.

The availability of capillary water to the plant depend upon its diffusion pressure deficit which is termed as the soil moisture stress. The plant cells much have a DPD more than the soil moisture stress for proper absorption of water.

(c) **Hygroscopic water :** This is the form of water which is held by soil particles of soil surfaces. The water is held tightly around the soil particles due to cohesive and adhesive forces. Hygroscopic water cannot be easily removed by the plants. Cohesive and adhesive forces greatly reduce the water protential (ψ_ω) and thus this type of water in soil is not available to plants.

(d) **Run away water :** After the rain, water does not enter the soil at all, but drained of along the slopes. It is called run away water. The quantity of run away water is controlled by factors like permeability of soil, moisture content of soil, degree of slope and number of ditches present in that area. Plants fail to avail this water.

(e) **Chemically combined water :** Some of the water molecules are chemically combined with soil minerals (*e.g.*, silicon, iron, aluminium, etc.). This water is not available to the plants.

After a heavy rainfall or irrigation a very little amount of water is retained by the soil, rest of it moves away as surface run away water or gravitational water. The amount of water actually retained by the soil is called **field capacity** or **water holding capacity** of the soil. It is about 25–35% in common loam soil. The excess amount of water beyond the field capacity produces **water logging**.

(iv) **Soil atmosphere :** In moderately coarse soils as well as in heavy soils (fine textured soil) that are with aggregated particles; there exists large interstitial spaces which facilitate the diffusion of gases. As a result the CO_2 produced in a soil by respiration of soil organisms and roots is able to escape rather easily and oxygen used up in this process diffuses into the soil with corresponding case.

(v) **Soil organisms :** The soil fauna include protozoa, nematodes, mites, insects, earthworms, rats. Protozoons alone are approximately 1 million per gram of soil. Earthworms have the most important effect on the soil structure. Their activities result in a general loosening of the soil which facilitates both aeration and distribution of water. Blue green algae and bacteria increases nitrogen content by nitrogen fixation in soil.

(2) **Water absorbing organs :** Plants absorb water mostly from the soil by their roots, but in some plants even aerial parts like stem and leaves also do the absorption of atmospheric water or moisture. Some important examples of such plants are *Vitis, Solanum, Lycopersicum, Phaseolus, Kochia baosia* and *Beta*. The absorption of water by aerial parts is affected by various factors such as structure of epidermis, thickness of cuticle, presence of hair and degree of dryness of epidermal cells.

However, maximum absorption of water is done by the roots. The zone of rapid water absorption usually lies some 20 – 200*mm* from the root tip behind the meristem, where the xylem is not fully mature and the epiblema as well as the endodermis are still permeable (Kramer, 1956).

This area is usually characterized by the presence of root hairs which serve to increase the area of contact between the root surface and soil. However, presence of root hair is not essential for water absorption. Some roots, such as adventitious

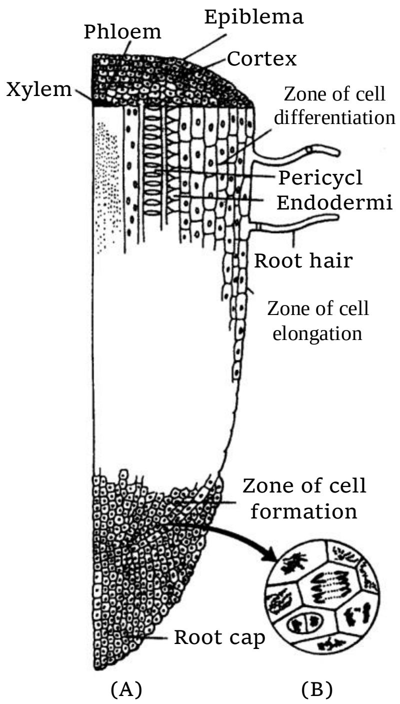


Fig : (A) Tip of a young root of a dicot plant showing different zones and regions of absorption of water and solution (B) Some cells of meristemetic zone showing mitosis

roots of bulbs, corms and rhizomes and those of some aquatic plants and gymnosperms do not have root hairs. The zone of rapid water absorption moves along with the growth of root, as the older cells become suberized and lose their ability to absorb water.

The root hairs develop mainly at the tip just above the zone of elongation (cell maturation). A root hair is the unicellular tubular prolongation of the outer wall of the epiblema. The cell wall of root hairs is two layered. The outer layer is made up of pectic substances and is therefore highly hygroscopic. The inner layer is made up of cellulose. Inside the cell wall is a thin layer of cytoplasm which surrounds one or more large vacuoles. The nucleus generally present at the tip.

During water absorption the plasma membrane of root hair, the cytoplasm and the vacuole membrane (tonoplast) behave together as a single differentially permeable membrane. Root-hairs are at the most 1.25 *cm* in length and never more than 10*mm* in diameter. As the root progresses through the soil, new root-hairs are formed at the beginning of the zone of maturation, the older hairs further back on the root, dry up and then disappear. Root-hairs elongate very rapidly and may attain full size within few hours.

The number of root-hairs may be simply enormous; it has been estimated that a single rye plant may have 14 billion root-hairs with a total surface area of 4000*sq*. feet. Thus the root-hairs of plants increase the absorption surface of a root system about 5 to 20 times and because they extend so widely through the soil they make available a supply of water that the plant could not otherwise obtain. Water potential of root hair cells is generally –1 to –4 atm.

(3) **Pathway of water movement in root :** Water in the root moves through three pathways such as apoplast pathway, symplast pathway and transmembrane pathways. Munch coined the term apoplast and symplast.

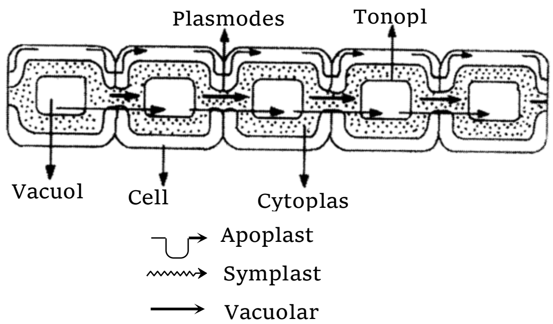


Fig : Three pathways of water

(i) **Apoplast pathway :** The apoplastic movement of water occurs exclusively through the cell wall without crossing any membrane.

(ii) **Symplast pathway :** The symplastic movement of water occurs from cell to cell through the plasmodesmata.

(iii) **Transmembrane pathway :** Water after passing through cortex is blocked by casparian strips present on endodermis. The casparian strips are formed due to deposition of wax like substance, **suberin**. In this pathway, water crosses at least two membranes from each cell in its path. These two plasma membranes are found on entering and exiting of water. Here, water may also enter through tonoplast surrounding the vacuole *i.e.*, also called as **vacuolar pathway**.

(4) **Mechanism of water absorption :** Two distinct mechanism which are independently operate in the absorption of water in plants.

These mechanisms are :

(i) Active absorption (ii) Passive absorption

Renner coined the term active and passive water absorption.

(i) **Active absorption :** Active absorption takes place by the activity of root itself, particularly root hairs. It utilizes metabolic energy. There are two theories of active absorption :

(a) **Osmotic theory :** It was proposed by Atkins (1916) and Priestly (1922). It is purely a physical process, which does not directly required expenditure of energy.

A root hair cell functions as an osmotic system. Water is absorbed by the root hair due to osmotic differences between soil water and cells sap. The osmotic pressure of soil water remains below 1 atm, but that of cell sap is usually 2–8 atms. Thus, there exists a great difference in the osmotic pressures of the two sides or in other words there exists, water potential gradient between the soil solution and cell sap. The soil solution having less OP, has higher water potential than the cell sap with more OP (*i.e.*, the cell sap has more negative water potential). Thus, water moves from the region of higher water potential towards the region of lower water potential. Water continues to enter the root hair cell as long as the water potential of the root cell sap is more negative than that of the soil solution, until the elasticity of stretched cell wall is sufficient to balance the osmotic potential or OP of the cell. Water moves from cell to cell along the water potential gradient and reach up to endodermis and pericycle. Finally water enters into the xylem. This type of absorption involves **symplast** *i.e.*, movement of water occurs through the living cytoplasm of the cells. The cells between the xylem and the soil solution may be considered as a single complex semipermeable membrane.

(b) **Non-osmotic theory :** It was proposed by Thimann (1951) and Kramer (1959). It has been observed that absorption of water still occurs, if the concentration of cell sap in the root hair is lower than that of the soil water, or water is absorbed against concentration gradient (*i.e.*, from higher DPD to lower DPD). Such type of water absorption occurs on the expense of energy obtained from respiration. The exact mechanism of utilization of energy is not well understood. It may be used directly or indirectly.

Following evidences support the view that energy is utilized during active absorption of water :

- Rate of water absorption is directly proportional to the rate of respiration.
- Factors like low temperature, deficiency of oxygen, respiratory inhibitors such as KCN, which inhibit respiration also inhibit the absorption of water.
- Auxins, which increase respiration also promote water absorption.
- Wilting of plants occur in non-aerated soils such as water logged soils, as roots fail to absorb water in absence of respiration.
- The occurrence of distinctive diurnal variation in water uptake and root pressure. It is faster during day time and slower during night. This fact is also true for respiration.

(ii) **Passive absorption :** It is the most common and rapid method of water absorption. It account for about 98% of the total water uptake by plant.

According to this theory, the forces responsible for absorption of water originate not in the cell of roots but in the cells of transpiring shoots. In other words in this type of absorption of water, the roots remain passive.

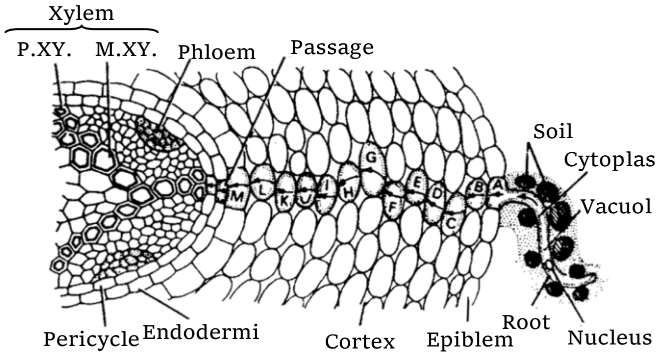


Fig : Passive absorption of water through root hair

Due to transpiration, the DPD of mesophyll cells in the leaves increases which causes absorption of water by these cells from the xylem vessels of leaves. As the water column is continuous from leaves to roots, this deficit is transmitted to the xylem elements of roots and finally to root hairs through pericycle, endodermis and cortex. In this way water is continuously absorbed due to transpiration pull created in the leaves. This type of water transport occurs mainly through the apoplast in cortex but through the symplast in endodermis and pericycle.

The path of water from soil upto secondary xylem is :

Soil → Root hair cell wall → Cortex → Endodermis → Pericycle → Protoxylem → Metaxylem.

Differences between active and passive absorption of water

S.No.	**Active absorption**	**Passive absorption**
(1)	Force for absorption of water is generated in the cells of root itself.	Force for absorption of water is created in the mesophyll cells.
(2)	Osmotic and non-osmotic forces are involved in water absorption.	Water is absorbed due to transpiration pull.
(3)	Water is absorbed according to DPD changes.	Water is absorbed due to tension created in xylem sap by transpiration pull.
(4)	Water moves through symplast.	Water moves mainly through apoplast.
(5)	Rate of absorption is not affected significantly by temperature and humidity.	Its rate is significantly affected by all those factors which influence the rate of transpiration.
(6)	Metabolic inhibitors if applied in root cells decrease the rate of water absorption.	No effect of metabolic inhibitors if applied in root cells.
(7)	Occurs in slow transpiring plants which are well watered.	Occurs in rapidly transpiring plants.
(8)	Rate of absorption is slow.	Very fast rate of water absorption.

(5) **Factors affecting rate of water absorption :** The different factors which influence the rate of water absorption by a plant can be divided into external or environmental and the internal factors.

(i) **External or Environmental factors**

(a) **The amount of soil water :** If the amount of water in the soil is between its field capacity and permanent wilting percentage, the rate of water absorption remains more or less uniform. But a decrease in the soil water below the permanent wilting percentage causes decrease in the absorption of water. If the soil water is increased much beyond the field capacity, as happens during floods, the air pores between soil particles are filled with water, and water absorption stops.

(b) **Concentration of solutes in the soil water :** If the concentration of solutes increases in the soil water, its OP also increases which slows down or even inhibits the absorption of water. It happens due to addition of enough fertilizers in the soil increasing its salinity. This is popularly called as physiological dryness and is different from physical dryness which is caused due to virtual lack of water as in xerophytes.

(c) **Soil aeration :** Water absorption is done more efficiently in well aerated soil. Any deficiency of oxygen stops the respiration of roots and causes accumulation of CO_2 thus the protoplasm becomes viscous and the permeability of plasma membrane decreases. Due to all these factors the rate of water absorption is reduced. This is the reason for death of plants in flooded areas.

(d) **Soil temperature :** The optimum temperature for maximum rate of water absorption ranges between $20°C$ and $30°C$. Too high a temperature kills the cells. At very low temperatures ($4°C$) water absorption is reduced or stopped due to

(i) Slower rate of diffusion of water.

(ii) Decreased permeability of cell membrane.

(iii) Increased viscosity of protoplasm.

(iv) Slower rate of metabolism of root cells.

(v) Slower rate of growth and elongation of roots.

(e) **Transpiration :** The rate of absorption of water is almost directly proportional to that of transpiration. A higher rate of transpiration increases the rate of absorption.

(ii) **Internal factors**

(a) **Efficiency of the root system :** A plant with deep and elaborate root system can absorb more water than one having a shallow and superficial root system because deep roots are always in contact with ground water at different levels. Moreover, the number of root hairs will be more in a highly branched and elaborate root system, thus its more surface area will be in contact with water.

In gymnosperms, the root hairs are absent, even then they are able to absorb water due to presence of **mycorrhizal hyphae**. These fungal hyphae retain water and make it continuously available to roots.

In epiphytes (orchid), the roots develop a special type of hygroscopic tissue called as **velamen** which can absorb atmospheric moisture.

(b) **Metabolic activity of roots :** The metabolic rate and the rate of water absorption are very closely related. The direct evidence in favour of this comes from the fact that poor aeration or use of metabolic inhibitors (*e.g. KCN*) inhibits the rate of water absorption. The metabolic activities help in proper growth of root system and generation of energy for absorption of certain vital minerals.

(6) **Absorption of water through leaves :** Many species of plants can absorb at least limited amounts of water through the leaves. Temporary immersion of aerial organs in flood waters takes place in some cases. Also the aerial organs of plants frequently become wet as a result of fog, dew or rain. The turgidity of wilted leaves of many species can be restorted by immersing them in water : Most of the water enters through the epidermal cells, although in some species hairs and specialized epidermal cells provide regions of high permeability. In general water absorption is more rapid in young leaves than in old leaves of the same plant.

Important tips

- Tensiometer is the instrument for measuring soil water potential.
- Apoplast is the non-living continuity of plant body which consists of cell walls, intercellular spaces and water filled xylem channels.
- Symplast pathway consists of the entire network of cell cytoplasm interconnected by plasmodesmata.
- Auxin treated cells can absorb water even from hypertonic solution by active process.
- Only capillary water is available to plants.
- The amount of water left in the soil after the plant has permanently wilted is the **wilted coefficient**.
- Humus and clay are two colloidal complexes of soil.
- All organic plant debris which has recently fallen on soil is called litter or A_{00} layer.
- The organic matter is colloidal, due to this water holding capacity is relatively high.
- Root system in a plant is well developed for increased absorption of water.
- Cell absorb water by osmosis and imbibition.
- Active uptake of water is affected by sucking power (DPD) of root hairs.

3.3 Ascent of sap

Land plants absorb water from the soil by their roots. The absorbed water is transported from roots to all other parts of the plants to replace water lost in transpiration and metabolic activities. The stream of water also transports dissolved minerals absorbed by the roots. The water with dissolved minerals is called **sap**. 'The upward transport of water along with dissolved minerals from roots to the aerial parts of the plant is called ascent of sap'. At mid day hours the xylem sap is in a state of tension because the rate of transpiration is very high.

(1) **Path of ascent of sap :** It is now well established that the ascent of sap takes place through xylem. In herbaceous plants almost all the tracheary elements participate in the process, but in large woody trees the tracheary elements of only sap wood are functional. Further, it has been proved

experimentally that sap moves up the stem through the lumen of xylem vessels and tracheids and not through their walls.

(2) **Theories of ascent of sap :** The various theories put forward to explain the mechanism of ascent of sap in plants can be placed in following three categories :

(i) Vital force theories

(ii) Root pressure theory

(iii) Physical force theories

(i) **Vital force theories :** According to these theories the forces required for ascent of sap are generated in living cells of the plant. These theories are not supported by experimental evidences hence they have been discarded. Some of the important vital force theories are mentioned below :

(a) **According to Westermeir** (1883), ascent of sap occurred through xylem parenchyma; tracheids, and vessels only acted as water reservoirs.

(b) **Relay pump theory :** According to Godlewski (1884) ascent of sap takes place due to rhythmatic change in the osmotic pressure of living cells of xylem parenchyma and medullary rays and are responsible for bringing about a pumping action of water in upward direction. Living cells absorb water due to osmosis from bordering vessels (which act as reservoirs of water) and finally water is pumped into xylem vessel due to lowering of pressure in living cells. Thus a staircase type of movement occurs. Janse (1887) supported the theory and showed that if lower part of the shoot is killed upper leaves were affected.

Criticism

- **Strasburger** (1891) and **Overton** (1911) used poisons (like picric acid) and excessive heat to kill the living cells of the plant. When such twigs were dipped in water, ascent of sap could still occur uninterrupted. This definitely proved that no vital force is involved in ascent of sap.
- Xylem structure does not support the Godlewski's theory. For pumping action living cells should be in between two xylem elements and not on lateral sides as found.

(c) **Pulsation theory :** Sir **J.C. Bose** (1923) said that living cells of innermost layer of cortex, just outside the endodermis were in rhythmatic pulsations. Such pulsations are responsible for pumping the water in upward direction. He inserted a fine needle into the stem of *Desmodium*. The needle was connected to a galvanometer and an electric circuit. The fine needle was inserted into the stem slowly. The galvanometer showed slow oscillations which were because of local irritations. But when needle touched the innermost layer of cortex, oscillations turned violent indicating that cells in this layer were pulsating *i.e.*, expanding and contracting alternately. According to Bose, the pulsatory cells pump the water into vessels.

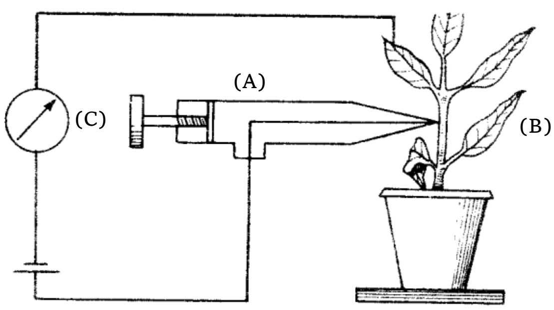


Fig : Diagrammatic representation of electricprobe experiment of J.C. Bose.
(A) Electric probe (B) Plant (C) Galvanometer

Criticism : Dixon failed to verify the results of Bose. It has been estimated that sap should flow through 230–240 pulsating cells per second to account for normal rate of pulsations. This rate is several times higher as would be possible to the Bose theory (Shull, MacDougal, Benedict).

(ii) **Root pressure theory :** It is proposed by Priestly. According to this theory the water, which is absorbed by the root-hairs from the soil collects in the cells of the cortex. Because of this collection of water the cortical cells become **fully turgid**. In such circumstances the elastic walls of the cortical cells, exert pressure on their fluid-contents and force them towards the xylem vessels. Due to this loss of water these cortical cells become flaccid, again absorb water, become turgid and thus again force out their fluid contents. Thus the cortical cells of the root carry on intermittent pumping action, as a result of which considerable pressure is set up in the root. This pressure forces water up the xylem vessels. Thus the pressure, which is set up in the cortical cells of the roots due to osmotic action, is known as the root pressure. This term was used by **Stephan Hales**. According to **Style**, root pressure may be defined as "*the pressure under which water passes from the living cells of the root in the xylem*".

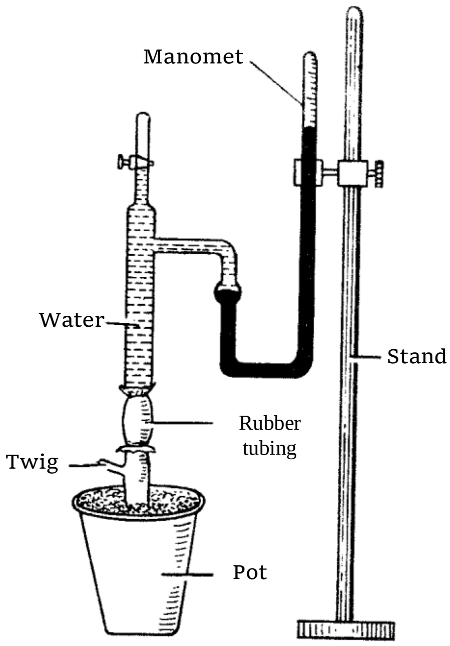


Fig : Demonstration of root

The root pressure is said to be active process which is confirmed by the following facts :

(a) Living cells are essential in root for the root pressure to develop.

(b) Oxygen supply and some metabolic inhibitors affect the root pressure without affecting the semipermeability of membrane systems.

(c) Minerals accumulated against the concentration gradient by active absorption utilising metabolically generated energy lowers the water potential of surrounding cells, leading to entry of water into the cells.

Objections : Root pressure theory for ascent of sap has following limitations :

- Taller plants like *Eucalyptus* need higher pressure to raise the water up. While the value of root pressure ranges from 2-5 atmospheres, a pressure of about 20 *atm*. is required to raise the water to tops of tall trees.

- **Strasburger** reported the ascent of sap in plants in which the roots were removed.

- Plants growing in cold, drought or less aerated soil, root pressure fails to appear and transport of water is normal.

(iii) **Physical force theories :** According to these theories the ascent of sap is purely a physical process. Some of the vital force theories are mentioned below :

(a) **Capillarity theory :** It was proposed by **Boehm** (1809). According to him, in the fine tubes, the water rises as a result of surface tension to different heights depending on the capillarity of the tube.

The finer the tube, the greater will be the rise of water in it. But the xylem vessels are sometimes broader than the capillarity range, and hence the rise due to surface tension will be negligible.

Objections

- Capillarity implies free surface but the water in the xylem elements in not in direct contact with the soil water.
- Atmospheric pressure can support a column of water only up to the height of 34 feet.
- Water can rise only up to the height of one metre in xylem vessels having diameter of 0.03*mm*.

(b) **Imbibitional theory :** It was proposed by **Unger** (1868) and supported by **Sachs** (1879). According to them, water moves upward in the stem through the wall of the xylem vessels. This theory is not accepted now because it is proved that water moves through the lumen of the xylem vessels and tracheids.

(c) **Atmospheric pressure theory :** Due to the loss of water by transpiration, the leaves draw water from the xylem vessels through osmotic pressure, which creates a sort of vacuum in the vessels. The atmospheric pressure acting on the water in the soil forces the water to rise up in the xylem vessels to fill the vacuum. But the atmospheric pressure can force the water to a height of only 10 metres. So it is evident that atmospheric pressure alone cannot force water to a height of 100 metres or more.

(d) **Cohesion and transpiration pull theory :** This is the most widely accepted theory put forth by Dixon and Jolly in 1894, and further supported by **Renner** (1911, 1915), **Curtis** and **Clark** (1951), **Bonner** and **Golston** (1952), **Kramer** and **Kozlowski** (1960).

It is also known as Dixon's cohesion theory, or transpiration pull theory or cohesion-tension theory.

This theory depends on the following assumptions, which are very near the facts :

(a) The xylem vessels are connected with each other, thus the water in them is in a continuous column from the root hairs to the mesophyll cells.

Walls of tracheids and vessels of xylem are made up of lignin and cellulose and have strong affinity for water (adhesion). The cell wall of adjacent cells, and those between the cells and xylem vessels all through the plant do not affect the continuity of the water column.

(b) Due to the transpiration from leaves, a great water deficit takes place in its cells. As a result of this deficit the water is drawn osmotically from the xylem cells in leaf veins, and by the cells surrounding the veins, and by the cells surrounding the veins. Thus a sort of pull is produced

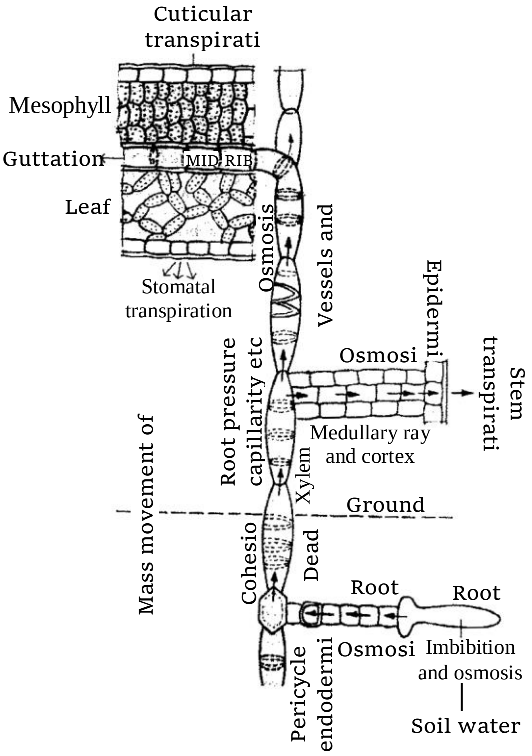


Fig : Path of ascent of sap showing transpiration pull

in the uppermost xylem cells in the leaves. It is called as the transpiration pull.

(c) The water molecules have a great mutual attraction with each other or in other words we can say that they have tremendous **cohesive power** which is sometimes as much as 350 atmospheres. Thus the transpiration pull developed a negative pressure in the uppermost xylem cells is transmitted from there into the xylem of stems, and from there to the roots.

In this way the water rises due to the transpiration pull and the cohesive power of water molecules from the lowest parts of the roots to the highest peaks of the trees. The osmotic pressure in the transpiring leaf cells often reaches to 30 atmospheres whereas only 20 atmospheres are needed to raise the water to the tops of highest known trees.

Objections : This is the most generally accepted theory, yet there are some objections against it which it fails to explain.

The most important objection is that leaving smaller plants, the water column has been found to contain air bubbles, and so their continuity breaks at such places. This phenomenon is known as cavitation and has been demonstrated by **Milburn** and **Johnson** (1966). However, **Scholander** overruled this problem by suggesting that continuity of water column is maintained due to presence of pits in the lateral walls of xylem vessels.

(3) **Velocity of ascent of sap : Huber** and **Schmidt** (1936) calculated the velocity of ascent of sap using radioactive ^{32}P, specific dyes and also by heat-pulse transport between two specific points of stem. It varies between 1 and 6 meters per hour but under high transpirational conditions, it may be as high as 45 meters per hour. It is more in ring porous woods having large vessels. It is slowest in gymnosperms.

Important tips

- Root pressure is absent in gymnosperms.
- Imbibitional force in pea is 1000 atm.
- Cohesive force is called as tensile strength of water.
- In soft stem, the ascent of sap can be prevented by applying squeezing pressure which closes the lumen of xylem channels.
- Overlapping cuts are given by Preston (1958) in stem in order to break continuity of xylem channels. However, ascent of sap continued.
- Manometer (Gk. manos – thin, metron – measure). An instrument for measuring pressure of tension (such as root pressure) in gases and liquids.
- Cohesive strength of 47-207 atm. in xylem sap is sufficient to meet the stress of transpiration pull, so that water column does not break.
- **Adhesion :** The attraction between the molecules of dissimilar substances.
- **Cohesion :** The attraction between the molecules of the same substances.
- Osmotic pressure is maximum in noon. At this time water contents in the cell are minimum.
- In night, root pressure will be maximum because in night transpiration is zero.

- Presence of pulsation in the cortical cell was demonstrated by electric probe.
- Pressure bomb technique was used by Scholander et al.

3.4 Transpiration

Land plants absorb a large quantities of water from the soil, but only a very small fraction of water utilized in various metabolic activities by the plants. The rest amount of it, evaporates from the stem and leaves. About 98 percent of the water absorbed by land plants evaporates from the aerial parts and diffuses into the atmosphere. "The loss of water in the form of vapour from the aerial parts of a plant is called transpiration". Maximum transpiration occurs in mesophytic plants.

Basically it is an evaporation phenomenon but it differs from the general process of evaporation. Evaporation is referred to the loss of water vapours from a free surface, whereas in case of transpiration of water passes through the epidermis with its cuticle or through the stomata. Transpiration maintained the atmospheric temperature.

Differences between transpiration and evaporation

S.No.	Transpiration	Evaporation
(1)	It is a physiological process and occurs in plants.	It is a physical process and occurs on any free surface.
(2)	The water moves through the epidermis with its cuticle or through the stomata.	Any liquid can evaporate. The living epidermis and stomata are not involved.
(3)	Living cells are involved.	It can occur from both living and non-living surfaces.
(4)	Various forces (such as vapour pressure, diffusion pressure, osmotic pressure, etc) are involved.	Not much forces are involved.
(5)	It provides the surface of leaf and young stem wet and protects from sun burning.	It causes dryness of the free surface.

(1) **Magnitude of transpiration :** As far as the magnitude of transpiration is concerned, Meyer (1956) had reported that some of the herbaceous plants, under favourable conditions, transpire the entire volume of water which a plant has and it is replaced within a single day. A tropical palm under well watered conditions may lose as much as 500 litres of water per day. Daily loss of water by an apple tree may be 10-20 litres. A maize plant may lose 3-4 litres of water per day.

Crotolaria juncea evaporates 27 *kg* of water in its life cycle of 140 days and *Helianthus annuus* about 56 *kg* of water. According to estimates at least 1000 gallons of water are lost every month during summer by a 9-10.5 metres high tree. A birch tree with 200,000 leaves evaporates 300-400 *kg* of water on a hot day, whereas a 15 years old beech tree evaporates 75 *kg* water per day during summer. A beech forest of 400-600 trees evaporates some 20,000 barrels of water per day.

(2) **Types of transpiration :** Transpiration occurs from all aerial parts of a plant and water is stores in large amount of leaves. However, most of the transpiration takes place through the leaves. It is called **foliar transpiration**. Stems transpire very little. Transpiration from stem is called **cauline transpiration**. Depending upon the plant surface involved, transpiration is of three types – cuticular, lenticular and stomatal transpiration.

(i) **Cuticular transpiration :** Cuticle is a layer of wax like covering on the epidermis of leaves and herbaceous stems. It provides a relatively impermeable covering. If it is thin, upto 20 percent of the total transpiration may take place through it, but with the increase in its thickness (*e.g.*, in xerophytes), the water vapour loss is reduced.

(ii) **Lenticular transpiration :** Lenticles are the areas in the bark of woody plants which are filled with loosely arranged cells known as complementry cells. Loss of water vapour through lenticels is called lenticular transpiration. It amounts to about 0.1 percent of the total water loss through transpiration.

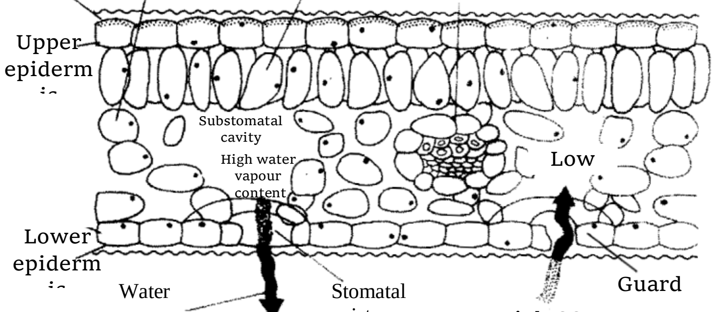


Fig : Water movement through the leaf to the atmosphere in the form of vapour

(iii) **Stomatal transpiration :** Stomata are minute pores in the epidermis of leaves, young green stems. The loss of water vapour, which occurs through stomata is called stomatal transpiration. It amounts 80-90 percent of the total water vapour loss from the plants. It is the most common type of transpiration. **Arora** and **Lamba** (1982) have reported the presence of stomata on fruit wall of *Raphanus sativus* var. *caudatus* and *Brassica oleracea* var. *botrytis*.

(3) **Structure of stomata :** Stomata are the microscopic openings most commonly found in the leaves. These may be present in young stems and sometimes even in fruits (*e.g.,* citrus, banana, cucumber, etc.). Each stomatal opening is surrounded by two specialised epidermal cells, called as the **guard cells**.

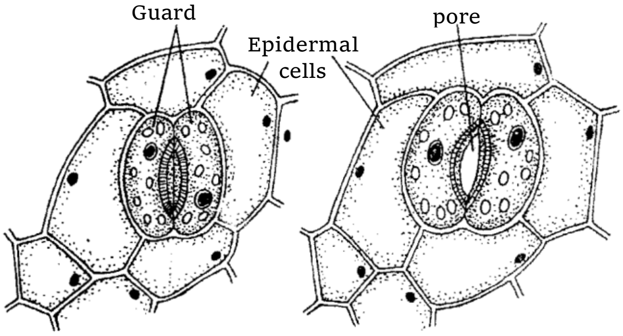


Fig : Stomatal apparatus (A) Closed (B) Open

Because of their small size, the guard cells are rapidly influenced by turgor change and thus regulate the opening and closing of stomata. The guard cells of dicot leaves are **kidney-shaped** or **raniform** whereas those of monocots (family Gramineae) are **dumbel-shaped** or **elliptical**. The guard cells are surrounded by epidermal cells called as the **accessory cells** or **subsidiary cells**. These are different from the normal cells of epidermis having chloroplasts. The stoma with subsidiary cells is called stomatal apparatus. Each stoma leads into a air space called sub stomatal cavity. Both kidney shaped and dumbel-shaped guard cells have been reported in **Cyperus**. Each guard cell has a thin layer of cytoplasm along the cell wall and a large vacuole. Its cytoplasm contains a distinct nucleus and several chloroplasts. The cell wall of guard cells around the stomatal pores are thickened and inelastic due to presence of a **secondary layer of cellulose**. Here the cellulose microfibrils are radially arranged and they radiate away from the pore. Rest of the wall is thin, elastic and semipermeable.

The size of stomatal pore varies from species to species – for example of fully opened stomatal pore of *Zea mays* measures 26μm long and 4μm wide, whereas in *Phaseolus* it measures 7 × 3μm. The average length of stomata is 20 to 28μm and breadth 3-10μm.

(4) **Number of stomata on leaves :** The number of stomata is not equal on both surface of leaves in different plants.

Name of the plant	**Number of stomata/mm^2**	
	Upper surface	**Lower surface**
Helianthus annuus	58	156
Lycopersicum esculantum	12	130
Phaseolus vulgaris	40	281
Solanum tuberosum	51	161
Zea mays	52	68
Avena sativa	40	43

(5) **Types of stomata :** On the basis of orientation of subsidiary cells around the guard cells, **Metcalfe** and **Chalk** classified stomata into following types :

(i) **Anomocytic :** The guard cells are surrounded by a limited number of unspecialised subsidiary cells which appear similar to other epidermal cells. *e.g.*, in Ranunculaceae family.

(ii) **Anisocytic :** The guard cells are surrounded by three subsidiary cells, two of which are large and one is very small. *e.g.*, in Solanaceae and Cruciferae families.

(iii) **Paracytic :** The guard cells are surrounded by only two subsidiary cells lying parallel to the guard cells *e.g.*, Magnoliaceae family.

(iv) **Diacytic :** The guard cells are surrounded by only two subsidiary cells lying at right angles to the longitudinal axis of the guard cells. *e.g*., Acanthaceae and Labiatae families.

(v) **Actinocytic :** The guard cells are surrounded by four or more subsidiary cells and which are elongated radially to stomata.

(6) **Distribution of stomata :** The stomata differ in their distribution on the two surfaces of the leaf. The leaves are classified into following types on the basis of stomatal distribution on them :

(i) **Epistomatic (Water Lily type) :** Stomata are present only on the **upper** epidermis of leaves. These are found in water Lily, *Nymphaea* and many other floating hydrophytes.

(ii) **Hypostomatic (Apple or Mulberry type) :** Stomata are present only on the **lower** surface of leaves. *e.g.*, Apple, mulberry, peach and walnut.

(iii) **Amphistomatic :** Stomata are present on both the surfaces of leaves. It can further be subdivided into two types :

(a) **Anisostomatic (Potato type) :** The number of stomata is more on the lower surface and less on the upper surface. In other words, the lower surface is multistomatic and the upper surface is paucistomatic. Such leaves are also called as **dorsiventral** leaves. *e.g.*, Potato, tomato, bean, pea, and cabbage.

(b) **Isostomatic (Oat type) :** The stomata are equally distributed on both the surfaces of leaves. These leaves are also called as **isobilateral** leaves. These are found in monocots *e.g.*, Oat, maize, grasses, etc.

(iv) **Astomatic (*Potamogeton type*) :** Stomata are either absent altogether or vestigial. *e.g.*, *Potamogeton* and submerged hydrophytes.

(7) **Daily periodicity of stomatal movement :** Loftfield (1921) classified the stomata into four types, depending upon the periods of opening and closing.

(i) **Alfalfa type (Lucerne type) :** The stomata remain **open** throughout the day but close during night, *e.g.*, Pea, bean, mustard, cucumber, sunflower, radish, turnip, apple, grape.

(ii) **Potato type :** The stomata close only for a few hours in the evening, otherwise they remain open throughout the day and night *e.g., Cucurbita, Allium, Cabbage, Tulip, Banana* etc.

(iii) **Barley type :** These stomata open only for a few hours in the day time, otherwise they remain closed throughout the day and night, *e.g.*, Cereals.

(iv) **Equisetum type :** The stomata remain always open through out the day and night. *e.g.*, Amphibious plants or emergent hydrophytes.

(8) **Mechanism of opening and closing of stomata :** Opening and closing of stomata occurs due to turgor changes in guard cells. Due to endosmosis, an increase in turgor of guard cells takes place which finally results in stretching and bulging out of their outer thin walls. This results in the pulling apart of the opposed inner thicker walls creating an opening or pore in guard cells of stomata. When the

turgor pressure of guard cells decreases, inner walls sag, leading to closure of space between them. This is due to the loss of water (exosmosis) from guard cells, resulting in thicker walls to move closer and finally shut the opening. The transpiration is regulated by the movement of guard cells of stomata.

Several theories have been put forth to explain the opening and closure of stomata. Which have been discussed below :

(i) **Photosynthetic theory :** According to Von Mohl (1856) the chloroplasts present in guard cells prepare osmotically active substances by photosynthesis. As a result, their osmotic pressure increases and their turgor pressure increases due to endosmosis. This results in opening of stomata.

This theory is not accepted because in many cases, chloroplasts of guard cells are poorly developed and incapable of performing photosynthesis.

(ii) **Starch ⇄ sugar interconversion theory :** According to **Lloyd** (1908), turgidity of guard cells depends upon interconversion of starch and sugar. This fact was supported by **Loftfield** (1921) who found that guard cells contain sugar during day time when they are open and starch during night when they are closed. Later **Sayre** (1926) observed that stomata open in neutral or alkaline *pH* which prevails during day time due to constant removal of CO_2 by photosynthesis. They remain closed during night when there is no photosynthesis and due to accumulation of CO_2, carbonic acid is formed which causes the *pH* to be acidic, Sayre thus proposed that interconversion of starch and sugar is regulated by the *pH*. Sayre's hypothesis was supported by **Scarth** (1932) and **Small** *et al* (1942). This hypothesis was further supported by detection of the enzyme *phosphorylase* in guard cells by **Yin** and **Tung** (1948). This enzyme is responsible for starch-glucose interconversion.

$$\text{Starch} + \text{Pi} \underset{pH=5\ \text{(Night)}}{\overset{\text{Phosphorylase, } pH=7\ \text{(Day)}}{\rightleftharpoons}} \text{Glucose} - 1 - \text{phosphate}$$

In the light of above facts, stomatal opening and closing can be explained in the following way :

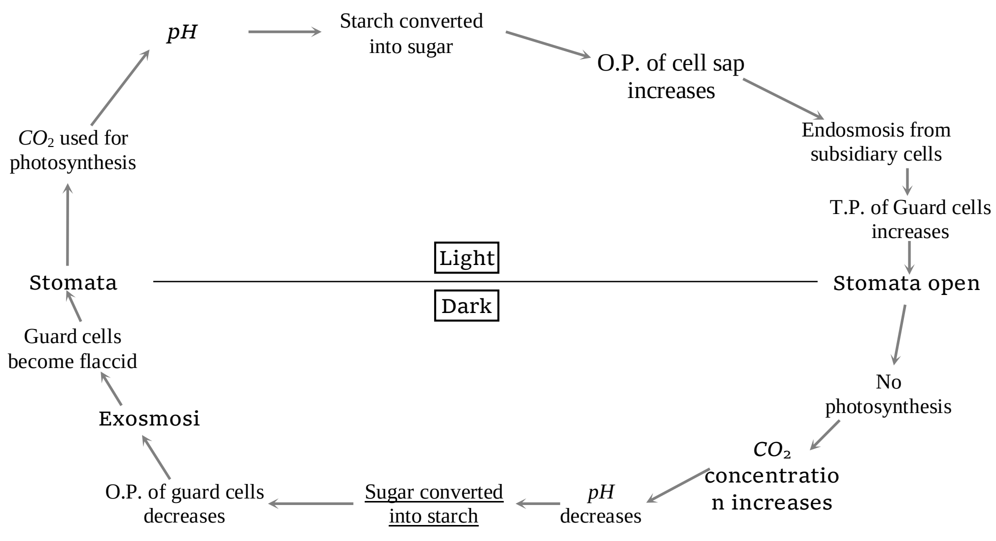


Fig : Graphical representation of mechanism of opening and closing of

Criticism : Starch ⇄ Sugar hypothesis has been criticised because of the following objections raised against this theory :

(i) Starch ⇄ Sugar interconversion is a slow process which can not account for rapid stomatal movement.

(ii) Starch or other polymerised polysaccharide do not occur in onion plant where stomatal movement occurs.

(iii) Glucose is not detectable in the guard cells when stomatal opening occurs.

(iv) The theory could not explain the extra-effectiveness of blue light at the time of stomatal opening.

Stewards modification : According to **Steward's** *pH* theory CO_2 accumulates in guard cells in dark, thus reducing the *pH*. As a result acidity increases. Sugar to starch conversion is thus favoured. This results in exosmosis causing the closure of stomata. During the day time in sunlight CO_2 is consumed (in mesophyll cells). This is responsible for increase in *pH* and reduction in acidity. Thus hydrolysis of starch to sugar is favoured. Due to increase in osmotic concentration endosmosis occurs in guard cells and stomata open. Steward said that glucose-I-phosphate should be further converted into glucose as glucose-I-phosphate is not capable of changing osmotic pressure. In this process of stomatal opening and closing, enzymes like phosphorylase, phosphoglucomutase, phosphatase and hexokinase are present in guard cells.

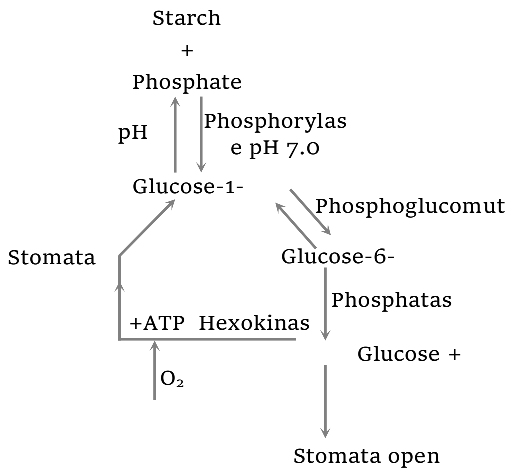


Fig : Mechanism of opening and closing of stomata according to Steward

(iii) **Glycolate theory : Zelitch** (1963) proposed that stomata open due to production of glycolic acid by photorespiration in guard cells under low concentration of CO_2. The glycolic acid thus produced is converted into soluble carbohydrates which increase the O.P. of guard cells.

This theory is rejected due to following objections :

(i) It fails to explain the opening of stomata in dark (*e.g.,* in succulents).

(ii) In some plants stomata have been found to remain closed even during day times.

(iii) It fails to explain the effect of blue light on stomatal opening.

(iv) **Active K^+ transport theory : Imamura** (1943) and many other scientists found accumulation of K^+ in the guard cells when they are exposed to light. **Fujino** (1967) suggested that stomatal opening and closing occurs due to an active transport of K^+ into or out of the guard cells.

(v) **Proton transport theory :** It was proposed by **Levitt** (1974). It incorporates good points of Scarth's classical *pH* theory and active K^+ -transport theory. According to this theory stomatal opening and closing can be explained in the following manner :

(a) **Mechanism of stomatal opening**

(i) During day time due to rapid rate of photosynthesis, the concentration of CO_2 decreases in the guard cells. As a result their *pH* is increased. At higher *pH*, starch in the guard cells is converted into organic acid by the enzyme **phosphoenol pyruvate carboxylase (PEPC)**. This enzyme was discovered by **Willmer** *etal*. (1973). It can convert several others carbohydrate into organic acids.

(ii) The organic acid (*e.g.* malic acid) dissociates into H^+-ions (protons) and malate ions.

(iii) The protons (H^+) are actively transported into subsidiary cells in exchange for K^+ with the help of an energy (ATP) driven H^+-K^+-pump. The uptake of K^+-ions is balanced by uptake of *Cl* and the negative charge on malate-ions.

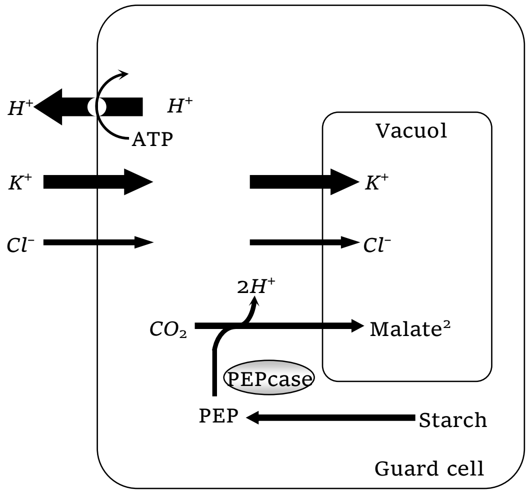


Fig : Role of potassium, chloride and malate ions in stomatal opening

(iv) Increased concentration of K^+ and malate ions in the guard cells increases the O.P. of guard cells.

(v) Water enters from adjoining subsidiary cells by endosmosis.

(vi) Turgor pressure of guard cells increases. Turgidity of guard cell is controlled by potassium, chloride and malate.

(vii) Stomata open.

(b) **Mechanism of stomatal closure :** According to **Cowan** *et.al*. (1982) closure of stomata depends upon abscisic acid (ABA) which is in fact an inhibitor of K^+-uptake. It becomes functional in presence of CO_2 or in acidic conditions (low *pH*).

(i) During night photosynthesis stops which results in increased concentration of CO_2 which causes lowering of *pH*.

(ii) At lower *pH*, ABA inhibits K^+-uptake by changing the permeability of guard cells.

(iii) The K^+-ions now start moving out of the guard cells which results in lowering of the *pH*.

(iv) At low *pH*, organic acids are converted back into starch by PEPC.

(v) The O.P. of guard cells decreases and water moves out of them into subsidiary cells by the process of exosmosis, thus decreasing their turgor pressure.

(vi) The guard cells become flaccid and the stomata close.

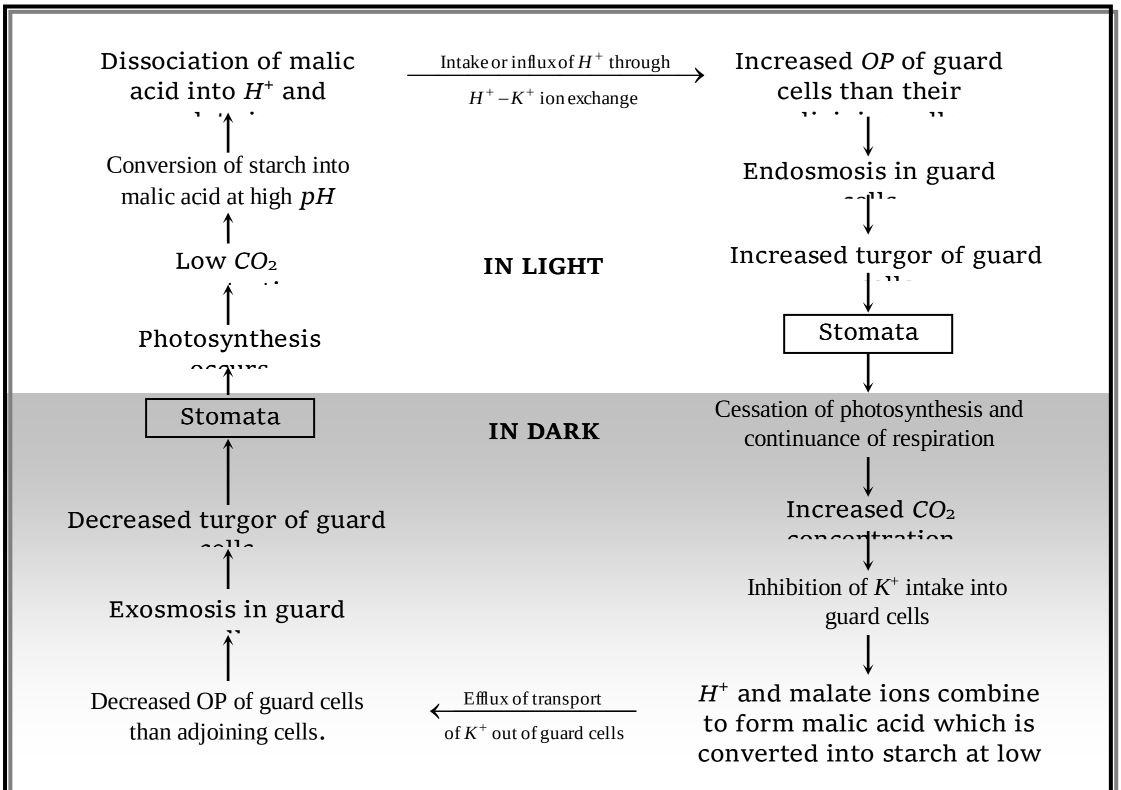


Fig : Steps involved in the process of opening and closing of stomata

(9) **Stomatal opening in succulent plants :** The stomata in succulent plant or CAM plants (like Opuntia, Bryophyllum etc.) open during night (darkness) and remain closed during the day time and found in lower surface. This type of stomatal opening is called 'Scotoactive type' and the stomata which open during day are called as photoactive. Stomata closed and open due to the activity of water. This types of stomata is known as hydroactive stomata. The opening and closing mechanism of scotoactive stomata was explained by **Nishida** (1963). In succulent plants, during night, there is incomplete oxidation of carbohydrates and accumulation of organic acids (*e.g.*, malic acid) without release of CO_2. During day time the accumulated organic acids breakdown rapidly releasing excess amount of CO_2 for photosynthesis as well as to keep the stomata closed.

During night : $2\underset{\text{Glucose}}{C_6H_{12}O_6} + 3O_2 \rightarrow 3\underset{\text{Malic acid}}{C_4H_6O_5} + 3H_2O$

During day : $C_4H_6O_5 + 3O_2 \rightarrow 4CO_2 + 3H_2O$.

(10) **Factors affecting rate of transpiration**

(i) **External factors**

(a) **Atmospheric humidity :** If the atmosphere is humid, it reduces the rate of transpiration. When the air is dry, the rate of transpiration increases.

(b) **Temperature :** It affects the rate of transpiration only indirectly. Increase in the temperature of the air decreases the humidity of the air and therefore more water is vapourised and lost from the transpiring surface. The lowering of the air-temperature, on the other hand, increases the humidity and rate of water-loss as well.

(c) **Light :** Light affects the rate of transpiration due to its effect on temperature and photosynthesis. During daytime stomata open wide but during night they close. Moreover, during the daytime the light also helps in raising the temperature. Thus increased temperature and presence of wide open stomata increase the rate of transpiration. Light is the most important factor in the regulation of transpiration.

(d) **Atmospheric pressure :** The rate of transpiration is inversely proportional to the atmospheric pressure.

(e) **Available soil water :** If the available water in the soil is not sufficient the rate of transpiration is decreased. Under internal water deficiency the stomata are partially or completely closed.

(f) **Wind velocity :** A transpiring surface of leaf continuously adds water vapours to the atmospheric air. Once the immediate area becomes saturated, it reduces the rate of transpiration. Wind velocity removes the air of that area, which is replaced by fresh air and result in an increases in the rate of transpiration. Wind velocity is measured by anemometer.

(ii) **Internal factors/Plant factors**

(a) **Leaf area :** If leaf area is more, transpiration is faster. However, the rate of transpiration per unit area is more in smaller leaves than in larger leaves due to high number of stomata in a small leaf. Number of stomata per unit area of leaf is called stomatal frequency.

$I = \frac{S}{E + S} \times 100$ here, I = Stomatal index

S = No. of stomata per unit area

E = No. of epidermal cells in unit area.

(b) **Leaf structure :** The anatomical features of leaves like sunken or vestigial stomata; presence of hair, cuticle or waxy layer on the epidermis; presence of hydrophilic substances such as gums, mucilage *etc*. in the cells; compactly arranged mesophyll cells etc. help in reducing the rate of transpiration.

(c) **Root shoot ratio :** According to **Parker** (1949) the rate of transpiration is directly proportional to the root-shoot ratio.

(d) **Age of plants :** Germinating seeds show a slow rate of transpiration. It becomes maximum at maturity. However, it decreases at senescence stage.

(e) **Orientation of leaves :** If the leaves are arranged transversely on the shoot they lose more water because they are exposed to direct sunlight. If placed perpendicularly they transpire at slower rate.

(11) **Significance of transpiration :** The advantages and disadvantages of transpiration are discussed below :

(i) **Advantages**

(a) Transpiration is important for plants because it directly influences the absorption of water from the soil.

(b) Transpiration exerts a tension or pull on water column in xylem which is responsible for the ascent of sap.

(c) Transpiration helps in the movement of water and minerals absorbed by the roots to the other parts of the plant.

(d) The evaporation of water during transpiration contributes to the cooling of leaves (and also the surrounding air) and protects leaves from heat injury particularly under conditions of high temperature and intense sunlight.

(ii) **Disadvantages**

(a) Transpiration often results in water deficit which causes injury to the plants by desiccation.

(b) Rapid transpiration causes mid-day leaf water deficit (temporary wilting). If such condition continues for some time, permanent water deficit (permanent wilting) may develop, which causes injury to plants.

(c) Many xerophytes have to develop structural modifications to reduce transpiration. These modifications are extra burden on the plants.

(d) Excessive rate of transpiration leads to stunted growth of plants.

(e) Deciduous trees have to shed their leaves during autumn to check transpiration.

(f) Since approximately 90 percent of absorbed water is lost through transpiration, the energy used in absorption and conduction of water goes waste.

Besides all the above mentioned disadvantages, the process of transpiration is unavoidable, because of the anatomical structure of the leaves. Since stomata are required for gaseous exchange in photosynthesis and respiration, the loss of water through them cannot be avoided. Therefore, **Curtis** (1926) truely called '**transpiration as a necessary evil**'.

(12) **Anti-transpirants :** Most of the water absorbed by plants is lost to the atmosphere by transpiration and hence water use by plants is very inefficient. In recent years efforts have been made to improve the efficiency of water use by the plants. One of the approaches is to reduce transpiration by the application of certain chemical substances. '*The chemical substances which reduce transpiration* (*by increasing leaf resistance to water vapour diffusion*) *without affecting gaseous exchange, are called anti-transpirants*'. Anti-transpirants are of two types metabolic inhibitors and film forming anti-transpirants.

(i) **Metabolic inhibitors :** They reduce transpiration by causing partial closure of stomata, without influencing other metabolic processes, the most important of these inhibitors are phenyl mercuric acetate (PMA) and abscissic acid (ABA).

(ii) **Film forming anti-transpirants :** They check transpiration by forming a thin transparent film on the transpiring surface. They are sufficiently permeable to carbon dioxide and oxygen to allow photosynthesis and respiration, but prevent movement of water vapour through them. The important chemicals of this group are silicon emulsion, colourless plastic resins and low viscosity waxes.

(13) **Guttation :** The process of exudation of liquid drops from the edges of leaves is called guttation or the process of the escape of liquid from the tip of uninjured leaf is called guttation. Usually it is occur through stomata like pores called hydathodes. Exudation may some time occur from stem through the scars of leaves and lenticles. Guttation usually occurs when the plant is put in more saturated atmosphere.

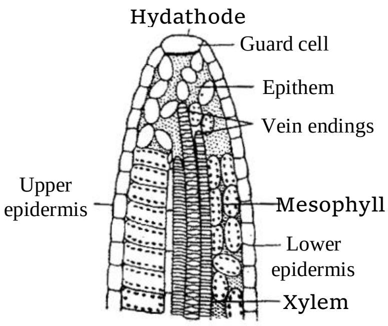


Fig : Vertical section of a leaf showing hydathode

Hydathodes are generally present at the tip or margin of leaves. These pores are present over a mass of loosely arranged cells with large intercellular spaces called epithem. This mass of tissue lies above a vein ending. The xylem of a small vein usually terminates among the thin walled parenchymatous cells of epithem. Guttation is caused due root pressure. It is found in 115 families and 333 genera of woody and herbaceous plants. *e.g.*, Garden nasturtium (*Tropeolum*), Oat (*Avena*), *Calocasia* etc. growing in moist, warm soil and under humid conditions. When the absorption of water exceeds that of the transpiration, hydrostatic pressure is built up in xylem ducts. As a result, water is pushed in the xylem ducts and comes out through the hydathodes. The water of guttation contains several dissolved inorganic and organic substance.

Differences between transpiration and guttation

S.No.	Transpiration	Guttation
(1)	It occurs during day time	It usually occurs in the night.
(2)	The water is given out in the form of vapour.	The water is given out in the form of liquid.
(3)	The transpired water is pure.	Guttated water contains dissolved salts and sugar.
(4)	It takes place through stomata lenticel or cuticle.	It occurs through special structure called hydathode found only on leaf tips or margin.
(5)	It is a controlled process.	It is uncontrolled process.
(6)	It lowers down the temperature of the surface.	It lacks such relationship.

Differences between stomata and hydathode

S.No.	Stomata	Hydathode
(1)	Stomata occur on epidermis of leaves, young stems, etc.	Hydathodes generally occur at the tip or margins of leaves of those plants that grow in moist shady places.
(2)	Stomatal aperture is guarded by two kidney shaped guard cells.	The aperture of hydathode is surrounded by a ring of cuticularised cells.
(3)	The two guard cells are generally surrounded by subsidiary cells.	The subsidiary cells are absent.
(4)	The opening and closing of stomatal aperture is regulated by guard cells.	Hydathode pore remains always open.
(5)	These are the structure involved in transpiration and exchange of gases.	Hydathodes are involved in guttation.

Important Tips

- **Psychorometer** is used for measuring relative humidity as well as transpiration.
- **Hydrometer** is used for measuring the density or specific gravity of a liquid.
- **Barometer** is used for measuring atmospheric pressure.
- **Barograph** represents the recording of barometer.
- **Porometer** is used for measuring the size of stomata.
- **Atmometer** is used for measuring pull caused by evaporation of water from a porous pot.
- **Potometer** is used for measuring the rate of transpiration.
- **Transpiration ratio :** It is number of units of water transpired for manufacturing 1 unit of dry matter. Transpiration ratio is 50 in CAM plants, 100–200 in C_4 plants, 300–500 for most mesophytes and 900 in Alfalfa.
- **Schwendener** (1881) was the first to point out that stomatal opening and closing is due to turgor changes in guard cells.
- **Photoactive stomata :** Stomata open in response to light. The action spectrum consists of red and blue light (blue light is more effective in stomatal opening; Mouravieff, 1958). Since, most of the transpiration is stomatal, the action spectrum of transpiration is red and blue light.
- Stomata remain open at relative humidity above 70% and close below relative humidity of 50%.

- **Transpiration of hills :** High due to lower atmospheric pressure but low due to lesser hours of light and lower temperature. Transpiration is therefore, near normal but the plants show xeromorphy due to lesser water availability.
- The term guttation was coined by Bergerstein (1887).
- In Saxifraga, the rate of guttation is high during flowering.
- **Lactuca scariota** and **Syiphium laciniatum** are called **compass plants** as their leaves remain vertically in north-south direction.
- Maximum opening of stomata occurs at about 10:00 AM and 3:00 PM (At 12:00 noon, partial closure of stomata occurs).
- In C_3 plant the rate of transpiration is high.
- In angiosperm stomata does not open during at midnight.
- Cobalt chloride paper method was first used by **Stahl** (1894). It is used to compare rate of transpiration on two surfaces of leaf. Cobalt chloride is blue in anhydrous state. In contact with water vapour it turns pink.
- Bleeding is the exudation of sap (water along with dissolved organic and inorganic substances) from the injured parts of the plant e.g., exudation of latex from laticiferous ducts in Euphorbia and members of family moraceae (mulberry family) are the cases of bleeding.
- In many plants like **Oleander** (Nerium) the stomata are not only sunken but are further protected by the presence of trichomes or epidermal hairs.
- In many plants like India-rubber, cabbage, sugar-cane etc., the leaves are covered with "bloom", which is a waxy substance and as such prevents a certain amount of cuticular transpiration.
- The rate of transpiration will greatly depends upon position of stomata.
- The presence of gums, mucilage, latex etc., in the tissues of the leaf also checks transpiration of water.
- When transpiration is very low and absorption is high, the root pressure is maximum.
- In aquatic and submerged plants stomata are absent e.g., Vallisnaria.

3.5 Translocation of organic solutes

The synthesis of carbohydrate food materials, mainly through the process of photosynthesis, occurs in green cells of plant. The non-green cells are therefore, dependent on photosynthetic cells for their carbohydrate supply. The organic food mainly from the leaves, is transported to the non-green parts where it is needed for respiration and biosynthesis. "This movement of organic food or solute in soluble form, from one organ to another organ is called translocation of organic solutes."

It has been now well established that carbohydrates are translocated from leaves to roots and storage organs (tubers, bulbs, fruits, etc.) along the phloem in the form of sucrose. They are transported through living sieve elements of phloem (chiefly sieve tube members in seed plants). The process of translocation requires expenditure of metabolic energy and the solute moves at the rate of 100*cm/hr*.

(1) **Directions of translocation**

(i) **Downward translocation :** It is of most important type, *i.e.*, from leaves to stem and roots.

(ii) **Upward translocation :** From leaves to developing flowers, buds, fruits and also during germination of seeds and tubers, etc.

(iii) **Radial translocation :** From pith to cortex and epidermis.

Thus we find that the translocation of food takes place from organs where food is in high concentrations (*e.g.*, leaf, tuber, rhizome) to organs where it is in low concentration (*e.g.*, roots). The first are called supply ends and the later as consumption ends.

(2) **Path of translocation**

(i) **Downward translocation of organic solutes :** Phloem is the path for downward translocation of organic food. Following evidences are in support of it :

(a) **Elimination of other tissues :** Tissues other than phloem cannot account for downward translocation of solutes. Because xylem is responsible for upward movement of water and minerals, so it cannot account for downward translocation of solute at the same time. Cortex and pith are not structurally suitable for this purpose. Thus only **phloem** is left (where there is end to end arrangement of sieve tubes united by sieve pores). Which is responsible for translocation of solutes in downward direction.

(b) **Chemical analysis of phloem sap and xylem sap :** Chemical analysis of sieve tube sap proves that concentrated solution of sucrose is translocated from the place of synthesis to other parts of the plant body. Glucose and fructose are sometimes found in traces only. The amount of sucrose is more in phloem sap during the day and less in night. In xylem the amount of sucrose is in traces and also there is no diurnal fluctuation.

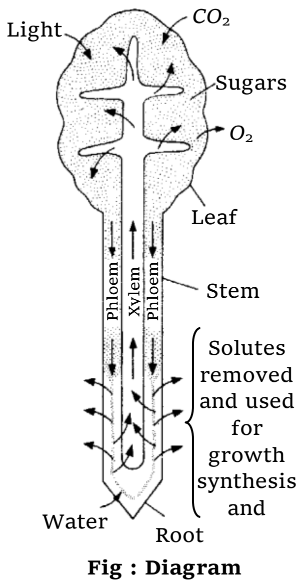


Fig : Diagram representing the translocation of sugars through phloem

(c) **Isotopic studies :** If leaf of potted plant is illuminated in the presence of radioactive $C^{14}O_2$ it forms radioactive products of photosynthesis which are then transported to stem. It was detected by autoradiographic studies that these substances are translocated through phloem particularly sieve tubes. Radioactivity is found below and above the nodes of the leaf to which radioactive carbon was provided. Burr and others (1945) allowed bean leaf to photosynthesize in an atmosphere of carbon isotope (^{13}C or ^{14}C) and observed that labelled sugar moved in the phloem.

(d) **Blocking of phloem :** Blocking of sieve pores by **'callose'** during winter blocks translocation of solutes.

(e) **Ringing or Girdling experiment :** It was first performed by **Hartig** (1837). On removing the ring of bark (phloem + cambium) above the root at the base of stem, accumulation of food occurs in the form of swelling just above the ring, which suggests that in absence of phloem, downward translocation of food is stopped.

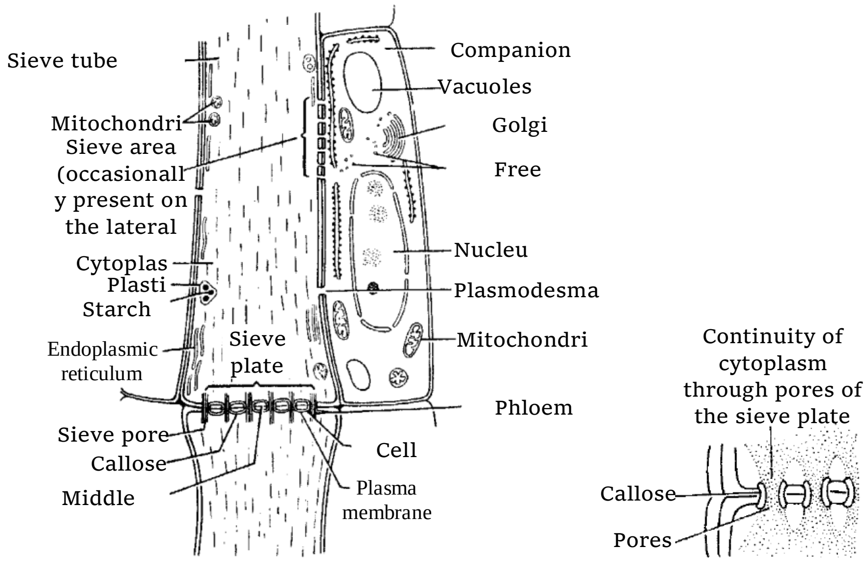


Fig : Phloem structure : (A) Sieve tube with companion cells (B) L.S. of sieve tube through sieve plate showing cytoplasmic connections through the pore

(f) **Structure of phloem :** The structure of phloem tissue is well modified for conduction of solutes. Phloem tissue of an angiosperm consists of sieve tubes, companion cells several kinds of parenchyma cells, fibres and scleroids. Of these sieve tubes are involved in sugar translocation. Sieve tubes are elongated cells arranged longitudinally end to end. Parenchyma cells are closely associated with them and remain connected through fine cytoplasmic thread called plasmodesmata.

During maturation of a sieve tube, cell wall undergoes certain distinctive changes. It develops pores in its transverse wall. Each pore has a single strand of cytoplasm extending through it and connecting the protoplast of adjoining sieve tube. These pores may also be present in lateral walls in certain cases. In general, these sieve areas (pores) are localised on the end walls and are called *sieve plates*. The border of each pore becomes impregnated at maturity with callose (a polysaccharide) and thus cytoplasmic strand within pore remains encased in a cylinder of callose.

In addition to the changes in the cell wall, the protoplast of sieve element also undergoes remarkable changes during maturation. Nucleus, tonoplast and vacuole undergoes disintegration and disappear Esau (1966) believes that in case of mature sieve tubes, the cytoplasm and vacuole become one system called *mycotoplasm*. A proteinaceous component called P-protein (phloem protein) makes its appearance in the cytoplasm of young sieve tube as discrete *slime bodies*. The slime bodies consist of thread-like filaments.

(ii) **Upward translocation of organic solutes :** According to Dixon the upward conduction of foods takes place through the xylem. However scientists are not in agreement with him. According to Curtis upward conduction of foods also takes place through phloem. This view is based upon ringing experiments. He took three woody plants. In plant A ringing was done as described in ringing experiments. In plant B xylem was injured in a ring but phloem was left intact. In plant C xylem and phloem were in normal position. In plant A and B all leaves above the ring were removed. In A there was no growth above the ring and also the dry weight of this part was less. This proves that upward conduction of food takes place through phloem. So organic food moves upwardly and downwardly through the phloem.

(3) **Mechanism of translocation**

(i) **Diffusion hypothesis :** Mason and Maskell (1928) working on cotton plant demonstrated that the translocation of foods occurs from the place of high concentration (place of manufacture or storage) to the place of lower concentration (place of consumption). But this concept can not be supported considering the translocation rate. The actual rate of translocation is many time faster than the rate of diffusion. Hence, Mason and Phillis (1936) modified this concept and proposed activated diffusion hypothesis. According to this concept the food particles are first energy activated then translocated. This hypothesis is not accepted due to lack of experimental evidence.

(ii) **Protoplasmic streaming hypothesis :** This concept was proposed by de Vries (1885). According to him the food is transported across by streaming current of protoplasm. The cell protoplasm shows a special locomotion movement called **cyclosis**. It is of two types, **rotation** and **circulation**. While rotation is circular movement of protoplasm, circulation is radial movement forming eddies around the vacuoles. The hypothesis involves two phenomenon, such as streaming of sieve protoplasm and diffusion of metabolites through sieve pores.

This hypothesis not only explains faster rate of translocation but also the bidirectional movement of metabolites across a single sieve element. This hypothesis was supported by Curtis (1950).

(iii) **Transcellular streaming : Thaine** (1964) suggested modification to cytoplasmic streaming theory. He observed the presence of transcellular strands in sieve tubes which contains particles. These strands move up and down. He defined transcellular streaming as "the movement of the particulate and fluid constituents of cytoplasm through linear files of longitudinally oriented plant cells. "He further proposed that transcellular strands are proteinaceous and characteristic microtubules to afford rhythmic contraction. Thus, transcellular streaming is an attractive mechanism as it would explain the phenomenon of bidirectional translocation.

(iv) **Interfacial hypothesis :** According to Van den Honert, (1932) food is translocated by interfacial flow along transcellular strands which provide greater surface area. The solute molecules are absorbed on the interface and as a result the surface tension decreases. This concept is comparable to spreading of oil drop on water surface. By this concept we can explain faster rate of translocation.

(v) **Contractile proteins :** Fensom and Williams (1974) observed a network of interlinked microfibrils in the sieve tube which oscillated in a manner resembling moving flagella in other organisms. They suggested that particles attached to microfibrils move with a bouncing motion. These movements suggested that the microfibrils were composed of contractile threads of *P*-protein.

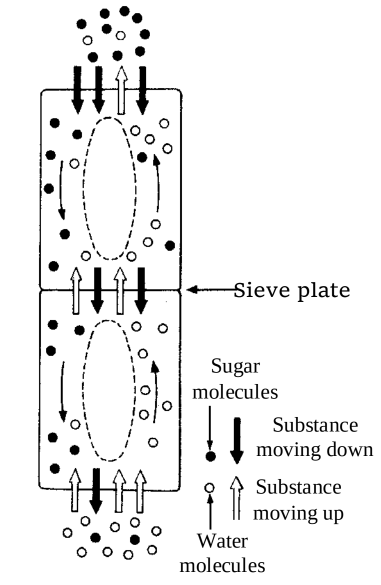


Fig : Representation of protoplasmic streaming hypothesis

(vi) **Electro-osmotic hypothesis :** A mechanism involving electro-osmosis was proposed independently by Fensom (1957) and Spanner (1958). According to this hypothesis the solute moves in the positive direction of the electrical gradient along with K^+ ions. Important features of the mechanism are as follows :

(a) The sieve plates are negatively charged, hence they repel negatively charged ions (anions).

(b) There is high concentration of potassium ions (K^+) in the sieve tube solution. These and other cations can pass through the sieve plate.

(c) An electrical gradient builds up across the sieve plate in the direction of the flow; when the solute is moving in downward direction anions begin to accumulate below the sieve plate and cations above it (when solutes move in upward direction, K^+ ions may accumulate below the sieve plate).

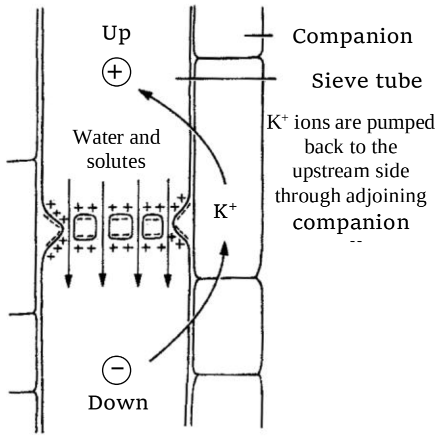


Fig : Electro-osmotic flow of solutes through sieve plate

(d) A current of K^+ passes through the sieve pores by electro-osmosis, and sugar and water molecules adhered tightly to K^+ are carried along with them. Thus each sieve plate is an '**electro-osmotic pumping station**' which induces mass flow of solution along with the movement of K^+ ions. The energy for this movement is supplied by ATP from the companion cells and sieve tubes.

(e) The K^+ ions from the downstream side of the sieve plate are pumped back to the upstream side of the sieve plate through adjoining companion cells.

The evidence in support of electro-osmosis are as follows :

- High concentration of K^+ ions is found in the sieve cells.
- Role of companion cells in supplying ATP has been established.
- The charged porous surface of the sieve plates is suitable for the flow of solutes by osmosis.

The hypothesis has, however, been rejected on following grounds.

- The hypothesis fails to explain the bidirectional transport of metabolites in phloem.
- Considerable energy would be required to maintain a continuous circulation of potassium ions.

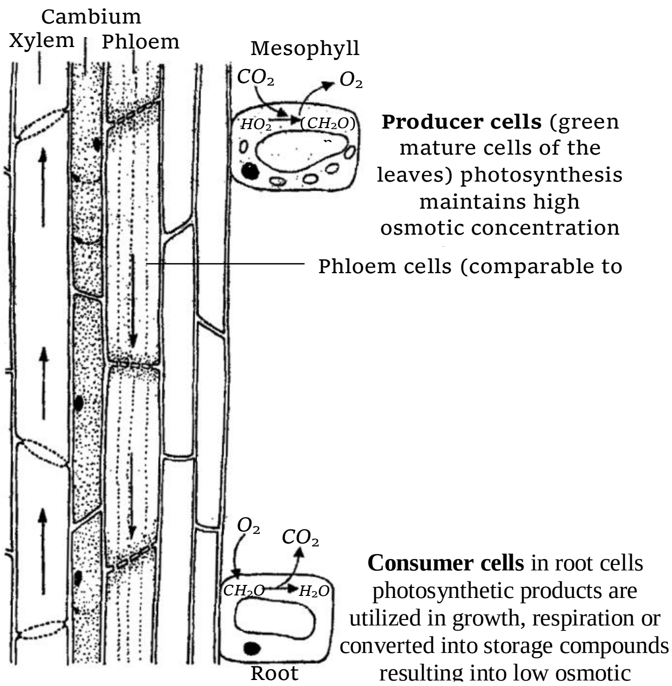


Fig : Diagrammatic representation of the mechanism of solute translocation according to the Munch Hypothesis

(vii) **Munch mass flow or pressure flow hypothesis :** The mass flow or pressure flow mechanism was first proposed by Hartig (1860). It was later modified by Munch (1930). Crafts elaborate it further in (1938). Munch assumed that the protoplasm of sieve tube is connected through plasmodesmata and forms a continuous system, called as the symplast. The translocation of solutes occur in a mass alongwith cell sap through the sieve tubes form a region of higher turgor pressure to low turgor pressure (*i.e.*, along a turgor pressure gradient).

The principle of mass flow can be explained with the help of following laboratory model. Two osmometers **A** and **B** are bounded by semipermeable membrane and are interconnected by tube **P**. They are now dipped in two separate troughs **X** and **Y** respectively. The troughs are also interconnected by a tube **T**. It is assumed that initially entire system is filled with water and is at equilibrium. If sugar is added in osmometer **A** its osmotic pressure and suction pressure increase, as a result water enters into it by the process of endosmosis. This causes an increase in the turgor pressure in osmometer **A** due to which water starts flowing in mass towards osmometer **B**. The water molecules also carry solutes alongwith them. This movement of water and sugar molecules from **A** to **B** will continue until the concentration of entire system becomes uniform and will stop once a state of equilibrium is achieved. But if at **B** sugar molecules are either removed or converted into starch, the movement will continue endlessly.

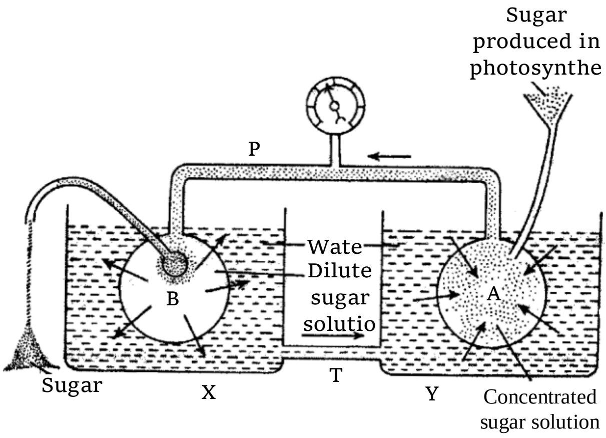


Fig : A model demonstrating the Munch mass flow hypothesis

The above said system is comparable to the system of transport operating in a living plant. The osmometer **A** represent the leaves where mesophyll cells manufacture sugar by photosynthesis. It increases their osmotic pressure and suction pressure due to which water is drawn in from the adjoining cells thus the turgor pressure of mesophyll cells is increased. Tube **P** represents the phloem which transmits the solutes along the turgor pressure gradient to osmometer **B** representing the storage or consumption end (*e.g.*, roots, fruits and other living cells). Tube **T** represents xylem which transfers water from roots to leaves. This hypothesis satisfactorily explains the flow of solutes through sieve tubes under high pressure.

Munch's hypothesis has been supported further by the following :

- When a woody or herbaceous plant is girdled, the sap containing high sugar content exudates from the cut end.
- Positive concentration gradient disappears when the plants are defoliated.
- Movement of viruses and growth hormones is fast in illuminated leaves as compared to shaded leaves.

Objections to the Munch's hypothesis

- The hypothesis fails to explain bidirectional movement of metabolites which is common in plants.
- Osmotic pressure of mesophyll cells and that of root hair do not confirm the requirements.
- Munch's hypothesis gives a passive role to the seive tube elements and the protoplasm.

(4) **Factors affecting translocation**

(i) **Temperature :** Swanson and Whitney (1953) reported that translocation out of the leaf was highly sensitive to temperature. Optimum temperature for translocation ranges between 20-30°*C*. The rate of translocation increases with the increase of temperature upto an upper limit and then starts declining. At low temperature, the rate of translocation decreases but such an effect is only transient because the resultant steeper concentration gradient quickly brings about readjustment of translocation rate.

(ii) **Light : Hartt** and his coworkers (1964) proposed that the movement of assimilates of a leaf can depend upon radient energy. The increase in light intensity more food starts being translocated to roots than to shoots. At lower intensity the growth of root and shoot is inhibited thereby the rate of translocation also decreases.

(iii) **Hormones :** Cytokinins have a pronounced effect on the translocation of water soluble nitrogen compounds.

(iv) **Oxygen :** Oxygen is necessary during transfer of food from mesophyll cells into phloem which is called as **phloem loading**.

(v) **Minerals : Boron** is highly essential for translocation of sugar. Translocation of sucrose occurs in the form of **sucrose-borate** complex. **Phosphorus** also helps in translocation of solutes.

(vi) **Water :** Translocation of photosynthates out of the leaves is highly sensitive to the amount of water in the plant cells. However, it does not have much effect on movement of solutes through phloem.

(vii) **Metabolic inhibitors :** The metobolic inhibitors which inhibit the process of respiration (*e.g.*, iodoacetate, *HCN*, carbon monoxide etc.) adversely affect the process of translocation because phloem loading and unloading require ATP.

Important Tips

- **Mittler** (1958) develop a technique for the collection of phloem sap using an aphid stylet.
- In a girdled plant, root die first and ultimately shoot dies.
- Medullary rays is the path of radial translocation of organic solutes.
- The principle pathway by which water is translocated in angiosperm is xylem and vessels.
- The food stored in the ripening fruit is derived from nearest leaves.
- Marshall and Wardlaw (1973) proposed the solution flow hypothesis.
- Active mass flow in which oxygen is required was proposed by Mason and Phillis (1936).
- Bimodal theory of translocation was putforth by Fenson (1971).
- Mature sieve tubes do not show streaming movement.

***

ASSIGNMENT

CONCEPTS OF WATER RELATIONS

Basic Level

1. Who is called father of plant physiology

   (a) Calvin (b) J.C. Bose (c) Stephen Hales (d) Van Helmont

2. Movement of particles of matter in the cell due to its own kinetic energy is called

   (a) Imbibition (b) Diffusion (c) Gummosis (d) None of these

3. Osmotic concentration of a solution may be governed by

   (a) Concentration of solute (b)Temperature of solution

   (c) Ionization of solute (d) All of these

4. Selective permeability identifies the process of transmission through semipermeable membrane is called

   (a)Diffusion (b) Osmosis (c) Plasmolysis (d) Imbibition

5. Dry seeds when placed in water swells due to

   (a) Imbibition (b) Absorption (c) Diffusion (d) Adsorption

6. Which of the following is not against concentration gradient

   (a) Transpiration (b) Diffusion (c) Translocation (d) All of these

7. In hypertonic solution a cell water potential

   (a) Decreases (b) Increases

   (c) First increases then decreases (d) No change

8. When a grape is placed in concentrated sugar solution, then it will show

   (a) Endosmosis (b) Exosmosis (c) Imbibition (d) None of these

9. In xerophytes, the osmotic concentration of cell sap is

   (a) Less than normal (b) Normal

   (c) More than normal (d) No osmotic pressure at all

10. Wheat grains before germination absorb water by

    (a) Endosmosis (b) Exosmosis (c) Plasmolysis (d) Imbibition

11. Why *jams* and *pickles* are immersed in concentrated sugar solution or oil

    (a) They do not rot due to their own growth

    (b) They do not rot due to fungal or bacterial action

    (c) They do not dry (d) They become good in taste

12. If a cell with incipient plasmolysis is placed in a hypertonic solution it will show

    (a) Deplasmolysis (b) More plasmolysis (c) Exosmosis (d) None of these

13. Gaseous exchange in land plants takes place through stomatal opening, while in submerged hydrophytes it takes place by

    (a) Lenticels (b) Stomata

    (c) Hydathodes (d) General surface of the cells by diffusion

14. With an increase in the turgidity of a cell, the wall pressure will

(a) Increase (b) Decrease (c) Fluctuate (d) Remain unchanged

15. Plasmolysis can be used for

(a) Good growth of plants (b)Good growth of weeds

(c) Killing the weeds (d) None of these

16. The cell is fully turgid when

(a) DPD = TP (b) OP = DPD (c) DPD = SP (d) DPD = Zero

17. The turgor pressure of a turgid cell is equal and opposite to

(a) Root pressure (b) Wall pressure (c) Diffusion pressure (d) All of these

18. Under given suitable conditions, the DPD will be more than OP

(a) When OP is equal to TP (b) When OP is less than TP

(c) When OP is greater than TP (d) When TP is negative

19. Imbibition process involves

(a) Both diffusion and capillary action (b) Only diffusion

(c) Only capillary action (d) None of the above

20. The osmotic parameter determining flow of water from one cell to another is

(a) Osmotic pressure (b) Turgor pressure

(c) Diffusion pressure deficit (d) Hydrostatic pressure

21. DPD of a cell mainly depends upon

(a) OP (b) TP (c) WP (d) None of these

22. 0.1 *M* solution of a solute has a water potential of

(a) – 2.3 *bars* (b) 0 *bars* (c) 22.4 *bars* (d) + 2.3 *bars*

23. Exchange of substances between individual cells and their environments takes place by

(a) Osmosis (b) Diffusion (c) Active transport (d) All of these

24. In the process of osmosis in the cell

(a) Both cell wall and protoplasm will act as a membrane

(b) Entire protoplast act as a membrane

(c) Only outermost layer of protoplasm act as a membrane

(d) Only cell wall act as a membrane

25. If a potato tuber is placed in concentrated salt solution

(a) It would become limp (shrink) due to loss water from its cells

(b) It will become turgid by absorbing water from salt solution

(c) Nothing would happen

(d)It would die

26. Water moves across a selectively permeable membrane

	From	To
(a)	Region of higher water potential	Region of lower water potential
(b)	Lower water concentration	Higher water concentration
(c)	Higher solute concentration	Lower solute concentration
(d)	Region of higher osmotic potential	Region of lower osmotic potential

27. If a cell is reduced in size on placing in a solution of sugar, the solution is

(a) Hypertonic (b) Hypotonic (c) Isotonic (d) Saturated

28. A professor kept some moist seeds in an airtight jar and started lecturing. At the end of the experiment an explosion occurred in the jar. What did the professor want to explain

(a) Osmosis (b) Diffusion (c) Anaerobic respiration (d)Imbibition

29. Incipient plasmolysis occurs when the osmotic concentration and osmotic pressure of a solution in which the tissue is suspended is

(a) Hypertonic (b) Hypotonic (c) Near isotonic (d) Near hypotonic

30. Deplasmolysis occurs in a cell when it is placed in

(a) Hypotonic solution (b) Hypertonic solution (c) Isotonic solution (d) Buffer solution

31. What happens when formalin preserved *Spirogyra* filament is placed in a hypertonic sugar solution

(a) It gain turgidity (b) It looses turgidity

(c) It becomes plasmolysed (d) Nothing happens

32. Why the rapid plasmolysis caused by hypertonic KCl is reversed; because

(a) KCl breaks down inside the cell (b) KCl breaks down outside the cell

(c) KCl slowly enters into the cell (d) KCl slowly leaks out of the cell

33. What should happen if a thin slice of sugarbeet is placed in a concentrated solution of $NaCl$

(a) It should loose water from the cells (b) It should become turgid

(c) It should neither absorb water nor loose it (d) It should absorb water from the salt solution

34. In which of the following conditions a slice of fresh beet root should release more betanin pigment

(a) $NaCl$ solution (b) Low temperature (c) High temperature (d) pH 7.0

35. What shall be the sequence of events during wilting of a plant

(a) Exosmosis, deplasmolysis, wilting (b) Endosmosis, plasmolysis, wilting

(c) Exosmosis, plasmolysis, wilting (d) Endosmosis, deplasmolysis, wilting

36. During osmosis, water moves through a membrane

	From	To
(a)	Low water potential	High water potential
(b)	High solute concentration	Low solute concentration
(c)	High osmotic potential	Low osmotic potential
(d)	A hypotonic solution (Less solute)	A hypertonic solution (More solute)

37. When plant cells are kept in hypertonic salt solution they get

(a) Plasmolysed (b) Deplasmolysed (c) Turgid (d) Lysed

38. Imbibition is very significant property of

(a) Hydrophilic surfaces (b)Hydrophobic surfaces

(c) Lipophilic surfaces (d) All the above

39. If wood is kept under water, then it becomes swell due to activity of

(a) Protein (b) Cellulose (c) Both (a) and (b) (d) Minerals

40. Powerful imbibant is/are

(a) Pure protein (Gelatin) (b)Fungal hyphae

(c) Meristematic cells (d) All of these

41. In the course of imbibition, the volume of the system

(a) Decreases (b) Increases (c) Unchanged (d) None of these

42. When osmotic pressure becomes equal to the wall pressure, than

(a) The flow of water will be inside the cell (b) The flow of water will be outside the cell

(c) Both flow will occur inside as well as outside (d) There will be no flow

43. In the process of plasmolysis

(a) Endosmosis occurs (b) Exosmosis occurs (c) Imbibition occurs (d) Diffusion occurs

44. What is the direction of the movement of water if two cells have the same OP but differ in TP

(a) No net flow (b) From lower TP to higher TP

(c) From higher TP to lower TP (d) Data insufficient

45. Water potential can be obtained by

(a) $OP + TP$ (b) $OP = WP$ (c) $P - \pi$ (d) $OP - DPD$

46. Percentage of water left in the soil when a plant begins to wilt is known as

(a) Wilting coefficient (b) *pH* value of soil

(c) Field capacity (d) Water holding capacity

47. Path of greater resistance in transpiration is

(a) Stomatal (b) Cuticular (c) Pectin (d) All equally

48. Plant cells do not burst in distilled water, because

(a) Cell wall is elastic, rigid and get stretched (b) Cell wall is living

(c) Cell wall is the outer most layer of plant cell (d) Cell wall is permeable

49. Which plant is used for demonstrating plasmolysis in the laboratory

(a) *Tropeolum* (b) *Impatiense balsamia* (c) *Tradescantia* (d) All of these

50. Which of the following demonstrates imbibition

(a) A piece of rubber in kerosine oil (b) A piece of wood in kerosine oil

(c) A piece of rubber in water (d) A grape fruit in saturated solution

51. Plant cells submerged in distilled water will become

(a) Turgid (b) Flaccid (c) Plasmolysed (d) Impermeable

52. Absorption of water by gram is the process of

(a) Diffusion (b) Imbibition (c) Endosmosis (d) Exosmosis

53. The potential exerted by insoluble colloids is termed as
(a) Osmotic potential (b) Diffusion pressure (c) Matric potential (d) Water potential

54. The water potential and osmotic potential of pure water are
(a) 100 and Zero (b) Zero and Zero (c) 100 and 200 (d) Zero and 100

55. When a fish of marine water kept in fresh water then it will die due to
(a) Endosmosis (b) Exosmosis (c) Imbibition (d) Isotonic solution

56. Water potential (ψ) measured in *bar* or in
(a) lb/in^2 (b) *mm* of *Hg* (c) *atm* (d) All of these

57. Symbol of osmotic potential is
(a) ψ (b) ψ_s (c) P_t (d) P_w

58. The membrane which allows passage of certain substances more readily than others is termed as
(a) Permeable (b) Selectively permeable (c)Semipermeable (d) Impermeable

59. Osmosis involves
(a) Cell to cell movement of water (b)Movement of water through cortical cells
(c) Active absorption of water through roots (d) All the above

60. When a cell is fully turgid, which of the following will be zero
(a) Wall pressure (b) Osmotic pressure (c) Turgor pressure (d) Water potential

61. In the process of osmosis, volume of solvent
(a) Increases (b) Decreases
(c) Remains same (d) Volume is not related in osmosis

62. Rapid germination of pea seed takes place in presence of
(a) H_2 (b) O_2 (c) CO_2 (d) H_2O

63. Which of the following seeds will show more imbibitional pressure
(a) Til seeds (b) Gram seeds (c) Wheat seeds (d) Rice seeds

64. When osmotic potential is either zero or negative and pressure potential is positive, then the water potential will be
(a) Negative (b) Positive
(c) Sometimes negative and sometimes positive (d) None of these

65. Water potential is affected by
(a) Osmotic potential (b) Matric potential (c) Pressure potential (d) All of these

66. Which of the following is effected by hydration of solute molecules
(a) Absorption (b) Transpiration (c) Osmosis (d) None of these

67. The osmosis help in
(a) Distribution of water across the cells (b) Turgor of the guard cells
(c) Resistance to the frost (d) All the above

68. Osmosis is helpful to plant because

(a) Growth of the young cells is brought about by osmotic pressure and turgor pressure of these cells

(b) Certain turgor moments in plants are determined by osmosis

(c) Both (a) and (b)

(d) None of these

69. Osmosis can be demonstrated by

(a) Potato osmoscope (b) Ganong's respiroscope (c)Microscope (d) All of these

70. Process of osmosis shall cease when

(a) Solutions become isotonic or DPD becomes equal

(b) Water concentration becomes equal

(c) There is no light (d) The level of water falls

71. How the molecules of water would behave if pure water is separated from a colloidal suspension with the help of a selectively permeable membrane. It would cause a net movement of water to

(a) Colloidal side (b) Water side (c) Either side (d) Neither side

72. Why osmosis cannot be demonstrated by a potato osmoscope using a solution of *NaCl* instead of sugar; because the potato tissue is

(a) Permeable to *Na* ion (b) Permeable to *Cl* ion

(c) Permeable to salt solution (d) Impermeable to salt solution

73. What is the direction of the net movement of water between two cells *X* and *Y* if the DPD of *X* is lower than *Y*

(a) *X* to *Y* (b) *Y* to *Y* (c) Out of *X* (d) No net movement

74. Water potential can be calculated by

(a) OP + TP (b) π + WP (c) ψ + PW (d) π + TP

75. When a cell is fully turgid which of the following will be zero

(a) Turgor pressure (b) Wall pressure (c) Suction pressure (d) Osmotic pressure

76. When seeds are soaked in water, these show imbibition due to the process of

(a) Absorption (b) Adsorption (c) Higher O.P. (d) Lower O.P.

77. When pea seeds and wheat seeds are put in water, which of the two will imbibe more water

(a) Wheat seeds (b) Pea seeds

(c) Both will imbibe equal amount of water (d) Pea seeds imbibe water only at alkaline *pH*

78. Rate of diffusion of solids, liquids and gases in the increasing order is

(a) Solutes, liquids and gases (b) Liquids, solutes and gases

(c) Gases, liquids and solutes (d) Solutes, gases and liquids

79. The reduction in the diffusion pressure of a substance in a system over its pure state is known as

(a) Turgor pressure (b) Osmotic pressure

(c) Diffusion pressure deficit (d) Turgor pressure deficit

80. When a cell is placed in 0.15 *M* concentrated sugar solution, there is no change in it, the concentration of cell sap would be

(a) 0.15 *M* (b) 0.015 *M* (c) 15 *M* (d) None of these

81. Which one of the following doesn't help in molecule transport

(a) Diffusion (b) Osmosis (c) Surface tension (d) Active transport

82. Mark the correct statement

(a) The value of T.P. becomes Zero at the time of limiting plasmolysis and below Zero during incipient and evident plasmolysis

(b) The value of T.P. becomes below Zero at the time of limiting plasmolysis and zero at the time of incipient and evident plasmolysis

(c) The value of T.P. remains same at the time of limiting, incipient and evident plasmolysis

(d) The value of T.P. becomes negative in all the stages of plasmolysis

83. Proteins being amphoteric imbibe

(a) Maximum at their isoelectric point

(b) Maximum at their isoelectric point provided the temperature is below 20°C

(c) Least at their isoelectric point

(d) Maximum in the beginning and slow down with the fall or rise in temperature

84. The loss of kinetic energy during the process of imbibition is known as

(a) Heat of wetting (b) Heat of solution (c) Heat of imbibition (d) Heat of combustion

85. In rainy season, the doors get wet due to

(a) Imbibition (b) Absorption (c) Diffusion (d) Endosmosis

86. Resurrection plants of *Selaginella* and lichens remain air dry for considerable periods because they can absorb water from the slight downpour. By which physiological process water is absorbed

(a) Active absorption (b) Passive absorption (c) Imbibition (d) Osmosis

87. The lowest water potential is found in the xylem channels of

(a) Stem (b) Root in the root hair zone

(c)Leaves (d) Root

88. The first accurate osmometer using semipermeable membrane of copper ferrocyanide was developed by

(a) Pfeffer (1830) (b) Pfeffer (1887) (c) Abbe Nollet (d) Blackman (1887)

89. The process of osmosis was first discovered by

(a) Abbe Nollet (1748) (b) Pfeffer (1887) (c) Berkeley and Hartley (d)None of these

90. Another term used to indicate imbibition pressure is

(a) Metric potential (b) Absorption potential

(c) Imbibitional potential (d) Chemical potential

91. With the increase in temperature, the process of imbibition

(a) Decreases (b) Increases

(c) Remains the same (d) No effect

92. Tick the correct statement

(a) The closely packed imbibant will imbibe less water than the loosely packed one

(b) The closely packed imbibant will imbibe more water than the loosely packed one

(c) Both will imbibe the same amount of water

(d) The amount of water absorbed by closely packed and loosely packed imbibant will depend upon the temperature of the medium

93. The relationship of D.P.D, to O.P. and T.P + W.P is

(a) DPD = OP – TP (WP) (b)DPD = – OP + TP (WP)

(c) DPD = OP + TP (WP) (d)DPD = – OP – WP (TP)

94. If salt is presents in higher concentration in a cell than out side is

(a) Water will pass from inside the cell to out side the diffusion

(b) Water will enter the cell by osmosis

(c) Salt will escape from the cell through the semipermiable membrane

(d) There will be no movement of substances between the cell and its environment

95. When a cell is kept in 0.5 *M* solution of sucrose its volume does not alter. If the same cell is placed in 0.5 *M* solution of sodium chloride the volume of the cell will

(a) Increase (b) Decrease

(c) Cell will be plasmolysed (d) Will not show any change

96. The maximum diffusion pressure is that of

(a) Molar solution (b) Molal solution (c) Pure water (d) Hypotonic solution

97. In cell transport the difference between permeable transport and bulk transport relates to

(a) Structure of molecules allowed to pass through

(b) Solvent system as well as structure of molecules are applicable

(c) Solvent system is applicable

(d) Molecular weight of atoms allowed to pass through

98. Uniformly sweet taste of Tea or Coffee is due to

(a) Spreading (b) Osmosis (c) Permeability (d) Diffusion

99. In thistle funnel experiment, entry of water into thistle funnel stops after some time automatically due to

(a) Diffusion of sugar out of thistle funnel

(b) External and internal solutions become isotonic

(c) Development of hydrostatic pressure in the thistle funnel

(d) Development of hydrostatic pressure in the beaker

100. An animal cell placed in pure water will

(a) Swell up and burst (b) Shrink and die

(c) Shrink and undergo plasmolysis (d) Swell up and develop turgidity

101. Osmotic potential is depicted as

(a) (–) (b) (+) (c) X (d) (÷)

102. The term water potential was coined by

(a) Sayre (b) Von Mohl (c) Lloyd (d) Slatyer and Taylor

103. Which of the following is not a function of water in cell

(a) It provides energy for chemical reaction (b) It acts as a solvent

(c) It provides a medium for chemical reaction (d) It releases hydrogen ions on ionisation

104. If the plant cell is immersed in water, the water continues to enter the cell until the

(a) Concentration of the salt is the same inside the cell as outside (b) Cell bursts

(c) Diffusion pressure deficit is the same inside the cell as outside

(d) Concentration of water is the same inside the cell as outside

105. Diffusion pressure deficit is the amount by which two solutions differ in their

(a) T.P. (b) O.P. (c) D.P. (d) W.P.

106. A higher plant cell covered with cutin and suberin is placed in water. After 15 minutes, the cell

(a) Will be killed (b) Size will increase

(c) Size will remain unchanged (d) Size will decrease

107. Compared to 1 M sucrose solution, the ψ_w of 1 M sodium chloride solution is

(a) High (b) Same (c) Lower (d) None of these

108. Seed germination is accompanied by

(a) Absorption of heat (b) Starch synthesis (c) Evolution of heat (d) Fat synthesis

109. In plants water moves from

(a) Less negative to more negative gradient (b) More negative to less negative gradient

(c) Similar gradient (d) Zero gradient

110. Movement of water through semipermeable membrane produces

(a) Wall pressure (b) Suction pressure (c) Osmotic pressure (d) Turgor pressure

111. Adding solute to pure water will cause development of

(a) Positive water potential (b) More positive water potential

(c) More negative water potential (d) Negative water potential

112. Osmosis is the diffusion of a solution of a weaker concentration, when both are separated by semipermeable membrane. What is the error in the statement

(a) The movement of water molecules is not specified

(b) There is no mention of DPD

(c) Behaviour of semipermeable membrane is not specified

(d) The exact concentrations are not indicated

113. Mango dipped in concentrated $NaCl$ solution will

(a) Burst (b) Contract (c) Swell (d) No effect

114. Cotton fibres dipped in water absorb water through

(a) Endosmosis (b) Exosmosis (c) Capillarity (d) Imbibition

115. Land plants grow in soils which possess an osmotic concentration

(a) Hypotonic in relation to cells (b) Hypertonic in relation to cells

(c) Isotonic in relation to cells (d) Ultrotonic in relation to cells

116. Water potential is equal to

(a) ψ_s + O.P. (b) ψ_s = T.P. (c) $\psi_p + \psi_w$ (d) $\psi_s + \psi_p$

117. Osmotic pressure in a vacuolated plant cell is

(a) Equal to W.P. (b) Equal to T.P. (c) More than D.P.D. (d) Less than D.P.D.

Advance Level

118. When a plant cell is placed in a solution which is hypotonic to the cell sap, which of the following conditions will not apply

(a) The water potential of the cell sap will rise (b) The suction pressure of the cell sap will fail

(c) The cell will become turgid (d) The wall pressure of the cell will fail

119. You are given three cells, a root hair, a cell of the inner cortical layer and a cell of the mesophyll. Arrange them in the ascending order of DPD

(a) Root hair < Cortical cell < Mesophyll (b) Cortical cell < Mesophyll < Root hair

(c) Mesophyll < Root hair < Cortical cell (d) Root hair < Mesophyll < Cortical cell

120. In a fully turgid cells, the values of DPD, OP and TP will show the tendency

(a) DPD = 10 atm. OP = 15 atm. TP = 5 atm. (b) DPD = 5 atm. OP = 12 atm. TP = 7 atm.

(c) DPD = 2 atm. OP = 7 atm. TP = 5 atm. (d) DPD = 0 atm. OP = 15 atm. TP = 15 atm.

121. Purple cabbage leaves do not loose their colour in cold water but do so in boiling water because

(a) Plasma membrane get inactivated in boiling water

(b) Hot water can enter the cells readily

(c) The pigment is not soluble in cold water (d) The cell wall is killed in boiling water

122. If cell A with OP = 5 and TP = 4 is surrounded by cells with OP = 3 and TP = 1. What will be the direction of water movement

(a) From cell A to other cells (b) From other cells to cell A

(c) Water will not move (d) Water will move up

123. A cell is plasmolysed after being kept in a hypertonic solution. What will be present between cell wall and plasmalemma

(a) Isotonic solution (b) Hypertonic solution (c) Air (d) Hypotonic solution

124. Which of the following plants will have maximum osmotic pressure

(a) Epiphyte (b) Mesophyte (c) Parasite (d) Halophyte

125. An ideal molar solution at 0°C will have an osmotic pressure of

(a) 10 atmosphere (b) 20 atmosphere (c) 22.4 atmosphere (d) 14.3 atmosphere

126. What will be the direction of movement of water when a solution A having water potential of – 9 bars and another solution B of – 4 bars is separated by a semipermiable membrane

(a) B to A (b) A to B (c) Both directions (d) None of these

127. An example of selectively permeable membrane is

(a) Plasmalemma (b) Cell wall

(c) Mitochondrial membrane (d) Chloroplast membrane

128. Plasma membrane controls

(a) Passage of water

(b)Passage of water and some solutes in and out of the cell

(c) Passage of water and solutes into the cell

(d) Movements of the cell contents out of the cells

129. 0.5 *M* sucrose solution develops a pressure of 15 *bars* in an osmometer. Which of the following statement is wrong for such a solution

(a) That its osmotic potential is – 15 *bars* (b) That its water potential is – 15 *bars*

(c) That its pressure potential is – 15 *bars* (d) That its osmotic pressure is + 15 *bars*

130. How water potential (ψ) is affected by the presence of solutes and insoluble colloids

(a) ψ is increased (b)ψ is decreased

(c) Remains unchanged (d)Increased for solutes and decreased for colloids

131. DPD is abbreviated form of

(a) Daily photosynthetic deficit (b) Daily phosphorus deficit

(c) Daily pressure deficit (d) Diffusion pressure deficit

132. Pollen grains of some of the plants germinate on stigma soon but they burst in water or dilute sugar solution

(a) Exosmosis (b) Endosmosis (c) Imbibition (d) Plasmolysis

133. Which of the following has more imbibition power

(a) Cellulose (b) Hemicellulose (c) Fat (d) Protein

134. The exchange of carbon dioxide, oxygen and water vapours simultaneously through the stomata of leaf represents the process of

(a) Independent diffusion (b)Diffusion (c) Osmosis (d) Both (a) and (b)

135. The relative rates of diffusion of substances are

(a) Inversely proportional to the square root of their densities

(b) Directly proportional to the square root of their densities

(c) There is no relation between diffusion and density

(d) Depends upon the substance *i.e.*, whether it is solid, liquid or gas

136. At the time of seed germination, when water is absorbed by the seeds due to imbibition, the seed coat breaks as it swells to a lesser degree than the kernel because

(a) The kernel is made up of proteins, lipids and starch while the seed coat is formed of cellulose

(b) The kernel is made up of cellulose while the seed coat is made up of proteins, lipids and starch

(c) Both kernel and seed coat are made up of same constituents, it depends on the nature of medium

(d) None of the above

137. 1 *gm* molal solution is

(a) 1 *gm* mole of solute dissolved in 1,000*gms* of solvent

(b) 1 *gm* mole of solute dissolved in 1,000*ml* of solvent

(c) 1 *gm* of solute dissolved in 1,000*ml* of solvent

(d)1 *gm* mole of solute dissolved in 1,000*ml* of solution

138. 1 *gm* molar solution is

(a) 1 *gm* of solute dissolved in 1,000*ml* of solvent

(b)1 *gm* of solute dissolved in 1,000*gms* of solvent

(c) 1 *gm* of solute dissolved in 1,000*ml* of solution

(d) 1 *gm* mole of solute dissolved in 1,000*ml* of solvent

139. That the cell membrane is selectively permeable can be best deduced by

(a) The entry of water from root hair (b) The entry of mineral salts from the root hair

(c) Both together (d) The rise of sap in plants

140. The value of osmotic potential of an electrolyte is always

(a) More than non electrolyte (b) Less than non electrolyte

(c) Same as non electrolyte (d) None of these

141. The cell A has an osmotic potential of – 20 bars and a pressure potential of +6 bars. What will be it's water potential

(a) – 14 *bars* (b) + 14 *bars* (c) – 20 *bars* (d) + 20 *bars*

142. Potato slices are immersed in a series or solutions of different osmotic concentrations, no change in its volume or weight is observed with slices in a 0.4 *M* solution. The osmotic concentration of the vacuolar sap is, therefore

(a) 0.4*M* (b) Greater than 0.4*M*

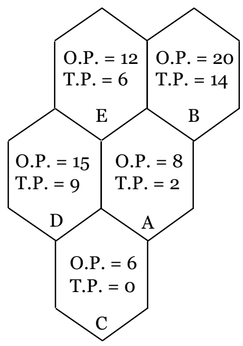
(c) Less than 0.4*M* (d) Not related at all to the outside solution

143. The cell wall is permeable and not a semipermeable structure can be best deduced from the passage of water and mineral salts from

(a) Soil into periplasmic space of root hairs (b) Root hairs to cortical cells

(c) Cortical cells to pericycle (d) Pericycle to trachea

144. In the following diagram, if the T.P. of cell B increases to 18, what would be the changes with regard to water movement



(a) A, C, D and E absorb water from B

(b) Water diffuses into B

(c) B actively absorbs water from neighbouring cells

(d) No movement

145. If a cell A with D.P.D. 4 bars is connected to cells B, C, D, whose O.P. and T.P. are respectively 4 and 4, 10 and 5 and 7 and 3 bars, the flow of water will be

(a) C to A, B and D (b) A and D to B and C (c) A to B, C and D (d) B to A, C and D

146. Solution A has ψ_s = – 30 bars and ψ_p = 5 bars. Solution B has ψ_s = – 10 bars and ψ_p = 0 atm. The two are separated by semipermeable membrane. Flow of water will be

(a) B to A (b) A to B

(c) Equal in both directions (d) No flow of water

147. All the following involves osmosis except

(a) Water from soil entering a root hair

(b) Water passing from root hair to adjacent cells

(c) Water passing up a xylem vessel element to xylem vessel element above it

(d) Water entering a mesophyll cell from xylem vessel element

ABSORPTION OF WATER

Basic Level

148. Which of the following factors affect the absorption of water by roots

(a) Soil temperature (b) Soil aeration (c) RH of the atmosphere (d)All the above

149. When water enters in roots due to diffusion, it is termed as

(a) Osmosis (b) Endocytosis (c) Active absorption (d) Passive absorption

150. Which of the following method is adopted by plant for the absorption of water when a cut shoot is fitted in a potometer

(a) Active (b) Passive (c) Partly both (d) None of these

151. Plants get which type of water from soil

(a) Hygroscopic water (b) Capillary water (c) Gravitational water (d) All type of water

152. Holding capacity is highest in

(a) Clay soil (b) Lome soil (c) Silt soil (d) Sandy soil

153. The plant from which there is rapid transpiration, it will show

(a) Active absorption (b) Passive absorption

(c) Active osmotic absorption (d) Active non-osmotic absorption

154. Why the roots of the plant die in the flooded condition of the soil

(a) Due to more absorption (b) Due to more evaporation

(c) Due to more transpiration (d) Root die due to absence of air

155. When root pressure is more, which of the process will be rapid

(a) Absorption (b) Transpiration (c) Respiration (d) None of these

156. The initial stage of water absorption by root cells is by

(a) Adsorption (b) Absorption (c) Osmosis (d) Imbibition

157. In many epiphyte (Orchid) plants which tissue is present in cortex of root and helps in water uptake

(a) Velamen (b) Cork cambium (c) Pericycle (d) Medullary rays

158. Root system in a plant is well developed
(a) Due to deficiency of auxin (b)Due to deficiency of cytokinins
(c) Due to deficiency of minerals (d)For increased absorption of water

159. Cells absorb water by
(a) Osmosis (b) Osmosis and imbibition (c)Imbibition alone (d) Diffusion

160. Absorption of water by root is increased by
(a) Increase in transpiration (b)Increase in the rate of photosynthesis
(c) Decrease in transpiration (d)Decrease in salt uptake

161. Water enters into root hairs from the soil on account of
(a) Turgor pressure (b) Osmotic pressure (c) Suction pressure (d) Root pressure

162. The amount of water held by the soil after drainage is known as
(a) Mineral water (b) Soil water
(c) Field capacity (d) Gravitational capacity

163. As absorbed water passes towards vascular cylinder, it must enter the cytoplasm of
(a) Pericycle cells (b) Endodermal cells (c) Cortical cells (d) Xylem parenchyma

164. By which mechanism water is absorbed under low transpiring conditions
(a) Osmosis (b) Active absorption (c) Either or both (d) Passive absorption

165. Water will be absorbed by root hairs when
(a) Concentration of salt in the soil is high
(b) Concentration of solutes in the cell sap is high
(c) Plant is rapidly respiring
(d) They are separated from soil by a permeable membrane

166. A plant absorbs water from the soil on a sunny day by
(a) Active absorption (b) Passive absorption (c) Osmosis (d) Capillary force

167. Which of the following plant absorb water from atmosphere
(a) Jamun (b) Orchid (c) Melia (d) Moringa

168. Where does transpiration-cohesion pull theory works
(a) Active absorption (b) Inactive absorption
(c) Active and inactive absorption (d)None of these

169. Root pressure is due to
(a) Passive absorption (b) Active absorption
(c) Increase in transpiration (d) Increase in photosynthesis

170. Storage capacity of the soil is the extent to which it can hold
(a) Gravitational water (b) Capillary water (c) Hygroscopic water (d) All of these

171. Cell walls of root hairs for absorbing water must be
(a) Hydrophobic (b) Hydrophilic (c) Semipermeable (d) Impermeable

172. In active absorption of water in plants the metabolic energy is supplied by
(a) Photosynthesis (b) Respiration (From cell) (c)From soil water (d) All of these

173. Which of the following is importance of water to the plant life

(a) In translocation of solutes (b) In the mobility of gametes

(c) Provides support to the aquatic plants (d) All of these

174. A thin film of water, held by the soil particles under the influence of internal attractive force, is called which of the following water

(a) Capillary (b) Combined (c) Hygroscopic (d) Gravitational

175. During absorption of water by roots, the water potential of cell sap is lower than that of

(a) Pure water and soil solution (b) Neither pure water nor soil solution

(c) Pure water but higher than that of soil solution

(d) Soil solution but higher than that of pure water

176. In some plants, the leaves drop down during day while become normal during night

(a) Due to temporary wilting (b) Permanent wilting

(c) Both (a) and (b) (d) None of these

177. Which soil is most suitable to water uptake

(a) Sandy soil (b) Clay soil (c) Loamy soil (d) None of these

178. Mark the correct statement

(a) Passive absorption of water continues day and night and in all seasons

(b) Passive absorption of water occurs during the day and stops at night in all seasons

(c) Passive absorption of water occurs during the night and stops during the day time in all seasons

(d) Passive absorption of water is maximum during morning and evening in all seasons

179. Root pressure occur due to

(a) Low D.P.D. of leaves

(b) High D.P.D. of leaves

(c) Osmotic flow of water into xylem of absorbing part of root

(d) Imbibitional flow of water into xylem of absorbing part of root

180. When aerial parts of a plant are cut the sap exudes from the root with a force, the phenomenon underlying this is

(a) Imbibition pressure (b) Root pressure (c) Osmotic pressure (d) Capillary force

181. Root pressure shows diurnal rhythm. The statement is

(a) True (b) False

(c) True when soils are saline (d) True when transpiration is maximum

182. The terms active water absorption and passive water absorption were given by

(a) Dixon and Joly (b) Renner (c) Mac Dougal (d) Godlewski

183. When the soil contains high concentration of soil solution, it is considered to be

(a) Physically dry (b) Physiologically dry (c) Water logged soil (d) Saline soil

184. At 0°C soil temperature the rate of water absorption

(a) Increase (b) Not affected (c) Decrease (d) Appreciable

185. The retaining of water on the surface of root is due to

(a) The presence of cellulose on the outer part of wall

(b) Presence of pectic compounds on the outer part of the cell wall

(c) Presence of both cellulose and pectic compounds on the outer part of the cell wall

(d) Presence of lignin and pectin on the outer part of the cell wall

186. By which of the following active uptake of water is affected

(a) Sucking power (DPD) of the root hairs (b) Typical tissue organization

(c) Tension due to transpiration

(d) Osmotic concentration of the cell sap of the leaves

187. The rate of absorption is stimulated by

(a) Auxins (b) CO (c) Acids (d) Iodoacetates

188. The movement of water from one cell of the cortex to the adjacent one in roots is due to

(a) Accumulation of inorganic salts in the cells

(b) Accumulation of organic compounds in the cells

(c) Chemical potential gradient

(d) Water potential gradient

189. Electro-osmotic theory of water transport was proposed by

(a) Blinks (b) Bennet-Clark (c) Fensom (d) Keller

190. Soil water potential is measured with the help of the instrument called

(a) Porometer (b) Tensiometer (c) Paedometer (d) Vacuum gauje

191. A water logged soil is physiologically dry because of

(a) Non-movement of water capillaries (b) Anaerobic conditions

(c) Increase viscosity of water (d) Abundance of salts

192. The main difference between active and passive transport across cell membranes is that

(a) Active transport occurs more rapidly that passive transport

(b) Passive transport in non-selective

(c) Passive transport requires a concentration gradient across the cell membrane whereas active transport requires metabolic energy

(d) Passive transport is confined to anions and active transport is for cations only

193. Absorption of water during night time in believed to be

(a) Passive because water is absorbed against a concentration gradient

(b) Active because water is absorbed even if there is plenty of concentrated water in the xylem

(c) Non-osmotic because root sap is dilute

(d) Osmotic because xylem sap is rich in inorganic and organic solutes

194. Absorption of water by root is increased by

(a) Increase in rate of photosynthesis (b) Increase in respiration

(c) Decrease in salt up take (d) Decrease in transpiration

195. Water will be absorbed by root hairs when

(a) Concentration of salt in the soil is high (b) Plant is rapidly respiring

(c) Concentration of solutes in the cell sap is high

(d) They are separated from soil by a permeable membrane

196. Active absorption of water created

(a) Positive pressure in the Xylem sap of shoot (b) Negative pressure in the Xylem sap of root

(c) Positive pressure in the Xylem sap of root (d) Negative pressure in the Xylem sap of shoot

197. Root hairs emerge from

(a) Epidermis (b) Outer most cortex (c) Pericycle (d) Endodermis

198. The active absorption of water does not require a direct supply of energy is known as

(a) Non osmotic active absorption (b) Osmotic active absorption

(c) Passive water absorption (d) Electrosmotic active absorption

199. Osmotic theory for active absorption of water was proposed by

(a) O. Hertig (b) Thimann (c) J.C. Bose (d) Atkin and Priestley

200. What is needed for active transport

(a) Evolution of heat (b) Availability of light and heat

(c) Presence of light (d) Availability of energy

201. For absorption of water, the root hair cells acts as

(a) Sucking organs (b) Osmotic system (c) Monometer (d) Anemometer

Advance Level

202. The path of water from soil upto secondary xylem is

(a) Soil $\rightarrow$ Root hair cell wall $\rightarrow$ Cortex $\rightarrow$ Endodermis $\rightarrow$ Pericycle $\rightarrow$ Protoxylem $\rightarrow$ Metaxylem

(b) Metaxylem $\rightarrow$ Protoxylem $\rightarrow$ Cortex $\rightarrow$ Soil $\rightarrow$ Root hair

(c) Cortex $\rightarrow$ Root hair $\rightarrow$ Endodermis $\rightarrow$ Pericycle $\rightarrow$ Protoxylem $\rightarrow$ Metaxylem

(d) Pericycle $\rightarrow$ Soil $\rightarrow$ Root hair $\rightarrow$ Cortex $\rightarrow$ Endodermis $\rightarrow$ Protoxylem $\rightarrow$ Metaxylem

203. If the rates of transpiration and water absorption of a flowering plant are measured over a period of twenty four hours, it is found that the rate of transpiration reaches its peak at about mid-day and then declines, whereas the peak for water absorption is reached approximately two hours later.

Which one the following statements provides the best explanation of these results

(a) There is a temporary reduction of light intensity at mid-day, which reduces the rate of transpiration

(b) Water absorption is mainly due to root respiration and this is affected by soil temperature, which does not reach a maximum for some hours after the maximum air temperature has been reached

(c) The high rate of transpiration causes a water deficit which results in stomatal closure and an increased concentration of leaf cell sap, which in turn causes continued water uptake

(d) The high light intensity results in high internal oxygen concentrations and so increase water uptake

204. Which of the following helps in the absorption of water and mineral salts

(a) Mycorrhiza (b) *Anabaena* (c) *Nostoc* (d) None of these

205. Which of the following water comes under echards

(a) Available to the plant (b) Whole of the soil water

(c) Amount of water not available to the plant (d) None of these

206. Root cap has no function in water absorption, because

(a) Its vascular system is not directly connected (b) Its cells are loosely placed

(c) It has cells without chloroplast (d) It has no root hair

207. Suitable temperature for active absorption of water by root is

(a) $40 - 45°C$ (b) $10 - 15°C$

(c) $20 - 30°C$ (d) Can take at any temperature

208. In a young root, the most active absorption of water takes place through

(a) Root cap region (b) Root hair region

(c) Zone of elongation (d) Mature region with a corky cover

209. Root hairs occur in the zone of

(a) Cell division (b) Cell elongation (c) Cell maturation (d) Calyptrogen

210. Soil moisture beyond field capacity produces a condition of

(a) Temporary wilting (b) Permanent wilting (c) Water logging (d) Both (a) and (b)

211. Water potential found in root hair cells is generally

(a) 1–2 *atm.* (b) –1 to 2.0 *atm.* (c) –1 to 4 *atm.* (d) –1 to –4 *atm.*

212. Contribution of passive water absorption to total water absorption is

(a) 50% (b) 70% (c) 80–90% (d) 96–100%

213. When soils are deficient in Oxygen and have high proportion of salts or toxic substances the process of active absorption

(a) Stops (b) Remains unaffected

(c) Increases (d) Decreases

214. Which of the following statement is not correct

(a) Plants absorb excess quantity of water

(b) Plants take in small quantity of mineral salts through the soil water

(c) Water and inorganic salts are taken in simultaneously by root hairs

(d) Plants absorb only one thing at a time, water or inorganic salts

215. The dead cell differs from a living cell because

(a) Its vital force has been destroyed

(b) A change of its surrounding environment has occured

(c) A change in its specific organization has occured

(d) It has been separated from other cells

ASCENT OF SAP

Basic Level

216. A sufficient atmospheric pressure required to push the water upto the top of tall plants must be

(a) 2 *atm* (b) 6 *atm* (c) 20 *atm* (d) All of these

217. At mid-day hours, the xylem sap is in a state of

(a) Compression (b) Tension (c) Relaxation (d) Adhesion

218. The potential of water in the vessels of xylem is low. It is due to

(a) High osmotic concentration (b) High OP

(c) Transpiration induced tension (d) Root pressure

219. Veins are present in the leaves carry

(a) Wast products (b) Alkaloids (c) Sap (d) Oxygen

220. Positive root pressure can be demonstrated

(a) At noon (b) In the early morning (c) In the evening (d) Only during night

221. Who proposed the "Relay pump theory" of ascent of sap

(a) Bose (b) Westen (c) Godlewski (d) Strasburger

222. According to one vital force theory, ascent of sap is due to active pulsation of innermost layer of cortex. This theory was given by

(a) J. C. Bose (b) Dixon (c) Strasburger (d) Sacks

223. Pressure bomb technique was used by

(a) Scholander *et al* (b) Kramer *et al* (c) Dixon *et al* (d) None of these

224. How water rises from the rhizoids of *Riccia* to its assimilatory filaments ? It is through

(a) Osmosis (b) Root pressure (c) Capillary (d) Transpiration pull

225. In plants, movement of water against gravitational force is due to

(a) Biostatic theory (b) Transpiration pull

(c) Water cohesion (d) Transpiration pull and water cohesion theory

226. The cohesion property of water is

(a) Attraction between the water molecules
(b) Dettachment between the water molecules
(c) Visocity between the water molecules
(d) Spliting (breaking) of water molecules

227. If cut end of tree is put in eosin solution

(a) Leaves will quickly die because ascent of sap stops
(b) Leaves remain fresh but ascent of sap stops
(c) Phloem gets coloured because of ascent of sap
(d) Xylem elements get stained showing ascent of sap through them

228. On keeping a freshly out leafy twig in fuschin solution reveals

(a) Veins become coloured and ascent of sap occurs
(b) Veins become coloured and ascent of sap stops
(c) Veins remain normal while ascent of sap stops
(d) Veins remain normal while ascent of sap occurs

229. The principle pathways by which water is translocated in angiosperms is

(a) Xylem and phloem together
(b)Sieve tubes and members of phloem
(c) Sieve cells of phloem
(d)Xylem vessel system

230. Pulling force in plant body develop at the top of tree by

(a) Evaporation
(b) Photosynthesis
(c) Transpiration
(d) Absorption

231. Which of the following is more during the night

(a) Root pressure
(b) Absorption
(c) Evaporation
(d) Transpiration

232. Dixon and Jolly are famous for

(a) Anaerobic respiration
(b) Light reaction of photosynthesis
(c) Cohesion theory
(d) Apical dominance

233. Xylem conducts sap from

(a) Leaves to roots
(b) Roots to leaves
(c) Root to stems
(d) Stems to roots

234. Ascent of sap means

(a) Diffusion of water
(b) Building up of carbohydrates
(c) Loss of water from leaves
(d) The vertical rise of water in the stem against the force of gravity

235. Boucherie (1840) rejected the vital force theory on the basis that

(a) Living cells are capable of growth
(b) Living cells are capable for ascent of sap
(c) Dead cells are capable for ascent of sap
(d) Dead cells are incapable for ascent of sap

236. The term tensile strength represents that

(a) There is a strong cohesion force between water molecules, so the column does not break and it is stretched by transpiration pull

(b) There is a strong adhesion between water molecules and walls of xylem vessels so the column does not break and it is stretched by transpiration pull

(c) There is absence of vacuoles in the vessels, so the column does not break and it is stretched by transpiration pull

(d) There is loss of water by leaves, so a positive tension is created and column does not break and it is stretched by transpiration pull

237. The plant tissue specialized for vertical transport belongs to

(a) Xylem and phloem (b) Xylem and epidermis (c) Medulla and cortex (d) Phloem and cortex

238. The term root pressure was coined by

(a) Priestley (1729) (b) Stephan Hales (1727) (c) Sachs (1809) (d) J.C. Bose (1923)

239. Root pressure theory was proposed by

(a) Godlewski (b) Bennedict (c) Priestley (d) Sachs

240. In a branch cut from a rapidly transpiring plant, water snaps away from the cut end. It shows that

(a) It is under tension (b) It is in excess in vessels

(c) It has been absorbed by capillary force (d) It has been absorbed by imbibition force

241. A man applied fertilizers heavily on his lawns then he gave more water. A few days later the grass turned brown because

(a) Transpiration rate increased due to excessive water

(b) The roots were killed due to loss of water by osmosis

(c) Heavy fertilizers affected photosynthesis

(d) Excessive water fertilizer caused diffusion of water in sub soil water

242. Imbibition theory of sach as explanation for ascent of sap, is wrong because

(a) Water moves through lumen and not along the walls

(b) It involves expenditure of energy

(c) Sap rises along the walls of living cells

(d) Cellulose walls of xylem do not show imbibition

243. Wilting in plant occurs when

(a) Xylem is blocked (b) Phloem is blocked

(c) Pith is removed (d) Epidermis is peeled off

244. Maintenance of continuity of water was demonstrated by the use of

(a) P^{32} (b) O^{18} (c) C^{11} (d) C^{14}

245. According to relay pump hypothesis, water rises in stem due to activity of cells of

(a) Medullary rays (b) Inner cortex (c) Pericycle (d) Endodermis

246. Presence of pulsation in the cortical cell was demonstrated by

(a) Electric probe (b) Dendrography (c) Pressure Bomb (d) Porometer

247. The transport velocity of sap in xylem may be as high as

(a) 2 *meters/hour* (b) 10 *meters/hour* (c) 25 *meters/hour* (d) 45 *meters/hour*

248. Strasburger rejected vital force theory of on the ground that

(a) Living cells are incapable of translocation (b) Water rises in dead cells

(c) Respiration occure in living cells (d) Living cells are capable of growth

249. Root pressure helps in ascent of sap by

(a) Pumping food in phloem (b) Pumping sap into xylem in roots

(c) Pumping sap in stem for sending it to roots (d) All of these

250. Root pressure can be measured by means of

(a) Porometer (b) Potometer (c) Auxanometer (d) Manometer

251. Root pressure theory of ascent of sap is unacceptable because

(a) Water can ascend without root or root pressure

(b) Root pressure cannot explain ascent of sap beyond 10 *meters*

(c) Root pressure is more during early morning than afternoon

(d) Root pressure does not occur in spring

252. Ringing/girdling experiment was first performed by

(a) Hartig (b) Strasburger (c) Godlewski (d) Bose

253. Capillarity theory was proposed by

(a) Unger (b) Sachs (c) Bohm (d) Mac Dougal

Advance Level

254. The ultimate force which propels water against the gravity is generated by

(a) Osmosis (b) Imbibition (c) Transpiration (d) ATP hydrolysis

255. The cohesive force of water is due to

(a) *O*–bonds (b) *H*–bonds (c) *OH*–bonds (d) *S*–bonds

256. Most widely accepted explanation for the ascent of sap in tree is

(a)Capillarity (b) Roll of atmospheric pressure

(c) Pulsating action of living cells (d) Transpiration cohesion theory of Dixon

257. The most important force which pulls water up in tall trees is

(a) Imbibition force (b) Osmotic force

(c) Cohesive force (d) Electromagnetic force

258. Root pressure is maximum when

(a) Transpiration is high and absorption is very low

(b) Transpiration is very low and absorption is high

(c) Transpiration is very high and absorption is also high

(d) Transpiration and absorption both are slow

259. The force of tension-cohesion exceeds root pressure on a

(a) Rainy day (b) Foggy morning (c) Sunny day (d) Full-moon night

260. Cohesion-tension theory is directly related with

(a) Absorption (b) Transpiration (c) Evaporation (d) Guttation

261. The value of transpiration tension and negative hydrostatic pressure is about

(a) 20 *atms* (b) 25 *atms* (c) 30 *atms* (d) 35 *atms*

262. The value of cohesion force for plant sap has been calculated to be about

(a) 35-107 *atms* (b) 45–207 *atms* (c) 55–207 *atms* (d) 25–107 *atms*

263. The maximum resistance for the movement of water through individual cells is offered by

(a) Cell wall and central vacuole (b) Cell wall

(c) Cell wall, cytoplasm and central vacuole (d) Cell wall and cytoplasm

264. If transpiration pull and cohesion of water molecules theory is correct than air bubbles in the water column should

(a) Increase the rate of water absorption (b) Have effect on respiration

(c) Block the conducting tissues (d) Have no effect

TRANSPIRATION

Basic Level

265. Which of the following would increase the rate of transpiration from the leaves of a potted plant

(a) Put it in the dark for twenty four hours (b) Put it in the drought of an electric fan

(c) Put it in a cold room (d) Put it outside when it is raining

266. Which one of the following describes a possible reason for the opening and closing of the guard cells

(a) Stomata open in daylight because photosynthesis occurs in the guard cells producing sugar resulting in higher osmotic pressure

(b) Stomata open in daylight because guard cells have chloroplasts and the epidermal cells do not, and so a differential osmotic pressure arises

(c) Stomata open in daylight because starch is changed to osmotically active substances which increase the turgidity of the guard cells

(d) Stomata close in darkness because the starch produced in daylight by photosynthesis, it is changed into sugars and translocated from the guard cells

267. Which one of the following would lead to stomatal closure

(a) Decrease in carbon dioxide concentration in the intercellular spaces of the leaf

(b) Active photosynthesis in the stomatal guard cells

(c) Conversion of sugar to starch in the stomatal guard cells

(d) Increase in *pH* in the stomatal guard cells

268. In *Vallisneria*, stomata are

(a) Present on upper epidermis of leaf (b) Present on lower epidermis of leaf

(c) Present on both the epidermis of leaf (d) Not present

269. In the mechanism of opening of stomata, the important factor is the

(a) Shape of the guard cells (b)Chlorophyll content of the cells

(c) Hormone content of the cells (d)Protein content of the cells

270. Generally stomata found on the lower surface of leaf. Thus approximate percentage of transpiration through abaxial surface is

(a) 47% (b) 57% (c) 67% (d) 97%

271. In walnut, stomata are found on

(a) Only upper surface of the leaf (b)Only lower surface of the leaf

(c) Both the surfaces of the leaf (d)Absent on both the surfaces

272. In pea plant, type of stomata is known as

(a) Apple type (b) Potato type (c) Oat type (d) None of these

273. Stomata is absent in

(a) Submerged plants (b) Desert plants (c) Floating plants (d) All the above

274. Stomata closed and open due to activity of water then movement is known as

(a) Photoactive (b) Scotoactive (c) Hydroactive (d) Autonomous

275. Stomata opens in the night at alkaline or neutral *pH* (in the atmosphere of ammonia vapours). This statement was given by

(a) Van Helmont (b) Van Neil (c) Sayre (d) Von Mohl

276. Stomata of CAM plants

(a) Never open (b) Are always open

(c) Open during the day and close at night

(d) Open during the night and close during the day

277. Guttation takes place during night when

(a) Root pressure is positive (b) Root pressure is negative

(c) Always takes place (d) It does not take place at all

278. Which of the following causes maximum loss of water during transpiration

(a) Cuticular transpiration (b)Stomatal transpiration

(c) Lenticular transpiration (d)Equal in all the cases

279. In which part of the plant water is stored

(a) Roots (b) Stem (c) Leaves (d) Bark

280. Which of the following plants do not transpire

(a) Algae (b) Fungi

(c) Submerged hydrophytes (d) All the above

281. Transpiration efficiency is the ratio of

(a) Absorption to transpiration (b) Rate of ascent of sap to transpiration

(c) Dry matter produced/ *kg* of transpired water (d) Transpiration to area of the leaf

282. A small mesophytic twig with green leaves is dipped into water in a big beaker under sunlight. It demonstrates
(a) Photosynthesis (b) Respiration (c) Transpiration (d) None of these

283. Which one is not related to transpiration
(a) Regulation of plant body temperature (b) Absorption and distribution of mineral salts
(c) Circulation of water (d) Bleeding

284. Maximum transpiration occurs in
(a) Mesophytic plants (b) Hydrophytic plants (c) Xerophytic plants (d) Algal cells

285. Which of the following is a plant showing scotoactive opening of stomata
(a) *Opuntia* (b) *Nerium* (c) *Arachis* (d) All of these

286. In barley type of plant, the stomata open
(a) For few hours during day (b) During night
(c) Throughout day and night (d) Remain closed

287. Stomatal frequency means
(a) No. of stomata per unit area of leaf surface
(b) No. of epidermal cells per unit area of leaf surface
(c) No. of mesophyll cells in the per unit area of leaf (d) None of these

288. Water drops present on leaf margins of *Tropaeolum*, Balsam and grasses in early morning are due to
(a) Guttation (b) Dew (c) Osmosis (d) Transpiration

289. Conversion of starch to organic acid is essential for
(a) Stomatal closure (b) Stomatal opening (c) Stomatal initiation (d) Stomatal growth

290. Clarification of mechanism of opening and closing of guard cells is based on which of the following theory
(a) Entry and exit of potassium in guard cell
(b) Photosynthetic process taking place in guard cell
(c) Starch-sugar conversion (d) Transpiration

291. What is the action spectrum of transpiration
(a) Green and ultraviolet (b)Orange and red (c) Blue and far red (d) Blue and red

292. Turgidity in guard cells is controlled by
(a) Chloride (b) Malic acid
(c) Potassium (d) Potassium, chloride and malic acid

293. In which of the following the rate of transpiration is high
(a) CAM plants (b) C_3 plants (c) C_3 and C_4 plants (d) C_4 plants

294. Which of the process is responsible for loss of sugars and salts from plants
(a) Transpiration (b) Guttation (c) Both (a) and (b) (d) None of these

295. Who devised the apparatus to determine the degree of opening of stomata
(a) Ganong (b) Farmer (c) Darwin (d) All of these

296. The rate of transpiration will be higher when

(a) Water vapour is saturated
(b) Water vapour saturation deficit more
(c) Water vapour pressure high
(d) None of these

297. What will be the effect of water deficit (in soil) on rate of transpiration

(a) It will increase
(b) Decrease
(c) In some plants increasing affect
(d) No change in rate

298. The number of stomata present per mm^2 of leaf is

(a) Less than 100
(b) 1000 to 6000
(c) One million
(d) None of these

299. Stomata in angiosperms does not open during

(a) Noon
(b) Twilight
(c) 11 O'clock
(d) At midnight

300. Increase in temperature and velocity of wind cause an increase in transpiration initially but later it slows down, because

(a) Of closure of stomata
(b) Water is not made available
(c) The air around the plant becomes humid
(d) Of mechanical disturbance

301. Use of anti- transpirant may check

(a) Transpiration in fruit plants
(b) Transpiration in vegetable plants
(c) Transpiration in crop plants
(d) All the above

302. In most of thin leaf mesophytes, the leaf stomata open during day and close during night. It comes under

(a) Barley type
(b) Potato type
(c) Alfalfa type
(d) Bean type

303. Which of the following is not a controlled process

(a) Transpiration
(b) Guttation
(c) Both (a) and (b)
(d) None of these

304. Position and frequency of stomata can be determined by

(a) Calculating the loss of water
(b) Cobalt chloride paper method
(c) Potometer
(d) Porometer

305. In both transpiration and evaporation, water is lost in the form of vapour yet they differ, because

(a) Both transpiration and evaporation are similar but the rate of water loss differs
(b) Frequency of water loss is different in both of them
(c) Transpiration is a physical process and evaporation is a physiological process
(d) Transpiration is a physiological process and evaporation is a physical process

306. In hot summer day, plant cooling is due to

(a) Loss of water vapours from leaf
(b) Transport of water in plant
(c) Loss of liquid water
(d) Loss of water from entire plant

307. When cut stump of a plant is fitted with a manometer, the level of mercury rises due to the accumulation of

(a) Water
(b) Oxygen
(c) Mercury
(d) Gas

308. In water lily, stomata are found on

(a) Upper surface of leaf
(b)Under surface of leaf
(c) Present on both the surfaces
(d) No stomata at all

309. In which of the following the stomata are sunken type

(a) Mesophyte (b) Hydrophyte (c) Xerophyte (d) All of these

310. Which of the following is an adaptation of reduce water loss

(a) Presence of thick cuticle (b) Change of leaf into spines

(c) Change of leaf into phylloclade (d) All the above

311. Basis of stomatal opening is

(a) Exosmosis (b) Endosmosis

(c) Decrease in cell sap concentration (d) Plasmolysis of guard cells

312. The principle transpiring organ of plant is

(a) Root (b) Flowers (c) Stem (d) Leaves

313. For photoactive opening of stomata, the proton transport concept was given by

(a) Lewitt (b) Milborrow (c) Ziegler (d) None of these

314. Enzyme phosphorylase is first of all discovered in guard cells by

(a) Yin and Tung (b) Noggle (c) Scarth (d) All of these

315. The scientist, who proposed that production of glycolic acid in guard cells is an important factor in stomatal opening, is

(a) Kumar (b) Steward (c) Zelitch (d) Lewitt

316. According to proton transport theory, which plays an important role

(a) Mg^{++} (b) Mn^{++} (c) Cl^{-} (d) K^{+}

317. Nishida (1963) explained stomatal opening and closing mechanism in

(a) Aquatic plants (b) Succulent plants (c) Evergreen plants (d) All of these

318. 'Guttation' word is given by

(a) Fritz (b) Burgerstein (c) Noggle (d) Lewitt

319. Guttation is found mostly in

(a) Herbaceous mesophytic plant (b) Shrubs

(c) Wood plants (d) None of these

320. Steward's theory of stomatal opening and closure assumes the presence in the guard cells, of the following enzymes

(a) Phosphorylase and phosphatase

(b) Hexokinase and phosphoglucomutase

(c) Phosphorylase, phosphoglucomutase, phosphatase and hexokinase

(d) Phosphorylase, phosphoglucomutase

321. Which of the following theories is not related to the opening of stomata

(a) Sachs (b) K^{+} transport (c) Karper-Kappa theory (d) Lewitt theory

322. Guard cell movement furnishes an example of

(a) Turgor movement (b) Tactic movement (c) Nastic movement (d) Cyclosis movement

323. Guard cells differ from epidermal cells in having

(a) Mitochondria (b) Vacuoles (c) Cell wall (d) Chloroplasts

324. Stomata open at night and close during day in
(a) Xerophytes (b) Gametophytes (c) Mesophytes (d) Hydrophytes

325. When an oak leaf stoma is open more widely, the most likely process involved is
(a) Water molecules are entering in the guard cells through adjacent cells
(b) The atmosphere outside the stoma is becoming less humid
(c) Salt molecules are being excreted by the adjacent guard cells
(d) Auxins are accumulating in the guard cells

326. Transpiring organ in plants is
(a) Epidermis (b) Xylem (c) Cortex (d) Phloem

327. Increase in CO_2 concentration around leaf results in
(a) Rapid opening of stomata (b) Partial closing of stomata
(c) Complete closure of stomata (d) There will be no effect on stomatal opening

328. Guttation is caused due to
(a) Imbibition (b) Osmosis (c) Root pressure (d) Transpiration

329. Which of the following wall of guard cells is thick
(a) Outer (b) Inner (c) Side wall (d) All the three

330. Out of the following which one is the most common type of transpiration
(a) Foliar (b) Stomatal (c) Lenticular (d) Cuticular

331. Which one of the following will reduce the rate of transpiration
(a) Increase in wind velocity (b) Rise in temperature
(c) Increase in water uptake by plants (d) Decrease in light intensity

332. Wilting of leaves in hot weather is due to
(a) Excessive transpiration
(b) Excess of transpiration as compared to water absorption
(c) Excessive water absorption by roots (d) Lack of water absorption

333. Who proposed the theory of photosynthesis in guard cells
(a) Steward (b) Von Mohl (c) Zelitch (d) None of these

334. Theory of starch-glucose interconversion was proposed by
(a) Yin and Tung (b) Zelitch (c) Imamura (d) None of these

335. When the relative humidity of atmosphere is 100% in day time, the stomata shall
(a) Continue to remain open (b) Become closed to stop transpiration
(c) Remain partially opened (d) Become partially closed

336. Transpiration would be lowest when
(a) Wind velocity is high (b)Enough water is in the soil
(c) Atmospheric RH is high (d) High temperature and light

337. Which of the following exhibits a direct proportionality to transpiration
(a) Light and relative humidity (b) Temperature and relative humidity
(c) Temperature and wind (d) Relative humidity and wind

338. In summer months, the rate of transpiration is lowest at
(a) 10 AM (b) 1 PM (c) 5 PM (d) None of these

339. Transpiration increases by
(a) High humidity (b) Wetness in soil (c) High temperature (d) Low wind velocity

340. By which process atmospheric temperature is maintained
(a) Transpiration (b) Respiration (c) Photosynthesis (d) Phosphorylation

341. Which of the following factors is the most important in the regulation of transpiration
(a) Humidity (b) Light (c) Temperature (d) Wind

342. In terms of permeability the cell wall and plasmalemma are
(a) Permeable and differentially permeable respectively (b)Both semipermeable
(c) Semipermeable and differentially permeable (d)Both differentially permeable

343. The chief role of transpiration in plants is to cause
(a) Loss of surplus water (b)Cooling of the plant
(c)Rapid ascent of sap (d)Rapid rise of minerals

344. Due to low atmospheric pressure, the rate of transpiration will
(a) Decrease slowly (b) Decrease rapidly (c) Increase (d) Remain unaffected

345. The transpiration is regulated by the movements of
(a) Subsidiary cells of the leaves (b)Guard cells of the stomata
(c) Mesophyll tissue cells (d)Epidermal cells of the leaves

346. Epithem is
(a) Loosely arranged mass of parenchyma in hydathodes
(b) Large intercellular spaces of hydathodes
(c) Xylem element of hydathodes (d)Phloem below the air chamber

347. Who had said that "transpiration is a necessary evil"
(a) Curtis (b) Steward (c) Andersen (d) J.C. Bose

348. Temporary wilting occurs when the rate of absorption is
(a) Equal to transpiration (b)Greater than transpiration
(c) Lesser than transpiration (d) Less than guttation

349. Transpiration occurs through
(a) Leaves (b) Stem (c) All aerial parts (d) Roots

350. Which of the following is used to determine the rate of transpiration in plants
(a) Porometer (b) Potometer (c) Auxanometer (d) Tensiometer

351. Which of the following leaves would dry up last
(a) Upper surface greased (b)Lower surface greased
(c) Both surfaces greased (d)Both surfaces ungreased

352. The number of stomata per unit area of leaf are generally more on the lower surface in case of
(a) Isobilateral leaf (b) Dorsiventral leaf (c) In herbaceous stem (d) In woody stem

353. When oxygen is deficient in the atmosphere
(a) Stomata start closing up (b) Stomata open fully
(c) Stomata close up provided temperature is high
(d) Stomata open provided water in the soil is maximum

354. Smaller plants lose more water per unit of leaf area as compared to the larger plants due to
(a) High root shoot ratio in former (b) Low root shoot ratio in former
(c) More stomatal frequency (d) Value of stomatal index is high

355. The instrument which measures wind velocity is
(a) Lactometer (b) Photometer (c) Anemometer (d) Hygrometer

356. Cobalt chloride method was first used by
(a) F.Darwin (1912) (b) Stahl (1894) (c) Curtis (1926) (d) Leibeg (1840)

357. Cobalt chloride is blue in anhydrous state. In contact with water vapours it turns
(a) Red (b) Violet (c) Pink (d) Yellow

358. Which of the following shows guttation
(a) Colocasia (b) Sunflower (c) Petunia (d) Carrot

359. Stomata remain open at night in
(a) Bryophyllum (b) Neem (c) Sunflower (d) Grasses

360. Transpiration ratio is the ratio of moles of H_2O transpired/moles of CO_2 fixed. This ratio is measure of
(a) The efficiency of guard cells on stomatal movement
(b) Effectiveness of stomata is maximizing photosynthesis while minimizing water loss
(c) Distinguishing a xerophyte from a glycophyte
(d) Stomatal pore size of the leaves

361. The following percentage of water absorbed by herbaceous plants is lost in transpiration
(a) 80 (b) 60 (c) 90 (d) 40

362. The metal ion involved in the stomatal regulation is or Stomata will open, if there is accumulation of the following element in the guard cells
(a) Iron (b) Magnesium (c) Zinc (d) Potassium

363. The loss of water in the form of vapour from aerial plant parts is known as
(a) Osmosis (b) Respiration (c) Photosynthesis (d) Transpiration

364. Guard cells are found in
(a) Stomata (b) Root tips (c) Ovary (d) Lenticels

365. Grafted flower is contained in saline water because
(a) Suitable nutrient available to flower
(b) Flower become fresh in long duration due to less transpiration
(c) Flower become fresh in long duration due to regulated osmotic pressure of flower cell
(d) Flower is protected by microbes

366. The process of the escape of liquid from the tip of uninjured leaf is called

(a) Evaporation (b) Transpiration (c) Guttation (d) Evapo-transpiration

367. Stomata open during day time because the guard cells

(a) Photosynthesize and produce osmotically active sugars or organic acids

(b) Are thin-walled

(c) Are bean shaped

(d) Have to help in gaseous exchange

368. In the terrestrial habitat which of the following factors affect temperature and rainfall conditions

(a) Translocation (b) Transformation (c) Thermo-denaturation (d)Transpiration

369. Wilting of a plant results from excessive

(a) Respiration (b) Photosynthesis (c) Absorption (d) Transpiration

370. The conditions under which transpiration would be most rapid

(a) High humidity

(b) Excess of water in soil

(c) Low humidity, high temperature, guard cells are turgid (Open) and moist soil

(d) Low velocity of wind

371. The transpiration in plants will be lowest

(a) When there is high humidity in the atmosphere (b) High wind velocity

(c) There is excess of water in the cell (d) Environmental conditions are very dry

372. Phenyl mercuric acetate

(a) Reduces transpiration rate (b) Reduces photosynthesis

(c) Reduces respiration (d) Kills the plant

373. In succulent plants the stomata open in night and close in day. Which among the following would be best hypothesis to explain the mechanism of stomatal action in night only

(a) CO_2 accumulates, reduces pH, stimulate enzymes resulting in accumulation of sugars

(b) Increase in CO_2 concentration, conversion of organic acids into starch resulting in the increased conversions into sugars resulting in K^+ transport

(c) Low CO_2 concentration accumulates organic acids resulting in the increased concentration of cell sap

(d) CO_2 used up, increase pH results in accumulation of sugars

374. Potometers are made on the principle that

(a) Humidity causes reduction in transpiration

(b) The amount of water transpired is less than the amount of water absorbed

(c) The amount of water transpired is more than the amount of water absorbed

(d) The amount of H_2O transpired is approximately equal to amount of water absorbed

375. Water potential in the leaf tissue is positive (+) during

(a) Excessive transpiration (b)Low transpiration

(c) Excessive absorption (d)Guttation

376. The rate of absorption of water is slow at temperature near freezing point

(a) Cell membrane becomes more viscous (b) It is mainly a metabolic process

(c) Growth of cells stop (d) Transpiration is retarded

377. For apple leaves are taken namely A, B, C and D. Now vaseline is applied on the lower surface of B, upper of C and on both the surfaces of D. Their drying sequence shall be

(a) $A \to B \to C \to D$ (b) $A \to C \to B \to D$ (c) $D \to B \to C \to A$ (d) $D \to C \to B \to A$

378. Leaves that appear wilted in the day time recover at night because

(a) Light is essential for photosynthesis

(b) The stomata close down, temperature decreases, transpiration is reduced and the plant is able to absorb more water from the soil

(c) Respiration and translocation of organic substances both increase

(d) The plant is sleeping because of dark conditions

379. A good antitranspirant is the one that

(a) Increases leaf and mesophyll resistance (b) Decreases leaf and mesophyll resistance

(c) Decreases leaf resistance only (d) Increases leaf resistance only

380. In xerophytic leaf the stomata are situated

(a) On both surfaces (b) On upper surface

(c) On lower surface (d) Absent from both surfaces

381. Common between guard cells and mesophyll cells is

(a) Dumbell shaped (b) Differentially thick walls

(c)Presence of chloroplasts (d) Uniformly thin cell wall

382. Stomata remain open when relative humidity is

(a) Above 70% (b) 50–70% (c) 30–50% (d) Below 30%

383. Stomatal index I is equal to

(a) $\frac{S}{E-S}$ (b) $\frac{S}{E+S}$ (c) $\frac{E}{E+S}$ (d) $\frac{E+S}{E}$

384. In majority of plants, the guard cells are

(a) Dumb-bell shaped (b) Reniform (c) Rounded (d) Polygonal

385. Rate of transpiration is measured by

(a) Ganong's potometer (b) Porometer (c) Auxanometer (d) Respirometer

386. Of the following four dorsiventral leaves which will show the maximum loss of weight

(a) Smeared with vaseline on both surfaces (b) Smeared with vaseline on the upper surface

(c) Smeared with vaseline on the lower surface (d) Unsmeared

387. For keeping stomata open, besides K ions the guard cells require a constant supply of

(a) ABA (b) ATP (c) Organic acids (d) Protons

388. An adaptation for better gaseous exchange in plant leaves is

(a) Hair on lower surface (b)Multiple epidermis

(c) Waxy cuticle (d)Stomata on lower surface away from direct sun rays

389. Epidermal cells containing chloroplasts are

(a) Hydathodes (b) Accessory cells (c) Stomata (d) Guard cells

390. Actual water vapour content of atmosphere is

(a) Relative humidity (b) Differential humidity (c) Absolute humidity (d) Positive humidity

391. Instrument that can be used to demonstrate pull due to vaporisation of water is

(a) Potometer (b) Atmometer (c) Auxanometer (d) Anemometer

392. A well watered herbaceous plant exhibits a decrease in rate of transpiration in intense light, this is due to

(a) High rate of photosynthesis (b) Partial closure of stomata

(c) Photo-oxidation of chlorophyll (d) Loss of water from the soil

393. The sugarcane plant has

(a) Dumb-bell shaped guard cells (b) Pentamerous flowers

(c) Reticulate venation (d) Capsular fruits

Advance Level

394. The rate of transpiration will greatly depends upon

(a) Frequency of stomata (b)Position of stomata (c) State of stomata (d) None of these

395. It *rc* and *rs* respectively represents cuticular and stomatal resistances, the total resistance (R) could be expressed as

(a) $R = rc + rs$ (b) $R = rc - rs$ (c) $\frac{1}{R} = \frac{1}{rc} + \frac{1}{rs}$ (d) $\frac{r}{R} = \frac{1}{rc} - \frac{1}{rs}$

396. The primary osmolite which causes an opening and closing of stomata is

(a) Sugars (b) Starch (c) K–malate (d) Water

397. Guttation is the process of elimination of water from plants through or Guttation occurs from or The pores in leaves through which water comes out in the form of droplets are celled or A specialized multicellular structure in leaves which excretes water droplets is called as

(a) Stomata (b) Hydathodes (c) Lenticels (d) Wounds

398. Guttation usually occurs when the plant is put

(a) In more saturated atmosphere (b) In more humid soil

(c) In dry condition (d) In deserts

399. Concentration of CO_2 from nature which is able to induce closure of stomata is

(a) 0.01 – 0.02% (b) 0.03 – 0.05% (c) 0.06 – 0.08% (d) 0.08 – 0.09%

400. Guttation is found in

(a) 115 families and 333 genera (b) 333 families and 366 genera

(c) 115 families and 366 genera (d) 100 families and 300 genera

401. Which of the following is produced during water stress and causes closure of stomata

(a) Cytokinin (b) Auxin (c) GA_3 (d) ABA

402. Sugar is converted into starch when

(a) H^+ ions concentration of guard cells decreases

(b) H^+ ions concentration of guard cells increases

(c) H^+ ions concentration remain the same (d) None of these

403. Transpiration is minimised by the deposition of

(a) Cellulose (b) Pectin (c) Cutin (d) Mucilage

404. If dried cobalt chloride paper is clipped on the under surface of a leaf its colour changes from blue to pink because

(a) It reacts with chlorophyll of the leaf (b) Paper is moistened by the transpiring water

(c) The clipper puts in pressure of a paper (d) It comes in contact with the green leaf

405. Lenticels and hydathodes are small pores with following common attributes

(a) Their opening and closing is not regulated (b) They allow exchange of gases

(c) They always remain closed (d) They are found on the same organ of plants

406. The hormones which help in the intake of K^+ ions by guard cells and hence speed up the opening of stomata are

(a) Cytokinins (b) Auxins (c) Gibberellins (d) Ethylene

407. The diameter of stomatal pore ranges between

(a) 25–50μ (b) 15–25μ (c) 3–10μ (d) 1–2μ

408. Some leaves are removed from the stem cuttings planted for vegetative propagation. This is done

(a) To increase water uptake (b) Because it helps in rooting of cuttings

(c) To reduce water loss (d) Because the cuttings need less food

409. Assertion : Stomata remain open during day time

Reason : Stomata help in exchange of gases

(a) If both are true with reason being correct explanation

(b) Both true but reason is not correct explanation

(c) Assertion is true but reason is wrong (d) Both are wrong

410. Find the correct order for instrument used for measuring

(i) Transpiration (ii) Size of stomata (iii) Atmospheric pressure (iv) Osmosis

(a) Potometer, manometer, porometer, osmometer

(b) Manometer, potometer, porometer osmometer

(c) Porometer, manometer, potometer, osmometer

(d) Potometer, porometer, manometer, osmometer

411. When half the leaves are removed randomly, transpiration will show

(a) Higher magnitude but lower flux or rate per unit

(b) Lower magnitude but higher flux

(c) Both magnitude and flux increase (d) Both magnitude and flux decrease

TRANSLOCATION OF ORGANIC SOLUTES

Basic Level

412. The movement of materials through the vascular tissue of plants is called
(a) Transpiration (b) Translocation (c) Transcription (d) Transduction

413. Cytoplasmic strands are present in
(a) Tracheids (b) Vessels (c) Sieve tubes (d) Wood fibre

414. By cutting the ring of phloem which of the following process is affected
(a) Downward flow of sugars (b) Upward flow of salts
(c) Distribution of hormones (d) All of these

415. The part which provides sugar to the phloem is called
(a) Source (b) Primary producer (c) Upper end (d) None of these

416. The part through which sugars flows from one cell to other are called
(a) Pits (b) Sieve pores (c) Sieve walls (d) None of these

417. Who supported the cytoplasmic flow
(a) Williams (b) Koch (c) Munch (d) Curtis

418. The cytoplasmic flow is called
(a) Linear flow (b) Cyclosis (c) Cell current (d) None of these

419. Which one of the following elements is necessary for the translocation of sugars in plants
(a) Iron (b) Manganese (c) Molybdenum (d) Boron

420. There is no translocation at low temperature has been invented by
(a) Swanson and Whitne (b)Fenson (c) Spanner (d) Munch

421. Who studied the effect of light on translocation
(a) De Vries (b) Blackman (c) Williams (d) Hart

422. Theory which gives translocation to some distance at interval
(a) Protoplasmic streaming (b) Munch theory (c) Transcellular streaming (d) None of these

423. In trees, death of protoplasts is essential for a vital function such as
(a) Stomatal movements (b)Both water and food transport
(c) Water transport (d)Food transport

424. The flow of organic solutes in plants is in
(a) Upward direction (b) Downward direction (c) Lateral (d) All of these

425. According to Munch theory, the cause of flow of soluble substances is
(a) Protoplasmic flow (b)Mass flow due to reduction in turgor pressure
(c) Diffusion (d) None of these

426. The part of the plant where metabolism takes place is called
(a) Aerial (b) Sub-aerial (c) Underground (d) All of these

427. Bidirectional translocation of minerals takes place in
(a) Xylem (b) Phloem (c) Parenchyma (d) Cambium

428. Which of the following is more important for conduction

(a) Phloem (b) Xylem

(c) Both are of equal importance (d) Sclerenchyma

429. The food stored in the ripening fruit is derived from

(a) Roots (b) Farthest leaves (c) Nearest leaves (d) Aerial stem

430. The term apoplast and symplast were use at first by

(a) Fisher (b) Clark (c) Munch (d) Dixon

431. Translocation of sugar in flowering plants occurs in the form of

(a) Maltose (b) Glucose (c) Sucrose (d) Starch

432. Which of the following trees would die quicker

(a) Pruned (b) Hollow hearted (c) Girdled (d) Deciduous

433. Gradient pressure was given as a possible mechanism of translocation of food by

(a) Curtis (b) Munch (c) Dixon and Jolly (d) Mason and Maskel

434. The removal of a ring of bark from trunk of a tree eventually kills it, since

(a) Mineral salts cannot go up

(b) Water cannot go up

(c) Food does not travel down and roots are starved

(d) The exposed part becomes infected with fungi

435. Bimodal theory of translocation was putforth by

(a) Fenson (b) Anderson (c) Swanson (d) None of these

436. "Active mass flow in which oxygen is required" was proposed by

(a) Fenson (b) Anderson (c) Mason and Phillis (d) None of these

437. Marshall and Wardlaw proposed the theory of

(a) Solution flow (b) Volume flow (c) Active mass flow (d) None of these

438. When a plant is girdled

(a) The root dies first (b) The shoot dies first

(c) The root and shoot die at the same time (d) Neither the root nor the shoot will die

439. By which of the following technique we can prove the phloem as an element for food translocation

(a) Tracer technique (b) Sap analysis technique (c)Chemical analysis (d) All of these

440. Chemical analysis of phloem shows the presence of

(a) More amount of carbohydrates (b) Organic nitrogenous compounds

(c) Minerals (d) Both (a) and (b)

441. Ringing experiment is related with

(a) Ascent of sap (b) Translocation of food (c) Both (a) and (b) (d) Mineral nutrition

442. The prevalent view for the translocation of organic solute in plants is
(a) Tension cohesion theory (b) Mass flow or pressure gradient hypothesis
(c) Root pressure hypothesis (d) Pulsating activity concept

443. "Cytoplasmic streaming hypothesis" is concerned with
(a) Salt absorption (b) Water absorption (c) Phloem transport (d) Movements

444. Which tissues are removed when a plant is girdled
(a) Xylem and pith (b) Xylem and phloem (c) Phloem to epidermis (d) Phloem to pith

445. Mass flow hypothesis was first described by
(a) Swanson (b) Buchnan (c) Kursanov (d) Munch

446. Which of the following is the consumption end of the plant
(a) Stem tip (b) Leaf (c) Root (d) None of these

447. By protoplasmic streaming theory, how sugar is translocated from one sieve tube to other
(a) Diffusion (b) Osmosis (c) Absorption (d) Active transport

448. Who suggested that the transcellular strands are made up of protein
(a) Fenson (b) Curtis (c) Mitlar (d) Thaine

449. Spanner and Jones suggested which of the following methods for translocation through phloem
(a) Electro-osmosis (b) Osmosis (c) Plasmolysis (d) Diffusion

450. In phloem flow is always from
(a) Sugar source to sugar sink (b) Sugar sink to sugar source
(c) Leaf to xylem then the phloem (d) Leaf to a root

451. Diffusion hypothesis most satisfactorily explains
(a) The direction of flow of food substances from the regions of low concentration to those of higher concentration
(b) The direction of flow of food substances from the regions of higher concentration to lower concentration
(c) Flow of food substances upwardly
(d) Flow of food substances downwardly

452. Which is correct about transport or conduction of substances
(a) Organic food moves upwardly through xylem
(b) Organic food moves up through phloem
(c) Inorganic food moves upwardly and downwardly through xylem
(d) Organic food moves upwardly and downwardly through phloem

453. Which of the following cells may show turgidity
(a) Xylem vessels (b) Xylem tracheids (c) Sieve tubes (d) All of these

454. The living component of phloem tissue is
(a) Sieve tube (b) Companion cells (c) Bast parenchyma (d) All of these

455. Aphid stylate sap analysis can be used to know

(a) Path of water flow in plant (b) Path of flow of organic solutes

(c) Both (a) and (b) (d) None of these

456. When the bark is stripped from a tree the vital vascular tissue removed is the

(a) Cork cambium (b) Vesseles (c) Phloem (d) Pith

457. Which would do maximum harm to a tree

(a) The loss of its branches (b) The loss of half of its leaves

(c) The loss of its bark (d) The loss of half of its branches

458. The protoplasmic streaming theory is not acceptable because

(a) Young cells show streaming

(b) Mature phloem cells show streaming movement

(c) Mature sieve tubes do not show streaming movement

(d) Protoplasm is not capable of streaming movement, phloem being dead

Advance Level

459. Much of the starch is deposited in banana fruit as it matures. Which of the following explains how the starch gets there

(a) Starch solution passes through cells such as companion cells to fruit

(b) Starch solution passes through cells of phloem to fruit

(c) A sugar solution passes through phloem cells to the fruit where it is changed to starch

(d) Starch grains passes through cells from xylem to fruit

460. Starch is insoluble in water yet it is accumulated in large quantities in potato because

(a) It is synthesized in potato tuber itself

(b) It is translocated from the leaves to the potato tuber in the form of sugar

(c) Soil micro-organism deposit starch in tuber

(d) It is useful consumption

461. During transport of sugar or amino acid through cell membrane

(a) Na^+ ions move against the direction of concentration gradient

(b) Na^+ ions move in both directions irrespective of its concentration gradient

(c) No net Na^+ ions movement

(d) Na^+ ions move in the direction of its concentration gradient

462. Meaningful girdling (Ringing) experiments can not be done on sugarcane because

(a) Phloem is present inside the xylem (b) It can not tolerate the injury

(c) Vascular bundles are scattered (d) Plants are very delicate

463. What is the substrate for flooting of food in the plants

(a) IAA (b) Abscisic acid (c) GA (d) K^+ ion

464. Which plant part shows upward flow in more quantity

(a) Developing seed (b) Germinating seed (c) Dormant seed (d) All of these

465. Intensity of light required for translocation of sugar as compared to photosynthesis is

(a) More (b) Less (c) Equal in both (d) None of these

466. The cytoplasm of surrounding cells remain connected through each other by plasmodesmeta. This continuity is called

(a) Symplast (b) Protoplast (c) Desmoplast (d) All of these

467. Which of the following theory shows bidirectional translocation

(a) Electro-osmosis (b) Transcellular streaming

(c)Protoplasmic streaming (d) All of these

468. Who proposed blood like translocation of solutes

(a) Spanner (b) Munch (c) Williams (d) Jones

469. A girdle between fruit and leaves

(a) Decreases the growth of fruit (b) Increases the growth of fruit

(c) Growth of fruit remains same (d) None of these

470. Cucurbitaceous plants are least affected by ringing because of

(a) Low respiration (b) Internal phloem

(c) Larger cambium cells (d) Regeneration of phloem

ANSWER

ASSIGNMENT (BASIC & ADVANCE LEVEL)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
c	b	d	b	a	d	a	b	c	d	b	b	d	a	c	d	b	d	a	c
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
a	a	d	c	a	a	a	d	c	a	d	c	a	c	c	d	a	a	c	d
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
b	d	b	c	c	a	b	a	c	b	a	b	c	b	a	d	b	b	d	d
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
c	b	b	a	d	c	d	c	a	a	a	c	a	a	c	b	b	a	c	a
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
c	a	c	a	a	c	c	b	a	a	b	a	a	b	b	c	a	d	c	a
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
a	d	a	c	c	c	c	c	a	d	d	a	b	c	a	d	d	d	a	d
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
a	a	b	d	a	a	a	b	c	b	d	b	d	a	a	a	a	c	c	a
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
a	a	a	b	d	a	c	d	d	b	b	a	b	d	a	d	a	d	b	a
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
c	c	b	c	b	b	b	b	b	b	b	b	d	c	a	a	c	a	c	b
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
a	b	b	c	b	a	a	d	c	b	b	c	b	b	c	c	a	b	d	d
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
b	a	c	a	c	d	c	b	c	c	d	d	a	d	a	c	b	c	c	b
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
c	a	a	a	d	a	d	a	d	c	a	c	b	d	c	a	a	b	c	a
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
b	a	a	a	a	a	d	b	b	d	a	a	c	c	b	d	c	b	c	b
261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
a	b	c	d	b	c	c	d	a	d	b	b	a	c	c	d	a	b	c	d
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
c	c	d	a	a	a	a	a	b	a	d	d	b	b	c	b	b	a	d	a

301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
d	c	b	b	d	a	a	a	c	d	b	d	a	a	c	d	b	b	a	c
321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340
c	a	d	a	a	a	b	c	b	b	d	b	b	a	a	c	c	b	c	a
341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
b	a	c	c	b	a	a	c	c	b	c	b	a	a	c	b	c	a	a	b
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380
c	d	d	a	b	c	a	d	d	c	a	a	b	d	b	d	b	b	d	c
381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
c	a	b	b	a	d	b	d	d	c	b	b	a	b	c	c	b	a	b	a
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
d	b	c	b	a	a	c	c	b	d	b	b	c	a	a	b	d	b	d	a
421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440
d	a	c	d	b	d	b	c	c	c	c	c	b	c	a	c	a	a	d	d
441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460
c	b	c	c	c	c	a	d	a	a	b	d	c	d	b	c	c	c	c	b
461	462	463	464	465	466	467	468	469	470										
a	c	d	b	b	a	c	b	a	b										

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