

Transport Mechanism

Multicellular organisms need a transport system as the distance between the cell and the surface is large. Thus, diffusion alone cannot allow transport.

Transport In Plants:

Plants need to transport two substances.

- Transport of water from the soil to leaves.
- Transport of solutes from leaves to other cells.

Transport Of Water

The transport of water can be divided into various steps.

The first is transported from soil to root hairs.

1. Then, from root hairs to the xylem.
2. Finally from xylem to leaves.

Transport From Soil To Root Hairs:

The primary root is covered by a cap called a root cap which makes it impermeable for the absorption of water and other substances.

To overcome this, the epidermis sends out fine branches called root hairs. These root hairs are involved in the absorption of substances. They also increase the surface area for absorption.

Absorption Of Water Down The Concentration Gradient:

The soil has a higher water potential than root hairs. It contains solutes and other ions but the solution is dilute.

In contrast, the cell has a high concentration of ions in cell sap making it at low water potential.

Thus, water is easily transported from soil to root hairs across the concentration gradient.

Transport From Root To Xylem:

Now, the water has to be transported from the roots to the xylem.

The figure shows a cross-section of the root. Water has to be transported first from root hairs to the cortex than it enters the stele where the xylem is located.

Water potential in the xylem is at a lower water potential than the root hairs thus the water can easily move through it.

There are two routes that water takes to enter the xylem.

Routes Taken By Water:

1) Symplast

Symplast is the movement of water from one cell to another cell. The water enters the cytoplasm then the cell sap of one cell then to others.

2) Apoplast

The movement of water from the cell wall to the cell wall without entering the cytoplasm is called the apoplast pathway.

Water can take any of the two pathways to cross the cortex and reach the stele.

Movement From Stele To Xylem:

Once the water has reached the stele now the apoplast pathway is stopped. This is because the endodermis is surrounded by a waxy layer called the Casparian strip. This layer is impermeable to water.

Thus, water can move only by the symplast pathway.

Movement Of Water From Leave To Atmosphere:

Transpiration

The leaf has a layer of cells called spongy mesophyll in the centre. These cells are not tightly packed and have air spaces in between them. Water from the mesophyll cells evaporates into the air spaces. If the water potential of air spaces inside the leaf is higher than the air outside water diffuses across the water potential gradient.

This loss of water mainly depends upon the opening and closing of stomata. Stomata are open when plants need CO₂ for photosynthesis and closed when plants are not performing photosynthesis.

Thus, transpiration is mainly an inevitable consequence of gaseous exchange by plants. Although when plants need to conserve water they adapt various alternate ways for gaseous exchange minimizing transpiration.

This process of excretion of water in the form of water vapours is called transpiration.

Factors Affecting Rate Of Transpiration

Several factors affect the rate of transpiration.

Opening And Closing Of Stomata:

Plants have to regulate the opening and closing of stomata according to their need. Stomata serve as a passage for the diffusion of gases. Thus, when the plant is performing photosynthesis they need more CO₂ during the daytime. So plants keep their stomata open. While at night when photosynthesis is stopped plants close their stomata.

This increased rate of transpiration during the daytime.

Light

Light increases the rate of photosynthesis thus it increases gaseous exchange. That means stomata will remain open and the rate of transpiration will be increased.

Humidity

The rate of transpiration will be increased in a less humid environment. This is because the water potential gradient between the atmosphere and air inside the leaf will be high.

Wind Velocity

High wind velocity will also increase the rate of transpiration. That is because it distributes the water vapours present in the air creating a gradient.

Temperature

Transpiration is also increased by increasing temperature.

Adaption In Xerophytic Plants:

Transpiration can be a problem for plants living in a xerophytic condition(dry). To counter this, they have developed many adaptations.

- The surface area of leaves is reduced by turning them into spikes.
- Roots are well developed. There is a vast system of horizontal roots to absorb water.
- The stem is succulent and filled with water.
- Stomata are sunken.
- The thick cuticle is present to prevent loss of water.

Movement Of Water From Xylem To Leaf:

Structure Of Xylem:

The xylem is a compound tissue which means it is made up of different cells.

Vessels

These are the lignin-fortified cells that are responsible for the conduction of water. They are connected end to end with each other. When the cell wall is deposited with lignin the parenchyma of the cell dies. Leaving behind a hollow structure. The cell wall between cells is dissolved making a continuous column for conduction of water.

Fibres

These are dead cells that are responsible for providing support to the plant.

Parenchyma Cells

Parenchyma cells are young plant cells with a thin cell wall. They have all the plant organelles.

Transport Of Water:

As said before the leaf is continuously losing water by transpiration. This reduces the hydrostatic pressure. While the xylem is continuously receiving water which increases the hydrostatic pressure. Thus, water is moved up from high pressure to low pressure. This is the same as sucking water from a straw. When you suck at the top the pressure is reduced creating a pressure difference. Due to which water moves up.

The movement of water in the xylem is mass flow. That is all the molecules move together in the form of liquid. There are two properties of water which aid in this.

Cohesion

Water molecules have an attraction between each other due to hydrogen bonding. This is called cohesion thus when one molecule moves up it takes another one as well.

Adhesion

Water molecules also have attracting forces between their molecules and the xylem wall. Thus, it helps them in climbing up.

Phloem Translocation:

The movement of solutes in phloem is called translocation. These solutes are substances that are made by the plant itself during photosynthesis.

Structure Of Phloem

Phloem is associated with the transport of organic substances within plants.

It consists of:

- Sieve element: These are cells that are connected end to end to make a continuous column. They have a very thin cytoplasm lying close to the cell wall and are associated with transport. The end of two sieve elements has a sieve plate. It has numerous gaps which allow transport.
- Companion cells: these are normal plant cells with all the components. They lie close to sieve elements.

Mechanism Of Phloem Translocation:

The substances are pumped into the phloem actively. Thus, phloem translocation is an active process as compared to water transport in the xylem which is passive.

Phloem Loading

Mesophyll cells in the leaf produce carbohydrates by photosynthesis. These are moved into the companion cells and then into sieve elements by active transport. Due to the entry of solutes water potential is decreased.

Phloem Unloading

The solutes in the sieve element are then pumped into any cell which needs it. This is also an active process as the concentration of solutes is already higher in these cells. This active pumping increases the water potential.

Pressure Flow Hypothesis

The active phloem loading creates a negative water potential at that end of the sieve element. While the phloem unloading increases the water potential at the other end of the tube.

The decrease in water potential results in the entry of water from the xylem into the phloem. While on the other side, water leaves the phloem due to an increase in water potential. This creates a pressure difference at both ends. Thus, water is moved from high pressure to low pressure. It can be concluded from here that phloem translocation is pressure-driven.