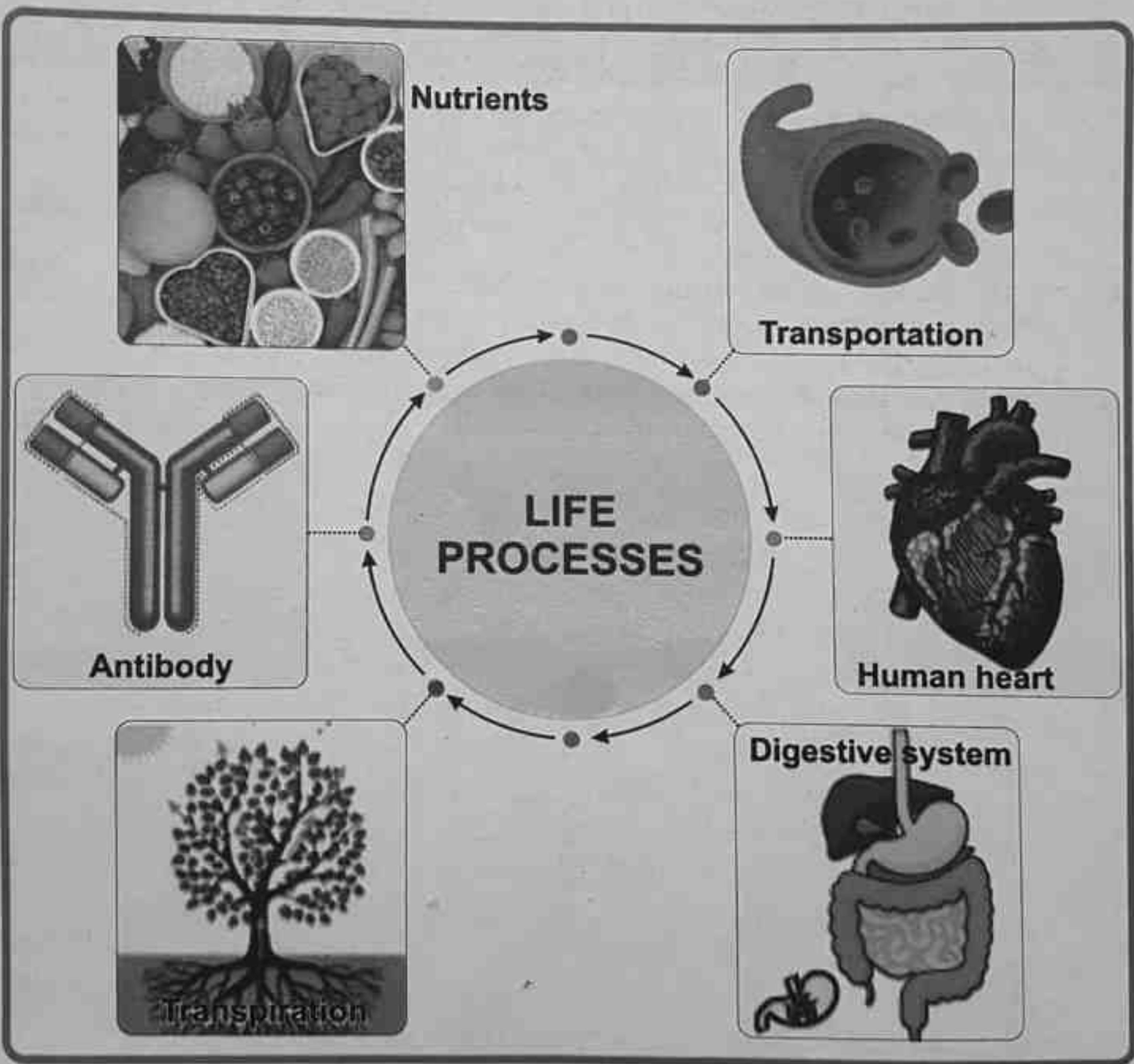
Section 03

LIFE PROCESSES

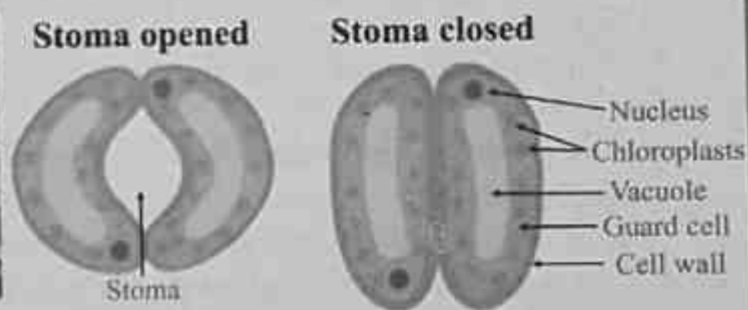


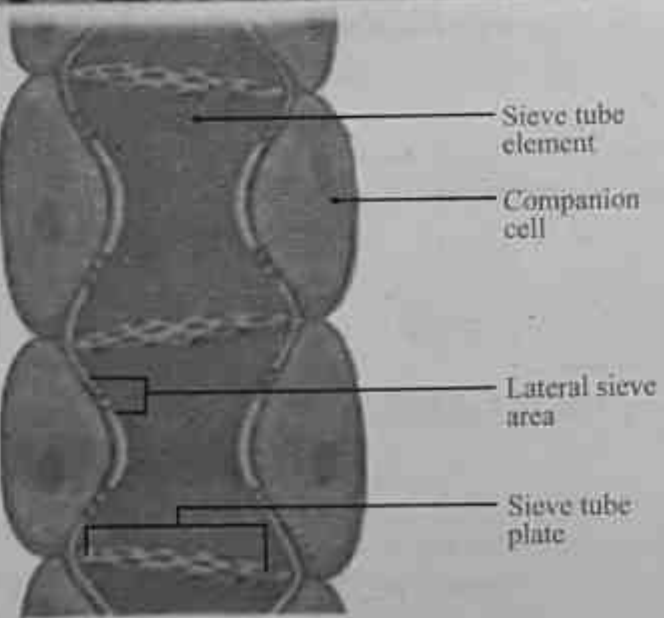
UNIT 10

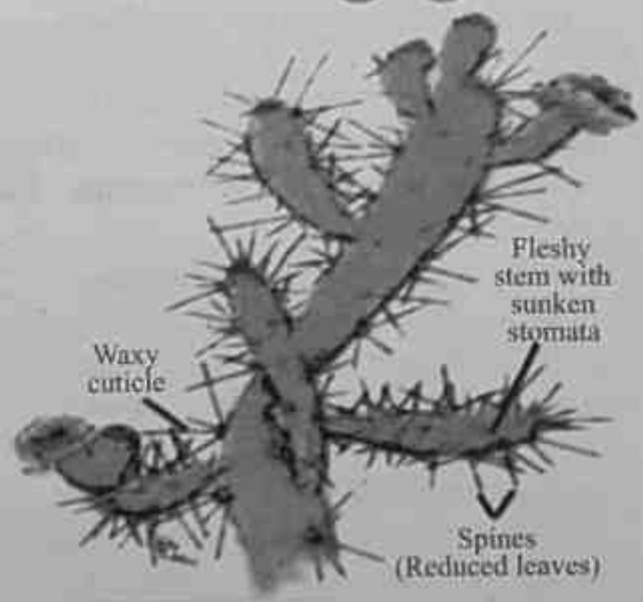
FORM AND FUNCTION IN PLANTS

Major Concepts

10.1 Nutrition in Plants
10.2 Gaseous Exchange in Plants
10.3 Transport in Plants
10.4 Homeostasis in Plants
10.5 Support in Plants
10.6 Growth and Development of Plant
10.7 Growth Response in Plants







Students Learning Outcomes

On completion of this unit students will be able to:

- List the macro and micro-nutrients of plants highlighting the role of each nutrient.
- State the examples of carnivorous plants.
- Explain the role of stomata palisade tissue in the exchange of gases in plants.
- Relate transpiration with gas exchange in plants.
- Describe the structure of xylem vessel elements, sieve tube elements, companion cells, trachieds and relate their structure with function.
- Explain the movement of water between plant cells, and between the cells and their environment in terms of water potential.
- Explain the movement of water through roots in terms of symplast, apoplast and vacuolar pathways.
- Explain the movement of water in xylem through TACT mechanism.
- Describe the mechanisms involved in the opening and closing of stomata.
- Explain the movement of sugars within plants.
- Identify vessel elements and phloem sieve tubes from the microscopic slides of L.S. of a dicot stem.
- Illustrate diagrammatically the pathway of water in root, stem and leaf.
- Define osmotic adjustment.
- Explain movement of water into and out of cell in isotonic, hypotonic and hypertonic conditions.
- Describe osmotic adjustments in hydrophytic (marine and fresh water), xerophytic and mesophytic plants.
- Explain the osmotic adjustment of plants in saline water.
- List the adaptation in plants to cope with low and high temperatures.
- Explain the turgor pressure and explain its significance in providing support to herbaceous plants.
- Describe the structure of supporting tissues in plants.
- Define growth and explain primary and secondary growth in plants.
- Describe the role of apical meristem and lateral meristem in primary and secondary growth.
- Explain how annual rings are formed.
- Explain influence of apical meristem on the growth of lateral shoots.
- Explain the role of important plant growth regulators.
- Explain the types of movement in plants in response to light, force of gravity, touch and chemicals.
- Define photoperiodism.
- Classify plants on the basis of photoperiodism and give examples.
- Describe the mechanism of photoperiodism with reference to the mode of action of phytochrome.
- Explain the role of low temperature treatment on flower production especially to biennials and perennials.

Introduction

It is common observation that organ and organ system level of organization is poorly developed in plants than animals. Although plants are more ancient but they are less developed because plants have to perform less range of activities and functions.

However, processes like nutrition, gaseous exchange, transport, homeostasis, support, growth and development and movements in response to external and internal stimuli etc., occur in plants.

10.1 Nutrition in Plants

Plant nutrition is the study of chemical elements and compounds necessary for plant growth, plant metabolism and their external supply. A **nutrient** is a component in food that an organism uses to survive and grow. Almost all plants are autotrophs, i.e., they can manufacture their own organic compounds by obtaining inorganic nutrients such as water, CO_2 and certain minerals from environment. A nutrient that is able to limit plant growth is considered as essential plant nutrient. There are **16 essential plant soil nutrients** besides the three major elemental nutrients, i.e. carbon, hydrogen and oxygen. Plants must obtain these mineral nutrients from their growing medium. Some of these minerals required in comparatively large amount are called **macronutrients**, e.g., nitrogen, phosphorous, sulfur, magnesium, iron, carbon, hydrogen, oxygen. Some mineral nutrients required in **trace amount** are called **micronutrients**, e.g., boron, chlorine, manganese, zinc, copper, molybdenum, cobalt, sodium. These elements are present in soil as salts which ionize in water so plants absorb them in the form of ions.

Table 10.1 Minerals Nutrition (Nutrients) in Plants

Macronutrients	Functions	Deficiency Symptoms
Carbon, hydrogen and oxygen	Needed for all biological organic substances (lipids, proteins, carbohydrates and nucleic acids).	Most plants get these nutrients regularly from air and water thus deficiency chances are less.
Nitrogen	Needed for the formation of proteins, nucleic acids, chlorophyll and coenzymes.	Chlorosis (lack of chlorophyll) delayed flowering, reduction of leaf size and early defoliation.
Phosphorus	Components of nucleic acids, phospholipids and ATP.	Stunted growth of root and shoot, premature fall of leaf and delayed flowering.
Calcium	Activator for many enzymes, helps in formation of cell wall and involved in membrane permeability.	Premature fall of flowers. Chlorosis leading to necrosis.

Macronutrients	Functions	Deficiency Symptoms
Magnesium	Activator of enzymes (needed for carbohydrate metabolism).	Chlorosis (inter veinal), also produce anthocyanin, sometime necrosis.
Sulphur	Amino acid formation and part of many vitamins.	Chlorosis and stunted growth.
Potassium	Enzyme activator, stomatal opening, osmosis and ionic balance.	Decreases apical dominance, retards growth and causes chlorosis.

Do you know?

Mineral deficiency is a lack of dietary minerals. The cause may be a poor diet, impaired uptake of minerals.

Table 10.2 Mineral Nutrients in Plants (Micronutrients)

Micronutrients	Functions	Deficiency Symptoms
Iron	Component of enzymes, which are needed for respiration, photosynthesis and nitrogen fixation.	Chlorosis
Zinc	Part of photosynthetic enzymes.	Growth decreases, mottled leaves.
Manganese	Part of respiratory enzymes and nitrogen metabolism.	Mottled leaves, chlorosis.
Boron	Helps in utilization of calcium and membrane transport system.	Thick, brittled and curly leaves, number of flower decreases.
Molybdenum	Needed for enzymes involved in nitrogen metabolism.	Causes Whiptail disease in cauliflower and necrosis in old leaves.
Chlorine	Maintains ionic balance, needed for photosynthesis.	Necrosis, chlorosis of leaf tips.
Copper	Part of photosynthetic enzymes.	Necrosis

in the same soil again and again. The possible remedy for this problem i
fertilizers in soil and cultivation of different crops alternatively in the same
cultivation of legume plants along with normal crops.

10.1.1 Nutrition in Carnivorous Plants

Insectivorous or carnivorous plants are those types of plants that o
their nutrients especially nitrogen by consuming insects or protozoans. Th
adapted to grow in places where the soil is thin and poor in nutrients. The
plants include the **Venus fly trap, pitcher plants *(Nepenthes)*, butterw
cobra lily** and hundreds of others. However, these plants do not deper
insects and small animals for their nutrition. The main source of er
autotrophic mode of nutrition like other plants. These plants trap inse
animals just to fulfill their mineral nutrient deficiency. These plants have s
capture prey and enzymes to digest the prey.

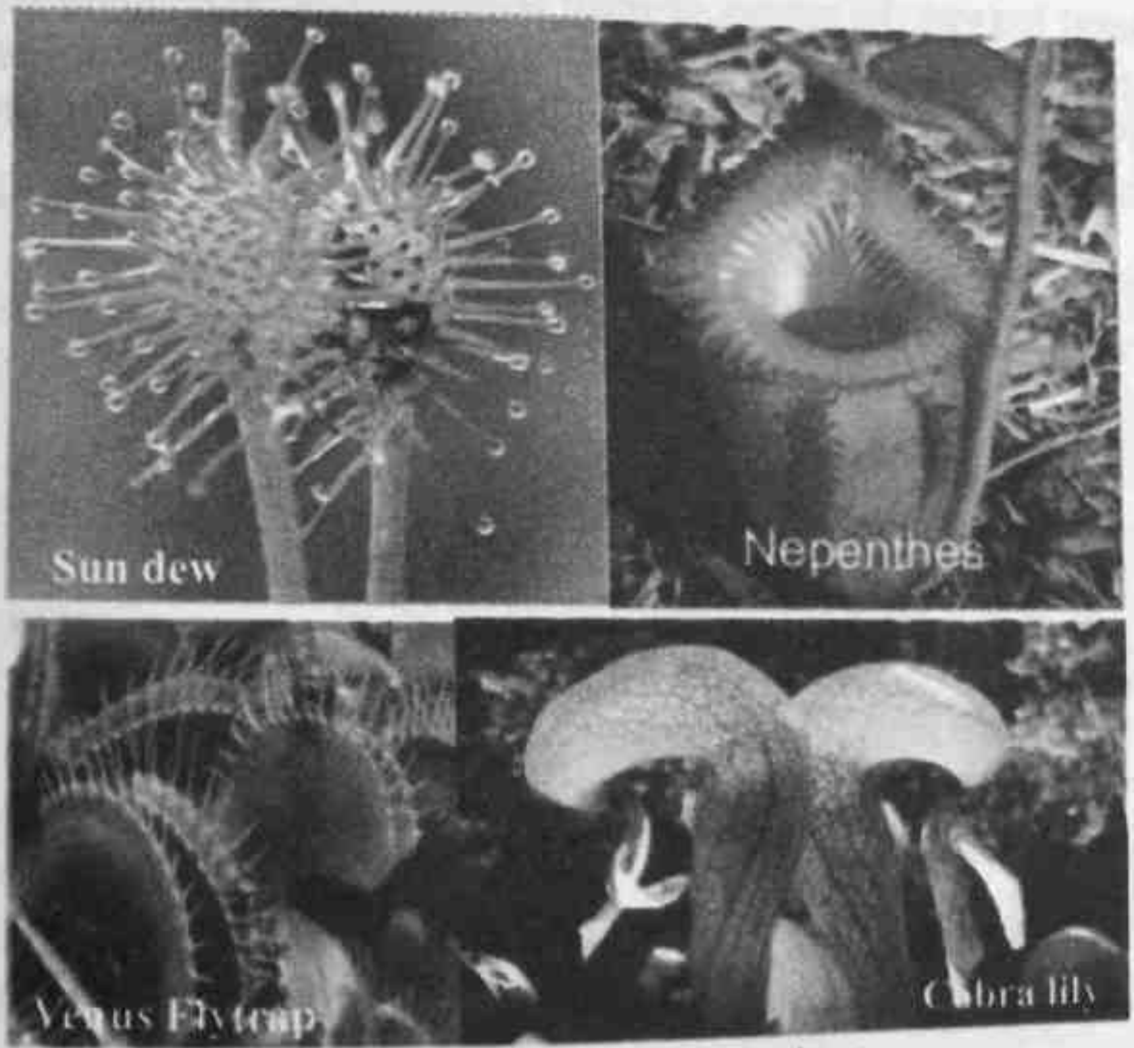


Fig. 10.1 Insectivorous plants

10.2 Gaseous Exchange in Plants

> **Tit bits**
>
> *All respiratory surfaces need to be thin, have a large surface area, be kept moist and have a good supply of oxygen.*

Like animals, plants also need oxygen for cellular respiration and get rid of CO_2 produced during this process. This exchange of gases takes place by diffusion. In the daytime, leaves are photosynthesizing, so oxygen produced during photosynthesis is enough for respiration. At night oxygen diffuses into the leaves through the stomata. This oxygen dissolves in the thin layer of moisture around the cell and diffuses across the cell wall and cell membrane. The roots get their oxygen from the air space in the soil.

10.2.1 Role of Palisade and Spongy Mesophyll in Exchange of Gases

Most of the interior of the leaves between upper and lower side of epidermis contains **parenchyma** or **chlorenchyma** tissue called **mesophyll** (Greek for middle leaf). This tissue is the primary location of photosynthesis. The mesophyll is divided into two layers. An **upper palisade** layer of vertically donated cells one or two cells thick and obtain more chlorophyll and without spaces between them. Beneath the palisade layer is a **spongy layer**. The cells of this spongy layer are not tightly packed so there are large intercellular spaces thus exchange of gases takes place more easily. These cells contain less chloroplast.

Types of mesophyll in dicot and monocot:

In dicot both spongy and palisade mesophyll cell layers are present, such leaves are called **bifacial leaves**. In monocot only spongy mesophyll layer is present between both upper and lower epidermis, such leaves are called **monofacial leaves**. The mesophyll cells are metabolically active cells due to photosynthetic process, therefore, these cells are rapidly involved in exchange of gases.

Leaf Cross Section

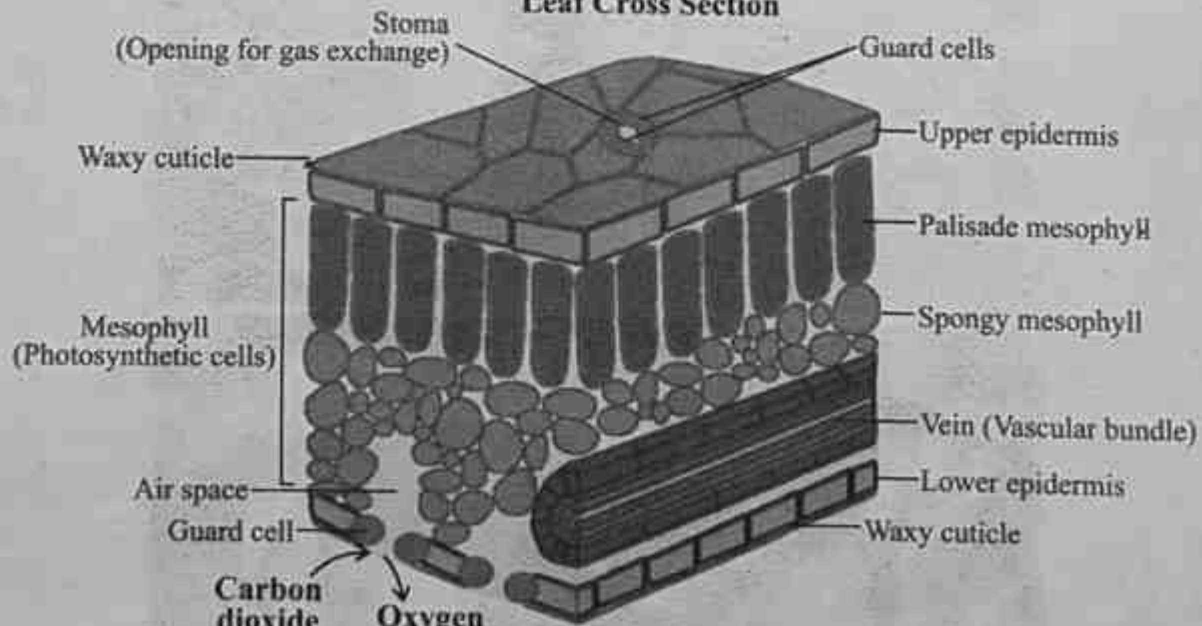


Fig. 10.2 Cross Section of Bifacial leaf

10.2.2 Role of Stomata in Gaseous Exchange and Transpiration

Stomata (singular stoma) are pores found in the epidermis of leaves, stems and other organs that facilitate gas exchange.

Stomata structure: Each pore of stomata is surrounded by two guard cells. In dicot plants guard cells are bean or kidney shaped while in monocot plants guard cells are dumb-bell shaped. The inner wall of guard cell is non elastic and thick while the outer wall is elastic and thin. In each guard cell nucleus and many chloroplasts are present. The opening and closing of stomata are regulated by change in the shape of guard cells.

Transpiration: The escape of water in the form of vapours from the surface of plant is called transpiration. Transpiration mostly takes place through stomata. During day light stomata are widely open, therefore, transpiration rate is high as compared to night. The other factors like air, temperature, humidity, concentration of CO_2 and water also contribute in the rate of transpiration.

10.2.3 Pattern of Exchange of Gases Between Plants and Environment

In plants pattern of exchange of gases is different in day and night. This difference is due to the fact that during day time both photosynthesis and respiration occur in plant but at night only respiration takes place.

Exchange of gases in day:

In day time plants absorb CO_2 and release O_2 because CO_2 consumption or fixation is more in photosynthesis than produced in respiration.

Exchange of gases at night:

At night photosynthesis slows down. Therefore, the pattern of exchange of gases in plants become animal like, i.e., release CO_2 and absorb O_2. As a result oxygen deficiency occurs near plants at night.

Compensation point of photosynthesis:

When the rate of photosynthesis exactly matches the rate of respiration, the uptake of CO_2 through photosynthetic pathway is exactly matched to respiratory release of CO_2 and the uptake of O_2 by respiration is equal to the photosynthetic release of oxygen. This time is called **compensation point** of photosynthesis. The compensation point is reached during early morning when sun arises (dawn) and late evenings when sun is about to set (dusk). At this level product of photosynthesis is used up in respiration so that plants are neither consuming nor building biomass.

10.3 Transport in Plants

The movement of materials into the body, within the body and out of the body of the organism is called transport. In plants the examples of transport are absorption of water and minerals from the soil through roots and the movement of organic solutes from leaves to different parts of the plants.

10.3.1 Movement of water between plant cells and their environment

The movement of water between plant cells and their environment takes place by osmosis. **Osmosis** is the movement of water from a region of higher water concentration towards lower water concentration through a semipermeable membrane. The absorption of water from soil to roots is example of osmosis in plants. If water moves into the cell by osmosis then it is called endosmosis and if water moves out of the cell then it is called exosmosis.

Water relations of the cells:

On the basis of movement of water into and out of cell, there are three kinds of water relations, i.e., water potential, solute potential and pressure potential.

Water potential:

The total kinetic energy of water molecules due to which they move from place to place is called water potential. The greater concentration of water molecules in a system, the greater is the kinetic energy of water molecules. The potential is denoted by a Greek symbol Ψ (Psi), so water potential is denoted by Ψw. The Potential is expressed in the unit of pressure called Pascal (Pa).

Two factors determine the water potential in plants:

i) Solute concentration, i.e., osmotic potential of solute (Ψs)

ii) Pressure polential (Ψp) so $\Psi w = \Psi s + \Psi p$

Pure water has maximum water potential. Thus water potential is zero. By definition water molecules always move from a region of higher water potential to a region of lower water potential.

> **Critical Thinking**
>
> *Do you know why we usually water plants in the morning or evening but not in the afternoon?*

Applications of water potential:

There are following applications of water potential.

i) Water potential can be used to measure the tendency of water to move between any two systems.

ii) Water potential can also be used for movement of water from soil to roots, from leaf to air, from air to soil.

The following example will help to understand the concept of water potential. Two adjacent vacuolated cells are shown with Ψw, Ψp, Ψs. The kPa = 1000 pascal.

Example

Cell A		Cell B	
Ψw	=-1400 kPa	Ψw	= -600 kPa
Ψs	= 600 kPa	Ψs	= 800 kPa
Ψp	= -2000 kPa	Ψp	= -1400 kPa

Qusestions

- Which cell has higher water potential?
- In which direction will water move by osmosis?

- What will be the water potential of the cell at equilibrium?
- What will be the solute potential and pressure potential of the cell at equilibrium?

Solute potential: (Osmotic potential):

The change in water potential of a system due to addition of solute is called osmotic potential or solute potential. **Solute potential** is always negative, i.e., with increase in solute the osmotic pressure will also increase. **Osmotic pressure** is an important factor affecting cells. In hypotonic solution the cell gets swell, in hypertonic solution the cell gets shrink while in isotonic solution the cells retain their shape and size.

Pressure potential (Ψp):

The pressure exerted by the protoplast against the cell wall of plant cell is called pressure potential. Water potential increases when pressure greater than atmospheric pressure is applied on pure water solution. It is equivalent to pumping water from one plant to another. Such situation may arise when in living cells the water enters into plant cell by osmosis. This water builds up pressure inside the cell and make the cell turgid. It also increases the pressure potential. The pressure potential helps to maintain the shape of the cell.

10.3.2 Uptake of Water by Roots and Pathways

The root hairs are located on the edge of the roots while xylem vessels are in the center. Before the water can be taken to the rest of the plant, it must reach to xylem vessels through root hairs. There are following three pathways taken by water to reach the xylem vessels.

a. Apoplast pathway
b. Symplast pathway
c. Vacuolar pathway

Apoplast pathway:

The movement of water through the extra cellular pathway between the cell walls of adjacent cells is called apoplast pathway. The ions easily reach the endodermis by this

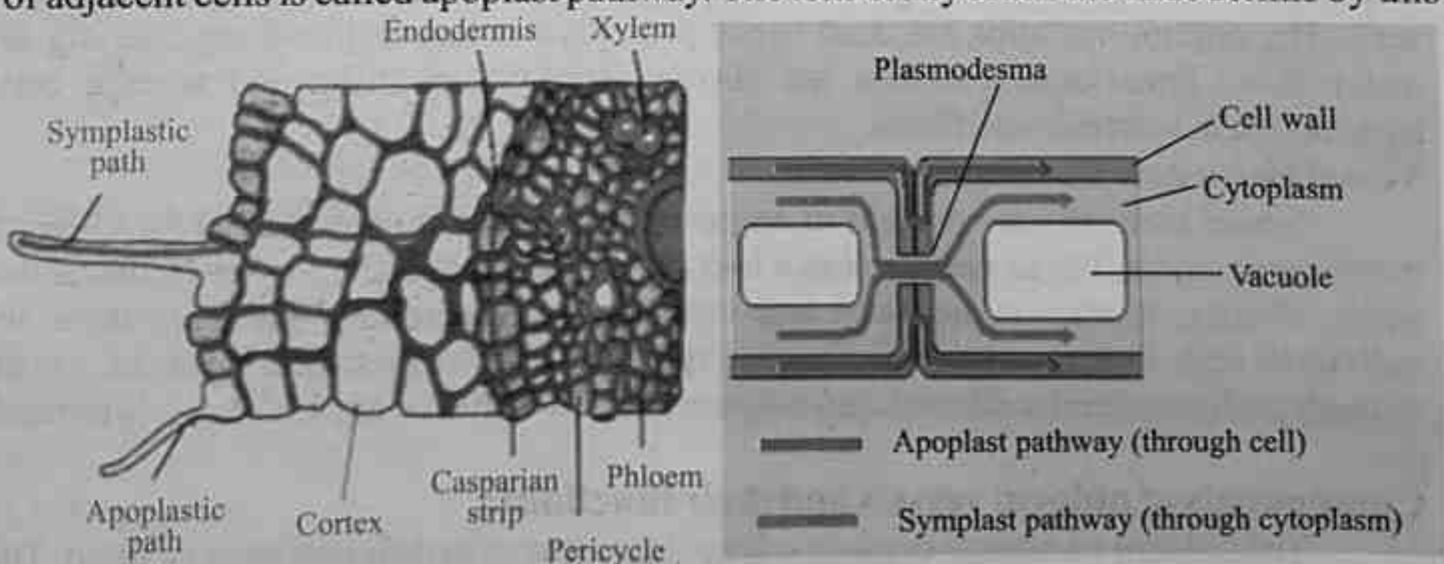


Fig. 10.3 Pathway of water

pathway, but the **casparian strips** prevent further movement. The casparian strip is a band of cell wall material deposited in the radial and transverse walls of root endodermal cells. It is chemically composed of suberin (a water proof waxy substance). Thus these ions must enter into the endodermal cells by diffusion or active transport. They enter into cytoplasm or vacuole of the endodermal cells.

Symplast pathway: The movement of cell sap through the plasmodesmata of cell is called symplast pathway. **Plasmodesmata** (singular plasmodesma) are cytoplasmic microscopic channels between cell walls of adjacent plant cells which enables transport and communication between them. There is a concentration gradient down the cells of cortex, endodermis, pericycle and sap of xylem so minerals move down through plasmodesmata into the cells of cortex, endodermis, pericycle and then to the sap of xylem.

The vacuolar pathway: The movement of water molecules in plant cells via the vacuoles located in the cytoplasm of the cell. The water molecules encounter high resistance and as a result little flow usually occurs, making this pathway less efficient than apoplast and symplast pathway. Water moves by osmosis across the vacuoles of the cells of root system.

10.3.3 Structure and Function of Xylem and Phloem

Xylem and phloem are two types of transport tissues in vascular plants. The basic function of xylem is to transport water from roots to shoots and leaves but also transport some nutrients. The phloem transports organic food from photosynthetic cells to all parts of plants for use and storage.

Components of xylem: The word xylem is derived from the Greek word *"xylon"* meaning wood. These are elongated cells and tubular water transport system because these cells are connected end to end with each other. There are two main kinds of cells in xylem, i.e. Tracheids and Vessel elements.

Tracheids: Tracheids are elongated cells up to 80 nm wide with secondary lignified cell wall. The mature tracheids are dead hence protoplast is lost and creating opening for water flow. Functional tracheids are surrounded by supporting and storage cells paraenchyma, sclereids and fibres.

Vessel elements:

Vessel elements are present in angiosperms. These are specialized for efficient water conduction. These reduce water loss by transpiration. The vessel elements are wider, shorter, thinner walled and less tapered than tracheids. Vessel elements are individual cells linked end to end froming xylem vessel. Water stream from cell to cell through perforated end walls and also migrate laterally between adjacent vessels through pits.

Components of phloem vessels and their functions:

The phloem transports organic solutes from leaves to different parts of plant. The phloem tissue is present on outside of xylem tissue. The phloem is a permanent tissue that is composed of three living cells and one dead cell. The living cells are sieve tube elements, companion cells and the phloem parenchyma while the dead cell is sieve tube. The **sieve tube** are long elongated cells placed end to end with the walls composed of cellulose. The end walls of sieve tubes are perforated. The perforated area looks like a sieve thus known as sieve plate. These pores of sieve tube help in translocation of solutes. The **companion** cells are thin walled elongated cells associated with sieve tube. These are living cells containing cytoplasm and elongated nucleus. The companion cell and sieve tube are in communication with each other through plasmodesmata. The companion cells provide energy to sieve tubes. The phloem tissue also possesses parenchyma that has storage function and very thick walled fiber cells which provide support.

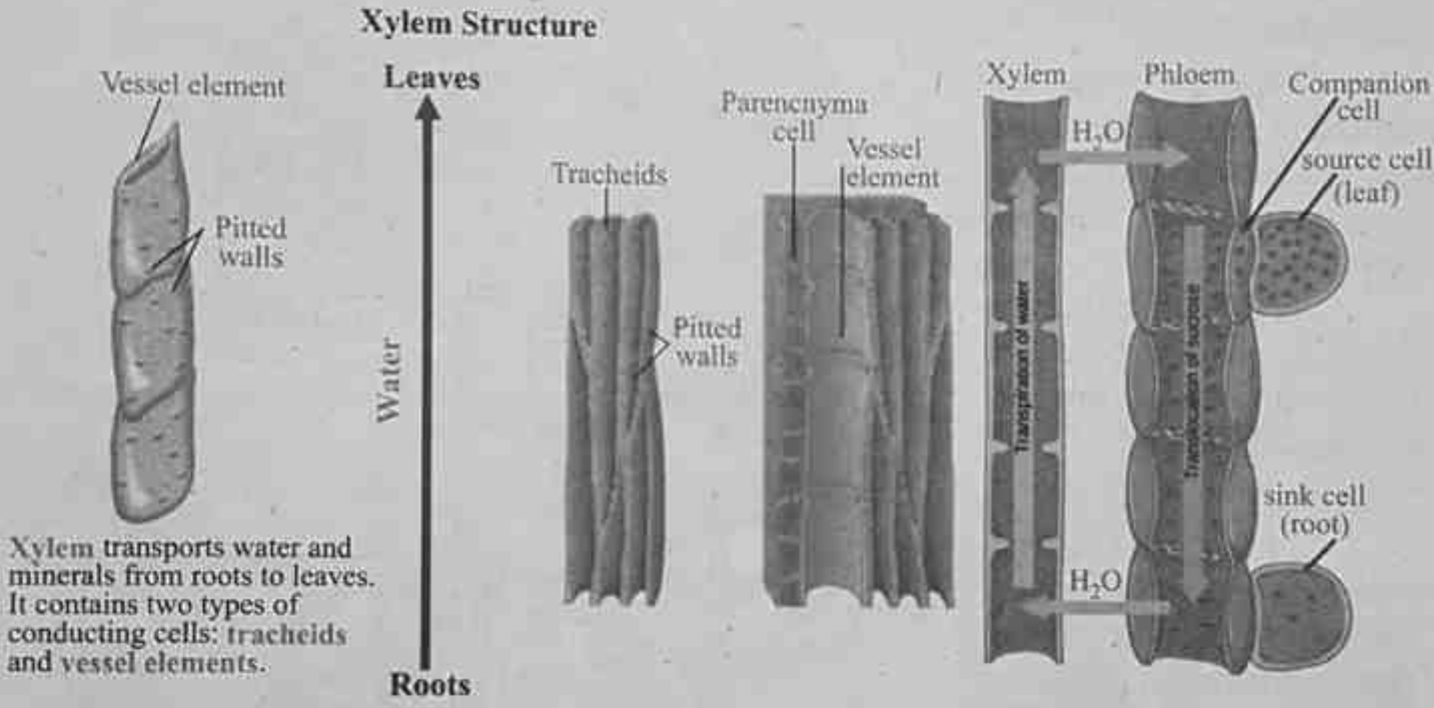


Fig.10.4 Structure of Xylem and phloem

10.3.4 Ascent of sap

The pull of water and dissolved minerals through the xylem tissue towards the leaves is known as ascent of sap. The water and dissolved minerals are collectively called sap and ascent means upward movement. Dissolved minerals from soil enter in root hairs and then move through the following path ways:

Epidermis ⟶ cortex ⟶ endodermis ⟶ pericycle ⟶ xylem ⟶ leaves

As the ascent of sap is against the gravity, therefore, a considerable force is required to transport the sap especially in tall plants. The sap is transported from roots to leaves through xylem by TACT forces. These TACT forces also known as TACT theory, responsible for ascent of sap.

TACT theory:

The TACT stands for Transpiration pull, Adhesion, Cohesion, Tension. The ascent of sap through "these forces" are called TACT theory.

Transpiration pull:

The transpiration involves in the pulling of water upward by utilizing the energy of evaporation. Transpiration pulls the water at much higher speed (upto 8 m/h). About 99% of pulled water is transpired while remaining 1% is used for various activities like photosynthesis.

Adhesion:

The force of attraction between the water molecules and other substances is called adhesion. The water and cellulose are polar molecules, therefore, strong attractive forces are present between water and cellulose, so the water molecules adhered to xylem tissue and column of water does not break.

Cohesion:

The forces of attraction present between the molecules of same substances are called cohesion.

The high cohesive force is present between water molecules due to hydrogen bonding.

Tension:

The pulling of water upward produces tension in xylem tubes. The transpiration provides the necessary energy. The hydrogen bonds between water molecules produce this tension. In xylem water tension is much stronger. It can pull the water upto 200 m (more than 600 feet) in plants.

Mechanism of TACT force:

The evaporation of water from the aerial parts of plants especially through stomata of leaves is called **transpiration.**

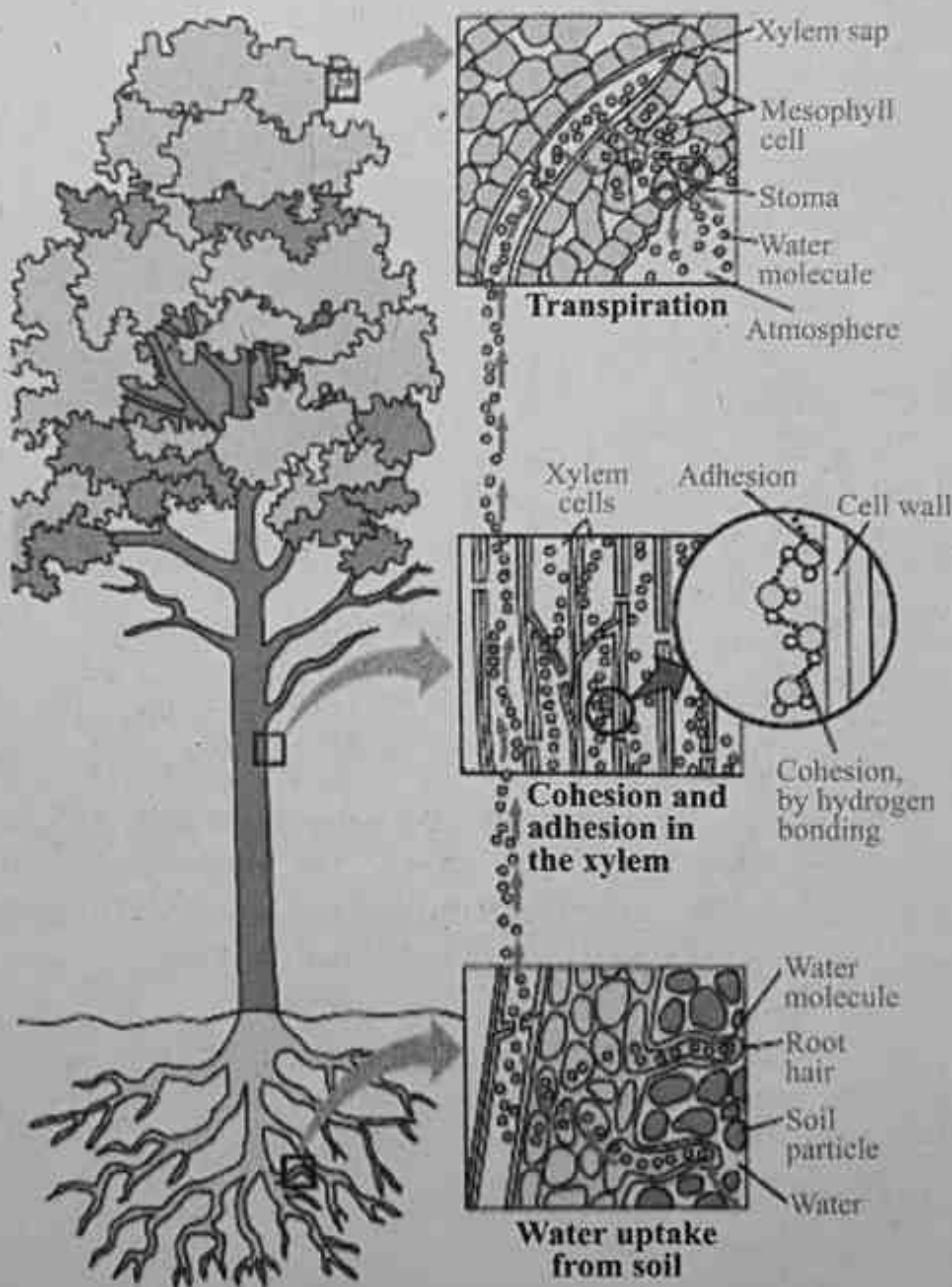


Fig. 10.5 Movement of water in xylem through TACT mechanism

Due to transpiration water potential of mesophyll cells drops which causes water to move by osmosis from xylem cells of leaf into dehydrating mesophyll cells. The water molecules leaving the xylem are attached to other water molecules in the same xylem tube by hydrogen bonds (cohesion of water molecules), therefore, when one water molecule moves in the xylem, the process continues all the way to the roots where water is pulled from xylem.

> **Tit bits**
>
> *The combination of adhesion, cohesion and surface tension allow water to climb upward. It is called capillary action.*

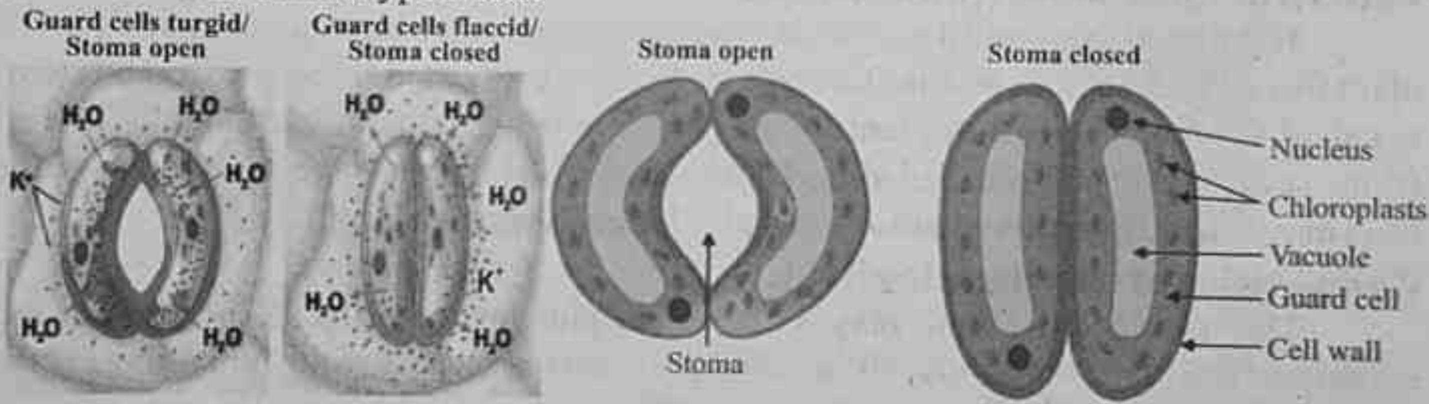
This pull also causes water to move down its concentration gradient transversely from root epidermis (root hairs) to the cortex endodermis and to pericycle. It is estimated that the column of water molecules within the xylem is atleast as strong as a steel wire of the same diameter.

10.3.5 Opening and closing of stomata

As discussed earlier in this chapter stomata are the openings between two guard cells. The guard cells play important role in opening and closing of stomata. There are two hypothesis for explaining the opening and closing of stomata.

a. Starch sugar hypothesis.

b. K^+ ions influx hypothesis.



(b) Role of potassium in stomatal opening and closing

Fig. 10.6 Opening and closing of stomata.

a. Starch sugar hypothesis:

This hypothesis was proposed by German botanist Hugo von Mohl. According to this hypothesis the guard cells are the only photosynthesizing cells of leaf epidermis because they have high contents of chlorophyll than the surrounding epidermal cells.

Opening of stomata: Photosynthesis takes place during day time so sugar is produced in the guard cells during day time. The increase in sugar level increases the solute concentration in the cell. Therefore, water potential in the cell decreases. As a result the guard cells absorb water and become turgid and curved. This creates an opening in stoma.

Closing of stomata: The process of photosynthesis slows down at night. The already present sugar is utilized in respiration or stored in the form of insoluble starch. So the osmotic potential of guard cells is higher. Thus water leaves the guard cells, they become flaccid and stomata are closed.

b. K^+ ions influx hypothesis:

According to this hypothesis when photosynthesis starts in morning, this causes a decrease in level of CO_2 in guard cells. The low level of CO_2 stimulates the inward movement of K^+ ions into the guard cells.

Opening of stomata: The accumulation of K^+ ions in guard cells decreases the osmotic potential so water enters the guard cells by osmosis. As a result guard cells become more turgid so stomata are opened.

Closing of stomata: The stomata close by reverse process. There is a passive diffusion of K^+ ions from guard cells to outside so water also moves out by osmosis. The guard cells become flaccid and close the stomata. The level of CO_2 in the space inside the leaf and light control the movement of K^+ ions into and out of guard cells.

10.3.6 Translocation of organic solutes

The movement of sucrose and amino acids in phloem, from region of production to region of storage or to regions of utilization is called translocation of organic solutes.

Pattern or direction of translocation:

The direction of translocation of food is always from source to sink. The part of plant from which sucrose and amino acids are being translocated (green leaves and stem) is called **source.** The part of plants where they are being translocated (yellow leaves, fruits, seeds and roots) is called **sink.** During cold when there is no photosynthesis, the food moves from the parts where it is stored to the parts where it is utilized.

Composition of translocating fluid:

The translocating fluid may be called as phloem sap. 10-25% of phloem sap consists of dry matter and about 90 % of this dry matter is sucrose while remaining are the other organic molecules like proteins, lipids etc.

Mechanism of translocation:

There are different views about the mechanism of translocation but most acceptable one is pressure flow or mass flow theory.

Pressure flow theory:

Ernst Munch proposed a hypothesis in 1927 to explain the mechanism of translocation. This hypothesis states that an osmotically generated pressure gradient between source and sink drives the solution through the **sieve elements.** Now this hypothesis has been given the status of theory. The pressure flow theory accounts for the mass movement of molecules within phloem. It may be noted that carbohydrates from the mesophyll cell to phloem tissue involve diffusion and active transport. Then in phloem tissue the movement of materials takes place in bulk and according to the pressure flow mechanism.

10.4 Homeostasis in Plants

The ability of an organism to maintain its internal environment at nearly constant state is called **homeostasis**. As the external environment is always changing which may disturb their internal environment. The plants have many adaptations to prevent such harmful changes. There are three elements of homeostasis, i.e., osmoregulation, thermoregulation and excretion.

10.4.1 Osmoregulation (Osmotic Adjustment)

The maintenance of water and solute level in the body at nearly constant state is known as osmo-regulation. There are three kinds of situations on the basis of water and solute concentration such as hypotonic, hypertonic and isotonic conditions.

Isotonic solution: It is a type of solution in which the amount of solute is exactly similar to that of cell. The cell will retain its shape and size if kept in such solution.

Hypotonic solution: It is a type of solution in which the amount of solute is less as compared with cell so the cell will swell up if kept in such solution.

Hypertonic solution: It is a type of solution in which the amount of solute is higher than the cell and the cell will get shrink if kept in it.

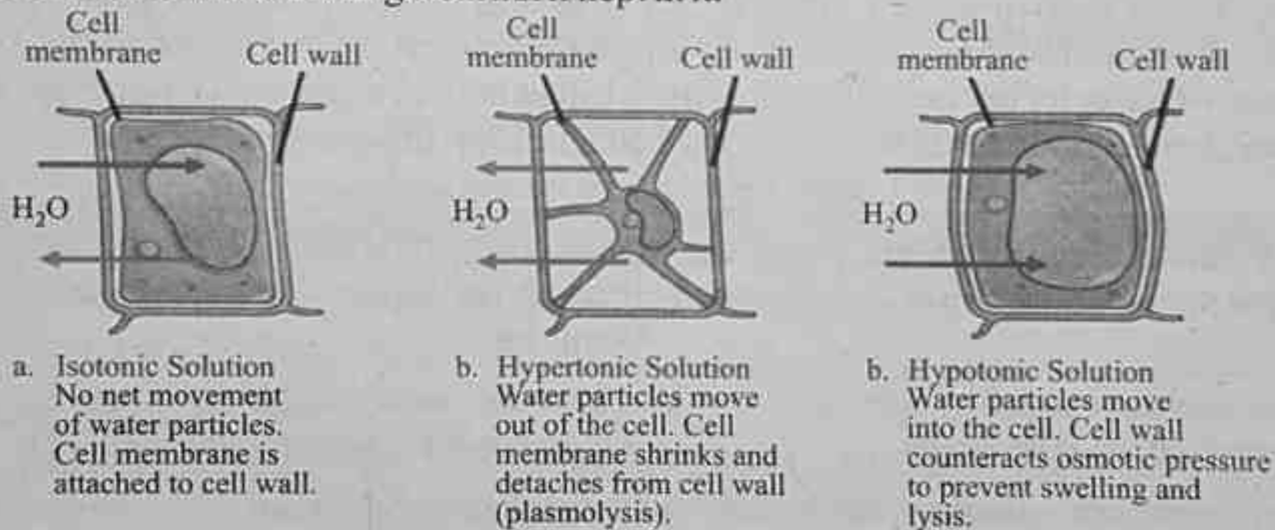


Fig. 10.7 Types of solutions and their effects on cell

10.4.2 Osmoregulation in Plants of Different Environments

Due to the ability of osmoregulation plants are able to grow in wide range of habitats. On the basis of water availability plants are classified into following four groups.

1. **Hydrophytes:** Such plants which live in fresh water or damp places where abundant water is available in soil. These plants face the problem of flooding and excess of water. Following adaptations are made to overcome the problem of excessive supply of water such as short roots having no or less root hairs, no cuticle, long monofacial leaves having large number of stomata etc.

2. **Halophytes:** Such aquatic plants which live in very salty and hypertonic

medium. These plants have to face the problems of excess of solutes and shortage of water because water continuously comes out of the surface of plants due to hypertonic surrounding. These plants show some adaptations to prevent water loss and absorb more water such as long roots with huge number of root hairs, thick cuticle, small leaves, salt tolerance and excretion of extra salts through hydathodes etc.

3. **Mesophytes:** These are terrestrial land plants which are adapted to neither a particularly dry nor particularly wet environment. Mesophytes are largest group of plants.

These plants face the problem of shortage of water. To meet with this challenge, these plants generally show some adaptations like extensive fibrous root system to absorb water, bifacial leaves to minimize water loss through stomata, automatically regulated stomata, have structures like rhizomes and bulbs to store food and water during drought.

Activity

Make a list of adaptive characters of Xerophytes, Mesophytes, Hydrophytes and halophytes through field survey or searching encyclopedia.

4. **Xerophytes: (from Greek xeros: dry, phyton: plant):** These plants are adapted to survive in an environment with little water such as desert or an ice or snow covered region in arctic. These plants show many adaptations to conserve water and to store large amount of water for dry periods. such as thick leaves to store water, sunken stomata, short stature, long period of seed dormancy, thick cuticle, short life cycle etc.

Table 10.3 Comparison between stomata and hydathodes

Stomata	Hydathodes
Found in epidermis of leaves, young stem etc.	Present on the tips of the leaves at the vein end.
These are surrounded by pair of chlorophyllous guard cells.	These are surrounded by a ring of cuticularised achlorophyllus cells.
Stomata are surrounded by subsidiary cells.	Subsidiary cells absent.
These are concerned with transpiration.	These are concerned with guttation.

10.4.3 Thermoregulation in Plants

The ability of an organism to keep its body temperature within certain boundaries even when the surrounding temperature is very different is known as thermoregulation. Like animals, plants also need a suitable temperature for their metabolic activities. Plants show many adaptations to tolerate low and high temperature changes.

Adaptations in plants to tolerate low temperature:

The low temperature mainly affects permeability of cell membrane by changing the phospholipids into crystalline structure, as a result solutes may come out of the cell.

Moreover, low temperature also affects enzyme activity and protein structure, formation of ice crystals in cytoplasm. To avoid these problems of low temperature plants show adaptations, such as:

- Increase the proportion of unsaturated fatty acids to maintain structure of cell membrane.
- Possess antifreeze proteins to prevent crystal formation.
- Low transpiration rate due to fall of leaves to reduce cooling.
- The stems and leaves are mostly hard to tolerate low temperature.
- Well developed bark and fast life cycle.

Adaptations in plants to tolerate high temperature:

The high temperature may affect plants in different ways, e.g., it may cause dehydration in plants by increasing transpiration rate, slow down or stop metabolic activities by denaturing enzymes and proteins.

To escape from these damaging effects plants show different adaptations such as:

- Shiny cuticle which reflects much of radiations of sun.
- Heat resisting proteins to avoid denaturation.
- High transpiration rate which keeps plants cool.
- Extensively branched root system to absorb more water from soil to keep plant cool.
- Thick waxy cuticle to prevent the entrance of strong harmful radiations.

10.5 Support in Plants

All organisms need support against gravity. Terrestrial organisms need more support than aquatic organisms. In plants, support is mainly provided by parenchyma, collenchyma and schlerenchyma tissues.

Parenchyma Tissues:

In herbaceous plants the mechanical supporting tissues, i.e., collenchyma and sclerenchyma are not common. Therefore, support is mainly provided by parenchyma tissues. These tissues consist of thin walled living cells, containing large central vacuole filled with water. The vacuole applies pressure on the cell wall and make it turgid. So this pressure is called **turgor pressure.** The turgidity of cells provides strength and support to the different parts of plant. The cells of parenchyma tissues are usually spherical or oval in shape. The parenchyma cells make the bulk of the soft part of plant, including the inside of leaves, flowers and fruits.

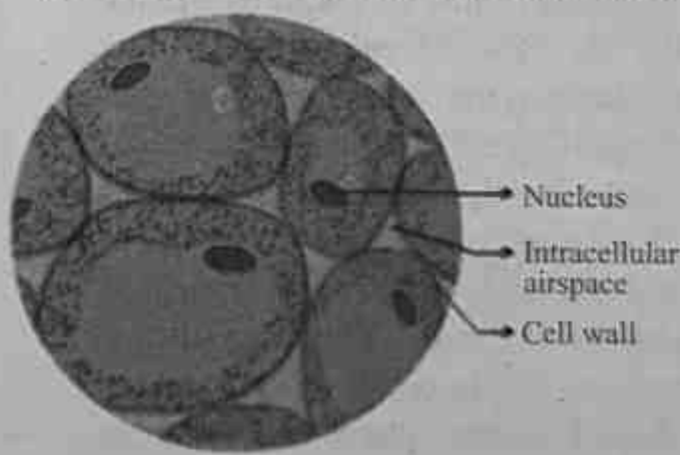


Fig. 10.8 (a) Parenchyma Tissue

Activity

Land plants usually have bifacial leaves. What are the advantages of such leaves for them.

Mechanical Supporting Tissues:

Such tissues having thick walled cells and provide mechanical support and specific shape to parts of body are called mechanical tissues. In plants mechanical tissues include collenchyma and sclerenchyma.

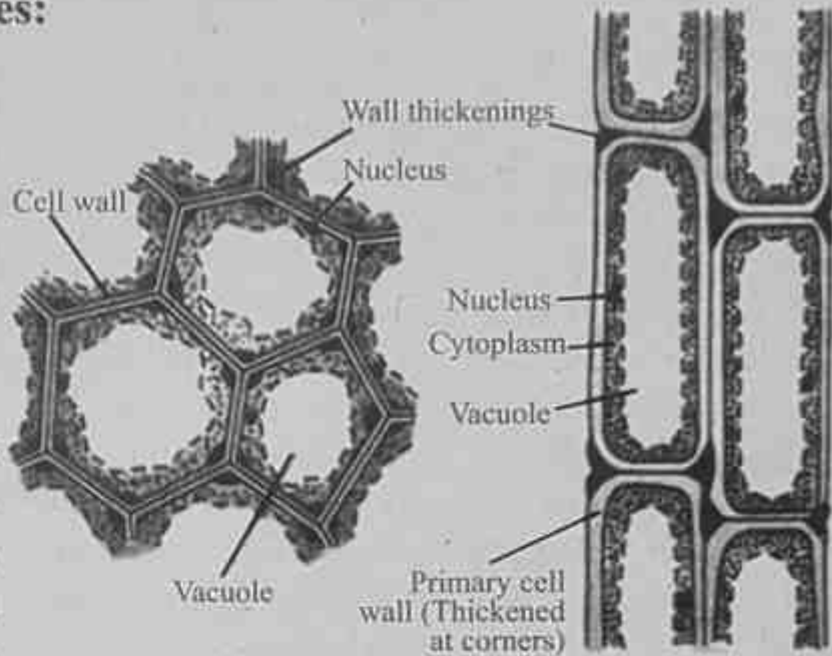


Fig. 10.8 (b) Collenchyma Tissue

Collenchyma Tissues:

These are composed of elongated cells with irregularly thickened walls. They provide support to growing shoot, located beneath the epidermis of dicot stems, petioles of leaves and pedicel of flowers. These tissues are usually living and having only thick primary cell wall composed of cellulose and pectin.

Sclerenchyma Tissues:

These are also supporting tissues that make the plant hard and stiff. The mature sclerenchyma is composed of dead cells with extremely thick cell wall that make up the 90% of cell volume. The sclerenchyma cells are principal supporting cells in plant tissues that have ceased elongation. Two types of sclerenchyma cells exist, fibers and sclereids. Fibers are elongated slender like cells. The sclereids are roughly spherical or variously shaped. Fibers are usually found associated with xylem, phloem and

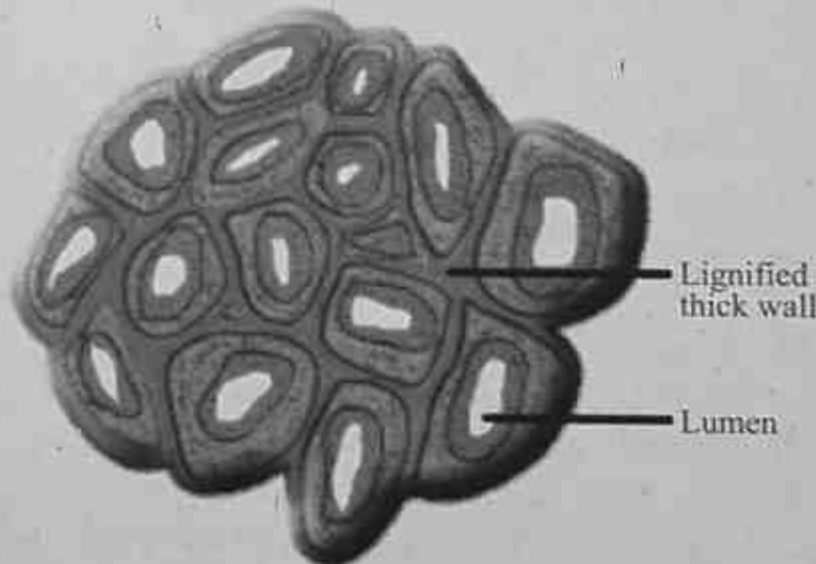


Fig. 10.8 (c) Sclerenchyma Tissue

Tit bits

The term meristem was first used in 1858 by karl Wilhelm Von Nageli. It is derived from the Greek word "Merizein" meaning to divide.

pericycle of stem, while sclereids are mostly found in seed coats, nuts, drupes.

The ring arrangement of vascular bundle in dicot plants also provide support to plant body.

10.6 Growth and Development in Plant

Growth means increase in size or mass of cells over a period of time. The **development** is a programmed series of irreversible changes in shape, form, complexity in structure and function.

Phases of growth in plant: There are four phases of growth in plant.

Cell division phase: Production of new cells.

Cell elongation phase: Enlargement in size of cell.

Cell maturation phase: The attaining of maximum size and starting function.

Cell differentiation phase: A process where a cell changes from one cell types to another.

10.6.1 Meristematic Tissues (Meristems)

In lower plants, entire body of a plant is capable of growing but in higher plants cell division and growth is localized. Infact it can only occur in particular regions called meristems. A **meristem** is a group of plant cells which retain the ability to divide by mitosis. When a meristem cell divides, one of the cells produced remains meristematic while the other give rise to specialized cells. There are three types of meristematic tissues.

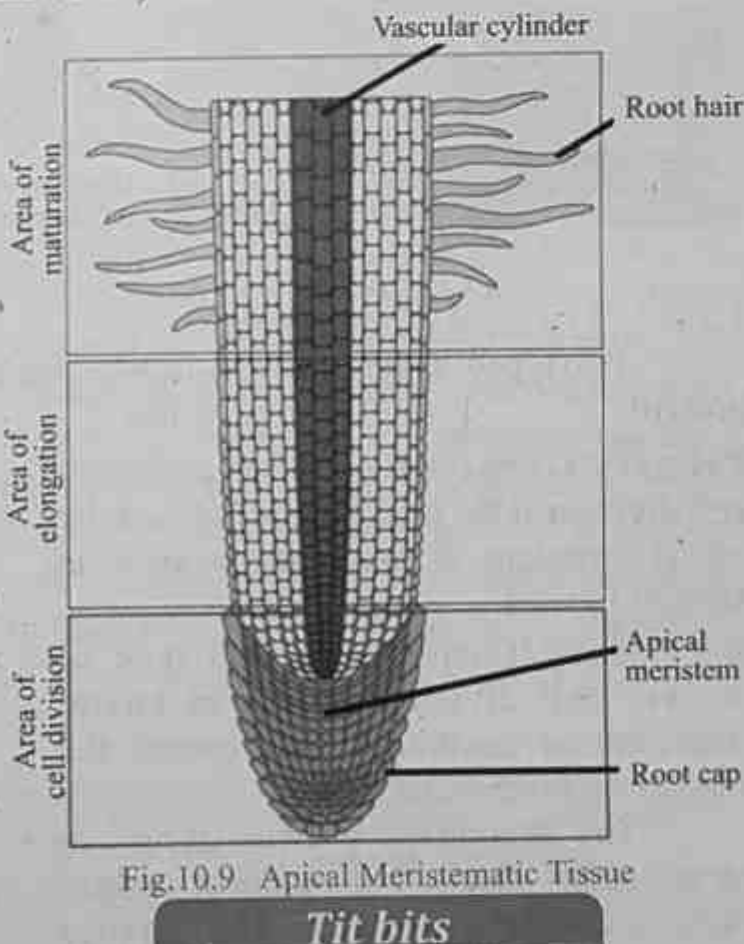


Fig.10.9 Apical Meristematic Tissue

Tit bits

In plants growth continues throughout life. This pattern of growth is called open growth.

1. **Apical Meristem:** This type of meristem is located at the tips of stems and roots and is responsible for primary growth of the plants, i.e., increases the length of stem and root. The meristem of stem tip is called stem apical meristem (SAM) and meristem of root tip is called root apical meristem (RAM).

2. **Intercalary Meristem:** This type of meristem occurs in between permanent tissues as in internodes of

grasses, bamboos, sugar canes etc. This meristem allows an increase in length in position other than the tips.

3. **Lateral Meristem:** This type of meristem is also called secondary meristem, occurs as cylinder towards the outer part of the stem. It is responsible for secondary growth, resulting in thickening. There are two types of lateral meristems, i.e., **vascular cambium** which produces secondary xylem and phloem. **Cork cambium** which gives rise to periderm that replaces the epidermis. The cork cambium is also called phellogen.

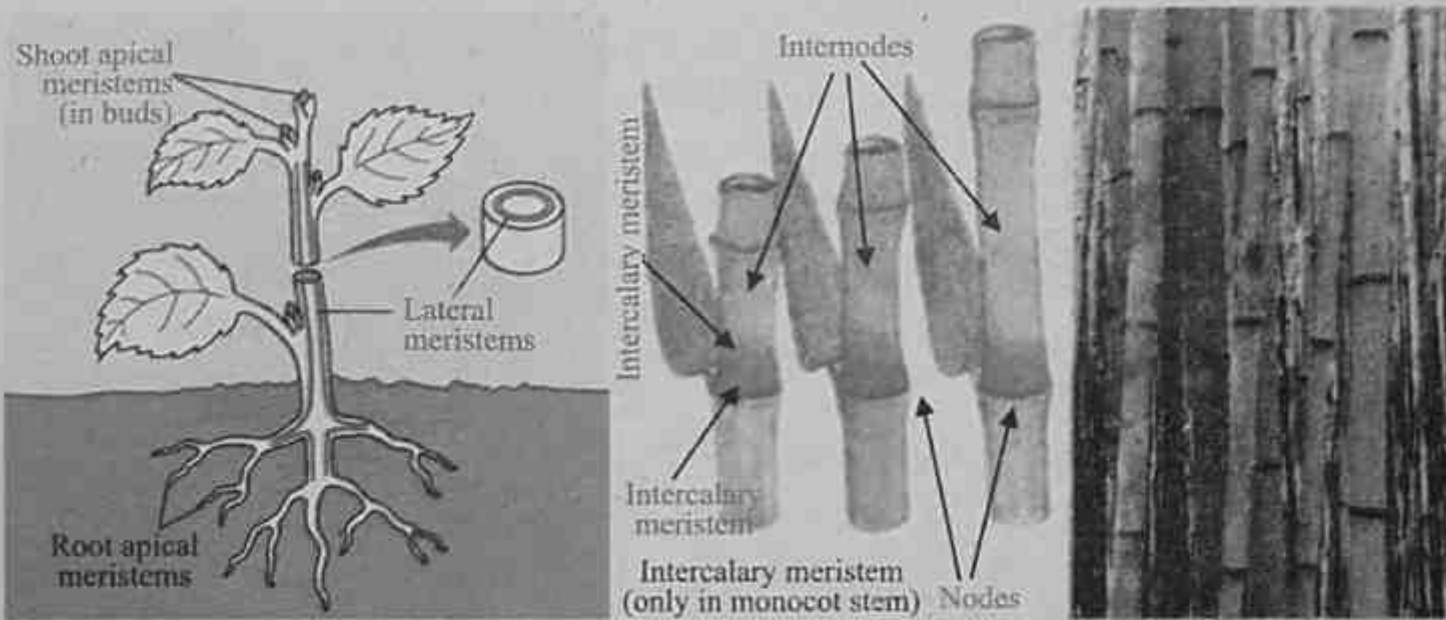


Fig. 10.10 Three Types of Meristem

10.6.2 Types of Plant Growth

Two types of plant growths are noticeable. That is Primary growth and Secondary growth.

Primary Growth: It occurs as a result of cell division at the tips of stem and roots by apical meristem. It causes the increase in length of plants.

Secondary Growth: In this type of growth cell division occurs in lateral meristem or cambium. This causes the thickening of stem and roots.

The secondary growth occurs in most seeded plants, but monocot usually lack secondary growth. The tissues produced as a result of secondary growth are called secondary tissues while the tissues that are already present in plant are called primary tissues.

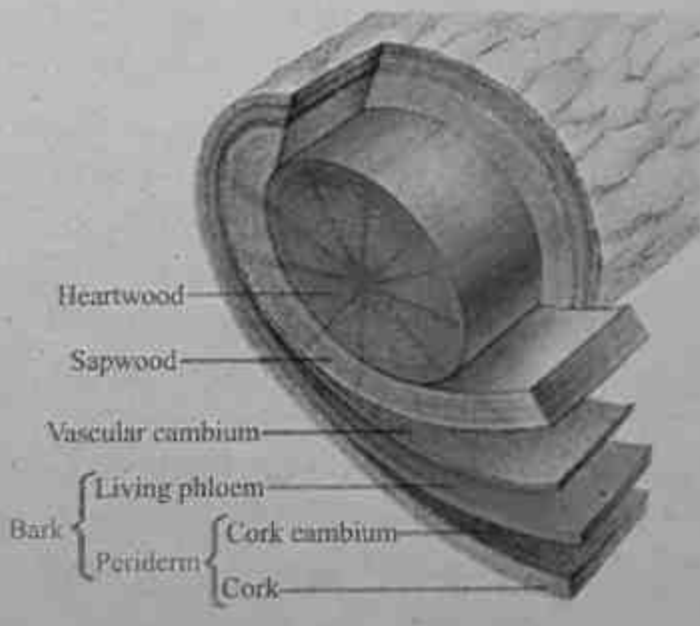


Fig. 10.11 Secondary Growth

The secondary growth causes thickness of stem, branches and roots. This thickness is helpful to support growing plants.

Fig. 10.12 Annual Rings

Growth Rings or Annual Rings: The growth rings also known as tree rings or annual rings. These rings can be seen in horizontal cross section cut through the trunk of a tree. These rings are formed as a result of new growth in the vascular cambium. Visible rings result from change in growth speed through the seasons of the year. The growth takes place during spring is called **spring wood** or early wood. The growth is rapid and less dense and usually lighter in colour due to more concentration of minerals in soils. In **autumn or late wood** secondary growth occurs slowly and the wood formed is more dense and darker due to less concentration of minerals in soil. Both spring and autumn wood is collectively called one annual ring. By counting annual rings at basal trunk help to determine the age of a tree. The study of properties of annual rings can also be used to determine past climate.

Wood and Bark: Wood is a porous and fibrous structural tissue found in stems of woody plants. It is an organic material mainly composed of cellulose and lignin. In living trees it performs support functions and also help in transport of water and nutrients. The inner dead darker part of the wood is called **heart wood.** The woody plants usually store wastes in this part of wood. The outer softer living part of wood containing vascular tissues is called soft wood or **sap wood.** This part of the wood is lighter in colour.

The outer most layer of stems and roots of woody plants, the bark is usually composed of tannins, lignin, suberin and polysaccharides. The bark overlaps the wood and consists of inner bark and outer bark. The inner bark is a living tissue while outer bark includes the dead tissues.

10.6.3 Growth Correlations

The conditions prevailing in one part of plant body affect the growth of other parts. This phenomenon is called growth correlations, e.g., growth of vegetative parts sharply checked during fruiting. The growth correlation may be inhibitory or compensatory.

Tit bits

Dendrochronology:
It is the scientific method of dating tree rings to the exact year they were formed in order to analyse atmospheric conditions during different periods in history.

Inhibitory growth correlation (Negative growth): In this type of growth correlation, growth of one part of plant inhibits the growth of other part. e.g., apical dominance.

Apical dominance: In many plants it has been observed that unless apical bud is removed, lateral bud is unable to develop. It is called apical dominance. The apical dominance is due to auxin produced by apical meristems. The apical dominance may be complete or incomplete.

Compensatory growth correlation (Positive growth): In higher plants by reducing the number of repeated parts the extra ordinary growth of remaining parts can be achieved, e.g., positive growth in *Chrysanthemum* by reducing the number of flower buds larger flowers can be obtained. This type of growth correlation is called positive or compensatory growth correlation.

Application of apical dominance: Apical dominance inhibits the sprouting of lateral buds, e.g. eyes in potatoes by using synthetic auxin which increase the storage period of potatoes from one to three years. It also plays an important role in the tap root development. It's application in horticulture and everyday gardening, increase the number of lateral branches and large size flowers.

10.7 Growth Responses in Plants

> **Tit bits**
>
> *The substantces that inhibit the action of auxins are called antiauxins.*

Plants respond to environmental changes usually by growing in different directions. These growth changes are controlled by plant **hormones** also called plant **growth regulators** (PGRs). Plant growth regulators are chemicals produced in very small quantities in one part of the plant and transported to another part where they promote, inhibit or modify growth. There are five classes of plant growth regulators i.e. Auxins, Gibberellins, Cytokinins, Abscisic Acid and Ethylene.

Auxins: These are a class of plant hormones which are mainly responsible for bringing about cell elongation in shoots. They are also known as to control many physiological processes and influence other hormones. The principal natural auxins are chemically indole acetic acid (IAA). Its formula is $\mathbf{C_{10}H_9N\,O_2}$. Besides the natural auxins, a number of synthetic auxins have been developed. These include 2-4 dichlorophenoxy acetic acid, alpha naphthalene acetic acid etc. Auxins are synthesized in the tips of shoots and roots.

Gibberellins: These are growth regulating substances bring about a rapid and great elongation of the stem and various other developmental processes like germination, dormancy, flowering, leaf and fruit senescence (ageing). There are more than 75 different types of gibberellins have been discovered. They are named as GA_1, GA_2, GA_3 and so on. The most active and best known gibberellins is Ga_3 (Gibberellic acid, $\mathbf{C_{19}H_{22}O_6}$) obtained from rice fungus.

Cytokinins: These are a class of plant growth hormones that promote cytokinesis so called cytokinins. Chemically these are derivatives of adenine like kinetin and zeatin

($C_{10}H_{13}N_5O$). These are synthesized in the tissues of plants where cell division occurs.

Abscisic Acid (ABA): It is the plant hormone which helps in many plant developmental processes, including bud dormancy, fruit drop, leaves drop and also involve in stress responses. ABA is chemically a terpenoid and is formed in leaves, fruits and seeds. Like the other growth substances ABA moves in the vascular system.

Its formula is $C_{15}H_{20}O_4$. The abscisic acid owes its name to its role in abscission of plant leaves.

Ethylene: It is relatively simple organic molecule that exists as a gas at normal temperature. It is produced naturally in trace amount in most of the organs of higher plants. The main role of it is to promote fruit ripening. However, it also involves in breaking bud dormancy, promote abscission of fruit and leaves etc. Its formula is C_2H_4.

10.7.1 Growth Movements in Plants (Tropic movements)

Plants do not show locomotion. However, organs of higher plants, i.e., stems, roots and leaves exhibit movement that are usually very slow to be noticed. Plants show different types of movements in response to different stimuli such as tactic, tropic and nastic movements. In this chapter we will learn about tropic movement and its types.

Tropic movement: A tropic movement or tropism (Greek *Tropos*: a turning) is a biological phenomenon indicating growth or turning movement of plant in response to an environmental stimulus. In tropism this response is either towards stimulus (positive tropic movement) or away from stimulus (negative tropic movement).

Types of tropic movements: There are many types of tropic movements on the basis of stimulus. Some noticeable tropic movements are as under.

Geotropism: Growth in response to gravity is called geotropism.

Phototropism: Growth movement in response to light or colour of light.

Thermotropism: Growth movement in response to temperature.

Thigmotrpism: Growth movement in response to touch or contact.

Hydrotropism: Growth movement in response to water.

Chemotropism: Growth movement in response to chemicals.

Aerotropism: Growth of plant towards or away from a source of oxygen.

10.7.2 Protoperiodism

The photoperiodism is the physiological reaction of organism to the length of day or night. The length of day light period has a marked influence on the behaviour of the plants, particularly on the development of flowers and fruits. The relative length of day and night to which the plant is exposed is called the photoperiod while the response of plant to photoperiod is called photoperiodism.

Tit bits

Pfr can also be converted into Pr by a process called dark reversion where long period of darkness triggers the conversion of Pfr.

Classification of plants based upon photoperiodism:

According to photoperiod response, the plants are classified into three groups.

Short day plants: These plants require a relatively short day light period for flowering. Therefore, in these plants by shortening the photoperiod flowering can be hastened. Usually the plants which develop flowers in late summer are known as short day plants. All short day plants have a certain critical photoperiod and will blossom only when the day length is below that photoperiod, otherwise these plants will continue to grow vegetatively. Examples of short day plants are *Maryland mammoth*, *Cocklebur*, *Chrysanthemum*, sugar cane etc.

Long day plants: These plants require a comparatively longer photoperiod for flowering. These plants have a critical photoperiod which must be exceeded before the start of flowering. Examples of long day plants are spinach, sugar beet, henbane, cabbage, spring wheat etc.

Day netural plants: Some plants are quite indifferent to photoperiod as far as their flowering is concerned. These plants are called day neutral, photoneutral or indeterminate plants. The examples of day neutral plants include rose, tomato, sweat pea, beans etc.

Tit bits

New concept:

Now it has been discovered that the actual stimulus for flowering is uninterrupted dark period rather than the light period. So short day plants are actually long night plants and long day plants are actually short night plants.

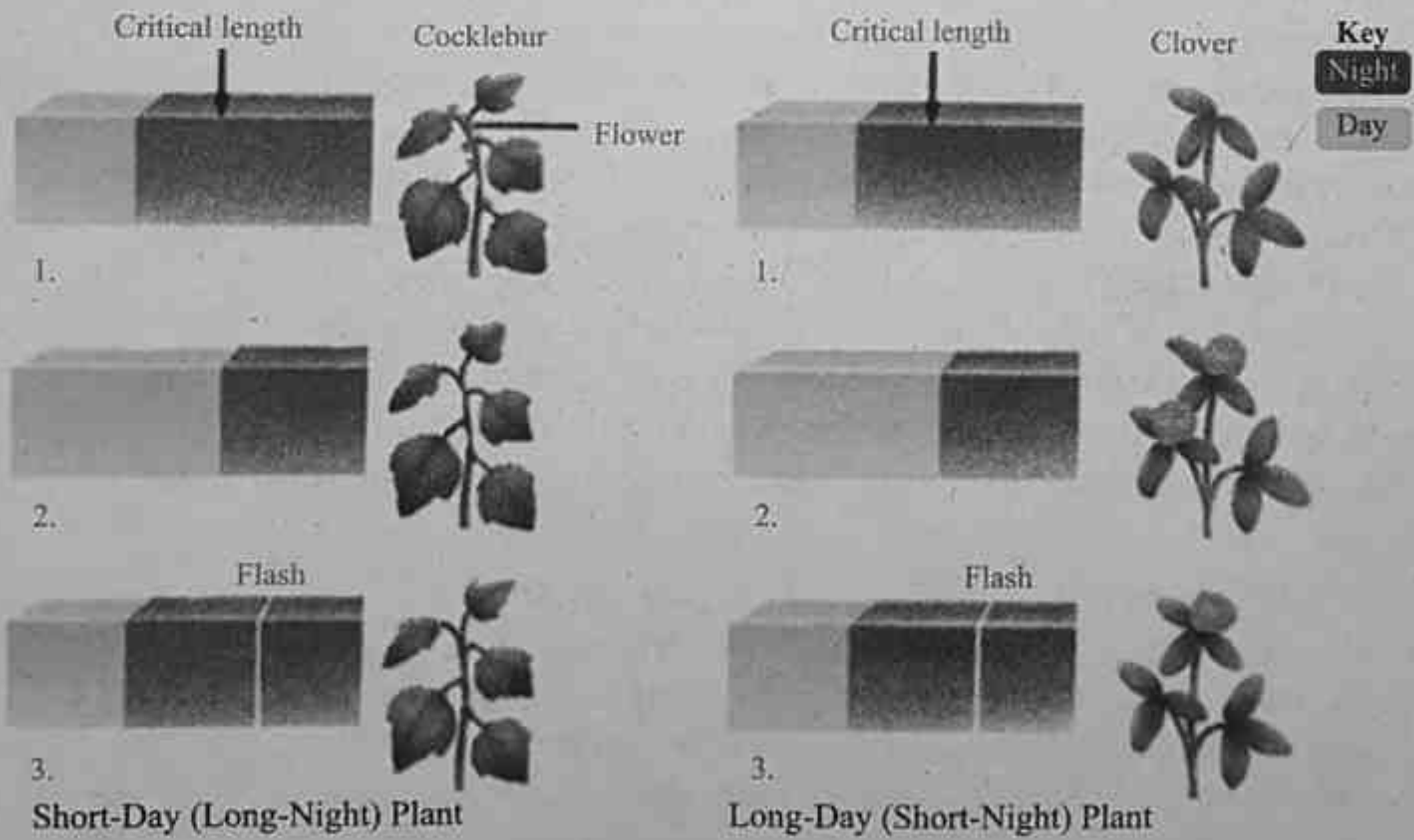


Fig.10.14 Effect of light on flowering plant

Florigen concept: It is believed that the effect of photoperiod is due to the formation of flowering hormone called florigen, i.e., "flower maker". This hormone is synthesized in the leaves and transferred to the bud meristems where it induces flowering. The florigen consists of two parts, gibberellins and anthesins. Flowering occurs only if both of these substances are present.

Phytochrome concept: The phytochrome is a type of photoreceptor that plants use to detect light. They are sensitive to light for red and far-red region of the visible spectrum. Therefore, there are two types of phytochrome, i.e., phytochrome red (Pr) which receives red light (660 nm) and phytochrome far-red (Pfr) which receives far-red light (730 nm).

The short day plants require higher ratio of Pr while long day plants require higher ratio of Pfr so both types of phytochromes, i.e., Pr and Pfr induce flowering but Pr induces flowering in short days and Pfr in long days.

> **Tit bits**
>
> *Day length is also very vital for many animals. A number of biological and behavioral changes are affected by day length. e.g., Colour of fur and feathers, migration, entry into hibernation, sexual behavior etc.*

Interconversion of phytochrome: As mentioned earlier in this chapter phtyochrome exists in two forms, i.e., Pr and Pfr. Red light (which is present during the day) converts phytochorme to its active form Pfr. This, then triggers in plant growth of flower. In turn, far red light is present in night (dark) and this converts phytochrome from Pfr to Pr. Pr is the inactive form of phytochrome and will not allow for plant growth.

This system of Pfr to Pr conversion allows the plant to sense whether it is night and or it is day. This conversion of Pfr into Pr and Pr to Pfr is important with regards to flowering in short day and long day plants.

Stimuli required for induction of flowering: In short day plants the inactive phytochrome Pr causes flowering. In short days the ratio of inactive phytochrome is higher than active phytochrome due to long period of darkness.

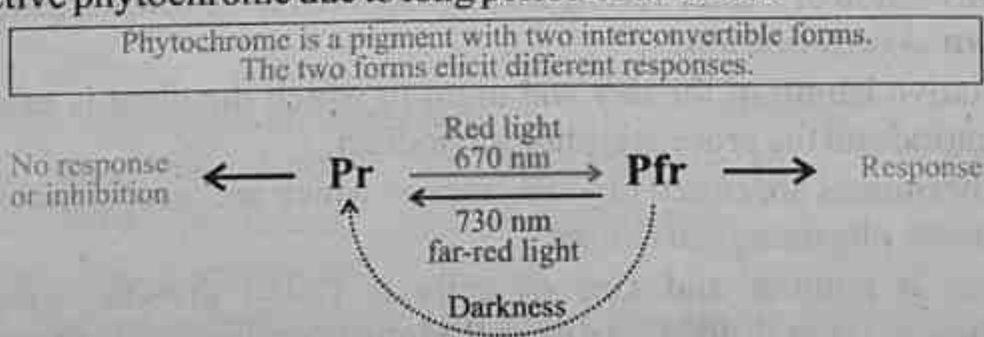


Fig. 10.15 Interconversion of two forms of phytochromes

On the other hand long day plants need active phytochrome (Pfr) to induce flowering. In long days the ratio of active phytochrome (Pfr) is higher than inactive phtochrome (Pr) due to long period of light.

10.7.3 Vernalization (Latin *Vernus*; the spring)

It is the induction of a plant's flowering process by exposure to prolonged low temperature of winter or by an artificial equivalent. After vernalization plants have acquired the ability to flower. It is because low temperature stimulates production of an hormone **vernalin.** This hormone transforms vegetative buds to the floral bud thus flowers are produced. Typical vernalization temperature are between $0 - 10^{\circ}C$. However, $4^{\circ}C$ is best temperature for vernalization for most of plants. The biennial plants are other group of plants which are generally vernalized. Biennials are monocarpic plants that normally flower and die in second season. Sugar, cabbage and carrot are some of the common biennial plants.

Critical Thinking

Predict what would happen if there were no transpiration?

Activity

Find out how the different factors affect the rate of transpiration in plants through searching internet.

SUMMARY

- Nutrition in plants is the source of inorganic minerals requirements obtained directly or indirectly from the soil.
- Turgor pressure is caused by the uptake of water through the cytoplasm of the cells so that pressure is exerted at the plasma membrane on the cell wall.
- Carnivorous or insectivorous plants commonly grow in areas where nitrogen is deficient due to unfavorable atmosphere for nitrifying bacteria.
- Each stoma is formed by two bean- shaped guard cells.
- The inhibition of lateral buds to develop by the activity of apical bud is called inhibitory correlation or apical dominance.
- The conversion of winter variety into spring variety by low temperature exposure is known as vernilization.
- The relative length of the day and night to which the plant is exposed is called photoperiod and the process is photoperiodism.
- Plants hormones are called phytohormones which are mostly protein, control the growth and physiological factors.
- Increase in number and size of cells is called growth, which consist of four phases. (i) cell division (ii) cell elongation (iii) cell maturation and (iv) differentiation.
- Thigmotropism is the movement due to the touch stimulus.
- Geotropism is the movement of plants parts, either towards or away from force of gravity.

- An auxin was the first plant hormone identified. It is manufactured primarily in the shoot tips.
- In some plants, the requirement of low temperature period is absolute, meaning that they will not flower without vernalization.

EXERCISE

Section I: Objective Questions

Multiple Choice Questions

A) **Select correct answer.**

1. Which of the following is an essential element of organic compounds
   (a) Manganese (b) Nitrogen
   (c) Carbon (d) Sodium
2. Which one of following is the micronutrient
   (a) Oxygen (b) Calcium
   (c) Copper (d) Nitrogen
3. Apoplast is the movement of water through
   (a) Interspaces (b) Chloroplast
   (c) Vacuole (d) Cell wall
4. Plants which live in fresh water are called
   (a) Hydrophytes (b) Xerophytes
   (c) Mesophytes (d) Halophytes
5. Carnivorous plants use insects as source of
   (a) Water (b) Glucose
   (c) Oxygen (d) Nitrogen
6. Collenchyma is the supporting tissue in
   (a) Seeds (b) Trees
   (c) Herbs (d) Leaves
7. Thigmotropism is an example of
   (a) Nastic movement (b) Tactic Movement
   (c) Tropic Movement (d) None of these
8. Spinach is an example of
   (a) Day natural plants (b) Short day plants
   (c) Long day plants (d) Halophytes
9. The effect of duration of light on flowering is called
   (a) Geotropism (b) Phototropism
   (c) Photoperiodism (d) Thigmotropism

10. The optimum temperature required for most of plants for vernalization is

(a) $10^{\circ}C$ (b) $4^{\circ}C$

(c) $20^{\circ}C$ (d) $0^{\circ}C$

11. The primary growth is due to

(a) Apical meristem (b) Lateral meristem

(c) Pholem tissue (d) Xylem tissue

B. Fill in the blanks.

1. The promotion of flowers by exposure to low temperature is known as ________.
2. Plant hormones are also called growth ________.
3. Annual rings help to determine the ________ of plants.
4. Plants living in saline environment are called ________.
5. The theory that explains the mechanism of translocation of organic solute is known as ________ theory.
6. Photosynthesis in leaves takes place in ________ cells.
7. The minerals required in large amount are called ________.

Section II: Short Questions.

1. Make a list of macro minerals.
2. What are mesophyll tissues and their types?
3. What is meant by compensation point of photosynthesis?
4. Differentiate between water potential and solute potential.
5. Differentiate between Apoplast and symplast.
6. Define TACT theory and write the components of this force.
7. Differentiate between sink and source.
8. Define Hydrophytes, Mesophytes and Halophytes.
9. Differentiate primary growth and secondary growth.

Section III: Extensive Questions.

1. What are different pathways of uptake of water? Explain them in detail.
2. Explain the ascent of sap by relating to TACT theory.
3. Explain the mechanisms involved in opening and closing of stomata.
4. Describe the mechanisms of photoperiodism in detail.
5. Explain the role of different types of plant hormones in detail.
6. What are meristematic tissues? Explain the role of different types of meristematic tissues in plant growth.