4 Absorption by Roots — The Processes Involved

In the Chapter

Syllabus :

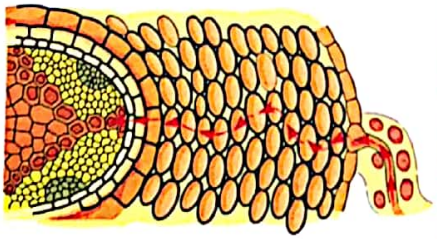
(i) Absorption by roots; imbibition; diffusion and osmosis; osmotic pressure; root pressure; turgidity and flaccidity; plasmolysis and deplasmolysis, the absorption of water and minerals, active and passive transport (in brief).

(ii) The rise of water up to the xylem; Forces responsible for ascent of sap.

Scope of Syllabus :

- Understanding of the processes related to absorption of water by the roots.
- Characteristics of roots, which make them suitable for absorbing water.
- Structure of a single full-grown root hair.
- A general idea of cohesive and adhesive forces; transpirational pull.
- Experiments to show the conduction of water through the xylem.

Plant physiology is the branch of biology which deals with the life functions or metabolism 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 not only fix the plant in the soil giving it support but the most important and life-supporting function of the roots is to absorb ***water*** and ***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

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 gets evaporated 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.

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.

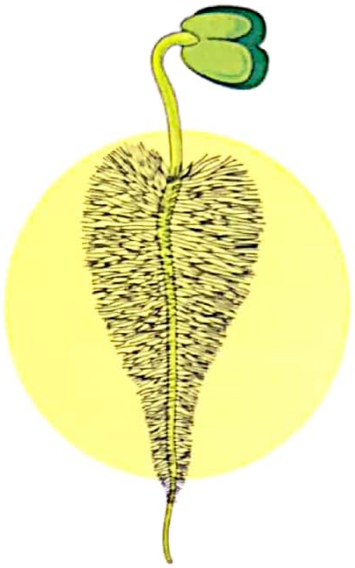


Fig. 4.1 : A freshly germinated seed showing the single root with root hairs

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 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 water from the outside *i.e.* for the occurrence of osmosis which is described later.

(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.
- 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.

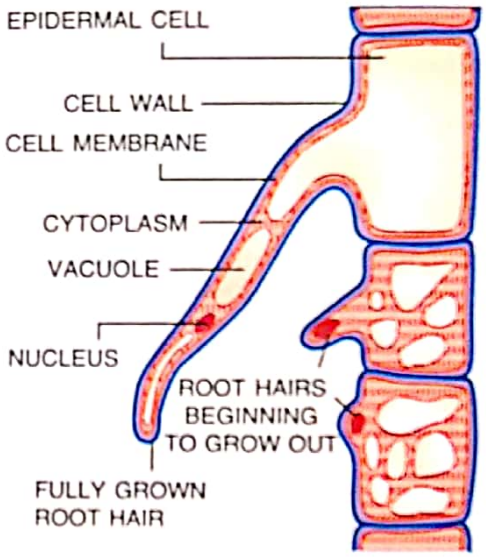


Fig. 4.2 : A single full grown root hair and two more in successive stages of growth from the epidermal cells

Progress Check

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

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

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.

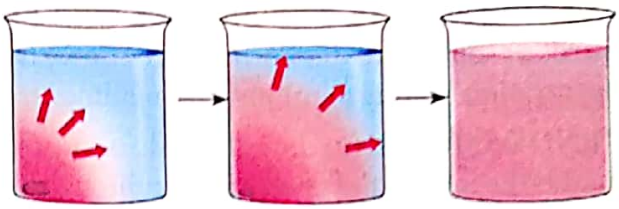


Fig. 4.3 : Diffusion of a soluble dye in water, forming a solution (schematic).
A – Diffusion started,
B – Diffusion progressing,
C – Diffusion completed, making a homogeneous solution; molecules of the solute are evenly distributed in the solvent.

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