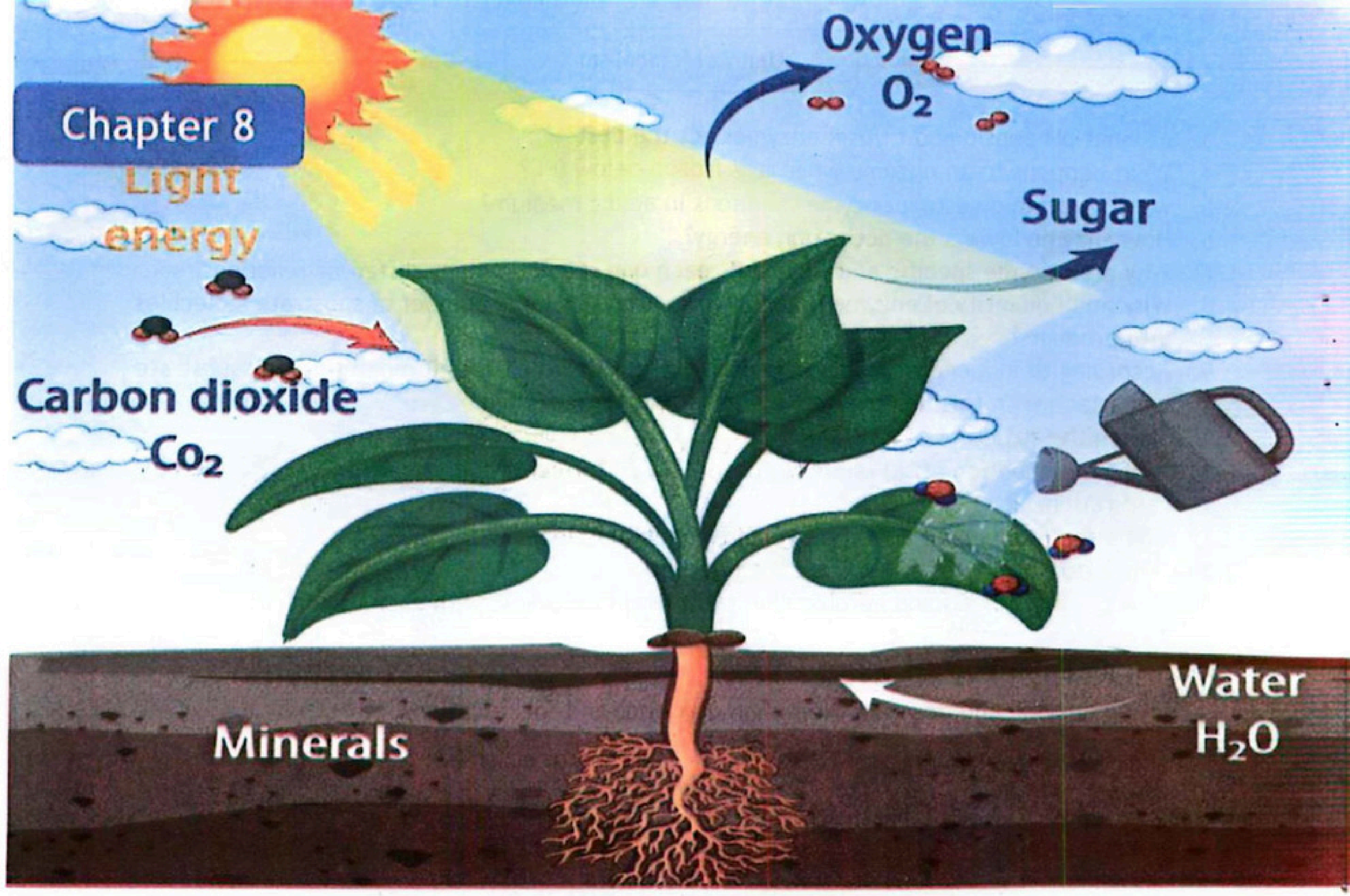

PLANT PHYSIOLOGY

SLOs: After completing this lesson, the student will be able to:

1. Define mineral nutrition in plants.
2. Categorize minerals nutrients of plants into micronutrient and micronutrients.
3. State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation.
4. Conceptualize the transport and its need.
5. Explain the internal structure of root and root hair.
6. Describe how roots take up water and minerals.
7. Describe how roots take up water and mineral salts by active and passive absorption.
8. Describe transpiration and relate this process with the cell surface and stomatal opening and closing.
9. Describe temperature, wind and humidity as factors affecting the rate of transpiration.
10. Explain the mechanism of food translocation by the theory of pressure flow mechanism.
11. Describe the process of gaseous exchange in plants.
12. Define homeostasis and describe its importance.
13. Describe the mechanism of adaptations of plants for the excretion.
14. Explain osmotic adjustment in plants

Plant physiology is the branch of botany, which deals with various questions related to the functions of plant body, such as, how plants grow from seed to the whole body, how plants absorb water and minerals and transport them to the leaves, how plants prepare organic solutes and transport them to the rest of the body, how plants exchange carbon dioxide and oxygen with their environment, how plants adapt themselves in changing environmental conditions and how plants produce their young ones to continue their species. Some of these functions will be studied in this chapter, while some have been discussed in other chapters.

8.1 NUTRITION IN PLANTS

Any substance that provides necessary elements to the organism for growth and metabolism is called **nutrient**. In general, a nutrient may be organic or inorganic, however, plant nutrients are inorganic. The term **nutrition** is applied to all the processes that are involved in the utilization of nutrients in growth or various metabolic activities of the body. Plants are autotrophs as they obtain inorganic nutrients such as water, carbon dioxide and certain minerals form the environment and convert them into organic compounds.

8.1.1 Types of plant nutrients

Sixteen elements have been found essential for plant growth. Nine of these are required in fairly large quantities (greater than 0.05% dry weights) and are therefore known as **macronutrients.** These include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium. The remaining seven elements are needed in traces or small amounts (less than 0.05% dry weight) for normal plant growth and development that are known as **micronutrients.** These include iron, boron, manganese, copper, molybdenum, chlorine, and zinc.

Although, each mineral nutrient is very important for normal plant growth, here you will learn about the importance of only nitrogen and magnesium. The role of rest of the plant nutrients will be discussed in biology grade 11.

Importance of nitrogen in protein synthesis

Nitrogen is a macronutrient in the plant which is mainly absorbed by the plant from soil through their roots in the form of inorganic nitrogenous compounds like nitrates (NO_3^-). The major source of nitrates in the soil is the decomposition of **dead organic matter**. However, in the **nitrogen depleted soils,** it can be added in the form of nitrogen fertilizers. In plant body these **nitrogenous compounds** are used to make amino acids, nucleotides, and chlorophyll. The amino acids are then utilised in protein synthesis. As the protein is the most abundant organic constituent of the plant body therefore, nitrogen deficiency in plant can lead to severe growth retardation. The most obvious symptom of nitrogen deficiency in

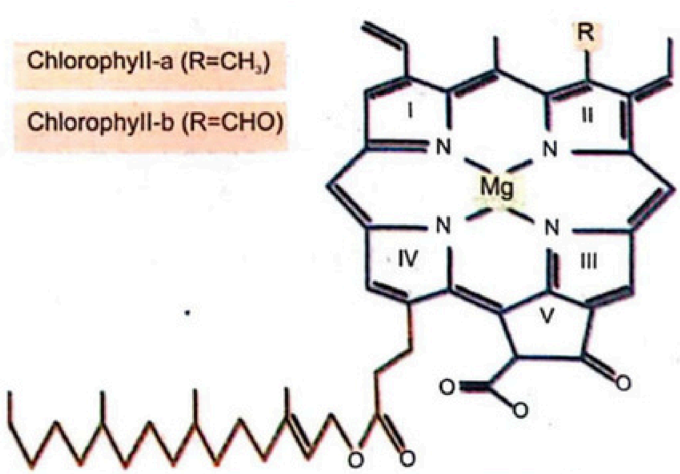

Figure: 8.1 Molecular Structure of Chlorophyll plant is the **chlorosis** i.e., yellowing of plant leaves due to deficiency of minerals, as the deficiency of nitrogen inhibits chlorophyll formation.

Importance of magnesium in chlorophyll formation

Magnesium is a macronutrient in the plant which is mainly absorbed by the plant from soil through their roots in the form of inorganic Mg^{+} ions. The major source of magnesium in the soil is the decomposition of **dead plant debris.** However, in the magnesium depleted soils, it can be added in the form of dolomitic limestone or magnesium fertilizers like Magnesium sulphate ($MgSO_4$). In plant body, the magnesium is used to make chlorophyll therefore, magnesium deficiency in plant can also lead to chlorosis.

8.2 TRANSPORT IN PLANTS

You have learnt that plants absorb nutrients from the soil which are then utilized in the leaves to prepare organic nutrients by photosynthetic activity. These **organic solutes** are also to be moved to different parts of the plant body. When organic solutes are utilized in plant body, some waste compounds are also produced which are then removed out of the plant body. All these movements of materials are generally referred to as transport in plants.

8.2.1 Need of Transport

In a plant body, transport occurs at three different levels:

At 1st level, the materials are moved from outside to inside the plant body because plant needs mineral nutrients and water to maintain its live activities which are to be absorbed from the soil, however, gases like CO_2 and O_2 are obtained from air.

At 2nd level, the materials are transported withing the plant body from one place to another because the inorganic nutrients must be transported to the leaves so that they can be used to prepare organic solutes by photosynthetic activity. These organic solutes are also to be moved to different parts of the plant body so that they can be used in plant growth and metabolism.

At 3rd level, the materials are moved from inside to outside the plant body because when organic solutes are utilized in plant body, some waste compounds are also produced which are then removed out of the plant body. These are the reasons why transport in plants occurs at three different levels.

8.2.2 Structure of root and root hairs

Root is an underground part of the plant, which serve as the **organ of uptake** of mineral nutrients and water. It possesses large surface area due to extensive branching system and root hairs which make them favourable for organ of uptake.

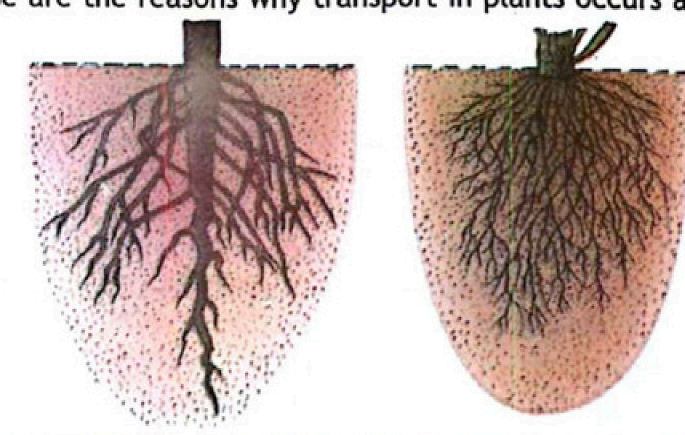

Figure: 8.2 Tap root in Dicot plants (Left), Fibrous Adventitious root in Monocot plants (Right)

Dicot plants have **tap root** which consists of a thick **primary root** that bears several secondary roots. Each secondary root further consists of large number of tertiary roots. On the other hand, monocot plants have **fibrous adventitious roots** that show no differentiation of primary, secondary, and tertiary roots.

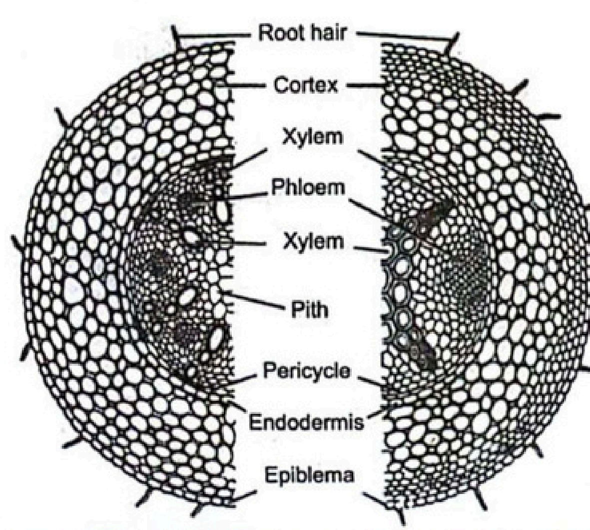

Figure: 8.3 T.S. of monocot root (Left), T.S. of dicot root (Right)

Internal structure of root and root hairs

In In both monopod and dicot roots, the outermost layer is called **epidermis**. Many cells of the epidermis have extensions that are penetrated the spaces among soil particles. These extensions of the root epidermal cells are called **root hairs**, which increase approximately 67% surface area of the root. Inner to the epidermis is a ground issue, the **cortex**. The inner lining of the cortex is called the **endodermis**. The endodermal cells have deposition of a vax, the **suberin** in their radial walls. These depositions are in the form of strips called the **Casparian Strips**. Inner to the endodermis is the **pericycle** which surrounds the innermost **vascular bundles**. The vascular bundle consists of xylem and phloem which are arranged in the form of ring in monocot root with central ground tissue called as **pith**. Whereas, in the dicot roots, the vascular bundles are present in the form of star shape in the centre of the root without the presence of pith.

8.2.2 Uptake of mineral salts and water by active and passive transport

Plant roots serve two vital functions: anchoring the plant in soil and absorbing essential minerals and water. To support the process of **photosynthesis**, plants require three key nutrients: carbon dioxide, water, minerals, and light. To obtain these nutrients, roots develop an extensive

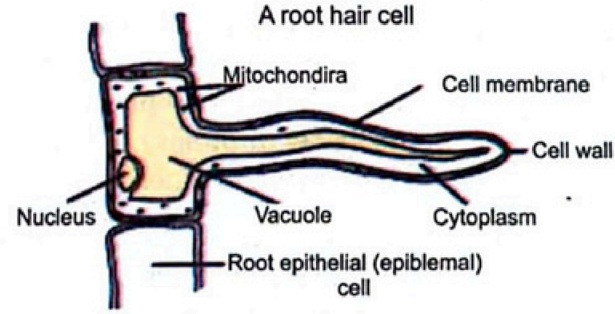

Figure: 8.4 Structure of root hair

branching system and are covered by root hairs. These root hairs are the primary sites for the absorption of water and minerals. With these raw materials (minerals and water from the soil, carbon dioxide from the air, and light energy), plants synthesize all the compounds they need. While most minerals enter the root hairs or epidermal cells of the roots through bulk flow with water, some are absorbed through **diffusion, facilitated diffusion**, or **active transport.**

Mechanism of mineral absorption by root

Plants absorb minerals from water in the soil. When minerals are stuck to soil particles and not dissolved in water, plants can't use them. Only those minerals can be absorbed that are dissolved in soil water. Plants take in minerals through root cells using both passive and active processes that require energy, specifically ATP.

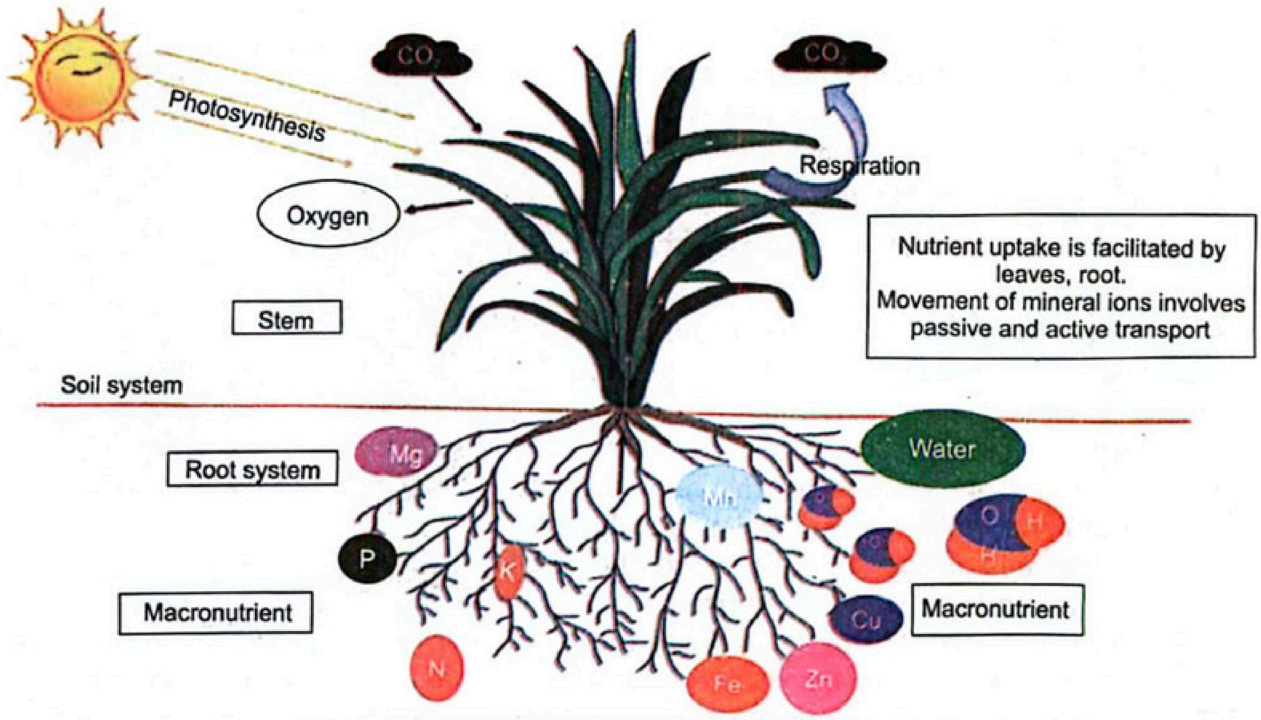

Figure: 8.5 Uptake of mineral nutrients by the plant

Passive uptake happens through **diffusion**, as minerals move along their **concentration gradient** through plasmodesmata to cells in the root's cortex, endodermis, and pericycle before reaching the xylem cells. They are then pulled up by transpiration.

Certain nutrients are transported from the soil into the epidermal cells of roots through their **cell** membranes by a process called **facilitated diffusion.** In facilitated diffusion, proteins within the cell membrane act as carrier molecules to help move nutrients across the membrane. These carrier proteins are found in the cell membranes of epidermal and other root cells.

Active transport, on the other hand, requires energy and allows plants to take in minerals even when their concentration inside the root cells is higher than in the soil. This is against the natural concentration gradient, and it involves the use of ATP. Active transport is selective and relies on respiration. Some ions can also move through **passive transport**.

Mechanism of water absorption by root

Absorption of water by roots occur by means of a passive transport mechanism called osmosis. This is the movement of water molecules through a partially permeable membrane from an area where they are more concentrated to an area where they are less

Science Titbits

One crucial nutrient, nitrogen (N), is often scarce in both rock particles and soil water. Many plants have developed beneficial partnerships with other organisms to obtain these limited nutrients. For example, mycorrhizal fungi and nitrogen-fixing bacteria in the root nodules of legumes are examples of such partnerships. Fungal associations with the roots of higher plants enhance the plant's ability to absorb minerals like phosphorus and trace metals such as zinc and copper. A root infected with mycorrhizal fungi can absorb phosphate at a faster rate than an uninfected root. In exchange for their services, mycorrhizal fungi receive sugars and protection from the plant, ultimately increasing the plant's efficiency in acquiring mineral nutrients. Mycorrhizae form associations with plants from a wide range of plant families, covering approximately 90% of flowering plants.

concentrated. If water moves into a cell through osmosis, it's called **endosmosis**, and if it moves out of the cell, it's called **exosmosis**.

In the epidermal cells of roots, the cell wall allows water and minerals to pass through freely. However, the cell membrane is **selectively permeable**, meaning it only allows certain substances from the solution to pass through. Water entering the epidermal cells follows the concentration gradient, moving through the cortex, endodermis, pericycle, and finally into the xylem cells.

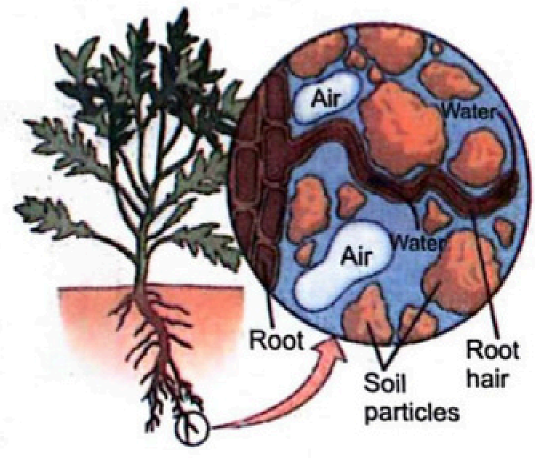

Figure: 8.6 Uptake of water by the plant

8.2.3 Transpiration

You have learnt that plants absorb water from the soil by the roots. This absorbed water moves in the areal parts of the plant from where the most of this water (approx. 99%) has been lost in the form of vapours into the atmosphere. This loss is called **transpiration**. 90% of this loss occurs through the stomata present mainly in the leaves and some other aerial parts of the plant. This is called **stomatal transpiration.** Some other amount of this absorbed water (7-9%) is lost from general body surface through the **cuticle,** called as **cuticular transpiration.** A very little amount of water (less than 3%) is also lost through **lenticels** which are scar like regions (with ruptured epidermis and loosely packed underlying cortical cells) present in the stem. This is called **lenticular transpiration.**

Critical Thinking

Does a submerged aquatic plant perform transpiration.

Transpiration is a vital process for the plant as it not only provides cooling to the plant but also help to absorb the water and dissolved minerals and to move them in upward direction to the leaves. Therefore, without transpiration plants are unable to survive. On the other hand, transpiration is generally regarded as disadvantageous as it shows great loss of absorbed water so, an unchecked excessive transpiration can lead to the wilting (loss of **turgor**) and ultimately death of the plant.

Critical Thinking

Why transpiration is sometimes called necessary evil.

Relation of transpiration with leaf surface area and Stomatal opening and closing

As you have learnt that transpiration is mainly occurs through the **stomata**, which are present on the leaf surface. So, the plants having large surface area of the leaves having more stomata show greater rate of transpiration as compared to the plants having narrow and reduced surfaces of the leaves having less stomata.

Critical Thinking

Can you think that the shape and the size of the leaves would be an adaptation of the plants in different habitats such as aquatic and terrestrial.

Similarly, more transpiration is generally observed in date time than night as the stomata are widely open during day and nearly close at night.

8.2.4 Factors affecting the rate of transpiration

The rate of transpiration is influenced by several environmental factors like temperature, wind, and **humility** etc. The rate of translation can be measured by using a simple apparatus called the potometer which is shown in the diagram. Students under the guidance of their teachers should plan simple experimental activities to investigate the effect of these factors on the rate of transpiration using the **photometer.**

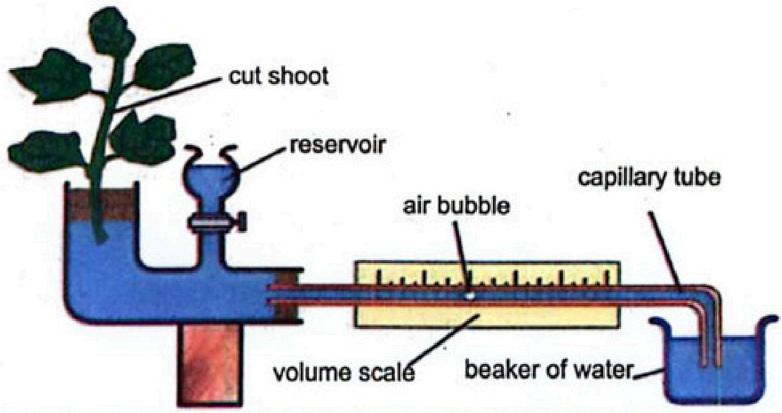

Figure: 8.7 Investigation of rate of transpiration by using

Effect of temperature

On a sunny day with strong sunlight, the air temperature rises, and this increase in temperature lowers the humidity in the air. As a result, more water evaporates from the surfaces of plant mesophyll cells, which leads to a higher rate of transpiration. For every 10°C increase in temperature, the rate of transpiration roughly doubles. However, when the environmental temperature becomes very high, around 40-45°C, it causes the stomata on plant leaves to close. This closure helps the plant conserve its much-needed water because excessive loss can be detrimental.

If these higher temperatures persist for an extended period and the soil doesn't have enough water, the plants may start to wilt and could eventually die.

Effect of Wind

Wind is moving air, and it speeds up the diffusion of water molecules. This leads to a higher rate of evaporation from the surfaces of mesophyll cells. In contrast, when the air is calm and still, the movement of water molecules (diffusion) slows down, resulting in a decreased rate of transpiration.

Scientific Enquiry

To instigate the effect of temperature on rate of transpiration, set the apparatus as shown in the figure 8.6, observe the movement of bubble in potometer and record the readings with appropriate intervals. Perform the experiment in different temperatures in a growth room. Remember that other conditions like sun light, wind and humidity should be constant. Take the mean reading of every experiment and plot a graph to show the relationship of rate of transpiration against temperature. Interpret your results and make conclusion.

To instigate the effect of wind on the rate of transpiration, set the apparatus as shown in the figure 8.6, observe the movement of bubble in potometer and record the readings with appropriate intervals. Perform the several experiments by putting the potometer at different distances in front of pedestal fan so that different velocities of wind can be investigated. Remember that other conditions like sun light, temperature and humidity should be constant. Take the mean reading of every experiment and plot a graph to show the relationship of rate of transpiration against different velocities of wind. Interpret your results and make conclusion.

Similarly, plan an activity to instigate the effect of humidity on the rate of transpiration.

Effect of Humidity

Humidity is the percentage of water vapours in the air. In dry air (low humidity), water molecules diffuse more rapidly from the surfaces of **mesophyll cells**, air spaces, and through stomata to the outside of the leaf. This results in more water being lost, which increases the rate of transpiration. Conversely, in humid air, the diffusion rate slows down, leading to a significant decrease in the rate of transpiration.

Similarly, can you predict the effect of other factors like sun light, CO_2 concentration and availability of soil water on the rate of transpiration.

8.2.4 Transport of water and salts within plant body (Ascent of Sap)

Root epidermal cells absorb water and minerals from the soil. These substances are then transported from the roots to the leaves. This upward movement of water and dissolved minerals through the xylem tissue is known as the "**ascent of sap.**" This process requires a passage and a significant amount of force because it occurs against the force of gravity, especially in tall plants. It is now quite evident that passage of ascent of sap is the xylem tissue and the most widely accepted theory that explains the force responsible for ascent of sap is called the "**TACT theory.**"

Passage of Ascent of Sap

Xylem is a complex and permanent tissue which act as passage for ascent of sap. Two type of xylem cells: **Tracheids** and **Vessel** are very important. Tracheids are long, dead cells with pointed ends and Xylem vessels are long, dead, and thick-walled tube-like structures formed by the fusion of vessel cells (vessel elements) placed end to end. Both are essential for water and mineral transport as well as structural support.

TACT Theory

According to the TACT theory, four factors work together to make a force that move water and minerals up a plant. These factors are **Transpiration pull**, **Adhesion**, **Cohesion**, and **Tension**, forming the acronym TACT.

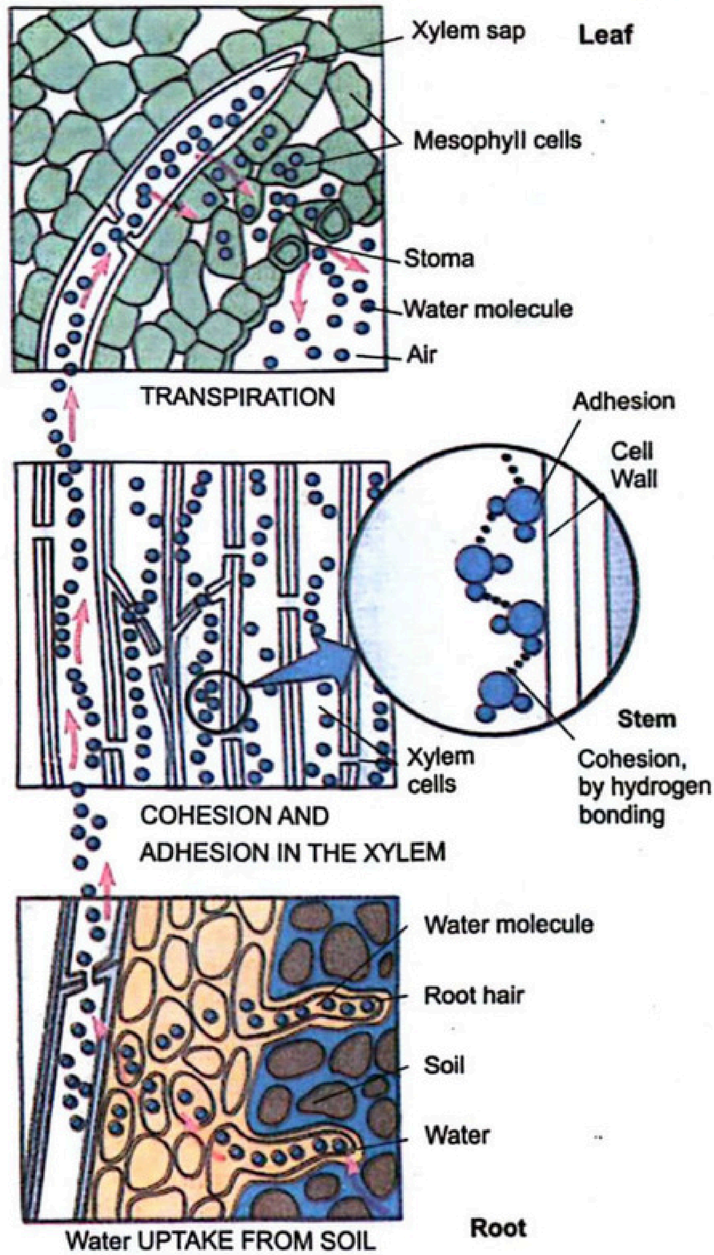

Fig. 8.8: Movement of water in xylem through TACT Mechanism

i) Transpiration Pull:

When stomata (tiny openings) on leaves are open, water evaporates from the leaves into the air, creating a pulling force known as **transpiration.** This pull makes water move from the roots to the leaves through the xylem tissue.

ii) Adhesion:

Adhesion is the attraction between water molecules and other substances. Water is strongly attracted to the walls of the xylem cells because both water and cellulose (in cell walls) are polar molecules. This adhesion helps water move upward in the plant against gravity. It also keeps water in the xylem when transpiration is not happening.

iii) Cohesion and Tension:

Cohesion is the attraction between nearby water molecules, which is possible because water is a polar molecule. Tension refers to the tension created in the water column. These forces help hold the water molecules together in a continuous column within the xylem.

How TACT Force Works

Imagine the column of water in the xylem as strong as a steel wire. Hydrogen bonds among water molecules create cohesion, holding the water molecules together like a string. As long as transpiration continues (water evaporating from leaves), the string of water remains tense and is pulled upward as a single unit. This bulk flow of water to the top of the plant is driven by solar energy, as it's the evaporation from leaves that causes the transpiration pull.

8.2.5 Transport of organic solute within plant body

The transport of prepared food (organic solutes) to different parts of the plant through the phloem tissue is **translocation.**

Passage of Translocation:

It is evident that translocation occurs through phloem tissues which are complex and permanent plant. Sieve tube elements and companion cells are important components of phloem.

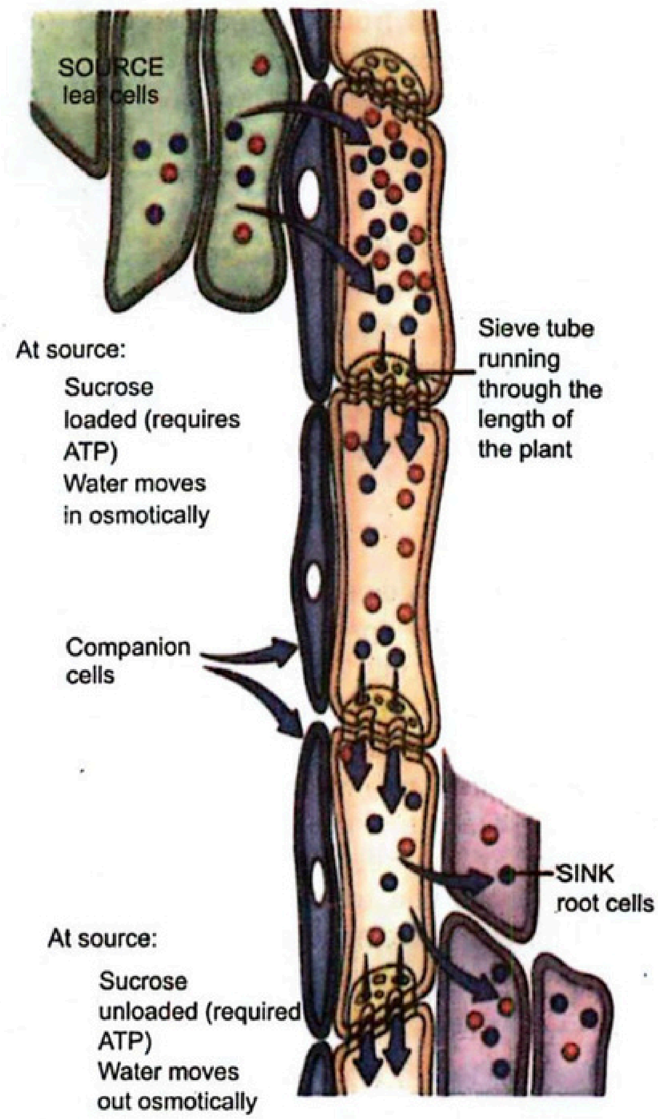

Figure: 8.9 Pressure flow Mechanism for Phloem Transport: Sugar is actively loaded into the sieve tube at the source. As a result, water moves into the sieve tubes by osmosis. At the sink, the sugar is actively unloaded, and water leaves the sieve tube by osmosis.

Sieve Tubes are long tube-like structures that transport organic solutes (like sucrose) throughout the plant. Since sieve tube elements lack nuclei, companion cells next to them control their functions. Together, sieve elements and companion cells act as conducting channels for moving organic solutes.

Direction of Translocation:

This movement is not just up or down; it goes in various directions. We usually say that translocation goes from a "**source**" to a "**sink**." A "source" supplies food (like leaves making food), and a "sink" uses food (like roots or storage organs). Leaves are sources, fruits are sinks, and stems and roots can act as both.

Composition of Translocating Fluid (Phloem Sap):

Phloem sap contains about 10-25% dry matter. Most of this dry matter is sucrose (a kind of sugar), with some other organic compounds.

Mechanism of Translocation (Pressure Flow or Mass Flow Theory):

The most accepted idea for how organic solutes moves in plants is the **"pressure flow" or "mass flow" theory**. Here's how it works:

1. Sugars produced in source regions, like leaves or storage areas, are loaded into the phloem's sieve tube elements by **companion cells**.
2. This active transport raises the sugar concentration and reduces the water concentration in the phloem. This makes the phloem cells more "sweet."
3. Water moves into the phloem through osmosis from nearby xylem cells, increasing **hydrostatic pressure** (pressure from water) in the phloem cells. This pressure pushes the sugary solution away from the source (usually a leaf).
4. The pressure difference, from the high-pressure source to the lower-pressure sink, causes translocation. It's like water being pushed through a hose.
5. When the solution reaches a sink, like the roots, root cells actively absorb the organic solutes. This makes the phloem sap less "sweet."
6. The loss of solutes in phloem sap increases solute potential and water potential, causing water to flow back into the xylem tubes.

So, it's like a system of moving food and water around the plant, driven by differences in pressure and the needs of different plant parts.

8.3 GAS EXCHANGE IN PLANTS

Gas exchange is the type of respiration that occurs at organismic level. Gas exchange is when the entire organism exchanges gases with the environment. The goal is to make sure that the organism must be provided with oxygen which is needed for cellular respiration, where complex organic compounds are broken down, and carbon dioxide is produced which is to be removed in outer environment. Every cell in a plant does its own gas exchange, depending on what it needs. This exchange mainly happens through two openings: stomata (tiny openings in leaves) and lenticels (small openings in stems). This exchange happens through a process called diffusion.

8.3.1 Pattern of gas exchange in leaves (Photosynthetic parts)

The plants being photosynthetic autotrophs show different pattern of gas exchange in day and night through the leaves.

Table: 8.1 Pattern of gas exchange between plant and environment		
	In daytime	**In nighttime**
Inhale	Carbon dioxide (CO_2)	Oxygen (O_2)
Exhale	Oxygen (O_2)	Carbon dioxide (CO_2)

During the day, plants are busy with both photosynthesis (making food) and respiration. The rate of photosynthesis varies throughout the day as it mainly depends upon light intensity. Generally, the rate of photosynthesis is greater than rate of respiration, therefore, the photosynthesis needs more carbon dioxide than what respiration produces, so plants bring in extra carbon dioxide from the environment. On the other hand, photosynthesis produces more oxygen than respiration needs, so plants release excess oxygen.

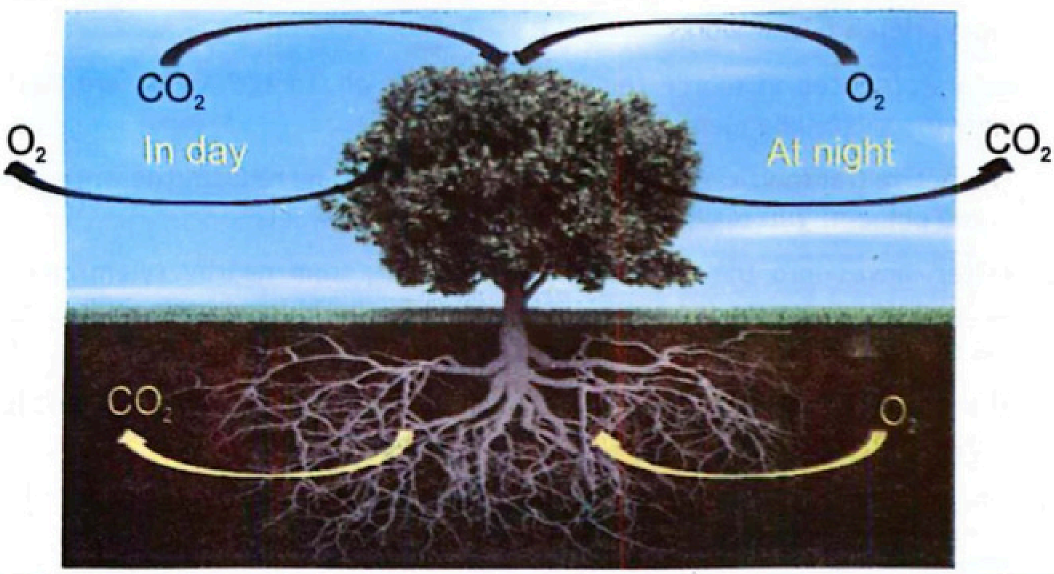

Figure: 8.10 Pattern of gas exchange in leaves and roots in day and night

At night, plants act more like animals. They absorb oxygen and release carbon dioxide because there's no photosynthesis happening in the dark.

During dawn and dusk, when light intensity is low, the rates of photosynthesis and respiration become equal. This means the carbon dioxide produced by respiration is enough for photosynthesis, and the oxygen released by photosynthesis is used in respiration. At this point, there's no net exchange of gases with the environment, and we call it the "**compensation point of photosynthesis.**"

8.3.2 Pattern of gas exchange in roots (non-photosynthetic parts)

Roots also exchange gases with soil air through root epidermal cells which involves absorption of oxygen and release carbon dioxide because there's no photosynthesis happening in the roots and it remains same day and night.

STEAM ACTIVITY

Green Breathing: Unveiling Plant Respiratory Patterns in Day and Night

Objective:

To recognize how does a plant's exposure to light and darkness impact its gas exchange?

Principle:

The increase or decrease in carbon dioxide concentration will be tested in this inquiry by using hydrogen carbonate indicator. It goes from pink or red to yellow when carbon dioxide builds up. The indicator becomes purple when carbon dioxide concentrations fall.

Procedure

1. Take three test tubes of 50ml volume and wash them properly with tap water then rinse them with distilled water and finally with hydrogen carbonate indicator (the indicator will change colour if the boiling tube is not clean).
2. Add 30ml hydrogen carbonate indicator solution into each of the three boiling tubes.
3. Place equal-sized pieces of **Canadian pondweed (Elodea)** or **Hydrilla** or any other locally available aquatic plant in tubes 1 and 2, then use stoppers to close all of the tubes.
4. Use a bench lamp to expose tubes 1 and 3 to light, then cover tube 2 with aluminum foil or put it in a dark cabinet or black box (Figure 8.11).
5. Note the colour of each tube's **hydrogen carbonate indicator** after a period of 24 hours.

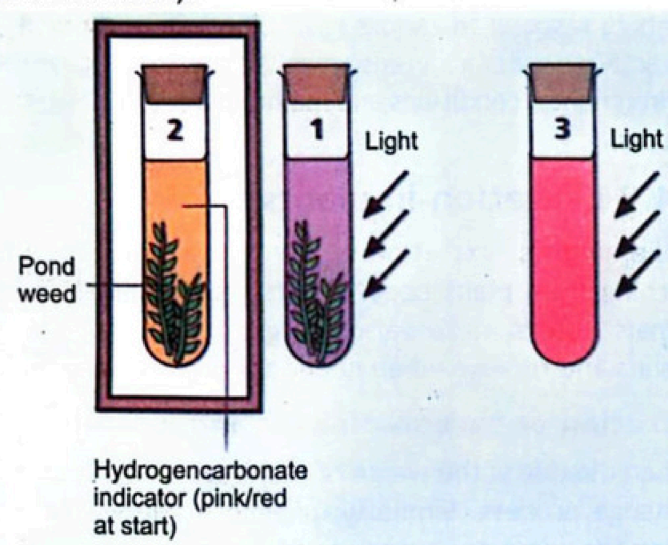

Figure: 8.11 Experiment to compare gas exchange in plants kept in the dark and in the light

Result

The indicator in tube 2 (plant in the dark) should turn yellow, the indicator in tube 1 (plant in the light) should turn purple, and the indicator in tube 3 (the control), which was initially pink/red, should not change colour.

Interpretation

In simple terms, hydrogen carbonate indicator helps us see changes in acidity caused by carbon dioxide. When there's more carbon dioxide, it turns orange/red, and when there's less, it becomes purple. An experiment with this indicator and plants showed that in light, plants use more carbon dioxide in photosynthesis than they produce in respiration. In the dark, plants produce carbon dioxide through respiration. A control tube without a plant showed that the plant caused the color change. However, it's noted that the indicator can react to changes in acidity or alkalinity, not just carbon dioxide. Despite this, understanding how leaves work suggests changes in carbon dioxide are more likely.

Reflection

Suggest students to emphasize the significance of gas exchange in plants for animal life on Earth. Encourage them to contemplate the potential consequences if plants were to become extinct.

8.4 HOMEOSTASIS IN PLANTS

Homeostasis in plants refers to the adjustment or adaptation of plants to varying degrees of environmental temperatures and availability of water and salts in the soil.

8.4.1 Importance of Homeostasis

Homeostasis in plants is essential for their survival, growth, and reproduction. Homeostatic mechanisms help plants respond to temperature changes, allowing them to survive in various climates. Homeostasis ensures that plants maintain adequate hydration levels. Homeostasis allows plants to respond to various stressors, such as drought, salinity, pathogens, and herbivores. Plants can activate specific defense mechanisms to mitigate damage. It enables them to adapt to changing environmental conditions and maintain internal stability, ultimately contributing to their ecological success.

8.4.2 Excretion in plants

Unlike animals, excretion in plants is a very broad term, which encompasses the removal of anything from plant body. Plants have a different way of getting rid of waste compared to animals. Plants make various organic and inorganic compounds that they store for different reasons and remove when needed. Following are different ways of excretion in plants.

Excretion of carbon dioxide and oxygen

Carbon dioxide is the waste of respiration which is excreted from plant body at night during gas exchange process. Similarly, oxygen is the waste of photosynthesis which is excreted in day during the same gas exchange process.

Excretion of water

Water is produced as waste of both photosynthesis and respiration and it is also absorbed from soil. The excretion of water occurs through the plant body during the process of transpiration.

Excretion through leaves

Plant cells have large vacuoles that can store useful stuff or waste. Sometimes, these stored substances can build up and form crystals in the vacuoles. Leaves are key players in this process. When the leaves are loaded with large amount pigmented compounds, they turn yellow. Remember, this yellowing is not due to lack of chlorophyll as happens in chlorosis. Such leaves are generally fallen from plants in autumn season. In this way leaves act as organ of excretion, therefore, such leaves are also called **excretophores**. This is why gardeners like using decomposed autumn leaves as a mineral-rich source for plants.

> **Critical Thinking**
>
> Can you differentiate between chloroted leaves and excretophores?

Excretion through stem and branches

Some trees deposit unusual chemicals in their branches and trunks, especially in old xylem that's no longer used for water transport. **Ebony trees**, for instance, produce very dark wood in their centres. Plant scientists consider these deposits as waste materials. Although, these wastes are not removed but are dumped in one part of the body as we put the trash in waste bin however, it is still present in the home.

Excretion through roots

Some plants actively release waste compounds into the soil, almost like using them as chemical weapons against other plants competing for resources. Conifer trees are known for this tactic.

8.4.3 Osmotic adjustment (Osmoregulation) in plants

Osmotic adjustment, also known as osmoregulation, is like a plant's way of maintaining the right balance of water and solutes in its body. This balance creates three different situations: hypotonic, hypertonic, and isotonic.

Hypotonic Situation

When a cell is in a watery environment with more water and less stuff dissolved in it (solute), water moves into the cell, making it swell up and firm (we call this "turgid").

Hypertonic Situation

If a cell is in an environment with less water and more dissolved stuff than it has inside (cell sap), water moves out of the cell, causing it to shrink and become limp (we call this "flaccid").

Both of these situations, hypotonic and hypertonic, require the plant to make adjustments to keep things in balance.

Ideal Situation (Isotonic)

The best scenario for a cell is when the water and solute balance inside and outside the cell is just right. In this "isotonic" situation, there's no net movement of water in or out of the cell. However, this balance is rarely found in a plant's natural environment.

Osmotic adjustment in different plants groups

Plants are categorized into three groups based on their water availability: **hydrophytes** (live in water-rich environments), **mesophytes** (thrive where water is moderately available), and **xerophytes** (adapted to extreme dry conditions). These groups have distinct adaptations:

1. Transpiration rates vary, with hydrophytes having the highest and xerophytes the lowest.
2. Stomatal placement differs, hydrophytes have them on the upper leaf surface, mesophytes on the lower surface, and xerophytes have sunken stomata.
3. Stomatal behaviour varies, hydrophytes keep stomata open day and night, mesophytes open them during the day, and xerophytes open them at night.
4. Cuticle thickness on leaves differs, with xerophytes having the thickest, mesophytes a thinner cuticle, and hydrophytes almost none.
5. Water storage capacity varies, with xerophytes, known as succulents, storing ample water.

SUMMARY

1. The chapter on plant physiology explores various aspects of plant functions, including nutrition, transport, gas exchange, and homeostasis.
2. Plants, as autotrophs, derive nutrients from the environment to synthesize organic compounds essential for growth and metabolism. Sixteen elements, including macronutrients and micronutrients, are crucial for plant health. Nitrogen and magnesium play pivotal roles in protein synthesis and chlorophyll formation, respectively.
3. Transport mechanisms facilitate the movement of water, minerals, and organic solutes within plant tissues. The roots absorb water and minerals from the soil, while translocation through the xylem and phloem ensures distribution to various plant parts. Transpiration, driven by factors like temperature and humidity, aids in water uptake and nutrient transport.
4. Plants engage in gas exchange through stomata and lenticels, regulating oxygen and carbon dioxide levels essential for photosynthesis and respiration. Diurnal variations in gas exchange patterns reflect the dynamic interplay between photosynthetic activity and environmental conditions.
5. Homeostatic mechanisms enable plants to maintain internal equilibrium amidst fluctuating environmental factors like temperature and water availability. Excretion processes, including gas release and waste deposition, contribute to plant health and ecological balance.
6. Plants regulate water and solute balance through osmotic adjustment, adapting to hypotonic, hypertonic, and isotonic conditions. Different plant groups exhibit distinct adaptations based on their water availability, showcasing the remarkable diversity of plant responses.
7. In essence, plant physiology elucidates the remarkable strategies plants employ to thrive in diverse habitats, highlighting their critical role in ecosystem dynamics and human well-being.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Chlorosis does not occur due to the deficiency of

   A) sulphur (B) magnesium

   C) phosphorus (D) calcium

2. Most of the uptake of water and minerals from soil takes place through

   A) epidermal cells (B) root cap

   C) root (D) root hair

3. The sugar moves through phloem is mostly in the form of

   (A) glucose (B) sucrose

   (C) maltose (D) lactose

4. Which category of plants stores a small amount of water and has a thin cuticle?
   A) Hydrophytes (B) Xerophytes
   C) Mesophytes (D) Succulents
5. What is a key role of leaves in managing waste in plants?
   A) Storing waste materials (B) Producing chlorophyll
   C) Absorbing water from the soil (D) Converting waste into energy
6. When the rate of photosynthesis become equal to that rate of respiration in the plant body, which of the following pattern of gaseous exchange occurs between plant and its environment:
   A) Carbon dioxide is absorbed, and oxygen is released
   B) Oxygen is absorbed, and carbon dioxide is released
   C) Both carbon dioxide and oxygen are absorbed
   D) Neither carbon dioxide nor oxygen are absorbed
7. What is the role of companion cells in the translocation process?
   A) They store excess solutes in the phloem
   B) They help regulate water potential in the xylem
   C) They actively transport sugars into the phloem's sieve tube elements
   D) They assist in the absorption of water by roots
8. What drives the translocation of organic solutes in plants?
   A) Differences in sugar concentration (B) Differences in leaf size
   B) Differences in root structure (D) Differences in stem length
9. According to the TACT theory, what are the four factors that work together to move water and minerals up a plant?
   A) Temperature, humidity, sunlight, and soil type
   B) Transpiration pull, Adhesion, Cohesion, and Tension
   C) Stomata, xylem, phloem, and roots
   D) Leaves, stems, roots, and flowers
10. What drives the bulk flow of water to the top of the plant according to the TACT theory?
   A) Root pressure B) Soil moisture
   C) Solar energy from photosynthesis D) Transpiration from the leaves

Section II: Short Answer Questions

1. Why is transpiration called necessary evil?
2. What is the composition of translocating flood?

3. Why gardeners like to use autumn leaves in their soil?
4. What is the effect of temperature on the rate of transportation?
5. Write any three osmotic adjustments in hydrophytes.
6. What is the pattern of gas exchange between plant and environment at the time of dawn and dusk?
7. White plants absorb carbon dioxide and release oxygen during daytime.
8. Define following terms:
   i. Osmotic adjustment,
   ii. Transpiration,
   iii. Translocation,
   iv. Micronutrients,
   v. Excretophores,
   vi. Vascular bundle,
   vii. Xylem
   viii. Adhesion,
   ix. Cohesion,
9. Write the difference between:
   (a) Micronutrients and macronutrients
   (b) Hydrophytes and xerophytes
   (c) Monocot root and dicot root
   (d) Transpiration and translocation
   (e) Translocation and ascent of sap
   (f) Xylem and phloem
   (g) Pattern of gas exchange in leaves and roots

Section III: Extensive Answer Questions

1. State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation.
2. Explain the internal structure of root and root hair.
3. Describe how roots take up water and mineral salts by active and passive absorption.
4. Describe transpiration and relate this process with the cell surface and stomatal opening and closing.
5. Describe temperature, wind and humidity as factors affecting the rate of transpiration.
6. Explain the mechanism of food translocation by the theory of pressure flow mechanism.
7. Describe the process of gaseous exchange in plants.
8. Describe the mechanism of adaptations of plants for the excretion.
9. Explain osmotic adjustment in plants.