KRISHNAGAR ACADEMY

Photosynthesis

Chapter -- 5

Biology

Class - 10

SYLLABUS

- *Photosynthesis : The nature of the process itself and the great importance of photosynthesis to life in general; experiments to show the necessity of light, carbon dioxide and chlorophyll and also the formation of starch and the output of oxygen; carbon cycle.*
- *The internal structure of chloroplast should be explained to give an idea of the site of light and dark reaction. Opening and closing of stomata should be explained. Teachers should stress upon the importance of a correct balanced chemical equation. The terms "photochemical" for light phase and "biosynthetic" for dark phase must be introduced. In the light reaction, activation of chlorophyll molecule followed by photolysis of water, release of O_2, formation of ATP and NADPH should be taught. In the dark reaction (detailed equations are not required), only combination of hydrogen released by NADP with CO_2 to form glucose to be discussed. Adaptations in a plant for pshotosynthesis and experiments with regard to the factors essential for the process should be discussed.*

PHOTOSYNTHESIS

The photosynthesis is a characteristic of all the green plants. It may be defined as a *process by which the green plants prepare their food (glucose) from carbon dioxide* (CO_2) *and water with the help of chlorophyll in presence of the sunlight.* This may be expressed by a simple equation as follows :

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

The interior of leaves between upper and lower epidermis is filled with two types of cells: those immedia tely beneath the upper epidermis, called the *palisade cells* are elongated with their long axes perpendicular to the surface. These cells are closely packed with almost no intercellular space. They have numerous chloroplasts which are arranged in such a way that they receive maximum light. Filling the space between the palisade layer and the lower epidermis are spongy *mesophyll cells* with irregular shape and arrangement. These contain fewer chlorop lasts as compared with the palisade cells. Between these cells are large *air spaces* which communicate with each other. The air spaces allow gases to diffuse freely among the cells.

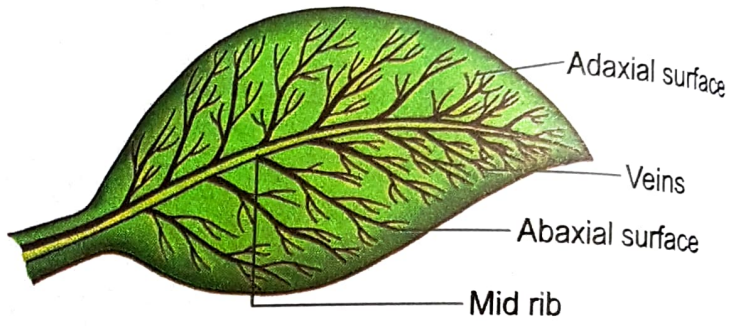


Fig. 1. External structure of typical leaf.

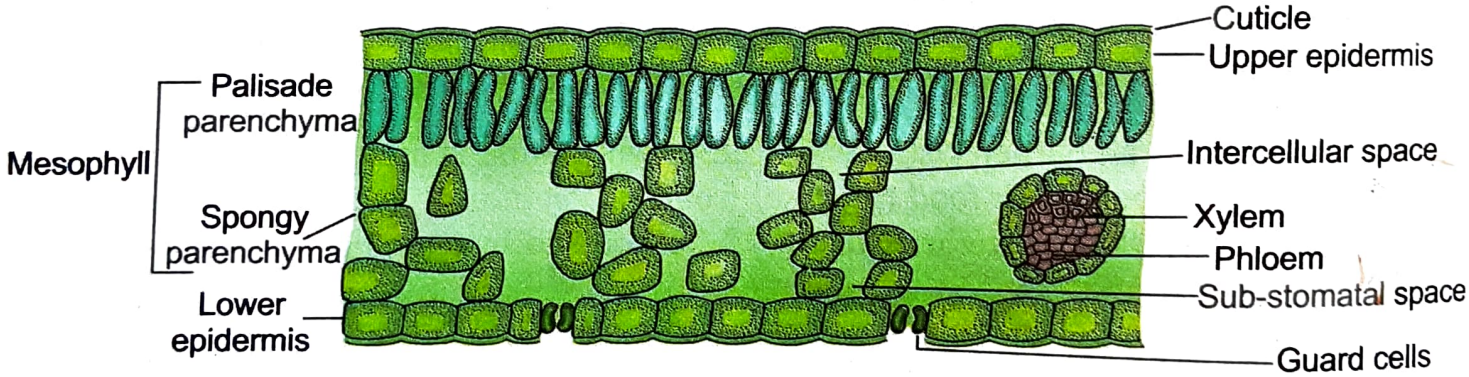


Fig. 2. Internal structure of a leaf.

The leaves have *mid-rib* and *its branches* through which the water supply to the leaf cells is maintained. The water from the xylem of the stem enters the xylem of the mid-rib. The mid-rib through the xylem of its branches (*veins*) makes water available to cells. Besides, the mid-rib and its branches provide mechanical strength to the leaf which may otherwise sag.

ELECTRON MICROSCOPIC STRUCTURE OF CHLOROPLAST

The chloroplasts, more in palisade cells are the sites wherein photosynthesis takes place hence each of them forms a *photosynthetic apparatus* or *photosynthetic factory*. The chloroplasts are biconvex disc-like organelles, measuring 4-10 μm in diameter and 2-3 μm in thickness.

Each chloroplast is bounded by double unit membrane. The inner space is filled with an aqueous matrix called stroma. In the stroma, several stacks of membranes appear as *flat discs* piled on top of each other. These stacks are called *grana* (singular, *granum*). Each disc of a granum represents a thylakoid. The grana are connected by *intergrana lamellae or frets*. A typical chloroplast contains approximately 60 grana, each consisting of about 50 thylakoids.

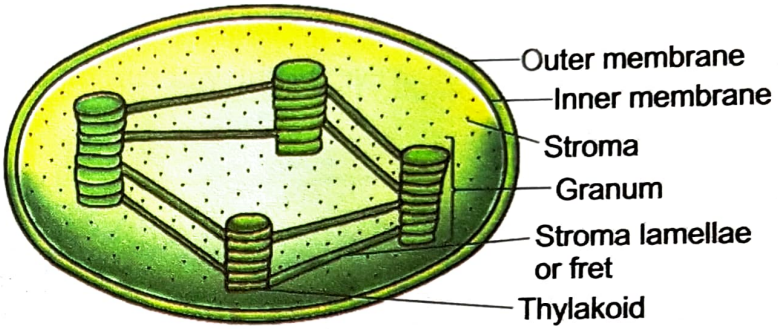


Fig. 3. Electron microscopic structure of chloroplast.

The chlorophyll and other photosynthetic pigments (carotenoids) are concentrated in the grana. The *stroma* also contains certain enzymes, proteins and a small piece of circular DNA. *The light reaction of the photosynthesis occurs in the grana and the dark reaction in the stroma.*

PHOTOSYNTHETIC PIGMENTS

These pigments trap solar energy. They are embedded in the membranes of thylakoids. These are of three types :

1. Chlorophyll : It is the most important photosynthetic pigment. It has a magnesium containing head and a tail of phytol (a type of alcohol). Chlorophyll exists in different forms (*e.g.*, chl a, b, c, d, e, bacteriochlorophyll etc.) out of which chlorophyll 'a' and 'b' are found in all green plants.

2. Carotenes : These are of orange to yellow colour.

3. Xanthophylls : These are of yellow colour.

Carotenes and xanthophylls are called accessory pigments. Their main function is to protect oxidation of chlorophyll by strong light (photo-oxidation).

ROLE OF STOMATA TO TAKE IN CARBON DIOXIDE

Stomata have two kidney shaped epidermal cells called guard cells. These cells have thick inner cell wall and chloroplasts.

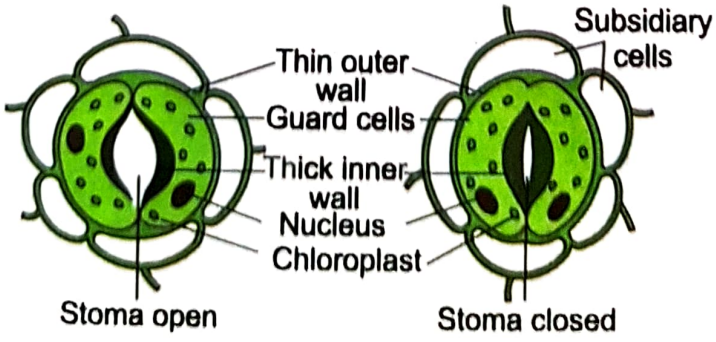


Fig. 4. Stomatal apparatus.

CEL

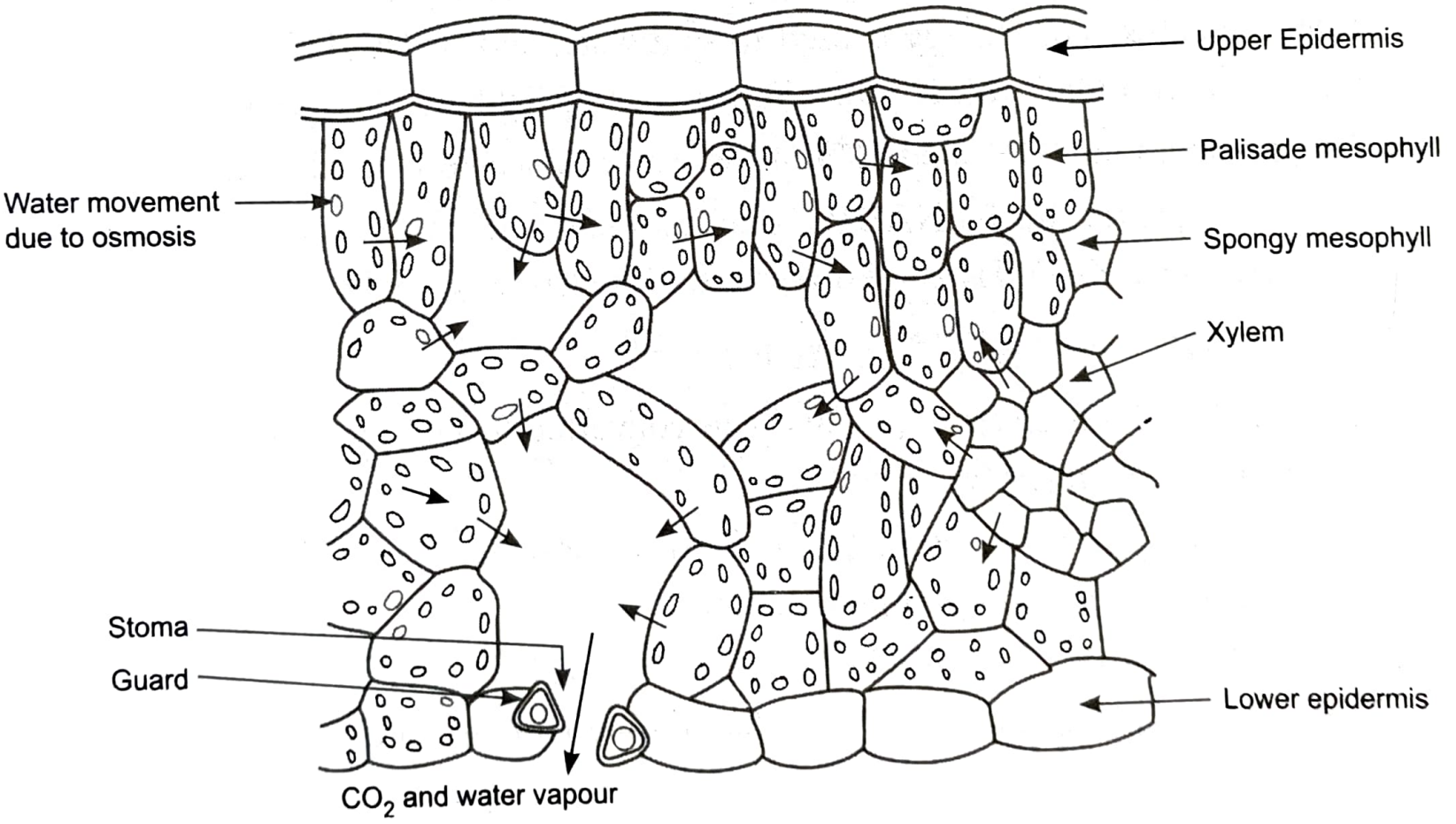
Site of photosynthesis: The leaves of plants contain chlorophyll that are specialize for the purpose of carrying out photosynthesis.

Internal structure of leaf:

(*a*) Upper epidermis allows light to pass through them to reach inner cells.

(*b*) Mesophyll region allow gases to diffuse into and out of the cells. The cells contain chloroplast and have many intercellular air spaces between them.

(*c*) Lower epidermis contain many stomata for exchange of gases as present in the dorsiventral leaves.



Cross-section of dorsiventral leaf showing water movement

Under condition of water scarcity, leaves tend to become narrow (as in oleander and pine) and have fewer stomata to minimise loss of water.

PROCESS OF PHOTOSYNTHESIS

Photosynthesis is a process which converts light energy to chemical energy. Green plants trap light energy of the sun and change it into chemical energy which is trapped in the form of carbohydrates.

The process of photosynthesis involves two phases. These are:

Light-Dependent Phase (Photochemical Phase): This phase is light-sensitive. Light initiates a series of reactions which converts light into chemical energy. As these reactions can occur only in the presence of sunlight, this phase is also called **photochemical phase**.

Light-Independent Phase (Dark Phase): This phase does not require sunlight and chlorophyll. The reactions utilise chemical energy stored during the light phase leading to the formation of carbohydrates. These reactions are also known as **Blackmann's reactions** and this phase is also called **biosynthetic phase** because of the synthesis of carbohydrates.

It should be clearly understood that both the phases—**photochemical** and **biosynthetic**, occur simultaneously.

Light reaction: (Photochemical phase)

(*a*) The chlorophyll in the chloroplast get excited when light falls on the leaves and the energy level increases. This energy is used to split water molecules. This process of splitting of water molecules into OH^- and H^+ ions in presence of light is called photolysis.

(*b*) The reactive ions (OH^- and H^+) of the water molecule is used in two directions.

1. H^+ is picked up by NADP (Nicotinamide Adenine Dinucleotide Phosphate) to from $NADPH_2$, $NADPH_2$ is used in the dark reaction to reduce CO_2.

$$NADPH^+ + e^- \xrightarrow{\text{enzyme}} NADPH$$

2. OH^- ions loses electron (e^-) and gets converted to OH radicals. Two radicals react to form H_2O and liberates O_2.
3. The energy from electrons (e^-) is used to form ATP from ADP and inorganic phosphate, which is called photophosphorylation.

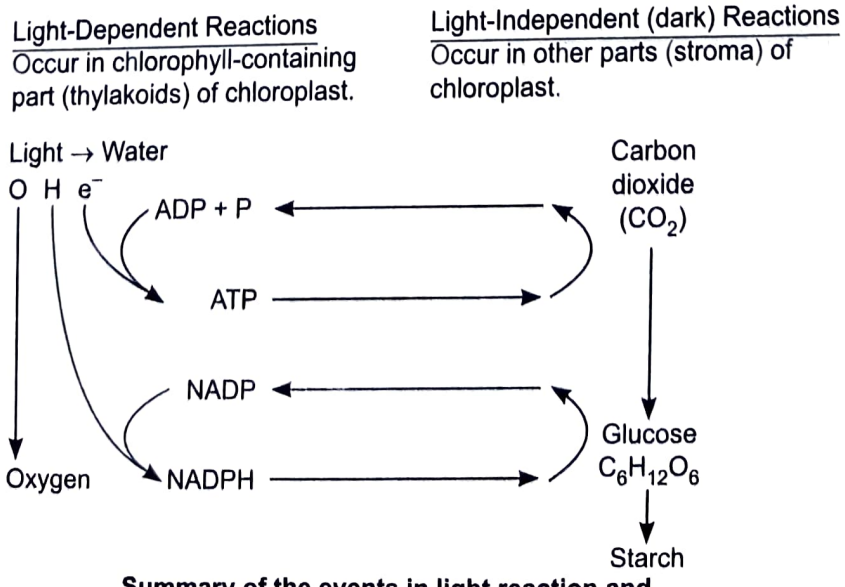
$$\underset{\text{(adenosine diphosphate)}}{ADP + iP} \longrightarrow \underset{\text{(adenosine triphosphate)}}{ATP}$$

Dark reaction: (Biosynthetic phase)

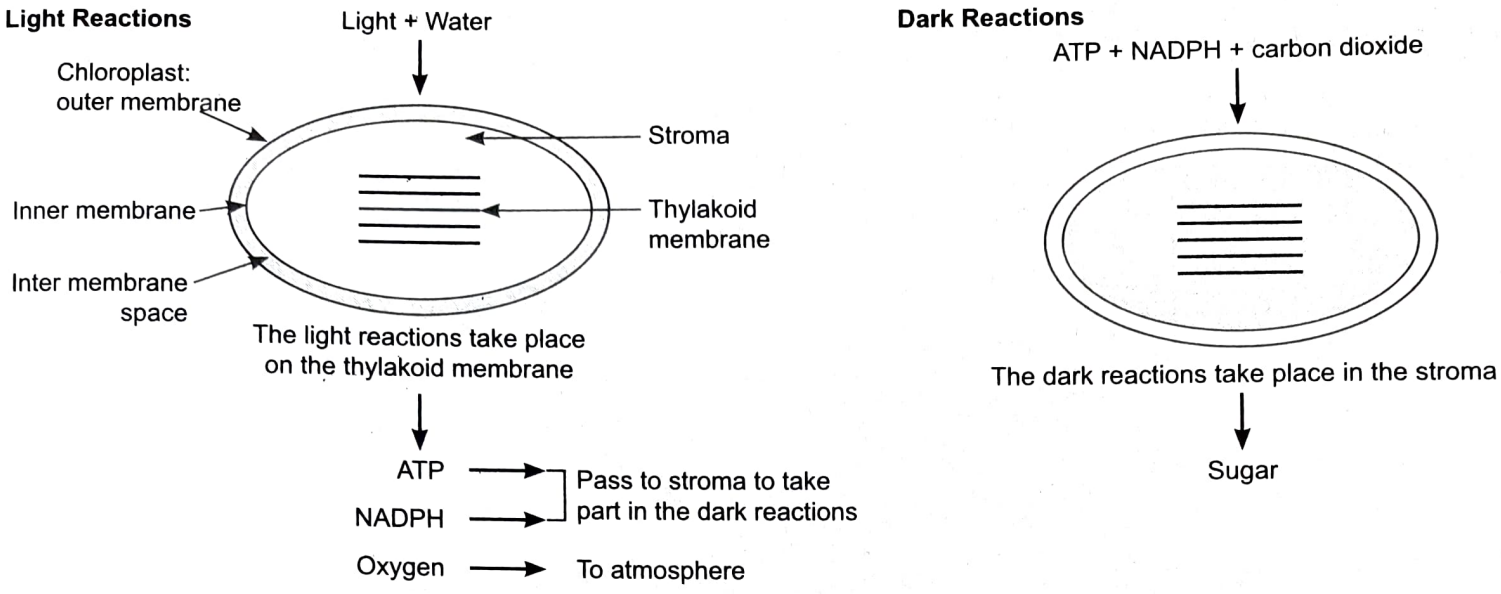
The end products of photosynthesis are—glucose, water and oxygen. The immediate product of photosynthesis, glucose is stored in the form of starch.

Summary of the events:

- The by-product of photosynthesis is oxygen which is the life supporting gas. Light reactions take place in grana of chloroplast.
- Dark reactions take place in the stroma of chloroplast.



Summary of the events in light reaction and dark reaction of photosynthesis



Two stages of photosynthesis (diagrammatically)

Adaptations of leaf for photosynthesis: The leaves are modified so that photosynthesis can be carried out effectively. Important adaptations are:

(*a*) Large surface area, broader leaves absorb more sunlight than narrow leaves.

(*b*) Leaf arrangement, stem and leaves and branches are arranged so that maximum sunlight falls on them.

(*c*) Network of veins is essential for rapid transport of substances, to and fro.

(*d*) Distribution of stomata for effective and rapid exchange of gases (CO_2 and O_2).

(*e*) Presence of chloroplast on the upper layers of leaves are more for absorption of sunlight.

(*f*) Thin leaves reduces the distance between cells for faster transport of materials.

Factors Affecting Photosynthesis:

- Internal factors— (*a*) Age of the leaf, (*b*) Leaf anatomy, (*c*) Chlorophyll content, (*d*) Accumulation of end products
- External factors— (*a*) Light intensity, (*b*) Carbon dioxide content, (*c*) Temperature, (*d*) Water content

Importance of Photosynthesis:

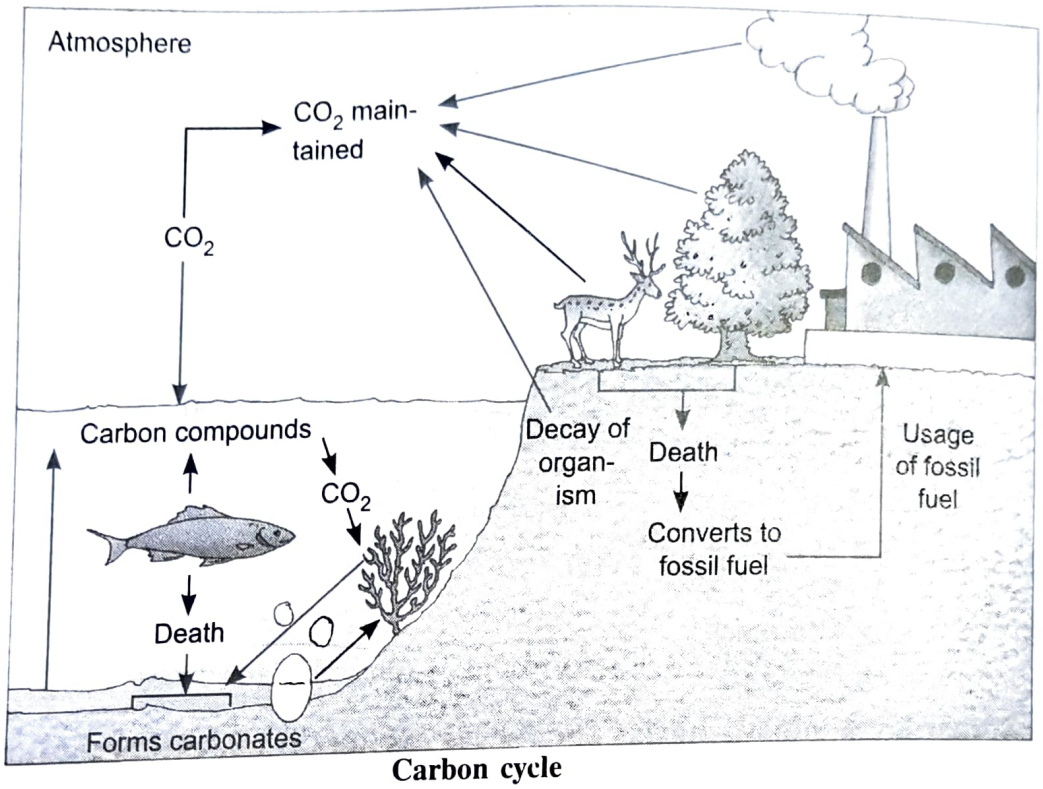
(*a*) To produce food for all the organisms

(*b*) Release oxygen which is a life supporting gas.

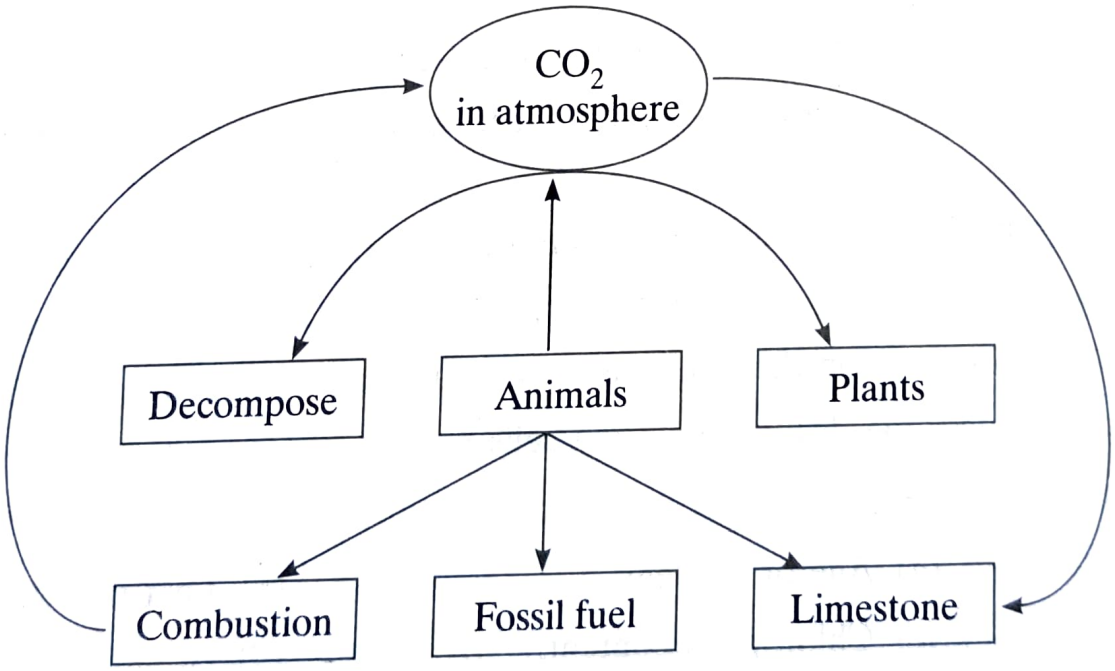
Carbon Cycle: It is a series of chemical reactions in which atmospheric CO_2 is used by organisms and returned to the atmosphere. Photosynthetic plants use carbon as CO_2 from the air synthesising organic compounds. By respiration, burning, decay, etc. the carbon is returned to the atmosphere. Carbon is one of the main constituent of living organism. It is found in carbohydrate, fat, proteins and nucleic acid. The three major reservoirs of carbon are:

(*a*) Atmosphere (*b*) Ocean (*c*) Carbonate rocks like limestone, coal and petroleum.

Carbon is present in the atmosphere in gaseous form (0.4%) and in ocean, it is present in lesser quantities. However, an equilibrium is maintained between atmospheric CO_2 and the ocean.



Carbon cycle



The plant leaves (autotrophs) takes in CO_2 from the air through the stomata by the process of photosynthesis. It uses this carbon to produce glucose (6-carbon substance), a simple carbohydrate that is later stored in the form of starch, sucrose, etc. From plants, the carbohydrate reaches other trophic animal. When the animals and plants die, they are decomposed by soil bacteria and fungi which help to release carbon back into atmosphere.

Other sources of carbon dioxide:

(*a*) Organisms release CO_2 during respiration.
(*b*) Burning wood or other carbonic material.
(*c*) CO_2 released during fossil fuels.
(*d*) CO_2 released from volcanic eruption.
(*e*) When acid rain falls on carbonic rocks, CO_2 is released.
(*f*) Decomposition of carbonic matter releases CO_2.

Law of Limiting Factors

Photosynthesis is not affected by all the environmental factors at a given time.

In 1905, **Blackmann** postulated the **Law of Limiting Factors**. It states that when a process is conditioned or governed by a number of different factors, the rate of the process is limited by the pace of the slowest factor or the factor present in the least amount. In other words,

- if all the other factors are kept constant, the factor affecting the rate is at its minimum.
- the rate of the process does not increase further even though the amount of this factor is increased as now another factor has become a limited factor being in least amount.
- the rate of the process is, therefore, now dependent on the second factor available in the smallest amount.

Dipping the leaf in boiling water kills the cells as it

- destroys enzymes in the protoplasm,
- prevents any chemical changes in the leaf, and
- makes cells more permeable to iodine solution.

Boiling the leaf in methylated spirit removes chlorophyll as it

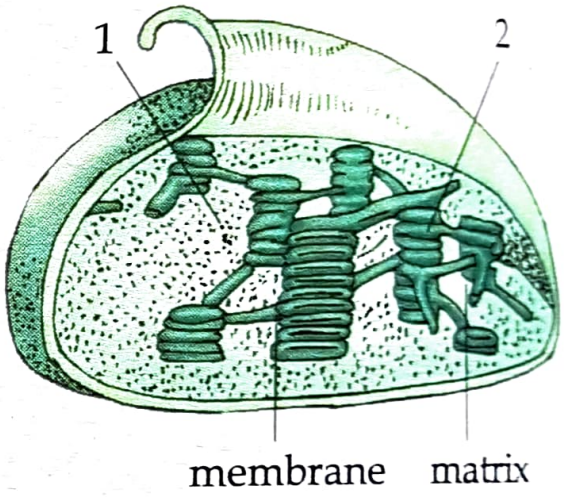
- dissolves all the chlorophyll in the leaf,
- makes the leaf white, and
- makes the colour changes more clear during iodine test.

Variegated Leaves

Variegated leaves have chlorophyll pigment in patches along with the presence of another colour such as yellow, red or purple. Thus, they have some green areas and some non-green areas, for example, leaves of *Coleus*, *Croton*, *Geranium*, etc.

. Why is photosynthesis regarded as the single most important biological source of energy?
. Name the two phases of photosynthesis. Why are they called so?
. State the Law of Limiting Factors.
. What is the source of oxygen produced during photosynthesis?
. How is light important for the process of photosynthesis?
. What is Calvin cycle?
. What are the sources of various raw materials required during photosynthesis?
. Why do leaves of a plant appear green in colour?
. List the various steps involved during light phase of photosynthesis.
. State the factors which influence the process of photosynthesis.
. Write the significance of photosynthesis.
. Illustrate the carbon cycle that occurs in nature and maintains the balance of carbon.
. Give the exact location and function of:
(*i*) thylakoids (*ii*) stoma
. Give reasons why the green leaves are thin and broad.

Given alongside is a diagrammatic representation of the internal structure of an organelle found in a plant cell. Study the same and then answer the questions that follow:



(*i*) Identify the organelle.

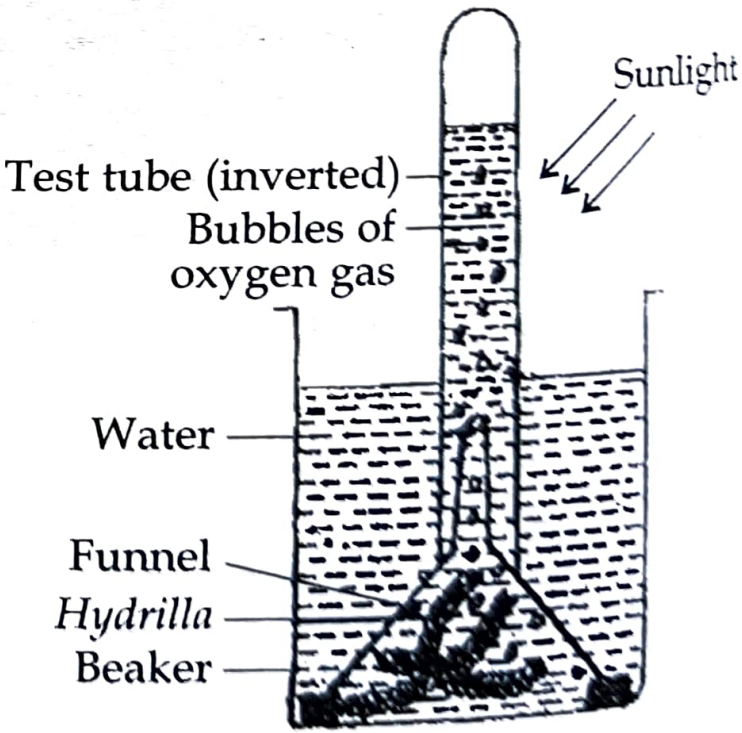
(*ii*) Name the physiological process occurring in this organelle.

(*iii*) Mention one way in which this process is beneficial to man.

(*iv*) Name the phases of the process occurring in the parts labelled 1 and 2.

(*v*) A chemical substance 'NADP' plays an active part in one of the phases. Give the expanded form of NADP and state its role in the above process.

The figure given alongside represents an experimental set-up to study a physiological process in plants.



(*i*) Name the physiological process being studied.

(*ii*) Explain the process.

(*iii*) What is the aim of the experiment?

(*iv*) Give a well-balanced equation to represent the process.

(*2010, 2016*)