4 Absorption by Roots — The Processes Involved

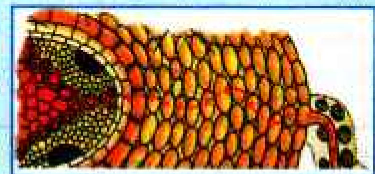
Syllabus:

(i) Absorption by roots; imbibition; diffusion and osmosis; osmotic pressure; root pressure; turgidity and flaccidity; plasmolysis and deplasmolysis, the absorption of water and minerals, active and passive transport (in brief); the importance of root hair.

(ii) The rise of water up to the xylem; a general idea of Cohesive, Adhesive forces and transpirational pull); demonstrated by the use of dyes.

Scope of syllabus : Characteristics of roots, which make them suitable for absorbing water, should be discussed with the process of absorption. Structure of a full-grown root hair should be explained.

Experiments to show the conduction of water through the xylem should be discussed. Mention of the causative forces must be made for better understanding but as per the syllabus.



Plant physiology is the branch of biology which deals with the **life functions** of the plant. It includes the functioning of cells, tissues, organs, organ-systems and the organism as a whole. This chapter deals with some of the most fundamental processes like osmosis, which have tremendous significance in the life of all organisms.

4.1 ABSORPTION BY THE ROOTS

The roots fix the plant in the soil giving it support but the most important and life-supporting function of the roots is to absorb

(A) ***water*** and

(B) ***mineral nutrients*** *from the soil,*

and conduct them into the stem for supply to the leaves, flowers, fruits, etc.

4.2 NEED OF WATER AND MINERALS FOR PLANTS

A. Need of water

Besides being a constituent of protoplasm, water is needed inside the plant body for four purposes : **photosynthesis, transpiration, transportation** and **mechanical stiffness.**

1. ***Photosynthesis :*** Water is used up in the green leaves as a raw material in the synthesis of glucose.
2. ***Transpiration :*** A large quantity of water is passed out as water vapour during transpiration, for cooling in hot weather, for producing a suction force, etc.
3. ***Transportation :*** Transportation of substances in water solution from the roots upward into the shoot (mineral salts) or from leaves to other parts (sugar, etc).
4. ***Mechanical stiffness :*** Water provides turgidity (fully distended condition), which is necessary for the stiffness of plant tissues.

B. Need of mineral nutrients

Mineral nutrients required by the plant are absorbed from the soil by the roots only. Some of these nutrients are absorbed as salts (nitrates, phosphates, sulphates, etc.) and some simply as ions (potassium, calcium, magnesium, chlorine, etc.). These elements are required as constituents of cell and cell organelles as well as in the synthesis of a variety of compounds or enzymes within the cell.

4.3 CHARACTERISTICS OF ROOTS FOR ABSORBING WATER

The ability of the roots to draw water from the soil is dependent on three characteristics : (i) **a huge surface area** provided by rootlets and root hairs, (ii) Root-hairs containing the solution (cell sap) at a **concentration higher** than that of the surrounding soil water and (iii) Root hairs having **thin walls**.

(i) **Surface area of roots is enormous** (Fig. 4.1).It is a common experience that even a small garden plant such as balsam, when gently uprooted from the soil, shows a thick bunch of rootlets (branch roots).

When carefully examined, each rootlet would show hundreds of root hairs. If all the root hairs of this plant were to be laid end to end, they would cover a length of many kilometres.

Fig. 4.1 : A freshly germinated seed showing the single root with root hairs

A botanist H.J. Dittmer (1937) worked out that a four-month-old rye plant had an aggregate root length of about 600 km. The number of root hairs in it exceeded 14 billion and their estimated total length would even exceed 10,000 km. Thus, altogether, the roots of any plant provide a huge surface area to facilitate the absorption of water.

(ii) **Root-hairs contain cell sap, of a higher concentration than that of the surrounding water.** Root hairs are the extensions of the outer (epidermal) cells of the root. They also contain large vacuoles filled with a sort of solution called cell sap. Some salts are dissolved in it and the cell sap, therefore, usually has a concentration higher than that of the surrounding water. This characteristic is an important requirement to draw in the outside water, i.e. for the occurrence of osmosis, which is described later (page 36).

(iii) **Root-hairs have thin walls.** Like all plant cells, root-hairs also have two outer layers – a cell wall and a cell membrane (Fig. 4.2).

- The cell wall is **thin** and **permeable**. It allows the movement of water molecules and dissolved substances freely in and out of the cell.

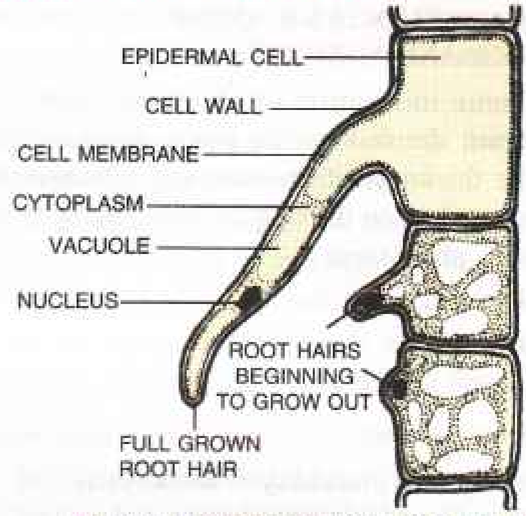


Fig. 4.2 : A single full grown root hair and two more in successive stages of growth from the epidermal cells

- The cell membrane is **very thin**, and **semi-permeable**, which means that it allows water molecules to pass through, but not the larger molecules of the dissolved salts. The secret of the absorption of water from the soil by the roots lies mainly in this characteristic.

? PROGRESS CHECK

1. List the three primary functions of root.
   (i) ....
   (ii) ....
   (iii) ....
2. Mention four purposes for which the plants need water.
   (i) ....
   (ii) ....
   (iii) ....
   (iv) ....
3. Where are the mineral nutrients mostly used in plants?
   ....
4. List three main characteristics of the roots that suit them to draw water from the soil.
   (i) ....
   (ii) ....
   (iii) ....

4.4 ABSORPTION AND CONDUCTION OF WATER AND MINERALS

The entire mechanism of absorbing water and 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 (Plasmolysis)

4.4.1 Imbibition :

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

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.

Activity. 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.

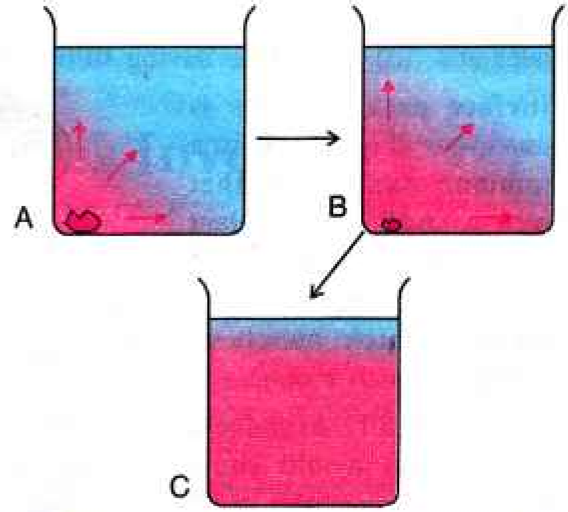


Fig. 4.3 : Diffusion of a soluble dye in water, forming a solution (schematic).
A – Diffusion started,
B – Diffusion progressing,
C – Diffusion completed, making a homogeneous solution; molecules of the solute are evenly distributed in the solvent.

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) to their region of lower concentration (concentrated solution) through a semi permeable membrane.

What is most important 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 (water molecules) lower concentration (in stronger solution or just a solution in relation to pure water).

Inward and Outward Osmosis

With reference to a cell, the 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 cell, in which direction will the net movement of water molecules be across the cell membrane?

INWARD / OUTWARD / NO NET MOVEMENT.

An experiment to explain 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**.

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.

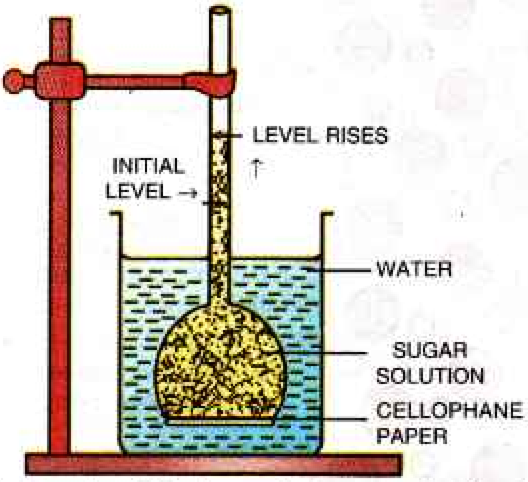


Fig. 4.4 : Experiment to demonstrate osmosis, showing thistle funnel containing sugar solution

- 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**.

The same experiment modified

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 moved into the more concentrated sugar solution in the thistle funnel, by crossing through the cellophane paper.

Rubber sheet and muslin 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 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.

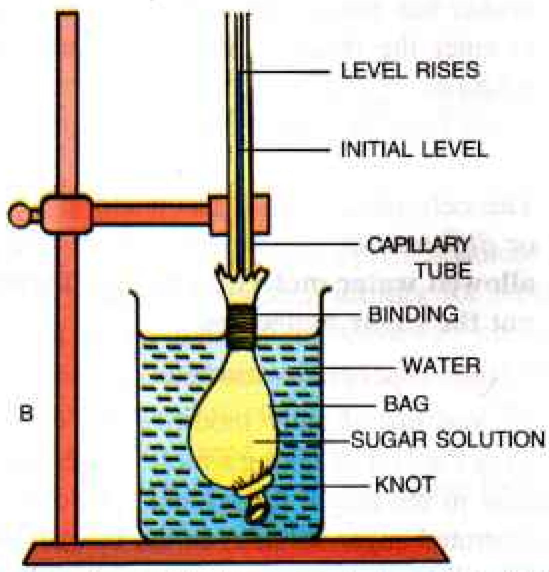


Fig. 4.5 : Experiment showing osmosis by using Visking bag containing sugar solution

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).

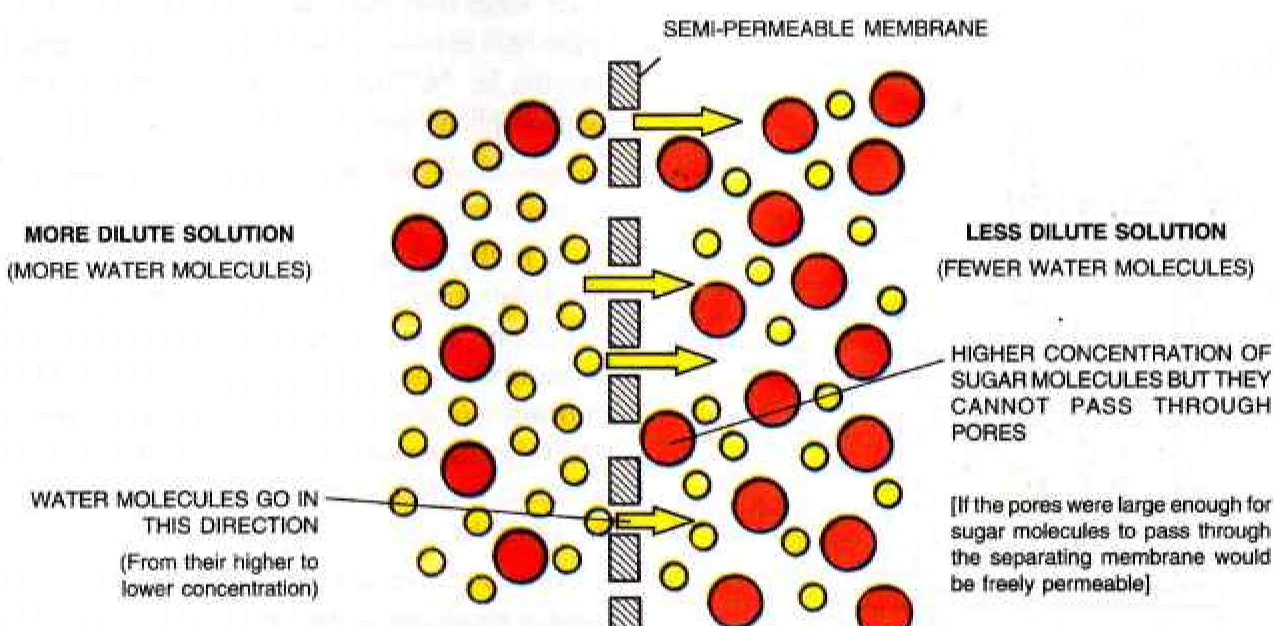


Fig. 4.6 : Schematic representation of osmosis and the nature of a semi-permeable membrane

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 weight of this column of solution would also increase. Such an increase in the weight of the rising column reduces further osmosis. A stage will be reached when no osmosis 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

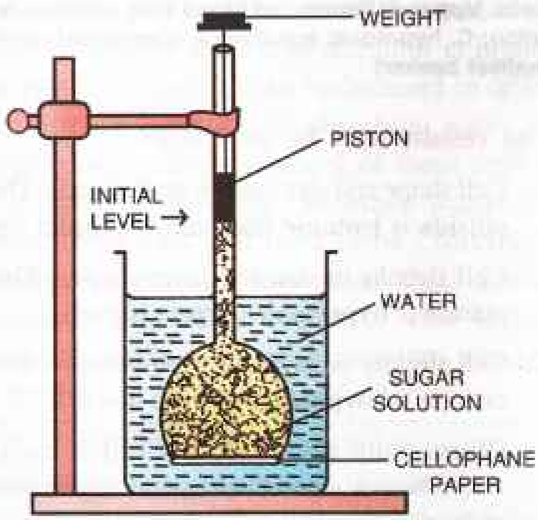


Fig. 4.7 : An experiment to demonstrate osmotic pressure

all, showing thereby that there was no entry of water. Thus, we may define osmotic pressure as:

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.

In other words, osmotic pressure is equal to the weight or pressure required to nullify 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.

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)**

SWELLING UP OF RAISINS & SHRINKING OF GRAPES???

Practically all biology books mention the following:

"If you leave some raisins in water for a few hours, they swell up and if kept for long, they may even burst. In this case, the water continues to diffuse in through the membranous cover of the raisins. This influx of water builds up an internal pressure that may reach a limit, which the outer skin of raisins may no longer bear and they burst. The reverse will happen if grapes are immersed in a very strong sugar solution or even salt solution (25 - 30%). The water from the grapes will be drawn out and they will shrink".

How much is the truth ?

1. Raisins left in water for some time certainly swell up. The condition is reached due to passive absorption (imbibition).
2. The opposite experiment with grapes is doubted. I (the author) have tried it repeatedly and I would urge all biology teachers and students to try it and see if it really works the way we talk and teach about it. In my trials, fresh ripe grapes were kept in a fully saturated sugar solution for almost a week and nothing happened to the grapes! They did not shrink even a bit. How do we explain this ? In all probability, the outer skin of those grapes must have been impermeable.

   Science is in doing things to investigate, and certainly so in such simple cases as the above experiment with grapes.

An enthusiastic student Wasiya Fargana of St. Mary Public School, Bangalore, repeated this experiment and got the same result – no shrinking (no exosmosis). However, *when the grapes were kept in saturated common salt solution for about a week, they shrank a little bit with the peel turning brownish as well as somewhat wrinkled suggesting some exosmosis.* The exact explanation is not available – perhaps strong salt somehow degraded the peel cells (cuticle) to permit some exosmosis. But this is just a hypothesis – the exact reason may be different.

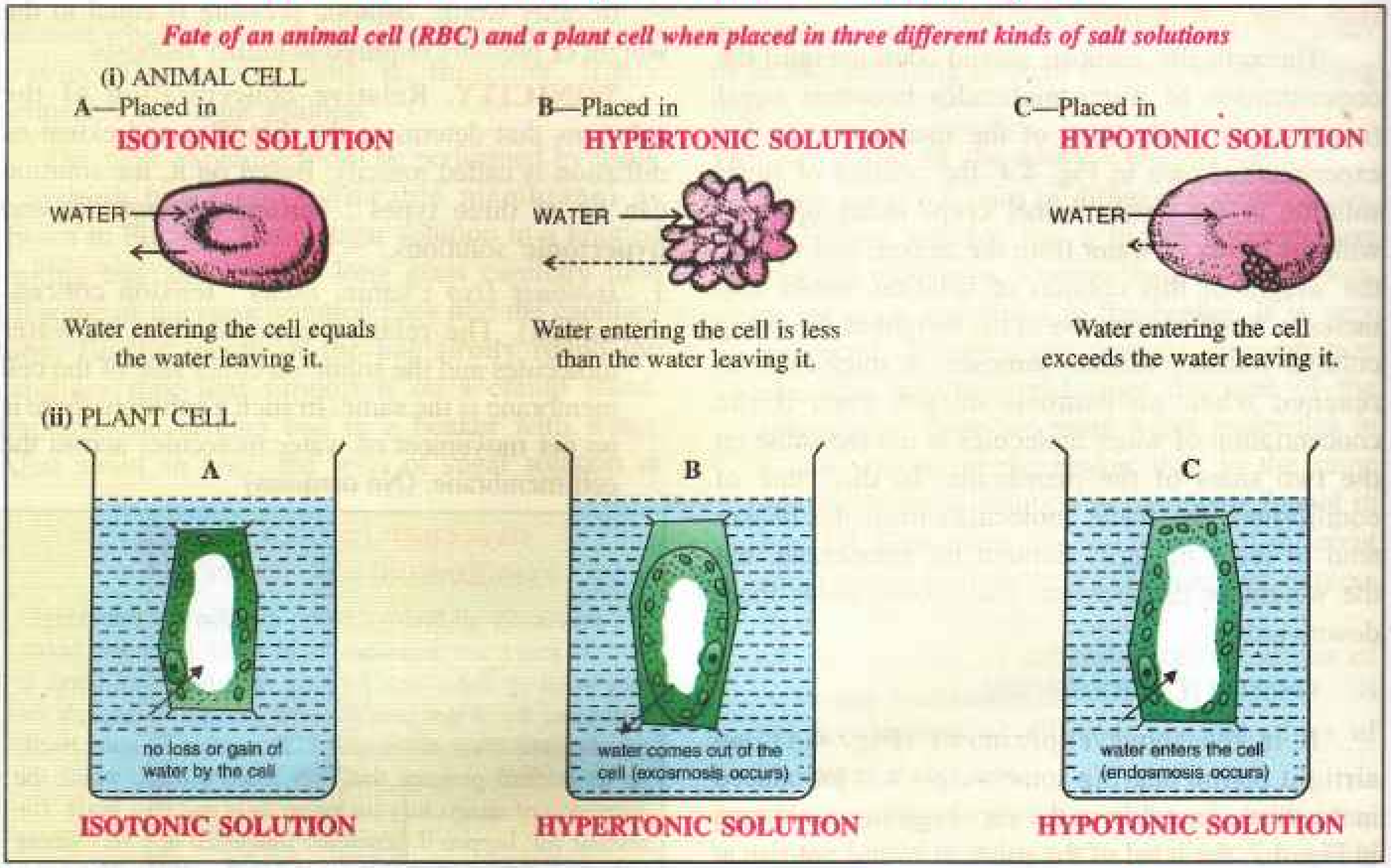


Fig. 4.8 : Salt solutions of different concentrations in relation to cells. Upper — human red blood cell; Lower — a plant cell. These were placed in — A. Isotonic solution; B. hypertonic solution; C. hypotonic solution (A conceptual representation only; even the largest plant cell cannot match the size of the smallest beaker)

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)**.

[The three terms **isotonic**, **hypotonic** and **hypertonic** are also expressed as **isoosmotic, hypoosmotic** and **hyperosmotic** emphasising the numerical basis of total moles of solute per kilogram of water.]

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, **tonic:** strength).

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 the **turgidity, plasmolysis** and **flaccidity** (described later in section 4.4.5 page 41).

Table 4.1 : Differences between diffusion and osmosis

DIFFUSION	OSMOSIS
1. **Liquids** and **gases** can diffuse over **considerable distances**	**Water** only transported over a short distance
2. Movement of the molecules of **solute** or **solvent**	Movement of the molecules of **only water** as a solvent
3. **Rapid in gases**, but slow in solutions	**Slow** process
4. 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)
5. Occurs with or without a non-living **permeable** membrane	Either a living or non-living **semi-permeable** membrane needed
Definitions *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

4.4.4 Active Transport

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

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 but just explaining its meaning. "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. Tick-mark the correct statements :
   - (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. ☐
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?

   ....

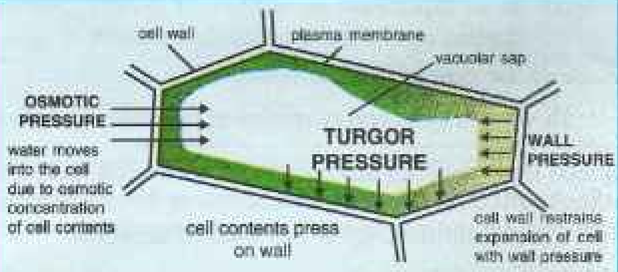
   ....

4.4.5 Turgidity and Flaccidity (Plasmolysis)

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.

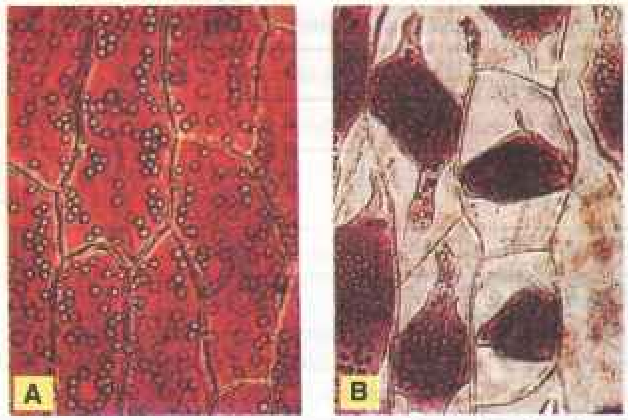
– When a cell reaches a state where it cannot accommodate any more water, *i.e.*, it is fully distended, it is called **turgid** and the condition is called **turgidity**.

- 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.
- **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

Plasmolysis and Flaccidity : When a living cell, such as the cell of a leaf of an aquatic plant, is placed 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 & C) just like a rubber bladder of a football pushes 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 & 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 the plasmolysis is the result of outflow of water from the cell and deplasmolysis is the result of its re-entry.

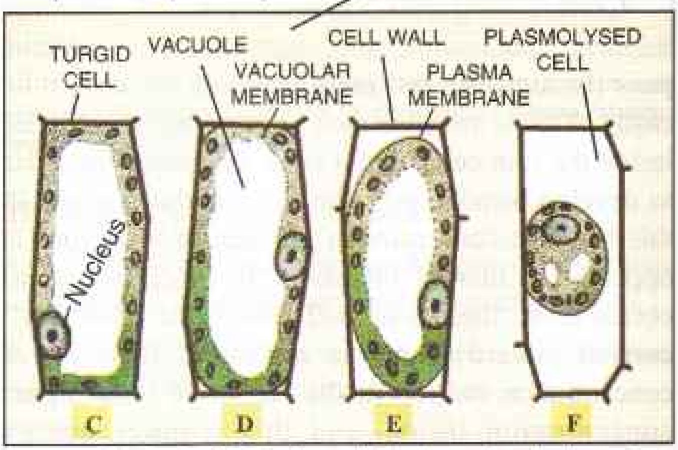


A – Cells in water, in normal turgid condition

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 & 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.

REMEMBER THE TERMS DEFINED

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

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.

Plasmolysis in practice

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.

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 have been seen to crack the walls or a concrete floor of an adjoining building. This again is due to turgor pressure.

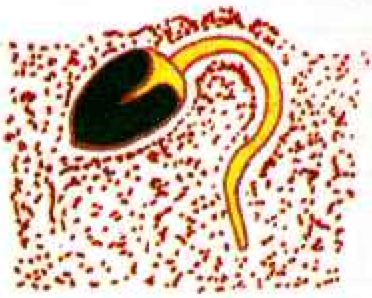


Fig. 4.10 : A germinating seed develops force to push through the upper layers of the soil

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**.

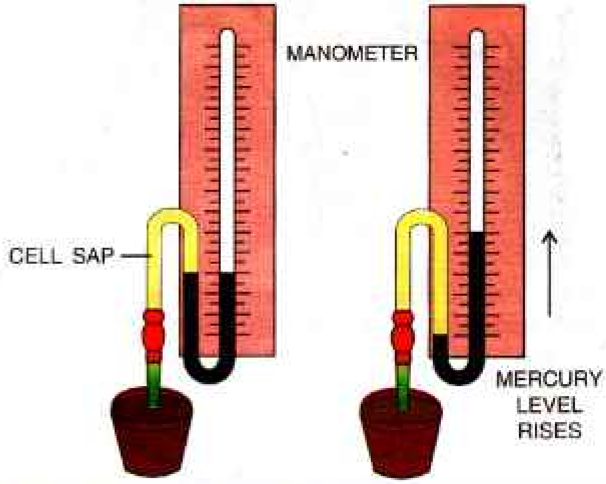


Fig. 4.11 : An experiment to demonstrate root pressure

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.

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.

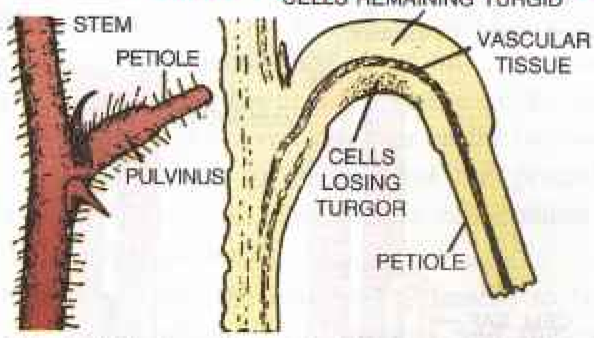


Fig. 4.12 : Petiole of sensitive plant (*Mimosa pudica*) is held up by turgid pulvinus tissue (left). When leaf is touched, cells of the lower side of pulvinus lose water, and the petiole collapses (right)

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 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.

4.5 ROOT PRESSURE

Root pressure is the pressure developed in the roots due to the inflow of water, brought about due to the alternate turgidity and flaccidity of the cells of the cortex and the root hair cell, which helps in pushing the plant sap upwards.

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

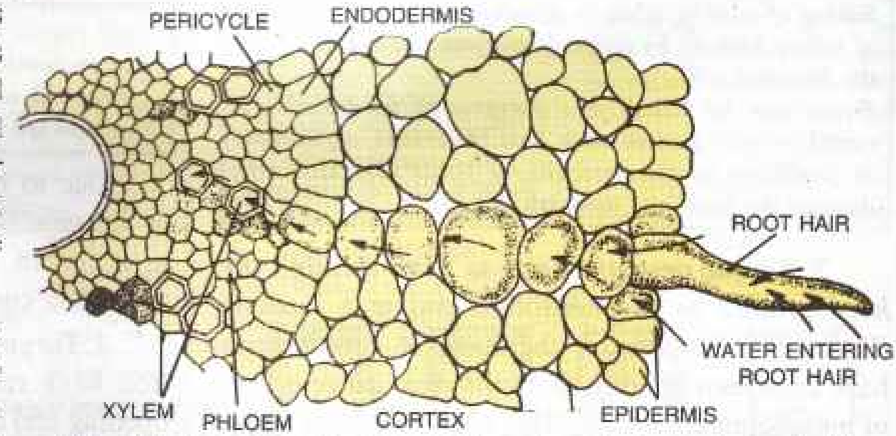


Fig. 4.13 : Diagrammatic cross-section of a part of a root showing by arrows the cell-to-cell conduction of water from a root hair to xylem

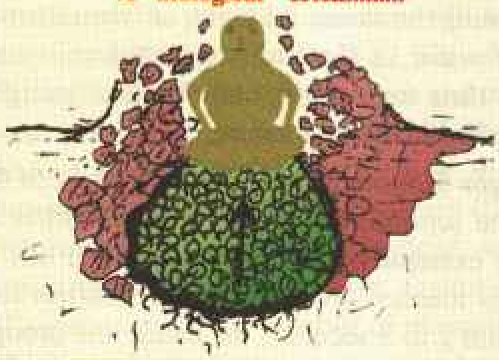
IMBIBITION AND TURGOR TOGETHER GENERATE MUCH FORCE

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** had flooded in.

A "biological" Trick.........



— Some cheats often play a trick. They take a large quantity of gram seeds, place them in a pit a couple of feet below the ground level, mount a "God" or a "Goddess" idol over the heap of grains and then cover up the entire set up by earth to level it with the ground. While one of the tricksters sits by the side of the spot, pretending to worship, the other sends word round the community that a certain "God" is to emerge on this spot in the next "couple of days". And it does "really happen!" The moisture in the ground gets into the seeds which swell up and create a force strong enough to push the earth above and then up and up emerges the "God" as the grains swell more and more. The ignorant faith-holding people are befooled.

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).

Drops of water along leaf margin due to excessive root pressure (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 part of a plant cell which is like the leather casing of a football ....
   (iv) The condition that is opposite to turgid. ....
   (v) The state of a plasmolysed cell after the re-entry of water ....
   (vi) 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 & 4.14). The turgidity acquired by the cells in the process also helps to push the water upwards through the xylem vessels.

Absorption of mineral elements from the soil involves active transport by the cells. Minerals may also be absorbed as ions rather than as salts.

The dilute solution of water and mineral salts, absorbed from the soil by the roots, can be used for food manufacture in the leaves, only if it can travel up to the highest points of the plant. This upward flow occurs through the xylem.

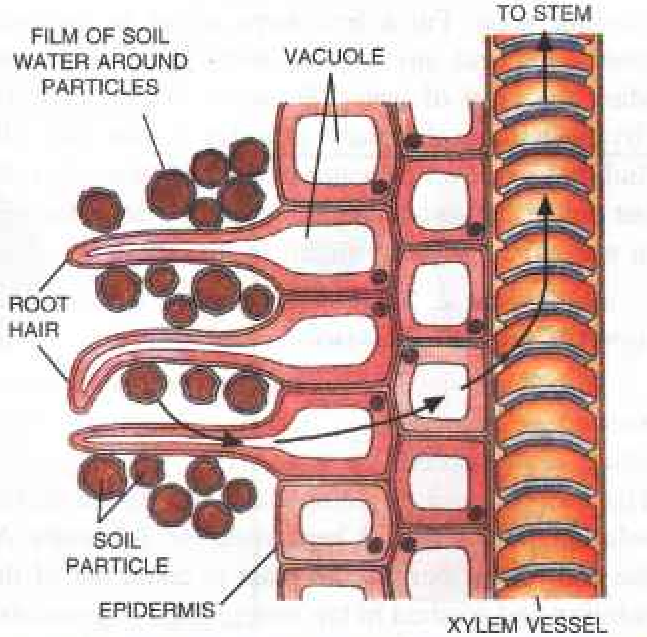


Fig. 4.14 : Root pressure builds up due to osmosis and turgidity of root cells, and up into the xylem vessel.

4.7 SOME EXPERIMENTS ON ABSORPTION AND CONDUCTION OF WATER IN THE PLANTS.

Experiment 1. **To show that roots absorb water** (Fig. 4.15).

Take a test-tube (A) filled with water. Pull out a young leafy plant (such as balsam) from the soil with its roots intact. Insert the roots into the

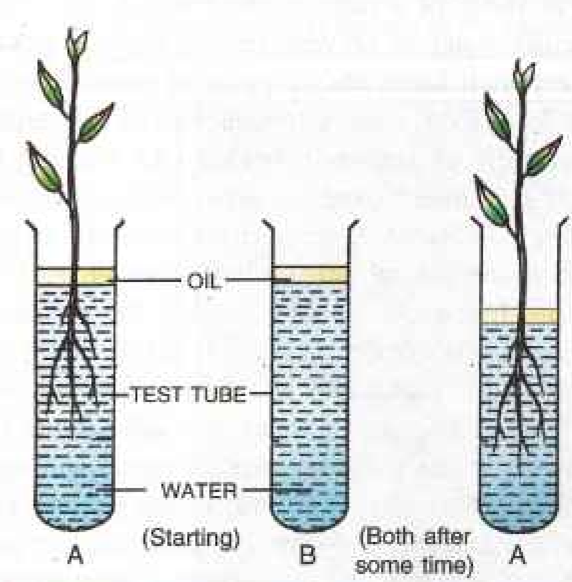


Fig. 4.15 : Experiment to show that the roots absorb water

test-tube soon. Put a few drops of oil in the test-tube to prevent any loss of water by evaporation. Mark the level of water. Set up a similar test-tube (B) but without the plant. In a day or two you will find that the level of water in the test-tube (A) falls but not in the test-tube (B), proving that water lost in test~tube A was absorbed by the roots.

***Experiment 2.* To show that water is conducted upwards through the xylem.**

A medium-sized young balsam plant is uprooted, washed and placed in a beaker containing a stain eosin solution (pink) in water (Fig. 4.16 page 47). The roots should be completely submerged in the solution. This set-up is kept aside for 3-4 hours. At the end of this period, the plant is taken out of the solution and washed in tap water. Then, a transverse section of the roots, stem and leaves is made and examined under a microscope. The xylem vessels will appear distinct from the rest, because these will be stained red by the dye.

Vascular bundles in the stem, root, leaf stalks and leaf veins are all continuous and form an unbroken system of tubes. Collectively, they form the transport system throughout the entire plant. Water and salt travel upwards mainly in the xylem and food substances travel up and down in the phloem.

Experiment 3. **Conduction of water through xylem** can also be shown by another but delicate experiment (Fig. 4.17 p. 47). Take two leafy shoots such as those of a balsam plant, which have been cut under water to prevent any air bubbles getting in. Keep their lower ends dipping in water. Remove about 3 cm long, outer ring (phloem) of the stem in one of them as shown in beaker (A), keeping the central part intact (ringing experiment also called **girdling**). In the other beaker (B), remove an equal length of the central part (xylem) after incising the stem for full thickness and keeping the peripheral part intact. The shoots are then fixed to stands and are allowed to remain for about two days with their lower ends immersed in water. It will be found that the leaves in the first twig remain turgid and stand out almost normally, but those in the second twig get wilted and droop down. The experiment proves that water is conducted upwards in a plant through the deeper part, *i.e.* xylem.

***Experiment 4.* To show that food from the leaves is conducted downwards through the phloem in the stem.**

Cut a ring round the stem of a healthy potted plant or around a thin twig of guava or any other tree, deep enough to penetrate the phloem and cambium but not the xylem (**girdling**). It will be seen that sap starts oozing out from the farther cut-margin of the stem showing thereby that sap in the peripheral parts flows in a downward direction. After some weeks, it will be observed that the part of the stem above the ring has grown in diameter (Fig. 4.18 p. 47), and the stem below the girdle has **stopped growing and may even die** when the stored organic contents of the lower part are exhausted. The fresh, healthy condition of the leaves, in this experiment, also proves that the leaves continue to get a supply of water through the deeper located xylem.

? ***PROGRESS CHECK***

1. Look at Fig. 4.15. Why was oil added over water in the test tubes ? ....
2. Look at the experiment shown in Fig. 4.16 on the next page. Why was it necessary to take coloured eosin solution in water in the beaker?
   ....
   ....
3. Which part in the stem, the xylem or the phloem, is located deeper internally ?
   ....
   ....
4. Look at Fig. 4.18 on the next page. Why has the stem below the ring stopped growing and even slightly decayed?
   ....

4.8 FORCES CONTRIBUTING TO ASCENT OF SAP

There are four main forces which contribute to the upward movement (ascent) of sap.

1. **Root pressure** builds up sufficient force to push the sap in the xylem vessels up to a certain height and may be enough for herbaceous plants.
2. **Capillarity** (narrow diameter) of xylem vessels causes the water from a lower level to rise to fill up the vacuum created by the loss of water due

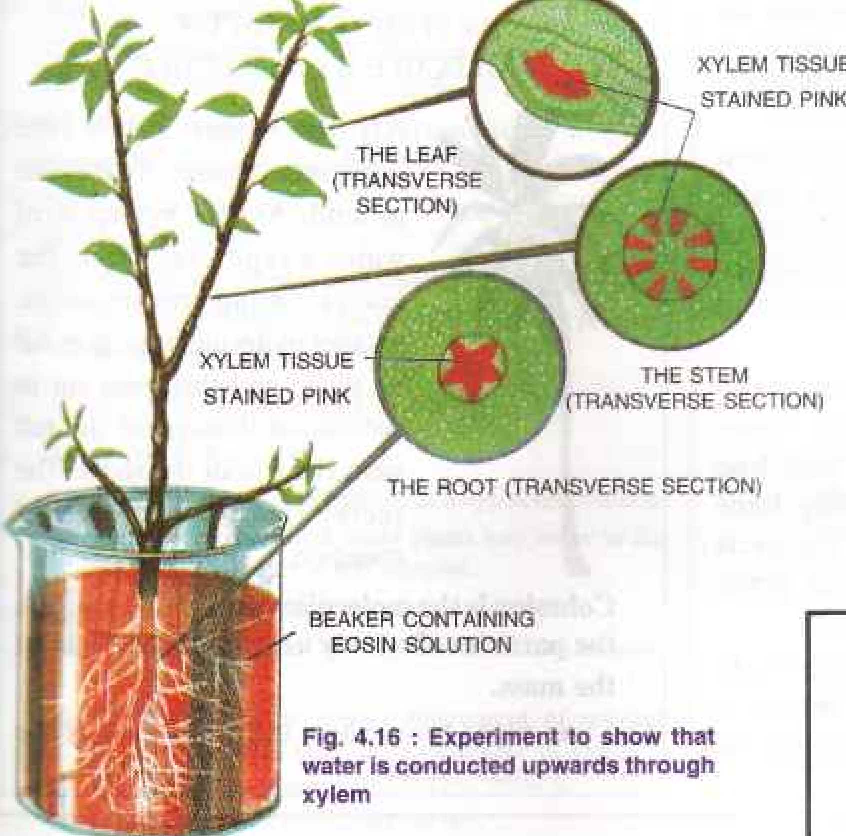


Fig. 4.16 : Experiment to show that water is conducted upwards through xylem

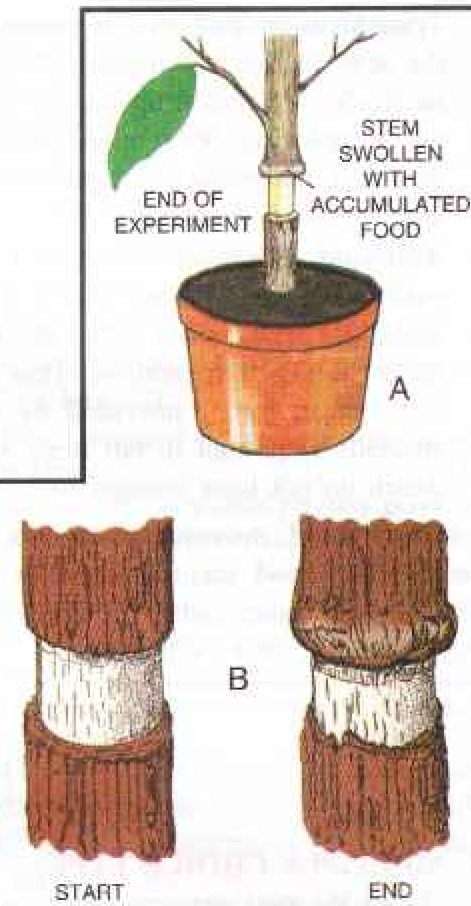


Fig. 4.18 : A — A woody stem was girdled by removing a ring of bark, leaving the xylem intact. A bulge develops above the girdle in a few weeks time. B — Bark compared at the start and at the end of the experiment

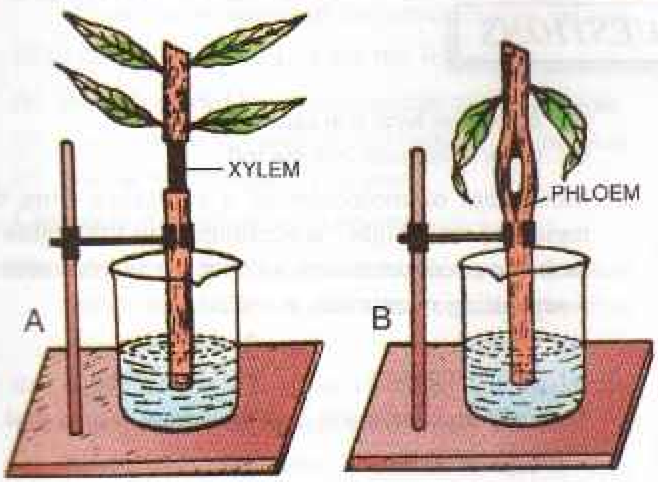


Fig. 4.17 : An experiment to show that water is conducted upwards through xylem
A—A twig with phloem removed and xylem intact,
B—A twig with xylem removed and phloem intact, leaves wilt

GIRDLING OF TREES

One of the numerous such cases that are occurring in the residential areas of several towns. But, here, one environment lover is looking after somehow to prevent the "death" of this peepal tree growing close to a four-storey house, whose occupant wanted to kill it by **girdling**.

to transpiration from the leaves. Narrower the diameter of a tube, greater will be the height of water rising in it exerting a force called **capillary force**.

3. **Transpiration pull**. As the water is lost from the leaf surface by transpiration, more water molecules are pulled up due to the tendency of water molecules to remain joined (**cohesion**), and thus to produce a continuous column of water through the stem.
4. **Adhesion**. It causes the water to stick to the surface of cells thus drawing more water molecules from below when the leaf cells lose water during transpiration. This pulling force (or suction force) provided by the leaves is specially important in tall trees, such as pines, which do not have enough root pressure.

Downward movement of sap is relatively simple. The food manufactured in the leaves is dissolved in water and it flows down mainly on account of the force of gravity.

WATER - UP AND UP

MOLECULE BY MOLECULE

All the water inside the coconuts comes from the ground. As one molecule of water evaporates from the leaves during transpiration, another molecule rises up to fill its place and this goes on in succession throughout the tall stem right from the roots. The secret lies in the force of cohesion.

Cohesion is the molecular attraction by which the particles of a body are united throughout the mass.

Can you guess from where the sweet taste of the "coconut milk" comes?

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Absorption of water by the plant cells by surface attraction is called :
   (a) Diffusion (b) Osmosis
   (c) Imbibition (d) Endosmosis
2. A plant cell placed in a certain solution got plasmolysed. What was the kind of solution ?
   (a) Isotonic sugar solution (b) Hypotonic salt solution
   (c) Hypertonic salt solution (d) Isotonic salt solution
3. The state of a cell in which the cell wall is rigid and stretched by the increase in volume due to the absorption of water is called
   (a) Flaccidity (b) Turgidity
   (c) Capillarity (d) Tonicity
4. Which one of the following is a characteristic NOT related with the suitability of the roots for absorbing water?
   (a) Tremendous surface area
   (b) Contain cell sap at a higher concentration than the surrounding soil water
   (c) Root hairs have thin cell walls
   (d) Grow downward into the soil
5. Movement of molecules of a substance from the region of their higher concentration to the region of their lower concentration without the involvement of a separating membrane, is called
   (a) Osmosis (b) Diffusion
   (c) Active transport (d) Capillarity
6. Osmosis and diffusion are the same except that in osmosis there is
   (a) a freely permeable membrane
   (b) a cell wall in between
   (c) a selectively permeable membrane in between
   (d) an endless inflow of water into a cell
7. The highest water potential (capacity to move out to higher concentrated solution) is that of
   (a) Pure water (b) 10% salt solution
   (c) Honey (d) 50% sugar solution
8. The space between the cell wall and plasma membrane in a plasmolysed cell is filled with
   (a) isotonic solution (b) hypotonic solution
   (c) hypertonic solution (d) water

9. What is responsible for guttation?
   (a) Osmotic pressure (b) Root pressure
   (c) Suction pressure (d) Capillarity

10. The most appropriate characteristic of a semi-permeable membrane is that
   (a) it has minute pores.
   (b) it has no pores.
   (c) it allows the solute to pass through but not the solvent.
   (d) it allows a solvent to pass through freely but prevents the passage of the solute.

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The **condition** of a cell placed in a hypotonic solution.
   (b) The **process** by which intact plants lose water in the form of droplets from leaf margins.
   (c) The **process** by which water enters root hairs.
   (d) The **tissue** concerned with upward conduction of water in plants.
   (e) The **term** for the inward movement of solvent molecules through the plasma membrane of a cell.
   (f) The **process** by which molecules distribute themselves evenly within the space they occupy.
   (g) The **pressure** which is responsible for the movement of water molecules across the cortical cells of the root.

2. **Give** the equivalent terms for the following :
   (a) Pressure exerted by the cell contents on the cell wall.
   (b) The condition in which the cell contents are shrunken.
   (c) Loss of water through a cut stem.

3. **Complete** the following statements :
   (a) Hypotonic solution is one in which the solution kept outside the cell has lower solute concentration than .... the cell.
   (b) Active transport is one in which the ions outside the roots move in with expenditure of energy ....
   (c) The bending movements of certain flowers towards the sun and the sleep movements of certain plants at night are examples of ....

4. **Fill in the blanks** by choosing the correct alternative from those given in brackets.
   (a) When placed in a more concentrated solution, the cell contents will .... **(shrink / swell up)**
   (b) The pressure by which the .... molecules tend to cross the semi-permeable membrane is called osmotic pressure. **(salt / water)**
   (c) Active transport is in a direction .... to that of diffusion. **(opposite / same)**

5. **Match** the items in column I with those in column II

Column I	Column II
(a) Xylem	(i) semi-permeable
(b) Phloem	(ii) permeable
(c) Cell membrane	(iii) downward flow of sap
(d) Root pressure	(iv) upward flow of water
(e) Cell wall	(v) guttation

C. SHORT ANSWER TYPE

1. **Differentiate** between the following :
   (a) Plasmolysis and deplasmolysis
   (b) Turgor pressure and wall pressure
   (c) Guttation and bleeding
   (d) Turgidity and Flaccidity

2. (a) **Mention** whether the following statements are **true** (T) or **false** (F).
   (i) A plant cell placed in hypotonic solution gets plasmolysed. (T/F)
   (ii) Addition of salt to pickles prevents growth of bacteria because they turn turgid. (T/F)
   (iii) Cells that have lost their water content are said to be deplasmolysed. (T/F)
   (iv) Xylem is the water conducting tissue in plants. (T/F)
   (v) The shrinkage of protoplasm, when a cell is kept in hypotonic solution. (T/F)
   (vi) The cell wall of the root cell is a differentially permeable membrane. (T/F)

   (b) **Correct** the false statements by altering the **last word** only.

3. **What** is the difference between 'flaccid' and 'turgid"? Give one example of flaccid condition in plants.

4. **Give reasons** for the following :
   (a) If you sprinkle some common salt on grass growing on a lawn, it is killed at that spot.
   (b) If you uproot a plant from the soil, its leaves soon wilt.
   (c) It is better to transplant seedlings in a flower-bed in the evening and not in the morning.
   (d) A plant cell when kept in a hypertonic salt solution for about 30 minutes turns flaccid.
   (e) Potato cubes when placed in water become firm and increase in size.

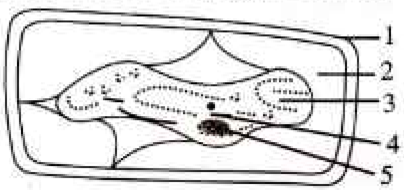
5. **Mention** whether the following statements are ***true*** **(T)** or ***false*** **(F)** and give **explanation** in support of your answer.
   (a) Plasmolysis is reverse of deplasmolysis. (T/F)
   (b) Guttation is another name for bleeding in plants. (T/F)
   (c) Soaked seeds burst their seed coats. (T/F)
   (d) If the phloem of a twig is removed keeping the xylem intact, the leaves of a twig wilt. (T/F)
   (e) Guttation in plants occurs maximum at mid-day. (T/F)
   (f) Dry seeds when submerged in water swell up due to endosmosis. (T/F)

D. LONG ANSWER TYPE

1. **Give** two examples of turgor movements in plants.
2. **Explain** the mechanism of closing and opening of the stomata.
3. Concentration of mineral nutrient elements is higher inside the root-hairs than in the surrounding soil. **How** do roots take them in from the soil ?
4. **Explain** how soaked seeds swell up and burst their seed coats.
5. Leaves of the sensitive plant wilt and droop down on a slight touch. **What** mechanism brings about this change ?
6. **What** is transpiration pull ? **How** is it caused ?

E. STRUCTURED/APPLICATION/SKILL TYPE

1. The following diagram represents a plant cell after being placed in a strong sugar solution.

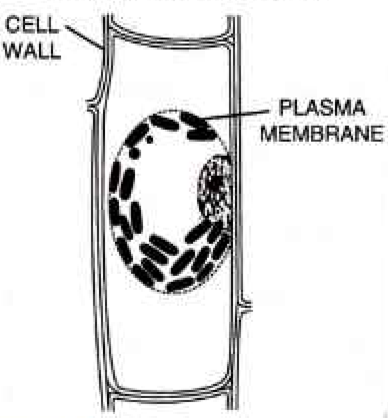


Guidelines 1 to 5 indicate the following :

(1) Cell Wall, (2) Strong Sugar Solution,
(3) Protoplasm, (4) Large vacuole,
(5) Nucleus

(a) **What** is the state of the cell shown in the diagram?
(b) **Name** the structure which acts as a selectively permeable membrane.
(c) If the cell had been placed in distilled water instead of strong sugar solution, **which** feature would not have been seen?
(d) **Name** any one feature of this plant cell which is not present in an animal cell.

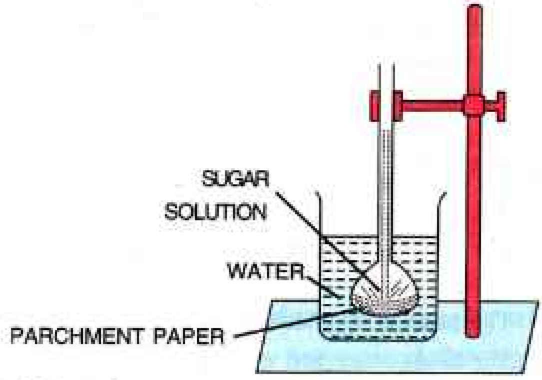
2. A leaf cell of a water plant was placed in a liquid other than pond water. After sometime, it assumed a shape as shown below :



(a) Give the term for the state of the cell it has acquired.
(b) **Comment** on the nature (tonicity) of the liquid surrounding the cell.
(c) **Redraw** in the space provided, the diagram of the cell if it is soon placed in ordinary water for some time.

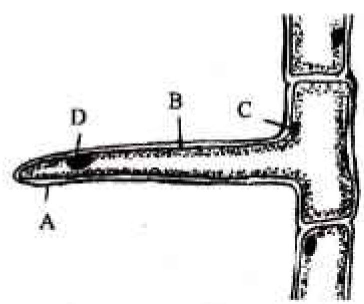
3. The diagram given below represents an experimental set-up to demonstrate a certain process. **Study** the same and **answer** the questions that follow :

p.50



(a) **Name** the process.
(b) **Define** the above-named process.
(c) **What** would you observe in the experimental set-up after an hour or so?
(d) **What** control experiment can be set up for comparison?
(e) Keeping in mind the root-hair, cell and its surroundings, **name** the parts that correspond to (1) concentrated sugar solution (2) parchment paper and (3) water in the beaker.
(f) **Name** any other substance that can be used instead of parchment paper in the above experiment.
(g) **Mention** two advantages of the process to the plants.

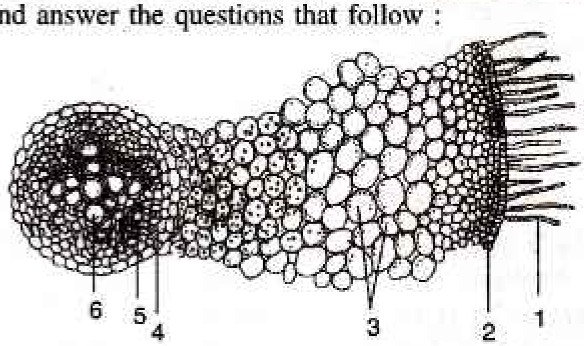
4. The diagram below represents a layer of epidermal cells showing a fully grown root hair. Study the diagram and answer the questions that follow:



(a) **Name** the parts labelled A, B, C and D.
(b) The root hair cell is in a turgid state. **Name** and **explain** the process that caused this state.
(c) **Mention** one distinct difference between the parts labelled A and B.
(d) **Draw** a diagram of the above root hair cell as it would appear when a concentrated solution of fertilizers is added near it.

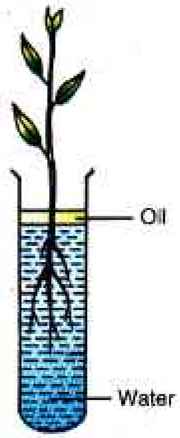
5. Two potato cubes each 1 cm^3 in size, were placed separately in two containers (A & B), the container (A) having water and the other (B) containing concentrated sugar solution. After 24 hours when the cubes were examined, those placed in water were found to be firm and had increased slightly in size and those placed in concentrated sugar solution were found to be soft and had somewhat decreased in size. Use the above information to answer the questions that follow :
   (a) **Account for** the firmness and increase in the size of the potato cubes placed in water.
   (b) **Account for** the softness and decrease in size of the potato cubes which were placed in sugar solution.
   (c) **Name** and **define** the physical process being investigated in this experiment.

6. Given below is the diagrammatic representation of the transverse section of a part of a plant. Study it and answer the questions that follow :



   (a) **Name** the part of the plant that is shown.
   (b) **Label** the parts 1 to 6.
   (c) **Write** the functions of parts 3 and 5.

7. Study the diagram given below and answer the questions that follow:



   (a) **Name** the process being studied in the above experiment.
   (b) **Explain** the process mentioned in (a) above.
   (c) **Why** is oil placed over water?
   (d) **What** do we observe with regard to the level of water when this set up is placed in (1) bright sunlight (2) humid conditions (3) windy day?
   (e) **Mention** any three adaptations found in plants to foster the process mentioned in (a) above.

8. **Show** by a series of diagrams, the change which a plant cell will undergo when placed in
   (a) Hypertonic salt solution and
   (b) Hypotonic salt solution.