SECTION-3
LIFE PROCESSES

CHAPTER-10
FORM AND FUNCTIONS IN PLANTS

Q1. What is plant nutrition?

Ans: Plants use inorganic minerals for nutrition, whether grown in the field or in a container. Complex interactions involving weathering of rock minerals, decaying organic matter, animals, and microbes take place to form inorganic minerals in soil. Roots absorb mineral nutrients as ions in soil water. Many factors influence nutrient uptake for plants. Ions can be readily available to roots or could be "tied up" by other elements or the soil itself. Soil too high in pH (alkaline) or too low (acid) makes minerals unavailable to plants.

Q2. Define/Describe/Explain briefly:
Nutrients, Nutrition, Macronutrients and Micronutrients.

Ans: Nutrients:

All those substances that provide necessary elements to the organism for growth and metabolism are called **nutrients** that may be organic or inorganic.

Nutrition:

The term **nutrition** is applied to all the processes that are involved in uptake of nutrients from the environment and their utilization in growth or various metabolic activities of the body. Plants are autotrophs as they obtain inorganic nutrients such as water, carbon dioxide and certain minerals form the environment and convert them into organic compounds.

Macronutrients:

Sixteen elements have been found essential for plant growth. Nine of these are required in fairly large quantities (greater than 0.05% dry weights) and are therefore known as **macronutrients.**

These include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium and magnesium.

Micronutrients:

The remaining seven elements are needed in traces or small amounts (less than 0.05% dry weight) for normal plant growth and development that are known as **micronutrients.** These include iron, boron, manganese, copper, molybdenum, chlorine and zinc.

Q3. Describe the different Diseases in plants due to the deficiency of different nutrients.

Ans: Deficiency Diseases:

All these elements have specific functions in plant body therefore; the deficiency of any one of them can cause serious complications that are generally called **deficiency diseases.**

For example:

Deficiency of nitrogen or magnesium causes yellowing of leaves called **chlorosis.** The deficiency of phosphorus causes stunted root growth and deficiency of potassium causes leaf margins yellow or brown and pre-mature death of plant.

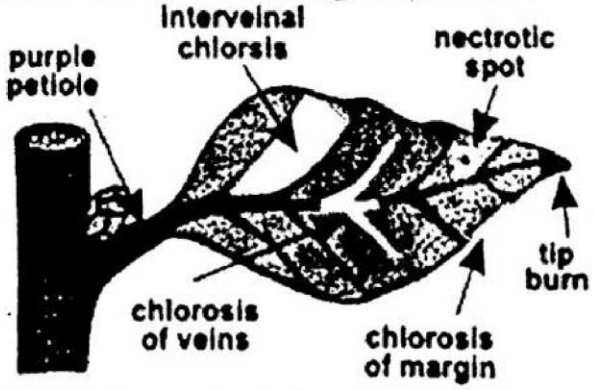
The nutrients may become deficient in the soil if a particular crop is grown again and again in the same soil. Therefore, **crop rotation** (cultivation of different crops alternatively in the same soil) or **addition of fertilizers** in the soil are possible remedies for this problem.

Science Titbits

Hydroponic culture is one of the most useful methods to test whether a certain element is essential for plant or not. In this method, plants are cultured or grown on net, which is placed on the surface of aerated water containing measured quantity of specific nutrients. The samples of water are analyzed time to time to determine which nutrient, the plant has absorbed.

Science, Technology and Society Connections

- **Identify some major symptoms of mineral deficiencies in plants, e.g., necrosis, chlorosis, stunted growth etc.**



Necrosis: It is the death of a part of plant body. It is due to deficiency of: Calcium, magnesium, copper and molybdenum.

Chlorosis: It is the yellowing of the green parts of a plant which show lack of chlorophyll due to mineral deficiency of nitrogen, and magnesium.

Stunted growth: It is less than normal growth due to the deficiency of phosphorus, sulphur, potassium in plants.

Q4. Explain the transport in plants.

Ans: Transport in Plants:

The roots of a plant not only anchor the plant body in the soil but also absorb minerals and water from the soil. These nutrients are first absorbed by root epidermal cells from where these are moved to the xylem and then through xylem these materials are ultimately reached to the leaves Tne leaves utilize these nutrients in photosynthetic activity. After photosynthesis, organic solutes are produced that also have to move to different parts of the plant body. All these movements of materials are generally refers to as transport in plants.

Q5. What are the main functions of xylem and phloem?

Ans: Function of Xylem and Phloem:

Plants have two systems for the transportation of substances - using two different types of transport tissue.

There are two types of conducting tissues in plants, namely xylem and phloem. These tissues constitute the vascular tissues Xylem conducts mainly water and minerals from the roots up to other parts of the plants Phloem conducts organic food from the leaves both up and down the plant.

Teacher's Point

Teachers would guide the students to illustrate diagrammatically the pathway of water in root, stem and leaf

Critical Thinking

In tropical climates, many tall plants shut stomata during the hot days and open at night. If their stomata are closed during day, why doesn't the water within the plant fall down the stem?

Ans: Because of transpirational pull and adhesive and cohesive forces between water molecules and xylem vessel the water doesn't fall down the plant stem even though its stomata are closed during hot summer days.

OR (Second Answer)

Lenticular transpiration keeps going from the stem, so ascent of sap goes on during the day.

Water is stored in parenchyma cells making them succulent plants. Therefore water is used up and is ascent of sap continues. That's why, inspite of the closure of stomata during day time, the water within the plant does not fall down the stem.

Teacher's Point

Teachers would guide the students to:

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

Critical Thinking

Transverse section of stem: Can you find out the approximate age of this plant?



Ans: Approximate age of this plant is 19 years (19 Rings).

Note: If the tree is already dead, you can count the rings on the exposed stump. The number of rings indicates the number of years the tree lived.
Keep in mind that most trees produce a two-colored ring per year, within the annual ring the thinner strip is the phloem and the thicker is the xylem. Thinner rings represent colder years whereas thicker rings represent warmer years.

Science Titbits

Different **cytokinins: auxin** ratios change the nature of organogenesis. If kinetin (cytokinins) is high and auxin low, shoots are formed; if kinetin is low and auxin high, roots are formed. Lateral bud development, which is retarded by auxin, is promoted by cytokinins.

Activity

1. Demonstration of the evolution of CO_2 from leaf discs placed in dark and light, with the help of indicator (hydrogen carbonate)
2. Microscopic observation of the slide of LS of a dicot stem, identifying and drawing vessel element, vessel, and phloem sieve tubes
3. Locating annual rings in the log of a tree and calculation of the age of a plant by counting number of annual rings
4. Demonstration of phototropism, geotropism and thigmotropism in plants
5. Demonstration of the folding of leaf after touch in Mimmosa pudica

EXERCISE

MCQs

1. Select the correct answer.

(i) It is found essentically in organic compounds

(A) calcium (B) nitrogen
(C) carbon (D) phosphorus

(ii) Chlorosis does not occur due to the deficiency of

(A) sulphur (B) magnesium
(C) phosphorus (D) calcium

(iii) Carnivorous plants use insects as a source of

(A) water (B) glucose
(C) oxygen (D) nitrogen

(iv) Most of the uptake of water and minerals from soil takes place through

(A) epidermal cells (B) root cap
(C) root (D) root hair

(v) Which of the following is closest to the centre of a woody stem?

(A) vasular cambium (B) young xylem
(C) old phloem (D) old xylem

(vi) Symplast is the movement of water through

(A) vacuoles (B) cell walls
(C) cytoplasm of cells (D) interspaces

(vii) Guard cells are the only cells of epidermis, which have

(A) vacuole (B) chloroplasts
(C) cytoplasm (D) leucoplasts

(viii) The sugar moves through phloem is mostly in the form of

(A) glucose (B) sucrose
(C) maltose (D) lactose

(ix) Succulent tissues are formed in

(A) hydrophytes (B) thallophytes
(C) mesophyll (D) xerophytes

(x) Collenchyma is a supporting tissue in

(A) seeds (B) seedlings
(C) herbs (D) trees

(xi) The phenomenon of growth includes

(A) cell differentiation (B) cell elongation
(C) cell maturation (D) cell decomposition

(xii) A researcher, who wants to study the composition of a plant's sap, inserts capillary tube into the phloem. What causes the sap to flow out of the tube?

(A) capillarity (B) hydrostatic pressure
(C) root pressure (D) transpiration stream

Answers

(i) C	(ii) C	(iii) D	(iv) D	(v) D	(vi) C
(vii) B	(viii) B	(ix) D	(x) B	(xi) B	(xii) B

SHORT QUESTIONS

2. What are carnivorous plants? Give examples.

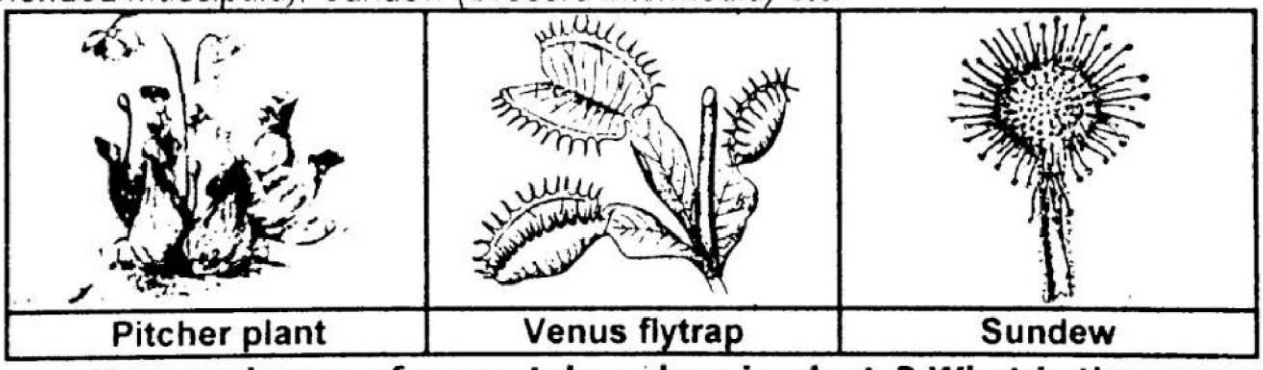
Ans: Carnivorous Plants:

Nutrition of Carnivorous Plants:

Carnivorous or insectivorous plants are true photosynthetic autotrophs but they also feed upon insects because they usually grow in places where nitrogenous salts are not readily available, e.g., marshy areas. Actually, they use insects and other small organ, ms as their source of nitrogen. Such plants have some modified leaves that are used to capture and digest insects. These plants also have certain symbiotic bacteria, which help them to digest insect proteins.

Examples:

The examples are Pitcher plant, *(Nepenthes pupurea)*, Venus flytrap *(Dionaea muscipula)*, Sundew *(Drosera intermedia) etc.*



Pitcher plant	Venus flytrap	Sundew

3. How exchange of gases takes place in plants? What is the purpose of gaseous exchange?

Ans: Gaseous Exchange in Plants:

In bioenergetics, you have studied that respiration occurs at two levels, i.e., organismic and cellular level. The respiration that occurs at organismic level is called **exchange of gases.**

The purpose of this gaseous exchange is to enable the organism to perform cellular respiration, which utilizes oxygen and releases carbon dioxide during the breakdown of complex organic compounds. Exchange of gases between organism and its environment is carried out by diffusion. In the absence of special organs, every cell of plant carries out the exchanges of oxygen and carbon dioxide according to its needs. This exchange of gases mainly occurs through two main openings, the stomata and lenticels.

(xii) A researcher, who wants to study the composition of a plant's sap, inserts capillary tube into the phloem. What causes the sap to flow out of the tube?

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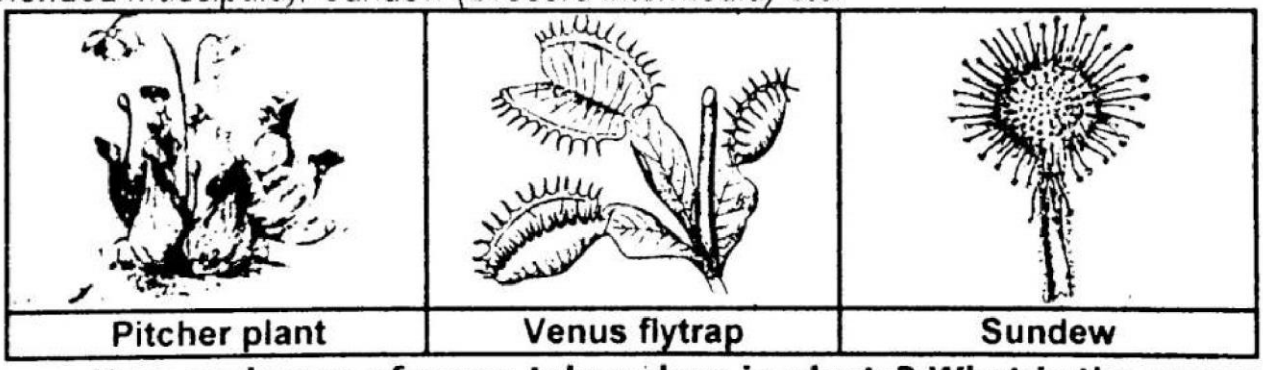
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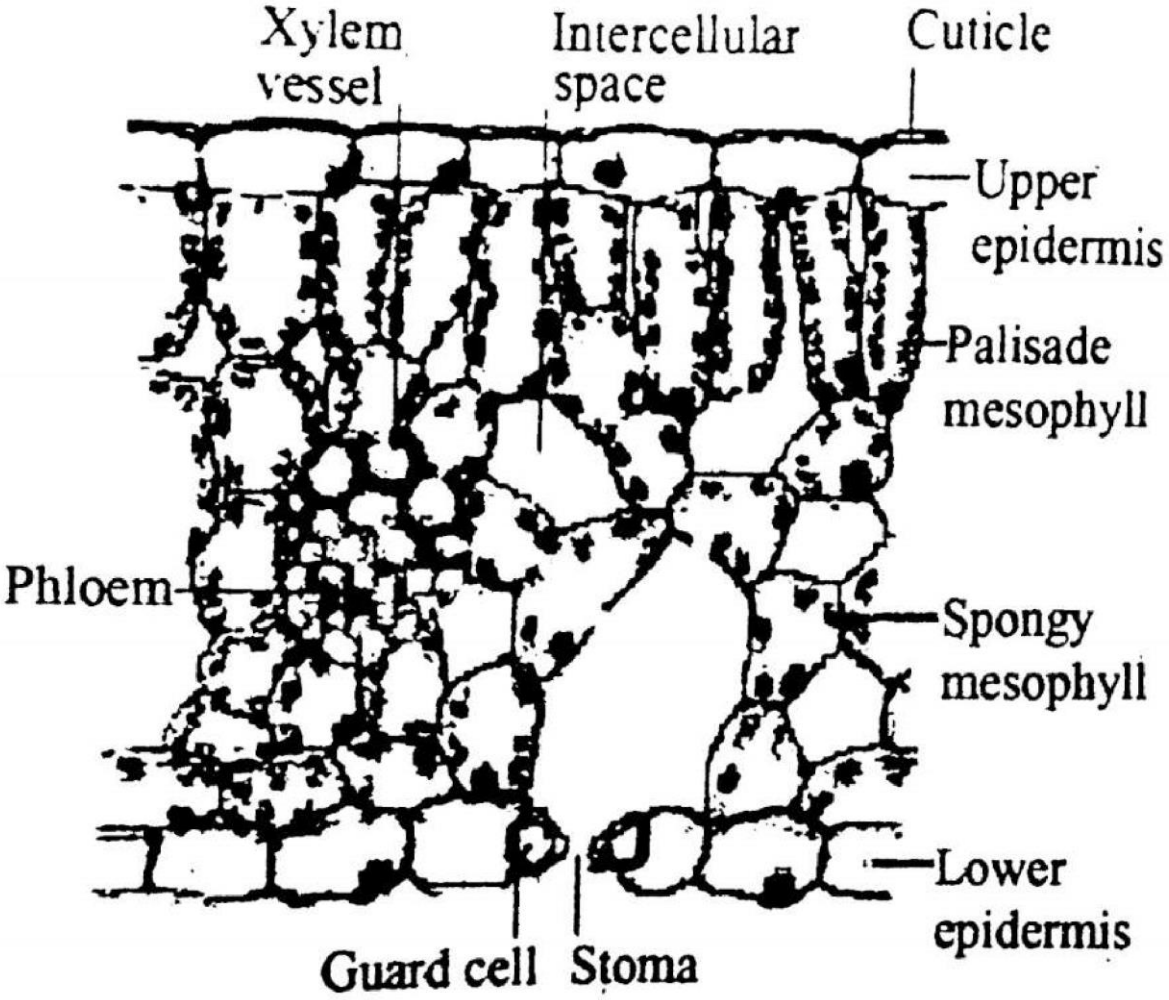
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4. Draw and label T.S. of bifacial leaf.

Ans:



T.S of Bifacial leaf

5. What is the role of transpiration in exchange of gases in plants?

Ans: Role of Transpiration in Exchange of Gases in Plants:

The **transpiration** is the loss of water in the form of vapours through aerial (above the ground) parts of the plants mainly through the stomata. It is not only responsible for transportation of water and minerals but also plays a vital role in the exchange of gases. During day light, the stomata are widely open and provide a wide passage for the exchange of gases.

6. Write a shot note on:

(a) hydrophytes (b) mesophytes (c) xerophytes

Ans: (a) Hydrophytes:

The plants that are found in the area where abundant water is available, are called **hydrophytes.** Aquatic plants of freshwater habitats are example of such plants. These plants are exposed in hypotonic conditions so face problem of flooding (excess of water). Such plants show highest rate of transpiration due to broad leaves with large surface area and distribution of stomata on upper epidermis, which are kept open day and night. These plants do not store water and either have very thin cuticle or almost none, on their surface.

Features of Hydrophytes	
Habitat	Aquatic
Osmotic conditions of medium	Hypotonic
Problems faced by plant	Flooding
Rate of transpiration	Very high rate
Stomatal distribution	On upper epidermis
Stomatal opening	Stomata remain open all the time
Thickness of cuticle	Very thin or none
Storage of water	None

(b) Mesophytes:

The plants that are found in the area where moderate supply of water is available are called **mesophytes.** Common crop plants such as wheat, rice corn are example of such plants. These plants are exposed in nearly isotonic conditions so face no drastic problem of flooding (excess of water) or dehydration (deficiency of water). Such plants show moderate rate of transpiration due to medium sized leaves with distribution of stomata on lower epidermis, which are generally open in day and close at night. However, these plants can close their stomata even in day. These plants store a very small amount of water, have very thin cuticle on their surface.

Features of Mesophytes	
Habitat	Terrestrial (moderate)
Osmotic conditions of medium	Nearly isotonic
Problems faced by plant	No drastic problem
Rate of transpiration	Medium rate
Stomatal distribution	On lower epidermis
Stomatal opening	Open in day and close at night
Thickness of cuticle	Less thick
Storage of water	Little storage

(c) Xerophytes:

The plants that are found in the area where very little amount of water is available are called **xerophytes.** Desert plants such as cactus, opuntia are example of such plants. These plants are exposed to severely hypertonic conditions so face extreme degree of dehydration.

Such plants show very reduced rate of transpiration due to narrow needle like leaves or due to complete modification of leaves into spines. They have stomata in depressions **(sunken stomata),** which are generally close in day and open at night. These plants store a very high amount of water therefore; they are also called **succulent plants.** They have very think cuticle on their surface.

Features of Xerophytes	
Habitat	Terrestrial (severely dry)
Osmotic conditions of medium	Strong hypertonic
Problems faced by plant	Severe dehydration
Rate of transpiration	Very low rate
Stomatal distribution	Sunken stomata

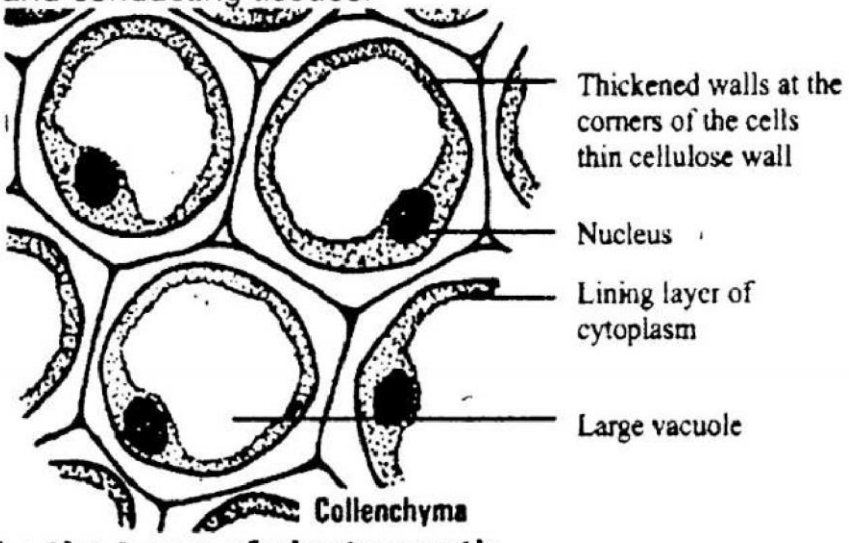
Stomatal opening	Close in day and open at night
Thickness of cuticle	Very thick
Storage of water	Succulent

7. What is the role of turgor mechanism for support in plants?

Ans: Role of turgor mechanism in support:

In plants the **parenchyma** cells have large central vacuoles which are filled with water. The water causes pressure on the surrounding walls, when the cells are turgid. This pressure on the walls keeps the cells, stiff and hard and is called **turgor pressure.**

In herbaceous plants where the specialized supporting tissues are not common, the turgidity of the cells provides support and strength and it grows uprightly. In these cases the plant may wilt or collapse due to a decrease in turgidity (decrease in the internal hydrostatic pressure). Besides the hydrostatic pressure the plants specially shrubs and trees have some supporting tissues, like collenchyma, sclerenchyma, and conducting tissues.



8. Describe the types of plant growth.

Ans: Types of plant growth:

Based upon origin there are two types of plant growth: Primary growth and secondary growth.

Primary growth:

When a plant starts its life after germination of seed, it begins to increase its length first, this increase in length of root and shoot is therefore, called **primary growth.** It remains continue throughout the life of a plant (indeterminate growth) however the rate of grow may vary in different periods of life. Primary growth is carried out by the cell division in **apical meristem.**

Secondary growth:

The increase in thickness and diameter of a plant is called **secondary growth.** This is characteristic of stems and roots of dicots and gymnosperms where it contributes a significant role in support of the plant body. All the tissues that are produced during secondary growth are called **secondary tissues.** Similarly, the tissues that are already present in plant before the onset of secondary growth are called **primary tissues.**

9. Classify plants based upon photoperiodism.

Ans: Classification of plants based upon photoperiodism:

Plants are classified into three main groups on the basis of how photoperiodism affects their flowering.

Short-day plants:

These plants flower when the photoperiod is less than a certain critical length, e.g., Maryland mammoth, cocklebur, chrysanthemum, tobacco etc.

Long-day plants:

These plants flower when the photoperiod exceeds from the critical length e.g., spinach, sugar beet, Henbane snapdragon, cabbage, spring wheat etc.

Day-neutral plants:

These plants can flower in any photoperiod after a considerable vegetative growth. The flowering is not affected by variation in day length or darkness in these plants, e.g., tomato, pansy, bean, sweet pea, rose, etc.

10. What is critical photoperiod?

Ans: Concept of Critical Photoperiods:

The concept of critical lengths of photoperiod for both long day and short day plan, .s different and its duration is also variable for every plant even they belong to the same group.

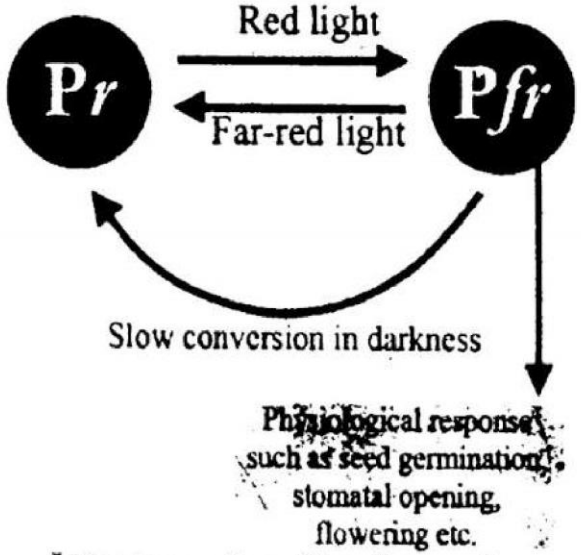
For example, for **tobacco, 14 hours** photoperiod is seemed to be critical and for **cocklebur 15.5 hours** photoperiod is critical, however both are short day plants. Actually, length of critical photoperiod depends upon the level and relative proportion of two forms of phytochromes in plant body. Critical photoperiod for short day plant can be defined as the maximum length of day, which is required to stimulate/induce flowering in a short day plant".

Similarly, "critical photoperiod for long day plant can be defined as the minimum length of day, which is required to stimulate/induce flowering in a long day plant". For example, for henbane 11 hours photoperiod is critical.

11. What are phytochromes?

Ans: phytochromes:

Phytochromes are found in two interconvertible forms. One form of phytochrome, designated as P_R or P_{660} strongly absorbs red light (at 660 nm) and is converted into the second form of phytochrome i.e., P_{FR} or P_{730}. When P_{FR} (P_{730}) absorbs far-red light, it reverts to the original form, PR (P660). Since red light is available in daytime so the conversion of P_R (P_{660}) to P_{FR} (P_{730}) occurs in day. Far-red light are invisible heat radiations that are present in both day and night but the conversion of P_{FR} (P_{730}) to P_R (P_{660}) occurs at night prominently because PR (P_{660}) cannot stay in daytime due to the presence of red light. In this way, the accumulation of either form of phytochrome in day and night enable the plant to determine that weather it is present in day or night. The rate of conversion of P_{FR}



Interconversion of two forms of phytochromes

(P_{730}) to P_R (P_{660}) that occurs at night also provides a biological clock to the plants to determine the length of their night.

12. What is vernalization?

Ans: Vernalization:

The promotion of flowering by exposure to low temperature is known as **vernalization**. The low temperature stimulus is received by the shoot apex of a mature plant or embryo (not by the leaves as in **photoperiodism**). Although the exact **temperature** and amount of time required varies among species, most vernalization temperature occurs between 0°C to 10°C, but temperature around 4°C is found to be most effective. Vernalization is the requirement of **biennial plants** (the plants that complete their life cycle during any months of two different calendar years).

Example:

For example, **winter wheat** is a biennial plant, which is sown in October or November and harvested in June or July of the next year. If it is sown in February or March like **spring wheat** (annual plant), it will show vegetative growth but will not flower. However, it can flower even it is sown in February or March, if its seeds are exposed to several weeks of low temperatures (4°C) stimulus.

In some plants, the requirement of **low temperature** period is absolute, meaning that they will not flower without vernalization. Low temperature stimulates production of **vernalin** hormone that transforms vegetative buds to the floral bud thus flower are produced. It has been now discovered that vernalin is actually **gibberellin.**

13. Why support is needed in terrestrial life?

Ans: When the life started on land from water, one of the very important needs for the organisms was to gain some sort of support and strength for keeping their bodies in shapes. Plants also have variety of mechanism for support.

Such as, turgor mechanism in parenchyma cells, mechanical tissues (thick walled e.g., collenchyma and sclerenchyma), arrangement of vascular bundles and secondary growth.

In plants the **parenchyma** cells have large central vacuoles, which are filled with water.

The water causes pressure on the surrounding walls, when the cells are turgid. This pressure on the walls keeps the cells, stiff and hard and is called **turgor pressure.**

In herbaceous plants where the specialized supporting tissues are not common, the turgidity of the cells provides support and strength and it grows uprightly

In these cases the plant may wilt or collapse due to a decrease in turgidity (decrease in the internal hydrostatic pressure).

Besides the hydrostatic pressure the plants specially shrubs and trees have some supporting tissues, like collenchyma, sclerenchyma, and conducting tissues.

14. Enlist the names of supporting tissue in plants.

Ans:
- **i.** Collenchyma
- **ii.** Sclerenchyma
- **iii.** Conducting tissues

15. What happens to the primary tissue of a stem when secondary growth occurs?

Ans: Lateral meristems are the dividing cells in **secondary growth**, and produce **secondary tissues**. **Secondary** xylem is the actual wood of the plant, and **secondary** phloem provides sugar transport. Lateral meristems are arranged into two cylinders that run through the roots and **stems**: the vascular cambium and the cork cambium.

16. Why does the wood of many tropical trees lack annual rings?

Ans: Rings occur where a tree grows more slowly during the winter (dark rings) vs. rapidly during the summer (light rings). In places where there's not much seasonal change in growing conditions the plant grows steadily all year and from year to year so there are no rings

17. What are the types of movement in plants in response to stimuli?

Ans: The plants as their characteristics do not show locomotion, but the individual plant organs may show movements by change in differential growth in response of various stimuli (internal or external).

Tropic movements or **tropisms** that are either towards or away from certain external stimuli such as light, force of gravity, touch and chemical.

Depending upon the nature of stimuli, these movements are of following types:-

i. Phototropism
ii. Geotropism
iii. Thigmotropism
iv. Chemotropism

18. Define/Describe/Explain briefly:

chlorosis, mesophyll, Mega Pascal, water potential, solute potential, pressure potential, apoplast pathway, symplast pathway, vacuolar pathway, tracheophytes, transpiration, mass flow theory, homeostasis, osmotic adjustment, hydrophytes, mesophytes, xerophytes, heat shock proteins, turgor pressure, meristem, annual growth, apical dominance, auxin, gibberellins, cytokinins, abscisic acid, ethene, phototropism, geotropism, thigmotropism, chemitropism, phytochrome.

Ans: Chlorosis:

Deficiency of nitrogen or magnesium causes yellowing of leaves called **chlorosis**.

OR

Chlorosis is a condition in which leaves produce insufficient chlorophyll. As chlorophyll is responsible for the green color of leaves, **chlorotic** leaves are pale, yellow, or yellow-white

Mesophyll:

Mesophylls are special types of parenchymatous cells (thin walled living cells) which are present between the two epidermal layers of leaves. These cells are modified to carry out photosynthesis.

Mega Pascal:

Potential or pressure is denoted by the Greek letter **Ψ** (psi) and is expressed in units of pressure (pressure is a form of energy) called Mega **Pascal (MPa)**.

Water Potential:

Water potential is a measure of the potential energy in water that enables it to move from one place to another.

Solute Potential:

Solutes reduce water potential (resulting in a more negative Ψ_w) by consuming some of the potential energy available in the water. This measure of decrease in water potential of a medium due to the addition of solutes is called **solute potential.**

Pressure Potential:

If pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. It is equivalent to pumping water from one place to another such a situation may arise in living system When water enters the plant cells by osmosis, pressure may be build up inside the cell making the cell turgid and increasing the water potential. This measure of increase in water potential of a medium due to the addition of water or due to the pressure greater than atmospheric pressure is called **pressure potential.**

Following example would help understand the concept of water potential. Two adjacent vacuolated cells are shown with Ψ_w, Ψ_s, *and* Ψ_p.

Apoplast Pathway:

The **apoplast** is the system of adjacent cell walls, which is continuous throughout the plant. When water moving through spaces in the cell walls reaches the endodermis, its progress is stopped by **casparian strips,** (a band of suberin and lignin bordering four sides of root endodermal cells). Therefore water and solutes particularly salts in the form of ions must pass through the cell surface and into the cytoplasm of the cells of the endodermis. In this way the cells of the endodermis can control and regulate the movement of solutes through the xylem. This is called **apoplast pathway.**

Symplast Pathway:

Movement of cell sap that involves cytoplasmic connection of adjacent cells is termed as **symplast pathway**. The **symplast** is the system of interconnected protoplast in the plant. The **cytoplasm** of neighbouring **protoplast** is linked by the **plasmodesmata.** Once water and any solutes it contains is taken into the cytoplasm of one cell it can move through the symplast without having to cross further membranes. Movement might be aided by cytoplasmic streaming. The symplast is an important pathway of water movement.

Vacuolar Pathway:

In the **vacuolar pathway** water moves from vacuole to vacuole through neighbouring cells, crossing the symplast and apoplast in the process and moving through membranes and tonoplast by osmosis. It moves down a water potential gradient.

Tracheophytes:

Tracheids are dead elongated cells with tapering ends and lignified walls. They have mechanical strength and give support and also involve in conduction of water and minerals. These cells are universally present in xylem tissue of all vascular plants, which are therefore, called **tracheophytes.**

Transpiration:

When stomata are open, the water molecules move from the region of high water potential (intercellular spaces of leave) to a region of low potential (in the air). This evaporation of water is called **transpiration.**

Mass Flow Theory:

The most acceptable theory that explains the mechanism of translocation of organic solutes is the pressure flow or mass flow theory.

According to this theory, the sugars produced in source regions, such as photosynthesizing leaves or storage places are loaded into the phloem's sieve tube elements by the companion cells.

Homeostasis:

Homeostasis is the ability to maintain a steady state within a constantly changing environment that contributes towards the success of living systems. The outer environmental conditions such as water availability, nutrients and temperature often show fluctuations that also affect these components within plant body. Plants have several adaptations to cope with these challenges.

Osmotic Adjustment:

The maintenance of water and solute level in the body is called osmotic adjustment or osmoregulation. Water and solute relations establish three kinds of osmotic situations such as hypotonic, hypertonic and isotonic.

Hydrophytes:

The plants that are found in the area where abundant water is available, are called **hydrophytes.** Aquatic plants of freshwater habitats are example of such plants. These plants are exposed in hypotonic conditions so face problem of flooding (excess **of** water). Such plants show highest rate of transpiration due to broad leaves with large surface area and distribution of stomata on upper epidermis, which are kept open day and night. These plants do not store water and either have very thin cuticle or almost none, on their surface.

Mesophytes:

The plants that are found in the area where moderate supply of water is available are called **mesophytes.** Common crop plants such as wheat, rice corn are example of such plants. These plants are exposed in nearly isotonic conditions so face no drastic problem of flooding (excess of water) or dehydration (deficiency of water). Such plants show moderate rate of transpiration due to medium sized leaves with distribution of stomata on lower epidermis. which are generally open in day and close at night However, these plants can close their stomata even in day These plants store a very small amount of water, have very thin cuticle on their surface.

Xerophytes:

The plants that are found in the area where very little amount of water is available are called **xerophytes.** Desert plants such as cactus, opuntia are example of such plants. These plants are exposed to severely hypertonic conditions so face extreme degree of dehydration.

Such plants show reduced rate of transpiration due to narrow needle like leaves or due to complete modification of leaves into spines. They have stomata in depressions **(sunken stomata),** which are generally close in day and open at night. These plants store a very high amount of water therefore they are also called **succulent plants.** They have very think cuticle on their surface.

Heat Shock Proteins:

Most plants have adapted to survive in such high temperature stress situations by synthesizing large quantities of special proteins called **heat shock proteins.**

Turgor Pressure:

In plants the **parenchyma** cells have large central vacuoles, which are filled with water The water causes pressure on the surrounding walls, when the cells are turgid. This pressure on the walls keeps the cells, stiff and hard and is called **turgor pressure.**

Meristem:

In lower plants, the entire plant body is capable of growing, but in higher plants, growth is limited to certain regions known as growing points that possess specialized tissues for growth, the **meristematic tissues** or **meristems.**

Annual Growth:

In autumn and winter seasons, comparatively smaller sized cells are produced due to deficiency of water while in spring and summer seasons, larger sized cells are produced probably due to availability of water. Because of this differential growth pattern distinct rings of smaller and larger cells are formed, which represent the growth of one whole year, therefore these rings are called **growth rings** or **annual rings.** We can determine the age of plant by counting the number of these growth ring as each ring is form in one year.

Apical Dominance:

Apical dominance is a kind of negative growth correlation in which the presence of a growing apical bud inhibits growth of lateral buds It is also found in roots where lateral root growth is inhibited by growth of the main root. The plants showing tall height with short side branches have very strong apical dominance and the plants showing short height and very dense growth of lateral branches have very little apical dominance.

Auxin:

An auxin or **indole-3-acetic acid** (IAA), was the first plant hormone identified. It is manufactured primarily in the shoot tips (in leaf primordia and young leaves), in embryos, and in parts of developing flowers and seeds. They are mainly responsible for cell elongation.

Gibberellins:

The gibberellins are widespread throughout the plant kingdom, and more than 75 have been isolated, to date. Rather than giving each a specific name the compounds are numbered, for example GA1, GA2, and so on **Gibberellic acid 3 (GA3)** is the most widespread and most thoroughly studied. The gibberellins are especially abundant in seeds and young shoots where they control stem elongation by stimulating both cell division and elongation.

Cytokinins:

These are named because of their role in cell division (cytokinesis), the cytokinins have a molecular structure similar to adenine. Naturally occurring **zeatin,** isolated first from corn *(Zea mays)*, is the most active of the cytokinins. Cytokinins are found in sites of active cell division in plants, for example, in root tips, seeds, fruits, and leaves

Abscisic Acid:

Abscisic acid (ABA) is synthesized in plastids from carotenoids during stress situations and diffuses in all directions through vascular tissues and parenchyma. Its principal effect is inhibition of cell growth. ABA increases in developing seeds and promotes dormancy. If leaves experience water stress ABA amounts increase immediately, causing the stomata to close.

Ethane:

Ethylene or ethene is a simple gaseous hydrocarbon produced from an amino acid and appears in most plant tissues in large amounts when they are stressed. It diffuses from its site of origin into the air and affects surrounding plants as well. Ethylene stimulates the ripening of fruit and initiates abscission of fruits and leaves.

Phototropism:

Phototropism is the movement of plants parts, either towards (positive) or away (negative) from light source. Such movements are found in shoots and roots. Shoots show positive phototropism (grow upward above the ground) and roots show negative geotropism (grow downward under the ground).

Geotropism:

Geotropism (gravitropism) is the movement of plants parts, either towards (positive) or away (negative) from force of gravity. Such movements are also found in shoots and roots. Shoots show negative geotropism (grow upward above the ground) and roots show positive geotropism (grow downward under the ground).

Thigmotropism:

Thigmotropism is the movement due to the touch stimulus. Such movements are shown by climbing plants that require any supportive structure such as a wall, a wooden stick or rod or even a rope to climb over.

Chemotropism:

In chemotropism the stimulus is a chemical (nutrients). Such movement is shown by fungal mycelium in which hyphae show more growth towards the nutrients.

Phytochrome:

Phytochromes are found in two interconvertible forms. One form of phytochrome, designated as P_R or P_{660} strongly absorbs red light (at 660 nm) and is converted into the second form of phytochrome i.e., P_{FR} or P_{730}. When P_{FR} (P_{730}) absorbs far-red light, it reverts to the original form, PR (P660). Since red light is available in daytime so the conversion of P_R (P_{660}) to P_{FR} (P_{730}) occurs in day. Far-red light are invisible heat radiations that are present in both day and night but the conversion of P_{FR} (P_{730}) to P_R (P_{660}) occurs at night prominently because PR (P_{660}) cannot stay in daytime due to the presence of red light. In this way, the accumulation of either form of phytochrome in day and night enable the plant to determine that weather it is present in day or night. The rate of conversion of P_{FR} (P_{730}) to P_R (P_{660}) that occurs at night also provides a biological clock to the plants to determine the length of their night.

19. Write the differences between:

(a) apoplast pathway and symplast pathway

(b) cohesion and adhesion

(c) endosmosis and exosmosis

(d) **hypotonic and hypertonic solution**
(e) **mesophytes and xerophytes**
(f) **collenchyma and sclerenchyma**
(g) **fibres and sclereids**
(h) **primary meristem and lateral meristem**
(i) **primary growth and secondary growth**
(j) **wood and bark**
(k) **phototropism and geotropism**
(l) **phototropism and photoperiodism**
(m) **red light and far red light**

Ans: (a) apoplast pathway and symplast pathway:

Apoplast pathway:

The **apoplast** is the system of adjacent cell walls, which is continuous throughout the plant. When water moving through spaces in the cell walls reaches the endodermis its progress is stopped by **casparian strips,** (a band of suberin and lignin bordering four sides of root endodermal cells). Therefore water and solutes particularly salts in the form of ions must pass through the cell surface and into the cytoplasm of the cells of the endodermis. In this way the cells of the endodermis can control and regulate the movement of solutes through the xylem. This is called **apoplast pathway.**

Symplast pathway:

Movement of cell sap that involves cytoplasmic connection of adjacent cells is termed as **symplast pathway.** The **symplast** is the system of interconnected protoplast in the plant. The **cytoplasm** of neighbouring **protoplast** is linked by the **plasmodesmata.** Once water and any solutes it contains is taken into the cytoplasm of one cell it can move through the symplast without having to cross further membranes. Movement might be aided by cytoplasmic streaming. The symplast is an important pathway of water movement.

OR (Second Answer)

Apoplast pathway	Symplast pathway
Definition:	
Apoplast refers to the nonprotoplasmic components of a plant, including the cell walls and the intracellular spaces.	Symplast refers to the continuous network of protoplasts of a plant, which are interconnected by plasmodesmata.
Components:	
The apoplast consists of nonprotoplasmic components such as cell walls and intracellular spaces.	The symplast consists of protoplast.
Living/Non-living:	
The apoplast is composed of nonliving parts of a plant.	The symplast is composed of living parts of a plant.
Water Movement:	
The water movement occurs by passive diffusion.	The water movement occurs by osmosis.

Resistance to Water Movement:	
The apoplast shows less resistance to the water movement	The symplast shows some resistance to the water movement
Speed of the Water Movement:	
Water movement through the apoplast is rapid	Water movement through the symplast is slower
Metabolic State of Roots:	
The metabolic rate of the cells in the root cortex does not affect the movement of water through the apoplastic route.	The metabolic state of the cells in the root cortex highly affect the water movement by the symplastic route.
Significance:	
With the secondary growth of the root, most of the water moves by the apoplastic route	Beyond the cortex, water moves through the symplastic route.

Conclusion:

Apoplast and symplast are two routes used by plants to transport water from root hair cells to the xylem of the root. Apoplast includes the non-living components of a plant such as cell walls and the intracellular spaces. Symplast includes the living components of a plant such as protoplasms. The water moves by the apoplastic pathway by passive diffusion. In contrast, in the symplastic pathway, water moves by the osmosis since water moves across the cell membranes. The main difference between apoplast and symplast is their mechanism of the water movement.

OR (Second Answer)

Basis of Distinction	Apoplast Transport	Symplast Transport
Definition	The uptake of water that takes place between the non-living parts of the plant.	The absorption of water that takes place between the non-living parts of the plant.
Transport	Water reaches the endodermis through the process of apoplast.	Water moves out with the help of symplast transport.
Process	Takes place at faster speeds as the non-living parts do not have much happening within them.	Takes place at slower speeds at they do face some other entities during the process.
Problems	Does not face any resistance.	Faces little or more resistance.
Flow	The metabolic state of root does not directly affects the pathway.	Roots are metabolically connected directly and has some effect on the passage of water flow.

(b) cohesion and adhesion:

Cohesion	Adhesion
Water is a polar molecule, with the oxygen carrying a slight negative charge while the hydrogen carries a slight positive charge. As a result, nearby water molecules attract one another forming weak hydrogen bonds. This attraction among water molecules is called **cohesion** and the hydrogen bonds formed between them are termed as **tension.**	**Adhesion** is the attractive force between water molecules and other substances. Because both water and cellulose are polar molecules so there is a strong attraction for water within the hollow capillaries of the xylem. Adhesion of the string of water molecule to the wall of the xylem cells assists upward movement of the xylem sap counteracting the downward gravity. Adhesion also helps hold water in the xylem when transpiration is not occurring.

OR (Second Answer)

Cohesion is the attraction among the water molecules which enables the water molecules to stick together.

Water flows freely due to cohesion. Water molecules also have attraction to polar surfaces. This attraction is called **adhesion**. Both cohesion and adhesion are due to hydrogen bonds among water molecules. These properties of water enable it to circulate in living bodies and to act as transport medium.

OR (Second Answer)

Cohesion	Adhesion
Definition:	
Cohesion is the attraction force between molecules of the same substance	Adhesion is the attraction force between different molecules.
Type of Attraction:	
Cohesion is an intermolecular attraction	Adhesion is an intramolecular attraction
Attraction Forces:	
Cohesion includes Van Der Waal forces and hydrogen bonding.	Adhesion includes electrostatic attractions.
Examples:	
Cohesion is the cause for the formation of water droplets on the surface tension of a liquid	Adhesion is the cause for the spreading of a liquid on a solid surface.
Conclusion: Adhesion and cohesion are two types of attraction forces that occur between molecules. These forces act on a substance at the same time. Therefore the effects that arise from these forces are caused by both adhesion and cohesion. The main difference between cohesion and adhesion is that cohesion is the attraction force between molecules of the same substance whereas adhesion is the attraction force between molecules of different substances.	

(c) endosmosis and exosmosis:

Different osmotic conditions cause different effects upon net movement of water in and out of the cells. If a cell is kept in a medium which has higher water potential and lower solute concentration than cell sap, the water begin to move from medium to the cell **(endosmosis)** and cell become turgid. Such medium is called **hypotonic medium.** On the other hand, if a cell is kept in a medium which has lower water potential and higher solute concentration than cell sap, the water begin to move from cell to the medium **(exosmosis)** and cell become flaccid. Such medium is called **hypertonic medium.** Both hypotonic and hypertonic type of osmotic conditions compel for osmotic adjustment. The ideal situation for a cell is **isotonic** in which water potential of both cell and outer environment is equal, therefore, there is no net movement of water in and out of the cell. However, this situation is rarely available to the plants in natural environment.

OR (Second Answer)

Endosmosis	Exosmosis
Endosmosis refers to the osmosis toward the inside of a cell or vessel.	Exosmosis refers to the osmosis toward the outside of a cell or vessel.
Water moves into the cell.	Water moves out of the cell.
Occurs when cells are placed in hypotonic solutions	Occurs when cells are placed in hypertonic solutions.
Occurs when the solute concentration of the surroundings is less than the solute concentration inside the cell.	Occurs when the solute concentration of the surroundings is higher than the solute concentration inside the cell.
Water potential of the surroundings is higher than that of the cytosol.	Water potential of the surroundings is less than that of the cytosol.
Cells may swell.	Cells may shrink.
Example: Absorption of capillary water from the soil by roots and the entrance of water into the xylem vessels.	Example: Movement of water from the root hair cells to the cortical cells of the root.

OR (Second Answer)

Endosmosis	Exosmosis
Definition:	
Endosmosis refers to the osmosis toward the inside of a cell or vessel.	Exosmosis refers to the osmosis toward the outside of a cell or vessel.
Water Movement:	
Water moves into the cell during endosmosis.	Water moves out of the cell during exosmosis.
Type of Solutions:	
Endosmosis occurs when cells are placed in hypotonic solutions.	Exosmosis occurs when cells are placed in hypertonic solutions.
Solute Concentration in the Surroundings:	
Endosmosis occurs when the solute concentration of the surroundings is less than the solute concentration inside the cell.	Exosmosis occurs when the solute concentration of the surroundings is higher than the solute concentration inside the cell.

Water Potential:	
The water potential of the surroundings is higher than that of the cytosol in endosmosis.	The water potential of the surroundings is less than that of the cytosol in exosmosis.
Result:	
The cells may swell as a result of endosmosis.	The cells shrink as a result of exosmosis.
Examples:	
The absorption of capillary water from the soil by roots and the entrance of water into the xylem vessels are the examples of endosmosis in plants.	The movement of water from the root hair cells to the cortical cells of the root is an example of exosmosis.
Conclusion: Endosmosis and exosmosis are the two types of osmosis in which the movement of water occurs across the cell membrane. Endosmosis is the movement of water into the cell when the cells are placed in a hypotonic solution. Exosmosis is the movement of water out of the cell when the cells are placed in a hypotonic solution The main difference between endosmosis and exosmosis is the direction of the movement of water in each of the process.	

(d) hypotonic and hypertonic solution:

Hypotonic solution	**Hypertonic solution**
Definition:	
Hypotonic solutions are solutions having lower osmotic pressures.	Hypertonic solutions are solutions having comparatively higher osmotic pressures.
Solute Concentration:	
Hypotonic solutions have a low concentration.	Hypertonic solutions have a high concentration.
Effect on Cells:	
Hypotonic environments cause cells to swell.	Hypertonic environments cause cells to shrink.
Food Preservation:	
Hypotonic solutions are not helpful in food preservation.	Hypertonic solutions are helpful in food preservation since they kill microbes in the food package.

Conclusion:
Tonicity is the relative concentration of solutes dissolved in a solution which determines the direction and extent of the movement of molecules across a semipermeable membrane. There are three types of solutions based on the tonicity; isotonic solutions, hypertonic solutions and hypotonic solutions. The main difference between isotonic hypotonic and hypertonic solutions is that isotonic solutions are solutions having equal osmotic pressures while hypotonic solutions are solutions having a lower osmotic pressure and hypertonic solutions are solutions with a high osmotic pressure.

OR (Second Answer)

Difference between Hypotonic and Hypertonic Solutions:

- The solution (water) concentration is high in hypotonic solutions while the solution concentration is low in hypertonic solutions.
- Solute concentration of hypertonic solution is high while that of hypotonic solution is low.
- Water molecules move into the cell when the cell is bathed in a hypotonic solution. In contrast, water molecules leave the cell (water inside the cell itself) when it is bathed in a hypertonic solution.
- When a cell with a cytoplasm is immersed in a hypotonic solution, endosmosis takes place. On the other hand, a cell immersed in a hypertonic solution, exosmosis takes place.
- Hypertonic solution causes the cell to shrink while hypotonic solution causes the cell to swell
- Cytolysis may occur in cells due to hypotonic solutions whereas plasmolysis may occur in plant cells due to hypertonic solutions.
- For dehydration, hypotonic solutions can be used while hypertonic solutions can be used for hemorrhage.

(e) mesophytes and xerophytes

Comparison of osmotic adjustment in different groups of plant:

Features	Mesophytes	Xerophytes
Habitat	Terrestrial (moderate)	Terrestrial (severely dry)
Osmotic conditions of medium	Nearly isotonic	Strong hypertonic
Problems faced by plant	No drastic problem	Severe dehydration
Rate of transpiration	Medium rate	Very low rate
Stomatal distribution	On lower epidermis	Sunken stomata
Stomatal opening	Open in day and close at night	Close in day and open at night
Thickness of cuticle	Less thick	Very thick
Storage of water	Little storage	Succulent

(f) collenchyma and sclerenchyma:

Role of mechanical tissues in support:

The term mechanical tissues is used for the tissues of thick walled cells i.e., collenchyma and sclerenchyma.

The **collenchyma** is characterized by the extra cellulose deposition at the corners of these cells. It is a mechanical tissue, providing support particularly in young plants, herbs and leaves etc., (where secondary growth does not occur) collenchyma is living so it can grow and stretch freely. In stems and petioles it plays more important role in support because of its location in peripheral regions near epidermis.

Sclerenchyma:

Sclerenchyma tissues are solely means for giving support and mechanical strength for the plants. The mature cells are dead due to the formation of very thick secondary lignified wall (lignin is a macromolecule that provide rigidness to the wall).

OR (Second Answer)

Collenchyma	Sclerenchyma
1. It is simple permanent tissue consisting of living cells	**1.** It is also simple permanent tissue but consisting of dead cells.
2. In T S. the cells are polygonal with localized thickening on their walls confined to the corners only Cells contains protoplasm when young	**2.** In T.S. the cells are also polygonal with uniform thickening. Cell walls are very much thickened due to deposition of lignin leaving a narrow lumen.
3. In L.S. the cells are elongated with longitudinal strips of thickening	**3.** In L.S. the cells are long, narrow and pointed.
4. It is elastic and also strong enough to provide mechanical support	**4.** It is rigid and provides mechanical support to plant.

OR (Second Answer)

Difference between Collenchyma & Sclerenchyma:

Collenchyma	Sclerenchyma
1. Living cells contain cytoplasm	Dead cells are empty.
2. Cell walls are cellulosic	Cell walls are lignified.
3. Lumen of the cell is wide	Lumen of the cell is narrow
4. The thickening of the cell wall is not uniform.	Thickening of cell wall is uniform
5. It provides mechanical support & elasticity to the plant body.	It is chiefly a mechanical tissue.

OR (Second Answer)

Difference Between Collenchyma and Sclerenchyma

Collenchyma	Sclerenchyma
Found in:	
Collenchyma cells are found in petiole, leaves and young stems, appearing as a continuous ring beneath the epidermis.	Sclerenchyma is found in the mature parts of the plant like herbaceous perennials and woody plants.
Specialized/Unspecialized:	
Collenchyma cells are specialized cells	Sclerenchyma cells are specialized cells

Cell Wall Thickness:	
Collenchyma consists of an unequally thin cell wall.	Sclerenchyma consists of a thick and rigid cell wall.
Cell Wall Constituents:	
Collenchyma cell wall is made up of cellulose and pectin.	Sclerenchyma cell wall is made up of waterproofing lignin.
Intercellular Space:	
No or little intercellular space is present between collenchyma cells.	No intercellular space is present between sclerenchyma cells.
Shape:	
Collenchyma cells are polygonal in shape.	Sclerenchyma cells are tubular in shape.
Type:	
Collenchyma produces permanent tissues, which can achieve meristematic activity when stimulated.	Sclerenchyma also produces permanent tissues, eliminating the ability of dividing
Alive/Dead at Maturity:	
Collenchyma consists of living cells at maturity.	Sclerenchyma consists of dead cells at maturity. Hence, their protoplast is absent.
Function:	
Providing mechanical support to the plant, resisting bending and stretching by the wind are the major functions of collenchyma.	Providing mechanical support, protection and transportation of water and nutrients are the major functions of sclerenchyma

OR (Second Answer)

Collenchyma	Sclerenchyma
1. It is made up of living cells.	**1.** Sclerenchyma cells are generally dead.
2. The cells are filled up with protoplasm.	**2.** The cells are empty.
3. Wall thickening is not uniform.	**3.** Wall thickening is uniform.
4. Wall thickening consists of cellulose.	**4.** Wall thickening can be of cellulose lignin or both.
5. Lumen or cell cavity is wide.	**5.** Lumen or cell cavity is usually narrow.
6. Pits are simple and straight.	**6.** Pits are usually simple and oblique. They may be branched.
7. Collenchyma provides mechanical strength as well as elasticity.	**7.** It is only a mechanical tissue.
8. It allows plant organs to stretch and elongate	**8.** Sclerenchyma occurs in areas which have stopped elongation.
9. It keeps the organ soft.	**9.** It provides hardness to the region where it occurs.

10. Collenchyma has a high refractive index.	**10.** Refractive index is comparatively low
11. Being living the cells can store food and take part in photosynthesis.	**11.** Sclerenchyma has no such function.

(g) fibres and sclereids:

The sclerenchyma is of two types, i.e., fibres and sclereids. Fibres are elongated cells and sclereids are roughly spherical or variously shaped cells otherwise both have heavily thickened walls with lignin and with great tensile strength. **Fibres** are found in the pericycle of stems forming a solid rod of tissue. Fibres also found in xylem and phloem tissues. **Sclereids** are common in fruit wall and seed coats.

OR (Second Answer)

Difference Between Fibres and Sclereids:

Fibres	Sclereids
Sclerenchyma fibres are elongated cells which have long tapered ends and are present in most parts of the plant	Sclerenchyma Sclereids are cells which have a varying shape and are distributed in the cortex, pith, xylem, and phloem of the plants.
Cell Origin:	
Origin of the fibres is meristematic.	Sclereids origin from mature parenchymal cells.
Shape:	
Fibres are elongated.	Sclereids are broad and in varied shapes.
Cell Endings:	
Fibres have tapering ends.	Sclereids have blunt ends.

OR (Second Answer)

Fibre	Sclereid
1. It is elongated and narrow like a thread.	**1.** It is usually broad.
2. End walls are tapering.	**2.** End walls are blunt in un-branched sciereids.
3. Fibres generally occur in bundles.	**3.** Sciereids occur singly or in loose groups.
4. Usually un-branched.	**4.** May be branched.
5. Pits narrow and un-branched.	**5.** Pits deep and commonly branched.
6. Pits are oblique.	**6.** Pits are straight.
7. Fibres are formed directly from derivatives of meristematic cells.	**7.** Sciereids arise by secondary thickening of parenchyma cells.
8. Fibres provide mechanical strength.	**8.** Sciereids provide stiffness only.

(h) primary meristem and lateral meristem:

Primary Meristems:

These are located at opposite ends of the plant axis in the tips of roots and shoots. Cell divisions and subsequent cellular enlargement in these areas lengthen the above and below ground parts of the plant. Since, these meristem are present in plants right from embryonic life, therefore, they are also known as **primary meristems.**

Secondary Meristem:

Lateral meristems are cylinders of dividing cells on lateral sides in stems and roots of dicots and gymnosperms and increase their thickness and diameter. These meristems are derived from apical meristem after embryonic life therefore, they are also called **secondary meristem.** Vascular cambium, cork cambium, and intercalary meristem are the types of lateral meristems. Some plants grow in diameter by producing new tissues laterally from a cylinder of tissue called the **vascular cambium,** which extends throughout the length of the plant from the tips of the shoots to the tips of the roots. **Cork cambium** also called **phellogen,** are found in the bark of roots and stems of woody plants where they contribute in width of plant body.

OR (Second Answer)

Primary Meristems	Secondary Meristems
1. It is present from the beginning.	**1.** Secondary meristem is formed later in the life.
2. It develops from another meristem.	**2.** Secondary meristem develops from the permanent cells due to dedifferentiation.
3. The cells are usually isodiametric (exception intra-fascicular cambium).	**3.** The cells are commonly elongated.
4. Central vacuoles are absent (exception intra-fascicular cambium).	**4.** The cells possess central vacuoles.
5. It usually gives rise to primary tissues (exception intra-fascicular cambium) that constitute primary growth.	**5.** Secondary meristem gives rise to secondary or supplementary tissues that constitute secondary growth. Secondary tissues either supplement or replace the primary tissues.
6. It usually produces growth in length (exception intra-fascicular cambium).	**6.** Secondary meristem produces growth in thickness.

OR (Second Answer)

Apical (Primary Meristems)	Lateral (Secondary Meristems)
Definition:	
A plant tissue with undifferentiated cells found at the tip of a shoot or root and is responsible for the primary growth.	A plant tissue with undifferentiated cells that is found along the length of stems and roots and is responsible for the secondary growth.

Location:	
Apical meristems are positioned at the apices of stems, roots, and their lateral branches	Lateral meristems are found along the entire length of stem and root except at apices.
Growth Type:	
Primary growth takes place at apical meristems	Secondary growth takes place at lateral meristems.
Growth:	
Apical meristem increases the length of a plant along its vertical axis.	Lateral meristem increases the girth of a plant
Content:	
Apical meristem gives rise to lead primordia and bud primordia unlike lateral meristem.	Lateral meristems consist of the vascular cambium and cork cambium unlike the apical meristem.
Tissue Types:	
Apical meristem gives rise to primary permanent tissues including epidermis xylem, phloem, and ground tissues	Lateral meristem gives rise to wood, inner bark and outer bark.

(i) primary growth and secondary growth:

Types of plant growth:

Based upon origin there are two types of plant growth: Primary growth and secondary growth

Primary growth:

When a plant starts its life after germination of seed, it begins to increase its length first, this increase in length of root and shoot is therefore, called **primary growth**. It remains continue throughout the life of a plant (indeterminate growth) however the rate of grow may vary in different periods of life. Primary growth is carried out by the cell division in **apical meristem.**

Secondary growth:

The increase in thickness and diameter of a plant is called **secondary growth.** This is characteristic of stems and roots of dicots and gymnosperms where it contributes a significant role in support of the plant body. All the tissues that are produced during secondary growth are called **secondary tissues.** Similarly, the tissues that are already present in plant before the onset of secondary growth are called **primary tissues.**

OR (Second Answer)

Primary growth	Secondary growth
1. It takes place by the activities of primary meristematic tissues such as apical cell, apical meristems, etc.	**1.** It takes place by the activities of secondary meristematic tissues and some times by the joint activity of both primary and secondary meristematic tissues.

2. It results in growth in longitudinal axis mainly.	**2.** It results in radial growth.
3. It is the first growth of the plant and its parts.	**3.** It is a later period of growth
4. It is for a short period and stops after complete tissue differentiation occurs in a part of the plant.	**4.** It continues only in matured part and occurs after the part of organ has completely developed.
5. It occurs in all plants and in all parts	**5.** It occurs in gymnosperms and angiosperms (except monocots).
6. Periderm and barks are not formed	**6.** It results in the formation of bark, periderm, lenticel, etc.
7. Tissue formed by this growth are various types and called primary tissues.	**7.** Tissues formed due to this growth are mainly secondary xylem and secondary phloem and are called secondary tissues.

OR (Second Answer)

Difference between Primary and Secondary Growth:

Primary Growth	Secondary Growth
Definition:	
Primary growth is the growth that occurs by the action of the primary meristem, which increases the length of the stem and adds appendages to the stem.	Secondary growth is the growth that occurs by the action of the cambium, which increases the diameter of the plant.
Occur by:	
The primary growth occurs by the action of the apical meristem.	The secondary growth occurs by the action of the lateral meristem.
Growth:	
The primary growth results in the growth in the longitudinal axis.	The secondary growth results in the radial growth.
Order:	
The primary growth of the plant occurs at the beginning.	The secondary growth follows the primary growth.
Duration:	
The primary growth stops after completion of the tissue differentiation.	The secondary growth only occurs in the mature parts (parts that are completely developed)
Location:	
The primary growth occurs in all parts of all plants.	The secondary growth occurs in both angiosperms and gymnosperms (except monocots).

Development:	
The epidermis cortex and the primary vascular tissues are developed during the primary growth.	The bark, periderm, lenticels, secondary phloem, and secondary xylem are developed during the secondary growth.

(j) wood and bark:

Wood:

During secondary growth, the bulk of tissues added laterally (inner to the vascular cambium) is mainly secondary xylem and is called **wood.**

(a) Heart Wood:

The inner region of wood (some secondary xylem, primary xylem and central most tissue, the pith) is blocked by the deposition of wastes in later life and therefore gives a dark appearance. It is called **heart wood.**

(b) Sap Wood:

However, the outer region of wood (consist of only secondary xylem) remain functional and therefore gives a light appearance. It is called **sap wood.**

Bark:

The outer region of stem from vascular cambium to epidermis is called **bark.**

(a) Inner Bark:

The portion of bark inner to the cork cambium is called **inner bark** (secondary phloem, primary phloem, pericycle, endodermis, primary cortex and secondary cortex)

(b) Outer Bark:

The portion of bark outer to the cork cambium is called **outer bark** (cork and epidermis).

(k) phototropism and geotropism:

Phototropism	Geotropism
Phototropism is the movement of plants parts, either towards (positive) or away (negative) from light source. Such movements are found in shoots and roots. Shoots show positive phototropism (grow upward above the ground) and roots show negative geotropism (grow downward under the ground).	**Geotropism (gravitropism)** is the movement of plants parts, either towards (positive) or away (negative) from force of gravity. Such movements are also found in shoots and roots. Shoots show negative geotropism (grow upward above the ground) and roots show positive geotropism (grow downward under the ground).

(l) phototropism and photoperiodism:

Photoperiodism	Phototropism
Photoperiodism is the regulation of plant development in response to the length of day or night.	Phototropism is the growth response of a plant according to the direction of the light.
Site of Reaction	
The stimulus of photoperiodism is the length of the day or night.	The direction of light is the stimulus of phototropism

Hormones	
Flowering is induced by cytokinin and GA in photoperiodism.	Phototropism is regulated by auxin

(m) red light and far red light:

Phytochromes are found in two interconvertible forms. One form of phytochrome, designated as P_R or P_{660} strongly absorbs red light (at 660 nm) and is converted into the second form of phytochrome i.e., P_{FR} or P_{730}. When P_{FR} (P_{730}) absorbs far-red light, it reverts to the original form, PR (P660). Since red light is available in daytime so the conversion of P_R (P_{660}) to P_{FR} (P_{730}) occurs in day. Far-red light are invisible heat radiations that are present in both day and night but the conversion of P_{FR} (P_{730}) to P_R (P_{660}) occurs at night prominently because PR (P_{660}) cannot stay in daytime due to the presence of red light. In this way, the accumulation of either form of phytochrome in day and night enable the plant to determine that weather it is present in day or night. The rate of conversion of P_{FR} (P_{730}) to P_R (P_{660}) that occurs at night also provides a biological clock to the plants to determine the length of their night.

OR (Second Answer)

Difference between PR form and PFR form:

PR form:

1. It is an inactive form is phytochrome.
2. Being inactive, it does not show phytochrome mediated responses.
3. It has an absorption maximum in red region (about 680 nm)
4. It is found diffused throughout the cytosol.
5. It is converted into P_{FR} form in presence of red light (660-665 nm).
6. When the extract is centrifuged at 20000 x g, it remains present in the supernatant.
7. It shows activity in presence of urea, metal ions Cu^{2+}, C^{2+}, Zn^{2+} etc., and N-ethyl maieimide.
8. Its original structure contains many double bonds in pyrrole rings.

PFR form:

1. It is an active form is phylochrome.
2. Being active, it shows phytochrome mediated responses.
3. It has an absorption maximum in far red region (about 730 nm)
4. It is usually found in discrete areas of cytosol.
5. It converted into P_R form in presence of far red light (730-735 nm)
6. On centrifugation P_{FR} form settles down in the form of pillets
7. It shows comparatively more activity in presence of these chemicals
8. The P_{FR} form shows rearrangement of double bonds in all four pyrrole rings.

EXTENSIVE QUESTIONS

20. Write the role of each macro and micronutrients of plants in a tabular from.

Ans: Mineral nutrition in plants:

Macronutrients	Major Functions
Carbon, Hydrogen, Oxygen	Component of carbohydrates, lipids, protein and nucleic acid molecules.
Nitrogen	Component of proteins, nucleic acids, chlorophyll and enzymes
Phosphorus	Component of nucleic acids, phospholipids, ATP and NADP
Calcium	Component of cell wall, involved in membrane permeability, enzyme activator
Magnesium	Component of chlorophyll, acts as enzyme activator.
Sulphur	Component of certain amino acids and vitamins.
Potassium	Osmosis and ionic balance opening and closing of stomata, enzyme activator
Micronutrients	**Major Functions**
Chlorine	Activator of enzymes involved in photosynthesis
Iron	Activator of enzymes components of cytochromes feridoxin, plastoquinone, assists in the manufacture of chlorophyll and other biochemical processes.
Manganese	Activator of enzymes, needed for chlorophyll production
Copper	Activator of enzymes, component of plastocyanin, helps plants to metabolize nitrogen
Zinc	Activator of enzymes used in development of enzymes and hormones. It is used by the leaves and needed by legumes to form seeds.
Molybdenum	Activator of enzymes, helps plants to use nitrogen.
Boron	Activator of enzymes, helps in cell development and helps to regulate plant metabolism.

21. What is the role played by the palisade and spongy mesophyll in exchange of gases in plants?

Ans: Role of Palisade and Spongy Mesophyll in Exchange of Gases:

Mesophylls are special types of parenchymatous cells (thin walled living cells) which are present between the two epidermal layers of leaves. These cells are modified to carry out photosynthesis

Types of mesophyll in dicot and monocot leaves:

In dicots, there are two distinct layers of mesophyll, the **palisade mesophyll** and the **spongy mesophyll.** The palisade mesophyll are elongated and compactly packed cells with no intercellular spaces between them

Upper Epidermis:

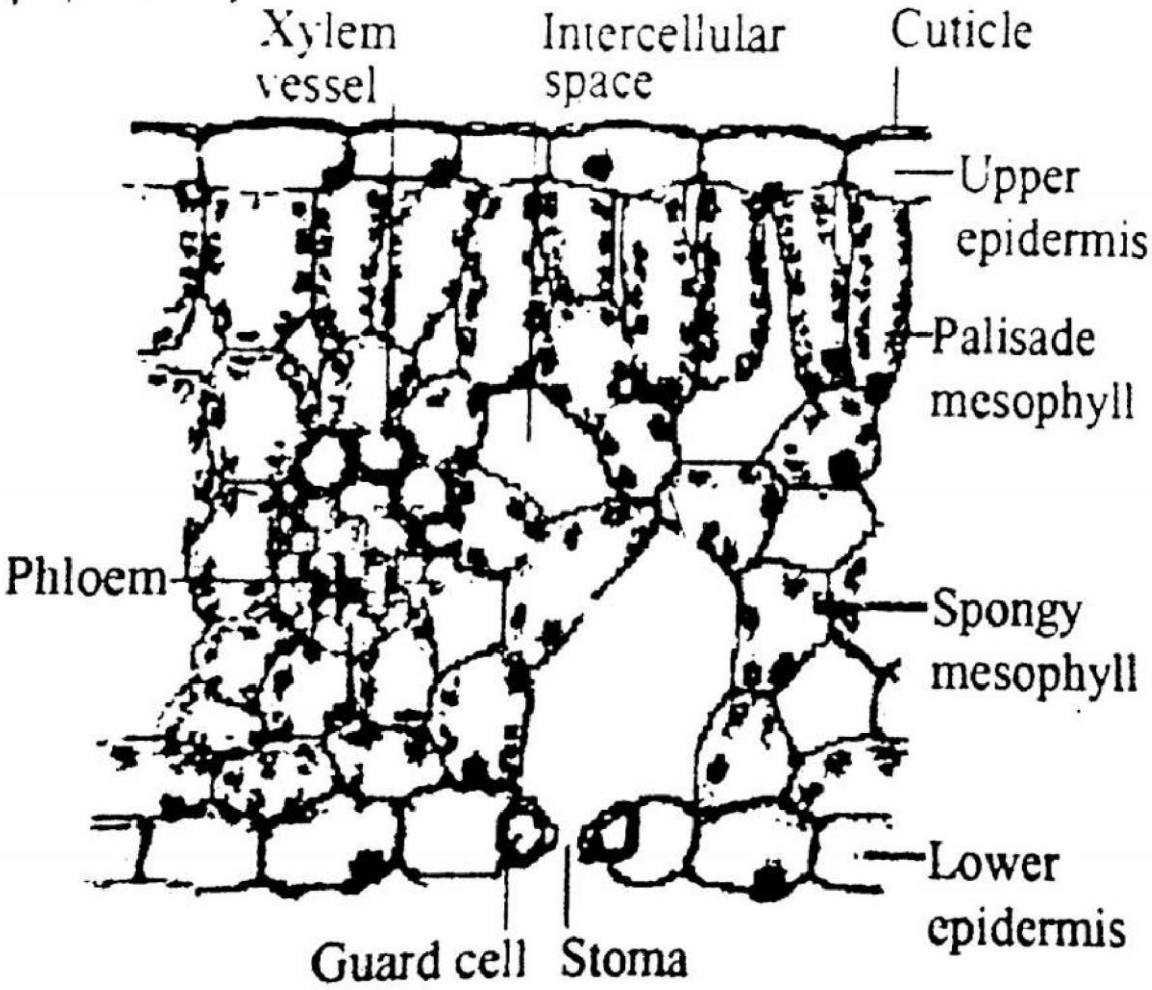
The epidermis beside palisade mesophyll is called **upper epidermis.**

Lower Epidermis:

On the other hand spongy mesophyll are loosely packed cell with large intercellular spaces. The epidermis beside spongy mesophyll is called **lower epidermis.**

Bifacial or Dorsiventral Leaves:

Such leaves, in which upper and lower epidermises can be differentiated because of the presence of two types of mesophyll cells, are called **bifacial** or **dorsiventral leaves.** In monocots, the leaves are **monofacial** or **isobilateral** as only spongy mesophyll cells are present between both epidermises. The mesophyll cells are metabolically active cells of the plant therefore; they are rapidly involved in exchange of gases. The passage for this exchange of gases through mesophyll tissue is provided by the stomata.



T.S of Bifacial leaf

Relationship of Stomata and Transpiration with Exchange of Gases:

Stomata:

Stomata are small biconvex shaped openings present in leaf epidermis. A stomatal aperture or stoma (singular) is formed by two, kidney or bean shaped guard cells, which are specialized epidermal cells of leaf. In bifacial leaves, more stomata are distributed in lower epidermis as intercellular spaces are present along this epidermis. Whereas, isobilateral leaves have equal number of stomata in both epidermises.

Transpiration:

The **transpiration** is the loss of water in the form of vapours through aerial (above the ground) parts of the plants mainly through the stomata. It is not only responsible for transportation of water and minerals but also plays a vital role in the exchange of gases. During day light, the stomata are widely open and provide a wide passage for the exchange of gases

22. Describe the exchange of gases between plants and environment.

Ans: Pattern of Exchange of Gases between Plant and Environment:

In daytime plants are involved in both photosynthesis and respiration but at night only respiration does occur. Therefore, pattern of gaseous exchange is different in day and night.

Exchange of gases in daytime:

In daytime, since the rate of photosynthesis is much faster than the rate of respiration so the carbon dioxide released from respiration does not fulfill the photosynthetic need. Hence, plants import carbon dioxide from the environment. Similarly, the oxygen released from photosynthesis is much more than the need of respiration, hence it is exported out of the plant body

Exchange of gases at night:

Plants begin to perform exchange of gases just like animals at night i.e., they absorb oxygen and release carbon dioxide to the environment because photosynthesis is stopped. Now oxygen required for respiration is absorbed from environment and the carbon dioxide produced from respiration is released outside.

Compensation point of photosynthesis:

At the time of dawn (sunrise) and dusk (sunset) the rate of photosynthesis becomes equal to the rate of respiration due to low intensity of light. In this situation, the carbon dioxide produces from respiration is sufficient to carry on photosynthesis and the oxygen released from photosynthesis is consumed in respiration. Therefore, the net gaseous exchange between plant and its environment is completely stopped. This is known as **compensation point** of photosynthesis.

23. Explain the movement of water between plant cells and their environment.

Ans: Movement of Water between Plant Cells and their Environment:

The uptake or loss of water by cells takes place by osmosis. The term osmosis is specifically applied to the movement of water from the region of its higher concentration to the region of its lower concentration through semipermeable membrane. The movement of water into the cell is called endosmosis while the movement of water out of the cell is called exosmosis. The movement of water into or out of the cell exhibits three kinds of water relations such as water potential, solute potential and pressure potential.

Water potential (Ψ_w):

Water potential is a measure of the potential energy in water that enables it to move from one place to another. Potential or pressure is denoted by the Greek letter Ψ (psi) and is expressed in units of pressure (pressure is a form of energy) called Mega **Pascal (MPa).** In this way, water potential is represented by Ψ_w. Water potential of a medium is directly proportional to the concentration of water in that medium; therefore, pure water has highest water potential. Water potential of pure water is designated a value of zero (even though pure water contains plenty of

potential energy, that energy is ignored) and it is taken as a reference because Ψ_w of all other solutions are compared with pure water. Water potential of all the solutions or the cells must be less than zero i.e., in negative range.

The water potential in plant solutions is mainly influenced by solute concentration and pressure greater than atmospheric pressure. Water potential can be broken down into its individual components using the following equation:

$$\Psi_w = \Psi_s + \Psi_p$$

where

Ψ_s = solute potential

Ψ_p = pressure potential

As the individual components change they raise or lower the total water potential of a system. When this happens, water moves to equilibrate, moving from the system or compartment with a higher water potential to the system or compartment with a lower water potential. Therefore, for water to move through the plant from the soil to the air (a process called transpiration), the conditions must exist as such

Ψ_w of soil > Ψ_w of root > Ψ_w of stem > Ψ_w of leaf > Ψ_w of atmosphere.

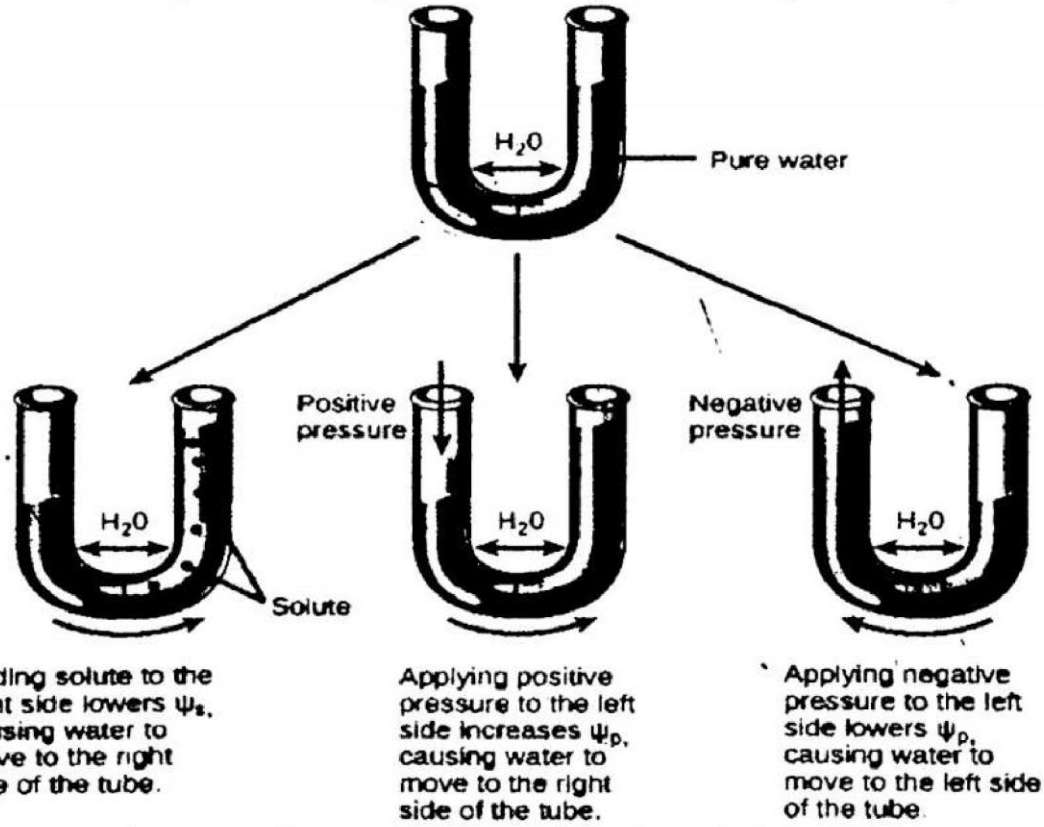


Fig Changes in Ψ_w of the two adjacent systems and their effects: In this example a semipermeable membrane is placed between two aqueous systems in a U shaped tube, water will move from a region of higher to lower water potential until equilibrium is reached. Solutes concentration and pressure greater than atmospheric pressure (positive pressure) influence total water potential for each side of the tube and, therefore, there will be a difference between total water potential on each side. Water moves in response to the difference in water potential between two systems (the left and right sides of the tube).

Solute potential (Ψ_s):

Solutes reduce water potential (resulting in a more negative Ψ_w) by consuming some of the potential energy available in the water. This measure of decrease in water potential of a medium due to the addition of solutes is called **solute potential.**

Solute potential is negative in a plant cell and zero in distilled water. Typical values for cell cytoplasm are -0.5 to -1.0 MPa Solute molecules can dissolve in water because water molecules can bind to them via hydrogen bonds; a hydrophobic molecule like oil, which cannot bind to water, cannot go into solution. The energy in the hydrogen bonds between solute molecules and water is no longer available to do work in the system because it is tied up in the bond. In other words, the amount of available potential energy is reduced when solutes are added to an aqueous system. Thus, Ψ_s decreases with increasing solute concentration. Because Ψ_s is one of the two main components of total Ψ_w of a system, a decrease in Ψ_s will cause a decrease in total Ψ_w

The internal water potential of a plant cell is more negative than pure water because of the cytoplasm's high solute content. Because of this difference in water potential, water will move from the soil into a plant's root cells via the process of osmosis. This is why solute potential is sometimes called osmotic potential.

Pressure potential (Ψ_p):

If pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. It is equivalent to pumping water from one place to another such a situation may arise in living system When water enters the plant cells by osmosis pressure may be build up inside the cell making the cell turgid and increasing the water potential. This measure of increase in water potential of a medium due to the addition of water or due to the pressure greater than atmospheric pressure is called **pressure potential.**

Following example would help understand the concept of water potential. Two adjacent vacuolated cells are shown with Ψ_w, Ψ_s, *and* Ψ_p.

Cell A	Cell B
Ψ_w = -1400 KPa	Ψ_w = -600 KPa
Ψ_s = 600 KPa	Ψ_s = 800 KPa
Ψ_p = -2000 Kpa	Ψ_p = -1400 KPa

i. Which cell has higher water potential?

Ans: Cell B

ii. In which direction will water move by osmosis?

Ans: From Cell B to Cell A.

iii. What will be the water potential of the cells at equilibrium?

Ans: Cells will have the water potential -1400 + -600 = -2000/2 = -1000 KPa at equilibrium.

iv. What will be the solute potential and pressure potential of the cells at equilibrium?

Ans: The solute potential of the cells will be 700 KPa and the pressure potential will be – 1700 KPa at equilibrium.

24. Describe the movement of water through roots.

Ans: Uptake of Water by Roots and Pathways:

The cell wall of epidermal cells of roots is freely permeable to water and other minerals. The cell membrane is differentially permeable. From root hairs water enters the epidermal cells by osmosis. The water moves along the concentration gradient. It passes through cortex, endodermis, and pericycle and reaches the xylem vessels.

There are three pathways taken by water to reach the xylem tissues

(a) The apoplast pathway

(b) The symplast pathway

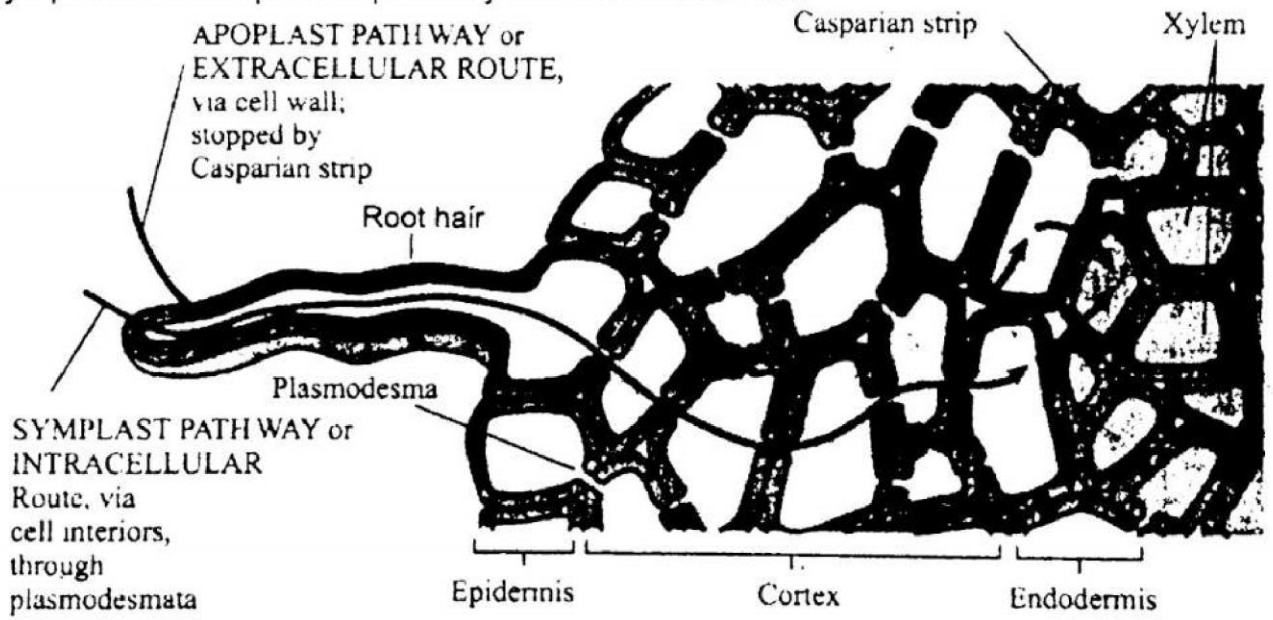
(c) The vacuolar pathway

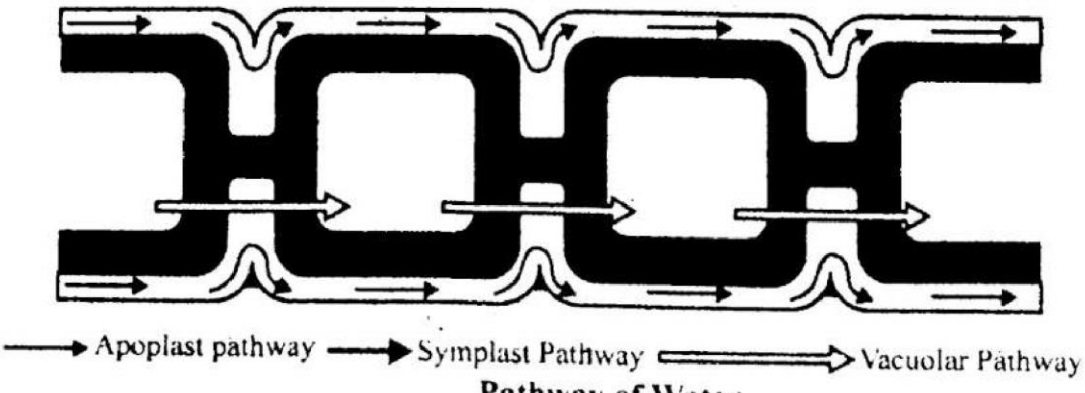
(a) Apoplast Pathway:

The **apoplast** is the system of adjacent cell walls, which is continuous throughout the plant. When water moving through spaces in the cell walls reaches the endodermis, its progress is stopped by **casparian strips,** (a band of suberin and lignin bordering four sides of root endodermal cells). Therefore water and solutes particularly salts in the form of ions must pass through the cell surface and into the cytoplasm of the cells of the endodermis. In this way the cells of the endodermis can control and regulate the movement of solutes through the xylem. This is called **apoplast pathway.**

(b) Symplast Pathway:

Movement of cell sap that involves cytoplasmic connection of adjacent cells is termed as **symplast pathway.** The **symplast** is the system of interconnected protoplast in the plant. The **cytoplasm** of neighbouring **protoplast** is linked by the **plasmodesmata.** Once water and any solutes it contains is taken into the cytoplasm of one cell it can move through the symplast without having to cross further membranes. Movement might be aided by cytoplasmic streaming. The symplast is an important pathway of water movement.





Pathway of Water

(c) Vacuolar Pathway:

In the **vacuolar pathway** water moves from vacuole to vacuole through neighbouring cells, crossing the symplast and apoplast in the process and moving through membranes and tonoplast by osmosis. It moves down a water potential gradient.

25. Describe the components and functions of xylem.

Ans: Components of xylem and their functions:

Xylem is a complex (made up of different kind of cells), permanent (lacks power of cell division) tissue that consists of four, cell types;

i. Tracheids **ii.** Vessel Elements

iii. Xylem Fibres **iv.** Xylem Parenchyma

i. Tracheids:

Tracheids are dead, elongated cells with tapering ends and lignified walls. They have mechanical strength and give support and also involve in conduction of water and minerals. These cells are universally present in xylem tissue of all vascular plants, which are therefore, called **tracheophytes.**

ii. Vessel Elements:

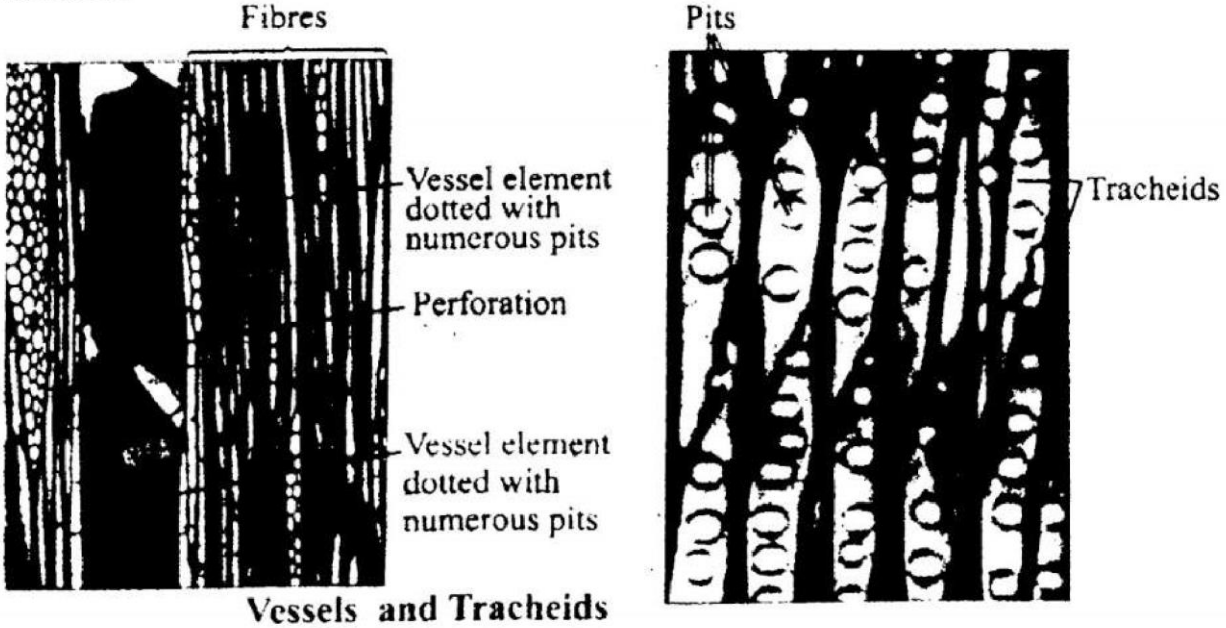
Xylem vessels are dead, very long, highly thick walled tubular structures formed by the fusion of several vessel cells (vessel elements) end to end in a row. **Vessel elements** are shorter than tracheids but they form pipeline in plant body as they are placed one above the other. Xylem vessels are only found in angiosperms where they are involved in conduction of water and minerals and also provide mechanical support to the body.

iii. Xylem Fibres:

Xylem fibres are also dead but narrow, highly elongated, highly thick walled cells with tapering ends. They are mainly responsible for mechanical support to the plant body.

iv. Xylem Parenchyma:

The only living cells of xylem are **xylem parenchyma,** which are thin walled, broad cells and are involved in the storage of water and minerals temporarily during conduction.



Vessels and Tracheids

26. Describe the components and functions of phloem.

Ans: Components of phloem and their functions:

Phloem tissues are also complex permanent tissues that are composed of three living cells (sieve tube elements, companion cells and the phloem parenchyma) and one dead cell (phloem fibre).

Sieve Tube Elements:

Sieve tubes are the long tube like structures, which translocate solutions of organic solutes (sucrose) throughout the plant body. These are formed by the end-to-end fusion of cells called sieve tube elements. **Sieve tube elements** are thin walled living cells but do not have nuclei, actually, their nuclei are lost as they mature. These cells are narrow from the centre and wide from the ends. A transverse or oblique pore bearing partition, the **sieve plate,** separates two successive sieve tube elements.

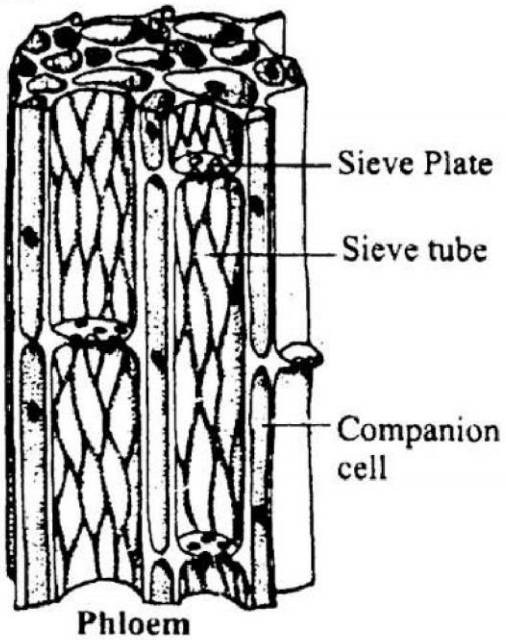
Companion Cells:

Due to the absence of nuclei, the functions of sieve tube elements are controlled by adjacent **companion cells.**

The sieve elements and companion cells, together form a functional unit that act as conducting channels and are involved in transport of organic solutes. Companion cells provide energy to sieve tube elements for their activities. Like xylem tissue, phloem also possesses parenchyma and fibre cells.

Phloem Parenchyma:

Phloem parenchymas are storage cells and phloem fibres are very much thick walled supporting cells.



Phloem

27. Describe the ascent of sap in xylem through TACT mechanism.

Ans: Ascent of sap:

Water and minerals are absorbed by the root epidermal cells of soil from where these substances are first moved to the root xylem cells and then to the leaves. This upward movement of water and dissolved mineral from root to the leaves through xylem tissue is called **ascent of sap.** Since this movement occurs against the gravity therefore, a considerable force is required to conduct water and

minerals in tall heighted plants. The most acceptable theory that explain this movement is generally called TACT theory.

TACT theory:

According to this theory, four factors such as Transpiration pull, Adhesion, Cohesion and Tension (TACT) are combined to form a collective force that is mainly responsible for ascent of sap.

Components of TACT Force:

TACT force consist of four components i.e., transpiration pull, adhesion, cohesion and tension.

1. Transpiration Pull:

When stomata are open, the water molecules move from the region of high water potential (intercellular spaces of leave) to a region of low potential (in the air). This evaporation of water is called **transpiration.** In the same way the dry intercellular spaces pull water from surrounding cells which in turn pull the water from the xylem tissue. Thus, the phenomenon of transpiration develops a pulling force, the **transpiration pull** that compels the water and minerals, to move upward through the xylem. In xylem, water and dissolved minerals are present in the form of a continuous column which is maintained by forces such as, adhesion, cohesion and tesnsion.

2. Adhesion:

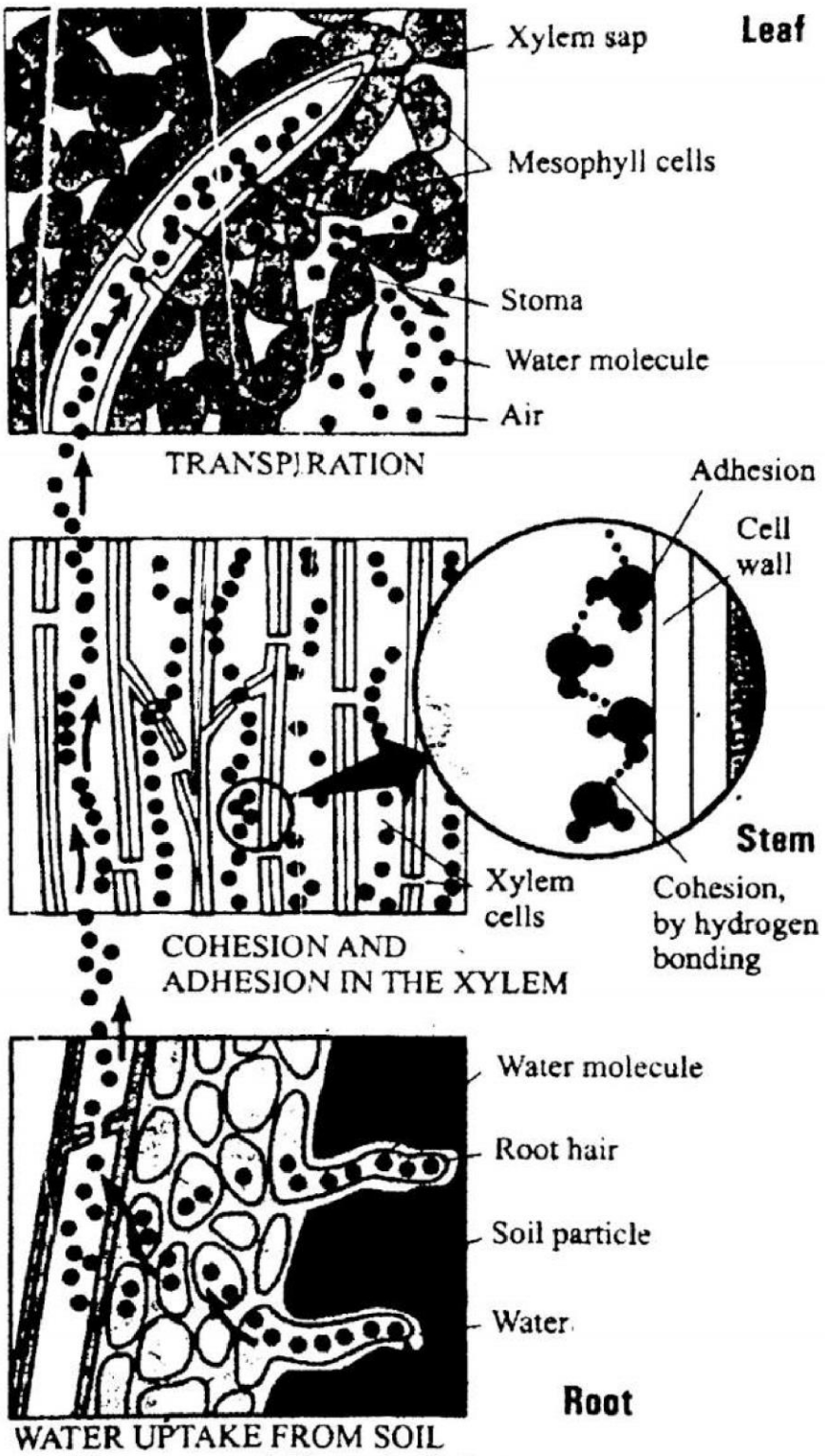
Adhesion is the attractive force between water molecules and other substances. Because both water and cellulose are polar molecules so there is a strong attraction for water within the hollow capillaries of the xylem. Adhesion of the string of water molecule to the wall of the xylem cells assists upward movement of the xylem sap counteracting the downward gravity. Adhesion also helps, hold water in the xylem when transpiration is not occurring.

3. Cohesion and tension:

Water is a polar molecule, with the oxygen carrying a slight negative charge while the hydrogen carries a slight positive charge. As a result, nearby water molecules attract one another, forming weak hydrogen bonds. This attraction among water molecules is called cohesion and the hydrogen bonds formed between them are termed as **tension.**

Mechanism of TACT Force:

The column of water molecule within the xylem is at least as strong and as unbreakable as a steel wire of the same diameter. Hydrogen bonds among water molecules provide the cohesion that holds together the 'string' of water extending the entire height of the plant within the xylem. As long as transpiration continues, the string is kept **tense** and is pulled upward as one molecule. 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.



Movement of Water in Xylem Through TACT Mechanism

Movement of water in xylem through TACT Mechanism

28. Explain the mechanism of opening and closing of stomata.

Ans: Opening and Closing of Stomata:

Stomata are generally open in day and close (incompletely) at night The opening and closing of stomata depends upon the changes in the turgidity of guard cells When guard cells are turgid, the stomata are fully opened but when they become flaccid, the stomata are closed

There are two theories, which may explain the opening and closing of stomata.

(a) Starch sugar interconversion theory

(b) K^+ ions Influx/efflux theory.

(a) Starch sugar interconversion theory:

According to this theory, the guard cells are the only photosynthesizing cells of leaf epidermis because they have high chlorophyll content than the surrounding epidermal cells.

In The Morning:

In the morning when plant is exposed to light, the process of photosynthesis is started. As the concentration of glucose (sugar) is increased (the product of photosynthesis), the solute potential and water potential of guard cells become low (more negative). Since, the surrounding epidermal cells have high water content at that time so water begins to move from surrounding epidermal cells to the guard cells. The entry of water into the guard cells makes them tugid and thus, stromata are opened.

In The Evening:

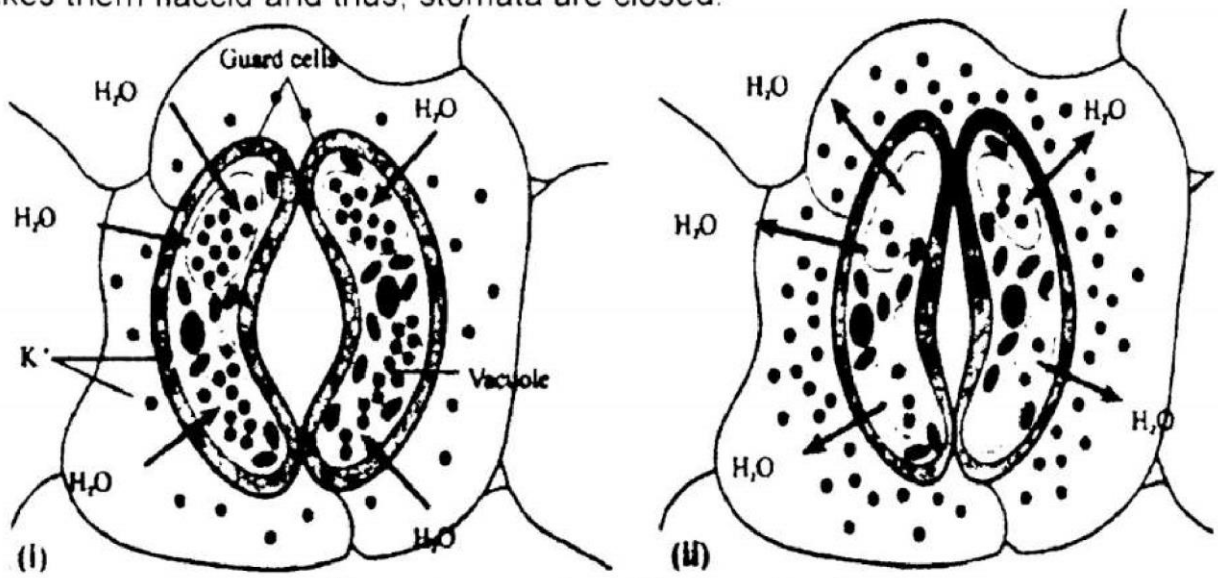
In the evening when the process of photosynthesis is stopped, the concentration of glucose is decreased because some glucose has been consumed in respiratory activities of guard cells, some of it is transformed into sucrose so that it can be transported to other parts, and the remaining glucose is converted into insoluble starch and is stored for later use. The decrease in glucose concentration causes an increase in solute potential and obviously water potential of the guard cells. In this way, water begins to move from guard cells to surrounding epidermal cells. Due to loss of water guard cells become flaccid, thus stomata are closed.

K^+ ions Influx/efflux theory:

According to this theory, the start of photosynthetic activity in the morning when plant is exposed to light, causes a decrease in level of CO_2 in the guard cells. Low level of CO_2 favours or stimulates the influx (inward movement) of K^+ ions (shown in red dots in the figure) into the guard cells from the surrounding epidermal cells by active transport. At the same time, malic acid is ionized into malate" ions and H^+ ions due to the exposure of blue light (a part of visible light). The accumulation of H^+ ions causes decrease in pH of guard cells, which are then pumped to surrounding epidermal cells in order to maintain the pH of guard cells. The incoming K^+ ions are combined with malate' ions to form potassium malate which is highly soluble in water thus decreases the solute potential and the water potential of the guard cells. In this way water begins to move from surrounding epidermal cells to guard cells. The entry of water into the guard cells makes them turgid and thus, stomata are opened.

In the evening, the photosynthetic activity is stopped and level of CO_2 rises in guard cells. High level of CO_2 favours or stimulates the efflux (outward movement) of K^+ ions (shown in red dots in the figure) from the guard cells into the surrounding epidermal cells by active transport. At the same time, malic acid is reformed by the combination of malate, ions and H^+ ions as there is no exposure of blue light now. Due to the absence of potassium malate, solute potential and the water potential of the guard cells are increased. In this way, water begins to move to

surrounding epidermal cells from guard cells. The loss of water from the guard cells makes them flaccid and thus, stomata are closed.



(i) Stomata opening (ii) Stomata closing

29. Describe the translocation of organic solutes in plants.

Ans: Translocation of organic solutes:

The movement of prepared food (organic solutes) to different parts of the plant body through phloem tissue is called translocation of organic solutes.

Pattern or direction of translocation:

Like ascent of sap, this movement cannot be characterized as upward or downward movements, because prepared food is to move to different directions. Therefore, in order to define the direction of this movement it is usually said that translocation always occurs from a source towards a sink. The term source is applied to the area of supply of food such as food manufacturing organ or storage organ (when it supplies the food). The term sink is used for the area of utilization of food such as metabolizing organ or storage organ (when it stores the food). Leaf is purely a source while fruit is particularly a sink on the other hand root and stem act as both source, and sink.

Composition of Translocating Fluid (Phloem sap):

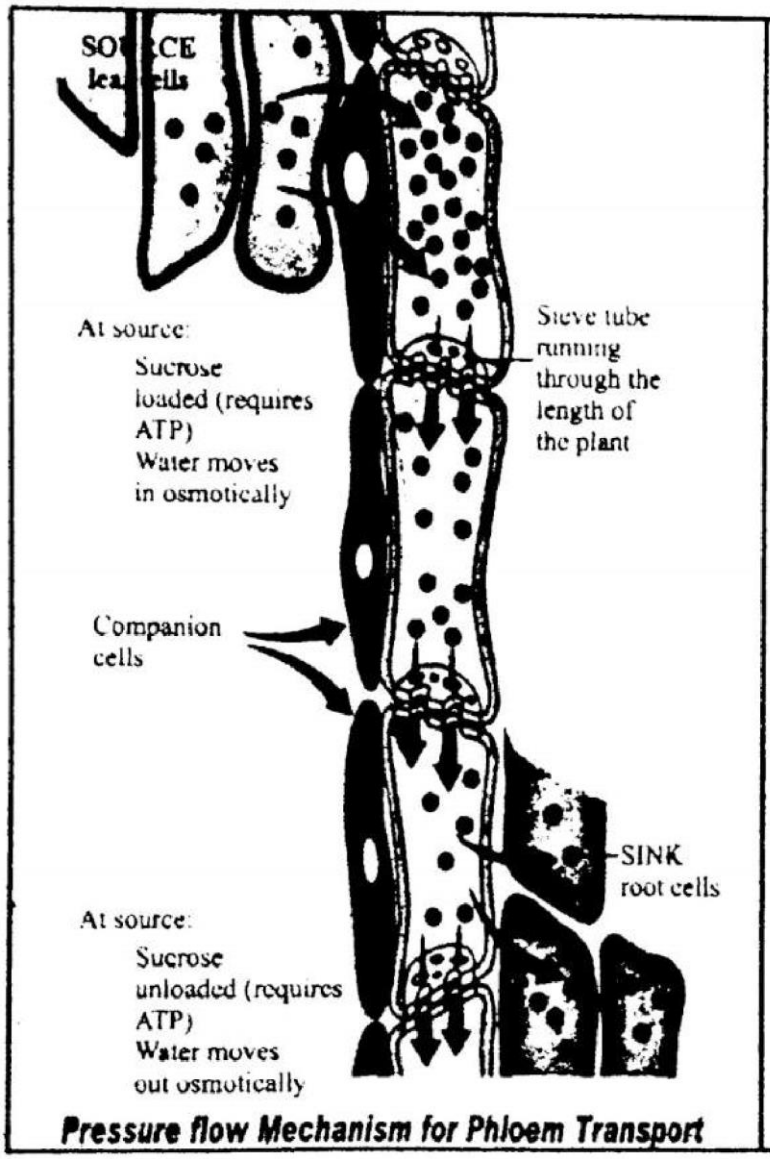
The studies of composition of phloem sap have revealed that it consists of 10-25% dry matter. The 90% of this dry matter is sucrose (cane sugar), while remaining are other organic compounds.

Mechanism of translocation:

The most acceptable theory that explains the mechanism of translocation of organic solutes is the pressure flow or mass flow theory. According to this theory, the sugars produced in source regions, such as photosynthesizing leaves or storage places are loaded into the phloem's sieve tube elements by the companion cells.

The active transport increases the concentrations of sugars in the phloem, thus solute potential and water potential are decreased. As a result, water moves to phloem by osmosis from the nearby xylem cells and increases hydrostatic pressure (any pressure by the presence of water) in the phloem cells, which pushes forcibly the sugary solution away from the leaf (source). The pressure gradient from source to sink causes translocation from the area of higher hydrostatic pressure (the source) to the area of lower hydrostatic pressure (the sink). When this solution is

reached to the sink such as roots, the root cells actively absorb the organic solutes from this solution. The loss of solutes in phloem sap causes an increase in solute potential water potential so the water from the phloem flows back to the xylem tubes.



Pressure flow Mechanism for Phloem Transport

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

30. Describe movement of water in and out of the cell in different osmotic conditions.

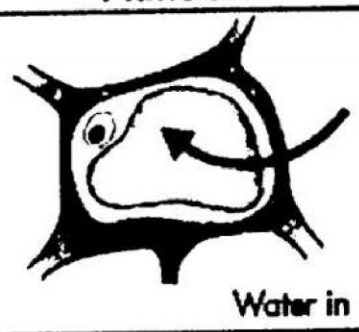
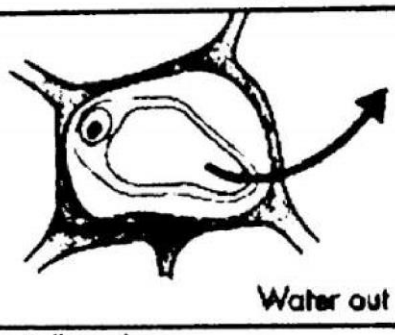
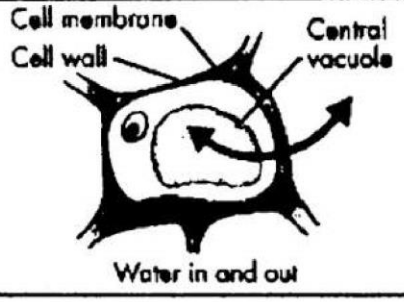
Ans: Homeostasis in Plants:

Homeostasis is the ability to maintain a steady state within a constantly changing environment that contributes towards the success of living systems. The outer environmental conditions such as water availability, nutrients and temperature often show fluctuations that also affect these components within plant body. Plants have several adaptations to cope with these challenges.

Osmotic adjustment (Osmoregulation):

The maintenance of water and solute level in the body is called osmotic adjustment or osmoregulation. Water and solute relations establish three kinds of osmotic situations such as hypotonic, hypertonic and isotonic.

Movement of water in and out of the cells in different osmotic conditions:

Medium and its effect	Plant cell
Hypotonic • Water potential is higher than cell sap • Solute concentration is lower than cell sap • Endosmosis i.e., movement of water inward.	
Hypertonic • Water potential is lower than cell sap • Solute concentration is higher than cell sap • Exosmosis i.e., movement of water outward.	
Isotonic • Water potential is same as in cell sap • Solute concentration is same as in cell sap • No net movement of water	

Movement of water in different osmotic conditions:

Different osmotic conditions cause different effects upon net movement of water in and out of the cells. If a cell is kept in a medium which has higher water potential and lower solute concentration than cell sap, the water begin to move from medium to the cell **(endosmosis)** and cell become turgid. Such medium is called **hypotonic medium.** On the other hand, if a cell is kept in a medium which has lower water potential and higher solute concentration than cell sap, the water begin to move from cell to the medium **(exosmosis)** and cell become flaccid. Such medium is called **hypertonic medium.** Both hypotonic and hypertonic type of osmotic conditions compel for osmotic adjustment. The ideal situation for a cell is **isotonic** in which water potential of both cell and outer environment is equal, therefore, there is no net movement of water in and out of the cell. However, this situation is rarely available to the plants in natural environment.

31. Describe osmotic adjustment in plants of different environment.

Ans: Osmotic adjustments in plants of different environment:

Based upon availability of water, plants are classified into hydrophytes, mesophytes and xerophytes. Each group exposed in different osmotic conditions therefore, show different osmotic adjustments.

Hydrophytes:

The plants that are found in the area where abundant water is available, are called **hydrophytes.** Aquatic plants of freshwater habitats are example of such plants. These plants are exposed in hypotonic conditions so face problem of

flooding (excess of water). Such plants show highest rate of transpiration due to broad leaves with large surface area and distribution of stomata on upper epidermis, which are kept open day and night. These plants do not store water and either have very thin cuticle or almost none, on their surface.

Mesophytes:

The plants that are found in the area where moderate supply of water is available are called **mesophytes.** Common crop plants such as wheat, rice corn are example of such plants. These plants are exposed in nearly isotonic conditions so face no drastic problem of flooding (excess of water) or dehydration (deficiency of water). Such plants show moderate rate of transpiration due to medium sized leaves with distribution of stomata on lower epidermis, which are generally open in day and close at night. However, these plants can close their stomata even in day. These plants store a very small amount of water, have very thin cuticle on their surface.

Table: Comparison of osmotic adjustment in different groups of plant:

Features	Hydrophytes	Mesophytes	Xerophytes
Habitat	Aquatic	Terrestrial (moderate)	Terrestrial (severely dry)
Osmotic conditions of medium	Hypotonic	Nearly isotonic	Strong hypertonic
Problems faced by plant	Flooding	No drastic problem	Severe dehydration
Rate of transpiration	Very high rate	Medium rate	Very low rate
Stomatal distribution	On upper epidermis	On lower epidermis	Sunken stomata
Stomatal opening	Stomata remain open all the time	Open in day and close at night	Close in day and open at night
Thickness of cuticle	Very thin or none	Less thick	Very thick
Storage of water	None	Little storage	Succulent

Xerophytes:

The plants that are found in the area where very little amount of water is available are called **xerophytes.** Desert plants such as cactus, opuntia are example of such plants. These plants are exposed to severely hypertonic conditions so face extreme degree of dehydration.

Such plants show very reduced rate of transpiration due to narrow needle like leaves or due to complete modification of leaves into spines. They have stomata in depressions **(sunken stomata),** which are generally close in day and open at night. These plants store a very high amount of water therefore; they are also called **succulent plants.** They have very think cuticle on their surface.

32. Describe osmotic adjustment of halophytes in saline soil.

Ans: Osmotic Adjustments of Plants (halophytes) in Saline Soils:

A saline soil is characterized by the presence of excessive salt concentration. High saline soils are characteristics of salt marshes. Saline soils due

to very low solute potential and water potential create a physiological drought i.e., plants are unable to absorb water even water is available in the soil. Therefore, plants living in saline environments **(halophytes)** have adapted mechanisms to deal with this problem.

Halophytes respond to salinity by taking up sodium and chloride at high rates and then accumulating these ions in the vacuoles of the leaf cells, keeping the salt concentration in the cytoplasm and organelles at a low level that does not interfere with the functions of their enzymes and metabolic machinery of their leaves. These plants use the accumulated salt for osmotic adjustment to the low water potential in the soil.

On the other hand some halophytes do not uptake salts form soil; instead, they make osmotic adjustment by accumulating their own dissolved substances compatible with enzymes and metabolism. These **"compatible solutes"** are mostly organic compounds such as the nitrogenous compounds glycine and, in some plants, sugar alcohols, such as sorbitol.

33. Describe adaptations in plants to cope with low temperature and high temperature stress.

Ans: Thermoregulation plants:

All organisms for optimum activity of their enzymes require a suitable temperature. Thermoregulation is a type of homeostasis by which an organism is able to perform necessary adjustment in response to low and high temperature stress. Plants also have certain adaptations that enable them to tolerate against low and high temperature changes.

Adaptations in plants to cope with the low temperature stress:

Low temperature affects the fluidity of cell membrane because lipids of the membranes become locked into crystalline structures, thus membranes become porous which affect the transport of solutes. The structure of membrane proteins is also affected. In addition, freezing temperature also" causes ice crystal formation with in cytoplasm that interferes with the metabolic activities of the cell.

In order to prevent crystallization in cell membrane, plants increase **the proportion of unsaturated fatty acids** (which have low freezing point), which help membrane to maintain structure at low temperature and the crystal formation is inhibited. In order to **prevent** crystallization within cytoplasm, the plants native to cold regions such as oaks, maples, roses and other have adapted to bring **changes in solute compositions** of the cells which causes cytosol to super cool without ice formation, although ice crystals may form in the cell **wall.**

These adaptations of plants to low temperature stress require time because of this reason rapid chilling to plants is more stressful than gradual drop **in** air temperature.

Adaptations in plants to cope with the high temperature stress:

High temperature stress causes excessive evaporative loss of water by transpiration that may leads to dehydration and ultimately wilting (loss of turgor). It also causes denaturation of enzymes and damages the metabolism therefore, harms or kills the plants.

In hot areas, the plants develop a shiny cuticle, which reflects much of the incident light. Thus preventing the heat absorption and overheating by the plant. The leaves contain numerous stomatal openings, which allow the loss of water

(transpiration), and remove the heat from the plant. However, very high temperature i.e., above 45°C, plants close their stomata to prevent the water loss. Therefore, most plants have adapted to survive in such high temperature stress situations by synthesizing large quantities of special proteins called **heat shock proteins.** Since these proteins are heat tolerant, so they embrace enzymes and other proteins thus help prevent denaturation.

34. What is the role of mechanical tissue to support in plants?

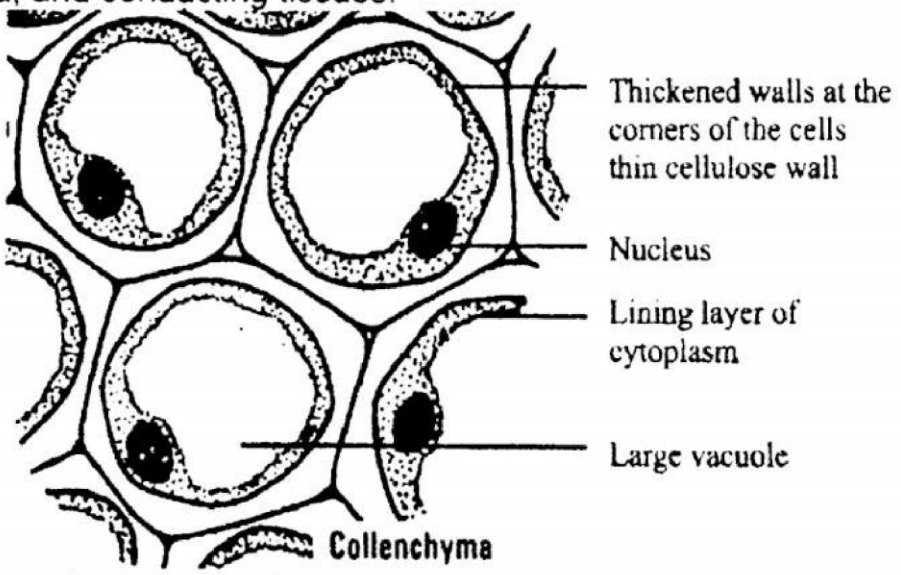
Ans: Support in Plants:

When the life started on land from water, one of the very important needs for the organisms was to gain some sort of support and strength for keeping their bodies in shapes. Plants also have variety of mechanism for support. Such as, turgor mechanism in parenchyma cells, mechanical tissues (thick walled, e.g., collenchyma and sclerenchyma), arrangement of vascular bundles and secondary growth.

Role of turgor mechanism in support:

In plants the **parenchyma** cells have large central vacuoles, which are filled with water. The water causes pressure on the surrounding walls, when the cells are turgid. This pressure on the walls keeps the cells, stiff and hard and is called **turgor pressure.**

In herbaceous plants where the specialized supporting tissues are not common, the turgidity of the cells provides support and strength and it grows uprightly. In these cases the plant may wilt or collapse due to a decrease in turgidity (decrease in the internal hydrostatic pressure). Besides the hydrostatic pressure the plants specially shrubs and trees have some supporting tissues, like collenchyma, sclerenchyma, and conducting tissues.



Role of mechanical tissues in support:

The term mechanical tissues is used for the tissues of thick walled cells i.e., collenchyma and sclerenchyma.

Collenchymas:

The **collenchyma** is characterized by the extra cellulose deposition at the corners of these cells. It is a mechanical tissue, providing support particularly in young plants, herbs and leaves etc.. (where secondary growth does not occur) collenchyma is living so it can grow and stretch freely. In stems and petioles it plays

more important role in support because of its location in peripheral regions near epidermis.

Sclerenchyma:

Sclerenchyma tissues are solely means for giving support and mechanical strength for the plants. The mature cells are dead due to the formation of very thick secondary lignified wall (lignin is a macromolecule that provide rigidness to the wall).

Types of Sclerenchyma:

The sclerenchyma is of two types, i.e., fibres and sclereids.

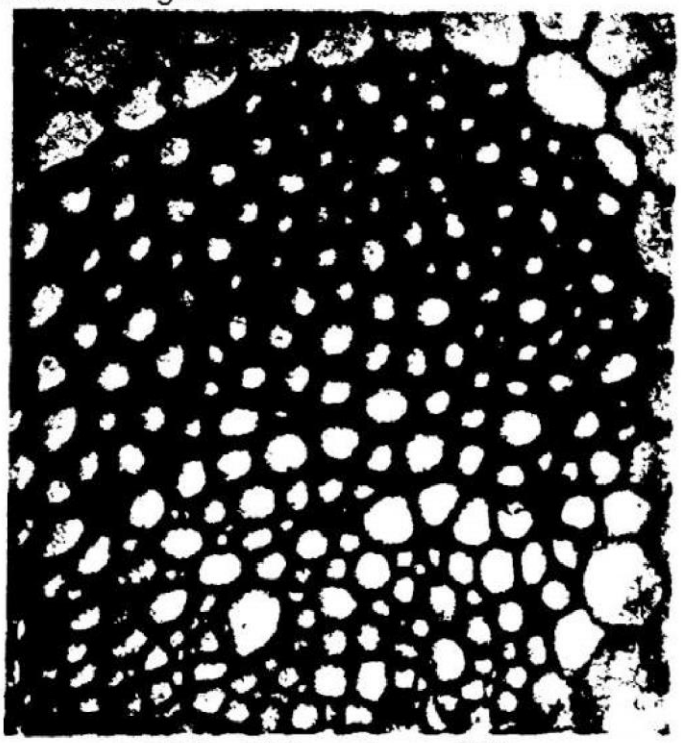
i. Fibres:

Fibres are found in the pericycle of stems forming a solid rod of tissue. Fibres also found in xylem and phloem tissues.

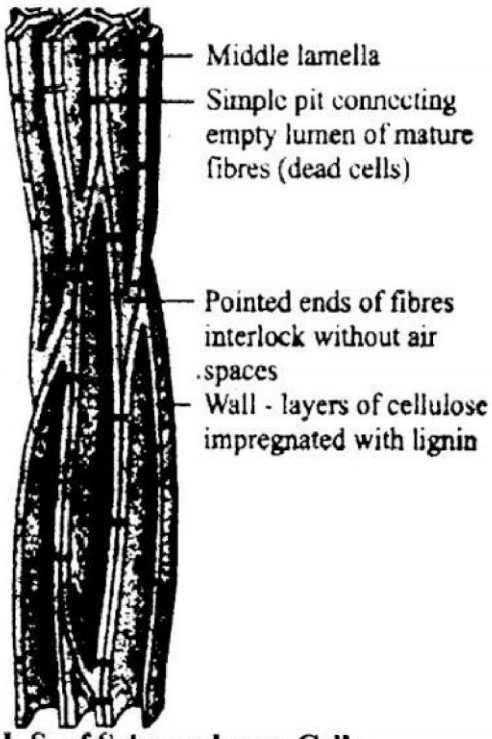
ii. Sclereids:

Sclereids are common in fruit wall and seed coats.

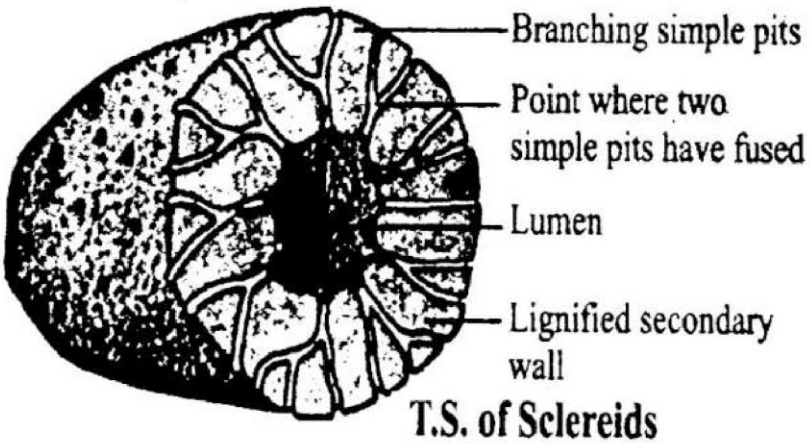
Fibres are elongated cells and sclereids are roughly spherical or variously shaped cells otherwise both have heavily thickened walls with lignin and with great tensile strength.



(a) T.S. of Sclerenchyma Cells



(b) L.S. of Sclerenchyma Cells



T.S. of Sclereids

Arrangement of vascular bundles:

In dicot plants, vascular bundles are arranged in the form of ring in stem. As compared to monocot plants in which vascular bundles are scattered in the stem, the ring arrangement of vascular bundle in dicot plants also provide support to the plant body.

35. Describe meristematic tissues in plants.

Ans: Growth and Development in Plants:

Development is a programmed series of changes by which an organism is converted from simpler to form that is more complex. The growth is part of development process which is characterized by an irreversible increase in the size and mass of an organism. In plants growth and development involve four phases: cell division (production of new cells), cell elongation (enlargement of cell size), cell maturation and differentiation (cells structurally and functionally become specialized to perform particular functions). Plants add new organs like, branches, leaves, roots etc throughout life. This unique pattern is called **open growth.**

Meristematic tissues (Meristems):

In lower plants, the entire plant body is capable of growing, but in higher plants, growth is limited to certain regions known as growing points that possess specialized tissues for growth. the **meristematic tissues** or **meristems.** The cells remain forever young and divide actively throughout the life of the plant in these tissues. When a meristematic cell divides in two, the new cell that remains in the meristem is called an **initial,** and the other is called the **derivative.** As repeated mitotic divisions of the initial cells add new cells, the derivatives are pushed farther away from the zone of active division. They stretch, enlarge and differentiate into other types of tissues as they mature. Meristematic cells are generally small and cuboidal with large nuclei, small vacuoles, and thin walls.

Types of Meristems:

A plant has two major kinds of meristems:

i. Apical Meristem **ii.** Lateral Meristem

i. Apical meristems (Primary Meristems):

These are located at opposite ends of the plant axis in the tips of roots and shoots. Cell divisions and subsequent cellular enlargement in these areas lengthen the above and below ground parts of the plant. Since, these meristem are present in plants right from embryonic life, therefore, they are also known as **primary meristems.**

ii. Lateral Meristems (Secondary Meristem):

Lateral meristems are cylinders of dividing cells on lateral sides in stems and roots of dicots and gymnosperms and increase their thickness and diameter. These meristems are derived from apical meristem after embryonic life therefore; they are also called **secondary meristem.**

Types of Lateral Meristems:

Vascular cambium, cork cambium, and intercalary meristem are the types of lateral meristems.

I. Vascular Cambium:

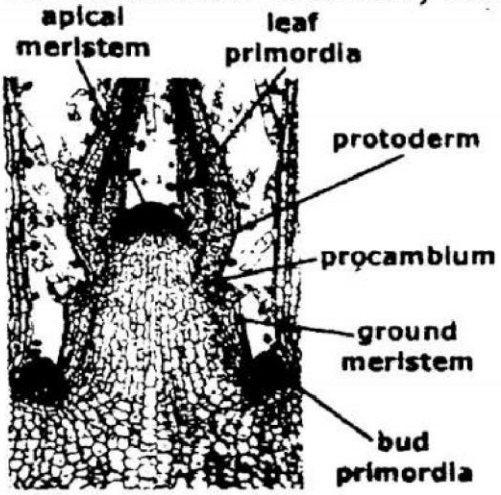
Some plants grow in diameter by producing new tissues laterally from a cylinder of tissue called the **vascular cambium,** which extends throughout the length of the plant from the tips of the shoots to the tips of the roots.

ii. Cork Cambium

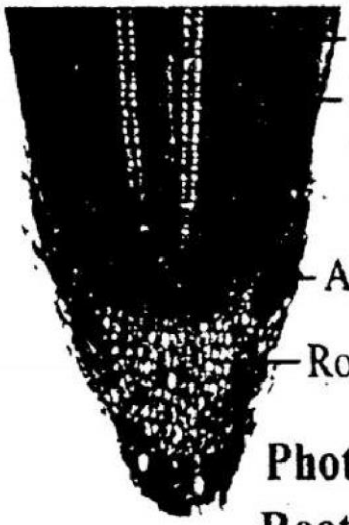
Cork cambium also called **phellogen**, are found in the bark of roots and stems of woody plants where they contribute in width of plant body.

iii. Intercalary Meristems:

Intercalary meristems originate from apical meristems but they are separated from them and are located along the stems near the nodes. Growth in these tissues give rise side branches, leaves and lateral buds that grow up to a certain size (determinate growth). Tissues produced by cell divisions of the any lateral meristem are secondary tissues.



Photomicrograph of shoot, apical meristem



Photomicrograph of Root Apical Meristem

36. Describe the role of lateral meristems in secondary growth.

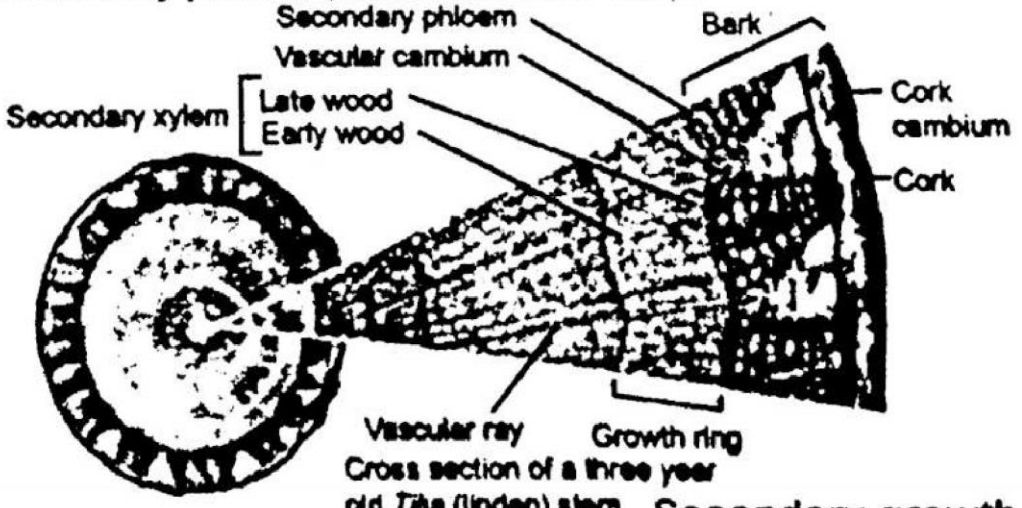
Ans: Role of lateral meristems in secondary growth:

Two lateral meristems i.e., cork cambium and vascular cambium mainly participates in secondary growth.

Role of vascular cambium:

As the plant grows lengthwise by the activity of apical meristem, vascular cambium is also produced. It is present in vascular bundle between primary xylem and primary phloem. Its rate of cell division is faster than cork cambium therefore it contributes more tissues in secondary growth.

It adds two new tissues in plant body: **secondary xylem** (towards its inner side) and **secondary phloem** (towards its outer side).



Secondary growth

The rate of production of secondary xylem is faster than secondary phloem and it is produced in two different ways during the whole year of growth. In autumn and winter seasons, comparatively smaller sized cells are produced due to deficiency of water while in spring and summer seasons, larger sized cells are produced probably due to availability of water. Because of this differential growth pattern distinct rings of smaller and larger cells are formed, which represent the growth of one whole year. therefore these rings are called **growth rings** or **annual rings.** We can determine the age of plant by counting the number of these growth ring as each ring is form in one year.

Role of cork cambium (Phellogen):

The cork cambium or phellogen generally originates from outer most layer of primary cortex. It adds two new tissues in plant body during secondary growth: secondary cortex (towards its inner side) and cork (towards its outer side beneath the epidermis). The cork cells become dead after sometimes due to which epidermis also becomes dead. Therefore, the outer surface of mature trees looks rough.

37. Describe growth correlation in plants.

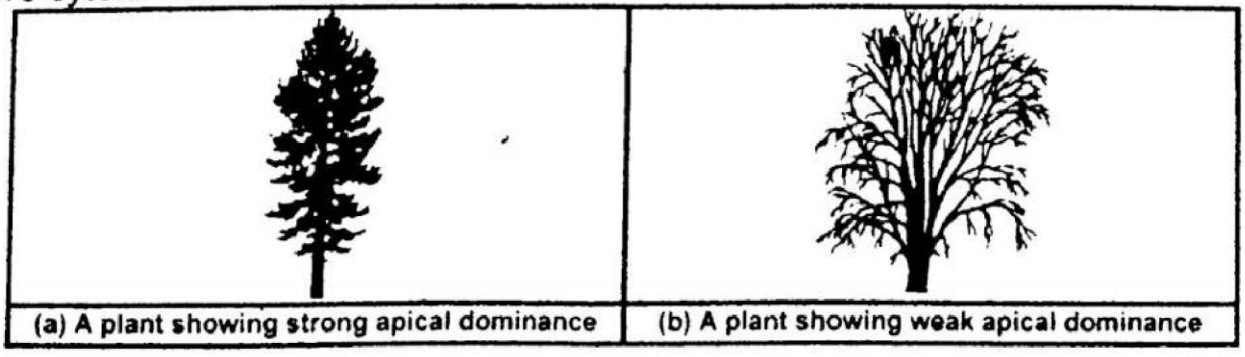
Ans: Growth correlations:

During the development of a plant, the rate of growth at different growing points is not constant, for example, growth of different meristem sometime influence upon each other. Such interactions among different growing points are called **growth correlations.** These growth correlations may be **positive** (if growth of one part promotes the growth of other part) or **negative** (if growth of one part inhibits the growth of other part).

Apical Dominance:

Apical dominance is a kind of negative growth correlation in which the presence of a growing apical bud inhibits growth of lateral buds. It is also found in roots where lateral root growth is inhibited by growth of the main root. The plants showing tall height with short side branches have very strong apical dominance and the plants showing short height and very dense growth of lateral branches have very little apical dominance.

Botanists have performed several experiments to study the cause of apical dominance and finally concluded that it is the auxin (a plant growth regulator) which is released from apical bud and inhibits the growth of lateral buds. It is also revealed that **cytokinin** produced by lateral buds (another plant growth regulator) works antagonistically to the **auxins** in apical dominance, thus neutralizes the influence of apical bud on lateral buds. It means that plants having strong apical dominance produce more auxins from apical bud and less cytokinin from lateral buds. Similarly, the plants having weak apical dominance produce less auxins from apical bud and more cytokinin from lateral buds.



(a) A plant showing strong apical dominance | (b) A plant showing weak apical dominance

38. Describe the role of growth regulators in plants.

Ans: Growth Responses in Plants:

Plants generally adjust themselves to changing environment by growth. The changes in plant shape or functions are often regulated by **plant hormones** (growth substances) produced in response to environmental factors. The plant hormones act at the level of cells to induce cell division, enlargement or cell maturation.

Plant Growth Regulators:

Plants are co-ordinated by chemicals, commonly known as **plant hormones,** which necessarily move from their sites of synthesis to the sites of action, and because their effects are usually on some aspect of growth, they are called **growth regulators.**

Types of Growth Regulators:

Five major types of growth regulators are recognized (a) auxins (b) gibberellins (c) cytokinins (d) abscisic acid (e) ethene.

Growth Promoters and Growth Inhibitors:

Auxins, gibberellins and cytokinins are called **growth promoters** because of their general role in promotion of growth while abscisic acid and ethene are called **growth inhibitors.**

(a) Auxins:

An auxin or **indoie-3-acetic acid** (IAA), was the first plant hormone identified. It is manufactured primarily in the shoot tips (in leaf primordia and young leaves), in embryos, and in parts of developing flowers and seeds. They are mainly responsible for cell elongation.

(b) Gibberellins:

The gibberellins are widespread throughout the plant kingdom, and more than 75 have been isolated, to date. Rather than giving each a specific name, the compounds are numbered, for example, GA1, GA2, and so on. **Gibberellic acid 3 (GA3)** is the most widespread and most thoroughly studied. The gibberellins are especially abundant in seeds and young shoots where they control stem elongation by stimulating both cell division and elongation.

(c) Cytokinins:

These are named because of their role in cell division (cytokinesis), the cytokinins have a molecular structure similar to adenine. Naturally occurring **zeatin,** isolated first from corn *(Zea mays),* is the most active of the cytokinins. Cytokinins are found in sites of active cell division in plants, for example, in root tips, seeds, fruits, and leaves.

(d) Abscisic acid:

Abscisic acid (ABA) is synthesized in plastids from carotenoids during stress situations and diffuses in all directions through vascular tissues and parenchyma. Its principal effect is inhibition of cell growth. ABA increases in developing seeds and promotes dormancy. If leaves experience water stress, ABA amounts increase immediately, causing the stomata to close.

(e) Ethylene or ethane:

Ethylene or ethene is a simple gaseous hydrocarbon produced from an amino acid and appears in most plant tissues in large amounts when they are stressed. It diffuses from its site of origin into the air and affects surrounding plants

as well Ethylene stimulates the ripening of fruit and initiates abscission of fruits and leaves.

Table: A comparison of effects of plants growth regulators on different plant parts:

Part Affected	Auxins	Gibberellins	Cytokinins	Abscisic Acid	Ethene
Stem	• Promote cell enlargement behind apex. • Promote cell division in cambium.	• Promote cell enlargement in the presence of auxin • Promote leave growth.	• Promote cell division in apical meristem and cambium • Promote leave growth	Inhibit growth during stress, e.g., drought, salinity and water logging.	Inhibit growth during stress, e.g., drought, salinity and water logging.
Root	• In low cone, promote growth • In high conc inhibit growth • Promote growth from cuttings and calluses	Nil	• Inhibit primary root growth	Nil	Inhibit root growth
Floral buds	Promote bud initiation	Promote bud initiation	• Promote lateral root growth • Promote lateral bud growth • Break bud dormancy	Nil	Promote bud initiation
Flowering	Nil	• Promote in long day plants • Inhibit in short day plants • Acts as substitute for red light • Antagonistic to Abscissic acid	Nil	• Promote in short day plants • Inhibit in long day plants • Acts as substitute for far red light • Antagonistic to gibberellin	Promote in pineapple
Apical dominance	Promote	Enhance the action of auxin	Inhibit	Nil	Nil
Fruit growth	Promote ripening	Promote ripening	Promote ripening	Nil	Promote ripening
Parthenocarpy	Rarely promote	promote	Rarely promote	Nil	Nil
Leaf senescence	Delay	Delay	Delay	Promote	Nil
Seed dormancy	Nil	Break	Break	Promote	Nil
Abscission	Inhibit	Inhibit	Inhibit	Promote	Nil
Stomatal opening	Nil	Nil	Promote	Inhibit	Nil

39. Describe growth movement in plants.

Ans: Growth movements in plants (Tropic Movements):

The plants as their characteristics do not show locomotion, but the individual plant organs may show movements by change in differential growth in response of various stimuli (internal or external). In this section, you are going to learn about **tropic movements** or **tropisms** that are either towards or away from certain external stimuli such as light, force of gravity, touch and chemical.

Phototropism:

Phototropism is the movement of plants parts, either towards (positive) or away (negative) from light source. Such movements are found in shoots and roots. Shoots show positive phototropism (grow upward above the ground) and roots show negative geotropism (grow downward under the ground).

Geotropism:

Geotropism (gravitropism) is the movement of plants parts, either towards (positive) or away (negative) from force of gravity. Such movements are also found in shoots and roots. Shoots show negative geotropism (grow upward above the ground) and roots show positive geotropism (grow downward under the ground).

Thigmotropism:

Thigmotropism is the movement due to the touch stimulus. Such movements are shown by climbing plants that require any supportive structure such as a wall, a wooden stick or rod or even a rope to climb over.

Chemotropism:

In chemotropism the stimulus is a chemical (nutrients). Such movement is shown by fungal mycelium in which hyphae show more growth towards the nutrients.

40. What is photoperiodism? Explain the mechanism of photoperiodism with reference to the mode of action of phytochromes.

Ans: Photoperiodism:

Light exerts its influence on living organisms through variation in intensity, quality and day length. Total duration of light in the whole day is called **photoperiod** and its effect on the development of flowers in some plants is called **photoperiodism.** This behavior is found in some plants in which due to the exposure of appropriate photoperiod their vegetative buds are transformed into floral buds and the flowers are begin to produce. If such plants do not get required, photoperiods their vegetative growth remains continue but flowers are not produced.

Classification of plants based upon photoperiodism:

Plants are classified into three main groups on the basis of how photoperiodism affects their flowering.

Short-day plants: These plants flower when the photoperiod is less than a certain critical length, e.g., Maryland mammoth, cocklebur, chrysanthemum, tobacco etc.

Long-day plants:

These plants flower when the photoperiod exceeds from the critical length e.g., spinach, sugar beet, Henbane snapdragon, cabbage, spring wheat etc.

Day-neutral plants:

These plants can flower in any photoperiod after a considerable vegetative growth. The flowering is not affected by variation in day-length or darkness in these plants, e.g., tomato, pansy, bean, sweet pea, rose, etc.

Concept of critical photoperiods

The concept of critical lengths of photoperiod for both long day and short day plan, .s different and its duration is also variable for every plant even they belong to the same group. For example, for **tobacco, 14 hours** photoperiod is seemed to be critical and for **cocklebur 15.5 hours** photoperiod is critical, however both are short day plants. Actually, length of critical photoperiod depends upon the level and relative proportion of two forms of phytochromes in plant body. Critical photoperiod for short day plant can be defined as the maximum length of day, which is required to stimulate/induce flowering in a short day plant".

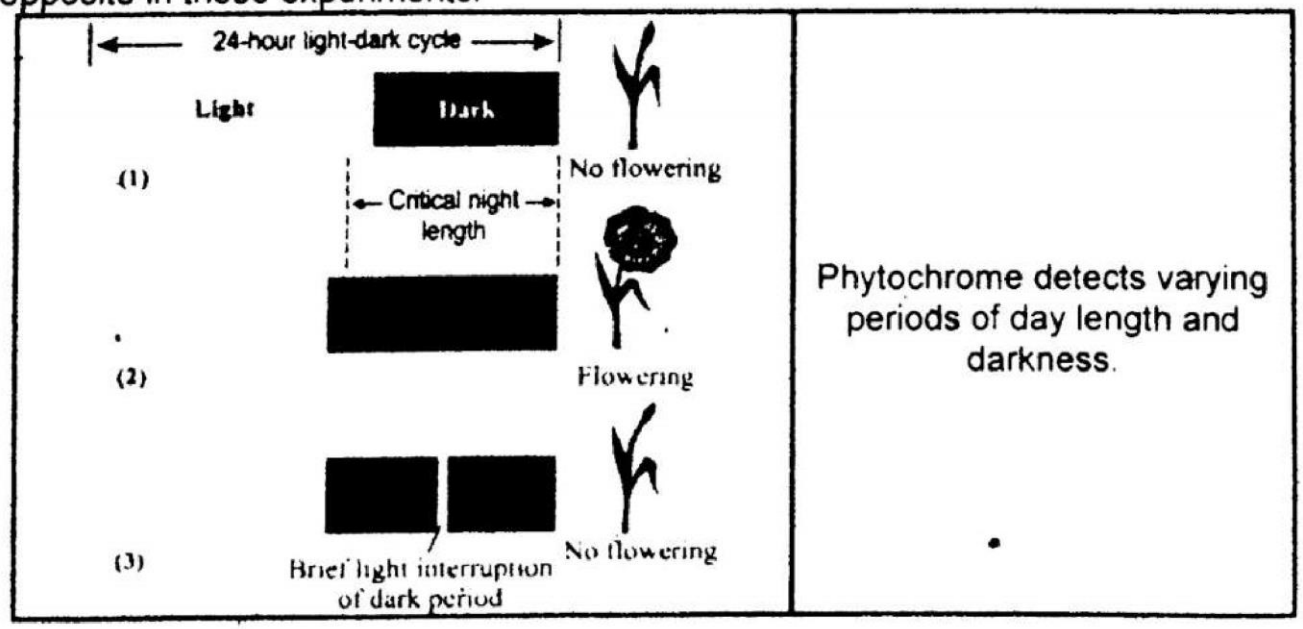
Similarly, "critical photoperiod for long day plant can be defined as the minimum length of day, which is required to stimulate/induce flowering in a long day plant". For example, for henbane 11 hours photoperiod is critical.

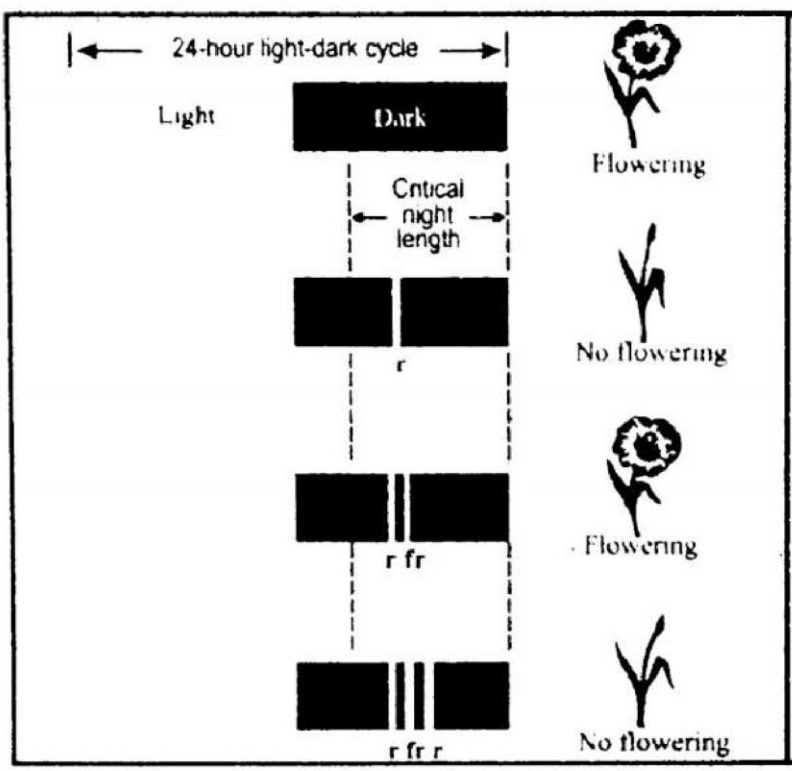
Significance of dark periods over photoperiods:

Now it has been discovered that the actual stimulus for flowering is the uninterrupted dark period rather than the light period. Therefore, it is really the length of dark period which is critical. For example, if a short day plant (e.g., cocklebur) is grown in appropriate short days (less than 15.5 hours), but its long nights (more than 8.5 hours) are interrupted by short light periods, flowering is prevented. Similarly, a long day plant (e.g., henbane) can flower in inappropriate short days (less than 11 hours), if its long nights or dark periods (more than 13 hours) are interrupted. Therefore, the short day plants are actually **long night plants** and long-day plants are **short-night plants.**

Effect of quality of light and discovery of phytochromes:

Further night interruption experiments on short day and long day plants have revealed that beside dark length the quality (wavelengths) of light is also important in promotion or inhibition of flowering. For example, cocklebur a short day plant, will not flower if its long nights are interrupted but experiments revealed that **red** light (660 nm wavelength) was effective in preventing flowering and the **far red light** (730 nm wavelength) reversed the effect of red light. It was also demonstrated that if more than one type of light exposures were given to interrupt the night, the last light treatment always determines the response. The behaviour of long day plants was opposite in these experiments.





Night interruption experiments on short-day plants using a red light interruption and combinations of red and far-red (fr) light interruptions

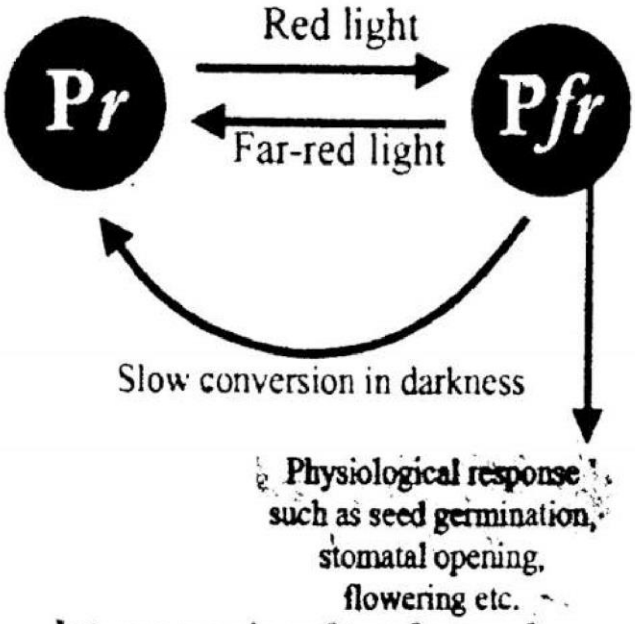
Based upon above observation, researchers concluded that there must be some kind of photoreceptors in plants, due to which plants respond differently to these lights. This struggle finally leads to the discovery of these photoreceptor pigments in the form of **phytochromes.**

Mechanism of Photoperiodism:

The mechanism of photoperiodism depends upon the rate of interconversion and the accumulation of either form of phytochromes. Phytochromes are blue-green pigment, which are involved in photoperiodism as photoreceptor. They are protein in nature but also contain an iron containing non-protein part.

Interconversion of phytochromes:

Phytochromes are found in two interconvertible forms. One form of phytochrome, designated as P_R or P_{660} strongly absorbs red light (at 660 nm) and is converted into the second form of phytochrome i.e., P_{FR} or P_{730}. When P_{FR} (P_{730}) absorbs far-red light, it reverts to the original form, PR (P660). Since red light is available in daytime so the conversion of P_R (P_{660}) to P_{FR} (P_{730}) occurs in day. Far-red light are invisible heat radiations that are present in both day and night but the conversion of P_{FR} (P_{730}) to P_R (P_{660}) occurs at night prominently because PR (P_{660}) cannot stay in daytime due to the presence of red light. In this way, the accumulation of either form of phytochrome in day and night enable the plant to determine that weather it is present in day or night. The rate of conversion of P_{FR} (P_{730}) to P_R (P_{660}) that occurs at night also provides a biological clock to the plants to determine the length of their night.



Interconversion of two forms of phytochromes

Stimuli required for induction of flowering:

A short day plant requires a low ratio of P_{FR} (P_{730}) to P_R (P_{660}). It (cocklebur) can flower if it is provided with an appropriate dark length (8.5 hours or longer) because this dark length can convert all the accumulated P_{FR} (P_{730}) to P_R (P_{660}), therefore, P_{FR} (P_{730}) to P_R (P_{660}) ratio become low. On the other hand, a long day plant requires a high ratio of P_{FR} (P_{730}) to P_R (P_{660}). It (henbane) can flower if it is provided with an appropriate dark length (13 hours or lesser) because this dark length cannot converts all the accumulated P_{FR} (P_{730}) to P_R (P_{660}), therefore, at the end of night P_{FR} (P_{730}) to P_R (P_{660}) ratio become high. This is the reason why red and far red lights affect differently in short day and long day plants.

Role of florigen hormone:

The specific ratios of P_{FR} (P_{730}) to P_R (P_{660}) at the end of nights (discussed above) trigger the production of a particular hormone in plants known as **florigen,** which transforms the vegetative buds into floral buds, thus flowers are produced.