Introduction

The plants upon which we depend for the food we eat, and for the oxygen we breathe, depend in turn upon the soil. A good soil supplies the plants with the mineral elements they use. Mineral nutrition thus comprises the study of how plants obtain mineral elements (either through water, air or soil) and utilize them for their growth and development. Like any other living organisms, plants lead a versatile life. They have a system for proper gaseous exchange, transport of materials, and an ability to adjust to the changes taking place in the environment. Plants are constantly undergoing the process of growth and development which is regulated by specialized tissue and hormones. In this chapter all these different aspects will be discussed.

10.1 Plant Nutrition

Plants need a variety of nutrients in order to sustain their daily life processes. Depending upon the amount of each nutrient required the mineral nutrients are divided into two groups: macronutrients and micronutrients

a. Macronutrients

Macronutrients can be divided into two more groups: primary and secondary nutrients. The primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). These major nutrients are usually less in soil because plants use these in large amounts for their growth and survival. The secondary nutrients are calcium (Ca), magnesium (Mg) and sulfur (S). These are usually present in reasonable amounts. Large amounts of Calcium and Magnesium are added when lime is applied to acidic soils. Sulfur is usually found in sufficient amounts from the slow decomposition of soil organic matter.

b. Micronutrients

Micronutrients are those elements essential for plant growth which are needed in only very small quantities. These elements are sometimes called minor elements or trace elements. The micronutrients includes boron (B), copper (Cu), iron (Fe), chlorine (Cl) etc. Recycling organic matter such as grass clippings and tree leaves is an excellent way of providing micronutrients to growing plants.

For Your Information

Soil pH is one of the most important soil properties that affects the availability of nutrients. Macronutrients tend to be less available in soils with low pH and micronutrients tend to be less available in soils with high pH. **Lime** can be added to the soil to make it less sour (acid) and also supplies calcium and magnesium for plants to use. Lime also raises the pH to the desired range of 6.0 to 6.5.

Table: 10.1 A Summary of Mineral Nutrition in Plants

Macronutrients	Used in the form of	Functions
Carbon	CO_2	Component of organic compounds
Oxygen	H_2O or O_2	Component of organic compounds
Hydrogen	H_2O	Component of organic compounds
Nitrogen	NO_3- or NH_4-	Amino acids, proteins, nucleotides, nucleic acids, chlorophyll, and coenzymes
Potassium	K-	Enzymes, amino acids, and protein synthesis. Activator of many enzymes. Opening and closing of stomata.
Calcium	Ca^{+2}	Calcium of cell walls. Enzyme cofactor. Cell permeability.
Phosphorus	$H_2PO_4^-$ or H_3PO_4	Formation of "high energy" phosphate compounds (ATP and ADP). Nucleic acids. Phosphorylation of sugars. Several essential enzymes. Phospholipids.
Magnesium	Mg^{2+}	Part of the chlorophyll molecule. Coenzyme A.
Sulfur	SO_4^{+2}	Some amino acids and proteins. Coenzyme A.
Micronutrients		
Iron	Fe^{2+} or Fe^{3+}	Chlorophyll synthesis, cytochromes, and nitrogenase.
Chlorine	Cl^-	Osmosis and ionic balance; probably essential in photosynthetic reactions that produce oxygen
Copper	Cu^2	Activator of certain enzymes.
Manganese	Mn^2	Activator of certain enzymes.
Zinc	Zn^{2+}	Activator of certain enzymes
Molybdenum	MoO	Nitrogen fixation. Nitrate reduction.
Cobalt	Co^{2+}	Required by nitrogen-fixing organisms.
Sodium	Na^+	Osmotic and ionic balance, probably not essential for many plants. Required by some desert and salt marsh species. May be required by all plants that utilize C-4 photosynthesis

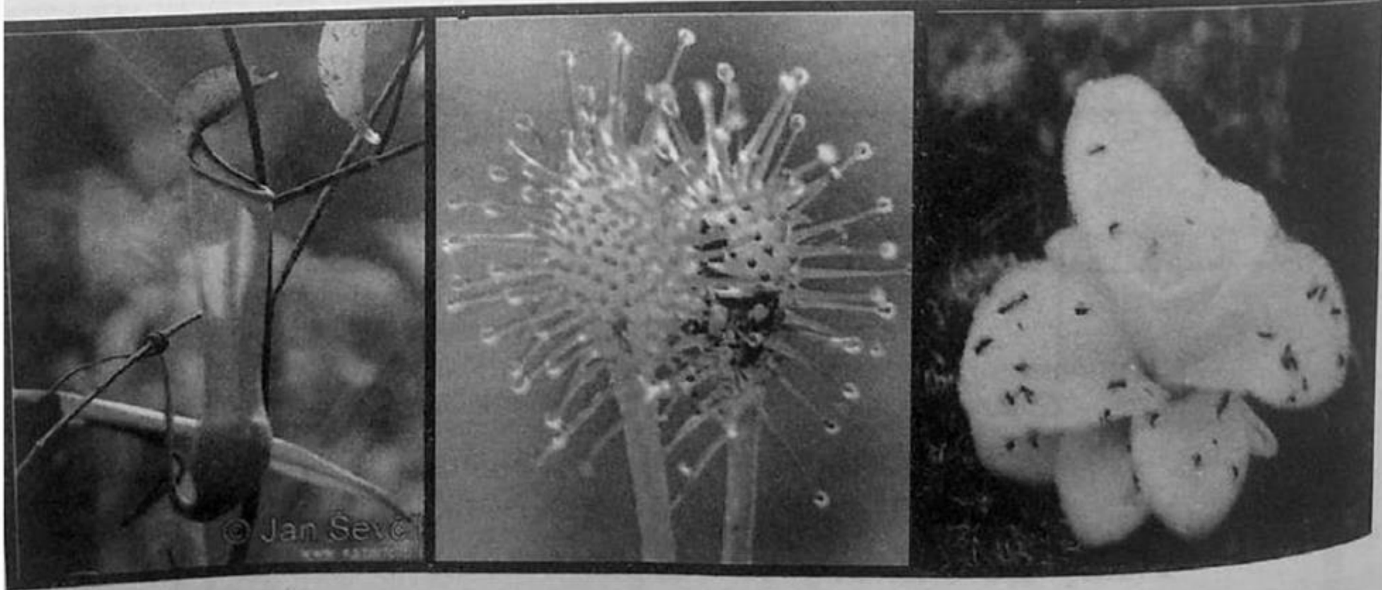
10.1.1 Special Mode of Nutrition in Plants

Plants are basically autotrophs because they are capable of manufacturing their own food. However, there are certain plants which have adopted certain heterotrophic mode of nutrition for their survival.

For Your Information

Deficiencies of the nutrients like nitrogen, phosphorus, potassium, and magnesium result in chlorosis (yellowing) and eventual necrosis (death) of older mature leaves. These nutrients are mobile elements that can be translocated from older to new leaves if their supply from the soil becomes limited and the young leaves become deficient in them. This translocation depletes the older leaves of these essential nutrients, leading to chlorosis and necrosis.

Depending upon the source of food such plants may carry out Parastic utrition in which parasitic plants wholly depend upon other plant or in some cases lants may be involved in saprophytic nutrition in which saprophytic plants extracts utrition form dead organic matter. However, the most interesting example of ieterotrophic nutrition is the carnivorous plants which feeds on insects.



a. Pitcher Plant b. Sundew c Butterworts

Fig: 10.1 Carnivorous plants.

Carnivorous plants may be subdivided into 2 major groups; those with passive traps and those with active traps. For some of these traps the actual method of insect decomposition involves digestive enzymes produced by the plant and bacterial decay within the trap.

A classic passive trap is the "pitfall trap" of pitcher plants, including *Darlingtonia* and *Sarracenia* of the Sarraceniaceae, and *Nepenthes* of the Nepenthaceae, where an insect falls into a vase-like modified leaf. Downward-pointing hairs on the slippery walls prevent the insect from crawling out, and the helpless victim ultimately drowns in a pool of digestive enzymes at the bottom.

Examples of active traps are the "flypaper" or adhesive traps of sundews (*Drosera*, Droseraceae) and butterworts (*Pinguicula*, Lentibulariaceae). In both of these unrelated genera, the leaves are covered with sticky, gland-tipped hairs (*Drosera*) or a sticky layer of mucilage (*Pinguicula*) which entangle the hopeless, struggling victim.

10.2 Role of Stomata in Gaseous Exchange and Transpiration

The small pores on the epidermis of leaves are called stomata. Each stoma or stomatal pore is surrounded by two guard cells. In dicot plants guard cells are kidney shaped or bean shaped. In monocot stomata, guard cells are dumb bell shaped.

The inner wall of guard cells are thick and non-elastic. The outer wall is thin and elastic. The adjoining cell walls of two guard cells around the pore are free and not attached with each other and this help them to stretch laterally during stomatal opening.

The epidermal cells surrounding the guard cells are called subsidiary cells. The stomatal pore, guard cells and the subsidiary cells are together called stomatal apparatus. Each guard cell contains a single nucleus and numerous chloroplasts. Starch is synthesized in guard cell by chloroplast and sugars transported to adjacent mesophyll cells and they are characterized by accumulation of starch during night (in dark) and their degradation during the day (in light).

Mesophyll cells accumulate starch during the day and decrease during the night. This property helps in the opening and closing of stomata.

Transpiration is loss of water through the aerial parts of the plant into the atmosphere by evaporation. Over 90% of the total transpirational water loss from the plant takes place through stomata.

Stomata are structures found within the leaf blade and are responsible for facilitating the gaseous exchange of CO_2 and O_2 during photosynthesis. The gas exchange function of the stomata also leads to the loss of plant water through transpiration.

10.3 Transport in Plants

10.3.1 Vascular Tissues and transport of materials

You have learnt that vascular plants or 'tracheophytes' have specialised tissue, termed xylem and phloem, for conducting water (plus solutes) and organic nutrients respectively. Let's discuss these tissues in detail.

10.3.1.1 Xylem

Xylem cells are elongated and connected end to end to form a tubular water-transport system throughout the plant, continuously replacing the large amount of water lost by transpiration, water that is essential for both photosynthesis and to maintain turgor pressure. The main kinds of xylem are tracheids and vessel elements.

a. Tracheids

Tracheids are elongated cells up to 80μm wide with secondary, lignified cell walls. When mature, tracheids are subject to loss of protoplast (nucleus and cytoplasm) and hence cell death, creating an open structure for water flow, retarded only by the thin cellulose barrier of the porous pits through which water flows from cell to cell. Functional tracheal conduits are surrounded by support and storage cells, including parenchyma, fibers and sclereids.

b. Vessel elements

Vessels are characteristic of the angiosperms, the most advanced and diverse group of plants. Vessels are specialized for efficient water conduction, reducing the costs of water loss by evapo-transpiration.

Vessels element are generally wider, shorter, thinner-walled, and less tapered than tracheids. Vessel elements are individual cells linked together end to end, forming long tubes or xylem vessels.

Water streams from element to element through perforated end walls. Water can also migrate laterally between neighboring vessels through pits.

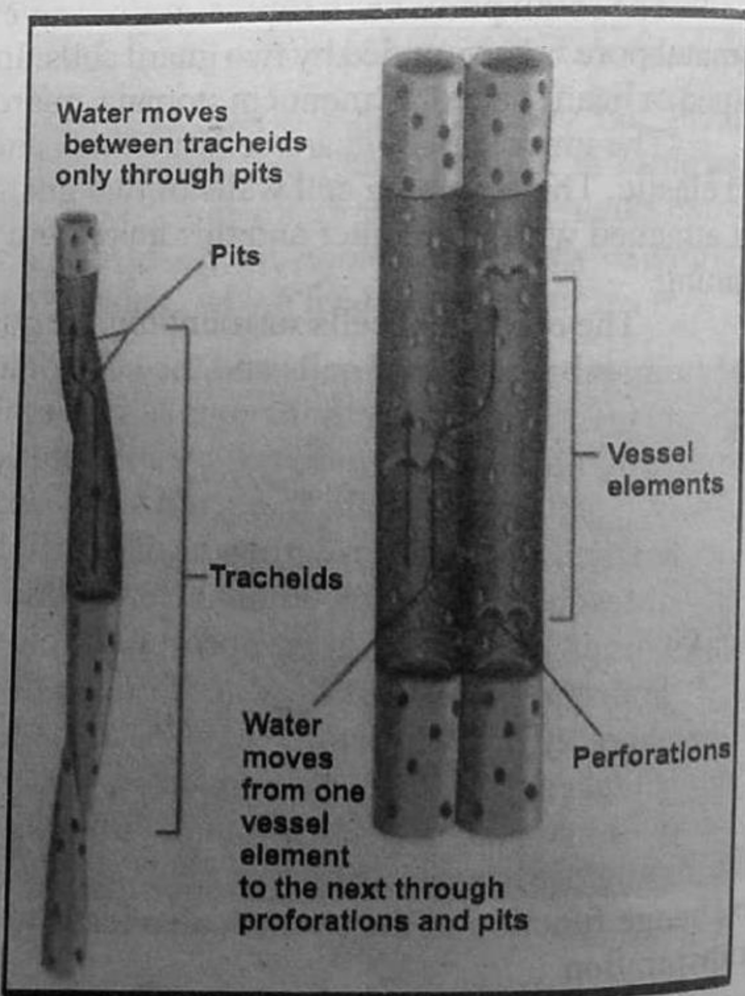


Fig: 10.2 Tracheids and vessel members of xylem tissue

10.3.1.2 Phloem

Organic solutes move through phloem which is generally found on the outer side of xylem tissues in plants. Phloem forms the inner bark. The cells of the phloem that transport the organic solutes through out the plant are the sieve tubes. Phloem is a complex tissue. It is present in all vascular plants. It consists of five different kinds of cells. Phloem parenchyma, phloem fibers, sieve tubes, companion cells and phloem ray cells. Out of these cells, the sieve tubes are especially adopted for the process of translocation.

a. Sieve tubes

Sieve tubes are elongated living cells, placed end to end with the walls consisting of cellulose. The end walls are perforated by a number of small pores. The perforated area of the end walls look very much like a sieve and is called **sieve plate**. The pores of the sieve plate are open channels which help in the translocation of solutes. Associated with almost every sieve tube is a thin walled elongated cell called companion cell.

b. Companion cell

Companion cell is living cell containing cytoplasm and elongated nucleus. The sieve tubes and the companion cells are in communication with each other by plasmodesmata. The companion cells supply energy to the sieve tube and help the sieve tubes in translocation.

The organic solutes from the mesophyll of leaf pass into the sieve tube through the **companion** cells via plasmodesmata. The companion cells are present in angiosperms but absent in gymnosperms and ferns.

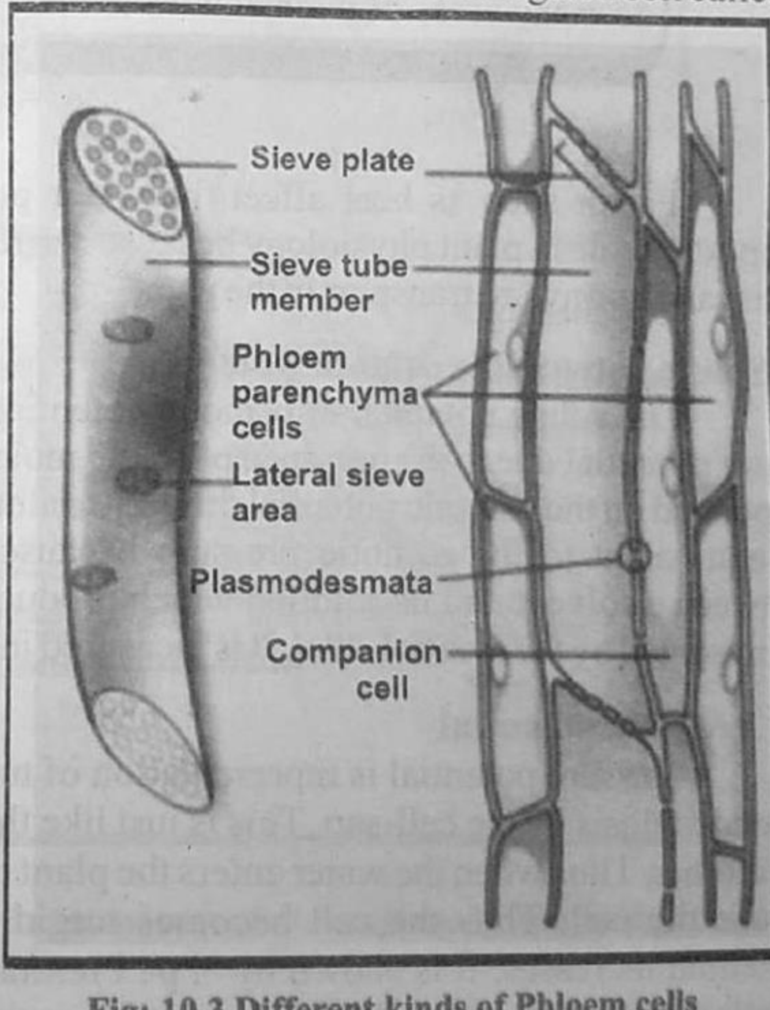


Fig: 10.3 Different kinds of Phloem cells

10.3.2 Water-status in plants

Water plays an important role in the life of plants. It is one of the factor used in photosynthesis.. The behavior of water with the respect to plant can be described by certain phenomena like water potential, osmotic potential, pressure potential etc.

a. Water potential

Molecules of water possess kinetic energy. Therefore, they are in constant motion from one place to another. Water potential is directly proportional to the concentration of water-molecules. Greater the concentration of water molecules in a system, greater is the kinetic energy of water molecules. This is called water potential. Pure water has maximum water potential. Water potential is represented by the symbol 'Ψw' (ψ; pronounced /sai/ sigh). It is measured in kilopascal 'Kpa' one Kpa=1000 Pascal.

For Your Information

Blaise Pascal was a very influencial French mathematician and philosopher who contributed to many areas of mathematics.

Factor such as heat affect the water potential. Water potential plays an important role in plant physiology because it affects absorption of water by the root hairs and its onward transport in the plant.

b. Solute potential or osmotic potential

The solute potential or osmotic potential is a measure of the change in the water potential due to the presence of solute molecules. Thus the rate of osmosis is depended on the osmotic potential difference along the two sides. Osmotic potential is equivalent to the osmotic pressure because it is this potential difference in between a solvent and its solution which produces the pressure. Solute potential is represented by the symbol 'Ψ s'. It is measured in 'Kpa' (kilopascal).

c. Pressure potential

Pressure potential is representation of turgor pressure developed as a result of endosmosis by the cell-sap. This is just like the pumping of water from one place to another. Thus when the water enters the plant cells by osmosis, pressure is built up inside the cell. Thus the cell becomes turgid, or we may say that the pressure potential increases. It is shown by 'Ψp'. Pressure potential plays a vital role in the erectness of soft plants and also in maintaining their shape.

10.3.3 Movement of water through roots

Water and minerals from the soil to the xylem move by the way of appoplast, sympalst and through vacuoles. Water from the soil is absorbed by the root hairs due to their high permeability.

The cell walls of epidermal cells of the roots are freely permeable to water and minerals. The cell membrane however is partially permeable to some substances in the solution. The water which enters the epidermal cells of the root passes through the cortex, endodermis, pericycle and finally to the xylem-cells through the paths which are described below.

a. Apoplast Pathway

Water from the soil is absorbed by the root hairs, from where it moves inwards across the cortex through a system of interconnecting cell-walls and inter cellular spaces and reach the endoderm and pericycle. Water is then poured into the xylem. This whole nonliving water path is called apoplast pathway.

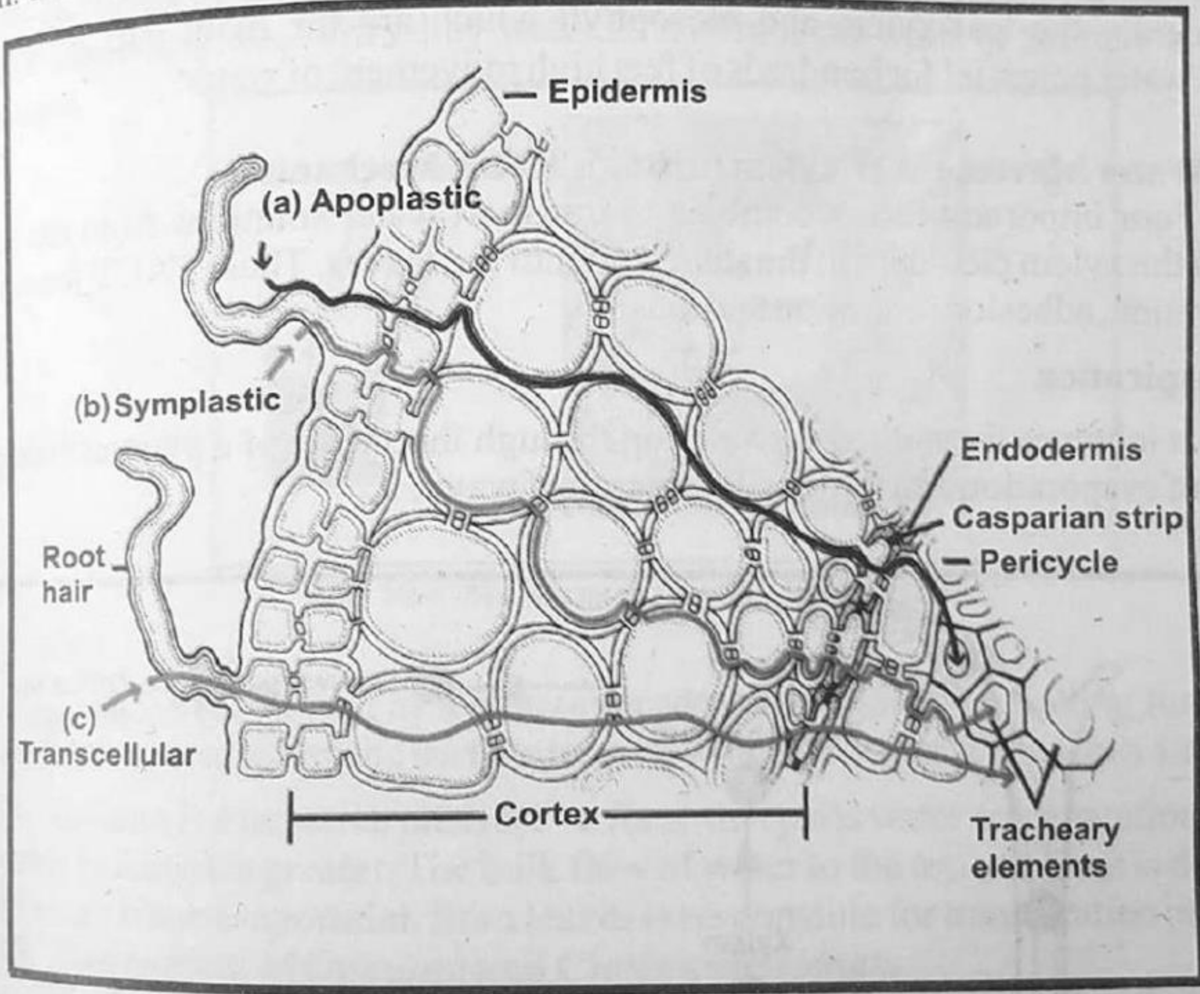


Fig: 10.4 Three different pathways of water movement through roots. Apoplast pathway shown by black line, symplast pathway shown by blue line, transcellular pathway by red line.

b. Symplast pathway

Water not only translocates along the nonliving cell walls and intercellular spaces but also moves inwards across the living cortical cells by the process of osmosis.

Such a living medium transport of water is termed as symplast pathway. It is the system of intercellular protoplasts (cytoplasm of the neighbouring cells) in the cells of roots. In the cells of the roots, both the cell membrane and cytoplasm act as one partially permeable membrane.

c. Vacuolar or transcellular pathway

The attached cells have interconnected vacuoles. Cells and the vacuoles are connected with one another by the plasmodesmata. Plasmodesmata are the cytoplasmic strands which extend through the pores in the adjacent cell walls). In this pathway water moves from vacuole to vacuole. The plasmodesmata act as a source of water movement across the cells towards the xylem. This is also symplast pathway but specially the vacuolar pathway. Whatever may be the path but water is absorbed by the roots from the soil and is transferred to the xylem of roots, stem and consequently the leaf-xylem and mesophyll which are the main part generating enough water potential for hundreds of feet high movement of water.

10.3.4 Water Movement in Xylem through TACT Mechanism

Four important forces combine to transport water solutions from the roots, through the xylem elements in the stem, and into the leaves. These TACT forces are: transpiration, adhesion, cohesion and tension.

a. Transpiration

It involves the pulling of water up through the xylem of a plant utilizing the energy of evaporation and the tensile strength of water.

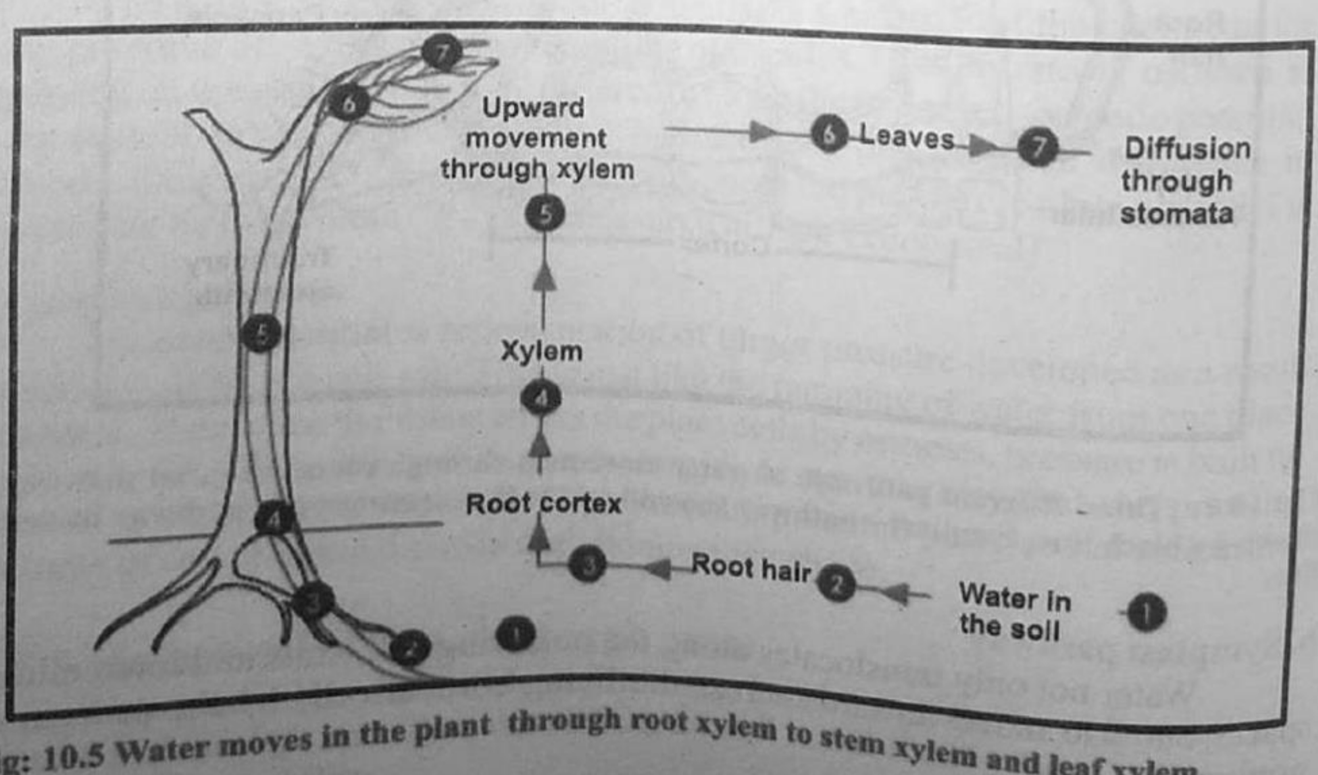


Fig: 10.5 Water moves in the plant through root xylem to stem xylem and leaf xylem.

b. **Adhesion**

It is the attractive force between water molecules and other substances. Because both water and cellulose are polar molecules there is a strong attraction for water within the hollow capillaries of the xylem.

c. **Cohesion**

It is the attractive force between molecules of the same substance. Water has an unusually high cohesive force due to the hydrogen bondings. It is estimated that water's cohesive force within xylem give it a tensile strength equivalent to that of a steel wire of similar diameter.

A combination of adhesion, cohesion, and surface tension allow water to climb the walls of small diameter tubes like xylem. This is called capillary action. The U shaped surface formed by water as it climbs the walls of the tube is called a meniscus

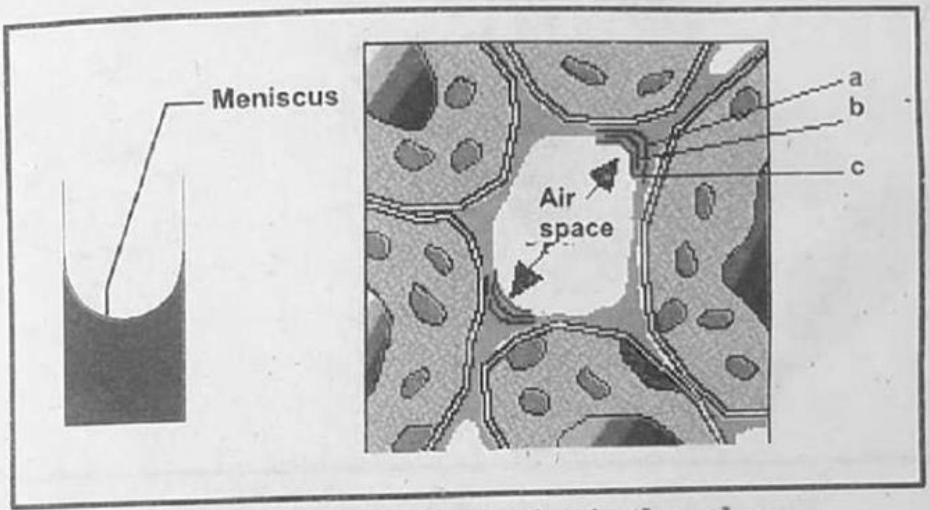


Fig: 10.6 Meniscus formation in the xylem

d. **Tension**

It can be thought of as a stress placed on an object by a pulling force. This pulling force is created by the surface tension which develops in the leaf's air spaces.

Tension is a negative pressure - a force that pulls water from locations where the water potential is greater. The bulk flow of water to the top of a plant is driven by solar energy since evaporation from leaves is responsible for transpiration pull.

10.3.5 Mechanism of Opening and Closing of Stomata

Mechanism of opening and closing of stomata can be studied by the following most acceptable theories.

1. Starch Sugar Theory

According to this hypothesis photosynthesis occurs in light by absorbing carbondioxide which lowers the H^+ ion of cell sap and pH of guard cell is increased. High pH favours the activity of enzyme phosphorylase which converts starch into glucose and phosphate. It dissolves in the medium and increases the concentration of cell sap.

This causes an increase in the osmotic pressure of guard cells and its diffusion pressure deficit (DPD) also increases which results in the movement of water into the guard cells from surrounding cells. Guard cells become turgid and swell. Thus the stomata open.

During dark, the level of carbondioxide in substomatal cavity is increased which results in the decrease in the pH of guard cells. At low pH glucose is converted back to starch in the presence of enzyme phosphorylase. Synthesis of starch leads to the dilution of cell sap by consuming its dissolved glucose molecule. Thus osmotic pressure of cell sap is decreased and its DPD (diffusion pressure deficit) is decreased. The turgid cells lose water to surrounding cells and becomes flaccid and stomata closes.

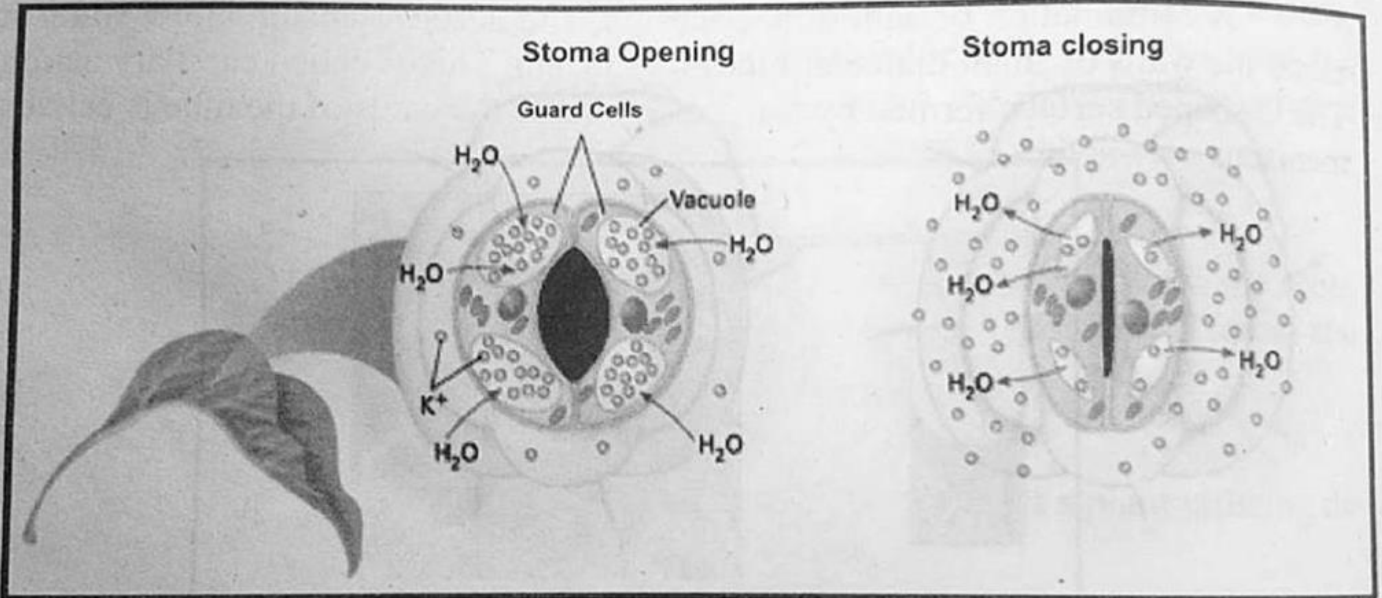


Fig: 10.7 Mechanism of stomatal opening and closing

2. Theory of K^+ ion transport

In the presence of light starch is converted into phosphorylated hexoses and then to phosphoenol pyruvic acid which combines with carbondioxide to produce malic acid. Malic acid dissociate into malate anion and H^+ ion in the guard cell. H^+ ions are transported to epidermal cells and K^+ ions are taken into the guard cells in exchange of H^+ ions. Increased concentraton of K^+ ions and malate ions in the vacuole of guard cells causes sufficient osmotic pressure to absorb water from surrounding cells. It results in the opening of stomata.

In the dark carbondioxide concentration is increased in the substomatal cavity which prevents proton gradient across the protoplasmic membrane in guard cells. As a result active transport of K^+ ions into guard cells ceases. As soon as the pH of guard cells decreases the abscissic acid inhibits K^+ ion uptake by changing the diffusion and permeability of guard cells. Malate ion in the guard cell cytoplasm combine with H^+ ion to produce malic acid. These changes cause reversal of concentration movement.

So the K^+ ion is transported out of guard cells into the surrounding epidermal cells. The osmotic pressure of guard cell is decreased which results in the movement of water from guard cells to surrounding cells and guard cells becomes flaccid and stomata closes.

10.3.6 Translocation of organic solutes

Green leaves are the photosynthetic machinery of the plant. These green leaves are regarded as **"source of assimilates "** because these are the sites of production of sugar during the process of photosynthesis. This sugar is converted into sucrose which is transported out of the leaf to the stem and then upwards to the buds ,fruits or seeds and downwards to the roots or the underground stems.

The buds, seeds, fruits, roots and the underground stems are together called **"sinks of assimilates"**. They utilize or store sugar. This transport of organic solutes from the source of assimilates to the sinks of assimilates is called translocation of organic solutes.

a. Pressure flow mechanism: (Mechanism of translocation of organic solutes)

Food, primarily sucrose is transported by the vascular tissue called phloem from a source to a sink. Unlike transpiration's one-way flow of water sap, food in phloem sap can be transported in any direction needed so long as there is a source of sugar and a sink able to use, store or remove the sugar. The source and sink may be reversed depending on the season, or the plant's needs.

Sugar stored in roots may be mobilized to become a source of food in the early spring when the buds of trees, the sink, need energy for growth and development of the photosynthetic apparatus.

Phloem sap is mainly water and sucrose, but other sugars, hormones and amino acids are also transported. The movement of such substances in the plant is called **translocation**.

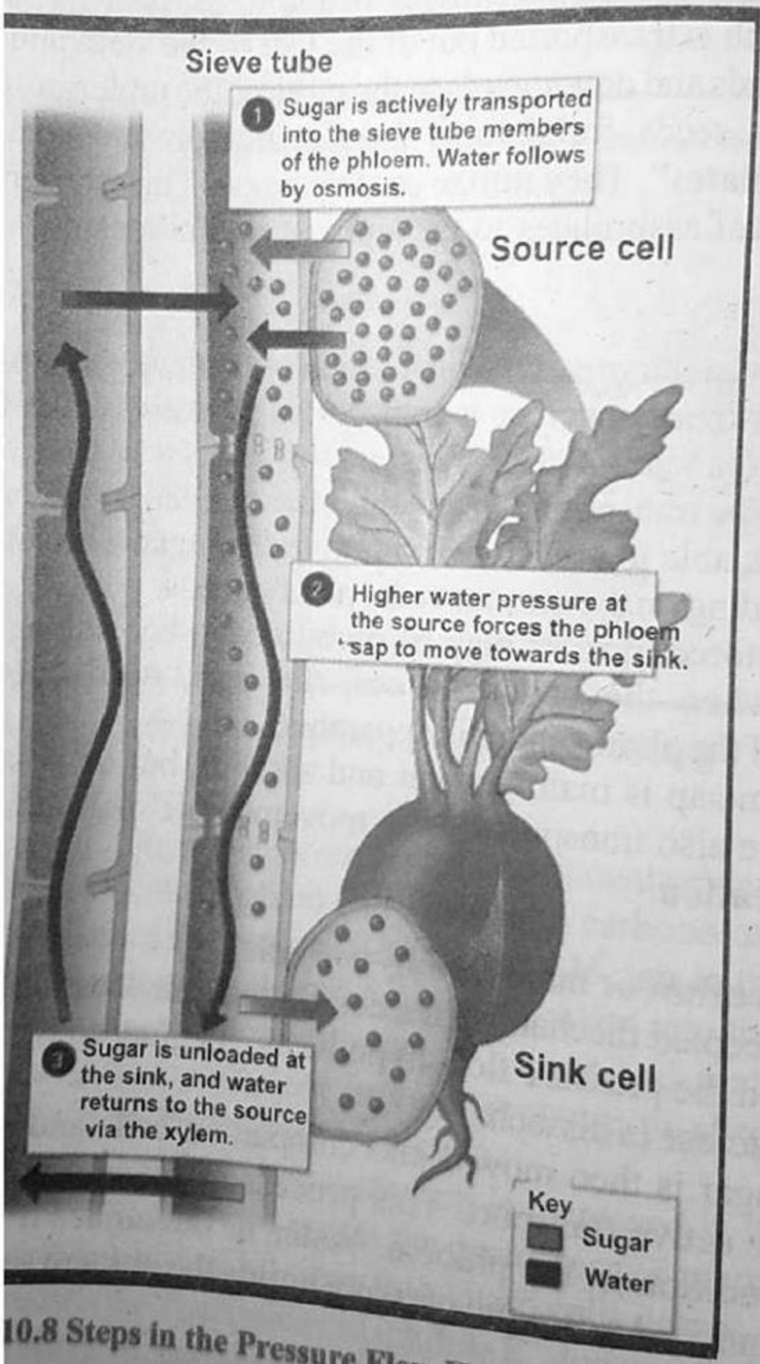
b. The Pressure flow or mass flow hypothesis

The accepted mechanism needed for the translocation of sugars from source to sink is called the pressure flow hypothesis. As glucose is made at the source it is converted to sucrose (a dissacharide).

The sugar is then moved into companion cells and into the living phloem sieve tubes by active transport. This process of loading at the source produces a hypertonic condition in the phloem. Water in the adjacent xylem moves into the phloem by osmosis. As osmotic pressure builds the phloem sap will move to areas of lower pressure.

k osmotic pressure must be reduced. Again active transport is the sucrose out of the pholem sap and into the cells which will use ting it into energy, starch, or cellulose.

are removed osmotic pressure decreases and water moves out of



10.8 Steps in the Pressure Flow Hypothesis

10.4 Homeostasis in Plants

Plants are present in diverse environmental conditions. In order to survive plants have to adopt various measures. Such measures are part of the homeostasis mechanism. Homeostasis is the ability of living organisms to maintain or nearly maintain constant internal conditions. It provides the organism with a certain degree of independence from variations in the external environmental conditions. Homeostasis does not mean to keep a fixed internal environment as changes with in a specific range are necessary for normal body functions. It refers to the fact that the composition of the tissue fluid in the body is kept within narrow limits. Most of plant mechanisms are related with the presence or absence of water. Osmoregulation or osmotic regulation is the homeostasis of water i.e. the control of gain or loss of water and dissolved salts. Plants are confronted with different situations in terms of their water availability.

Water moves readily across cell membranes through special protein-lined channels, and if the total concentration of all dissolved solutes is not equal on both sides, there will be net movement of water molecules into or out of the cell. Whether there is net movement of water into or out of the cell and which direction it moves depends on whether the cell's environment is isotonic, hypotonic, or hypertonic.

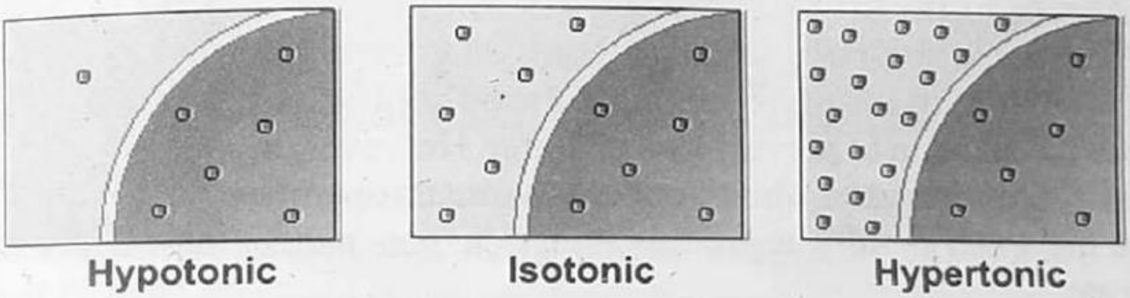


Fig: 10.9 Osmoregulation in different conditions.

a. Isotonic

When two environments are isotonic, the total molar concentration of dissolved solutes is the same in both of them. When cells are in isotonic solution, movement of water out of the cell is exactly balanced by movement of water into the cell.

b. Hypotonic

In a hypotonic solution the total molar concentration of all dissolved solute particles is less than that of another solution or less than that of a cell. If concentrations of dissolved solutes are less outside the cell than inside, the concentration of water outside is correspondingly greater. When a cell is exposed to such hypotonic conditions, there is net water movement into the cell. Cells without walls will swell and may burst (lyse) if excess water is not removed from the cell. Cells with walls often benefit from the turgor pressure that develops in hypotonic environments.

c. Hypertonic

A hypertonic solution is a particular type of solution that has a greater concentration of solutes on the outside of a cell when compared with the inside of a cell.

10.4.1 Osmoregulation in Plants

Of all the environmental factors that determine the vegetation of a habitat, water is considered to be the most important. Osmoregulation has enabled the plants to be distributed in wide range of habitat. Hence according to the amount of water available, plants are classified into four main groups:

Fig: 10.10 Hydrilla

a. Hydrophytes

Hydrophytes grow in the water or in wet and damp places such as ponds, streams etc. In these plants the absorption of water takes place over the whole surface of the plant, root hair being absent. The surface area of the leaves is large enough with plenty of stomata (in partly submerged hydrophytes). These features favour excessive transpiration. e.g. *Hydrilla, Vallisneria, Potamogeton* etc.

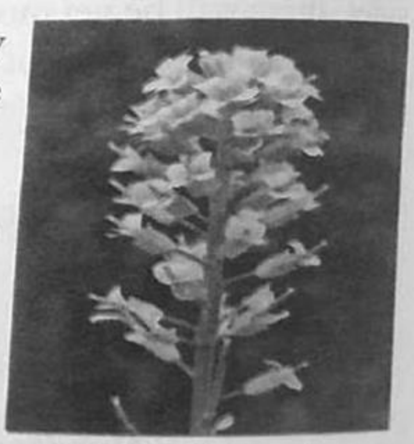


Fig: 10.11 Brassica

b Mesophytes

Mesophytes are the ordinary land plants, which grow under average condition of moisture. In limited supply of water, they close the stomata to prevent loss of water. However, in abundant supply of water, they keep the stomata open to transpire the water rapidly, e.g. citrus, brassica, pea, peach and rose etc.

c. Xerophytes

Xerophytes are desert plants which grow in dry, hot and sandy places with scanty rainfall. They have long roots to absorb water. The stem contains water storage tissue. The leaves are modified into spines or thorns to reduce evaporation of water. Hairs on the stem and leaves retard transpiration. The leaves are covered with thick cuticle. The stomata are usually very much reduced in number and sunken below the epidermis. Examples are *Cactus, Opuntia, Aloe, Ruscus, Acacia, Calotropis* and *Zizyphus* etc.

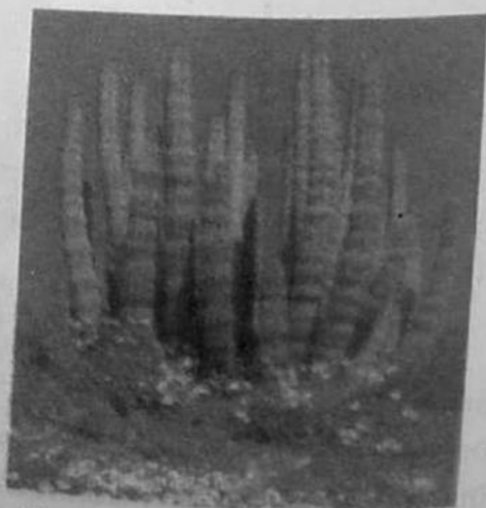


Fig: 10.12 The thick stems of *cacti* store water and carry out photosynthesis. Their leaves are reduced to spines, conserve water while providing protection.

d. Halophytes

Halophytes can grow in a soil containing large percentage of common salt and therefore occur on seashores forming special type of vegetation called mangrove. They are salt tolerators and not salt lovers. Although there is plenty of water in the soil, water absorption is fairly difficult due to abundance of salts in the soil water. Hence they show physiological drought and show xerophytic characters. The stems contain well developed water storage tissues. The leaves are covered with thick cuticle to prevent evaporation of water.e.g *Salsola* (saltwort) and *Rhizophora.*

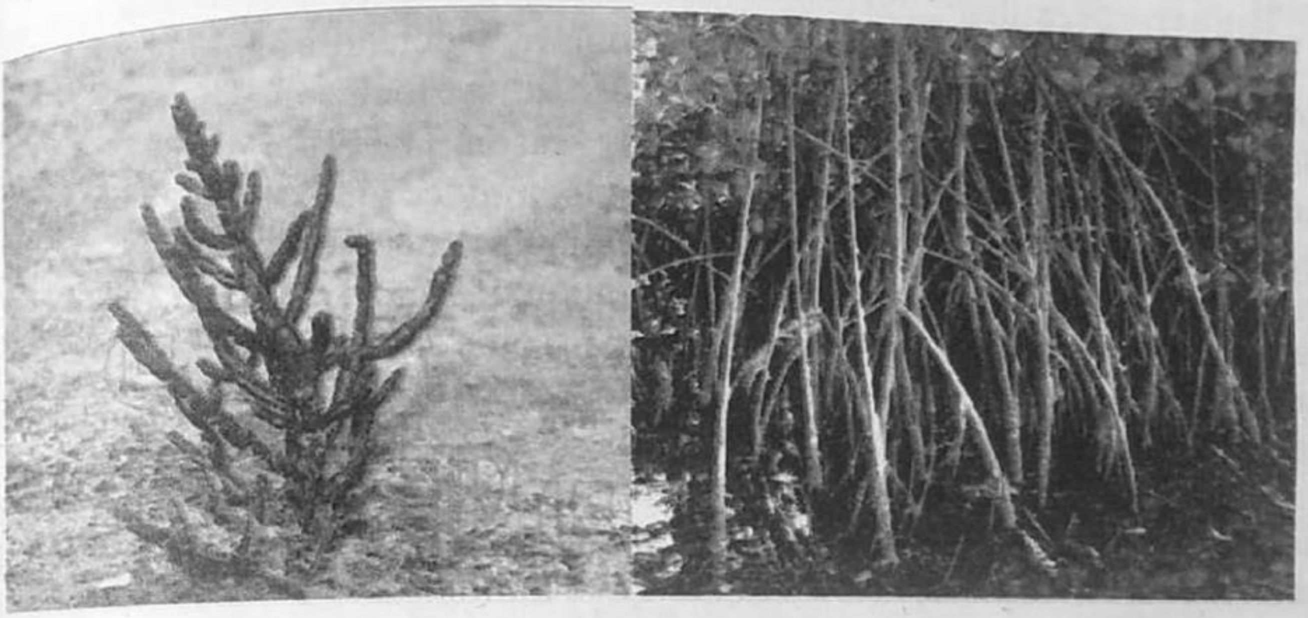


Fig:10.13 a. *Salsola* (saltwort) b. *Rhizophora*

a. *Salsola* (saltwort)is a halophyte (a salt-tolerant plant) that typically grows in coastal regions and can be irrigated with salt water.

b. *Rhizophora* is a dominate in mangrove forests around much of the world's tropics.

10.4.2 Adaptations of plants to low and high temperature

Temperature is one of the most important ecological factors. Temperature for a plant may be maximum, minimum, or optimum. Metabolism becomes slow at both low temperature and high temperature. Extremely high temperature causes heat injury in plants while the freezing temperature causes ice crystal formation. Both these effects are harmful to plants.

These variations in temperature range require the plants to adjust themselves to the environment and this is adaptation. Plants possess some morphological and anatomical structures to counter very high or very low temperature.

Some of them are as under:

1. Low temperature

Plants growing in low temperatures may suffer from ill-effects. To mange low temperature, they possess well-developed bark for protection and short life cycles. Such plants bring changes in the composition of solutes in the cell to prevent ice crystal formation. The leaves and stems are hard and can withstand low temperature. Most of them possess scale leaves and the rate of transpiration is low to retard cooling.

2. High temperature

The protoplasm, enzymes and proteins may denature at high temperature so, the plants use structures and mechanisms to adjust themselves to such condition. Plants absorb maximum water in short rainy season. The water is stored for carrying out various metabolic activities. Some plants produce an extensive branching root system, so they can absorb even the little available water. The extensive spreading of upper parts of the plant reduces the evaporation of water from the soil surface. The leaves of the plants contain thick cuticle and in some cases, an additional waxy layer. Such adaptations protect the plants from the strong rays of the sun and reduce water loss from the plant body.

The sunken stomata regulate transpiration and stems of some plants are succulent with large vacuoles to store water for the cell metabolism. In many plants leaves are modified into spines to reduce transpiration.

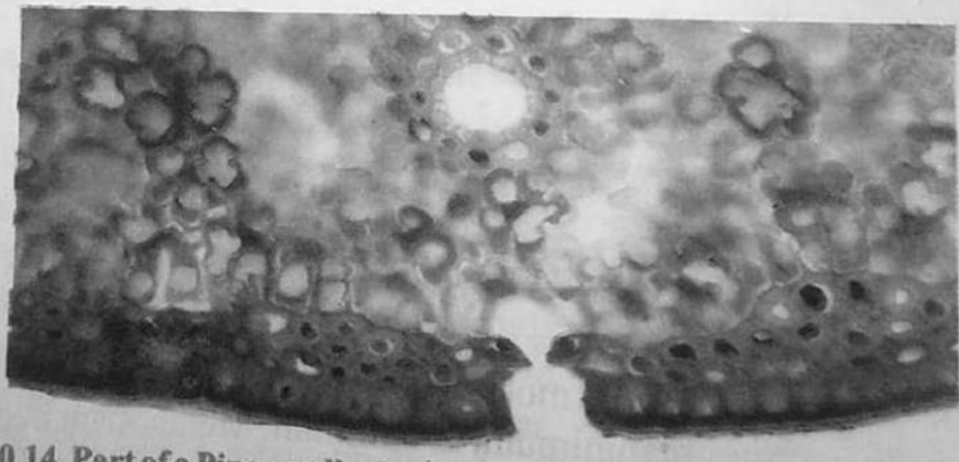


Fig:10.14 Part of a Pine needle showing the hypodermis and sunken stomata.

Observing, Analyzing and Interpreting

Interpret the adaptive differences through survey of xerophytic, mesophytic and hydrophytic plants. Illustrate the structure and position of stomata in xerophytic, mesophytic and hydrophytic plants.

10.5 Support in plants

Non-lignified plant tissues are supported by the pressure of cell contents against the (primary) cell walls of their tissues. This **turgor** pressure is caused by the uptake of water by the cytoplasm of the cells so that pressure is exerted at the plasma membrane on the cell wall. Herbaceous plant does not form a persistent woody stem. Herbaceous plants are often known for their attractive flowers or foliage.

It is a common observation that plants cannot remain upright if their hard tissue such as fibre is damaged or they lose turgor. Support to the plants is provided by the mechanical tissues, which consist of collenchyma and sclerenchyma. Non-woody plants are supported by turgidity (water pressure) of parenchymatous cells. These plants remain erect and firm because of the pressure within these cells. During the period of drought, the tissues of such plants lose water and result in wilting.

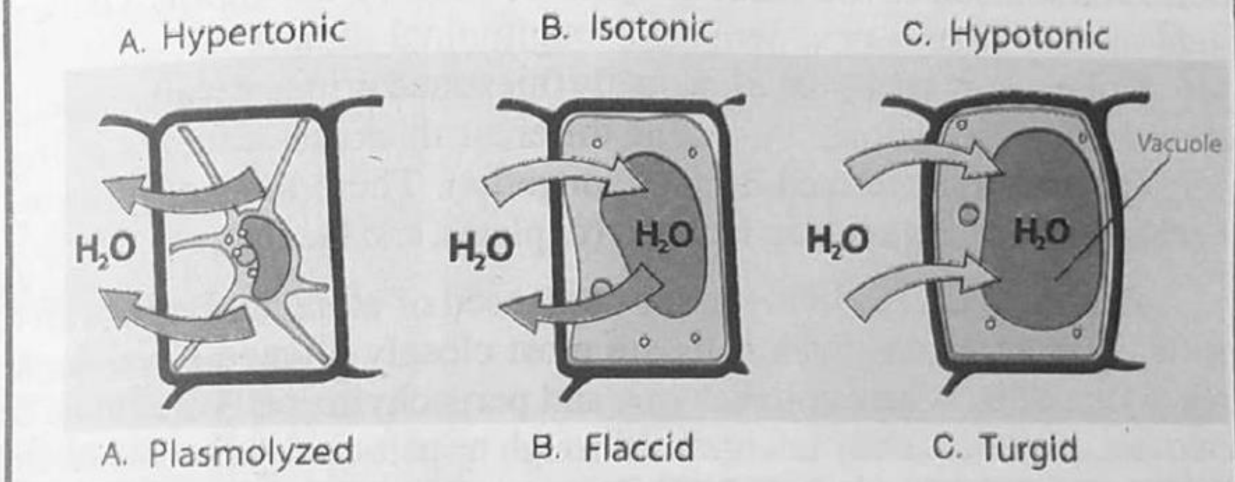


Fig: 10.15 Turgor pressure in different environments

Plant cells are surrounded by rigid cell walls. When plant cells are exposed to hypotonic environments, water rushes into the cell, and the cell swells, but is kept from breaking by the rigid wall layer. The pressure of the cell pushing against the wall is called turgor pressure, and is the desired state for most plant tissues. For instance, placing a wilted celery stalk or lettuce leaf in a hypotonic environment of pure water, will often revive the leaf by inducing turgor in the plant cells.

10.5.1 Structure of supporting tissues in plants

The development of stable supporting elements has been an important prerequisite for the evolution of large terrestrial organisms. Animals have endo- or exoskeletons that are similar in function to the woody stems or trunks of plants. The architectural design of the plant is very complex.

Thin petioles carry heavy and flat laminas, stems support leaves, flowers and fruits. All plant organs are exposed to mechanical strains. Extensive specialized supporting tissues exist only in vascular plants. Vascular plants have up to three main types of supporting tissue:

1. Collenchyma
2. Sclerenchyma
3. Vascular tissue

1. Collenchyma

The name collenchyma derives from the Greek word "kolla", meaning "glue", which refers to the thick, glistening appearance of the walls in fresh tissues. The collenchyma is the typical supporting tissue of the primary plant body and growing plant parts.

Collenchyma is characteristically found in leaves and elongating stems. In leaves, it appears as strands, often located above and below major veins, as well as in petioles and sometimes leaf blade margins. In stems, it appears as a hollow cylinder around vascular tissues, or as peripheral longitudinal strands.

Collenchyma cells have unequally thickened primary walls, especially when observed in cross-sectional view. The different thickness patterns of the wall is a characteristic feature formed during elongation. There are four primary types of collenchyma: angular, annular, lamellar (or plate), and lacunar.

Collenchyma is a living tissue composed of elongated cells with thick non-lignified primary walls. Such cells are most closely aligned physiologically with parenchyma cells. Where collenchyma and parenchyma cells are found adjacent to each other, they frequently intergrade through transitional cells. The resemblance to parenchyma is further stressed by the common occurrence of chloroplasts in collenchyma and by the ability of this tissue to undergo reversible changes in wall thickness, and to engage in meristematic activities. Thus, it is entirely appropriate to consider these two cell types in the same unit of study.

2. Sclerenchyma

The other true supporting tissue is the sclerenchyma. The term "sclerenchyma" is derived from the Greek "scleros", meaning "hard". It is their hard, thick walls that make sclerenchyma cells important strengthening and supporting elements in plant parts that have ceased elongation.

Two groups of sclerenchyma cells exist: fibres and sclereids. Their walls consist of cellulose or lignin. Sclerenchyma cells are the principal supporting cells in plant parts that have ceased elongation. Sclerenchyma fibres are of great economical importance, since they constitute the source material for many fabrics (flax, hemp, jute, ramie).

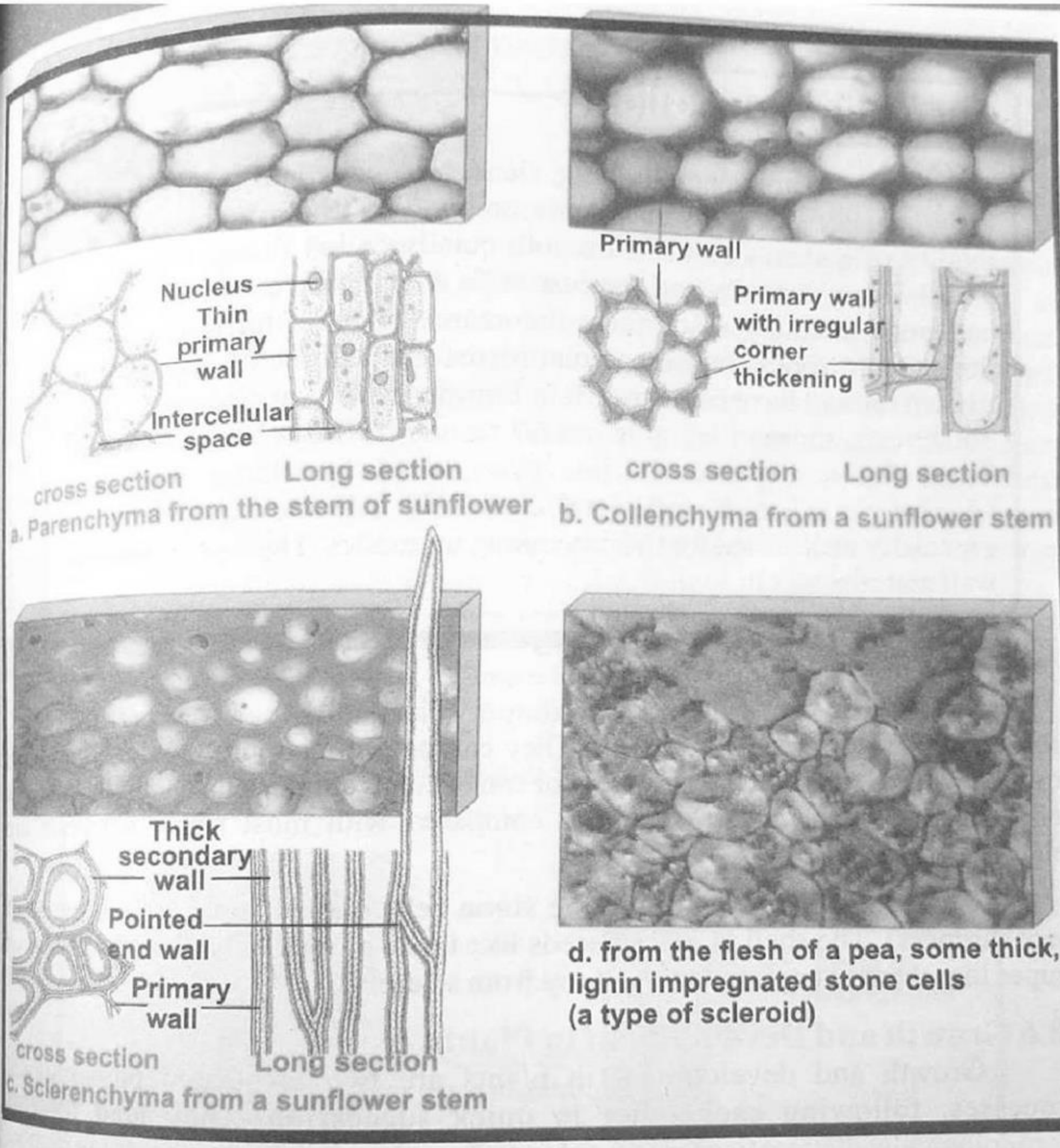


Fig: 10.16 Example of ground tissue, which make up the bulk of the plant body. The most common types are parenchyma, collenchyma and sclerenchyma (the stone cell in 'd' are a specialized form of sclerenchyma).

The difference between fibres and sclereids is not always clear. Transitions do exist, sometimes even within one and the same plant. Fibres arise from meristematic tissues. Cambium and procambium are their main centers of production. They are often associated with the xylem of the vascular bundles. The fibres of the xylem are always lignified. Fibres that do not belong to the xylem are bast (outside the ring of cambium).

For Your Information

Fibres are generally long, slender, so-called prosenchymatous cells, usually occuring in strands or bundles. Such bundles or the totality of a stem's bundles are colloquially called fibres. Their high load-bearing capacity and the ease with which they can be processed has since antiquity made them the source material for a number of things, like ropes, fabrics or mattresses. The fibres of flax *(Linum usitatissimum)* have been known in Europe and Egypt since more than 3000 years, those of hemp *(Canabis sativa)* in China for just as long. These fibres, and those of jute *(Corchorus capsularis)* and ramie (*Boehmeria nivea*, a nettle), are extremely soft and elastic and are especially well suited for the processing to textiles. Their principal cell wall material is cellulose.

Sclereids are variable in shape. The cells can be isodiametric, prosenchymatic, forked or branched. They can be grouped into bundles, can form complete tubes located at the periphery or can occur as single cells or small groups of cells within parenchyma tissues. But compared with most fibres sclereids are relatively short.

Characteristic examples are the **stone cells** (called stone cells because of their hardness). The shell of many seeds like those of nuts as well as the stones of drupes like cherries or plums are made up from sclereids.

10.6 Growth and Development in Plants

Growth and development in plants are two associated physiological processes, following each other in quick succession. They lead towards morphologically distinct tissues and organs. Growth is defined as increase in number and size of cells. Three phases of growth can be identified in the growing root and stem. They are: (a) Phase of cell division (b) Phase of cell elongation (c) Phase of cell maturation and differentiation.

The flowering plants (**angiosperms**) go through a phase of **vegetative growth** — producing more stems and leaves — and a flowering phase where they produce the organs for sexual reproduction. Meristems are undifferentiated, perpetually juvenile plant tissues which are capable of dividing mitotically, producing plant growth.

Merstematic tissues are of two main kinds;

1. Apical meristem
2. Lateral meristem

1. Apical Meristems

Apical meristems are areas of actively dividing cells at the tips of all roots and shoots. The apical meristem gives rise to the three primary meristems (protoderm, ground meristem and procambium) and these in turn produce all tissues. As in roots, the outermost layer of a primary shoot is the epidermis, which arises from the protoderm. The epidermis may contain stomata or lenticels for gas exchange, or may have a waxy or hairy surface to prevent dessication. The shoot cortex arises from ground meristem. The primary vascular tissues, the primary phloem, vascular cambium and primary xylem, arise from the procambium. These three tissues are organized into separate vascular bundles. Finally, the innermost shoot tissue is the pith. It is produced by the central ground meristem, and functions for a short period as a storage tissue as shown in the following figure.

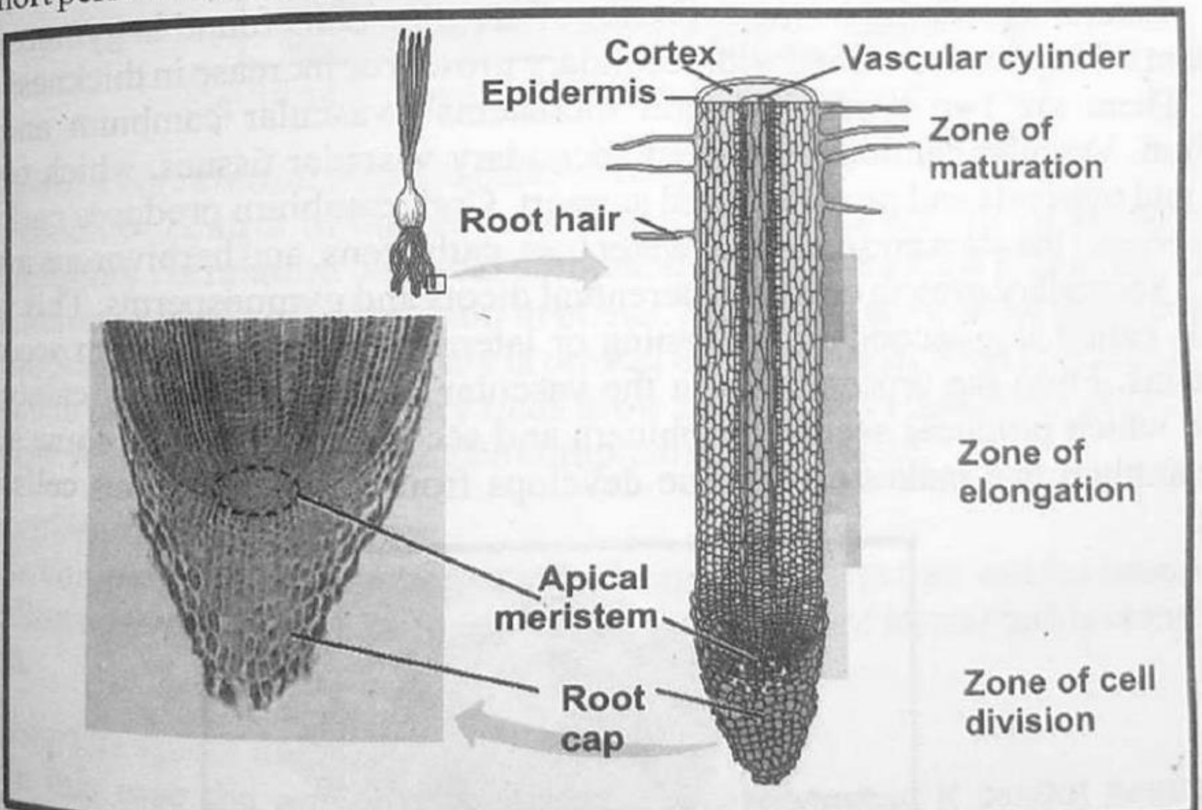


Fig: 10.17 Root tip showing different phases of growth.

Being present at the tips of root and shoot, apical meristems help in increasing the length of the plant body. This elongation is called primary growth. All vascular plants, whether herbaceous or woody, undergo primary growth. Production of lateral branches leaves and flowers also occur by primary growth. Primary growth is found in most monocots and some herbaceous annual dicots.

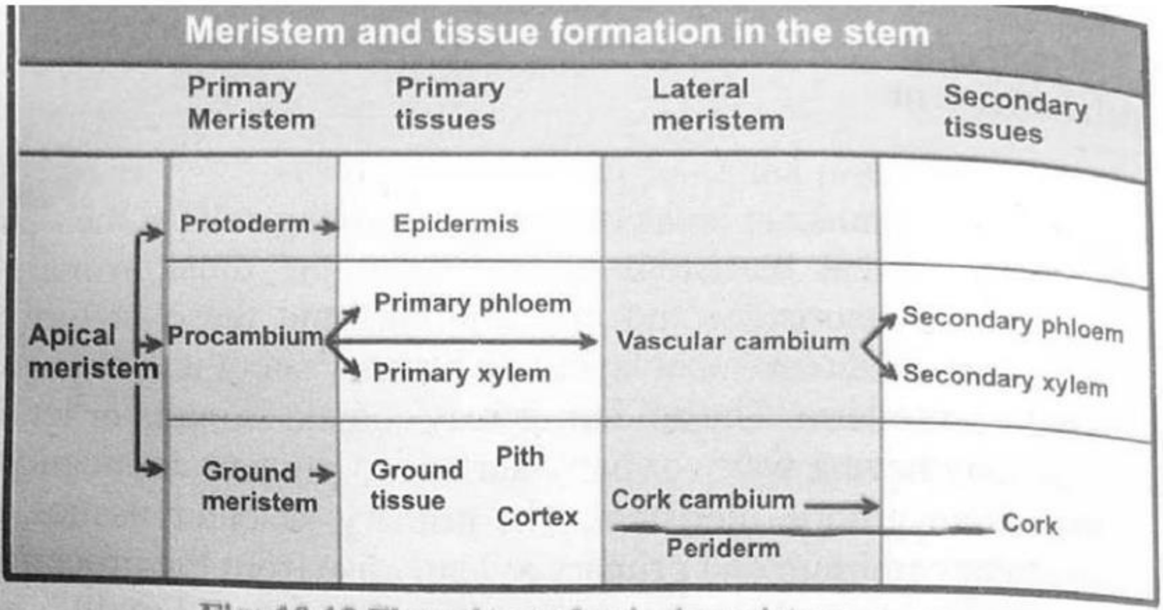


Fig: 10.18 Flow chart of apical meristem.

2. Lateral Meristems

Lateral meristems are the cylinders of dividing cells found in gymnosperms and dicots. They are concerned with secondary growth or increase in thickness of the plant. There are two types of lateral meristems—vascular cambium and cork cambium. Vascular cambium produces secondary vascular tissues, which conduct water and nutrients and provide added support. Cork cambium produces cork cells, which protect the stem and root from water loss, pathogens, and herbivorous insects.

Secondary growth occurs in perennial dicots and gymnosperms. This type of growth, called also secondary thickening or lateral growth, arises from secondary meristems. From the procambium in the vascular bundles secondary cambium is formed which produces secondary phloem and secondary xylem. In some species cork cambium that makes cork tissue develops from parenchymatous cells in the cortex.

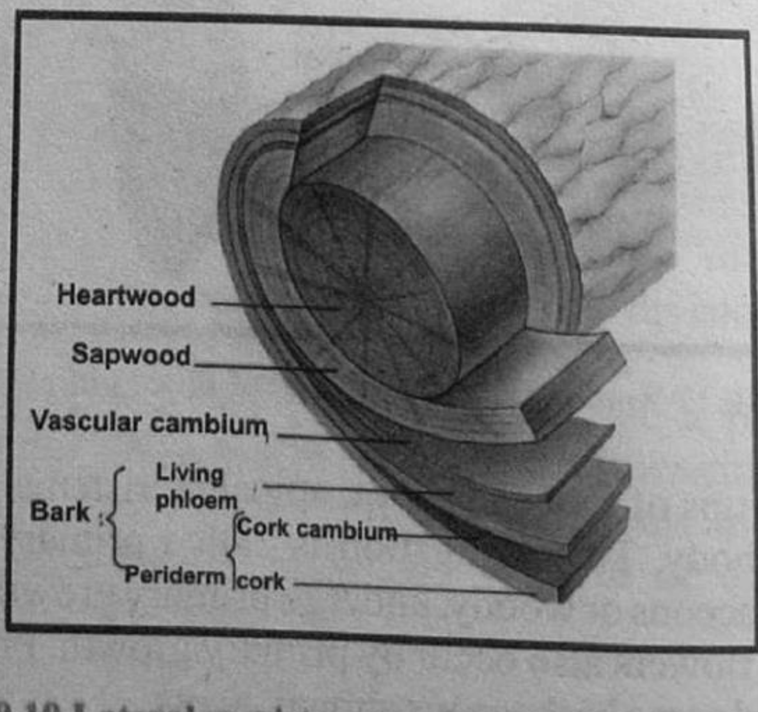


Fig: 10.19 Lateral meristem results in secondary growth.

10.6.1 Growth Correlation

In a growing plant, the development of every organ is affected by the physiological processes occurring in some other organ e.g. the vegetative growth of many plants is highly affected during fruiting. Similarly, the formation of flower buds and flowers may be controlled by the processes taking place in leaves. Such reciprocal relationship for growth among the different organs of a plant is called growth correlation. The correlation may be inhibitory or compensatory.

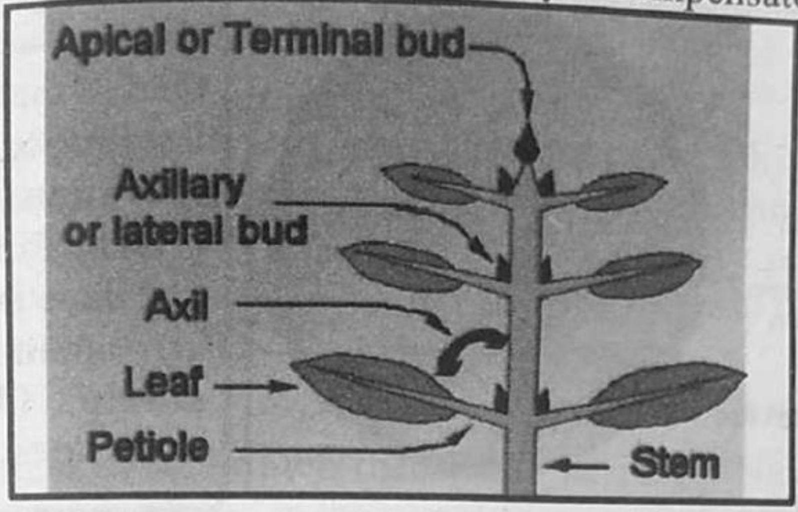


Fig: 10.20 A young stem showing apical and axillary buds.

1. Inhibitory correlation (Apical dominance)

The inhibition or control of lateral buds to develop by the activity of apical bud is called inhibitory correlation or apical dominance. This is the most important and the most common example of correlation in plants. The active apex of the shoot controls the development of lateral buds. This is proved by the fact that if the apical bud is cut off, then one or more of the axillary buds grow out and exert inhibitory effect on the buds below. Apical dominance may be complete or incomplete.

(a) Complete apical dominance

In complete apical dominance only the main shoot grows and the lateral buds are not allowed to developed, as in sunflower the growth of lateral bud is completely inhibited.

(b) Incomplete apical dominance

In this case the apical dominance is weak because it cannot control the development of lateral buds, which grow out to form a bushy appearance e.g. in tomato.

2. Compensatory Correlation

When the removal of one part enhance (increase) the growth of other part is called compensatory correlation. Example: Thinning of fruits can cause the remaining fruits to grow larger in size. In *Chrysanthemum* removal of all buds except one results in the development of one large single flower.

10.6.2 Annual rings

Every tree keeps its own diary of climatic changes or other events that affect its growth. Each year a page is added which records whether that was a lean year or a fat one. Each year, beneath the bark, the tree adds a layer of wood to its trunk. When conditions are ideal, the layer is thick. When there is a severe drought, or a plague of insects that destroy most of its leaves in early summer, or some other trouble, the layer will be thin. If the tree is cut down with a saw, those layers appear on the stump as a series of concentric rings called Annual Rings or Tree Rings. A tree ring is simply a layer of wood produced during one tree's growing season. Each tree ring marks a line between the dark late wood that grew at the end of the previous year and the relatively pale early wood that grew at the start of this year. One annual ring is composed of a ring of early wood and a ring of late wood.

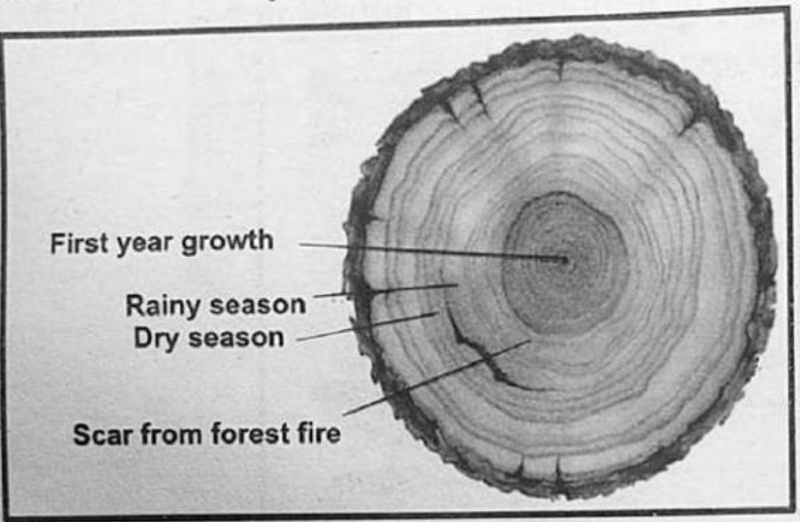


Fig:10.21 Annual Rings or Tree Rings are layers that appear on the stump as a series of concentric rings.

For Your Information

One of the most accurate way to estimate tree age is to count the annual rings of wood growth. For trees that are dead and have been cut down, you can count the rings on the stump. This provides an accurate estimate of its age.

The growth occurs in the cambium. In spring, the cambium begins dividing. This creates new tissue and increases the diameter of the tree at two places:

1. **Outside the cambium:**

The outer cells become part of the phloem. The phloem carries food produced in the leaves to the branches, trunk, and roots. Some of the phloem dies each year and becomes part of the outer bark.

2. **Inside the cambium:**

The inner cells become part of the xylem. These cells contribute most of a tree's growth in diameter. The xylem carries water and nutrients from the roots to the leaves. These cells show the most annual variation:

When a tree grows quickly, the xylem cells are large with thin walls. This early wood or springwood is the lighter-colored part of a tree ring. In late summer, growth slows; the walls of the xylem cells are thicker.

This late wood or summerwood is the darker-colored part of a tree ring. When conditions encourage growth, a tree adds extra tissue and produces a thick ring. In a discouraging year, growth is slowed and the tree produces a thin ring.

10.7 Growth Responses in Plants

Plants show growth responses by releasing certain chemicals or by showing differential growth rate or movement.

10.7.1 Plant Growth Substances

Hormones of plants are referred as Phyto Hormones. Phyto Hormones are organic substances which are naturally produced in plants; control the growth or other physiological functions, at a sight remote from its place of production and active in extreme minute quantities. There are five major growth hormones namely auxins, gibberellins, cytokinins, abscisic acid and ethylene.

1. Auxins

Auxin is a Greek word, which means "to increase". Naturally occurring auxin is a hormone that is produced in the apical meristems of shoots and the tips of coleoptiles. Indole acetic acid with other related compounds are collectively called as auxin. Auxins control and regulate many physiological processes. Auxin travels by diffusion toward the base of the plant, where it controls the lengthening of the shoot and the coleoptile, chiefly by promoting cell elongation.

Auxin also plays a role in differentiation of vascular tissue and initiates cell division in the vascular cambium. It often inhibits growth in lateral buds, thus maintaining apical dominance. The same quantity of auxin that promotes growth in the stem inhibits growth in the main root system.

2 Gibberellins

The gibberellins were first isolated from a parasitic fungus that causes abnormal growth in rice seedlings. They were subsequently found to be natural growth hormones present in many plants. The most dramatic effects of gibberellins are seen in dwarf plants, in which the application of gibberellins restores normal growth, and in plants with a rosette form of growth, in which gibberellins cause bolting. Gibberellins cause seed germination in grasses. In the barley seed, the embryo releases gibberellins that cause the aleurone layer of the endosperm to produce several enzymes, including alpha-amylase, which breaks down the starch stored in the endosperm, releasing sugar. The sugar nourishes the embryo and promotes the germination of the seed.

It can break the dormancy of the seed and cancels the effects of the inhibitory substances. In apples and grapes the exogenous application causes more fruit set. Gibberillins promote flowering, helps in growing seedless grapes and improves storage life of banana etc.

3. Cytokinins

The cytokinins were first discovered as a consequence of their capacity to promote cell division and bud formation in cultures of plant tissues. They are chemically related to certain components of nucleic acids. Cytokinins can also act along with auxin to cause cell division in plant tissue culture. In tobacco pith cultures, a high concentration of auxin promotes root formation, while a high concentration of cytokinins promotes bud formation. In intact plants, cytokinins promote the growth of lateral buds, acting in opposition to the effects of auxin. Cytokinins prevent senescence in leaves by stimulating protein synthesis.

4. Abscisic Acid (ABA)

After the discovery of auxins, plant physiologists suspected a dormancy causing chemical in plants. At last a substance that promotes abscission of cotton fruit was purified and was called "abscision II". At the same time a substance was obtained from *Bitula pubescence*, which promoted bud dormancy and was called 'dormin', similar to abscision II on chemical analysis. The abscision II was later named "abscisic acid" due to its abscision character and acidic nature.

Abscisic acid causes bud dormancy and seed dormancy. It inhibits active growth of seedling flowering in long day plants and promotes abscision. During stress conditions (water deficiency or drought) the concentration of abscisic acid increases which causes stomata to close and facilitates influx of water into the roots. Therefore abscisic acid is also called stress hormone that helps plant cope with adverse conditions.

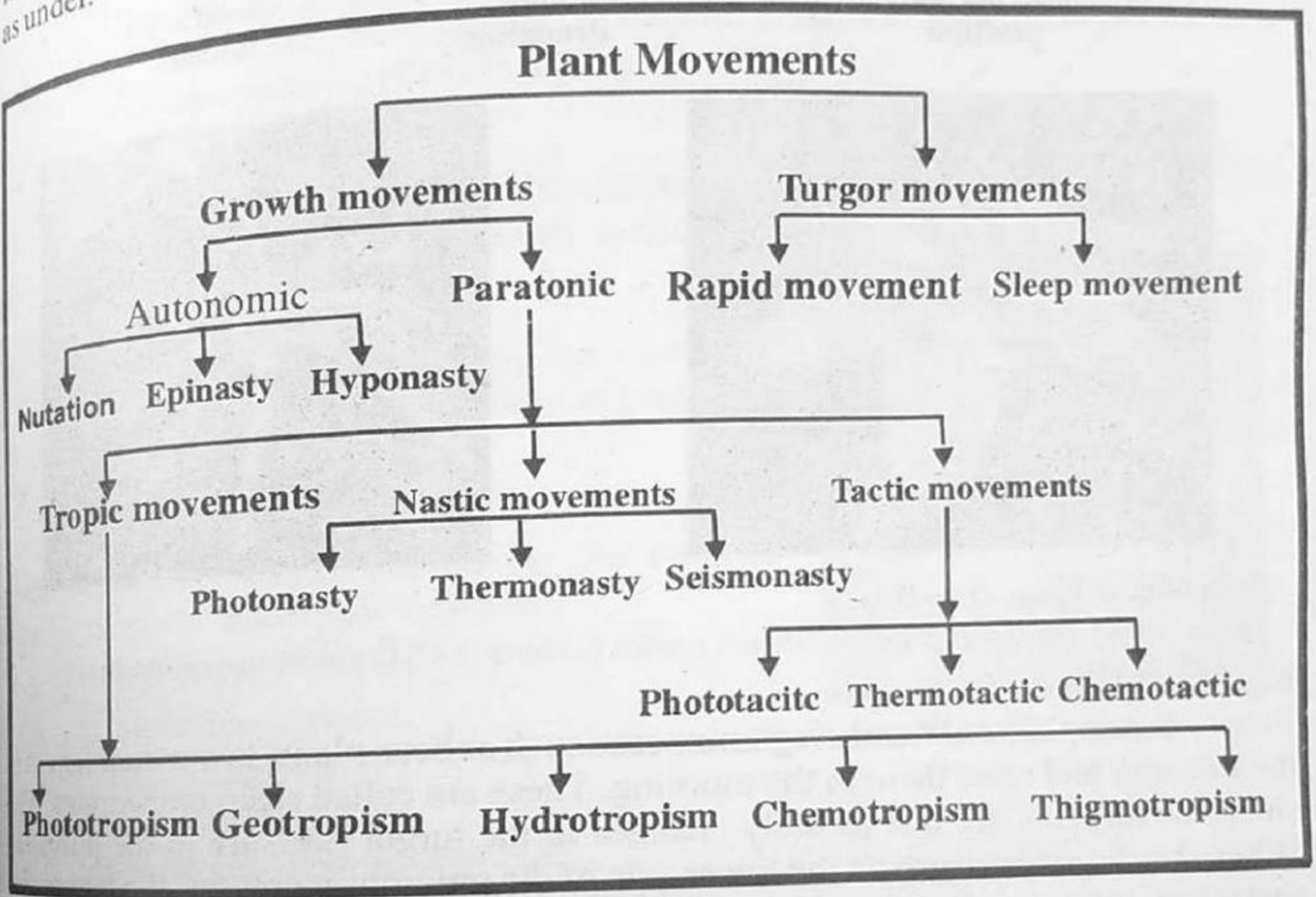
5. Ethylene

Ethylene, a gaseous hormone diffuses through the plant in air spaces It inhibits root growth and development of axillary buds when present in high concentration. Ethylene also stimulates fruit ripening and induces several aspects of senescence in plant cells and organs. The mechanism of leaf abscission involve decrease auxin and increase ethylene production.

10.7.2 Plant Movements

Plant movements are usually too slow for the direct observation but the results are easily noticed e.g. the closing and opening of flowers, unfolding of buds, bending towards light, twining of tendrils, locomotion of *Chlamydomonas* and the gametes of algae, bryophytes and pteridophytes etc.

Generally movement of plant parts can be classified according to the mechanism involved. Plants movements are classified into two major types; turgor movements and growth movements, rest of the classification of plant movements is as under.



1. Turgor Movement

Turgor movements are due to the differential changes in turgor and size of the cells as a result of the gain or loss of water and are easily reversible. The effective cells are often different from ordinary cells and may be concentrated in certain areas The rolling of leaves of many grasses in dry weather is caused by loss of water from the bulli-form cells, which form longitudinal rows in epidermis. The dropping folding up in some plants at night are caused by turgor changes in the cells of the pulvinus which are present at the base of the leaf or leaflet.

The pulvinus is composed of parenchyma cells with large intercellular spaces and a central strand of vascular tissue. The water passes into or out of these cells more freely on one side of the pulvinus than on the other side. This unequal movement of water causes unequal enlargement or shrinkage (turgor response) and a consequent movement of the petiole and leaf blade.

Turgor movement may be: (a) rapid movements (b) sleep movements..

a. Rapid Movement

When the leaves of Mimosa or "touch me not" are touched, the lower cells of the pulvinus loose their turgidity. The leaves bend downward. After some time the leaves regain their turgidity and thus become erect.

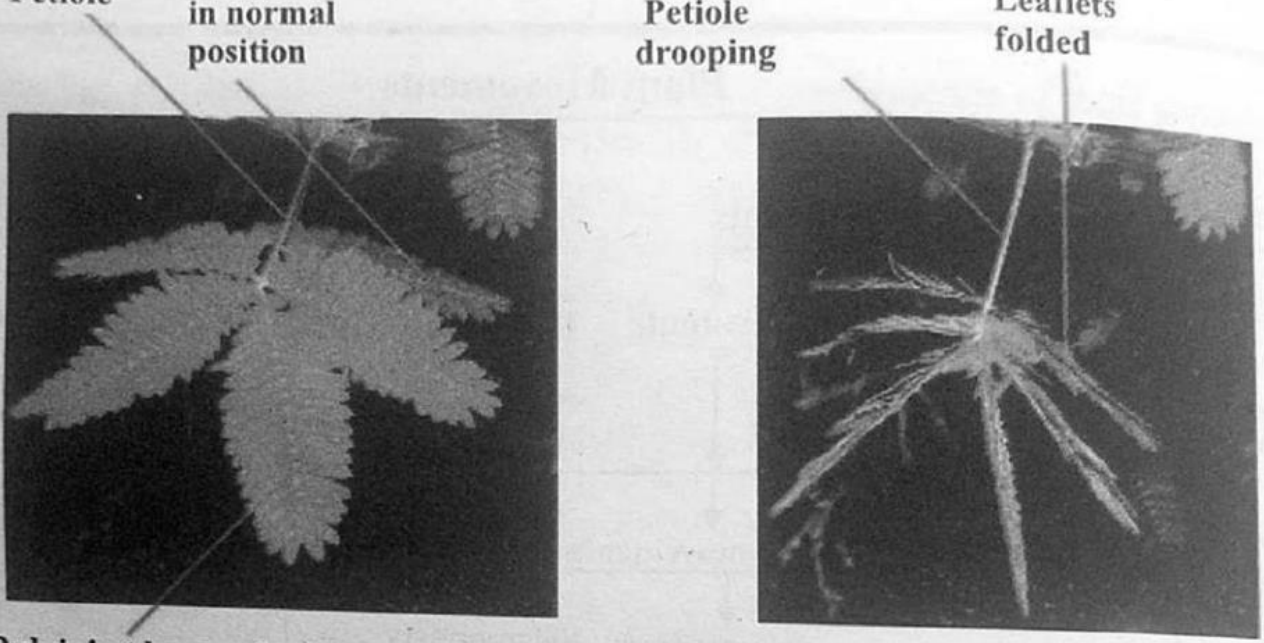


Fig: 10.22 Response of *Mimosa pudica* to shock. Left (before) and right (after)

b. Sleep Movements

Some plants of family leguminoceae such as bean plants lower their leaves in the evening and raise them in the morning. These are called sleep movements. The sleep movements are due to daily changes in the turgor pressure in the pulvinus. When the turgor pressure on the lower side of the pulvinus increases, the leaves rise and when decreases, the leaves lower. This is called sleep movement.

2. Growth Movements

Growth movements may be self controlled or induced by the plant organs by external stimuli. They are irreversible movements, caused due to unequal growth on both sides of the plant organs like roots, stems, buds and tendrils. On this basis the growth movements are classified into:

a.. Autonomic b. Paratonic

a. Autonomic Movements

Movement in which the whole plant shifts from one place to another is called locomotion. These are spontaneous movements or self control movements e.g. certain algae such as *Chlamydomonas* and *volvox* move through water. Also the zoospores and motile gametes of lower plants show locomotion. These move in response to stimuli i.e sweet fluids etc. The protoplasm of the living cells of many plants shows streaming movements around vacuole.

Following are the types of the autonomic movements.

i. Epinasty ii. Hyponasty iii. Nutation

i. Epinasty

It is seen in the petals and leaves especially in the bud condition. The upper surface of the leaf shows more growth in the bud condition than the lower surface, which results in the opening of the buds.

ii. Hyponasty

It is also shown by petals and leaves in bud condition, the lower surface of the leave shows more growth than the upper surface which keeps the bud closed.

iii. Nutation

The growing tip of the young stem moves in zig zag manner due to alternate change in growth on opposite side of the apex.

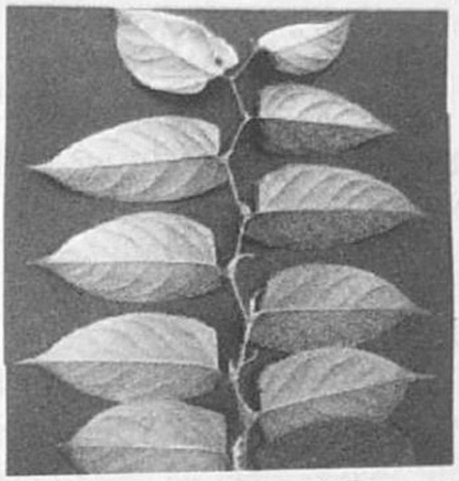


Fig: 10.23 Young stem of Japanese Knotweed growing along the ground rather than upright into canes often have a zig-zag appearance.

b. Paratonic Movements

These movements are induced by the external stimuli. Paratonic movements may be:

i. Tropic movements
ii. Nastic movement
iii. Tactic movements

i. Tropic Movements

These are induced movement of curvature shown by the plant organ (shoot or root), which are capable of turning in any direction. The direction of movements is determined by the direction of stimulus (light, water, gravity etc). Tropism or tropic movements are classified as under:

a. Geotropism

Geotropism occurs in radially symmetrical organs like root and stem. The orientation of stem and roots in response to the force of gravity is called geotropism. The roots grows towards the force of gravity and are said to be positively geotropic, the stem grows away from the force of gravity and is there fore called negatively geotropic.

b. Phototropism

The tropic movement of curvature induced in plants organs in response to the unilateral effect of light is called phototropism.

Young stems are positive phototropic, turn towards light. The curvature is due to the greater growth on the shaded side then on the side on which the light acts. Roots are usually indifferent to stimulus of light, their orientation being determined chiefly by the gravity.

c. Hydrotropism

This is the movement of the plant organs in response to the stimulus of moisture. The primary roots, secondary roots of higher plants, rhizoid of liverwort and hyphae of certain fungi exhibit growth movement in response to variation in the amount of moisture. Roots are sensitive to variations in the amount of moisture in the soil.

d. Thigmotropism

These movements of the plant organs is in response to the stimulus of touch, contact or friction e.g. the plants, which climb by means of tendrils, are sensitive to the stimulus of contact. The tendrils are found in a number of plants e.g. in *Passiflora*, *Lathyrus*, *Smilax* etc.

Thigomotropic responses are also met within the roots. If the tip of the young root comes in contact with a solid object such as small stone, the root bends away from it. This negative curvature helps the root to avoid obstacle in the soil. The stamens of certain plants are sensitive to touch and their dehiscence takes place only when the body of an insect rubs them.

Fig:10.24 Passiflora species have tendrils that allow them to crawl all over everything.

(e. Chemotropism

This is the movement of a part of the plant in response to a chemical stimulus. The plant organ may grow either towards the chemical stimulus or away from it e.g. the pollen tube grows towards the egg in the angiosperms due to the disintegration of the synergid cells, which produced chemicals. Similarly the tentacles of *Drosera* (or sundew) show positive chemotropism. The chemicals like the proteins, phosphates and the salts of ammonia cause the tentacles to bend. In the same way the hyphae of many fungi shows positive chemotropism towards sugar, peptones. The hyphea of the fungi show negative chemotropism towards acids and alkalis.

ii. Nastic Movements

The movements brought about by the stimuli which are non directional but diffuse are called nastic movements. It is the variation in the intensity of some intensity of some external factor rather than its direction, which acts as a stimulus.

The direction of the movement is here determined by the structure of the plant organs like the leaves and the petals of flowers, which can bend only in one direction. Nastic movements may be the result of growth changes or they may be the movements of variation.

Nastic movements may be:

a. Photonasty
b. Thermonasty
c. Seismonasty

a. **Photonasty**

This nastic movement is induced by variation in the intensity of light. Many leaves, which keep their surfaces fully exposed during the daytime, drop at night. The dropping of the leaves is brought about by changes in the turgidity of parenchymatous cells of the pulvini i.e. Many flowers such as oxalis close up at night or when the light is diminished on a cloudy day and open during the daytime in sunshine.

b. **Thermonasty**

This is due to variation in the degree of temperature. Many flowers open when illuminated and close up when it is dark e.g. crocus, tulips etc.

c. **Seismonasty**

This nastic movement is induced by mechanical stimuli such as touch or friction etc e.g. when the leaf of *Mimosa pudica* is touched the leaflets close and the whole leaf drops. This shock movement of *Mimosa pudica* is called seismonastic movement. These movements are caused by the differential loss and support of turgor on the two sides of the pulvinus.

iii. **Tactic Movements**

These are the movements of the entire organism or of motile organs and are induced by the external stimuli, which influence their direction. The stimuli can be light, temperature or chemicals.

a. **Phototactic**

It is the locomotary movement of free swimming organisms or their organs in response to one-sided illumination e.g. *Chlamydomonas*, *Volvox* and the zoospores of *Ulothrix* and many other algae when illuminated by weak light move towards the light, thus showing positive phototaxis. When illumination is too intense, they move away from light, showing negative phototaxis. Similar movements are also exhibited by the chloroplast in the pallisade cells of the green leaves.

b, **Thermotactic**

This is the movement of free organism in response to the stimulus of temperature. When there is difference in temperature, the unicellular algae are seen to move toward the warmer side.

c. **Chemotactic**

This is the movement of free organism or their gametes in response to chemical stimuli. The spermatozoids of bryophytes and pteridophytes move towards the chemical substances like sugar and proteins secreted by the archegonia.

Fig:10.25 The sperm cells of ferns are typically multiflagellate.

For Your Information

Photoperiodism corodinates seasonal activities such as growth, development, reproduction, migration, and dormancy that make a direct contribution to survivorship and reproductive success of the species. Depending on the length of the day, animals show behavioural and biological changes. Day length affects their fur colour, migration, hibernation and also sexual behaviour. For example, the singing frequency of the canary bird depends on the length of the day.

10.7.3 Photoperiodism

The relative lengths of the day and night to which the plants are exposed have remarkable effects on the behaviour of plants particularly on the development of flowers. The relative length of the day and night to which the plant is exposed is called photoperiod and the response of the plant to photoperiod is the photoperiodism. According to photoperiodism, plants are classified into three types which are short day plants, long day plants and day neutral plants.

1. Short day plants

Short day plants produce flowers in early spring when the day length is shorter than a critical value Examples of short day plants are tobacco, Dahlia, Soya bean and *Chrysanthemum* etc. For short day plants the critical value is maximum for flowering.

2. **Long day plants**

Long day plants produce flowers in summer when the day length is longer than a critical value. Examples of long day plants are *Hibiscus*, beet, spinach and potato etc. For long day plants the critical value is a minimum value for flowering.

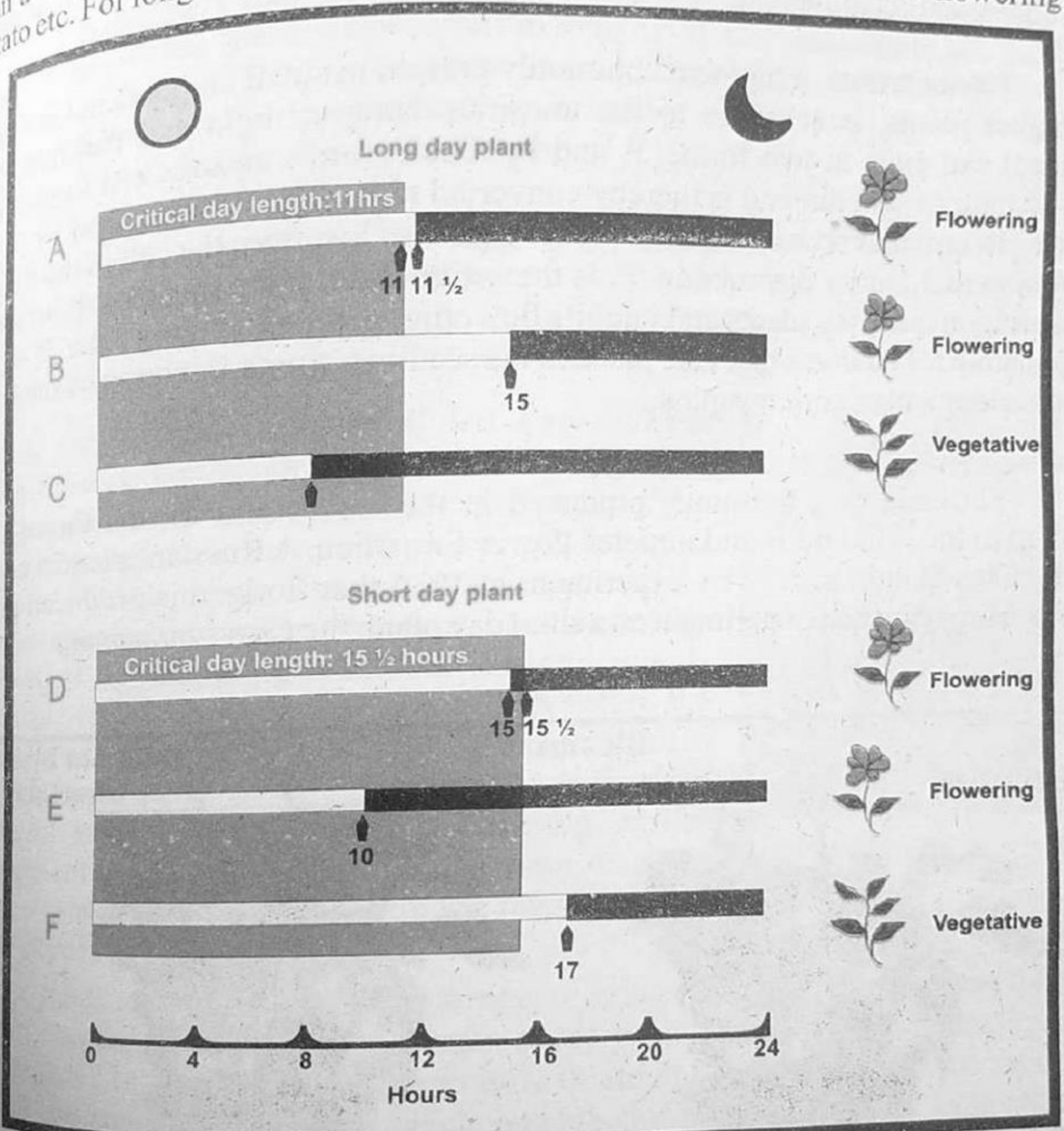


Fig: 10.26 Comparison of hypothetical long day and short day plants. The difference is that the critical day length is minimum value for the long day plant and maximum value short day plant. Thus the long dat plant will flower when the day length is slightly above the critical value (A) or when it is much above the critical value (B). But will not flower when it is below the critical value (C). Conversely, the short day plant will flower when the day length is slightly below the critical value (D) or when it is much below the critical value (E), but will not flower when it is above the critical value (F).

3. Day neutral plants

Day neutral plants are independent of the day length and therefore not affected by the day length. They produce flowers whenever they become mature, irrespective of the day length. Examples of day neutral plants are maize, tomato, sunflower and cucumber etc.

10.7.3.1 Phytochrome

Phytochrome, a pigment commonly present in small amounts in the tissues of higher plants, is sensitive to the transition between light and darkness. The pigment can exist in two forms, P_r and P_{fr} .The P_r forms absorbs red light with a wavelength of 660 nm and is thereby converted to P_{fr}. The P_{fr} form absorbs far red light (730 nm) and is converted to P_r. The P_{fr} is also lost from the cell in the dark by reversion to P_r, or by destruction. P_{fr} is the active form of the pigment. It promotes flowering in long day plants and inhibits flowering in the short day plants. P_{fr} also is responsible for changes that take place in the seedling, for germination of seeds and for development of anthocyanins.

Flowering hormone (Florigen)

Florigen, is a hormone, produced in the leaves and travels through the phloem to the floral buds and initiates flower formation. A Russian scientist named M. H. Chailakhain proved by experiment in 1936 that florigen is produced in the leaves. He performed experiment on a short day plant, the *Chrysanthemum*.

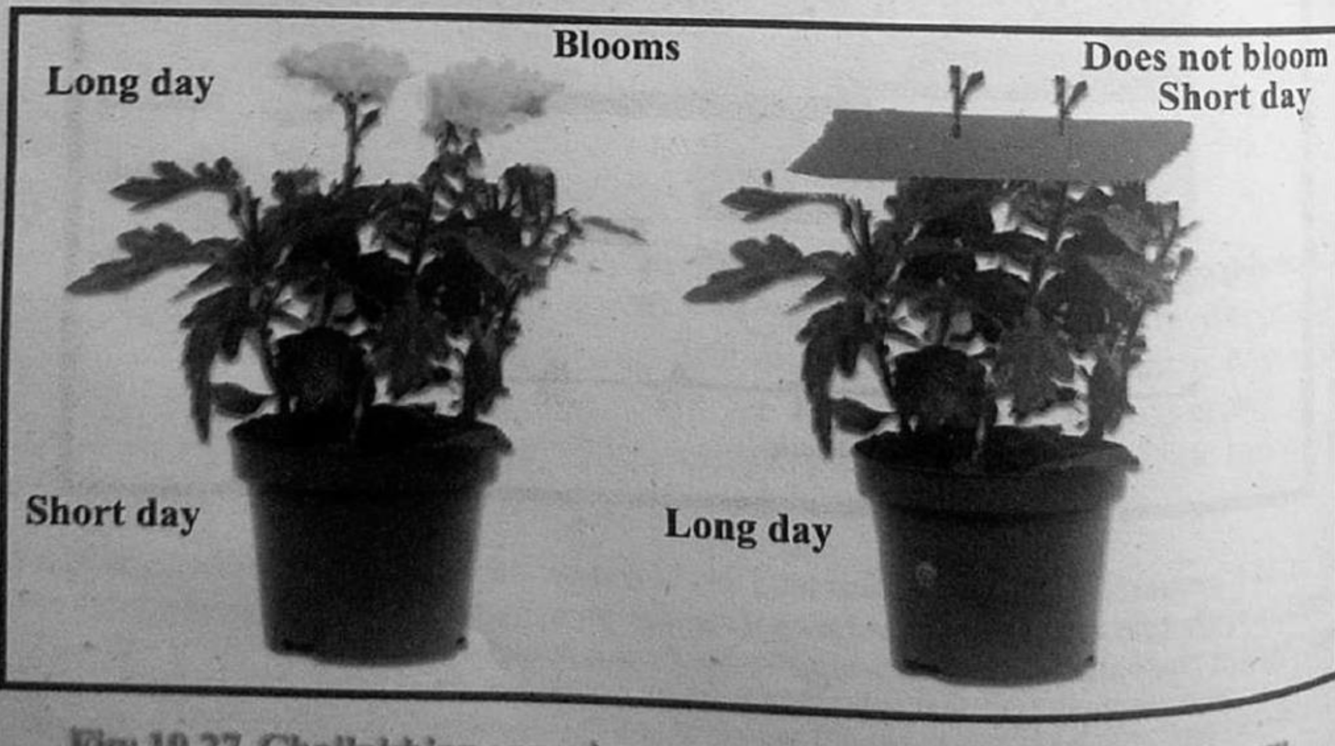


Fig: 10.27 Chailakhian experiment on short day plant *Chrysanthemum*.

He took two plants and removed the leaves from the upper half of both plants but left the leaves on the lower half. He then exposed the upper half of one plant to long days and the lower half of the same plant to short days. The result was that the plant produced flowers.

He then exposed the defoliated (leaves removed) upper half of the other plant to short days and the foliated lower half to long days. The result was that the plant produced no flowers. From this experiment Chailakhian, concluded that the flowering hormone or florigen is produced in the leaves and then transmitted to the floral bud where it initiates flower formation.

10.7.4 Vernalization

Vernalization is a Latin word meaning "spring". The conversion of winter variety into the spring variety by low temperature treatment is called vernalization. This term was coined by Lysenko in 1928. Some plants require a period of low temperature before producing flowers.

If this condition is not fulfilled, they will not produce flowers. For example, if the germinating seeds of winter wheat are exposed to low temperature, the plants developed from them will flower much earlier than would have done otherwise. This method of stimulating the earlier production of flowers by subjecting the germinating seeds to low temperature is known as vernalization. Vernalization is therefore the promotion of flowering by applying low temperature to seeds and buds before sowing or grafting. Vernalization is helpful to the agriculturists in inducing earlier development of flowers and earlier ripening of crops and also in extending cultivation to the regions where temperature is very low.

Fig:10.28 Lysenko studying wheat

It has enabled the Russian farmers to grow crops in Siberia where the soil remains covered with ice for ten months of the year. Biennial and perennial plants are stimulated to flower by low temperature treatment. The embryo of the seed and apex of the stem are the parts which receive the stimulus of low temperature. Temperature around 4°C is found to be effective. It produces a hormone, the vernalin, which induce vernalization. Vernalization procedure was applied on large scale to cereal crops, particularly wheat in Northern Europe during 1930 and 1940, where the chilled winter varieties were grown as spring varieties.

KEY POINTS

- Depending upon the amount of each nutrient required the mineral nutrients are divided into two groups: macronutrients and micronutrients.
- Macro nutrients include nitrogen, phosphorus, potassium. calcium, magnesium, and sulfur. The micronutrients includes boron, copper, iron, chlorine.
- Carnivorous plants may be with passive traps or active traps in both of them method of insect decomposition involves digestive enzymes produced by the plant and bacterial decay within the trap.
- Tracheophytes' have specialised tissue, termed xylem and phloem, for conducting water (plus solutes) and organic nutrients.
- Water potential is directly proportional to the concentration of water-molecules. Greater the concentration of water molecules in a system, greater is the kinetic energy of water molecules.
- Water and minerals from the soil to the xylem moves by the way of appoplast, sympalst and through vacuoles.
- Four important forces combine to transport water solutions from the roots, through the xylem elements, and into the leaves. These TACT forces are: transpiration, adhesion, cohesion and tension.
- Green leaves are regarded as "source of assimilates " because these are the sites of production of sugar during the process of photosynthesis while the buds, seeds, fruits, roots and the underground stems are together called "sinks of assimilates" because sugar produced is either stored or utilized here.
- Osmoregulation has enabled the plants to be distributed in wide range of habitat.

KEY POINTS

- According to the amount of water available, plants are classified into four main groups: Hydrophytes, mesophytes, xerophytes and halophytes.
- Plants possess some morphological and anatomical structures to counter very high or very low temperature.
- Turgor pressure is caused by the uptake of water by the cytoplasm of the cells so that pressure is exerted at the plasma membrane on the cell wall.
- Growth is defined as increase in number and size of cells. Three phases of growth are: (a) Phase of cell division (b) Phase of cell elongation (c) Phase of cell maturation and differentiation.
- Apical meristems are areas of actively dividing cells at the tips of all roots and shoots. Lateral meristems consists of vascular cambium and cork cambium. Vascular cambium produces secondary vascular tissues and cork cambium produces cork cells, which protect the stem and root from water loss, pathogens, and herbivorous insects.
- The inhibition or control of lateral buds to develop by the activity of apical bud is called inhibitory correlation or apical dominance.
- Phytohormones are organic substances which are naturally produced in plants, control the growth or other physiological functions, at a sight remote from its place of production and active in extreme minute quantities.
- The relative length of the day and night to which the plant is exposed is called photoperiod and the response of the plant to photoperiod is the photoperiodism
- Phytochrome, a pigment commonly present in small amounts in the tissues of higher plants, is sensitive to the transition between light and darkness.
- The conversion of winter variety into the spring variety by low temperature treatment is called vernalization.

EXERCISE

A. **Choose the correct answers in the following questions.**

1. The thick walled dead cells like tracheid and vessels are included in:
   a. parenchyma
   b. sclerenchyma
   c. collenchyma
   d. mesenchyma

2 The increase in thickness of the plant due to the activity of cambium is called.
   a. primary growth
   b. secondary growth
   c. tertiary growth
   d. stunted growth

3 The movement restricted to bifacial organs like the leaves and petals of flower is the:
   a. tactic movement
   b. nastic movement
   c. tropic movement
   d. chemotactic movement

4 In plant, regions of continuous growth are made up of:
   a. dermal tissue
   b. vascular tissue
   c._meristematic tissue
   d. permanent tissue

5. Chlorosis is:
   a. the uptake of the micronutrient chloride by a plant.
   b. the formation of chlorophyll within the thylakoid membranes of a plant.
   c. yellowing leaves due to decreased chlorophyll production.
   d. a contamination of glassware in hydroponic culture.

6. Carnivorous plants have evolved mechanisms for trapping and digesting small animals. The products of this digestion are used to supplement the plant's supply of
   a. carbohydrates
   b. lipids and steroids
   c. nitrites
   d. water

7. All of the following are elements that plants need in very small amounts (micronutrients) **EXCEPT**
   a. Hydrogen
   b. Iron
   c. Chlorine
   d. Copper

8. The tissue most likely to provide flexible support is the:
   a. epidermis
   b. sclerenchyma
   c. parenchyma cell
   d. collenchyma

EXERCISE

9. Fibres like hemp and flax are made up of:
   a. epidermis
   b. sclerenchyma
   c. parenchyma cell
   d. collenchyma
10. The primary growth of a plant is due to the action of the ______.
    a. lateral meristem
    b. vascular cambium
    c. apical meristem
    d. cork cambium
11. Which bonds are responsible for the cohesion of water molecules?
    a. Ionic
    b. Hydrogen
    c. Non polar covalent
    d. Polar covalent
12. In a sugar sink, such as a taproot, sugar is converted into ______.
    a. fatty acid
    b. proteins
    c. glycogen
    d. starch
13. Plants are able to detect photoperiod changes by the ______.
    a. alternation of the two forms of phytochrome
    b. settling of amyloplasts
    c. direction of the light source
    d. movement of potassium ions
14. Which one of the following is true for annual ring?
    a. It is composed of a ring of early wood and a ring of late wood.
    b. Its growth is co- related with the production of abscisic acid.
    c. It is produced from the axillary buds.
    d. It is produced as a result of primary growth

B. Write short answers to the following questions.

1. Why insectivorous plants depend on insects?
2. What do you mean by water potential?
3. Differentiate between mesophytes and xerophytes.
4. How turgor provide support to the herbaceous plants?
5. Differentiate between primary and secondary growth in plants.
6. Briefly describe the mechanism of formation of annual rings in plants.
7. List the adaptation in plants to cope with low temperatures.

C. Answer the following questions in detail.

1. Elaborate the role of macro and micronutrients plant growth and development.
2. Explain the movement of water in xylem through TACT mechanism.
3. Explain the movement of sugars within plants.

EXERCISE

4. How the osmotic adjustments of plants in saline soils take place?.
5. Describe the structure of supporting tissues in plants.
6. Discuss the role of important plant growth hormones.
7. Classify plants on the basis of photoperiodism and give examples.
8. Describe the mechanism of opening and closing of stomata.

Projects:

- Prepare a temporary slide, by cutting a T.S of a dicot stem.
- Collect and write taxonomic classification of at least five plants exhibiting xerophytic, mesophytic and hydrophytic characters respectively.
- In your local area identify some major symptoms of mineral deficiencies in plants e.g. necrosis, chlorosis, stunted growth etc.