minerals from the soil by the roots, its movement through the thickness of the root and subsequently its upward conduction through the stem, is the result of five main phenomena :

1. Imbibition
2. Diffusion
3. Osmosis
4. Active transport
5. Turgidity and Flaccidity

All definitions are important

4.4.1 Imbibition :

Imbibition is a phenomenon by which the living or dead plant cells absorb water by **surface attraction**.

Full para

Substances which are made up of cellulose or proteins are hydrophilic (strong affinity for water). They imbibe water or moisture and swell up, e.g., dry seeds, wooden doors, swell up on contact with water or on exposure to moist air. Due to imbibitional pressure, seed coat ruptures in case of germinating seeds. It is also an important force in the ascent of sap.

4.4.2 Diffusion

Diffusion is the **free movement** of molecules of a substance (solute or solvent, gas, liquid) from the region of their **higher concentration** to the region of their **lower concentration** when the two are in a ***direct*** **contact.**

Diffusion can be easily demonstrated by a simple activity.

Read only.

Experiment 1. Place a sugar cube or a small tablet of a soluble dye or a crystal of potassium permanganate in a beaker containing water, in one corner (Fig. 4.3). The sugar, the dye, or the potassium permanganate slowly dissolves and spreads in the liquid. Eventually, the molecules of this substance are diffused, or distributed uniformly throughout the water.

In the movement of molecules, there was no obstacle of any kind in the path of the molecules of the dye (solute) and they could move freely in water in all directions.

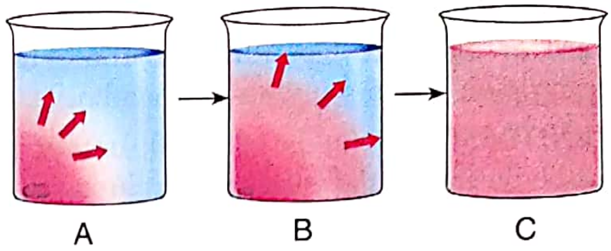

Fig. 4.3 : Diffusion of a soluble dye in water, forming a solution (schematic).
A – Diffusion started,
B – Diffusion progressing,
C – Diffusion completed, making a homogeneous solution; molecules of the solute are evenly distributed in the solvent.

Let us see how the definition of diffusion applies in this case:

- The molecules of the dye are more crowded (more concentrated) in and near the tablet of the dye.
- These molecules move away farther and farther in the regions where they are fewer or absent (less concentrated).
- This movement continues until the molecules are uniformly distributed. Stirring with a spoon or glass rod hastens the process of uniform diffusion and you get a homogeneous solution much faster.

4.4.3 Osmosis and osmotic pressure

A. OSMOSIS

Osmosis is the movement of **water* molecules** from their region of higher concentration (dilute solution or with a lower solute concentration) to their region of lower concentration (concentrated solution or with a higher solute concentration) through a semi permeable membrane.

An important thing to note in the above definition is that only the water molecules move from their higher concentration (whether in dilute solution, or in pure water) to their lower concentration (in stronger solution or just a solution in relation to pure water).

* Solutions having solvents other than water can also show osmosis. The solvent molecules will move from their higher to lower concentration through a semi-permeable membrane specific to their size.

Read

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With reference to a cell, osmosis can be either inward or outward depending on the extent of concentration of the solutions surrounding it.

ENDOSMOSIS (*endo* : inward, *osmo* : push/thrust) is the inward diffusion of water through a semi-permeable membrane when the surrounding solution is less concentrated. This tends to swell up the cell.

EXOSMOSIS (*exo*: outward) is the outward diffusion of water through a semi-permeable membrane when the surrounding solution is more concentrated. This tends to cause shrinkage of the cell.

CAN YOU ANSWER IT?

If the concentration of the surrounding solution is the same as that inside the cel, in which direction will the net movement of water molecules be across the cell membrane?
INWARD / OUTWARD / NO NET MOVEMENT.

Read full carefully

Experiment 2 (explaining osmosis). Take some concentrated sugar solution in a thistle funnel. Cover the mouth of the thistle funnel with a cellophane paper (or egg membrane or animal bladder) and tie it securely. Invert the thistle funnel in a beaker containing water and suspend it as shown in Fig.4.4. Mark the level of the sugar solution on the stem of the thistle funnel. This is the **experimental set-up**.

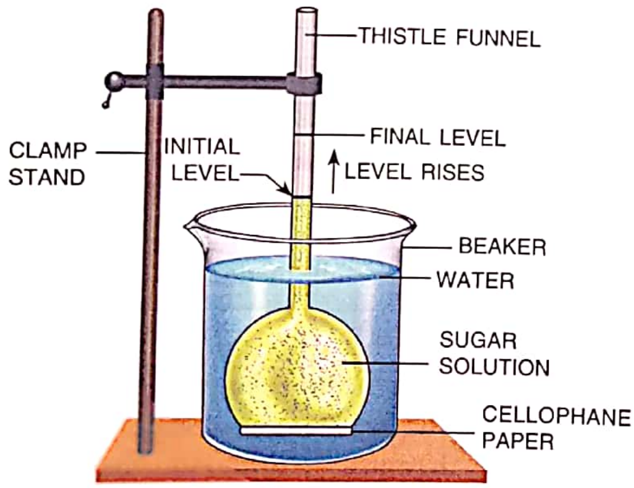

Fig. 4.4 : Experiment to demonstrate osmosis, showing thistle funnel containing sugar solution

As a **control** (for comparison), take another thistle funnel with plain water filled in it and suspend it in another beaker also containing water. Again mark the level on its stem.

- After a few hours, the level of the sugar solution in the thistle funnel in the **experimental set-up** will rise.
- The level of water in the thistle funnel **in the control** will remain unchanged.
- The level of water in the beaker in the experiment will drop slightly while the one in the beaker in the control will remain unchanged.
- If the water in the beaker in the experimental set-up is tasted, it is **not found sweet.**

Three main conclusions from this experiment:

1. In the experimental set-up, some water of the beaker has passed through the cellophane paper to enter the thistle funnel containing the sugar solution.
2. Sugar from the thistle funnel has not passed into the beaker.
3. The cellophane paper has acted as *selectively* or *differentially permeable membrane.* It has **allowed water molecules to pass through**, but **not the sugar molecules.**

Modified version of experiment 2

Experiment 3. If you had slightly modified the experimental set-up in Fig. 4.4 by taking a more concentrated sugar solution in the thistle funnel and very dilute or less concentrated sugar solution in the beaker, the result would still be the same, *i.e., the level of the solution in the thistle funnel would rise.* This again is because some water from the less concentrated sugar solution in the beaker would move into the more concentrated sugar solution in the thistle funnel, by crossing through the cellophane paper.

Rubber sheet and muslin cloth instead of cellophane as a barrier

If in the set-up, we had used a rubber sheet and in another similar set-up, a muslin cloth instead of cellophane as in the above experiment, what would happen? Obviously, no change in the **level of sugar solution** would occur in the first case — **the rubber sheet is impermeable** and would not allow the water molecules from the beaker to cross over to the other side.

In the second case, the meshes or **pores of the muslin cloth are so large** that they would not hold

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back even the sugar molecules, and the entire sugar solution would flow down to a common level due to gravity. The muslin cloth is, therefore, freely permeable for sugar solution.

The same experiment can be performed by using a visking bag (semi-permeable membrane) as shown in Fig. 4.5. Place sugar solution in a knotted visking bag and insert a long glass capillary tube till some of the sugar solution rises into the capillary tube. Tie the mouth of the bag firmly round the capillary tube and support it on a clamp stand. Immerse the visking bag in a beaker with water. After about an hour, the level of sugar solution in the capillary tube rises. This rise is due to the water molecules diffusing through the wall of the visking bag.

Two key points in the above experiments

1. There are two liquids of different concentrations. The sugar solution has a higher concentration of sugar molecules, whereas there may be fewer, or no sugar molecules in the beaker. It is very important to understand that the concentration can also be visualized from the side of the solvent, *i.e.* there are more water molecules in a unit volume in the beaker than in the same volume of sugar solution in the thistle funnel in Fig. 4.4. Thus, there are two regions of different concentrations **(tonicity)** which you may express in the following ways —

   (i) two regions of different concentrations of water molecules, or

   (ii) two regions of different concentrations of sugar molecules.

2. The two liquids are separated by a cellophane paper which behaves like a semi-permeable membrane. A ***semi-permeable membrane is one which allows the passage of molecules selectively.*** It allows a solvent (*e.g.* water molecules) to pass through it freely but prevents the passage of the solute (sugar or salt molecules in solution) (Fig. 4.6). Till here reading

How long can osmosis continue ?

Theoretically, osmosis should continue until the concentration of water molecules becomes equal (isotonic) on both sides of the membrane. In the experiment shown in Fig. 4.4, the column of sugar solution in the thistle funnel keeps rising upwards with the influx of water from the beaker, and with it, the height and weight of this column of solution would also increase. Such an increase in the height and weight of the rising column reduces further osmosis. But A stage will be reached when no osmosis

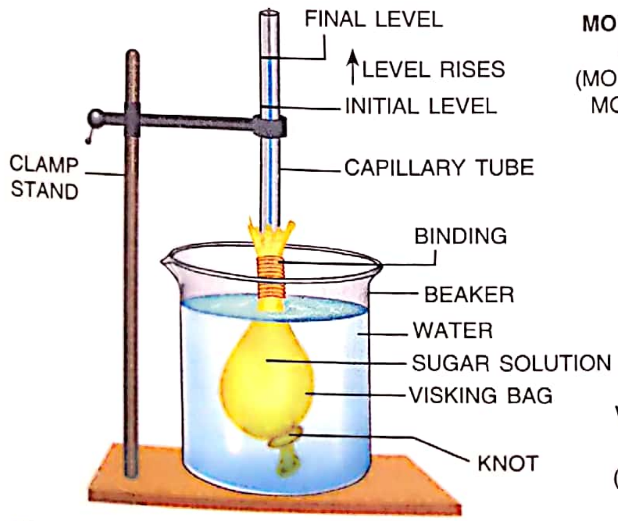

Fig. 4.5 : Experiment showing osmosis by using Visking bag containing sugar solution

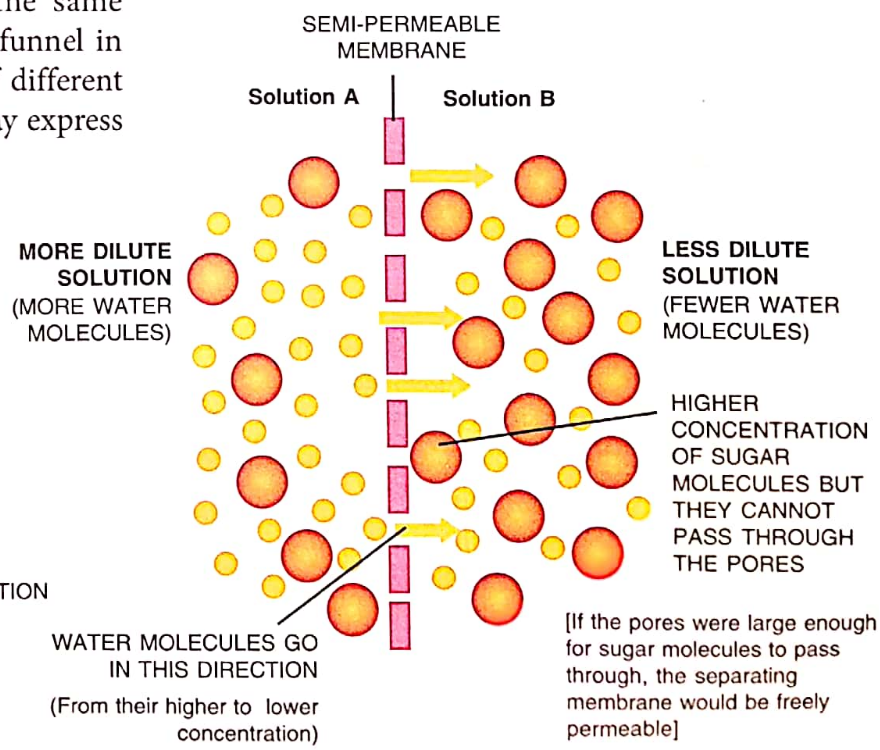

Fig. 4.6 : Schematic representation of osmosis and the nature of a semi-permeable membrane

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occurs even if the concentration of water molecules is not the same on the two sides of the membrane. In this state of equilibrium, the water molecules from the beaker tend to force upwards through the membrane, but the weight or the pressure from above holds them downwards.

B. OSMOTIC PRESSURE

If in the above experiment (Fig. 4.4), an airtight piston bearing some weight was introduced in the thistle funnel from the very beginning as shown in Fig. 4.7, the level of the solution would not rise at all, showing thereby that there was no entry of water. Thus, we may say that osmotic pressure is equal to the weight or pressure required to nullify osmosis.

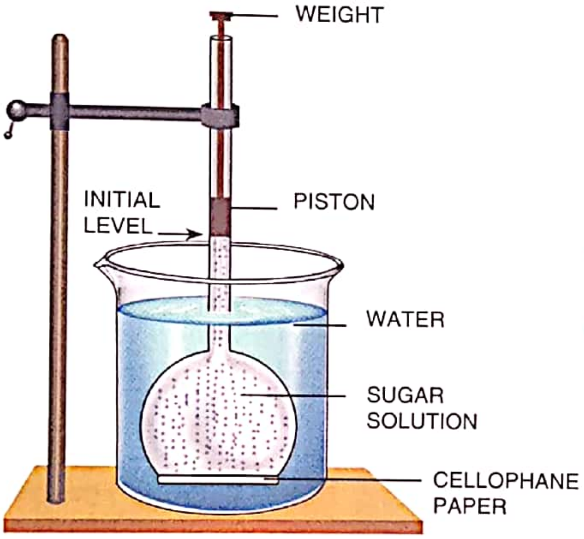

Fig. 4.7 : An experiment to demonstrate osmotic pressure

> Osmotic pressure is the minimum pressure that must be exerted to prevent the passage of the pure solvent into the solution when the two are separated by a semi-permeable membrane.
>
> OR, very simply
>
> Osmotic pressure of a solution is a *measure* of its tendency to take in water by osmosis.

TONICITY. Relative concentration of the solutions that determine the direction and extent of diffusion is called tonicity. Based on it, the solution can be of three types : **isotonic, hypotonic** and **hypertonic** solutions.

Read & write the points in short = 1, 2, 3 & A, B, C

1. ***Isotonic*** (*iso* : same, *tonus* : tension concentration). The relative concentration of water molecules and the solute on either side of the cell membrane is the same. In such a solution, there is no net movement of water molecules across the cell membrane. (**No osmosis**)
2. ***Hypotonic*** (*hypo* : lower). In this condition, the solution outside the cell has a lower solute concentration than the fluids inside the cell. As a result, the water molecules from outside will move into the cell (**endosmosis**).
3. ***Hypertonic*** (*hyper* : higher). In this condition, the solution outside the cell has a higher solute concentration than the fluids inside the cell. Consequently, the water molecules from the interior of the cell will move out (**exosmosis**).

To understand the above three conditions, we may suppose that (i) a red blood cell and (ii) a plant cell have been placed in three different kinds of solutions as shown in Fig. 4.8.

The results may be as follows :

A. Cell shape and size remain unchanged – The solution outside is **isotonic** (**iso:** similar).

B. Cell shrinks in size and loses shape – The solution outside is **hypertonic** (**hyper:** higher).

C. Cell slightly enlarges or even bursts – The solution outside is **hypotonic** (**hypo:** lower).

[When fully distended, the cell is called *turgid*, *i.e.*, when it cannot withstand any further inflow of water molecules].

In the case of plant cells, another striking feature determines the behaviour of the cell when subjected to varying external fluid environments. This feature is the **rigidity of the cell wall** which resists bulging and protects the delicate cellular parts inside. The phenomena related to this behaviour are **turgidity**, **plasmolysis** and **flaccidity** (described later in section 4.4.5).

4.4.4 Active Transport

> Active transport is the passage of a substance (salt or ion) from its lower to higher concentration through a living cell membrane using energy from the cell. [Active transport is in a direction opposite to that of diffusion.]

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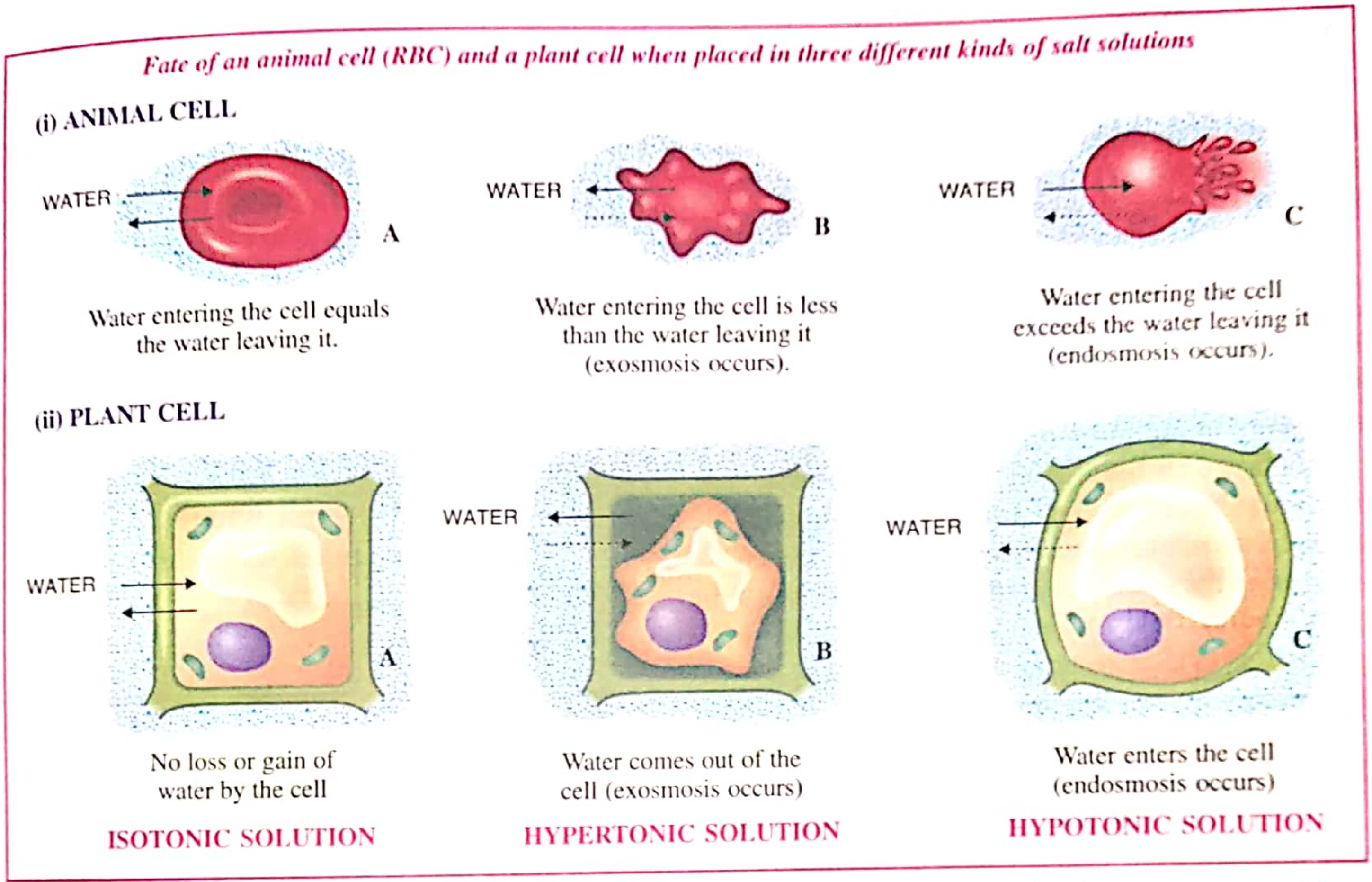

Fig. 4.8 : Salt solutions of different concentrations in relation to cells. Upper — human red blood cell; Lower — a plant cell. These were placed in — A. isotonic solution; B. hypertonic solution; C. hypotonic solution.

Read to understand.

Certain nutrients such as ions of nitrates, sulphates, potassium, zinc, manganese, etc. **cannot pass through the cell membrane of the root cells easily**. This is because their concentration is higher inside the root cells, and it is so maintained in order to develop osmotic pressure for absorbing water. In this way, the concentration gradient of these ions is opposite to that of diffusion. In other words, to obtain them, these ions will have to be **"forcibly"** carried inward from the region of their lower concentration outside to the region of their higher concentration inside, and this requires energy supplied by the cell in the form of ATP.

PASSIVE TRANSPORT

Passive transport is nothing different from diffusion "Passive" refers to requiring no input of energy. There is a free movement of molecules from their higher concentration to their lower concentration.

? Progress Check

1. Write true or false.
   (i) Diffusion is the movement of molecules from a region of their lower concentration to that of a higher one. ☐
   (ii) Osmosis includes diffusion, but not vice versa. ☐
   (iii) Osmosis is unidirectional. ☐
   (iv) Exosmosis may cause bursting of a cell. ☐
   (v) Semi-permeable membrane prevents the passage of the solute molecules. ☐
   (vi) In an experiment on osmosis, if external pressure is applied on a dilute solution, less water will pass into the concentrated solution. ☐

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2. In what way is active transport opposite to diffusion?
3. A cell kept in a certain solution bursts after some time. Comment upon the kind of solution.
4. Which process– diffusion, osmosis or active transport, needs involvement of energy ?
5. Can we call diffusion passive transport ? If so, how?

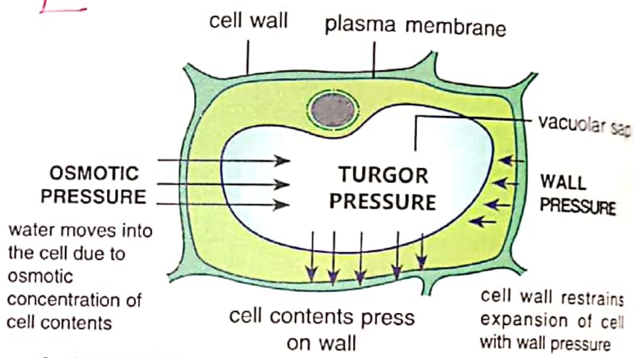
4.4.5 Turgidity and Flaccidity

Every living plant cell, 'directly or indirectly' is in contact with fluids. The root hairs, in particular, are surrounded by soil water. All such cells are subjected to osmosis and the water continues to enter as long as the cell sap is more concentrated than the surrounding fluids.

- When a cell reaches a state where it cannot accommodate any more water, *i.e.*, it is fully distended, it is called **turgid** and the condition is called **turgidity**.
- When a cell is turgid, its wall is stretched under pressure from inside, and in its turn, it presses the cell contents towards the centre of the cell. *The pressure of the cell contents on the cell wall is called* **turgor pressure** and the pressure exerted by the cell wall on the cell content is called **wall pressure**.
- If, at any time, the cell wall is unable to bear the turgor pressure, it ruptures and the cell contents burst out. This is exactly what happens when fruits and vegetables sometimes burst.

Read

- **When turgid, the cell is in a somewhat balanced state** — no more water is entering or leaving it. Its turgor pressure counter-balances the wall pressure and, therefore, there is no further absorption of water even though the concentration of solutes inside the cell may be greater than that outside the cell.



A plant cell showing osmotic pressure, turgor pressure and wall pressure represented together

Imp. Read full.

Plasmolysis and Flaccidity : When a living cell, such as the cell of a leaf of an aquatic plant, is placed

Imp Can learn from here only

Table 4.1 : Differences between diffusion, osmosis and active transport

DIFFUSION	OSMOSIS	ACTIVE TRANSPORT
1. ***Diffusion*** is the transport of **gases** or **dissolved substances** in solution from a region of high concentration to a region of low concentration when the two are in direct contact.	***Osmosis*** is the transport of **water** through a semi-permeable membrane from a solution of low concentration to a solution of high concentration.	Active transport is the passage of salt or an ion from its lower to higher concentration using energy from the cell through a living membrance.
2. **Liquids and gases can diffuse over considerable distances.**	**Water** only transported over a short distance.	Cell energy from ATP is needed for transpiration.
3. Movement of the molecules of **solute** or **solvent.**	Movement of the molecules of **only water** as a solvent.	Movement of ions only other than water.
4. **Rapid in gases**, but slow in solutions.	**Slow** process	Rapid process.
5. Transport from **high** to **low** concentration along a **gradient.**	Transport of **water** from a solution of low concentration (more water molecules) to that of a **high** concentration (fewer water molecules).	It is movement of molecules against a concentration gradient.
6. Occurs with or without a non-living **permeable** membrane.	Either a living or non-living **semi-permeable** membrane needed.	A living selective membrane is essential.

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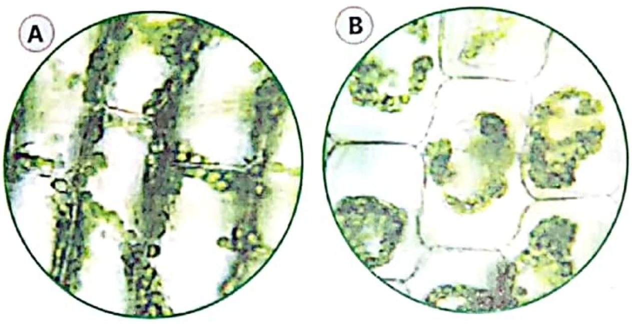
in fresh water, it remains in a fully distended condition. Its plasma membrane remains in close contact with the cell wall and presses against it (Fig 4.9 A and C) just like a rubber bladder of a football pushing against the leather casing. If this plant cell is now kept in 5% salt solution for a few minutes, it will lose its distended appearance, the cytoplasm will shrink and the plasma membrane will withdraw from the cell wall (Fig. 4.9 B and D-F). This shrinkage from the cell wall is called **plasmolysis** and the cells in this state are said to be limp or **flaccid** (the condition is called **flaccidity**). *Flaccidity is the reverse of turgidity*. If, however, a plasmolysed (flaccid) cell is returned to water before it is dead, its protoplasm again swells up pressing tight against the cell wall. The recovery or the reversal of plasmolysis is called **deplasmolysis**. You can easily understand that plasmolysis is the result of outflow of water from the cell and deplasmolysis is the result of its re-entry.

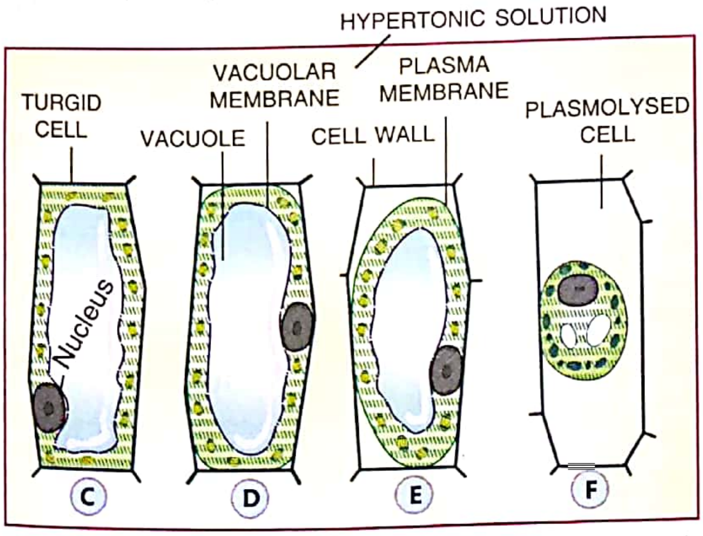


A – Cells in water, in normal turgid condition

B – After keeping in 5% salt solution for a few minutes, the protoplasm shrinks and the cell becomes flaccid (plasmolysed). If the plasmolysed cell is soon returned to the ordinary water, it regains its original (turgid) condition (deplasmolysed).

Fig. 4.9 : UPPER (A and B) : Plasmolysis of leaf cells in a water plant

LOWER (C - F) : Diagrammatic representation of sequence in plasmolysis



C – a turgid cell, **D, E & F** – the cell after immersion in a hypertonic solution showing the successive stages in the shrinkage of the protoplasm from the cell wall caused by the withdrawal of water from the vacuole, after immersing the cell in a hypertonic solution.

The terms defined

Imp

Turgidity is the state of a cell in which the cell wall is rigid and stretched by an increase in the volume of vacuoles due to the absorption of water. The cell is then said to be turgid.

Plasmolysis is the contraction of cytoplasm from the cell wall caused due to the withdrawal of water when placed in a strong (hypertonic) solution.

Flaccidity is the condition in which the cell content is shrunken and the cell is no more "tight". The cell is then said to be flaccid.

USES OF TURGIDITY TO PLANTS

Read

1. *Turgidity provides rigidity to soft tissues such as the leaves.* When there is not enough water in a leaf, it wilts, *i.e.*, its petiole and lamina become loose and the leaf droops down.
   - Wilting of the leaves is usually noticed when a plant is exposed to the hot afternoon sun when the amount of water lost during transpiration is more than the water absorbed through the roots.
   - In the evening, when transpiration is reduced, the quantity of water absorbed exceeds the loss of water through transpiration, the turgidity of the leaf cells is restored and the leaves again stand out.

V.Imp **Plasmolysis in practice** Can learn from here

Salting of meat or addition of salt to pickles is a method of killing bacteria by plasmolysis - water is drawn out of the bacterial cells.

Weeds can be killed in a playground by sprinkling excessive salts around their base. Excessive application of fertilizers in the agricultural fields may similarly damage the roots and diminish the yield.

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2. ***Turgor pressure helps to push through the hard ground*** as in mushrooms and in a seedling (Fig. 4.10). Sometimes, the roots of certain trees (can) have been seen to crack the walls or a concrete floor of an adjoining building. This again is due to turgor pressure.

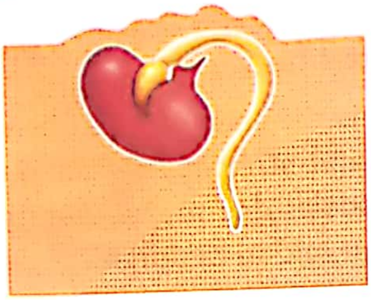

Fig. 4.10 : A germinating seed develops force to push through the upper layers of the soil

3. ***Turgor in root cells builds up root pressure :*** If you cut a well-watered pot plant (e.g. balsam) a few centimetres above the soil and immediately fix a glass tubing to it by means of a rubber connection, water will start coming out of the cut end of the stem and rise up in the glass tubing. This rising water can raise the mercury filled in a connected manometer (Fig. 4.11). This upward flow of water is due to a heavy pressure from the roots which is called **root pressure.**

Read

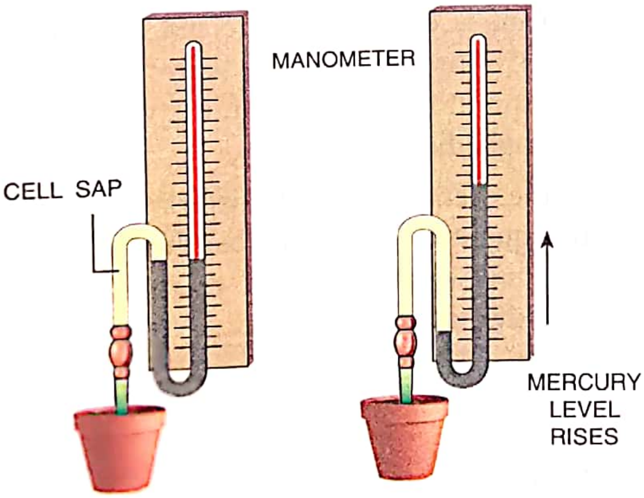

Fig. 4.11 : An experiment to demonstrate root pressure

> ***Root pressure*** is the pressure developed in the roots due to continued inward movement of water through cell-to-cell osmosis which helps in the ascent of cell sap upward through the stem.

Due to root pressure, water (cell sap) can rise in the tube (or in the stem in natural condition) up to a certain height only. Loss of water (cell sap) through a cut stem is called **"bleeding"**.

4. ***Turgor in the opening and closing of stomata :*** You have read about stomata in Class IX. Their opening and closing depend on the turgidity of guard cells. Each guard cell has a thicker wall on the side facing the stoma and a thin wall on the opposite side. Guard cells contain chloroplasts (Chapter 6, Fig. 6.2). As a result of the synthesis of glucose during photosynthesis and some other chemical changes, the osmotic pressure of the contents of the guard cells increases and they absorb more water from the neighbouring cells, thus becoming turgid. On account of turgor, the guard cells become more arched outwards and the aperture between them widens, thereby opening the stoma. At night or when there is shortage of water in the leaf the guard cells turn flaccid and their inner rigid walls become straight, thus closing the stomatal aperture.

Read full

5. ***Turgor Movement :*** The rapid drooping of the leaves of the sensitive plant (*Mimosa pudica*) is an outstanding example of turgor movement. If one of the leaves is touched, even lightly, the leaflets fold up and within 2 to 3 seconds, the entire leaf droops. If the leaf is touched somewhat strongly, the wave of folding and drooping spreads from the stimulated leaf to all neighbouring leaves. Slowly, the leaves recover

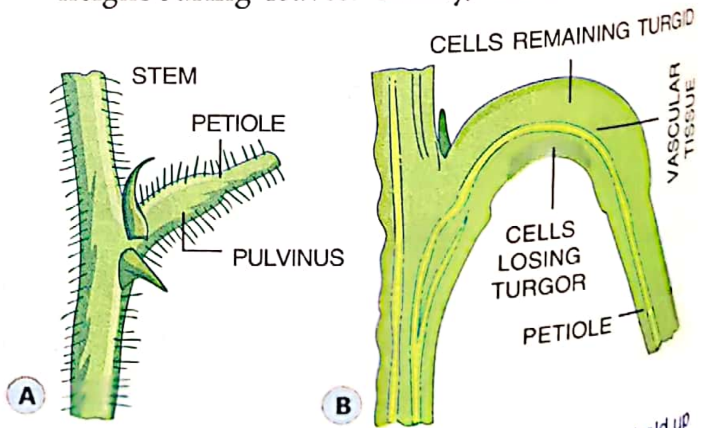

Fig. 4.12 : Petiole of sensitive plant (*Mimosa pudica*) is held up by turgid pulvinus tissue (left). When leaf is touched, cells of the lower side of pulvinus lose water, and the petiole collapses (right)

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and again stand erect. In this plant, the stimulus of touch leads to loss of turgor at the base of the leaflets and at the base of the petioles called *pulvinus* (Fig. 4.12). Somewhat similar turgor movements are found in insectivorous plants whose leaves close up to entrap a living prey.

The bending movement of certain flowers towards the sun and the sleep movements of the leaves of certain plants at night are also due to turgor movements.

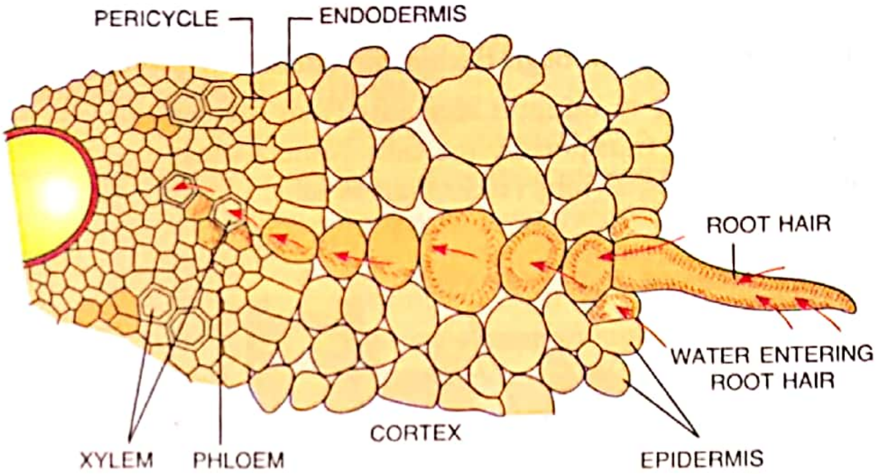

Fig. 4.13 : Diagrammatic cross-section of a part of a root showing by arrows the cell-to-cell conduction of water from a root hair to xylem

Read imp

IMBIBITION AND TURGOR TOGETHER GENERATE MUCH FORCE

Imbibition is the passive absorption of water by substances such as cellulose (in cell wall) and starch. Turgor is the pressure set up inside the plant cells due to hydrostatic pressure on the cell walls on account of incoming water as a result of endosmosis. The seeds and grains swell up when soaked in water due to imbibition and endosmosis. The force generated by the water thus absorbed is strong enough to make the seed coats burst. Some other observed examples are as follows :

— Soaked seeds when kept in a fully filled closed container burst it open with a great pressure.

— Basement godowns fully stocked with bags containing **foodgrains** have got their walls cracked after the **rain-water** has flooded in.

4.5 ROOT PRESSURE

Experience : If you cut off the shoot of a plant, the water pushes out from the root stump. This is due to root pressure.

Root pressure is built up due to cell-to-cell osmosis in the root tissue (Fig. 4.13 & 4.14). As one turgid cell presses the next cell, the force of the flow of water increases inward. When water reaches the xylem vessels (centrally placed vertical channels), it enters the pores of their thick walls with considerable force. Thus, the root pressure is one of the forces to raise water up through the stem into the leaves (Fig. 4.14). But this force alone cannot push water up to the top of a tall tree (you will read more about it in section 4.7).

Guttation : In certain plants, like tomato, grass, banana or ferns, the root pressure is high enough to force the water all the way through the stem and comes out through the ends of leaf veins. This water apppears as tiny drops along the margins or the tips of the leaves (next chapter Fig. 5.12), especially in the early mornings. This loss of excessive water is called **guttation**.

? Progress Check

1. Name the following :
   (i) The state of a cell when it cannot accommodate any more water.
   (ii) Pressure of the cell contents on the cell wall.
   (iii) The condition that is opposite to turgid.
   (iv) The state of a plasmolysed cell after the re-entry of water.
   (v) The pressure under which water passes from the living cells of a root into xylem.

4.6 IMPORTANCE OF ROOT HAIRS AND THE UPWARD MOVEMENT OF ABSORBED WATER AND MINERALS

Absorption of water by the root is by means of root hairs. A root hair contains cell sap which has a higher concentration of salts as compared to the outside soil water. This difference sets off osmosis and the outside water diffuses into the root hair. From the cell bearing root hair, water continues to pass to adjoining cells one after another to finally enter the xylem vessels (Fig. 4.13 and 4.14). The turgidity

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